Final Report of the Commission for the Study of Alternatives to the Panama Canal

Volume XIII

Biological Inventory

Commission for the Study of the Alternatives to the Panama Canal

BIOLOGICAL INVENTORY

FINAL REPORT

Volume I
Text

Prepared by:

CONSORTIUM UNIVERSITY OF PANAMA
AND
ANCON CONSORTIUM

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INDEX

1) EXECUTIVE SUMMARY

a) TERRESTRIAL

(1) The Physical Environment

Due to climatic conditions and soil evolution, the natural plant cover of the isthmus of Panama is forest.

A report on Life Zones of Panama (Tosi, 1971) following the Holdridge method of classification of plant formations of the world, recognizes most of the study area as "tropical humid". Annual rainfall varies north to south from about 3,400 mm to 1,850 mm with a 26 °C biotemperature.

The lower watershed (southwest sector) includes Gatun Lake and its tributaries (Gatun, Ciri Grande and Trinidad). The upper watershed (northeast sector) comprises Alajuela Lake and its tributaries (Chagres, Pequeni and Boqueron).

On the lower watershed, about 95% of the area has been depleted of its original forest cover. A gentle topography and relatively flat lands maintain a low rate of erosion.

On the upper watershed, even with a much lower deforestation rate, a combination of higher rainfall and steeper topography are factors accelerating erosion.

From the point of view of vegetation growth, the combination of hight temperature and rainfall plays a main role on soils.

The Rural Census of Lands and Waters of the Republic of Panama (CATAPAN), a project completed in 1965, surveyed, analyzed, and mapped soil types of Panama, including the study area. This project sampled and analyzed (both physically and chemically) the soils of the permanent sampling sites and found results that closely matched those of CATAPAN.

(2) Flora

Field work was carried out during twelve months in order to detect seasonal variation.The study area included both sections of the Panama Canal watershed (northeast or upper watershed, and southwest or lower watershed) which account for the formation of Gatun and Alajuela (Madden) lakes, the sources of all the water needed for the canal operation.

In the field, a total of 29,528 individuals were recorded; 12,948 of them provided herbarium samples for later identification in the laboratory. Of the total, 27,700 where identified to family (94%) and 27,581 to species (93.4%).

A total of 1,920 person/days were utilized to complete all field and laboratory work.

The following are the most outstanding results and conclusions from the flora inventory:

-Original plant cover (tall forest) has been reduced to approximately 30% of the total area. On cleared land a mixture of extensive grazing lands, secundary forest (pioneer, early secondary and late secondary) and abundant but small cultivated patches have been established by slow continuous colonization. This deforested area also includes all land occupied by lakes, engineering structures (canal, roads, buildings and different types of installations for the operation and maintenance of the Canal) and human dwellings are included.

-The reduction of natural plant cover increases erosion and siltation rates and threatens the expected operational life of the canal. This condition is not very serious in the lower wartershed due to a relatively gentle topography of the area, but in the high watershed, with a rough and steep topography and higher rainfall rates, the situation requires immediate attention to protect the Canal operations.

-No large volumes of commercial timber were found in the area which would support a reasonable yield in felling operation. Extraction of valuable timbers by local artisans has been occuring for many years, even before the construction of the Canal. However, this is not a recommended activity for this area, even though it produces low scale damage and poses no significative threat.

-The study area is located in the "tropical humid", the most extensive life zone of the Republic of Panama, and most of the collected species are also present in sites adjacent to the study area.

The following recomendations have been derived from the flora inventory:

-The Panama Canal watershed requires protective measures to reduce or, at least, to stabilize human activities within the area.

-Existing settlements should be technically and financially supported in order to increase permanent crops and reduce to a minimum temporary ones.

-Protected areas quickly return to a forest type cover by natural succession. This process should be complemented with plantations of native forest species on those sites so deteriorated that natural regeneration has become difficult.

-After selection of a proper alternative to the Canal, some specific biological studies should be carried out around affected areas.

(3) Fauna

(3.1) Entomology

The insects study concentrated on the following objectives:

-To identify insect species that affect man and animals, emphasizing on those that transmit diseases.

-To determine their distribution and relative abundance throughout the established sampling period.

-To identify beneficial insects acting as biological control agents, as well as insects important to forestry, agriculture and others.

The field and laboratory work was started in July 1992, with weekly surveys performed during nine months, totalling 37 sampling weeks up to June 1993.

The work was conducted at four sampling sites (Paraiso, Gamboa, Arraijan and Arenosa). These sites were chosen because of their North, South, East and West orientation to the Panama Canal and their proximity to residential areas that may be affected by the construction and operation of any of the canal alternatives.

Throughout the present study, eleven different sampling methods were used, seven of which consisted of utilizing various insect traps. These methods were systematically used during the nine months of sampling period.

A total of 138,184 insects of medical importance were collected belonging primarily to the Diptera, including the following Families: Culicidae (14,575 specimens belonging to 14 Genera and 19 species); Psychodidae (1,346 specimens which included 18 species and two genera); Ceratopogonidae (14,383 specimens, the majority belonging to the genus *Culicoides* of which 43 species were identified); Calliphoridade (21,908 individuals of the genus *Chrysomya*); 12944 Muscidae, 9,712 Sarcophagidae, and 55 Tabanidae. In addition, a total of 28,093 Formicidae, 10,134 Staphylinidae, 1,292 Apoidea, 177 Vespoidea, and 103 Battidae were collected. In addition to insects, 23,462 Acari were also collected.

Regarding the distribution and relative abundance of insects of medical importance, the following can be mentioned:

-In the Culicidae Family, *Culex* was the genus most commonly found in the four localities. *Anopheles*, *Aedes*, *Mansonia* and *Sabethes* were also collected.

As to the most prominent species captured, it is worth mentioning the presence of *Anopheles albimanus*, *A. vestitipennis*, *A. punctimacula*, *A. pseudopuntipennis*, *Aedes taeniorhynchus*, *Mansonia titillans*, and *M. indubitans*. *Anopheles albimanus* has been ordinarily known as the most important transmitter of malaria in Central America and Panama, although at present it is well known that other species are able to transmit this noxious blood parasite in the region.

Aedes taeniorhynchus and the *Mansonia* species are considered important because they are potential transmitters of the Venezuelan equine encephalitis. On the other hand, the *Culex* species are particularly important because of their transmission capability of filariasis and the encephalitis virus.

-Out of 43 species of the *Culicoides* genus (Ceratopogonidae), the highest numbers were found at Arenosa; of these, 16 species were commonly found in the four localities. The highest population density was obtained at Arenosa, and the lowest at Paraíso.

Among the anthropophilic species collected, it is worth mentioning in rank of importance the following: *C. furens*, *C. guyanensis*, *C. reticulatus*, *C. camposi*, *C. iriartei* and *C. paraensis*, the latter being considered as a transmitter of the "oropouche" virus. This group was most abundant during the rainy season, although this was not true for all the species. Their predominance varied within the different locations.

-Although the total number of individuals of the genus *Lutzomyia* (Psychodidae) was relatively low, six out of seven species ordinarily known for their anthropophilic habit and for acting as transmitters of leishmaniasis disease were collected. These species were *L. gomezi*, *L. olmeca*, *L. panamensis*, *L. pessoana*, *L. trapidoi* and *L. ylephiletor*.

Gamboa was the location where the greatest number of specimens and species were obtained. With respect to the influence the wet or dry season may have had on the populations of these groups, it seems it had little effect, except for *L. panamensis*, which was severely affected by the dry season.

-The genus *Chrysomyia* of the Family Calliphoridae was represented by four introduced species. These seem to have displaced a native species, *Cochliomyia macellaria*, a necrophagous fly, in the sampling sites.

Using the various sampling methods, it was possible to observe a high degree of diversity in groups of beneficial insects totaling 56 Families. Of these, 31 Families belong to the Hymenoptera. It is important to mention that spiders were always present in all the sampling sites.

The presence of insects important to forestry or agriculture was not particularly prominent; however, several crop and forestry pests were collected.

In conclusion, important insect groups of medical importance which are influenced by humid environments were found in considerable and stable population densities due to the prevailing conditions in the study area.

The Family Culicidae was represented by insect species and genera known to be transmitters of diseases that affect man, as well as species of *Culicoides* (Ceratopogonidae) and *Lutzomyia* (Psychodidae).

The diversity and abundance of insect groups found is common of the surveyed areas, where little or no predominance of any group or species was observed, as it frequently happens in more disturbed environments.

(3.2) Herpetology

The inventory of amphibians and reptiles was performed in six study sites: (1) Cirí, (2) Sherman, (3) Gaillard Cut (Corte Culebra), (4) Cocolí, (5) Pequení, and (6) Tranquilla. Each site was visited and sampled on five occasions during the 16 month study. Samplings were made approximately every three months. The sampling method consisted of generalized searches and walks along transects, complemented with the use of anuran vocalizations to determine the presence of some species, and questions posed to inhabitants about the threatened or endangered species in the area. The most important results and conclusions derived from this study are the following:

-During the study, a total of 60 species of amphibians and 58 species of reptiles were found. The number of species observed per site varied between 42 and 60, Cirí being the site containing the lowest diversity and Pequení the highest diversity. This could be partly associated to the existence of various types of habitats in Pequení, whereas Cirí is pasture land containing very reduced areas of forest.

-Two presently undescribed species were found during the study. A frog of the genus *Atelopus* and a fuscoauratoid *Anolis* lizard, which were known to exist in the area since about two decades ago. Also, the distribution range of the dendrobatid frog *Phyllobates lugubris* was extended.

-The species composition and their abundance varied among the study sites. Only 8 species of amphibians and 4 of reptiles were found in all the study sites, four of them being abundant in these sites: the frogs *Centrolenella fleischmanni*, *Eleutherodactylus fitzingeri* and *Hyla microcephala*, and the lizard *Anolis limifrons*. In general, the anurans seem to be more abundant than any other group of amphibians and reptiles. This abundance could be attributed to the conspicuousness of the males of several anuran species that congregate and call from the surroundings of bodies of water. Snakes are relatively scarce, being observed infrequently.

-The threatened and endangered species such as the caiman (*Caiman crocodilus*), the crocodile (*Crocodylus acutus*) and the green iguana (*Iguana iguana*), with the exception of the first one, are uncommon in the study sites. At those sites were caimans were found they were numerous, not so in the case of the crocodiles. In the sites inhabited by man, the green iguana is infrequently seen, because it is indiscriminately hunted, even during the closed hunting season.

-Walks along the transects showed the existence of a seasonal pattern in the abundance of some anurans. The frogs of the forest floor tend to concentrate in the moist areas along the margins of the streams during the dry season, and with the beginning of the rains they disperse throughout the moist forest floor. Some anurans aggregate to breed along the margins of ponds and streams during the wet season, but they are absent during the dry season. This seasonality in the reproductive behavior of several species of anurans is evident with the beginning of the rains and the formation of choruses within the surroundings of appropriate breeding sites.

(3.3) Ornithology

This study comprised the avian fauna related to tropical rain forests, open areas (grasslands), littoral and aquatic habitat, and the coastal marine zone. A total of 405 bird species were recorded out of the 564 found in the area within the last 150 years.

The most important results and conclusion from this inventory are:

-The forest habitat contained more species than the aquatic and littoral, the open area, and the marine habitat.

-Gaillard Cut, Pequení, the North Entrance to the Canal and the South Entrance to the Canal maintain some forest, and thus contain more species than Tranquilla and Cirí, where pasture lands predominate.

-Threatened and endangered species inhabit the surveyed areas; also are present birds of prey, raptors and sparrows.

-Eighty five migratory species out of the 122 registered for the country were found; certain species were in transit and others were wintering.

-Out of the 480 local species registered, 326 were located during the study period. In each habitat, and in each place, the number of resident species and individuals was greater than the migratory species.

-In general, for each place and for each habitat, seasonality was observed, where the number of species and individuals grew with the progress of the rainy and the migratory seasons. The maximum abundance was reached during the climax of the rainy season and

towards the peak of the north-south migration, in November, and later decreased in the dry season. This was very obvious for the migrants, where big groups were observed during their return flights towards the north, during February-March.

-The resident birds use the study area for all the activities that allow them to survive there in the current conditions.

-A new species was registered, *Junco hyemalis* (Linnaeus, 1758) for the ornithologic fauna of Panama, and several others for the area of the Panama Canal.

(3.4) Mammals

A species inventory of the mammals present in the area of the Panama Canal was carried out. The area was qualitatively surveyed and divided into 20 regions according to the state of the habitat. A total of 12 specific sites were visited by two teams of biologists, one concentrating on bats and the other on non-volant mammals.

The bat team placed mist nets at ground level and at about six meters above ground, at each site for each of two nights at each site. Netted animals were identified, sexed, weighed, marked with a temporary mark and released. In addition to bats, all sightings of non-volant mammals were also recorded.

The non-volant mammals were sampled at specific sites by setting out 5 lines of 10 traps each. Trapped animals were identified, sexed, roughly aged and released. In addition, mammal tracks, fruits or seeds that are eaten in specifically identifiable ways, identifiable vocalizations and other reliable signs, were recorded at each site.

A computer stored map of the study area was prepared and the data for each species entered into this.

The most prominent results and conclusion from the mammal inventory are the following:

-A total of 41 positively identified bat species was netted; in addition, two more have been identified to genus but not yet to species. Two species (*Furipterus horrens* and *Lichonycterus obscura*) have not been netted in the study area before. Eisenberg (1989) lists bats as probably occurring through Panama if they have been found in Costa Rica and Colombia or elsewhere on both sides of Panama, and lists 110 species as occurring in Panama. Most bats can only be positively identified in the hand; some of those assumed to be here have not actually been identified in Panama. A total of about 53 species has been netted on Barro Colorado Island, where netting has been most intensive in Panama. The true number of species actually present in the study area is thus probably between 53 and 110.

-Some species of mammals are very rarely seen because they are rare, others because they are cryptic, arboreal and/or nocturnal.

-The bushdog (*Speothos venaticus*) falls into the first of these categories. No specimen has ever been collected further West than the Cerro Pirre region of the Darien and there has never been even a suspicion that bushdogs exist in the study area. But one recent sighting by a pair of Smithsonian scientists and another by two ecotourist guides make it appear probable that there are at least a few (perhaps only one group of three) bushdogs in the area.

-The silky or pygmy anteater (*Cyclopes didactylus*) in the Order Edentata, falls into the second category. It is a small animal which is totally arboreal, nocturnal and very cryptic in the daytime sleeping position, and it does not have a bright "eyeshine" in the light of a headlamp so that it is difficult to see even when it is active. Only one specimen of *Cyclopes* has been observed in the present study, and two others have been reliably reported. The species is probably considerably more common in the study area than the data indicate.

-The overall impression is that the area of the Parque Nacional Soberanía, the Barro Colorado Nature Monument and the west bank of the canal opposite Gamboa together constitute a refuge for many mammalian species which should be more widely distributed in Panama, and that hunting and habitat destruction have rendered such areas as the land around the Trinidad arm of Gatun Lake and the area around Alajuela Lake practically sterile with regard to non-volant mammal species. Even in areas such as the mouth of the upper Chagres, where it enters Alajuela Lake, the forest appears to be in good condition but one does not hear howler monkeys (*Alouatta palliata*) at dawn or dusk. Howler monkeys are seldom persecuted (local hunters deny that they eat them) and their total absence from what appears to be eminently suitable habitat indicates that other, more popular, game species have been entirely eliminated. Since many of these game species are important seed dispersers, their absence may be presumed to have already precipitated a decline in the diversity of tree species in the area.

b) FRESHWATERS

(1) Water Quality

Sampling and field measurements were accomplished according to the terms of reference (TOR), followed by laboratory analysis to determine the corresponding parameters and compounds.

Available data and results are used to evaluate the state of water quality and its variation according to the season of the year. Emphasis was placed to define and evaluate the individual water quality of Lake Alajuela, Lake Gatun, and their tributaries. The study provides information which describes the role of various parameters concerning the water quality of the system.

Consequently, the following major factors are recognized to affects the water quality in the area:

-Natural changes due to seasonal variations of the area climatology and hydrography.

-Indirect induced changes caused by deforestation of the area, which contributes to increased sedimentation, a relevant aspect in the case of Lake Alajuela.

-Changes induced through the direct introduction of tributary rivers into lakes Alajuela and Gatun.

-Changes induced through direct pollution due to sewage discharges into the Panama Canal freshwater system.

The most important results and conclusions from this study are the following:

-There are seasonal changes in lakes Alajuela and Gatun. Contrary to Gatun Lake, Alajuela Lake shows thermal stratification during the rainy season. Distribution of dissolved oxygen is of a clynograde type. Higher concentrations of dissolved oxygen in the hypolimnion, as compared with the metalimnion, is due to dense currents of tributary rivers which provide oxygen to the deep waters of Lake Alajuela, except during the dry season.

The moderate oxygenation of subsurface waters of the lake during the dry season is supplied by winds, which induces the mixing process and destroys the thermal stratification present during the rainy season.

-There is an interaction between these two systems. According to the relatively low concentrations of dissolved oxygen and similar concentrations of nutrients in the bottom waters, the characteristics of Lake Alajuela derived from its tributaries, are perceived close to Gamboa, and even Paraiso, throughout the year.

-Along the Gatun Lake there is no thermal stratification during the whole year. With few exceptions, the water is very well oxygenated; the concentration of BOD, suspended solids and turbidity are low. In general, the water is free of total and fecal coliforms, and the bacterial levels are lower than the international standard for recreational waters. Sediments of Gatun and Alajuela lakes frequently present very high values of organic matter. However, there is no evidence that could indicate a serious pollution of the Panama Canal freshwater system.

-The Lake Alajuela is considered to be meso-eutrophic, this represents the third stage of eutrophication according to the general limnological classification.

-The Gatun Lake is defined as mesotrophic, in the second stage of eutrophication.

(2) **Sediments Quality**

Results of granulometric analysis from 7 sampling stations in Gatun Lake revealed that sediments in the areas of Darien and Bajo island are mostly made up of silts and clays. The remaining stations sediments had an important sand fraction.

Regarding the quality of the sediments, the chemical analysis have revealed the following:

-Total nitrogen in the sediments of the study area presented a constant distribution with values ranging between 200 and 900 ppm which, in general, is a very high concentration. The observed ratio between total organic carbon and total nitrogen ranged between 10:1 and 15:1.

-The concentration of metals in the sediments is within the normal ranges and corresponds to the values usually found in igneous rocks. There is no evidence of metal contamination in the sediments.

-The analysis of high molecular weight hydrocarbons revealed that, in general, accumulation in the sediments is very low (19.90 to 58.60 μg/g of dry sediment). The exception is the area at the Gatun anchorage where values up to 168 μg/g of dry sediment have been recorded. Distribution in the concentration of hydrocarbons seems to be related mostly to the transit of ships in the canal and the time ships remain at the anchorage sites in the Gatun Lake.

(3) **Aquatic Macrophytes**

The collected information on the distribution of floating aquatic macrophytes reflects a clear temporal and/or seasonal as well as cultural situation (aquatic weed control).

The most relevant results and conclusions from this study are the following:

-The plant community displays a greater variability in its abundance in response to seasonal changes. Most are the free floating macrophytes.

-The spatial and/or temporal distribution of some floating macrophytes, i.e. *Pistia* sp., as well as their abundance, seem to be associated with more long lasting cycles rather than seasonal climatic changes.

-In areas subject to the control of submerged and floating aquatic vegetation using manual, mechanic and chemical methods for a period of about 70 years, i.e., the sector of the Chagres River at Gamboa and other canal operational areas, the natural successional processes are disrupted. This causes an apparent decrease in diversity, and a clear dominance of species best fit to this system of aquatic weed control.

-Shoreline and/or emergent macrophytes, subject to periodical or seasonal floods, have greater stability within the seasonal cycles, and play an important role in the natural successional processes.

-In the aquatic ecosystem of the Panama Canal, specially in the Gatun Lake, the most widespread submerged macrophyte with the greatest biomass continues to be the *Hydrilla verticillata*, *Hydrilla* sp. and *Chara* sp. These macrophytes are colonizing parts of Lake Alajuela associated to recreational boat activities.

-All of the aquatic macrophytes identified during observations in this inventory have been recorded in previous studies.

-A very important aspect, from the ecological point of view, has been the accidental introduction in Gatun Lake (1983), of the snail *Pomacea* sp. Due to its great voracity, its high biotic potential and its present preference for *Hydrilla*, this organism has turned into an efficient biological control agent. The dispersion of the snail in the whole lake is being favoured intentionally by dwellers near lake villages to solve problems of access and aquatic mobility to their homes and working sites.

-Observations from the landing at Arenosa, scanning the shoreline zone toward the South and North, revealed that the snail *Pomacea* sp. has almost erradicated *Hydrilla* sp. from the shoreline. In most cases *Chara* sp. has replaced *Hydrilla* sp.

(4) Benthos

Benthos samples were taken at seven stations in Lake Gatun. Collections were made using a Ponar dredge in areas devoid of aquatic weeds with depths greater than 10 m.

The summarized results and conclusions from this study are as follows:

-Granulometric analysis revealed that the profundal benthic region of Gatun Lake was dominated by fine particles, mainly detrital mud. The benthic community was dominated by three taxons: gastropods (snails), pelecypods (clams) and annelids-oligochaetos (aquatic worms).

-The gastropods were represented mainly by *Melanoides*, *Potamopyrgus*, *Gyraulus* and *Lyogirus*, and the pelecypods by *Corbicula*, *Musculium* and *Sphaerium*.

-The families Tubificidae and Naididae were dominated by the annelids oligochaetos, with the prevalence in this group of the tubificid worm *Branchiura sowerbyi*.

-Of less numerical importance were the aquatic insects, nematodes (roundworms) and crustaceans. Greater densities of organisms were recorded at stations located in the mouth of Gatun River, and near the main channel. At this site, because of the proximity to one

intersection of the canal route, the ships must change direction. This requires increased engine power which creates strong turbulence and sediments upheaval. The physicochemical analysis revealed that these stations are subject to a continuous mixture of waters.

(5) **Fish and Macroinvertebrates**

In five samplings, 26 fish species were collected (9 peripheral or marine and 17 freshwater) included in 16 families (7 peripheral and 9 freshwater).

The most important results and conclusions from this fish study were the following:

-Dominant species were represented by *Cichla ocellaris*, *Hoplias microlepis*, *Brycon chagrensis*, *Cichlasoma maculicauda*, *Curimatus magdalenae* and *Rhamdia guatemalensis*, with a total of 86.6% of the catch and 86.0% of the weight.

-Except for the exotic species recently introduced, *Colossoma macropomum*, *Cyprinus carpio* and *Oreochromis niloticus*, the other species collected have been recorded in previous studies.

-Among the macroinvertebrates, five species of decapod crustaceans belonging to three families, and only one species of the recently introduced mollusk *Pomacea* sp., were captured. The most abundant and frequent species was *Callinectes toxote*, contained in more than 60% of the catchs. All these species of marine and freshwater decapods have been recorded in studies carried by Abele & Kim (1989) and Hildebrand (1939).

(6) **Commercial and Sport Fishery**

The most important freshwater fishing activities in Panama are concentrated in Gatun and Alajuela lakes. At present three types of fishing activities are carried: commercial fishing, subsistence fishing and sport fishing.

The most important species for the above mentioned fishing activities is the peacock bass (*Cichla ocellaris*), introduced accidentally in the Gatun Lake about 1967. Annual production of this species has been estimated between 150 to 300 metric tons for the Gatun Lake, and between 20 to 50 metric tons for Alajuela Lake.

On the whole, it is estimated that the production shares are as follows: subsistence fishing, 50%; sport fishing, 30% and commercial fishing, 25%.

Main centers for sport fishing in the Gatun Lake are Arenosa, Gamboa and Gulick. For commercial fishing the centers are Cuipo, Los Cedros, La Laguna and Gatun River.

In Lake Alajuela, commercial fishing is more important, and this activity is developed by various communities grouped in the "Union de Campesinos del Lago Alajuela", (UCLA).

(7) Aquatic Mammals

Aquatic mammals observations were carried out betweeen September 1992 to June 1993. The most important results and conclusions from the study are the following:

-Only one species of mammals in the study area was genuinely aquatic: the manatee *Trichechus manatus* (Trichechidae; Sirenia). Manatees were introduced in Gatun Lake in 1962.

-There are five species of semi-aquatic mammals, that is, mammals that principally forage in fresh water but spend much time on land, reported for the study area. These are the water opossum *Chironectes minimus* (Didelphidae; Marsupialia); the otter *Lutra longicaudis* (Mustelidae; Carnivora); the capybara *Hydrochaeris hydrochaeris* (Hydrochaeridae; Rodentia); and two small rodents: *Oryzomys couesi* and *O. alfari* (Cricetidae).

-The otter has steadily increased in numbers since the introduction of the peacock cichlid (*Cichla ocellaris*) into the study area in 1967. Otters now range throughout the Gatun Lake area, in the middle and upper Chagres River, over Lake Alajuela, up to major tributaries of these water bodies, and in many lakes and small ponds within the study area.

-The capybara arrived in the Gatun Lake area sometime in the early 60's, having spread westward from the Pacora marshes and down the upper Chagres. Capybaras are now found anywhere where there are grassy patches near bodies of water on both sides of the canal. No information is presently available on the two semi-aquatic cricetids in the area.

c) MARINE WATERS

(1) Oceanography and Water Quality

Seasonal changes in the oceanography and water quality were observed to be as follows:

-The condition of the water mass in the Bay of Panama during the rainy season indicates an uniform distribution of the properties in the water column. This includes the absence of thermal stratification and the presence of a mixed layer with relatively warm water from the surface to the bottom. This mixed layer has a relatively low salinity, low concentration of nutrients, and chlorophyll "a". All of these parameters were uniformly distributed in the water column. The concentration of dissolved oxygen in bottom waters was generally near 5 ppm.

-This study identifies and describes the development of the seasonal upwelling in the Gulf of Panama, during the dry season of 1993. This phenomenon was followed by a significant decrease in the water temperature and a pronounced increase of the salinity in the entire water column. Simultaneously with these changes, there is significant increase in the

concentration of total phosphorus (twice as much as found during the rainy season) and the concentration of nitrates (about three times more than observed during the rainy season). This same pattern was observed with chlorophyll "a".

-In contrast to these changes, the concentration of dissolved oxygen decreased below the thermocline. At the end of the dry season, the annual cycle started again.

-The yearly oceanographic cycle in the Caribbean is similar to that of the Bay of Panama. During the rainy season there is a lack of thermal stratification, while the properties are distributed uniformly in the water column. The water column indicates a rather high temperature, low salinity, high concentration of dissolved oxygen, low concentration of dissolved nutrients and chlorophyll "a".

-During the dry season the salinity of the water column is increased, which together with colder air masses that blows onshore increases the density of the surface water promoting the sink of of the water mass. This vertical mixing carry to the surface level a subsurface water mass with a low concentration of oxygen and high concentration of nutrients. By the end of the dry season, the annual cycle starts again.

-The study of the water quality, both in the Pacific and the Caribbean, showed slight levels of pollution.

-The analysis of volatile organics from samples collected during the first half of this project revealed that such compounds are not found in the area. The BOD concentrations were low and in general, the counts of total and fecal coliforms are below what the water quality standards indicate for recreational waters. This inventory has indicated that the marine area near the Fort Amador Causeway, an important recreational area, has a fairly good water quality. This same condition was observed in the studied area in the Bay of Limón, on the Caribbean side.

(2) **Sediments Quality**

Granulometric analysis of marine sediments revealed that 91 % (64 out of 70 samples) of all samples showed a typical muddy sediment composed of silts and clays (< 80 microns) in both the Pacific and the Caribbean study areas. The chemical analysis brought the following:

-The concentration of total nitrogen in the sediments from the Pacific remained fairly constant throughout this study. In general, the concentration of organic nitrogen ranged from 100 to 350 ppm (0.10 to 0.35%). The ratio between the total organic carbon and the organic nitrogen varied from 10:1 to 15:1. The concentration of heavy metals in these sediments indicated a uniform distribution with values similar to those reported by former studies. The ranges of metal concentration are: iron between 10,000 - 60,000, copper 30 - 65 ppm, manganese 400 -500 ppm, and zinc 80 - 135 ppm.

-The concentration of the organic nitrogen in the sediments in the Caribbean remained nearly constant throughout this study, the same as in the Pacific. The concentration of total nitrogen (0.10 to 0.20%) in sediments from the Caribbean is about half of the value normally found in the Bay of Panama. As suggested previously, this might be related to the smaller organic production in the Caribbean or to the higher concentration of dissolved oxygen. In general, the concentration of copper and zinc in sediments from the Caribbean are similar to those measured in the Bay of Panama. However, the concentration of iron and manganese in the Caribbean is higher than the reported for the Bay of Panama.

-In summary, the concentration of heavy metals, both at the Bay of Panama and in the Caribbean, are within the normal range reported for coastal areas.

-The analysis of High of Molecular Weight (HMW) hydrocarbons in the marine sediments revealed that the area with the highest concentrations (49.30 - 67.84 μg/g dry sediment) are related to the route of navigation through the Panama Canal, the docks, and the anchorage sites. But in overall, the concentration of HMW hydrocarbons in most of the studied areas were low (<15 μg/g dry sediment) and do not suggest an important accumulation of oil in sediments.

-In general, the concentration of HMW hydrocarbons in sediments decreased as the rainy season progressed.

(3) **Corals, Mangroves and Marine Grasses**

(3.1) Corals: The total area of the coral reefs in the Caribbean was 204.6 Ha, whereas in the Pacific these were just 3.9 ha. The main characteristic of these coral reefs are the following:

-The most important reefs in the Caribbean, regarding their size, were those of Payardí Island, Largo Remo Island, Galeta Island, Media Palma, and Brujas.

-The coral reefs in the Pacific area were only found in the surrounding islands of Taboga, Urabá, and Taboguilla. The coral reef located northeast of Taboga (in front of the town) is the largest and best developed of the area and covers almost 2 ha.; however, this coral reef is completely dead.

-The diversity of coral species observed in the Caribbean coast is three times greater to that observed in the Pacific. There are 48 species of hermatypic corals and 3 species of hydrocorals in the coral reefs of the Caribbean coast, whereas only 14 species of corals have been observed in the Pacific side.

-Only 11 species of corals were observed in the reef flats in the Caribbean.

-For the first time the genus *Siderastrea* is reported for the eastern and western Pacific, and in addition, a new species of coral is reported. There is the possibility that two new species

of *Siderastrea*, which are very similar to *Siderastrea siderea*, could be reported for the Caribbean.

-The diversity of the corals within the study area represents 53% and 82% of the diversity reported for the Caribbean and Pacific coast of Panama, respectively. The diversity of octocorals is less than 30% of the species reported for the rest of the country.

-The reefs studied along the Caribbean coast have a reduced area covered by life coral (<6%) but a high coverage by macroalgae (>80%). This is clearly evidenced by a disturbance caused by the construction and operation of the Panama Canal and the oil refinery.

-The history of the coral reefs on the Pacific entrance of the Panama Canal has been less dramatic than the one described for the Caribbean, since there was more construction material available from large land excavations in Gaillard Cut and some other areas. However, these coral are subjected to a high runoff and to low sea temperatures caused by seasonal upwelling, thus affecting their distribution.

-In summary, the coral reefs at both ends of the Panama Canal are not in good condition and it is evident that continued lack of management and protection in this part of the coastal zone might continue to adversely affect these reefs.

(3.2) Mangroves: There is a total of 36.08 km^2 (=3,608 ha) of mangrove forests in the study area. The Caribbean coast have a slightly smaller amount (17.11 km^2) compared to the Pacific (18.97 km^2). The Caribbean estimate however is still greater than that of an earlier estimate for the much larger Costa Arriba de Colón (13.41 km^2) which was provided by the Instituto Geográfico Nacional "Tommy Guardia". This was apparently caused by the different definition of mangrove forests, and possibly the different interpretations of satellite photography, compared with aerial photography.

Mangrove forests were observed in the following sites in the Pacific: Perequete, Caimito, Veracruz, Balboa, and Juan Diaz, whereas in the Caribbean mangroves were observed in Chagres, Colon, and Bahia Las Minas.

Eleven mangrove species, including the putative hybrid *Rhizophora* and two forms of *Pelliciera rhizophorae*, were observed in the study area. Several notable features were observed in the studied mangrove forests:

-The occurrence of species within all sections, namely *Laguncularia racemosa*, *Avicennia germinans* and *Acrostichum* sp.;

-The unique occurrence of *Mora oleifera* in the Río Caimito (Note: this site represents the northern extent of this unusual and uncommon tree; notable, since it has the largest cotyledons of any plant), and the putative *Rhizophora* hybrid, *R. harrisonii*, in the Río

Perequeté (Note: there are, however, problems with diagnostic characters for this taxon, and its occurrence is likely to be more widespread);

-The occurrence of both forms of *Pelliciera rhizophorae* on both the Pacific and Atlantic coasts (Note: the distinction between forms has not been noted prior to this report, indicating that occurrences of *Pelliciera* elsewhere need to be revised);

-The different zonation patterns of species and their associations with each other, particularly noting the occurrence of *Laguncularia racemosa* in low intertidal positions and along rocky exposed shorelines of the Pacific coast, while this habitat on the Atlantic coast is occupied by *Rhizophora mangle*.

(3.3) Marine Grass: Ten seagrass meadows were studied in the Caribbean coast. These proved to be similar to that described in the vicinity of Bahía Las Minas. In contrast, there are no seagrass meadows in the Pacific study area. The following conditions were observed in the seagrass beds in the area:

-Extensive seagrass meadows were found in locations wherever gradual coastal slopes prevailed and where water clarity was adequate.

-Densities of *Thalassia*, *Syringodium filiforme*, *Halodule wrightii*, and algae varied from site to site.

-*H. wrigthii* was typically found in very shallow water adjacent to shorelines or on tidally exposed sand bars.

-*T. testudinum*, the most abundant seagrass, covers most shallow bottoms in areas where water clarity is adequate.

-*S. filiforme* was usually mixed with *T. testudinum* along the deeper edges of grassbeds or it occurred in monospecific seagrass stands at depths past of the point of penetration of *T. testudinum*.

-A fourth seagrass species, *Halophila decipiens* was found mixed in with dense beds of algae along the deep fringes of seagrass beds.

-The zonation pattern throughout this area is also typical of many other areas in the Caribbean.

-Thirty two species of fish were collected over seagrass beds within the study area. Several species in this collection are sought by local fishermen. They are present as juveniles in seagrass beds because of the protective covering provided by the seagrass leaves. They also feed on many of the invertebrates and fish that are abundant in Panama's seagrass beds.

-Despite the fact that total acres of seagrass are relatively small within the study area the ecological importance of the grasses should not be overlooked. Seagrasses provide juvenile and adult habitat for many species as demonstrated by the numerous fish and invertebrate species collected in this study. The loss of any significant part or the seagrass community on this coast may result in decreased stocks of the fishes that are commonly eaten by local inhabitants.

(4) Benthos

Benthic collections were quarterly performed in the Pacific and in the Caribbean. A total amount of 3,378 benthic organisms were collected of which 55 % (1,848 organisms) were found in six (6) Caribbean stations. Identification of the benthic community (1.00 mm mesh size) yielded 171 taxa including one new isopod species of *Cyathura* found offshore from the Limon Bay stations on the Caribbean side.

The results from this study revealed the following:

-Mean abundance of benthic organisms was greater in the Caribbean area with 227 org./m^2 than that of the Pacific with 160 org./m^2 for the mean case. Mean abundance and number of species was 1.6 times greater for the offshore stations than those located within Limon Bay in the Caribbean. Those stations closest to the Panama Canal entrance in both oceans (Pacific: MB-01 and Caribbean: MB-09 and MB-10) exhibited a reduction in relative abundance and diversity.

-In general, mean abundance of benthic organisms in the Pacific follows a typical bimodal pattern through time, with peaks of abundance during March and July. Mean abundance of benthic organisms in the Caribbean followed a typical unimodal pattern with a peak abundance in July.

-Polychaeta, Crustacea and Mollusca were the dominant groups accounting for almost 90 % of total benthic organisms counted. Polychaeta was found in almost all stations within each sampling period. A total of 57 species or crustacean taxa (grouped in 13 taxonomic sub-categories: 1 Class, 6 Orders, 3 Infraorders and 3 Sections) were found. The peracarideans dominated the benthic community in terms of relative abundance, comprising about 20 % of total crustaceans, and relative diversity being represented by five orders (20 species): Mysidacea (2), Cumacea (2), Tanaidacea (1), Isopoda (7) and Amphipoda (8).

-Within the superorder Peracarida the dominated groups found were gammaridean amphipods and isopods (*Cyathura spp.*). With regards to the Mollusca a total of 58 living species were identified, of which 15 species are Gastropoda (14 genera in 12 families) and 43 species are Bivalves (24 genera in 14 families). Bivalves belonging to the Tellinidae, Veneridae, Corbulidae, Nuculanidae and Solecurtidae families were the most common molluscs found in the sediments.

-The distribution of benthic taxa, both in the Pacific and in the Caribbean, is fairly homogeneous with no apparent relationship with depth. However, mean abundance (277 vs. 175) and number of species or taxa (25 vs. 15) was greater in the offshore stations (MB-12 through MB-14) than those located within Limon Bay in the Caribbean.

(5) **Meroplankton**

Collections of meroplankton were carried out in July, August, November 1992, February and May 1993. The study has provided information on the abundance of eggs and larvae of fish and invertebrates.

Results showed the following:

-A peak of abundance of meroplankton during November 1992, especially at station MM-02 (Pacific) and MM-08 (Caribbean), both located at the entrances to the Panama Canal. The highest abundance of eggs of engraulid and clupeid fish was observed in the Caribbean area (17,560 and 9,091 eggs/100m^3), whereas in the Pacific the counts revealed densities of 3,503 and 2,861 eggs/100m^3 for clupeid and engraulid fish.

-The most common larvae of invertebrates at both sides were the Zoea, postlarvae of penaeid shrimps, and pteropod, gastropod, and bivalve larvae. In the Pacific area, the postlarvae of penaeids were particularly abundant between the November 1992, and February 1993 samplings. These postlarvae are believed to belong to the species *Penaeus occidentalis, P. stylirostris*, and *P. vannamei* which have been previously reported to be highly abundant in the area during this part of the year. Also, a high abundance of bivalve larvae was observed in the Pacific side and this might be related to the seasonal upwelling which enhances the phytoplankton productivity in the area.

-Larvae of engraulid, carangid, mugilid, and sciaenid fish were common in samples collected during November 1992 at both entrances to the Panama Canal (stations MM-02 and MM-08, respectively). In general, the overall abundance of meroplankton is higher in the Caribbean than in the Pacific. This might be related to the role of coral reefs, seagrass meadows, mangrove forests and estuaries as spawning and breeding areas for many marine species.

(6) **Fishes and Macroinvertebrates**

(6.1) Fish: A total of 197 species of marine fish were collected during this inventory, 113 species from the Pacific and 84 in the Caribbean. Among these, only 9 identical species were found in both oceans.

The results and conclusions from this study are the following:

-The highest diversity of sublittoral fish was related to the proximity to estuarine areas that are nursering grounds for fish larvae and postlarvae. A high diversity was recorded in the sampling stations located near the estuary of Chame, whereas the lowest diversity was observed in the shores along the Pacific entrance to the Canal. In the Caribbean, most of the diversity of species was gathered from the collections of fish in the stations located in front of Bahia Las Minas, another estuarine area.

-Fish were observed to be particularly abundant in the Pacific at the beginning of the rainy season (June 1992 and May 1993). To some extent this is believed to be related to the period that follows the dry season upwelling. Low sea temperature related to this upwelling move many fish and invertebrate species to the warmer shallow waters. The increase means the abundance observed a few weeks after the upwelling might suggest a intense recruitment of juveniles from the neighboring estuaries and mangrove bordered coast. This statement is supported by the high incidence of small sized fish collected within these samples.

-In general, the abundance of fish in the Caribbean remained fairly uniform throughout this inventory, although a slight increase in the abundance was recorded during February 1993.

-Regarding the importance of these fish within the food web, the most frequent species in both oceans are ranked as secondary consumers those that eat animals and plants (carangid and bothid fish in the Pacific and Caribbean, respectively), followed by primary consumers which feed on plankton and detritus as the gerreid fish.

-Among the commercially important fish studied in this project, the snappers *Lutjanus guttatus* and *Diplectrum eurypiectrum* (Pacific), and *L. synagris* and *D. formosum* (Caribbean) showed a gut content mostly comprised by crustaceans (shrimps, stomatopods, and crabs) and small fish. These species are placed in the category of third level consumers (exclusively carnivorous).

-The study of the gonad maturation of these fish revealed several spawnings: in August, in October, and during April.

-The genus *Diplectrum* showed sexual inversion, or protandric hermaphrodite, in both oceans (males changed into females) which explained the predominance of a single sex, mostly females, in the collections. The stages of gonad maturation were observed to occur almost simultaneously in both oceans, which is probably related to the seasonality of the climate.

(6.2) Macroinvertebrates: A total of 105 species of marine invertebrates were collected during this inventory, 56 species collected in the Pacific and 49 in the Caribbean. On the whole, 13,407 specimens were collected during the 5 quarterly samplings, 7,955 from the Pacific and 5,452 from the Caribbean.

The most important characteristics from this population are the following:

-The total collected biomass for the collections at both oceans was 239.08 kg (171.10 kg in the Pacific, and 67.98 kg in the Caribbean). The highest biomass in the Pacific was provided by the swimming crab *Callinectes arcuatus* in the rainy season collections, but during the upwelling, the squid *Lolliguncula panamensis* proved to be the dominant taxa. In the Caribbean, the biomass was mostly provided by the shrimp *Penaeus braziliensis* and another swimming crab, *Portunus anceps*.

-The species dominance in the Pacific occurred as follow: the swimming crab *Callinectes arcuatus* during the rainy season collections (July, August and December 1992); the sea pansy *Renilla amethystina* in December 1992, and February 1993; and the seabob shrimp *Xiphopenaeus riveti* in May 1993.

-In the Caribbean, another swimming crab, *Arenaeus cribarius* dominated during sampling from the rainy season (July, August, December 1992, and May 1993), this was followed by the shrimp *Penaeus braziliensis* during the dry season (February 1993).

-The composition of the samples revealed that both in the Pacific and the Caribbean crustaceans made up to 50% of the macroinvertebrates collected.

(7) **Commercial and Sport Fishery**

Most of the fishery resources of the country are located in the Pacific. In general, the fishery resources in the area have the following features:

-The most recent fishery prospections suggest that the extractable biomass in the Gulf of Panama might be around the 400,000 m.t. per year. Most of this fish stock is comprised by demersal fish and squids which are not fished (more than 100,000 m.t.). The demersal fish stock is estimated in the vicinity of 200,000 m.t. and it is mostly comprised by estromateid fish (dollar fish), some species of serranids, and snappers.

-In the Caribbean, the most important resources are the demersal species. Among these are: the snappers *Lutjanus vivanus, L. synagris*, and *Rhomboplites aurorubens*, sharks as *Rhizoprionodon sp.* and *Squalus cubensis*, some carangid fish (jacks), and the pink shrimp *Penaeus duorarum*. Bottom trawling is the best fishing gear for the snappers and the shrimps, and there is 1,000 km^2 of marine bottom suitable for this type of fishing.

-Most of the fishing effort is devoted to the penaeid shrimps stock, the anchovies and herring for the production of fish meal, and fish (mostly demersals) for human consumption. This fishing activity involves some 10,000 people and it is mostly concentrated along the Pacific coast of Panama. In the Caribbean, the fishing activity is of low intensity and mostly of the subsistence type.

-Sport fishing in Panama is based on a few species and in general, sport fishery is considered a low intensity activity and the catch is believed to be small.

2) INTRODUCTION

This Final Report includes field and laboratory data from the Biological Inventory performed between April 1992 and July 1993 as established by the Terms of Reference for the project Biological Background Data and Biological Inventory executed by the University of Panama Co nsortium-ANCON Consortium for the Commission for the Study of Alternatives to the Panama Canal.

The main objective of the study was to carry out a biological inventory and establish a data base on the following component of the fauna and flora both terrestrial and aquatic (freshwater and marine). The inventory also included the physical and chemical features in the canal freshwater system and its marine approaches. This information is intended to serve as a baseline for the environmental impact study and identify the ecological sensitivity of the area, regarding the construction of any of the proposed alternatives to the Panama Canal.

The components considered within this study are the following:

-Terrestrial flora, which studied the natural forests, grasslands, crops, and also verify the existing information on the soils in the area.

-Terrestrial fauna, which studied mammals, birds, amphibians and reptiles, and insects of medical or economical importance.

-Freshwater, gathered information concerning the water and sediment quality, aquatic plants, benthos, fish and macroinvertebrates, aquatic mammals, and a general description of the commercial and sport fisheries.

-Marine, studied the oceanography, water and sediment quality, coral communities, mangroves, seagrasses, benthos, meroplankton, fishes and macroinvertabrates, and a general description of the commercial and sport fisheries.

The study area exhibits ample ecological diversity as reflected by the large number of reported species. The forest cover has been notably reduced consequently affecting the wildlife, although some disperse remnants of the prototype species allows the reconstruction of the original physiognomy. An extense area has been covered by lakes Gatun and Alajuela as required for the canal operation, thus creating a large lenthic type aquatic habitat, non-existent prior to the construction of the canal. The marine approaches have been substantially disturbed by the construction, operation, and maintenance activities of the canal.

The complexity in the biodiversity in the study area fully justify the inventory and the interest of the Commission for the Study of Alternatives to the Panama Canal for a proper documentation of the biological resources in the area, which could be disturbed as a consequence of the possible environmental alteration.

3. MATERIALS AND METHODS

a) TERRESTRIAL

(1) The Physical environment

The information regarding the physical setting was obtained from existing references. The climatic and ecological information have been summarized from the technical report: Life zones, prepared by J.A. Tosi sponsored by the FAO (Tosi 1971). The soils in the studied area were surveyed by the Rural Census of Lands and Waters of the Republic of Panama (CATAPAN), from 1960 to 1965. During this study soils were sampled (10 at each permanent flora sampling site) and were analyzed in the Soil Analysis Laboratory at the University of Panama observing the standard procedures. Results were compared with those presented in maps from CATAPAN.

(2) Flora

(2.1) Selection of sampling sites

The initial reconnaissance period included the review of existing maps, helicopter overflights, and visits by land. A cartographic review was done for the entire area, using black and white photomosaics, some color aerophotographic lines, Life Zones maps, and vegetation maps.

The land reconnaissance was conducted by vehicle and on foot to investigate the western side of Lake Alajuela (Madden), the Camino de Cruces, the area between the Gaillard and Transistmica highways, the highway to Cerro Jefe, and the transisthmian road, including the road toward Salud and the western side of the final stretch of the Chagres River.

The areas reviewed by helicopter were Chico, Candelaria, Peluca, Puente Rio Gatun (Transistmica), the Bay of Colon, the mouth of the Chagres, Zorra Island, Juan Gallegos Island, Barro Colorado Island, Los Canones, El Chorro, Corte Culebra, the western bank of the Panama Canal, Loma Coba, Vacamonte, and Taboga.

Each site was flown over three or four times at a height of approximately, 150 m, in order to obtain a real impression of the vegetation coverage in the area:

-Chico: Secondary forest.

-Candelaria: Secondary forest and crops.

-Peluca: Secondary forest and pasture.

-Gatun River Bridge: Gallery forest and pasture.

-Bay of Colon: Aquatic (with signs of oil on the surface).

-Mouth of the Chagres: Primary forest or almost fully grown.

-Zorra Island: Late secondary forest.

-Juan Gallegos Island: Late secondary forest.

-Barro Colorado Island: Late secondary forest.

-Los Cañones: Pasture.

-El Chorro: Pasture.

-Corte Culebra: Area of land removal.

-West bank of the Canal: Secondary forest.

-Loma Coba: Semi-urbanized.

-Vacamonte: Semi-urbanized.

-Coast in front of Taboga: Underbrush with remnants.

Sampling sites (Map N° 1) were located according to the recommendations of the TOR, adjusted to the real conditions and the representativity of principal ecosystems, accessibility, and available time and personnel, and were established as follow:

SAMPLING SITES	COORDINATES	
	Longitude W	Latitude N
1. Cruces	79°38'	9°11'
2. Mandinga River	79°43'	9°06'
3. Cerro Jefe	79°23'	9°15'
4. Pequení	79°32'	9°22'
5. Chagres	79°59'	9°17'
6. Trinidad	80°02'	8°58'

At the sampling sites transverse strips (transects) 1 Km long and 10 m wide (1 hectare per transect) were established. The transects were sub-divided into 10 consecutive plots 100 x 10 meters each (1,000 m^2/plot).

(2.2) Plant collections and field measurements

In all the plots, arboreal species greater than 10 cm DBH were measured and identified, and in plots 2,4,6,8, and 10 (total register or RT parcels) every species was recorded (trees, bushes, vines, grasses, and epiphytes), and herbarium samples were taken. The transect gave the necessary information to determine abundance, frequency, density, trunk volume, mixture quotient, horizontal expansion, and the index of the importance value of trees with DBH > 10 cm. Furthermore, the RT parcels provided the necessary data to determine the same characteristics in other species found at the site.

Each sampling team noted information on "field sheets" prepared especially to register data necessary to fulfill the objectives of the study. The samples and the rest of the information were handed in after each field work day to be processed in the laboratory.

The following parameters were determined:

-Mixture Quotient (MC): Measures the mixture intensity in heterogeneous forests. The number of species found is divided by the total number of individuals in the sample to obtain a figure which represents the average number of individuals of each species in the association.

-Absolute Abundance: Is the number of individuals of each species in the sample.

-Relative Abundance: Is expressed as the percentage of each species in terms of the total number of individuals in the sample.

-Absolute Frequency: determines the regularity of the distribution of each species on the land. To obtain this figure, the sample was divided into equal sub-plots and the presence or absence of each species in each subplot was checked. The absolute frequency is then expressed as a percentage of the total number of sub-plots (100%) in which the species appears.

-Relative Frequency: represent the percentage that the absolute frequency of each species is from the sum of the absolute frequencies of all the species present.

-Horizontal Expansion: is the section of the soil surface indicated by the horizontal projection beam of the plant's body. It is equivalent, in forest analysis, to the sum of the projections of the crowns of each species. It is often impossible to determine these values in tropical forests because of the presence of superimposed crowns. To overcome this difficulty, a suggestion has been made to use the basal area as a substitute for the crown projections. The final result is expressed as a percentage of the individual basal area of each species in terms of the total basal area.

-Index of Importance Value (IVI): is the numerical sum of Relative Abundance + Relative Frequency + Horizontal Expansion. As this is the sum of three percentages, the total value for all the associated species should be 300.

For the lay out of sample strips the following aspects were considered:

-Type of sample: transverse sections (transects or strips) numbered 1 to 6.

-Dimensions of each strip: Length 1000 m.
Width 10 m (5 m each side of the axis).
Area 10,000 m^2 = 1 hectare.

-Bearing: was determined in each location according to the topographic conditions and the type of vegetation cover. In general, the axis runs perpendicular to the main slope.

-Tracing the axis: beginning at point "0" (origin), the total length was marked with stakes numbered 1 to 50, 20 meters apart, thus marking 50 sub-plots (200 m^2 each).

For the statistical evaluation, the sub-plots were combined into groups of five, for a total of ten parcels of 1000 m^2 each (100 x 10). The parcels are sampling units numbered 1 to 10. The stake numbers were established by two numbers hanging vertically in the following manner:

1 2 3 ... 5 6 7 1 1 1 ... 1 2 2

The first number identifies the station or sub-plot (from the origin point) up to 50, the last stake. The second number (from 1 to 10) identifies the number of the plot.

Examples: 1 first sub-plot
1

3 third sub-plot
1

6 sixth sub-plot
2

50 last sub-plot
10

The following parameters were recorded at each sample plot:

-Name: each individual in the sample should be identified with a name (species, genus, family, or common name) and a consecutive number.

-Numbering: each individual in the sample has a number (consecutive numbers beginning with 1). These numbers allow the location of any specimen that has not been named, or that is special interest. The specimen can be later identified in the field or laboratory to obtain the total number of individuals and the number per each species in each sub-plot, each plot, and each strip.

The numbers are written with indelible markers on a small peeled area on the front of each trunk. For those plants whose diameter is too small, a 15 cm band of polyethylene is used, and the number marked with felt tip marker.

-DAP or DAB *:(diameter above butress), is measured in centimeters, at a height of 1.3 m. When tabular roots prevent measurement at 1.3 m the diameter measurements are taken above the roots (DAB)(diameter above butresses) or are estimated. a special measuring tape is used (diameter tape), which converts circumference to diameter.

-Location of individuals: a system of coordinates is used for each specimen, the axis of the plot being the ordinate and the initial limit of the plot the abscisa. A letter I (izquierda), left, or D (derecha), right, establish the position of the plant in relation to the axis of the plot.

Collected samples were treated as follow:

-In the plots marked for the study, one or two samples of each individual that has been marked were taken. On one day field trips, the material collected was brought to the laboratory and immediately pressed, using conventional methods. On the week-long field trips, the samples were pressed on site and placed in plastic bags and moistened with 70% ethyl alcohol. Whatever the method used in the field, the material was processed and dried using the facilities of the Herbarium of the University of Panama.

During all the stages of the process, the material was carefully marked to prevent any confusion about its origin. All the information on specimens (DAP, number of individuals in the field, height, collection site, etc.) was noted in special notebooks (one per site) that were kept in the laboratory for the use of the personnel who identify the material. A file was also maintained in DBASE III+ which contained the data obtained from field samples. The samples were studied using existing equipment in the Herbarium of the University of Panama (stereoscopes, microscopes, etc.) and the attached bibliography (also found in the Herbarium). Then, the material was compared with material already deposited in the Herbarium of the University of Panama. The identification of the material was done in three stages. The first was carried out in the field, the second in the laboratory, which was provisional until the material can be verified by the principal investigator during the third stage.

(2.3) Laboratory procedures

Laboratory work considered three different aspects:

-Processing of samples: During the study 29,528 plants were recorded from the 6 visited sites. The collected samples (about 12,000) were pressed and oven-dried, and pertinent information annotated on specific site log book. Each, plant was given a collection number. Classification and family/genus or species sorting was completed.

-Identification of samples: From the 29,528 records processed during this study, 1,947 were determined only to family (6.6%) and 27,581 to species (93.4 %).

-Data processing: A computer program (Dbase) was created for the calculation of abundance (absolute and relative), frequency (absolute and relative), basal area, timber volume and other parameters needed for field data analysis. After several tests, verifications and corrections, the program was ready to be used. The analysis of each site file takes about eight hours of computer continuous running.

Two computer technicians entered 29,528 records, each of them implied up to 24 computer fields. For analysis of the data, partial files were created for each sampling site. Although an original effort of 10 m/d was estimated, this was changed to 19 m/d.

(2.4) Filed data

Field records from six sampling sites totalled 29,528 and these are distributed as follows:

CRUCES	MANDINGA	JEFE	PEQUENI	CHAGRES	TRINIDAD	TOTAL
3377	1780	12521	4308	2498	5044	29528

(3) **Fauna**

(3.1) Entomology

(3.1.1) Description of sampling sites

The locations that are described in the following paragraphs (Map N° 1) represent the general areas where samples were taken; however, as specific samples were taken from different places within each location, more precise information regarding this matter is contained in Table N°1.

-Paraiso: is located on the Pacific side at approximately 9° 01' latitude N and 79° 37' longitude W, on the eastern side of the Canal. It is an urban area containing grassy vegetation in vacant lots and forested areas.

The sample for aquatic insects, was taken on an inlet of Lake Miraflores. In Paraiso, the bottom is covered with rocky slabs. The water is clear with a great deal of turbulence because of the passing ships. There are few aquatic weeds and little accumulated leaf litter.

-Gamboa: is located on the Atlantic, at approximately 9° 07' N and 79° 41' W, east of the Canal. It includes a populated urban area and forested areas.

Aquatic sampling was carried out on the banks of the Chagres, which has abundant aquatic vegetation.

-Arraijan: is located on the Pacific side, at approximately 8° 58' N and 79° 39' W, west of the Canal. The sampling site is found 2.6 km (1.6 miles) from the Interamerican Highway, turning off on the road to Nuevo Emperador at a place known as "Botija". It is a farm with various types of fruit trees. There are rural houses in the area, small farms, and forested areas.

The aquatic sampling was conducted in the Cocoli River, on the same road, approximately 5 km from the Interamerican Highway. This particular source of water was chosen for aquatic insect sampling because water flows all year, even during the dry season.

-Arenosa: is located on the Atlantic side, at approximately 9° 02' N and 79° 56' W, west of the Canal. The town is located on the banks of Gatun Lake. The populated area is made up of houses surrounded by orchards.

On both sides of the access road, which begins at Interamerican Highway and continues 33.6 km (21 miles) to La Arenosa, one sees an uneven topography of small hills and rises, which have been converted into pastures, with scattered corozo palms. Cattle ranching predominates, with some fruit and poultry farms. There are few forested areas.

The aquatic sampling was carried out on the banks of Lake Gatun, near and to the side of the community's school.

(3.1.2) Field methods and laboratory procedures

-New Jersey black light traps (Photography N° 1): They run on electricity and are made of tin. They are cylindrical in shape, measuring 63 cm in height and 25 cm in diameter, and have a circular roof 38 cm in diameter. Inside the trap, in its upper part, there is a "U" shaped black light bulb lined on the outside by a 4 mesh screen, which allows mosquitoes, sandflies and other medium size insects to get in, but not the larger ones. Within the body of the trap, and under the light bulb, there is a small fan that sucks in the insects attracted

by the light, which are then collected in a killing jar attached to the lower part of the trap. This trap has a photoelectric cell which sets on the black light bulb at dusk and turns it off automatically at dawn.

Two traps had been installed at each sampling site, except in Arraijan, where there was only one. They were usually hung at a height of approximately 2.5 meters, and located one near the lake and the other within the town or village. During the week, each trap was operated during one night; the material caught was preserved in 70% ethyl alcohol, taken to the laboratory, sorted out and identified; particular interest was placed on insects that affect man and animals.

-Oviposition traps (Photography N° 2): Disposable containers, filled with water, were placed (one at each sampling site) in a wooded area. The water in the containers was collected weekly on each sampling date, taken to the laboratory and transferred to mosquito breeding chambers where emerging larvae and adults were identified. From the thirteenth week on, bamboo traps replaced the former.

-Aquatic net: consisted of a metallic frame and a 20.3 cm. (8") diameter strainer with 1 mm mesh. The strainer was attached to a 134 cm pole, which allowed the team to take samples further from the banks.

In the field, each netting sample (five in total) was emptied into a plastic basin (24 cm in diameter and 10.5 cm deep) filled with clean water to wash the sample. The sample was filtered through a plastic sieve (10.5 cm in diameter and 5.5 cm deep, with a mesh opening of 0.5 mm) and then placed in a polyethylene bag. 75% ethyl alcohol was added to cover the entire sample. After each sampling, a label with the following information was placed on the bag: location, type of sample, and date. The five netting samples were then placed in a polyethylene bag. All the samples were placed in a five gallon plastic tank, covered, and brought to the entomology laboratory.

In the laboratory, each sample was filtered with a plastic sieve to eliminate the alcohol which had been contaminated with sediments and chlorophyll. The sample was next placed on a metal tray and the specimens were separated using a 2x magnifying glass. This procedure was repeated four to five times in the case of the Gamboa and Miraflores samples, and once for the Arraijan and Arenosa samples. The former had greater amount of plant debris. Once separated, the specimens were placed in 9 dram plastic vials to later be identified by Order, Family, and genus, depending on their relative importance for the study.

-Hand dipper: This technique involves the use of a plastic container which looks like a dipper (11 cm. in diameter and 5 cm deep) with an adjustable aluminum handle, 116 to 162 cm long.

In the field, each dipper collection (ten in total) was filtered through a plastic sieve, and placed in a polyethylene bag. 75% ethyl alcohol was added to cover the entire sample. A label was placed on the sample with the following data: location, type of sample, and date. Ten dipperfulls placed in a polyethylene bag made up one sample. These samples were placed in a covered plastic tank to be brought to the laboratory. Once in the laboratory, the material was processed similarly to the aquatic net samples.

-Human bait: Was used to capture insects which bite human beings. At each sampling site, mosquitoes and other insects were collected for 10 to 15 minutes. A manual battery vacuum was used to capture the insects which hovered above the subjects at the sampling site. The insects were then brought to the laboratory, where they were placed in 7 x 9 cm flasks with ethyl acetate to kill them. Then they were mounted on insect pins, together with the collection data and the species identification. Once identified, the material was stored in entomological cabinets with its respective collection data.

-Carrion trap (Photography N° 3): is used to capture necrophagous insects. It consists of a two liter plastic bottle cut in half. On the upper part of the bottle, the mouth with the screw top is cut, inverted, and placed in the lower half as a trap. In the widest part of the trap, a small metallic screen with 1/4" mesh is placed. The small cage is 23 cm (9") high, with a diameter of 9 cm (3.5"). Two wooden stakes were placed around the trap to ensure that the trap components (the bottom, top, and metal cage) remained upright. The lower part was buried in the soil, and the plastic parts were placed between it and the cylinder cage. 75% ethyl alcohol was poured into the lower part to preserve the insects that were attracted to the trap. As the trap was being set up, a rat was killed by a blow to the head, and placed in the cylinder wire cage. This was repeated at each sampling station once a month. The cadaver attracted insects who slipped on the trap and fell into the alcohol. Once a week, the insects were taken out of the alcohol and transported to the laboratory in flasks with their respective collection data, location, and date.

In the laboratory, the sample was separated with the help of a table magnifying glass and a stereomicroscope. Then the insect Families and quantities were logged. All of the material was stored in vials with 70% ethyl alcohol, which were properly labeled.

-McPhail traps (Photography N° 4): used to capture carpophagous and saprophagous Diptera, as well as other miscellaneous insects and natural enemies. 16 glass, 300 cc McPhail traps were used, each equipped with rubber stoppers and wire hooks for installation. A solution of 5% hydrolyzed "torula" protein and 2% urea (46%N) were used as bait. 0.1% borax (sodium borate) was used as both a preservative and insecticide. The bait was prepared a day before the traps were placed in the field, for each week of sampling, using tap water to dilute it. The solution bait was carried to the field site in two liter plastic bottles.

At each sampling site, four traps were installed (from week No.8 on two traps were used at each location). If possible, the traps were installed in cultivated or natural fruit trees

found in the immediate sampling area. The traps were placed six to ten meter from one another. Each trap was baited with approximately 200 cc of solution.

A wooden pole, with two detachable 1.5 m sections and a hook on the end, was used to hang the traps which were usually hung on the third lowest branch of the selected tree. Depending on the height of the tree and terrain conditions, the traps hung two to five meters from the ground.

To check a trap, the team removed it from the tree with the wooden pole described above. The rubber stopper was removed and the contents were sifted through a fine mesh sieve. Then, tap water was poured into the trap, to collect whatever specimens might have stuck to the walls of the trap, as well as removing residues from the earlier solution. The trap contents were again poured through a sieve, which at the same time washed the biological sample. The biological material retained on the sieve was transferred with a synthetic fiber, medium sized brush, to a 40 cc, pre-labeled flask, filled with 15 to 20 cc of 70% ethanol.

Once this procedure was completed, the trap was rebaited and reinstalled following the procedure described above.

In the laboratory, each sample was emptied onto a 100 mm petri dish, and the sample was processed under a 15-45x stereomicroscope. The samples were separated and counted by Order, Family, and in some cases (Otitidae and Tephritidae) by genus. Species of the same taxon from the same sampling site were stored in glass vials with bakelite screw tops and filled with 70% ethanol. Vials from 0.5-2.0 drams were used, depending on the size and abundance of the samples. Each container was given a code and labeled. The results were logged on sheets designed especially for that purpose.

-Berlese funnel (Photography N° 5): was used to capture insects in underbrush and on soil surface. Once a week a square meter of leaf litter on the soil surface was collected at each sampling site. The leaf litter was placed in a black plastic bag, and labeled with the name of the station, the week, and date.

Once in the laboratory, part of the bag's contents were placed in the Berlese funnel, which contained 70% ethyl alcohol at the bottom, to preserve the Arthropods which emerged from the leaf litter. Every two days, the insects in the alcohol were removed, and more of the leaf litter was placed in the trap. The alcohol that preserved the insects was also changed on a regular basis. This procedure was repeated until the sample brought from the field was terminated. When the insects were removed from the alcohol in the Berlese funnel, they were placed in a flask with the same data as the sample. A portion of the insects were then emptied onto a 9 x 1.5 cm petri dish. The insects were separated and counted using a stereomicroscope and entomological tweezers. On a previously prepared work sheet, information on the type of collection, date, week, location, and taxa, were logged. The Family name was also written down, as well as the number of individuals for that sample of that particular location. This procedure was repeated for each site.

-Pitfall traps (Photography N° 6): to capture insects which walk on the ground, the "pitfall" trap was used. This trap consisted of an empty container, in this case, a one gallon can was used (from week No. 2 on traps made of disposable plastic bottles as shown in Fig. 1b were used). The trap, baited with hydrolyzed protein, was buried so that its upper edge was level with the soil to allow the insect easy access. A cover was placed on the trap to prevent it from filling with rain water.

Once a week, the insects in the traps were collected and processed in the laboratory. With the help of a stereomicroscope, the insects were separated and classified. The data were written down on a previously prepared sheet, which contained the collection date, location, and week. The Family name and the respective quantity were also recorded.

The processed material was stored in properly labeled vials with 70% ethyl alcohol. This routine was repeated once a week for each sampling station. Density was expressed as the number of insects per exposure period.

-Sweep net: At each site, 100 sweeps were made using a 38 cm (15") diameter net, distributed in five series of 20 sweeps, over grassy vegetation, making 180° angle sweeps. Sweeps were completed on both sides of the path covering a distance of approximately 60 meters in the following manner: first, 20 sweeps were made with the net, after the sweeps were completed, the collected insects were placed in a 20.5 x 36 cm polyethylene bag, coded earlier with the date, place, and series to identify the sample. In addition to the label, paper towels were placed in the bag to absorb the humidity and better preserve the specimens. This procedure was repeated five times, for a total of 100 sweeps. At each site, the same procedure was followed, and the polyethylene bags were stored in a 36 cm high (30 cm diameter) bucket, which was kept closed until arrival at the laboratory.

In the laboratory, the bags were opened one at a time, a sheet of toilet paper wetted with ethyl acetate was placed inside. The bags were then closed for a 30 to 40 minutes to kill the insects. In the meantime, twenty 4.8 x 3.4 cm vials were prepared with 70% ethyl alcohol, and coded for each sample. The specimens in the bags were transferred to the vials filled with alcohol, and some were mounted with pins.

Later, the insects in vials were classified by Order and Family. The specimens were counted and the data logged on a record sheet designed for this purpose. Genus and species were also registered, when known.

The samples preserved in alcohol and the mounted specimens were stored, after being properly coded.

-Insect from plant residues: Rotten woody parts of plants (stems, limbs) were collected at each sampling site, placed in black plastic trash bags, closed tightly and taken to the insectary; there they were put in 55 gallon drums (one for each locality) for observation. Each drum had two holes, 15 cm from the upper edge, to which a transparent plastic sleeve

18 cm long and 7 cm wide had been attached. Emerging insects attracted by light were caught in the plastic sleeve, retrieved for identification and pinned or preserved in alcohol.

(3.1.3) Data analysis

The data were analyzed for ecological diversity using the Shannon-Weaver (H') index. Pielou (1969, 1975) and Ludwig (1988) suggest the diversity in a biological community depends on the number of taxa present and the relative abundance of each group, the latter considered as the equitability index (J') or ecological equilibrium (Price, 1975).

(3.2) Herpetology

The inventory of the amphibians and reptiles was performed in the following study sites: (1) Cirí, (2) Sherman, (3) Corte Culebra (Gaillard Cut), (4) Cocolí, (5) Pequení, and (6) Tranquilla. These sites were selected during the reconnaissance surveys made in the Canal Watershed. A brief description of these six sites is presented next.

-Cirí: An area of difficult access. The trip consisted in traveling by boat from Cuipo, through the Gatún Lake, and the Cirí Grande River, to El Chorro; from there walking to a house near the Panama Canal Comission's station in Cirí Grande. This route is located in the Panamá and Colón Provinces.

The region is almost devoid of forest, predominating extensive pasture lands with streams bordered by reduced gallery forest. The terrestrial areas sampled were located inside 80°03'15"-80°04'09"W and 08°56'41"-08°58'18"N (Map N° 3). They are within the Tropical Moist Forest, according to Holdridge's life zonation, and at elevation of 20-220 m.

This site was selected because it could be affected, in case of the creation of an artificial lake for the operation of the Canal.

The sampled areas inside de forest of this region was made in the gallery forest bordering the Cirí Grande River near the station. In this zone, the river is somewhat wide with a strong current. In addition, the reduced gallery forests along several small streams adjacent to the pasture areas were sampled.

The sampling of the open areas were performed in the pasture lands close by the Canal Commission's station, these areas have pasture, low grasses and some small bushes. These pasture lands have several wet areas due to small streams, water holes and marshes with tall grass. Other open areas sampled were near cultivars.

The sampling of the aquatic zones and their margins was performed during the boat trip from Cuipo, through Gatún Lake and Cirí River, to the Chorro and viceversa (Map N° 3).

No transect was established in this study site, because we did not found a suitable place.

-Sherman: A site with an easy access by the Gatún Road (S2). The main study area was established in the Fort Sherman's Military Reserve, in a forested region delimited by the Gatún Lake, the Chagres River and the Panamá Canal. In this site there is a swamp known as the Mojinga Swamp, with a dense population of Cativo trees. Also, there is a coastal zone of mangroves. Another area sampled was located in the surroundings of Gatún. All the sampled areas were inside 79°54'11"-79°31'30"W and 09°22'00"-09°24'15"N (Map N° 3), in the Colón Province; within the Tropical Moist Forest, according to Holdridge's life zonation, and at elevation of 0-100 m.

This site was selected because it had relatively extensive areas of forest with open areas nearby, which facilitated their study. In addition, it is a site adjacent to the north entrance of the Panamá Canal.

The forested area has a somewhat disturbed secondary forest, apparently with areas of old forest. The forest has several small streams. Near the entrance to the Tropic Test Site (Skunk Hollow), two transect were established, one along the margins of a small stream and another besides this stream, approximately 10 m away, within the forest. Both transects were located at 79°57'18"W and 09°19'36"N.

The open areas sampled were the grassy zones along the roadside, which contained some ponds. A transect was established in an open area having an extensive zone of mid-sized grass, crossed by numerous channels of shallow water (approximately 10-40 cm deep); this transect was established along one of these channels. This locality was near the French Canal, at approximately 79°55'49"O and 9°17'11"N.

-Corte Culebra: The area of Culebra has an easy access, using the Gaillard Road, turning westward at Summit Gardens, and then by the Old Gamboa Road. This zone is crossed by several roads, used for the maintenance of the Canal. The study area was located inside 79°38'15"-79°40'16"W and 09°02'23"-09°05'00"N (Map N° 3), in the Panamá Province. It is within the Tropical Moist Forest, according to Holdridge's life zonation, and at an elevation of 20-140 m.

This site was selected because of the presence of forested areas and open areas near each other, facilitating its study. In addition, this site could be altered by the widening works for the Canal.

Some sampled areas were located within a forested zone close to the Panamá Canal. This zone has several forest streams. Near the forested zone and in the adjacent areas of the Canal, there are open grassy areas, mainly along the roads. Also, some U.S. military facilities are located in this site.

The forest is secondary, and somewhat disturbed. Within the forest two transect were established, one along the margins of the Masambí Grande River, and another close to this river approximately 10 m away. Both transects were located approximately at 79°39'32"W and 09°04'02"N.

A third transect was established in the open areas, it ran across ponds surrounded by tall and low grass at different sections. The open area transect was located in the vicinities of a road parallel and next to the Panamá Canal. Because of the short extension of the ponds, the transect was made in two nearby sectors situated approximately at 79°39'17"W and 09°03'25"N.

-Cocolí: Is a site with an easy access by the Cocolí roads: K2, K9 and K6. The area studied in this zone is located between 79°35'36"-79°38'20"W and 08°58'15"-08°59'30"N (Map N° 3), near the southwest entrance of the Panamá Canal, in the Panamá Province. It is within the Tropical Moist Forest, according to Holdridge's life zonation, and at an elevation of 0-160 m.

This site was chosen for the closeness of its forested areas and open areas, which facilitates sampling. In addition, it is situated adjacent to the south entrance of the Panamá Canal.

The forest of this zone is secondary, somewhat altered as it is part of a military training area, and it is crossed by several streams and rivers. Two transects were established within the forest; the first along the margins of the Cocolí River, and the second approximately 10 m away. Both sampling sites were located at approximately 79°37'00"W and 08°59'00"N.

In this site there are also many open areas next to the forested zones, generally along the edges of the roads. Some have small to large ponds, and in an abandoned quarry are 2-3 small lagoons bordered by tall grass. At this last location, a third transect was established, located at approximately 79°37'00"W and 08°58'30"N.

-Pequení: It is an area of difficult access. The trip consists of traveling by boat from Nuevo Vigía through the Alajuela Lake and along the Pequení River to reach the town of San Juan de Pequení. The area of terrestrial sampling was located between 79°30'48"-79°31'30"W and 09°22'30"-09°24'15"N (Map N° 3). It is situated mainly within the Tropical Moist Forest, but some areas being inside Premontane Wet Forest, according to Holdridge's life zonation; and at an elevation of 80-360 m.

This site was selected because it may be affected if an artificial lake is created for the functioning of the Canal.

The forests near the town of San Juan de Pequení are secondary and very altered. The majority limited to the edges of rivers and streams. This panorama dominates the entire area near the Pequení River, because the human activity is concentrated along its margins. Nevertheless, less altered forest is found several kilometers away from this town.

Two transects were established in the nearest forest area. The first was situated along the margins a stream which flows directly behind the Canal Commission Station; while, the second was 10 m away, within the forest. Both transects are located at 79°31'20"W and 09°23'00"N. It should be noted that this forest is extremely altered, as water pipes for an aqueduct were been installed. Furthermore, it is repeatedly interrupted by cultivated areas or by abandoned crops. For these reasons, the transect is irregular and interrupted in some sectors.

The prevalent habitat in this study site was open pasture areas. This type of habitat was sampled; however, no transect was established in it.

Another habitat studied in this area was the aquatic zone and margins of the Alajuela Lake and the Pequení River (Map N° 3). These zones are largely used for agriculture and cattle ranching, dominated by grasslands and underbrush. While most of the zone has calm waters, there are rapids in some sections of the river.

-Tranquilla: The trip consisted of a boat travel through the Alajuela Lake from Nuevo Caimitillo or Nuevo Vigía towards the settlement of Tranquilla.

Tranquilla is a populated zone. The vegetation consists of grasslands that extend on the entire area, and that are denser in the unpopulated areas near the margins of the lake. From the town, reduced and very altered forests interspaced with cultivated areas, can be observed. Also, can be observed zones modified for recreational purposes, such as fishing and aquatic sports. Nevertheless, the Tranquilla River and the adjacent stream have relatively lightly altered forested areas.

This site was selected because it may be affected if an artificial lake is created for the operation of the Canal.

The area of terrestrial sampling was located between 79°32'36"-79°33'27"W and 09°14'09"-09°15'16"N (Map N° 3), within the Tropical Moist Forest, according to Holdridge's life zones, and at elevation of 60-120 m.

Observations were made from the boat in the aquatic zones and their margins from Nuevo Caimitillo or Nuevo Vigía to the town or the Tranquilla River, in the Alajuela Lake (Map N° 3). In addition, were sampled the margins that consisted of open grassy areas around the town of Tranquilla, and forest of the Tranquilla River and the adjacent stream.

No transect was establish in this site, because an appropriate area was not initially found.

(3.2.2) Sampling of amphibians and reptiles

At each of the selected sites, the amphibians and reptiles were sampled within the categories of habitat, defined as follows: (1) open areas (i.e. without canopy): consisted mainly of pastures

and grasslands, scrublands, cultivated areas, peripheries of populated zones, lagoons, and ponds; (2) forests (i.e. a canopy present, even if incomplete): included in here are different states of secondary and primary forests, as well as streams or creeks that are found within the forests; (3) aquatic zones and their margins: composed by large rivers and lakes. These habitat categories roughly correspond to certain types of vegetation or plant groupings.

The inventory of herpetofauna was conducted in two forms: (1) through a generalized search, and (2) using transects. The generalized searches and transects were used to obtain the information needed for an inventory of species, based mainly on the observation of juveniles and adults. In addition, the transects were used to obtain data on the seasonal variation in abundance of individuals (i.e., juveniles and adults) of some species.

The generalized searches were conducted visually, walking, and checking the ground surface, leaf litter, vegetation, underside of logs and stones, cavities, ponds, the banks of lakes, rivers and streams and other appropriate sites. Any sampling bias due to searching in suitable places where amphibians and reptiles are expected to be found is inevitable, as a faunal inventory requires to find the highest number of species possible. Most of the generalized searches were made while walking; however, occasionally they were done from a boat or vehicle. The boat was used to sample the aquatic zones and their margins while traveling to the terrestrial sampling areas. The vehicle was used to sight animals in the edges or crossing the roads, and to locate sites from which the anurans vocalized; while, moving within the study area from one place to another. Generalized searches were carried out both during the day and at night. In each search were recorded the duration, the number of participants, the category of habitat where it was conducted, and the number of individuals of each species observed.

The vocalizations of anurans (i.e., frogs and toads), especially their species-specific advertisement calls, were used to determine the species that were present in study sites, even when not seen. Tape recordings of the calls of some species were occasionally made for posterior verification in the laboratory. These auditory observations were made during the generalized searches and walks along the transects.

Transects of 200 m in length were established in those study sites with suitable areas and conditions. The transects were made in the forested and open areas, whenever possible. They were established in the following manner: one along the margins of a pond for the habitat of open areas; another at least 5 to 15 m away from any source of water, for the forest habitat; and another in the same forest habitat but along the margins of a creek or small stream. These transects were walked by an observer, who during his walk noted the species and number of individuals of each species found, within a width of 1 m and a height of 2 m. The same person walked all of the transects to lessen variations caused by the observer. Two walks were made in each transect, one during the day and the other at night, in order to sample animals with different patterns of daily activity. The resources and time limitations did not permit the duplication of transects, although this would have been ideal. Nevertheless, in three study sites the walks along the transects were repeated by another person on a different day or night, to obtain an estimate of the variability in the counts.

Observations were made in aquatic zones and margins of lakes and rivers, while travelling by boat to the study sites, looking for crocodiles, caimans, turtles and basilisks. To complement the data obtained by us, local residents were questioned about the presence and abundance of crocodiles, caimans, iguanas, and poisonous snakes.

A non-destructive sampling of the habitats was made, always trying to minimize their alteration and to avoid any effect on the observation of animals.

(3.2.3) Data analysis

The sampling effort made in the generalized search is given in person-hours for each study site. The person-hours used during the walks along the transects was added to obtain the total effort.

In the list of amphibians and reptiles are shown all the species found visually during the generalized searches and the walks along the transects, and those anuran species that were determined by their vocalizations, even when not seen. The additional information given by local residents on some species was minimal, because most of these species were seen by us.

The abundance of each species was estimated in two ways: (1) using categories of abundance, and (2) using visual counts per effort unit.

The categories of abundance follow the work of Rand and Myers (1990). The observed species were assigned to one of the following categories of abundance: Common - when many individuals can be found, Usual - when can be found in the appropriate season or habitat, Infrequent - when unpredictable, and Rare - when rarely seen. The use of the categorization system has the advantage of allowing to present an estimate of abundance, not only for those species found visually, but also the ones difficult to see and that are heard. This is particularly important in the case of arboreal species. Nevertheless, a disadvantage in the use of this categorization system is its subjectivity.

The total number of individuals of each species found during the whole period of this study was used to calculate the abundance per effort unit. It includes all the individuals counted visually during the generalized searches and walks along the transects. The total number of individuals of each species was divided by the effort in person-hours, to obtain the number of individuals per effort unit. This number of individuals per effort unit was calculated for each category of habitat present in the study sites. The number of individuals per effort unit was used as an estimate of the abundance of each species according to the sampled habitat. However, to facilitate its presentation in the Results and Discussion Section, the number of individuals per effort unit was grouped by genus, but in the case of the snakes into the suborder Serpentes.

The seasonal changes observed in some species was extracted from the counts performed during the walks along the transects. Only the information on the commonly observed species was analyzed; those species found infrequently or represented by a few individuals were omitted from this analysis, because of insufficient data. It has to be mentioned that the obtained results are

not very accurate because the counts were only done in the preestablished five sampling periods, and they have a limited generalization for being performed for one year only.

In addition, seasonal changes in the reproduction of anurans were observed, based on the advertisement calls of some species. The advertisement calls are produced by males to attract conspecific females to mate. The result presented for a given species is a summary of a pool of observations made during the sampling periods at the several study sites.

During the generalized searches and the walks along the transects, general observations were made about the utilization of the habitats. These ecological observations for each species of amphibians and reptiles were presented in a list. This list also includes information on their daily activity pattern and breeding sites, based mainly on our experience and occasionally on the literature.

(3.3) Ornithology

(3.3.1) Sampling sites

At each selected site (Map N° 4) birds were studied according to the habitat categories as follows:

-Open areas (i.e., without canopy), consisting mainly of grasslands, pasturelands, bushes, crops, borders of populated areas, as well as streams within them.

-Forest (i.e., with a canopy, although sometimes incomplete), corresponding to different states of secondary and primary forests, including streams and brooks within.

-Aquatic zones and their littoral constituted by lakes, lagoons, swamps, large rivers and their littoral.

-Marine zone corresponding to marine waters, islands, and mangroves.

In these four categories of habitats the airspace above each site was included. The studied sites were the following (Photographs N° 7 to 19):

-South Entrance to the Panama Canal (Maps N° 4 and 5): This area is easily accessible, is located on the Pacific coast, near Panama City, between 8° 54' 01"- 8° 55' 41"N and 79° 31' 22" - 79° 34' 58"W. It belongs to the Tropical Rainforest life zone (Holdridge, 1979), at an altitude from 0 to 100 m. Here, forests, open areas, aquatic and marine habitats are found.

This area was chosen for its easy access, the variety of habitats and because it is likely to be affected by some alternatives to the Panama Canal.

In the secondary forest, the following plants predominate: *Ficus*, *Bromelia*, *Bursera*, *Bactris*, *Byrsonima*, *Guazuma*, *Alibertia*, *Genipa*, *Spondias*, *Xilopia*, *Thevetia*, *Didymopanax*, *Ochroma*, *Carludovica*, *Heliconia*, *Acacia*, *Enterolobium*, *Cecropia*, *Apeiba*, *Mangifera*, *Curatella* and *Terminalia*. A 2 km survey route was marked, including the internal and external part of the forest. It started within the forest at 8° 54' 44''N and 79° 33' 51''W, continuing to the SW to the 08°54'40''N-79°33'55''W, then continuing around the forest towards the North up to the point 8° 55' 27''N and 79° 33' 56''W.

The marine habitat corresponds to the Islands of Perico and Naos, the marine waters extending to Amador. The survey route consists of 3.2 km. It starts at 08°54'39''N-79°31'22''W in the landfill, continues through the road up to 8°55'41''N-79°32'36''W. The 2 km survey route ended at 08°55'10''N-79°32'09''W. This route is complemented by the 1 km survey route in the mangrove of Río Farfán, which started at 08°55'33''N-79°33'58''W and ended at 08°55'15''N-79°34'22''W.

The aquatic zone corresponds to the Lagoon of Farfán formed by Río Matutela. Here a 2 km long transect which started at 8°55'41''N-79°34'21''W continued around the border towards the SE up to the 08°55'33''N-79°33'58''W. It continued in a SW direction through the landfill between that lagoon and the mangrove thicket (*Laguncularia racemosa*) up to the point 8°55'18''N-79°34'34''W.

The open area was of approximately 80 hectares, surrounded by forest and covered with herbaceous plants (mainly *Saccharum spontaneum*, *Bachiaria*, *Panicum*). Towards the North there was an area covered with *Helicteres guazumifolia*, in the NW is a pond-like area and to the NE there was *Mimosa*. Here a 2 km transect was marked starting at 8°54'01''N-79°34'58''W, following to the North to 8°54'24''N-79°34'58''W, continued to the West to 8°54'24''N-79°34'40''W, then to the SE to 8°54'08''N-79°34'40''W, finally ending at the starting point.

-Gaillard Cut (Maps N° 4 and 6): This area is in the continental divide, is of easy access year round. It is located 35 minutes from Panama City, and is traversed by many roads used by maintenance personnel of the Panama Canal. The work zone is between the 09°02'13'' and 09°04'52''N, and the 79°38'27'' and 79°40'15''W with altitudes of 40 to 160 m. It is found in the Tropical Rainforest life zone (Holdridge, 1979).

This site was selected because of the presence of forest, open, and aquatic areas. There are all very close which makes sampling easier. On the other hand, it is likely that this area will be affected by the widening of the canal.

The secondary forest is bathed by the Sardinilla, Masambí Chico and Masambí Grande Rivers, as well as by many streams. Palm trees (*Scheelea*), *Ficus*, *Bactris*, *Carludovica*, *Isertia*, *Apeiba*, *Luhea*, *Mangifera*, *Byrsonima*, *Guazuma*, *Gustavia*, *Anacardium*, *Spondias*, *Thevetia*, *Didymopoanax*, *Ochroma*, *Pseudobombax*, *Cochlospermun*, *Heliconia*, *Miconia* and *Cecropia* are common. There are remains of small crops (*Musa*) and areas forested with *Gmelina*. In this habitat the survey route was 4 km long, following the old Gamboa

road. It started at 09°04'52''N-79°40'15''W, continued with SW direction to finish at 09°03'48''N-79°39'11''W. The 2 km transect ended at 09°04'12''N-79°39'55''W.

The open area goes just off the shore of the Panama Canal, is covered mainly by *Saccharum spontaneum* and is crossed by the Obispos River and small streams. Here, a 3 km route was marked which started at 09°03'43''N-79°39'34''W and ended at 09°02'41''N-79°38'27''W. The 2 km ended at 09°02'55''N-79°38'53''W. This route was complemented with a 300 m survey at the border of a 6 hectare clearing where grasses dominate, it started at 09°03'52''N-79°39'19''W and ended at 09°03'49''N-79°39'12''W.

The aquatic habitat corresponds to the Canal itself, here observations were made on the 5 km starting just before Cerro Cucaracha at 09°02'13''N-79°38'30''W, and continued to the NW ending at 09°04'14''N-79°40'18''W. The 2 km transect ended at 09°03'07''N-79°39'11''W. It was complemented by the 400 m survey around the border of two lagoons of approximately one hectare each located in the coordinates 09°03'38''N-79°38'59''W.

-North Entrance to the Panama Canal (Maps N° 4, 7 and 8): It is of easily accessible, found on the Caribbean coast and is cut by many roads. The study area included the northeastern part of Lake Gatún and part of the military reserve of Sherman, located between Chagres River and the Panama Canal in the Province of Colón. Here, forests, open areas, aquatic and marine areas were found.

The work area was located between the 09°14'08'' and 09°20'25''N, and 79°55'33'' and 79°57'13''W in the Tropical Rainforest life zone (Holdridge, 1979), with elevations of 0 to 40 m.

This site was selected because of the variety of habitats and its easy accessibility. Also because it is likely to be affected by some of the alternatives to the Panama Canal.

The secondary forest, with apparently old areas, contains *Birsonima*, *Guazuma*, *Gustavia*, *Anona*, *Spondias*, *Didymopanax*, *Cordia*, *Miconia*, *Luchea*, *Prioria*, and others. Here, a Y-shaped route was established with a length of 2.5 km, starting at 09°17'52''N-79°55'41''W on the road of Gatún, continuing on the West to the 09°17'50''N-79°56'32''W, where the 2 km transect ended. The remaining 500 m of survey correspond to the "Y" branch with NW direction, which followed the water pipes from the midpoint to the 09°18'02''N-79°56'25''W.

The open area was represented by the parachuting field in Sherman, on the side of the French Canal. It is a grassland with approximately 100 hectares where elephant grass (*Penicetum purpureum*) is dominant, but where *Saccharum spontaneum* and *S. oficinalis* is also found. Here a 2 km survey route was traced starting at 09°17'31''N and 79°55'36''W, ending at 09°16'47''N and 79°55'44''W. Towards the middle of the survey there was a branch 150 m to the right and another to the left. The area flooded and had sewage effluents; in addition, was surrounded by secondary forest.

The marine habitat category presented a 2 km survey route throughout the Gatún road between the Sherman mangrove and the Limón Bay coast. It started at 09°21'02''N-79°56'47''W and ended on the SW at 09°20'25''N-79°57'13''W. The mangrove ticket was constituted mainly of *Laguncularia racemosa*, but there was also *Rhizophora* and *Acrostichum aureum*. To the border there is *Conocarpus*, *Phryganocidia*, *Saccharum*, *Cochlospermun* and *Terminalia*.

On the aquatic habitat an 8 km route was traced to the NW of Lake Gatún. It started at 09°15'21''N-79°56'17''W, to 09°14'39''N-79°56'38''W, where the 2 km ended. Then, continued to the SW to the 09°14'09''N-79°56'55''W, from there on to the West passing through the south of Ceiba and Bambú islands up to the 09°14'08''N-79°56'02''W, continuing to the NE to Guarapo Island at 09°14'40''N-79°55'33''W, then goes to the North to the 09°15'31''N-79°55'38''W, ending on the West where it started.

-Tranquilla (Maps N° 4 and 9): It is an accessible place, it can be reached by car up to Nuevo Vigía, and from there on, by boat, to the point where the coastal survey of Lake Alajuela begins, which also includes the mouth of Río Chagres. At the lake's bank, around the town of Tranquilla, is the open area (pastureland) which can be reached by boat.

This site was selected because it is likely to be affected by the construction of an artificial lake to improve performance of the Panama Canal.

The edge of the lake presents remains of forest, pasturelands, crops, and of recreational areas (fishing and water sports).

The work area was located between the 09°13'09'' and 09°15'07''N, and between the 79°31'53'' and 79°34'12''W; and it is found in the Tropical Rainforest life zone (Holdridge, 1979). It had an irregular topography with elevations up to 200 m.

No survey route corresponding to the forest was marked since there was no adequate place, because the area is too disturbed.

The open area is represented by pasturelands in the slopes of Cerro San Juan where pastures for livestock are dominant. Here, some bushes, shrubs, and some dispersed trees are found, like: *Ficus*, *Psidium*, *Inga*, *Genipa*, *Enterolobium*, *Diphysa*, *Mangifera*, *Anona*, *Birsonima*, *Spondias*, *Cochlospermun*, *Bactris*, *Jatropha* and others. The survey route was 2 km in the shape of a cross. One started near to the top of the hill at 09°15'07''N-79°33'41''W to finish at 09°14'39''N-79°33'53''W. The other started at 09°14'55''N-79°33'31''W and ended at 09°14'49''N-79°34'01''W.

The aquatic and its littoral habitat present a survey route of 17.2 km, flanking Lake Alajuela and penetrating into the mouth of Río Chagres. This route started at 09°13'09''N-79°34'01''W to the mouth of Río Chagres at 09°13'31''N-79°33'31''W, continuing up river for 2 km to 09°14'04''N-79°31'53''W, continuing from the mouth through the lake's coast in a NW direction up to 09°15'00''N-79°34'12''W.

-Pequení (Maps N° 4, 10, and 11): Is a distant place with more or less difficult access, the first step is done by car (until Cerro Vigía) and the second by boat (up to San Juan de Pequení through Lago Alajuela and Río Pequení). It is a mountain river with a strong current, and numerous rapids that make it is difficult to navigate.

This site was selected because it is likely to be affected by the construction of an artificial lake to improve performance of the Panama Canal.

The work area was between the 79°30'36" and 79°36'30"W, located in the Tropical Rainforest life zone (Holdridge, 1979), with elevations of up to 200 m.

One of the habitats corresponded to the aquatic zone and its littoral (Lake Alajuela and Río Pequení). The coastal areas are mainly destined to cattle ranching and agriculture, pasturelands and stubbles are dominant. There are just a few remains of riverside forest and the following species are more or less abundant: *Ficus*, *Pithecolobium*, *Inga*, *Senna*, *Psidium*, *Didymopanax* and *Cecropia*.

Here, the survey route was 20.75 long, starting at 09°14'52"N-79°36'30"W, and 13.75 km afterwards, on the mouth of Río Pequení, at 09°21'09"N-79°33'04"W. Continued 5 km up river to 09°22'08"N-79°31'42"W (mouth of Quebrada San Francisco) where the 2 km transect started, which ended at 09°22'50"N-79°31'22"W up river, on the town of San Juan de Pequení.

The accessible forests have been disturbed, there only remain some patches separated by pasturelands and crop areas (*Zea*, *Manihot*, *Oriza* and *Musa*). There are mainly found on river banks and streams where human populations establish. On the distance secondary forests which looked less disturbed could be seen. The survey route was 2 km long, marked from 09°23'00"N-79°31'20"W on the forest starting behind the station of the Panama Canal Commission up to 09°23'18"N-79°30'36"W. The transect was serpentine, passing through tall, low, dense, disperse forests, and others interrupted by grass clearings, crop fields in used and abandoned. It is common to find *Guazuma*, *Inga*, *Anacardium*, *Spondias*, *Didymopanax*, *Psidium*, *Mangifera*, *Byrsonima*, *Musa*, *Bactris*, *Tectona*, *Isertia*, etc.

The open area correspond to pasturelands between the brooks of Tiarillo and Candelaria, where pastures are dominant and some fruit trees are present, such as: *Spondias*, *Psidium*, *Byrsonima*, *Chrysophyllum* and *Inga*. Here two serpentine transects, of 1 km each. One oriented to the NS starts at 09°23'15"N-79°31'50"W and ends at 09°22'54"N-79°31'30"W. The other, oriented EW, starts at 09°23'00"N-79°31'33"W and ends at 09°22'50"N-79°31'53"W.

-Cirí (Maps N° 4, 12, and 13): It is a distant place, of more or less difficult access. The first step is done by car up the town of Cuipo, the second is done by boat, and reaches the settlement of El Chorro, through Lake Gatún and the Cirí Grande river. The survey by boat takes approximately one hour and 15 minutes. The lake has submerged trunks which

some cases caused problems to navigation since some boats hit the trunks and even beached, and in some occasions the motors were damaged or loosened.

This site was selected because it is likely to be affected by the construction of an artificial lake to improve performance of the Panama Canal.

The sampling area is between the 08°56'56''N and 09°04'40''N and between the 80°02'24''W and 80°04'11''W; located in the Tropical Rainforest life zone (Holdridge, 1979), with elevations of up to 264 m.

In the shores of lakes, rivers, and streams pasturelands for cattle ranching predominate. Only small remains of a secondary forest remain. This situation is typical of all this region, even in areas far away from water sources.

A 15.7 km survey routes was traced in the aquatic and littoral habitat, starting in the pier of Cuipo at 09°04'40''N-80°02'24''W for 10.3 km S on the mouth of Río Cirí Grande, at 08°59'22''N-80°02'24''W. Continues for 3.4 km up river to the 08°58'28''N-80°02'47''W point, where the 2 km transect starts, culminating on Los Chorros at 08°58'22''N-80°03'12''W. Throughout the lake route, the abundance of *Didymopanax* and grasses outside the water was noted; but inside, junk was common. Towards the mouth of the river *Acrostichum*, *Eichornia*, *Hymenachne*, *Senna*, *Typha*, *Cecropia* and pasturelands can be seen. Throughout the two (2) last kilometers pasturelands, *Ficus*, *Cecropia*, *Senna*, *Pithecolobium*, *Inga* and *Enterolobium* were observed.

The secondary forest is represented just be remains, there are patches separated by grazing lands and crops (*Zea* and *Musa*, *Cajanus* and *Manihot*). The 2 km transect starts at 08°58'22''N-80°03'12''W, and ends at 08°57'32''N-80°03'46''W. This is a serpentine transect, it passes through areas of tall, low, dispersed and dense trees. In some parts it is wide, narrow, interrupted by small clearings with grasses and small crops, in use or abandoned. The following are common: *Spondias*, *Bactris*, *Anacardium*, *Cecropia*, *Byrsonima*, *Mangifera*, *Guazuma*, *Inga*, *Genipa*, *Chrysophyllum*, *Miconia*, *Cochlospermun*, *Bursera*, *Pseudobombax*, *Citrus* and *Coffea*.

The open area is represented by pasturelands. The survey route correspond to a rhomboidal transect of 2 km and irregular topography. It starts at the west border of Cirí Grande River at 08°56'56''N-80°03'53''W, continues to the NW up to 08°57'26''N-80°04'11''W continues northeasternly to 08°57'34''N-80°03'59''W, then continues to the SE to 08°57'23''N-80°03'46''W, to finally end to the south on the starting point. This section is covered by relatively low pastures, traversed by many streams, there are some muddy areas. There are also fruit trees such as: *Psidium*, *Inga*, *Byrsonima*, *Citrus*, *Percea*, *Eugenia*, *Anacardium*, *Coccos*, *Spondias* and *Mangifera* specially on the margins of streams.

(3.3.2) Field observations

Inventories were carried out through survey routes, in each habitat, whose length depended on the extension of those habitats. The shortest survey corresponded to two (2) kilometers. With surveys covering the entire route and the specific survey of 2 Km. In each enough information is intended to obtain an inventory of species. Besides, the 2 km survey gave more information about the seasonal variations on species abundance, and of group species and individuals of some species.

The survey routes were carried out on foot, very slowly, observing with the naked eye and with binoculars, the floor, trunks, branches, and foliage in general, and the airspace over each habitat. Routes on the sea, lake, and rivers, as well as marginal forests, open areas of the littoral, and those over the routes were surveyed.

The surveys started very early in the morning, preferably before dawn, and finish near noon. In each survey, starting and ending time are recorded, also amount of participants, category of habitat, name of species found, number of individuals of each species, plant/animal relationship or habitat use (feeding, reproduction, wintering, and others), bird condition (game, endangered, threatened, or migratory) were all recorded. Finally, those species captured on nets were also recorded. The latter could be observed in more detail and in closeup, which verified the identification of these birds.

Bird songs and other sounds were used to recognize species within the study area but were not seen. Recordings were made of the calls of certain species for later verification.

In the survey routes 2 km long transects were marked, whose width and depth was determined by the available visibility. Specifically transects were drawn on lakes, lagoons, and rivers and their littoral for the aquatic littoral are in groves for forests, in grasslands, pasturelands, and bushes for the open areas, and in the sea and mangroves for the marine habitat.

Each survey route, and therefore the 2 km portion was surveyed once and was always worked on by the same two (2) people to decrease variations caused by observers.

Boats were used to carry out surveys on lakes and rivers, in the case of islands and the sea, surveys were done walking through landfills and along the coast. In all other cases surveys were done on foot. The information was complemented with information obtained from local inhabitants and park rangers on the presence of game and pet birds.

A non-destructive survey of the habitats was carried out, none of the specimens captured in nets were retained. In every moment, disturbances to the environment were avoided, in order to diminish distortions of our observations. With the data obtained from surveys, conclusions were drawn on habitat use, and in turn, were categorized into types of vegetation and plant groups. To achieve a more effective sampling, repetitions were made on three (3) of the six (6) sampling sites, including the rainy and dry season. Selected sites corresponding to the North Entrance

to the Panama Canal, Gaillard Cut, and south entrance of the Panama Canal, were selected based on their accessibility.

Bird identification was confirmed with field guides by Robbins et. al. (1983) and Ridgely (1989). In the case of captured specimens whose identification needed confirmation, reference was made to keys by Wetmore (1965, 1968 and 1973), and Wetmore et. al. (1984). These same works were followed for spelling and sequence of taxa, as was the main list of the American Ornithologist's Union (1983).

The threatened species category was established with the list of CITES (1990), whereas that of endangered species, from the lists of RENARE (1967 and 1974). The Game bird category was drawn from Méndez (1979), and that of migratory (transient and wintering), locals, sparrows, and Passeriformes, appear on works already cited, of Wetmore and Ridgely.

The sampling effort was determined in human hours for each of the sites where surveys were conducted. The total effort is obtained by adding the human/hours invested exclusively on surveys for each site.

(3.4) Mammals

(3.4.1) Sampling sites

The study area was divided into regions within each of which the habitat was judged to be of approximately equal degree of disturbance (or lack there of). These regions are outlined in Map N° 14:

-Fort Sherman/Fort San Lorenzo: It is mostly covered with advanced second growth forest, with some older forest and patches of *Prioria copaiefera*. Some areas have poor drainage which may reduce angiosperm diversity. There is much human activity in the area, mostly on the part of the US military in training exercises. There is some hunting.

-Achiote forest: The vegetation is similar to that of #1. The area is also used extensively for military training.

-Cirí/Trinidad arm: This area is highly disturbed. Much of it is covered with cattle farms, some of which are abandoned and are covered with weed grasses such as *Saccharum spontanaeum*. There are small patches of young forest. There is little or no hunting because there is "nothing left to hunt".

-North Gigante: It is covered with continuous canopy forest ranging from young second growth (which may only look young because of edaphic conditions) to high, fairly mature forest. The area is protected by Smithsonian forest wardens and hunting has been greatly reduced since the mid 1970's. There are no, or very few, year-round streams.

-Panama City: Small pockets of scattered trees afford refuge for *Didelphis masupialis*, *Sciurus variegatoides*, *Bradypus variegatus*, *Choloepus hoffmanni* and *Dasypus novemcinctus*. *Dasyprocta punctata* and *Saguinus geoffroyi* also persist in the larger of these pockets. The forested are on and around Ancon hill is home to a breeding population of all of the above species and there are also breeding populations of *Adocoileus virgianus* and *Agouti paca* there. Several species of bats are also abundant in the residential areas, often making their roots in spaces under roofs. The most abundant of these are *Myotis nigricans* and *Molossus molossus*.

-Pacific dry forests: Some of these are protected by virtue of their being situated within military reservations. Those that are unprotected are heavily hunted and disturbed by other human activity.

-Veracruz/Vacamonte: There are extensive cleared patches and some patches of forest and mangrove.

(3.4.2) Field observations

The bat team, consisting of three people generally assisted by one or more volunteers and/or INRENARE personnel, placed five mist nets (four at ground level and one with its top about six meters above the ground) at each site. The specific locations for the nets were chosen by searching for "flyways", which are routes along which bats fly to and from their foraging sites. Such flyways may be along roads or paths, along streams or simply along more open areas under the forest canopy.

The nets were opened at dusk and were visited on a rotating basis until 10:00 pm, when they were closed again. This procedure was repeated for each of two nights at each site. Netted animals were sexed, weighed, marked with a temporary mark and released. In addition to bats, all sightings of non-volant mammals were also recorded.

The non-volant mammals were sampled at specific sites by setting out five lines of ten traps each. These traps were not placed according to a pattern. Traditional mammal trapping studies were conducted according to a grid or other form of mathematical spacing, but the habitat diversity in neotropical forest was so great that mathematical spacing, unless enormous numbers of traps were laid out over very large areas, would be senseless. Instead, the traps were laid out in short lines (the only rule followed being that the previous trap could be seen from each new site) along animal pathways or streams or through areas where trees were dropping fruits.

The traps were baited with a combination of banana and commercial cat food and were set between 4 pm and 6 pm on each of two nights. They were visited the following morning, and the occupants sexed, roughly aged and released. In addition, mammal tracks, fruits or seeds that were eaten in specifically identifiable ways, identifiable vocalizations and other reliable signs, were recorded at each site.

-Panama City: Small pockets of scattered trees afford refuge for *Didelphis masupialis*, *Sciurus variegatoides*, *Bradypus variegatus*, *Choloepus hoffmanni* and *Dasypus novemcinctus*. *Dasyprocta punctata* and *Saguinus geoffroyi* also persist in the larger of these pockets. The forested are on and around Ancon hill is home to a breeding population of all of the above species and there are also breeding populations of *Adocoileus virgianus* and *Agouti paca* there. Several species of bats are also abundant in the residential areas, often making their roots in spaces under roofs. The most abundant of these are *Myotis nigricans* and *Molossus molossus*.

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All live mammals sightings and road kills were recorded while travelling between specific sites or during other travels. Informal transects were made almost daily by boat and car, by daylight and at night, and mammals recorded. People who were encountered in or near trap sites were interviewed for their knowledge of local mammals and, during conversations, an attempt was made to judge their reliability as informers. Colleagues from STRI who were working in the field were also regularly interviewed as to what species of mammals they had seen.

b) FRESHWATER

(1) Water Quality

(1.1) Sampling methods

Sampling took place in thirteen (13) locations in accordance with the Terms of Reference (Map N° 15). Sampling schedule was executed on a quarterly frequency with five (5) sampling periods during the study. All locations were sampled within a time frame of five (5) days during each quarterly sampling. Water samples or readings were taken at surface and bottom. A Global Positioning System (GPS) supported by satelites was used to determine location of each sampling site. A Van Dorn type sampler, non metalic, approximately 2.5 lts., was used to collect water samples.

(1.2) Laboratory procedures

Following measurements and analysis were carried out: physical (turbidity,temperature, conductivity, secchi depth, and suspended solids), chemical analysis (dissolved oxygen, ammonia, alkalinity, Nitrate-N, Kjeldahl-N, total phosphorus, iron, lead, copper, zinc, and Mercury), and biological tests (clorophyll *a*, biological oxygen demand, and coliform bacteria).

In accordance with TOR guidelines replicate analyses (2) were conducted on samples and replicate readings (3) for in-situ measurements as well. Ten percent (10%) of field samples were repeated for Quality Analysis Control (QAC).

The following is a brief description of the analytical methods:

-Turbidity: was measured using the nephelometric method (EPA 1983). This method is applicable to potable water, surface, and sea water. It is based on the comparison of the intensity of light dispersed by the water sample under defined conditions with the intensity of light dispersed by a standard suspension under the same conditions. The greater the intensity of light dispersed, the greater the turbidity. The polymer formazine is used as the standard reference suspension.

-Total suspended solids: dried at 103-105°C (APHA 1985). A well-mixed water sample is filtered through a weighted glass-fiber filter and the residue retained on the filter is dried to a constant weight between 103-105°C. The increase in the weight represents the total suspended material.

-Conductivity: was determined using a salinometer LabComp model SCT-100.

-Dissolved oxygen: was determined according to Winkler's method (Strickland & Parson 1972). A divalent manganese solution, followed by a strong alkali, is added to the sample. The precipitaded manganese hydroxide is dispersed evenly throughout the sample. Any dissolved oxygen rapidly oxidizes an equivalent quantity of divalent manganese to basic hydroxides of higher valence states. When the solution is acidifies in the presence of iodide, the oxidized manganese again reverts to the divalent state and iodine, equivalent to the original dissolved oxygen content of the water is liberated. This iodine is titrated with standardized thiosulphate solution.

-Total nitrogen: was analyzed according to the Kjeldahl method described by APHA (1985). This method determines nitrogen in the trinegative state.

-Total phosphorus: was determined by oxidation with acid perosulfate. The acidified sample is autoclave for 30 minutes in a closed bottle with peroxodisulphate. Tests indicate that if the sample is initially acidc, the amount of oxidant could be decreased from 1 to 0.3%. The free chloride formed is reduced by adding ascorbic acid as the first reagent (Grasshoff et al. 1983).

-Nitrogen-Nitrate: was determined by reduction with cadmium as described by Grasshoff et al. (1983). A filtered sample is passed through a column containing granulated cooper-cadmium to reduce nitrate to nitrite. The nitrite (that is originally present plus reduced nitrate) is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediameme dihydrochloride to form a highly colored dye which is measured spectrophotometrically. Separate, rather than combined nitrate-nitrite values, are more easily obtained by conducting the procedure first, with, and then without, the Cu-Cd reduction step.

-Ammonia: the ammonia reacts in an alkaline solution with hypochlorite to produce monochloramine, which in the presence of phenol, catalytic amounts of nitroprusside ions, and excess hypochorite, gives indophenol blue which is measured colorimetrically (Grasshoff et al. 1983).

-Alkalinity: was determined using the sulfuric acid titration procedure described in the method N° 2320b in APHA (1985).

-Biochemical Oxigen Demand (BOD): Once in the laboratory, each sample is brought up to 20°C. Samples are diluted to obtain a residual oxygen value of approximately 1 mg/L and an oxygen uptake of at least 2 mg/L. The diluted samples are neutralized and treated with a nitrogen inhibitor. A reading of the initial concentration of oxygen is taken and written down. The bottles are sealed with distilled water, covered, and incubated at 20°C for five days. After five days of incubation, a reading is taken of the final oxygen concentration, and the BOD5 is the difference between the initial and final amounts of oxygen (APHA, 1985).

-Fecal coliforms: water was filtered through a membrane which retains the bacteria. The filter is transferred to an absorbent pad satured with nutrients. The growing colonies feed by capillary action through the filter pores (APHA 1985).

-Total coliforms: water was filtered through a membrane which retains the bacteria. The filter is transferred to an absorbent pad saturated with nutrients. The growing colonies feed by capillary action through the filter pores (APHA, 1985).

-Chlorophyll a: was determined by spectrophotometric analysis. The large zooplankton are removed by straining a sample through a nylon net of about 300-mesh size. Then the phytoplankters are filtered onto a Millipore AA filter or a glass filter. Pigments are extracted with an acetonic solution (90%) from the algae cells for estimation spectrophotometrically (Strickland & Parsons 1972).

-Heavy metals (copper, iron, lead, zinc, and mercury): chelation with APDC and extraction with MIBK in water. All of the determinations were performed by atomic absorption spectrometry (APHA 1985).

(2) Sediment Quality

Sampling was effected in seven (7) sites of Gatun Lake (Map N° 15). A Global Positioning System (GPS) supported by satelites was used to determine the location of each sampling station. Two (2) sediment samples were collected in each site using a Ponar dredge. One (1) of the samples was used for the grain size analysis and the other for the following chemical analysis: total carbon, total nitrogen, iron, copper, zinc, lead, and mercury.

The analytical procedure were the following:

-Granulometry: two sub-samples were taken from each of the samples for granulometric analysis. The method used was a quick sediment determination based on the Wentworth scale (Holme & McIntyre, 1984). Sediments were classified depending upon the average grain size obtained (in mm) according to the following classification: very coarse sand (1.00-2.00 mm), coarse sand (0.50-1.00 mm), medium sand (0.25-0.50 mm), fine sand (0.125-0.25 mm), very fine sand (0.062-0.125) and silts and clays (< 0.062 mm).

-Total nitrogen: the analysis was performed through Kjeldahl digestion.

-Total organic carbon: analysis performed using a carbon analyzer.

-Heavy metals (copper, iron, lead, zinc, and mercury): sediments were digested with $HNO_3/HClO_4/HF$ and measurements by atomic absortion spectrometry.

-HMW Hydrocarbons: sediment samples were analyzed using the SW-846 soxhlet extraction method 3540B. Following extraction, samples were cleaned up using a silica/alumina

column, collecting the hydrocarbon fraction. Samples were analyzed using a Varian 6000 equipped with a 30M DB-5 capillary column and a FID detector.

(3) Aquatic Macrophytes

A survey of aquatic macrophytes was carried out in the freshwater sections of the study area (Map N° 15). Distribution, quantitative and qualitative seasonal changes were recorded by direct field observations. A set of color aerial photography with approximate scale 1:9000 came too late in the study to effect sufficient ground verifications in areas covered during the surveyance.

On the ground observations were carried out in small fiber glass or aluminum punts, and supplemented with the GPS system supported by satelites to determine locations of the observation stations.

(4) Benthos

(4.1) Field methods

Benthos samples were collected in triplicate using a Ponar dredge measuring 6 by 6 in (15 by 15 cm) with a capacity of 145 cubic inches (3540 cubic cm). Map N° 15. For each of three samples, four of five throws were used until a sampling area of 0.1 m^2 was completed. The dredge was emptied into a plastic cube and diluted with filtered lake water (sieve of 35 microns). Following agitation, the sample was passed through a U.S. Standard N° 18 sieve (opening of 1 mm). The material retained in the sieve, and the material that passed through the sieve, was collected and placed in separate plastic bags (10 lbs or 4.5 kg capacity) and preserved in a mixture of 5% formalin and 0.2% Rose Bengal.

Tickets made of linen paper (100% cotton), indicating the sampling station, date, type of sampler; name of person collecting the sample, and other pertinent information was placed inside the bags with the sample material. The samples were assigned identification numbers in the field as well as in the laboratory, and the information on the tickets was transcribed into a permanent record.

(4.2) Laboratory procedures

Before processing the sample, the information contained on the ticket was transferred to a data sheet which provided information on: name of the lake, name of the person that transferred the data, name of person who took the sample, type of sampler, sampling date, sampling time, water temperature, depth, and sample number. This data sheet provided adequate space for scientific names and density values.

(5) Fishes and Macroinvertebrates

(5.1) Field methods

Fish were collected in the sampling sites indicated by the TOR (Map N° 15). Fish samplings were carried out using experimental gillnets of 50 m. long by 3 m. depth, which have 5 panels with different mesh sizes ranging of 2.5 cm. to 10 cm.

These gillnets were set in the sampling sites for about 14 to 16 hours mainly during the night time and were collected at next morning. Every collection was made with two replicates per station and all material collected was proccesed in the field, where were separated in species, measured their total body length in cm using a measuring board, and weight in grams using a spring scale.

The benthic macroinvertebrates were caught using as main fishing gear national and imported traps baited with plants and rotten meats.

(5.2) Laboratory procedures

Most of the fish species were identified in the field using keys, but sometimes some species were preserved and taken to the laboratory for their verification. Also we selected and preserved all specimens for the reference collection. Specimens were identified using the taxonomic keys from Meek & Hildebrand (1916), Meek & Hildebrand (1928), Hildebrand (1938), Breder (1944) and Bussing (1987).

All of the collected macroinvertebrates were identified in the laboratory according to Abele & Kim (1989) y Abele (1972).

(6) Commercial and Sport Fishery

The information on the fisheries was directly gathered in the field through interviews and census carried out among the inhabitants of the Canal lakes area. Also some officials from fishermen cooperatives colaborated providing valuable information. Sport fishermen were also interviewed during our routine field collection trips.

Additional data was obtained from the official records from the Department of Aquaculture of the Ministry of Agriculture, and the Institute of Natural Resources.

(7) Aquatic Mammals

Observations and collection of mammals, including aquatic and semi-aquatic mammals, were effected between September 22 and December 29, 1992

All live mammal sightings were recorded while travelling between specific sites or during other travels. Informal transects were effected by boat, by daylight and at night, and mammals recorded.

People encountered in or near trap sites were interviewed for their knowledge of local mammals and, during conversation, attempts were made to judge their reliability as informers. Colleagues from STRI working in the field were also regularly interviewed as to what species of mammals they have seen in the study area.

c) MARINE WATERS

The coordinates of the sampling station were determined using navigation charts #1019 for the Gulf of Panama and #26066 for the Cristobal harbor (Caribbean) prepared by the Defense Mapping Agency Hydrographic/Topographic Center, Washington D.C. The positions were verified using the Global Positioning System (GPS) which takes satellite information to located positions by triangulation. The precision of the GPS is between 50 and 100 meters. The coordinates of the sampling stations are presented in Table N° 3.

(1) Oceanography and Water Quality

(1.1) Water sample collections and field measurements

Samples were quarterly collected at 16 stations indicated by the TOR (Maps N° 16 and 17).

During the collection of samples for the study of the water quality: the following steps were taken:

-The position of the sampling station was located using the navigation mode of the GPSW, and this was corroborated with the information from the navigation charts.

-Depth was recorded with a depth finder Interphase model DC-500

-Water samples were collected using 2.5 liter Niskin bottles provided with protected type reversing thermometers, and launched with the help of a winch geared with a meter-wheel.

-In all of the stations deeper than 10m, samples were taken on the surface and at the bottom (at minimum). If water depth reached 20m, samples were taken at three levels (surface,mid-water, and the bottom). At least, four sampling levels were collected in sampling stations with more than 20m in depth.

-The slant of the cable was determined with an inclinometer, and necessary corrections made to achieve the correct sampling depth.

-The collection team waited approximately five minutes for the reversing thermometers to stabilize in order to determine the most accurate temperature of the surrounding water. The messenger was then launched and the bottles retrieved. Once the sampling bottles were aboard it were waited 10 to 15 minutes before the reading of the auxiliary and main thermometers in the protected type reversing thermometers. The thermometer readings were performed three times and all of these readings recorded in the field data sheet.

-The different sample bottles were filled in the following order: dissolved oxygen, bacteriology, volatile organics, BOD, nutrients, and metals. The bottle code and collection level for each sample was recorded on the field sheet.

-The water transparency was measured using a Secchi disc and these measurements were repited three times and then recorded the information in the field data sheet.

(1.2) Water samples analysis

The following is a summary of the laboratory procedures for the analysis of sea water samples:

-Turbidity: was measured using the nephelometric method (EPA 1983). This method is applicable to potable water, surface, and sea water. It is based on the comparison of the intensity of light dispersed by the water sample under defined conditions with the intensity of light dispersed by a standard suspension under the same conditions. The greater the intensity of light dispersed, the greater the turbidity. The polymer formazine is used as the standard reference suspension.

-Total suspended solids: dried at 103-105°C (APHA 1985). A well-mixed water sample is filtered through a weighted glass-fiber filter and the residue retained on the filter is dried to a constant weight between 103-105°C. The increase in the weight represents the total suspended material.

-Salinity: was determined through the measurement of the conductivity using a salinometer LabComp model SCT-100.

-Dissolved oxygen: was determined according to Winkler's method (Strickland & Parson 1972). A divalent manganese solution, followed by a strong alkali, is added to the sample. The precipitaded manganese hydroxide is dispersed evenly throughout the sample. Any dissolved oxygen rapidly oxidizes an equivalent quantity of divalent manganese to basic hydroxides of higher valence states. When the solution is acidifies in the presence of iodide, the oxidized manganese again reverts to the divalent state and iodine, equivalent to the original dissolved oxygen content of the water is liberated. This iodine is titrated with standardized thiosulphate solution.

-Total nitrogen: was analyzed according to the Kjeldahl method described by APHA (1985). This method determines nitrogen in the trinegative state.

-Total phosphorus: was determined by oxidation with acid perosulfate. The acidified sample is autoclave for 30 minutes in a closed bottle with peroxodisulphate. Tests indicate that if the sample is initially acidc, the amount of oxidant could be decreased from 1 to 0.3%. The free chloride formed is reduced by adding ascorbic acid as the first reagent (Grasshoff et al. 1983).

-Nitrogen-Nitrate: was determined by reduction with cadmium as described by Grasshoff et al. (1983). A filtered sample is passed through a column containing granulated cooper-cadmium to reduce nitrate to nitrite. The nitrite (that is originally present plus reduced nitrate) is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediameme dihydrochloride to form a highly colored dye which is measured spectrophotometrically. Separate, rather than combined nitrate-nitrite values, are more easily obtained by conducting the procedure first, with, and then without, the Cu-Cd reduction step.

-Ammonia: the ammonia reacts in an alkaline solution with hypochlorite to produce monochloramine, which in the presence of phenol, catalytic amounts of nitroprusside ions, and excess hypochorite, gives indophenol blue which is measured colorimetrically (Grasshoff et al. 1983).

-Biochemical Oxigen Demand (BOD): Once in the laboratory, each sample is brought up to 20°C. Samples are diluted to obtain a residual oxygen value of approximately 1 mg/L and an oxygen uptake of at least 2 mg/L. The diluted samples are neutralized and treated with a nitrogen inhibitor. A reading of the initial concentration of oxygen is taken and written down. The bottles are sealed with distilled water, covered, and incubated at 20°C for five days. After five days of incubation, a reading is taken of the final oxygen concentration, and the BOD5 is the difference between the initial and final amounts of oxygen (APHA, 1985).

-Fecal coliforms: water was filtered through a membrane which retains the bacteria. The filter is transferred to an absorbent pad satured with nutrients. The growing colonies feed by capillary action through the filter pores (APHA 1985).

-Total coliforms: water was filtered through a membrane which retains the bacteria. The filter is transferred to an absorbent pad saturated with nutrients. The growing colonies feed by capillary action through the filter pores (APHA, 1985).

-Chlorophyll a: was determined by spectrophotometric analysis. The large zooplankton are removed by straining a sample through a nylon net of about 300-mesh size. Then the phytoplankters are filtered onto a Millipore AA filter or a glass filter. Pigments are extracted with an acetonic solution (90%) from the algae cells for estimation spectrophotometrically (Strickland & Parsons 1972).

-Volatile organics: were determined using the EPA 8260 method, in which analysis is made by gas chromatography/mass spectrometry (GC/MS). These analysis were performed on samples from July, and August 1992.

-Heavy metals (copper, iron, manganese, and zinc): chelation with APDC and extraction with MIBK in water. All of the determinations were performed by atomic absorption spectrometry (APHA 1985).

Field trip blanks and equipment blanks were performed for each of the quarterly samplings.

(2) Sediment Quality

(2.1) Field methods

Collections were carry in all 14 stations as established in the TOR (Maps N° 18, and 19). Eight stations were located in the Pacific side (MB-01 through MB-08) and six in the Caribbean side (MB-09 through MB-14).

Pacific collections were done on the following dates: July 22-24 and 29, 1992 (Cruise I), August 27-28 and September 11, 1992 (Cruise II), December 1-3, 1992 (Cruise III), March 2-3 and 5, 1993 (Cruise IV) and May 18-20, 1993 (Cruise V).

Caribbean collections were done on the following dates: July 15 and 31, 1992 (Cruise I), September 2, 1992 (Cruise II), November 14 and December 12, 1992 (Cruise III), March 6, 1993 (Cruise IV) and May 21, 1993 (Cruise V).

The following steps were taken for the collection of samples:

-A Petersen grab, with an effective sampling area of 30.48cm X 30.48cm (0.10 m^2), was placed on the automatic hydraulic winch of the ship.

-Four replicates per station were made (three for counting the benthos and one for sediment analysis).

-The material from the three first replicates (A, B and C) was placed in large plastic bags, carefully labeled and marked, placing them in plastic cubes. All of these samples (used for organisms counts) were preserved with enough 37 % formalin immediately after its collection.

-The replicate material (replicate D) was separated into three sub-samples: one for granulometric analysis placed in small plastic bags and the rest for physical-chemical sediment analysis were placed on special containers. All of these samples were carefully labeled and marked lacking any preservative. All sediment analysis samples were placed and transported in ice chests at all times while the granulometric sample were placed in plastic buckets.

(2.2) Laboratory procedures

-Granulometry: two sub-samples were taken from each of the samples for granulometric analysis. The method used was a quick sediment determination based on the Wentworth scale (Holme & McIntyre, 1984). Sediments were classified depending upon the average grain size obtained (in mm) according to the following classification: very coarse sand (1.00-2.00 mm), coarse sand (0.50-1.00 mm), medium sand (0.25-0.50 mm), fine sand (0.125-0.25 mm), very fine sand (0.062-0.125) and silts and clays (< 0.062 mm).

-Total nitrogen: the analysis was performed through Kjeldahl digestion.

-Total organic carbon: analysis performed using a carbon analyzer.

-Heavy metals (copper, iron, lead, zinc, and mercury): sediments were digested with $HNO_3/HClO_4/HF$ and measurements by atomic absortion spectrometry.

-HMW Hydrocarbons: sediment samples were analyzed using the SW-846 soxhlet extraction method 3540B. Following extraction, samples were cleaned up using a silica/alumina column, collecting the hydrocarbon fraction. Samples were analyzed using a Varian 6000 equipped with a 30M DB-5 capillary column and a FID detector.

(3) **Corals, Mangroves and Seagrasses**

(3.1) Corals

This inventory comprise 3 basic aspects for the assessment of the coral reefs and the coral communities: 1) distribution and coverage in both entrances to the Panama Canal; 2) inventory of the corals diversity and selected coral reefs associated organisms; and 3) coverage and relative abundance of corals and most important sessile organisms in selected coral reefs considered as typical of the area.

-Location and coverage of the coral reefs: The study area (Maps N° 20 and 21) was overflown using a helicopter in September of 1993. The coral reef and the reef's flats were located and their distribution indicated in maps. In addition, during the overflight all of the observed development activities which could impact the coral reef communities in the area were recorded (i.e. industries, cities, harbors, etc.).

A set of color aerial photographs (scale 1:9,000) from the Panama Canal Commission of February-March 1990 was used to estimate the area of the coral reefs and reef's flats in the Caribbean area. The area in the photograph covered with coral reefs and reef's flats was digitalized using a Sigma-Scan digitalizer (Version 3.90). The reef's flat area includes the lagoons and channels within the flat. An estimated error of 10-15% in the assessment of the area of the coral reefs and reef's flats is considered as a consequence of the intense light reflexion on the surface of the sea and because of the waves in some sections of the

photographs. The coral reef in the Pacific side were directly measured, using measuring tapes, since there are no aerial photographs available for the Taboga, Urabá and Taboguilla Is. area.

All of the geographical names used in this inventory of corals reefs are based on the information provided by the maps (scale 1:50,000) from the Instituto Geográfico Nacional "Tomy Guardia" (1991), in the interest to facilitate the appropiate geographic reference.

-Preliminary reconnaissance of the coral reefs: The reef's flats in the Caribbean side were studied during the extreme low tides of August and September of 1992. The composition of species of corals and other sessile organisms, mostly macroalgae, was recorded. It was found that it was not necessary to quantify the coverage by sessile organisms in this sector of the reefs since these reef's flats are totally covered by macroalgae.

All of the coral reefs within the study area were studied using scuba or snorkel in order to produce a list of coral species, and to observe the biological estructure of the community. Some of the observations on the reef were carried out towing a diver from a boat at very low speed. This method is known as "manta" tow and allow the cualitative observation of extensive area of the coral reef, therefore increasing the possibility to find "rare" species that are not easily encountered when the study is exclusively based on transect lines. However, this method is unsuitable to assess the coverage of the coral reef (Fernándes et al. 1992).

-Structure of the coral reef community: After the preliminary reconnaissance of all of the coral reefs within the study area, those considered as the most representative were selected for further observations. The coverage of the coral reefs as well as the abundance of the most common sessile organisms were recorded at 11 coral reefs in the Caribbean and 3 coral reefs in the Pacific (Maps N° 21 and 22). Only the corals were identified to species. The study of the coral reef structure was carried out using 1 m^2 PVC quadrats which is the same method used in former studies in this area (Guzmán et al. 1991). Four transects were recorded in each of the selected coral reef, from a fixed point at the top down to the base of the reef (maximum depth of reef growth). The quadrat was placed along the transect at intervals of 3 m, depending on the length of the transect and the topography of the reef. Thirty square meters were sampled at each transect, making 120 m^2 in total per reef. Each quadrat was divided into 100 sections of 10cm X 10cm. This method was used to estimate coverage of each species of coral as well as the cover of other sessile organisms.

For the analysis of the data the quadrats were grouped into 4 range of depths: 0.5 - 3 m, >3 -6 m, >6 - 9 m, and >9 - 12 m. At each interval of depth it was recorded the mean coverage and the number of species of corals (m^2).

-Coral taxonomy: It is important to indicate that the taxonomy of the specimens collected in this study is based on the information provided by the most relevant scientific papers. Although, it is possible that some changes in the taxonomy might occur as new species are described or re-described (Knowlton et al. 1992).

(3.2) Mangroves

The study area was defined as those areas in proximity of both Pacific and Atlantic entrances to the Panama Canal. This area is shown in Map N° 23 with the eight sections of coastline defined in this study for the physical description of all major mangrove communities. There are five map sections covering the Pacific coast (notably Perequeté, Caimito, Veracruz, Balboa and Juan Díaz), and three covering the Atlantic (Chagres, Colón and Bahía Las Minas).

The methodology for this study was the following:

-Climatic and physical information: Area maps and data on annual and monthly rainfall, and mean monthly wind conditions, were derived from the Atlas Nacional de la República de Panamá (Instituto Geográfico Nacional 1988b). Rainfall stations referred to were at Cristóbal, near Colón on the Atlantic coast, and Altos de Balboa, near Panamá City on the Pacific. Information and data on tides were taken from a computer program produced by Micronautics Inc. Tidal stations were at Cristóbal, near Colón on the Atlantic coast, and Naos Island, near Panama City on the Pacific (Map N° 24).

-Mapping from aerial photographs: Photographs used in this study were mostly flown in 1990, and this was supplemented from other flights of aerial reconnaissance. The photographs were scaled around 1: 10,000.

Outlines of mangrove forests and other coastal features were drawn on overlays of transparent acetate film. These were then scanned into a MacIntosh computer for development of the final maps. Areas of mangrove forests were derived from their digitized outlines. All were thoroughly checked to remove any distortion errors and mistakes in transcription.

Determinations on the maps were based on detailed ground truth and consecutive studies of forest structure and species presence. Maps were scaled at 1: 50,000 for convenience and comparison with topographic maps.

-Species identification: Identification of species was based on the experience of the senior author (Duke 1992), and supplemented with reference to Tomlinson (1986) and Dr. Mireya Correa, STRI.

-Studies of forest structure: Mangroves are defined as tree vegetation growing in the intertidal zone, usually above mean sea level. Forest structure was assessed using either fixed quadrat plots, measuring tree heights, girth and basal area, or making similar measurements of trees using the angle gauge technique (Cintrón & Schaeffer-Novelli 1984).

-Measurements of salinity and temperature: Estimates of surface water salinity and temperature were made using a SCT-2 Meter, produced by LabComp, Oakland, California.

(3.3) Marine grass

The procedure for this study was as follows:

-Literature survey: a comprehensive survey of the literature on seagrass meadows in Panama was conducted as the first step in this effort. In addition to the Panamanian literature a synopsis of the available literature from other similar regions (e.g., Colombia, Costa Rica, Puerto Rico) is presented in an appendix to this report. Not all of the references located by the search are cited in this report but they do serve to show the ecological importance of seagrass ecosystems in tropical and subtropical coastal areas of the Americas.

Grassbeds along the Panamanian coastline tend to be located between fringing reefs and mangrove shorelines. In south Florida grassbeds are much more extensive and reach greater depths. They are ecologically important in all areas but they are not ecological equivalents. Thus it would be unwise to characterize Panamanian grassbeds from studies done elsewhere.

-Seagrass surveys: seagrass surveys were conducted along the coast between the Rio Chagres and the western side of Isla Payardi; including Bahia Las Minas, Bahia Margarita, Bahia Limon, and the numerous small coves between Bahia Limon and the Rio Chagres. Surveys began with a reconnaissance trip within the branches and along the shorelines of the two major coastal embayments. Survey routes were recorded by a Global Positioning System receiver connected to a laptop computer. The GPS unit was not used in tandem with a stationary unit. Therefore the accuracy of the recorded positions is variable. Small seagrass patch locations may or may not be located precisely at the recorded positions.

A fathometer was used to determine water depths; this was most useful along the banks of the Rio Chagres, where the bottom was not visible from the surface. Shorelines and shallow areas were observed by diving or by inspection from the surface when the water was clear. When seagrasses were located their positions were recorded; seagrass species composition, water depths, and estimates of aerial extent (for small patches) were also noted. Large seagrass beds were revisited to produce more thorough surveys and descriptions of site characteristics.

Sea bottom contours were profiled, as described below, within each of eight small to large seagrass beds. Several additional seagrass beds were located and described in areas that were not amenable to the type of surveys conducted at the eight profiled beds. The additional beds were either too small or they were located in areas that were probably highly polluted. Surveys from the sea surface were used in characterizing seagrass beds in the polluted areas.

At each site transects, marked by measuring tapes, were set out at right angles to the main axis of the shoreline. Transects began on the shore, if not covered by mangrove forest, or at the seaward edges of the mangrove forest. Starting points were marked with paint and their GPS positions were recorded. Afterwards each transect was either visually surveyed,

while wading or swimming, from the shore starting point to a stopping point several meters past the seaward edge of each seagrass bed. Bottom types (rock, sand, or mud) and living cover (seagrass, algal, or coral) descriptions, were noted at 2m intervals along each transect. The tip of a fiberglass rod was used as the marker point at which each bottom observation was made. The number of profiled transects surveyed at each site ranged from one to seven depending on the extent of each grassbed. Transect survey data were used to determine site specific characteristics including; 1) the percentage of bottom covered, at each site, by plants (seagrass and/or algae), coral, rock and sand, 2) depth penetrations by each seagrass species, and 3) the width of each seagrass meadow.

Seagrass shoot densities, blade counts, blade lengths, and blade biomass (as grams/m^2) were determined at a shallow (<1m) and at a deep (≥ 1m) station on all or on a subset of the total profiled transects at each site. Shoot densities and blade biomass (by species) were determined from a mean of five replicate cores (inside diameter = 11 cm) taken at each station. Algal biomass measurements were also averaged from the core samples. Macroalgae were identified to species but all species were dried and weighed together to obtain measurements of total algal biomass. Plants (seagrass blades and above ground algal tissues) were rinsed free of sediment, dried (for 5 days at 100°C) in tared foil wrappers, and weighed. Intact blades from seagrass shoots dug out of the bottom were counted and measured to obtain blade densities/shoot and a mean blade length for each seagrass bed.

Sediment depths were measured by pushing a thin fiberglass rod into the bottom until it either reached its maximum length (1.75m) or until it was stopped by hard substrata. Five such sediment depth measurements were taken at each point where seagrass samples were collected. Water column turbidity, salinity, and temperatures were measured over each large seagrass bed.

A set of color aerial photographs was examined to make certain that we did not miss any large patches of seagrass within the study area. Labeled copies of these photographs were used as figures in this report as the best possible means of locating seagrass beds along the study area coast.

-Fish collections: fish were collected from five of the larger seagrass beds with a small otter trawl of the same design as the one used by Heck (1979). Trawls were replicated five times in each seagrass bed. Tows were timed for 2 minutes each at a velocity determined by a mark on the outboard motor's throttle control. Coral heads and shallow water made it impossible to use this trawl at several of the study sites.

(4) Benthos

(4.1) Field methods

Benthic collections were performed with Ponar or Petersen dredges, according to the procedures previously described in section (2) Sediment Quality.

(4.2) Laboratory procedures

Processing of the benthic community samples followed the recommendations given in Holme & McIntyre (1984) and Parsons et al. (1985):

-The three replicate samples used for counting the benthic organisms (A, B and C) were sieved under a 1.00 mm standard sieve, using abundant water for washing.

-All of the retained material by the 1.00 mm sieve was placed in one gallon Ziplock plastic bags.

-A solution of a biological stain (Rhodamine B or Rose Bengal) was added to each bag enough to completely cover the sample. The biological stain solution was prepared by diluting 0.6 g of stain in one liter of 5 % formalin.

-All benthic organisms (red stained) were separated and counted under a dissecting scope.

-Organisms were placed on small 2 oz. glass vials with proper labels, being changed to 75 % alcohol as final preservative solution after one week.

In this report the identification as to species or to the lowest taxonomic category is given for all 16 animal Phyla found in five cruises. The taxonomic list of benthic organisms follows the phylogenetic order suggested by Barnes (1991).

Identification of benthic organisms was based on the following keys: Porifera (Barnes 1991), Cnidaria (Barnes 1991, Mendez 1987), Platyhelminthes (Hyman 1951), Nemertinea (Hyman 1951), Mollusca (Abbott 1974, Feinberg 1980, Keen 1971, Warmke & Abbott 1975), Crustacea (Rathbun 1937, Sieg & Win 1978, Abele & Kim 1989, Brusca & Iverson 1985, Murillo 1988, Kensley & Schotte 1989, Rodriguez 1980, Schram 1986), Sipuncula (Barnes 1991, Hyman 1959), Bryozoa (Barnes 1991, Voss 1976), Echinodermata (Barnes 1991, Downey 1973, Hyman 1955), Hemichordata (Smith 1977), Chaetognatha (Newell & Newell 1977, Smith 1977) and Pisces (Cadena & Flores-Coto 1981, Meek & Hildebrand 1923).

(5) **Meroplankton**

(5.1) Field methods

Collections were carried out in 11 stations (6 on the Pacific and 5 on the Caribbean) in five (5) quarterly samplings as follow: July, August, and November 1992, February and May 1993 (Maps N° 25 and 26). The positions of the sampling sites were established using navigation charts of the Gulf of Panama (Pacific) and Cristobal (Caribbean). The positions were verified using a GPS (Global Position System) with a precision of 50 to 100 meters. Depth was determined with a Hummingbird Sonar (Model LCR 400 ID) with a range of 600 feet. At each station, samplings were in triplicate using a plankton net 1m in diameter, 3m long, a mesh size of 300μ, and a General Oceanics flowmeter (Model 230R). The haul was done for 15 minutes

at a speed of two to three knots. Every five minutes the net rope was shortened in order to sample the entire water column. The samples were placed in one liter plastic bottles, properly identified, and preserved in 5% formaldehyde neutralized with Borax to saturation.

(5.2) Laboratory procedures

Samples were left to settle in 500 ml graduated cylinders for 48 hours and then the volume of the sedimented meroplankton was recorded. The sample was then divided in the Folson splitter. The aliquots used for the quantification and identification were poured into a Dollfus counting chamber to enumerate the samples into fish eggs, fish larvae, and invertebrate larvae using a Wild stereomicroscope Model-8 equipped with a zoom lens. Identification of meroplankters was performed using the following literature: Ahlstrom (1959), Cadena & Flores (1981), Cohen (1984), Fahay (1983), Hildebrand (1943), Howard & Landa (1958), Keitaro et al. (1958), Matus et al. (1989), Newell & Newell (1977), Peterson (1956), Smith (1977), Simpson (1959), and Tregouboft (1978).

(6) Fish and Macroinvertebrates

(6.1) Field methods

The five quarterly samplings (July, August, November 1992, February 1993, and May 1993) were carried out in the 19 stations indicated by the TOR, twelve (12) in the Pacific and seven (7) in the Caribbean (Maps N° 27 and 28). All collections were duplicated (38 stations in total) and 15 minutes of trawling were devoted to each collection). The sampling stations were splited into littorals: 5 in the Pacific (MF-01 to MF-05) and 4 in the Caribbean (MF-13 to MF-16), and sublittorals: 7 in the Pacific (MF-06 to MF-12) and 3 in the Caribbean (MF-17 to MF-19).

The schedule of the five quarterly samplings is presented next:

Area	Quarterly Samplings				
Pacific	I	II	III	IV	V
Littoral	14/Jul.	19/Aug.	16/Nov.	15/Feb.	4/May
Sublittoral	22,23,24/Jul.	27,28/Aug.	1,2/Dec.	2,3/Mar.	18,19/May
Caribbean					
Littoral	15/Jul.	20/Aug.	14/Nov.	25/Feb.	5/May
Sublittoral	30/Jul.	30/Aug.	26/Nov.	6/Mar.	21/May

The littoral samplings were carried out using two haul seines with 10 and 30 meters of length, 1.50-1.75m of height, and mesh size 0.64cm with a collection effort of 15 minutes. The sublittoral samplings, on the other hand, were carried out using a shrimp trawler outfited with twin otter trawls of 20m length and 8cm mesh size hauled simultaneously during 15 minutes.

(6.2) Laboratory procedures

The fish collected were identified using systematic keys provided by Jordan & Evermann 1896, Meek & Hildebrand 1923-1928, Bohlke & Chaplin 1968, Randall 1968, Chaplin & Scott 1972, Howell & Dawson 1974, and INP 1976. The measurement of the specimens was carried out in the laboratory where the total lenght (TL) in cm and the weight in grams was recorded.

For the monitoring of the gonad maturation the techniques described by Nielsen & Johnson (1983) were used. The gonads are removed, weighted and this weight is expressed as a percentage of the body weight prior to gonad removal (Gonadosomatic index, GSI). Also, because tropical fish reproduce throughout the year (Nikolsky 1963) and in order to document more accurately the reproductive patterns of the fishes it was also used the classification based on the phases of gonad maturation proposed by Snyder (1983). This classification is based on the appearance and the size of the gonads as follows:

-Phase I-Immature: The gonads of juvenile fish are generally very small and threadlike or stringlike, and they lie close to and under the vertebral column. They appear transparent, translucent, colorless or grey; in some species, the ovaries are wine-red and the testes are whitish to grey-brown. The oocytes in the ovaries are very small, transparent, and not visible to the unaided eye.

-Phase II-Developing, ripening, or maturing: The gonads enlarge until they finally fill the body cavity, reach a maximum weight, and have produced gametes in a mature, ripe, or gravid state. Testes generally turn from a reddish color to white. Ovaries become opaque turning from red to yellow or orange color because of the process of vitellogenesis, during which yolk is accumulated in the enlarging oocytes. Because or numerous blood capillaries, the ovaries may appear tinged with red. The developing eggs themselves change from very small, transparent oocytes to large, opaque, clearly discernible ova filled with yolk material, most becoming round and transparent just prior to spawning. Towards the end of this phase the testes may yield small amounts of milt when pressure or a milking force is applied to the abdomen, but they will not be in a running-ripe condition.

-Phase III-Mature, running-ripe, or spawning: The gametes of fish in this condition are in a mature form with eggs typically round and transparent. Both eggs and milt flow freely from the body with little or no pressure applied to the abdomen. Gonad size and weight decline rapidly during spawning activities.

-Phase IV-Spent or recovery: The testes and ovaries are emptied of most mature gametes and are considerably reduced in size and weight with organ walls striated. The gonads are red with prominent blood vessels; the ovaries may be bloody at the beginning of this phase. Residual sperm and advanced or mature eggs are broken down and resorbed. If the fish is to begin another cycle, small transparent oocytes may already be developing but remain invisible to the naked eye.

For the study of the gut content the eviscerated organs were preserved in neutralized formalin at 10%. The level of identification of the contents was conditioned to the level of digestion of the ingested items and it is expressed in terms of the dry weight.

The identification of collected macroinvertebrates was done using the taxonomic keys from the following authors: Rathbun 1937, Abott 1954, Garth 1958, Garth & Stephenson 1966, Morris 1966, Keen 1971, Voss 1971 and 1980, Olsson 1971, Gore & Abele 1971, Lindner 1977, Gosner 1978, Sabelli 1979, D'Croz 1982, Rodriguez 1982, Puertas 1984, and Mendez 1987. Measurement of the specimens was obtained from a caliper (Vernier), and weight from a balance OHAUS (capacity 2 kg).

(7) **Commercial and Sport Fishery**

The sources of information regarding the fishery resources of this country are based on several actions performed by international agencies. Among these, the Inter-American Tropical Tuna Comission (IATTC) who carried the assessment of the stock of anchoveta (*Cetengraulis mysticetus*), and the herring (*Opisthonema libertate*) in the Pacific coast of Panama (Howard & Landa 1958, Bayliff 1963a, 1963b, 1964, 1965, 1966, and 1969). This fish stock is the raw material for the production of fish meal. Paralell to these studies, the IATCC performed important oceanographic surveys in the area to support the research on the anchovetas (Smayda 1966 and Forsbergh 1969). The Food and Agriculture Organization of the United Nations (FAO) carried a regional fishery development project in Central America which actions took place from 1967 to 1971 (Vidal & Rosetti 1971). Some important fish stocks were assessed in this project, included the deep water shrimp, and the prospections of the lobster and shark resources. In 1987, framed within the project UNDP/FAO/GLO/82/001, the danish research vessel "Dr. Fridtjof Nansen" carried out some prospections of the fishery resources of the continental shelfs in the Pacific coast from the Gulf of Tehuantepec to the southern coast off Colombia, including the coast of Panamá (NORAD 1988). In addition, the Republic of China has implemented a fishery project for several years. Most of this project has been devoted to the assessment of the snapper stocks in the Pacific coast of Panamá, and in the training of local fishermen.

In the Caribbean side, the regional fishery development project of the FAO, also carried out some fishery prospections (Giudicelli 1971a and 1971b, Yesaki & Giudicelli 1971). But also the Japan International Cooperation Agency (JICA) organized and executed a project to assess the fishery resources in the Caribbean coast of Panamá (JICA 1984).

A summary of all this information has been used to describe the main fishery resources that are, in some extent, related to the study area of this Biological Inventory.

4) RESULTS AND DISCUSSION

a) TERRESTRIAL

(1) The physical environment

The Isthmus of Panama, due to its climatic characteristics and soil evolution, has natural conditions to sustain a forest type cover. Most of the area was covered with tall forest until the first half of the sixteen century, when the introduction of cattle, sugar cane and the production of food, firewood and timber for a growing population started a forest destruction that continues until today. These facts have been verified and commented by anthropologists, biologists and natural scientists in a number of publications since the second half of this century.

In the Gatun and Madden watershed (some 3,338 km^2), this destructive process was the same as in the rest of the country but with important variation. The 1904 Panama Canal Treaty reserved for construction and protection the so called Canal Zone; thus, the area remained out of Panamanian jurisdiction and under military control. This halted new colonizations, eliminated many of the existing farming and cattle raising schemes, and discouraged human occupation of the area, except for activities related to the operation and maintenance of the Panama Canal. These circunmstances favored a slow return of previously deforested areas to dense original forest. However, the colonization process never completely ceased, and in the past fifteen years it has increased with the expansion of agricultural and grazing frontiers threatening the integrity of the watershed and the survival of the Canal. The study area is now covered with an intrincate mosaic of remaining primary forest in the steepest terrain and in areas of difficult access, secondary forest in different stages of development, grasslands and small patches of temporary crops. The completed watershed of the Canal has aproximately 3,338.5 km^2 (1,289 square miles) and is divided in two sectors, SW low watershed including Gatun lake and its main tributaries (Gatun, Cirí Grande and Trinidad) and NE sector upper watershed, comprising Alajuela (Madden) lake and its principal tributaries (Chagres, Pequení and Boquerón).

On low watershed about 95% of the area has been depleted from the original forest cover. A gentle topography and relatively flat lands have encouraged low intensity agricultural activities and establishment of large areas with native and exotic grasses, appropriate for grazing. Apparently, erosion is not very important because of topographic condition and temporary use of land. Abandoned land, after temporary use, is covered with piooner vegetation, first stage of natural succession which protects soil and keeps rate of erosion low.

On the upper watershed, even with a much smaller deforestation rate, a combination of higher rainfall and steeper topography are factors of accelerated erosion. At the beginning of the century, Embera indians started the process by establishing crops for subsistence (rice, corn, plantain, coffee) in dispersed areas of less of two hectares which occasionally, were abandoned and replaced for new ones. The system is compatible with ecology; nevertheless, new colonizations mostly from central provinces, are threatening the watershed integrity especially the upper one. These farmers ("colonos") purpose is to raise cattle (Heckadon 1985); since vast spaces are needed to develop this activity, large areas of forest are cut and remanents are

burned. Continuous burning during dry season (every year) does not allow natural processes of succession to take place. These practices are especially dangerous for upper watershed, because combine with steep topography and heavy rain favor high erosion index and therefore sedimentation in canal lakes increases.

A report on Life Zones of Panama (Tosi, 1971) following the Holdridge method of classification of Plant Formations of the World, recognizes most of the study area as "Tropical Humid". Annual rainfall varies north to south from about 3400 mm to 1850 mm with 26°C of biotemperature[1]. Generally, precipitation decrease from north to south. In the Caribbean side, rain distribution througout the year is more uniform than in the Pacific side where a wet season (May to December) and a dry season (December to May) are well defined. From a vegetation growth point of view, the combination of high temperature and rainfall gives a principal role to soils. The rural census of lands and waters of the Republic of Panama (CATAPAN) from 1960 to 1965 surveyed, analyzed and mappped soil types of Panama including the Panama Canal watershed. This inventory sampled and analyzed (both physically and chemically) the soils in permanent sampling sites and these results match very close with those from CATAPAN.

The field and laboratory data from the soil samples collected during this inventory are presented in the following tables. The results from the chemical analysis of soils are as follows:

	Cruces	Mandinga	Cerro Jefe	Pequeni	Chagres	Trinidad
Texture class	clay	sandy-clay loam	sandy-clay loam	clay	sandy-clay loam	sandy-clay loam
pH	acid	acid	very acid	very acid	little	very
phosphorous	low	low	low	low	medium	low
potassium	medium	medium	medium	high	medium	medium
sodium	medium	medium	medium	medium	medium	medium
iron	high	medium	high	medium	low	medium
copper	high	low	medium	medium	low	medium
manganese	high	medium	medium	medium	medium	medium
zinc	medium	medium	low	medium	low	low
calcium	high	high	medium	medium	high	high
magnesium	high	high	medium	high	high	high
aluminum	low	traces	medium	high	traces	medium
organic matter	low	low	low	medium	high	medium

[1] Biotemperature: considers unitarian periods with T> 30 ° as 0. A value below normal temperature is obtained and it represents better the temperatures which allow regular physiological function in plants.

The physical conditions of the soils were observed as follows:

	Cruces	Mandinga	Cerro Jefe	Pequeni	Chagres	Trinidad
texture class	clay	sandy -clay loam	sandy -clay loam	clay	sandy - clay loam	sandy-clay loam
Epiped	umbric	ochric	ochric	ochric	ochric	ochric
Endoped	cambic	oxic	oxico	cambic	oxico	oxic
Drainage	moderately-well drained	well drained	well drained	well drained	well drained	well drained
Texture	clayish	fine clay	fine clay	fine clay	fine clay	clayish
Depth	shallow	moderately deep	moderately deep	moderately deep	moderately deep	moderately deep
Origin	limestone	igneous rock	extensive igneous rock	extensive igneous rock	sandy sedimentary rock	extensive igneous rock
Slope	45% - 75%	20% - 45%	45% - 75%	45% - 75%	8% - 20%	20% - 45%
Surface	moderate	little to moderate	little to moderate	little to moderate	little to moderate	little to moderate
Stoniness	moderate	moderate	moderate	moderate	moderate	moderate
Use capacity	VI	VII	VII	VII	IV	VII

Class IV soils are defined as tillable with severe limitations on plant selection or requiere very careful management.

Class VI soils are defined as non tillable, with severe limitations for agriculture, suitable for pasture land, forest, and biological reserve.

Class VII soils are defined as non tillable with very severe limitations for agriculture, suitable for forest, watershed protection, and biological reserves.

(2) Flora

Results from sampling sites are summarized in Tables N° 4 to 28.

In Table N° 4 a general summary for all vegetation sampling sites is presented. The percentage of samples identified to species level reached 93.4% (27,581 out of 29,528 samples); the rank fluctuates beetween 98.9% for Mandinga samples to 91.1% for Pequeni. Mixture ratio varied from 0.06 in Cerro Jefe (the most heterogeneous association) to 0.15 in Chagres, the association with lower diversity. As to number of trees with diameter equal or bigger of 10 cms. the most forested association was Cerro Jefe with 763 trees and Trinidad with 211 trees had the lower

result in tree count. Trees with 10 or more cms of diameter are considered an indicator of the "maturity" state of the stand and all our cases reveal a medium to late secondary forest, previous stages to the mature high forest to be expected in climatic and soil conditions of the studied areas. The virtual absence of big trees of commercial importance and absence of stumps suggests that these species were extracted long ago and regeneration has been innefective.

(2.1) Physiognomic association

A summary of the physical habit of the plants in sample sites is presented in Table N° 5. Cerro Jefe has the higher density of plants with 12,521 individuals per ha (42.39%) from an absolute total of 29,528). This condition and a larger amount of trees (palms included), 77.26% of the number of samples in the site, are indicators of advanced maturity of this stand as compared with all others. A marked absence of big trees of economic interest is also noted in this place and due to the same selective extraction carried on for many years in Panama.

Mandinga is the site with lower density of plants, 1,761 individuals per ha only 6.02% of all samples for the 6 sites but with a trees/all plants ratio of 68.20%. Chagres has the lower trees/all plants ratio with 49.23% beeing this result a confirmation of the lower complexity of this association wich with a mixture ratio of 0.15 is the simplest of the 6 studied associations.

(2.2) Abundance, frequency and Index of value of importance (I.V.I)

These characteristics are detailed in Tables N° 6 to 17 (odd number tables for all species and even number tables, trees only), being the I.V.I a key characteristic of ecological dominance between species sharing same habitat. As mentioned before all forest samples of this study revealed complex stands in secondary and middle aged stages. In this development stages the I.V.I runs from low (50-25) to very low (less than 25) being 300 the possible maximum which occurs only in monospecific associations, very rare in the tropics and practically absent in Panama. None of our samples reached an I.V.I of 25.

The three species with higher I.V.I at each of the six associations were:

Site	Species	Common name	I.V.I.
Cruces	Oenocarpus mapora	Palma	20.87
	Anacardium excelsum	Espavé	19.55
	Protium sp.	Caraño	12.62
Mandinga	Swartzia simplex	Naranjillo	20.25
	Faramea occidentalis	Huesito	16.80
	Gustavia superba	Membrillo	12.44
Cerro Jefe	Cyrilla racemiflora	?	23.72
	Colpothrinax cookii	?	12.67
	Trichipteris williamsii	Helecho	7.17

Pequení	Socratea exorrhiza	Jira	10.89
	Otoba acuminata	?	7.68
	Protium tenuifolium	Caraño	6.23
Chagres	Pseudobombax septenatum	Cedro espino	19.80
	Calycophyllum candidissimum	Madroño	17.47
	Cavanillesia platanifolia	Cuipo	13.91
Trinidad	Didymopanax morototoni	Pavilla	13.90
	Cupania scrobiculata	?	10.24
	Apeiba tibourbou	Peinecillo	7.00

(2.3) Basal area and timber volume

Considering only D.B.H. of 10 cm or higher timber volume was calculated (in m3 for each individual and the every one of the 50 subplots of each site).

Chagres with 462.05 m3/ha rank first in volume and Trinidad with 63.27 m3/ha was the association with lowest timber volume. Timber volume considered by itself is deceitful a very few of the big aund abundant species detected are actually of commercial importance. This is an important condition for discouraging organized timber extraction for commercial purposes.

(3) Fauna

(3.1) Entomology

(3.1.1) New Jersey black light trap (Tables N° 29, 30, and 31)

The following insect species were collected:

-Culicidae: 10 genera of the Culicidae Family were collected at the four localities, all of which were present at Gamboa, and Arenosa and 8 at Arraijan and Paraiso. Gamboa was the station with a greater number of specimens collected (4756), while at Paraiso 222 were collected. *Culex* was the genus more frequently found in all the localities, followed by *Aedeomyia, Uranotaenia, Mansonia, Anopheles, and Aedes*. Populations of Culicidae were drastically reduced in the dry season with the exception of *Aedeomyia* that went up during this period at Gamboa. It is worth mentioning there was a considerable increase in the population of this group at Arenosa in September. Due to the condition of the samples of Culicidae it was only possible to identify males, so the following species were determined: *Anopheles albimanus, A. vestitipennis, A. punctimacula, A. pseudopunctipennis, Aedes taeniorhynchus, Mansonia titillans, and M. indubitans.*

Among the insects found that may be considered of medical importance, the Anophelines occupy the first place because of their potentiality as vectors of malaria. Traditionally,

Anopheles albimanus has been considered the principal vector of malaria in Central America and Panama; although at present it is known that other species are capable of transmitting the disease in the area. *Aedes taeniorhynchus* and species of Mansonia are important because they are potentially capable of transmitting the Venezuelan equine encephalitis virus, and species of *Culex* are vectors of filariasis and the encephalitis virus.

Paraiso was the locality that exhibited a greater degree of ecological diversity (H'=0.715) and also, a higher equitability index (J'=0.792) followed by Arenosa (H'=0.701; J'=0.701), Gamboa (H'=0.681; J'=0.681), and Arraijan (H'=0.509; J'=0.564).

-Culicoides: 43 Culicoides species were identified, of which 7 are anthropophilic in habit, totaling 13638 specimens. Thirty seven species were collected at Arenosa, 27, 30, and 25 species were collected at Arraijan, Paraiso and Gamboa, respectively. Sixteen species were common in all four locations. Arenosa was the locality where more species and the highest populations were found with an average of 121 individuals, followed by Arraijan, Gamboa, and Paraiso with 99, 41, and 22, respectively.

Culicoides insignis, C. furens, C diabolicus, C. pseudodiabolicus, C. leopoldoi, and *C. hylas* were the predominant species at the 4 sampling localities. This is shown by the fact that in Arenosa, for example, *C. insignis* had an average of 50, *C. pseudodiabolicus* 28, *C. diabolicus* 19, *C. leopoldoi*, and *C. hylas* 5, while other species in the same locality averaged less than 5 specimens. *C. furens* was the most persistent and abundant species at Arraijan with an average of 82. No other species averaged more than 5. *C. diabolicus*, *C. hylas* and *C. insignis* averaging 26, 4, and 4 respectively, were the dominant species at Gamboa. Although the same pool of species appear as dominant at Paraiso,their populations did not vary much with little or no dominance for any single species.

The data analysis indicate that Paraiso was the locality with greater diversity and equitability (H'=0.981; J'=0.685); the locations of Arenosa, Gamboa and Arraijan exhibited lower diversity indexes (H'=0.774, J'=0.493; H'=0.609, J'=0.435; H'=0.396, J'=0.268).

The relatively high numbers of Culicoides was observed during the rainy season (May-December) at Paraiso, Gamboa, and Arenosa, not so in Arraijan, where populations remained the same in both wet and dry periods. On the other hand, *C. diabolicus, C. insignis, C. pseudodiabolicus, C. leopoldoi*, and *C. hylas* exhibited a higher number of individuals in the wet months at Paraiso, Gamboa, and Arenosa, while at Arraijan, *C. furens* was the most abundant and was present throughout both periods.

-Psychodidae: 16 different species of the *Lutzomyia* genus were collected at the 4 sampling stations. Twelve at Gamboa, 11 at Paraiso, 6 at Arenosa, and 5 at Arraijan. Two species of *Bruntomyia* were collected at Paraiso, Arraijan and Arenosa. Gamboa was the richest as to the number of species and individuals collected. *Lutzomyia carpenteri, L. dysponeta, L. gomezi*, and *L. panamensis* were present in every locality. However, *L. dysponeta* was more frequently found in three of the sampling sites, surpassed only by *L. panamensis* at Gamboa.

In general, the wet and dry seasons do not seem to have affected the populations of this group of insects. It is important to note that 6 out of 7 species traditionally known as anthropophilic in habit, *L. gomezi, L. olmeca, L. panamensis, L. pessoana, L. trapidoi,* and *L. ylephiletor,* were present. These have been reported as carriers of skin leishmaniasis in Panama. *L. sanguinaria* was the only anthropophilic species not found in this study. Other non anthropophilic species that were collected are important because they may contribute to maintain the parasite in wild reservoirs

Although Gamboa was the locality where more species were obtained, the greatest ecological diversity for this group was obtained at Paraiso (H'=0.699), followed by Arenosa (H'=0.677), Gamboa (H'=0.650), and Arraijan (H'=0.545); this was due to the high population of *L. panamensis* and *L. dysponeta* found in Gamboa. The equitability index was greater at Arenosa (J'=0.801), followed Arraijan (J'=0.701), Paraiso (J'=0.647), and Gamboa (J'=0.602).

-Oviposition traps (Tables N° 32 and 33)

Twenty five taxa were collected with this method in the 4 localities, of which 14 were present in Arenosa, 11 at Gamboa, and 10 each at Arraijan and Paraiso.

The Diptera, represented by 5 Families showed the greatest diversity, especially the Culicidae with a total of 8 genera and 7 identified species. The group most frequently collected was the Empididae which was dominant at Paraiso.

The Empididae Family as well as *Limatus* and *Culex* genera were most abundant at Arenosa; the Empididae and Lepidoptera at Arraijan, and the genus Trichoprosopon and the Empididae at Gamboa, the Empididae and Lepidoptera at Paraiso.

During the dry season an increase in numbers of Tabanidae larvae was observed at Arraijan, while a decrease of the Empididae population took place in the same locality. The Culicidae were present in high population densities in August at Gamboa and Arenosa. During the wet season, although present, no specific group of this Family was permanently present and in the dry season only 4 *Culex* specimens were collected at Arraijan. It is worth mentioning the presence of species of *Haemagogus* and *Sabethes*, known vectors of the yellow fever virus, and species of *Toxorhynchites*, which are predators of Culicidae larvae.

(3.1.3) Aquatic net (Tables N° 34 and 35)

Thirteen insect Orders and two Classes, totalling 50 taxa (32 at Paraiso, 35 at Gamboa, 25 at Arraijan and 29 at Arenosa) were obtained through the use of this methods. Odonata was the taxon more frequently collected at Paraiso, Gamboa, and Arraijan, while at Arenosa the Scirtidae were more abundant, followed by the Belostomatidae and Odonata. The taxa that were always present throughout the sampling period were Ephemeroptera, Odonata, and Trichoptera(insect Orders); Gerridae, Cicadellidae, Curculionidae, Dytiscidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Formicidae, Belostomatidae, Naucoridae (Families), and

Araneae (Arachnida). The major population fluctuations were observed on the Ceratopogonidae and Culicidae, which were collected only during the rainy season.

(3.1.4) Hand dipper (Tables N° 36 and 37)

A total of 43 taxa were collected, including 13 insect Orders, 29 Families, and 1 Class, distributed as follows: 23 at Paraiso, 33 at Gamboa, 18 and 16 at Arraijan, and Arenosa, respectively. The Odonata was the most abundant and frequently present group, at least in 3 localities. At the locality of Arenosa, the Scirtidae Family followed by Belostomatidae and Odonata were the most abundant. It should be mentioned that Odonata, Ceratopogonidae, and Formicidae were collected at the 4 sampling stations. The Araneae (Arachnida) and Copepoda are first recorded in March, but it does not mean they were not present on previous collecting dates. The presence of Copepoda is significant because of their potentiality as predators of Culicidae larvae. The Culicidae Family was poorly represented in the samples possibly due to the presence of predators, alteration of the habitat or water pollution.

(3.1.5) Human bait

During the sampling period 112 specimens belonging to 5 genera were collected at Paraiso and Gamboa. These included the following seven species of the Culicidae Family: *Aedes taeniorhynchus, A. euplocamus, A. serratus, Anopheles strodei, Sabethes chloropterus, Mansonia sp.* and *Culex sp.* During the wet season more insects were caught, particularly in August an September, wile in the dry season the presence of mosquitoes was nil.

(3.1.6) Carrion trap (Tables N° 38, 39, and 40)

A total of 58390 specimens belonging to 13 Orders and 109 Families were collected throughout this sampling period. The number of Families captured per locality is as follows: Paraiso 81, Arraijan 68, Gamboa 62, and Arenosa 58 Families. The highest number of specimens was obtained in Paraiso. Orders with greater number of Families were Coleoptera with 26, Diptera 22, Hymenoptera 14. Groups with higher number of individuals were Calliphoridae, Sarcophagidae, Formicidae, and Staphylinidae, which add up to a total of 34672 specimens (59% of the total). Following in importance were Muscidae, Phoridae, Sphaeroceridae, Trixoscellidae, Nitidulidae, Acari, and Araneae.

Utilizing the diversity index of Shannon-Weaver H' to determine the diversity of the different taxa per locality, it was found that Arenosa showed the greatest diversity (H'=2.441), followed by Arraijan (H'=2.354), Paraiso (H'=2.312), and Gamboa (H'=2.229). Regarding the equitability (J) it can be said that Arenosa (J=0.601) had the highest equitability among the taxa present, followed by Arraijan (J=0.558), Gamboa (J=0.540), and Paraiso (J=0.526). According to the analysis of the data obtained with this sampling method, Paraiso was the most disturbed locality.

(3.1.7) McPhail traps (Tables N° 41, 42, and 43)

During the sampling period a total of 43 major taxa were collected. Most of the material was identified to Family, and only a few sporadically caught, were identified to Order. At Gamboa and Arraijan 40 taxa were collected, while at Paraiso and Arenosa, 39 and 38 taxa were obtained, respectively. Thirty one of these taxa were caught at the 4 sampling stations. The Diptera were best represented with 27 Families, followed by Hymenoptera with 7, Coleoptera with 4, and 1 for the remaining taxa.

Considering all the taxa collected, Drosophilidae was the predominant Family at Paraiso, and Arenosa. Particularly at this location its dominance was very significant, while at Gamboa the Phoridae and Otitidae were very similar in numbers to Drosophilidae. At Arraijan the Otitidae Family was predominant over the Drosophilidae and Phoridae. These three groups together were dominant at this locality. It is interesting to observe the high population density shown by the Muscidae Family at Arenosa where it was second in dominance. Together with the Sarcophagidae mark the degree of ecological disturbance of the area. The high populations of Calliphoridae at Arraijan can be misleading because the peak occurred in September when a particularly high number of specimens of a migrant population of *Chrysomya* sp. were caught in the traps. Within the Hymenoptera, the Formicidae Family was predominant in all the localities except in Paraiso, where the Apidae were more abundant. It is worth mentioning the low numbers of insect parasites (Braconidae, Cynipidae, and Diapriidae) trapped in Arenosa. This was also true for pollinators in all the localities. With the exception of Paraiso very few bees were captured at Gamboa, Arraijan and Arenosa. Populations of Staphylinidae (Coleoptera) were always present although in lower proportions at Arraijan and Arenosa. This group includes important predators of Diptera larvae and pupae.

Comparing the population trends of all the taxa collected as influenced by the wet or dry seasons it can be said they were greatly affected as shown by a considerable reduction of their populations during the dry period. This situation is readily observed on Drosophilidae in all the localities, and for Muscidae and Sarcophagidae at Arenosa; the same phenomenon was observed for the Otitidae and Phoridae, although the lower humidity did not affect them so much at Paraiso. Generally speaking, these were the predominant groups in the dry season at Paraiso and Gamboa during the dry season, together with the Muscidae at Arraijan and Arenosa.

All that has been previously mentioned can be seen more clearly through the ecological analysis for this sampling method which show Arenosa with the lowest diversity indexes ($H'=0.565$, $J'=0.358$) and a higher level of ecological disturbance. On the other hand, Paraiso ($H"=0.806$, $J"=0.507$), Gamboa ($H"=0.841$, $J"=0.525$), and Arraijan ($H"=1.00$, $J"=0.625$) exhibited a higher degree of ecological diversity, the latter being the least disturbed of the sampling sites.

(3.1.8) Berlese funnel (Tables N° 44, 45, and 46)

Using this method it was possible to collect a total of 42237 specimens belonging to 17 Orders and 75 Families. The numbers per locality were as follows: Paraiso 54 Families, Arraijan 52, Gamboa and Arenosa 46 each. The predominant taxa were Acari, Formicidae, and Isoptera, adding up to 35856 individuals (84% of the total). Second in importance were the Araneae, Coleoptera larvae, Entomobryidae, Isotomidae, Rhinotermitidae, Scolytidae, Sminthuridae, and

Tenebrionidae. Orders with greater number of Families were Coleoptera, Hemiptera, and Collembola with 26, 11, and 6, respectively.

Arraijan was the locality with a higher degree of ecological diversity (H'=2.035), followed by Gamboa (H'=1.735), Paraiso (H'=1.683), and Arenosa (H'=1.116). On the other hand Gamboa was the locality with a greater equitability among the taxa obtained (J"=0.455), followed by Paraiso (J=0.422), Arenosa (J=0.291), and Arraijan (J=0.155). Based on this analysis, Arenosa showed a higher degree of ecological degradation.

The rainy and dry seasons had some effect on the distribution and abundance of some groups. Taxa with greater number of individuals during the rainy season were: Acarina, Entomobryidae, Formicidae, Isotomidae, and Tenebrionidae. The Tubulifera, Psocidae, and Coleoptera larvae were more abundant in the dry season.

(3.1.9) Pitfall traps (Tables N° 47, 48, and 49)

A total of 11233 specimens belonging to 12 insect Orders and 98 Families were collected throughout the sampling period. sixty four Families were collected at Arraijan, 61, 57, and 52 at Arenosa, Gamboa, and Paraiso respectively. As can be observed there was little variation as to the number of Families obtained on each sampling site. However, Arraijan was the location where the greatest number of taxa were captured. Orders with greater number of Families were: Coleoptera with 24, Diptera 21, and Hemiptera 10. The Formicidae, Staphylinidae, and Acari were the predominant groups totalling 7636 specimens (68% of the total number of specimens captured). Second in importance were Araneae, Scolytidae Nitidulidae, Histeridae, Coleoptera larvae, and Gryllidae.

The analysis for diversity indicates that Paraiso has the highest degree of ecological diversity (H'=2.583), followed by Gamboa (H'=2.532), Arraijan (H'=2.024), and Arenosa (H'=1.809). Paraiso also exhibited greater equitability (J=0.654) among the different taxa, followed by Gamboa (J=0.626), and Arraijan (J=0.487), and Arenosa (J"=0.440). According to the data obtained through this sampling method, Arenosa has a higher degree of ecological degradation.

(3.1.10) Sweep net (Tables N° 50, 51, and 52)

A total of 14 insect Orders and 182 Families were collected. Two Orders of the Arachnida were also collected throughout the sampling period.

The most abundant from the list of Insect Families were Chloropidae (Diptera); Tettigoniidae and Acrididae (Orthoptera); Braconidae and Formicidae (Hymenoptera); Chrysomelidae (Coleoptera); Cicadellidae and Membracidae (Homoptera); Pentatomidae and Lygaeidae (Hemiptera).

The wet or dry seasons did not affect much the populations observed throughout the sampling period. The number of insects was low in July (wet season) and were also low in March (dry

season). This was particularly true for the Chloropidae (Diptera) and Braconidae (Hymenoptera).

A total of 14 insect Orders were collected at Arenosa, 12 each at Paraiso, Gamboa, and Arraijan during the 9 months of sampling. More Families (137) were collected at Arraijan, followed by Paraiso with 134, Gamboa with 123, and Arenosa 121 Families.

Paraiso was the locality that showed a higher degree of ecological diversity ($H"=1.406$), followed by Arraijan ($H"=1.291$), Arenosa ($H"=1.241$), and Gamboa ($H"=1.237$). Likewise Paraiso had the highest equitability ($J"=0.661$), followed by Arraijan ($J"=0.604$), Arenosa ($J"=0.596$), and Gamboa ($J"=0.592$). According to the data obtained through this sampling method Gamboa exhibited a higher level of ecological disturbance.

(3.1.11) Insects in plant residues

Three insect Orders and 4 Families were collected using this method. These were Curculionidae (Coleoptera), Calliphoridae and Psychodidae (Diptera), Formicidae (Hymenoptera).

The same Families were collected at the 4 sampling sites, except for Arenosa, where the Psychodidae were lacking.

Very few specimens were obtained with this method which requires larger amounts of woody material and time of exposure for the emergence of insects.

(3.2) Herpetology

The historical events that took place in the central part of the Isthmus of Panama, due to the particular geographic features of this region, facilitated in a direct or indirect way the study of this biota. This aspect of the central region has been the better studied of the whole country.

In 1874-1875, during a survey for an interoceanic route carried out by american militaries, Dr. John F. Bransford made a small collection of amphibians and reptiles in the region. His collection consisted of a few specimens captured, when his other duties allowed him, mainly along the Panama Railroad (Savage, 1973). Subsequently, during the Smithsonian Biological Survey of the Panama Canal Zone, in the period of the construction of the interoceanic canal, a collection of amphibians and reptiles was made in the years 1911 and 1912 (Schmidt, 1933).

Within the former Canal Zone, the faunistic survey was concentrated in Barro Colorado Island, after been considered an exclusive area for scientific research. In early 1930s, appears a publication on the amphibians of Barro Colorado Island (Dunn, 1931), including information from nearby locations. Almost four decades later, a list of the amphibians and reptiles recorded from the island was published (Myers and Rand, 1969). The continuous flux of scientists to Barro Colorado Island, and the expansion of their activities to the vicinities, has greatly contributed to the knowledge of the herpetofauna in this region. The work of Rand and Myers (1990), in addition to present an updated list of the amphibians and reptiles of Barro Colorado

Island and adjacent areas, also synthesize studies on the ecology and behavior of some species, which were made by several investigators throughout the years.

To end this brief account about the surveying of the herpetofauna in the Canal Area, it is necessary to indicate that some additional contributions were made within or near military installations located in the Canal Zone. Such as, some notes on collections of amphibians and reptiles from the region (Swanson, 1945; Evans, 1947; Smith and Grant, 1958; Fouquette, 1960).

In the present study we provide an inventory of the amphibians and reptiles found in delimited study sites. Nonetheless, we have not expected to find all the species that have been recorded in the region of the Canal. This quantity has been accumulated throughout many years and with the effort of numerous investigators. In addition, we include information on the abundance, seasonal changes and ecology of the observed species. The present study is focused almost exclusively in our observations made at the selected study sites during the sampling periods.

(3.2.1) Inventory of amphibians and reptiles

During the five sampling periods a total of 117 species of amphibians and reptiles were found in the study sites (Table N° 53). Due to additional information, the turtle *Chelydra serpentina* was added to the total number of species, based on remains shown to us by local residents in Cirí. A list of the 60 amphibians and 58 reptiles (including *Chelydra serpentina*) found and their abundance at each study site are presented in the Table N° 54 and 55, respectively.

Among the interesting findings can be mentioned two new species, a frog of the genus *Atelopus* and a lizard of the genus *Anolis* from the *fuscoauratus* group. The existence of both species in the region is known since about two decades ago; nevertheless, they remain undescribed. In addition, the range of distribution of the frog Phyllobates lugubris was extended, presently being Cirí the locality that delimits the eastern extreme of its geographic distribution.

(3.2.2) Assessment of sampling effectiveness

The number of species known to be occur in the Canal Area has been accumulated since the last century. Hence, it will be impossible to find all the species recorded for the area in a short period. Nevertheless, is possible to estimate the effectiveness of our sampling methods by using a list of the species present in the Canal Area. The list presented in the **Biological Data Background** is not appropriate, because it includes species found within the extensive watershed of the Canal, some of them present outside of our limited study sites. Consequently, the use of a list less encompassing is preferable, such as the one presented by Rand and Myers (1990) for the Barro Colorado Island and vicinities, specifically the Barro Colorado Natural Monument and the Soberanía National Park.

The location of the study site in Corte Culebra was adjacent to the Soberanía National Park. Therefore, the list of amphibians and reptiles presented by Rand and Myers (1990) could be used to obtain a rough estimate of the efficacy of our sampling methods in this particular study site.

This is a very complete list of the species present in the area, which has been compiled for about 70 years and by several investigators.

The analysis was limited to the anurans (frogs and toads), saurians (lizards) and serpents. For this analysis we omitted some of the species listed by Rand and Myers (1990), which based in our experience in the region, are not expected to occur in Corte Culebra. Nevertheless, those species for which we doubt were not eliminated, especially in the case of most of the snakes. Therefore, the total number of species expected to be found for each group in Corte Culebra was: 41 Anura, 27 Sauria, and 46 Serpentes. We found 29, 14 (excluding the previously unrecorded *Leposoma rugiceps*) and 7, respectively. Therein, it is estimated that in Corte Culebra we have found 71% of the total anurans, 52 % of the total saurians, and 15 % of the total serpents present in this site.

If we reduce the list according to the category of abundance only to the usual species, we have found 75 % of the usual anurans, 50 % of usual saurians, and 25 % of the usual serpents occurring in Corte Culebra. In the same way, it is estimated that we have found 100 % of the common anurans, and 75 % of the common saurians present in this site. These rough estimates might be extrapolated to the other study sites.

In general terms, the anurans are relatively easy to sample, especially because many species tend to aggregate in suitable sites for breeding or concentrate in moist places during the dry season. In addition, they are more conspicuous than other groups, because the males give advertisement calls, enabling us to determine their presence by only listening. Whereas, the snakes are extremely difficult to sample, most of them are observed infrequently; which seems to be a normal condition in the lowlands of the region (Myers y Rand, 1969).

(3.2.3) Species diversity

Figure N° 1 shows the increment in the number of species as the sampling effort (i.e., person-hours) increases the study sites. The number of species per study site varied between 42 and 60. Pequení and Corte Culebra had the highest diversity of amphibians and reptiles, while Cirí had the least diversity of species. This contrast could be partly related to the higher habitat diversity of the area sampled in Pequení and Corte Culebra than the one sampled in Cirí, the latter site been a pasture land with reduced zones of regrowth, gallery forest or secondary forest.

(3.2.4) Abundance of amphibians and reptiles

Only 8 species of amphibians and 4 of reptiles were found in all the study sites, four of them being common in these sites: the small treefrog *Centrolenella fleischmanni* along the margins of forest streams, the small treefrog *Hyla microcephala* at the edges of ponds in open areas, and the frog *Eleutherodactylus fitzingeri*, and the lizard *Anolis limifrons* in the forest understory. The presence and abundance of a species usually vary among study sites; hence, this information has been summarized in Tables N° 54 and 55.

The Figures N° 2 to 7 show the number of individuals found visually per effort unit, according to the category of habitat, for each study site.

In Cirí, the most abundant genera found within the forest were: *Dendrobates* and *Eleutherodactylus* (Figure N° 2), being the frog *Dendrobates auratus* the most common and single species of the genus in this site. The genus *Rana* was the most abundant in the open areas (Figure N° 2), only with the species *Rana vaillanti*. The most abundant genus in the aquatic zones and their margins was that of the *Trachemys* turtles (Figure N° 2), represented only by *Trachemys scripta*.

In Sherman, the most abundant genus within the forest was *Colostethus* (Figure N° 3), being the litter-frog *Colostethus talamancae* the single species of the genus in this site. The lizard genus *Anolis* was the most abundant in the open areas (Figure N° 3), almost exclusively due to *Anolis auratus*. *Leptodactylus* was another abundant genus in the open areas, mainly because of the grassfrog *Leptodactylus labialis*.

In Culebra, the most abundant genera found within the forest were: *Bufo*, *Colostethus*, *Basiliscus* and *Eleutherodactylus* (Figure N° 4). Among these, the more numerous were the toads *Bufo typhonius* and *Bufo marinus*, the litter-frog *Colostethus flotator*, the semiaquatic lizard *Basiliscus basiliscus*, and the frog *Eleutherodactylus fitzingeri*. The anuran genera *Physalaemus*, *Leptodactylus*, and *Hyla* were the most abundant in the open areas (Figure N° 4), commonly represented by *Physalaemus pustulosus*, *Leptodactylus labialis* and *Hyla microcephala*.

In Cocolí, the most abundant genera found within the forest were: *Bufo* and *Eleutherodactylus* (Figure N° 5), being the toad *Bufo typhonius* and the frog *Eleutherodactylus fitzingeri* the most common. The anuran genera *Hyla*, *Physalaemus*, and *Leptodactylus* were the most abundant in the open areas (Figure N° 5), mainly represented by the species *Physalaemus pustulosus*, *Hyla microcephala*, and *Leptodactylus pentadactylus*.

In Pequení, the most abundant genera found within the forest were: *Bufo*, *Anolis*, *Colostethus* and *Eleutherodactylus* (Figure N° 6), being the toad *Bufo typhonius*, the semiaquatic lizard *Anolis poecilopus*, the litter-frog *Colostethus flotator*, and the toad *Eleutherodactylus bufoniformis*, the most common. The genera *Bufo* and *Ameiva* were the most abundant in the open areas (Figure N° 6), almost exclusively represented by the toad *Bufo marinus* and the teid lizard *Ameiva ameiva*. The most abundant genus in the aquatic zones and their margins was that of the *Trachemys turtles* (Figure N° 6), being *Trachemys scripta* the single species. Also, in the margins of the Pequení River were observed, from the genus *Bufo* (Figure N° 6), the toads *Bufo marinus* and *Bufo haematiticus*.

In Tranquilla, the most abundant genera found within the forest were: *Eleutherodactylus* and *Bufo* (Figure N° 7), being the most numerous, the frog *Eleutherodactylus fitzingeri* and the toad *Bufo typhonius*. The genus *Bufo* was the most abundant in the open areas (Figure N° 7), exclusively represented by the toad *Bufo marinus*. The most abundant genera in the aquatic zones and their margins were *Trachemys* and *Caiman* (Figure N° 7), being the turtle *Trachemys scripta* and the *Caiman crocodilus* the only species present of each genus.

(3.2.5) Seasonal changes

From the counts made along the transects, a seasonal pattern in the abundance of individuals of some species can be shown.

Seasonal changes in the abundance of three anurans were noticed in the transects located in Sherman: (1) the leaf-litter frog *Colostethus talamancae* decreased from the margins of the forest stream during the months with high rainfall, when the frogs disperse throughout the damp forest floor (Figura N° 8), (2) the glassfrog *Centrolenella fleischmanni*, whose breeding males were more abundant on the vegetation along the forest stream at the beginning of the wet season (Figura N° 9), and (3) the abundant treefrog *Eleutherodactylus diastema*, whose males call from concealed sites in the forest's vegetation, were more visible in January on the vegetation along the forest stream (Figura N° 9). Partly, this increase in the visibility of these frogs maybe related to their feeding activity during a moonlighted night.

In Corte Culebra, seasonal changes in six species were observed: (1) the grassfrog *Leptodactylus labialis*, active at night but frequently also in the daytime, was more abundant in the middle of the wet season (Figura N° 10), (2) the treefrog *Hyla microcephala*, whose breeding males concentrated on the pond vegetation during the wet season (Figure N° 11), (3) the terrestrial *Physalaemus pustulosus*, also resorted to the ponds to breed during the wet season (Figure N° 11), (4) the leaf-litter frog *Colostethus flotator*, whose individuals concentrated in the moist sites along the margins of the forest stream during the dry season (Figure N° 12), (5) the toad *Bufo typhonius* that breeds in this locality at the end of the wet season, and whose young toads concentrated along the margins of the forest stream in the dry season (Figure N° 12), and (6) the glassfrog *Centrolenella fleischmanni*, as in Sherman, the breeding males were more abundant on the vegetation along the forest stream at the beginning of the wet season (Figure N° 13).

In Cocolí, seasonal changes were noticed in five species: (1) the treefrog *Hyla ebraccata*, whose breeding males gathered on the pond vegetation in the wet season (Figure N° 14), (2) the treefrog *Hyla microcephala*, for the same reason of the previous one (Figure N° 14), (3) the terrestrial *Physalaemus pustulosus*, also resorted to the ponds to breed during the wet season (Figure N° 14), (4) the toad *Bufo typhonius* that breeds in this locality at the end of the wet season, and whose young toads concentrated along the margins of the forest stream in the dry season (Figure N° 15), and (5) the leptodactylid *Eleutherodactylus fitzingeri*, whose individuals also concentrated in the moist sites along the margins of the forest stream in the dry season (Figure N° 16).

In Pequení, the leaf-litter frog *Colostethus flotator* appeared in the transect along the forest stream in March, because the individuals concentrated in the moist areas along the margins of the forest stream during the dry season (Figure N° 17).

Observations on three of these transects were performed by another person in different days and nights, which had the purpose of estimating the variation that could occur under such conditions. In general terms, the most common species were found consistently in both circumstances, being relatively more abundant. Whereas, those species that are observed infrequently, were either

found or not. Nonetheless, these differences do not modify the previous discussion on seasonal changes.

From the observations made on some species about the calling activity of males for reproductive purposes, five patterns of activity were noticed: (1) species that call during the whole year, i.e., *Bufo marinus*, *Colostethus flotator*, *C. inguinalis* and *C. talamancae*; (2) species that call mainly during the wet season and occasionally during the dry season, i.e, *Agalychnis callidryas*, *Hyla crepitans*, *H. microcephala*, *H. rufitela* and *Smilisca phaeota*; (3) species that call throughout most of the wet season, i.e., *Centrolenella fleischmanni*, *C. granulosa*, *C. prosoblepon*, *C. pulverata*, *C. spinosa*, *Colostethus nubicola*, *C. pratti*, *Eleutherodactylus diastema*, *E. fitzingeri*, *E. taeniatus*, *Hyla ebraccata*, *H. rosenbergi*, *Leptodactylus insularum*, *L. labialis*, *L. melanonotus*, *L. pentadactylus*, *Scinax boulengeri*, *S. staufferi* and *Rana vaillanti*; (4) species that call during one or several brief periods during the wet season, i.e., *Chiasmocleis panamensis*, *Eleutherodactylus crassidigitus*, *Leptodactylus poecilochilus*, *Phrynohyas venulosa*, *Scinax rostrata*, and *S. rubra*; and (5) species that call only during the dry season, i.e., *Smilisca sila*.

(3.2.6) Ecological information on the amphibians and reptiles

Tables N° 56 and 57 show a list of the species of amphibians and reptiles, respectively, including the category of habitat and specific site of observation.

(3.3) Ornithology

The construction of the transisthmian railway and the preceding construction of the Panama Canal have been two events that have influenced the study of birds, not only in the Canal Area, but also throughout the Republic of Panama; one of the oldest and most complete work is the one of Salvin and Godman (1879-1904) who collected 85,000 individuals in Central America, of which 673 species belonged to Panama. Work by Mcleannen by mid century mentioned birds collected in Lion Hill, at present covered by the Gatun Lake. Wetmore (1965, 1968 and 1873) Wetmore, Pasquier & Olsson (1984), and Ridgely & Gwynne (1989) made descriptions and of the bird species reported up to date for the Republic of Panama, including the Canal area. Sturgis (1928) published a field guide of the birds on the Canal Zone which also includes some neighboring locations. Eisenmann & Loftin (1962) make a compilation of bird species reported for the Canal area and the cities of Panama and Colon. Drennen (1991) publishes the list of registered birds in the annual Christmas count for the Canal Zone in Panama.

In the area of study there are protected areas such as the Natural Monument of Barro Colorado (BCI), which started to be studied on the early XX century. The studies performed here, appear cited by Eissenmann (1952) and Willis and Eisenmann (1979) on the birds list of Taboga and Uraba. On 1978 N. Gale, J. Karr, E. Morton, R. Ridgely, N. Smith, N. Smythe, E. Willis and others, prepare a list of birds of Pipe Line Road which is a big part of the Parque Nacional Soberanía. Engelmann & Engelmann (1990) prepared a list of birds on the Parque Natural Metropolitano. Karr, Robinson, Blake, and Bierregaard (1990) published a list of birds for Barro colorado (BCI) and the Parque Nacional Soberanía.

The results from this bird inventory are in Tables N° 58 to 104. The Table N° 73 shows the effort of quarterly sample in hours/men (M/H). Includes the total of species and individuals as for the first sample, as for the second, third, fourth and fifth o the habitats of each visited place. Also shows the cumulative species for all the project. The great variations in hours/men followed on August, February-March, and May due to the repetitions made at the South Entrance, Gaillard Cut, and the North Entrance. The cumulative increase of hours/men corresponding with the number of registered species (cumulative), although the amount of species that have been added on each sample have been decreasing (Tables N° 73, 74, 90, 94, and Figure N° 18).

In general terms, the effort done shows that the population has been well sampled. This can be noted from the point of view of the total of samples (Figure N° 18) total by place (Figure N° 19), total by habitat (Figure N° 20), and total by place and habitat (Figure N° 21). The figures show excellent samples and at the least note a strong tendency to stability.

In this project observations have been carried out in 580.05 kms. as a result of the runs and their repetitions done on our normal (ordinary) route of 101.05 kms (Table N° 99). In total we have registered 53 912 individuals belonging to 405 species, 54 families, and 19 orders (Tables N° 58, 59, and 90). These species belong to 66.39% of the 610 reported for the Canal zone among the works of Wetmore (1952), Eisenmann and Loftin (1967), Willis and Eisenmann (1979), Ridgely and Gwynnne (1989), Engelmann (1990), Karr, Robinson, and Blake (1990), and Drennen (1991). From the 222 registered for the area that we did not observe in our sample and appear registered for the area by the already cited authors 127 (57.21%) belong to species name by Ridgely and Gwynne (1989) as rare, very rare, casual, accidentals, hypotheticals, irregulars, scarce or pelagic visitants. It is obvious that these conditions greatly influenced for its detection in our samples. On Table N° 58 and 59 it is shown the taxonomic list of all registered species on this inventory, with the abundance on each sample and also on each place, the list of additional species, obtained from the already cited references is shown on Table N°60.

We shall not ignore that birds of the Canal zone have been studied since approximately a century and a half (Salvin and Godman, 1879-1904) and that the present list of this zone is a result from studies made during all this time on the other hand, the present region of study has been very altered by falling and burning of trees, which influences on the number of species and the size of their populations, as for locals and for migrants. Ramos and Werner (1980), consider that the winter residence play a very important role on the bird's evolutive history therefore major efforts to preserve them should be made. Terborgh (1982), notes that forests are more important than previously thought for many migrant species. Also, the major or minor intensity of hunting contributes negatively.

On the inventory, we have registered a total of 17 species that were not included up to now on the birds list of the Panama Canal zone, increasing therefore, the number of species to 267 for this areas. The species included are:

Jacana espinosa, June and August, 1992 and March, 1993, B. Jimenez, E. Peña, P. Garces, R. Hinds, and J. Ortega, on Farfan Lagoon, Gatun Lake, Alajuela Lake, and Ciri River.

Touit costaricensis, June 13, 1992, B. Jimenez and R. Hinds, aquatic and littoral, Gaillard Cut.

Cypseloides rutilus, one sample, June 13, 1992, B. Jimenez and Hinds, aquatic and littoral, Gaillard Cut.

Glencis aenea, November 1992, February and May, 1993, E. Peña, R. Hinds, P. Garces, and J. Ortega, Gaillard Cut, Sherman and Pequeni.

Melanerpes formicivoras, one sample, June 27, 1992, B. Jimenez and R. Hinds, Forest, Pequeni.

Picoides villogus, one sample, February, 7, 1993, V. Tejera, J. Ortega, Forest, Gaillard Cut.

Syndactyla subalaris, June 28, 1992, B. Jimenez and R. Hinds, Forest, Pequení.

Lepidocolaptes affinis, one sample, June 28, 1992, B. Jimenez and R. Hinds, Forest, Pequeni.

Thamnophilus bridgesi one sample, May 8, 1993, P. Garces and R. Hinds, Aquatic and Littoral, Gaillard Cut.

Myrmotherule schisticolor, November 6, 1992, B. Jimenez and Hinds, Forest, Gaillard Cut, March, 1993, R. Hinds, Forest, Ciri, May 10, 1993, P. Garces and R. Hinds, Forest, North Entrance.

Pachyramphus albogriceus, 1 sample, February 27, 1993, J. Ortega, Manglar, North Entrance.

Pipra pipra, February 7, 1993, V. Tejera, J. Ortega, February 6, 1993, R. Hinds and E. Peña, Forest, Gaillard Cut.

Vireolanius eximius, 1 sample, February 7, 1993, R. Hinds, J. Ortega and E. Peña, Forest, Gaillard Cut.

Euphonia hirudinacea, June 12, 1992, B. Jimenez and R. Hinds, Forest, Gaillard Cut.

Piranga bidentata, 1 Sample, November 6, 1992, V. Tejera and J. Ortega, aquatic and littoral, Gaillard Cut.

Atlapetes atricapillus, 1 Sample, June 13, 1992, B. Jimenez and R. Hinds, aquatic and littoral, Gaillard Cut.

Junco hyemalis, 1 Sample, M.V.U.P. N°1445, November 13, 1992, V. Tejera y J. Ortega, open area, Sherman, Collected by W. Martinez.

It is important to note that this last species is the first report for the Republic of Panama. It has also been seen for the first time in the Gaillard Cut region, all throughout Obispo river, on the

open area, the *Pilherodius pileatus* (capped heron). It is probable that the *Oceadroma tethys* has been seen on Lake Alajuela, around Tranquilla area, Ridgely (1989) notes its existence only for Panama bay and specially off shore. Some of the migrants species have arrived before the noted date in Ridgely (1989). On the case of *Myiarchus crinitus* that was registered on August 8, 1992, the *Buteo platypterus* that was detected on August 4, 1992, the *Icterus galbula* that was seen on August 9, 1992, *Vermivora peregrina* seen on August 3, 1992 and *Seiurus noveboracensis* registered on August 29, 1992. Ridgely (UP. Cit.) noted its arrival since the month of September. The most representative species in all the sample in other words in all 580.05 kms run through the sample, it was the turkey vulture (*Catarthes aura*, with 8181 individuals, 15:17% followed by the black vulture (*Coragyps atratus*, with 3,066 individuals, 5.68%), the orange chirned parakeed (*Brotogeris jugularis*, with 1982, 3.67%), neotropic cormorant (*Phalacrocorax olivaceus* with 1873, 3.47%), the little egret (*Bubulcus ibis*, with 1597, 2.96%), gray breasted martin (*Progne chalibea*, with 1556, 2.88%), bern swallow (*Hirundo rustice*, with 1484 individuals, 2.75%), Brown Pelican (*Pelecanus occidentalis*, with 1,052 individuals, 1.95%) and the blue-gray tanager (*Thraupis episcopus*, with 1,034 individuals, 1.93%). The other species were below the 1,000 individuals. In general the number of individuals was low, there were 37 (9.13%) species that only a sample was seen (0.002%) and 160 (39.5%) species registered 10 (0.002%) or less individuals (Tables N° 58 and 59) (*Catharthes aura* and *Hirundo rustica* are migrants and more in his groups, but *Catharthes aura* does it in thousands of individuals, as we saw on the open area of the south entrance of the Panama Canal and Ciri. The most representative family was Emberizidae with 80 (19.75%) species, followed by Tyrannidae con 58 (14.32%) species, the order best represented was the Passeriformes with 16 (29.62%) families and 222 (54.81%) species, most number of individuals and species, corresponded the samples of November and February - March that exactly are the months of migratory peak, on November from north-to south and on February-March from south to north (Tables N° 58, 59, and 90). Taking on account the must of 2 kms, in all area run (Table N° 92), also results that the major number of species and individuals is given on the samples of November and February-March. We have to consider that the trip from south to north the routes can change and the population can also decrease.

Considering the total of runs on each place (Tables N° 59 and 73), results that Pequení has the biggest number of species (269 species, 6.6.41%) followed by Gaillard Cut (267 species, 65.92%), The North Entrance from the Panama Canal (254 species, 62.71%), the South Entrance of the Panama Canal (229 species, 56.54%), Ciri (209 species, 51.60%) and Tranquilla (165 species, 40.74%). There are factors as the repetitions and the length of the runs that have influenced on these results, but on Pequení no repetitions were made and yet the kilometers run are more, as the number of species, however we consider that the result must be influenced too by the proximity of the jungle to the places of study. Even through Tranquilla Shows a total run almost as the one zone in Ciri and bigger than the one on the South Entrance and than the one from Gaillard Cut, always showed the smallest number of species. This must be the result that only sampled the open area and the transect aquatic and littoral. The forest habitat was not sampled because it was not representative, prevailed the grass-lands, consequently there was less diversity of bioteped. Although in Ciri the distance run was superior to the one of South Entrance and to the one of Gaillard Cut, and trough the same type of habitats were sampled the number of species registered was less. The main reason of this can be that the area is very

disturbed, the pons has almost disappeared and prevail the grassland and the number of biotopes has decreased. In Gaillard Cut also there is to consider that is situated on the continental divide which permits the finding of species from both sides (Pacific and Atlantic).

Considering the total of runs on each habitat (Tables N° 85 to 88) was found-out that the forest showed bigger diversity of species (331 species, 81.27%), followed by aquatic and littoral with (292 species, 72.09%), open area (246 species, 60.74%) and marine (181 species, 44.69%). These results are influenced by the total length of the run that were not the same for each habitat (table 2.4.12), However the forest, which length of run was less then the aquatic and littoral and that the one from the open area, had for more species then each one of them. Is clear the influence of the diversity of existing biotopes in the forest. The sequence shown by the habitat based on the number of registered species on them is equal with and without repetition, only the numbers vary (Table N° 94).

The taxonomic list complete of registered species on each one of the sample done, with its respective abundance in the total run of each habitat in all the zone worked is noted on Tables N° 85 to 88.

On the runs of 2 kms of each habitat, but all trough out of the worked zone (Tables N° 81 to 84) results on the same sequence presented before. This way the forest had more richness (wealth) on species (152) followed by aquatic and littoral (150), open area (145) and marine continues to be the less diverse and the difference among forest, aquatic and littoral and open area has been reduced. The decrease on the number of individuals in due in part to the decrease on the length considered. The sequence of habitats maintained with or without repetition, only change the numbers (Table N° 96).

The taxonomic list of registered species on each one of the sample done, with its respective abundance on the 2 kms. Run for each habitat in all area worked appears on Tables N° 81 to 84.

Considering only the 2 kms runs on each one of the 6 places worked on (Table N° 74) we found the biggest wealth on species is presented again in Pequeni (247) followed by the North Entrance (234), South Entrance (226), Gaillard Cut (218), Ciri (186) and Tranquilla (144). Again is clear the smaller wealth of species on Ciri and Tranquilla that were places where forest have almost disappeared and prevail grass lands for Cattle. In other places the major wealth of species coincides with the existence of some forest, but is important to point out that the burning, felling of trees and hunting are still present constantly in some of these sites. The most abundant specie on Pequeni (Table N° 65) was *Brotogeris jugularis*, orange chinned parakeed, with 223 individuals, followed by *Thraupis episcopus*, bluegrey tanger with 193 individuals, *Tangara inornata* plain colored tanagers with 159 individuals and *Ramphocelus flamigerus* falme-rumped tanager with 110 individuals, the other species were below the 100 individuals, 31 families were registered and 18 others. Both on the forest as on the open are prevailed *Brotogeris jugularis*, which flew over the area "screaming" and possed on a high teak (*Tectona grandis*), "espavé" (*Anacardium exelsum*) "barrigon" (*Pseudobombax septenatum*) and others.

In the aquatic and littoral habitat the most common was *Thraupis episcopus*, blue-gray tanager, which flew over Pequeni river, alone, by pairs or in groups up to 5 individuals. It was also seen, heard on the trees on the border where (ayed down, cleaning from lice, drying off, shaking and looking for food see the same Table for the other species found in Pequeni.

In the North Entrance (Table N° 63) the most abundant species was *Coragyps atratus*, black vulture (436 individuals), followed by *Brotogeris jugularis*, orange clinned parakeed (345 individuals) and *Hirundo rustica*, barn swallow (273 individuals) 39 families and 19 others were noted. In the forest prevailed *Coragyps atratus* that flew over the area, possed on the trees and eating carrion. On the marine habitat the most representative was *Brotogeris jugularis*, flying over the area and living on the of the mangrove where its noises could be heard.

The most common in the open area was the *Hirundo rustica* and in its migratory movements flew over the grass in groups, catching insects on the wind nearly touching the plants or higher in the air, in all directions. Also stayed on the living remains of the cutted grass.

In the aquatic habitat and coastline the most abundant were the southern rough-winged swallow (*Stelgidopteryx ruficollis*) that flew over the lake in groups, on the edge of the surface or at few meters, higher catering insects. See the same Table for the other species found at North Entrance.

On the South Entrance (Table N° 61) the most abundant was *Cathartes aura*, turkey vulture, migrant bird that every year goes through the Canal area in big groups (Smith 1985 & Tejera, Gorrichategui & Castro 1993). Forty seven families and 19 orders were registered. On the forest of this place prevailed the *Coragyps atratus*, black vulture, overflying the area or resting on the trees where they lies sunbathing, cleaning themselves off lices and they were also seen eating on the ground.

On the open area the most abundant was the migrant prey *Cathartes aura* which crossed at low height over the area in a column of thousands of individuals although with less abundance the *Progne chalibea* was also present with greater contact with the area because they rested on antennas, cables, wires, wired fences, points of small houses and flew over the area on different heights and directions catching the insects they eat in the aquatic and littoral habitat prevailed *Dendrocygna autumnalis*, black-bellied whistling-duck, aquatic and colonial that ate in Farfan lagoon, flying over the zone and rested on the trees of a neighboring mangroves on the mouth of Matutela River. Also, there were in less number, *Actitis macularis*, spotted sandpiper, which fed on the coastline of the lagoon and the *Phalacrocorax olivaceus*, neotropic cormorant, aquatic and colonial birds that swam and dove here to obtain its food, it also flew over the site, rested and sunbathed in the lagoon. In the marine habitat the most abundant colonial bird was *Fregata magnificens* overflying the area, together with some vultures and pelicans. The pelican *Pelecanus occidentalis* followed it in abundance, posed and sunbathing on the Perico Island forest, diving to catch the fishes for food or staying calmed, floating or resting in the dockage of Naos Island. On third place of abundance was the *Coragyps atratus*, with 315 individuals, which represented less than 50% of total of magnificent frigate birds flying over the area usually

on a spiral way on hot air bags or stayed possed on trees, beaches and coastal rocks sunbathing with their open wings or eating carrion.

In Gaillard Cut (Table N° 62) the most common specie was the *Hirundo rustica*, bern swallow (420 individuals), followed by the *Amazona autumnalis*, red-lored amazon (378 individuals), *Coragyps atratus*, black vulture (336 individuals), and *Brotogeris jugularis* (365 individuals), 41 families and 16 orders were registered. In the forest prevailed *Ramphastos sulfuratus*, keel-billed toucan (91 individuals) 7.57% the other species were lower. In the open area the most abundant was *Hirundo rustica*, barn swallow (329 individuals, 12.93%) that usually went flying over the area, doing its proper screaming and seldomly was seen still. Followed in abundance *Brotogeris jugularis*, orange-chinned parakeed (198 individuals, 7.78%). These always flew over the area, alone, on pair or on groups up to 30 individuals, never stopped and screaming constantly. The other species were registered in lower abundance. On the aquatic and littoral habitat prevailed *Coragyps atratus*, (193 individuals, 13.86%). They were seen resting on the ground and on the trees by morning. Early in the morning, with the heat of the sun, they flew over the area on spirals. Followed in number was *Amazona autumnalis*, red-lored amazon (189 individuals 13.58%) always seen flying and heard screaming. On rare occasions they were seen alone. Most of the time they flew in groups that reached up to 50 individuals. Among the most abundant also were *Cassidix mexicanus*, great tailed crackle (172 individuals, 12.36%). Flew on groups along the Canal, toward north or south and close to the water surface.

In Ciri (Table N° 66) the most abundant species was the preying migrant *Cathartes aura*, turkey vulture (3314 individuals, 45.21%). Most of these individuals were observed on their migrant flight to the north during March. The most representative of the species that were observed in the area was *Bubulcus ibis*, cattle egret (315 individuals, 4.3%). In the disturbed forest of this area prevailed *Crotophaga ani*, smooth-billed ani (78 individuals, 5.05%). It was found on trees, bushes around the forest, and crop fields. *Sporophila americana* followed in abundance, seed-eater (71 individual, 4.59%) that was found as observed with the smooth-billed ani. In the open area the most representative species was *Cathartes aura* (3,284 individuals, 67.98%). As we note before it was a big group migranting to the North. It was followed by *Bubulcus ibis* (197 individuals, 4.08%) that fed on the cattle-lands. The other species were lower than these regarding their abundance.

On the aquatic and littoral habitat prevailed *Bubulcus ibis* (90 individuals, 9.44) were observed along the runway on Ciri Grande River on the adjacent river followed by *Coragyps atratus* (79 individuals, 8.29%) that flew over the river, resting on trees and logs on the border and feeding on the ground.

In Tranquilla (Table N° 64) the most abundant species also was the preying migrant, *Cathartes aura*, turkey vulture (827 individuals, 24.53%). Most of these individuals were returning back to the places of breeding in the north, 36 families and 17 orders were registered. In the open area prevailed *Cathartes aura* (819 individuals, 30.21%), most of them formed part of big migrant column coming from the south. The locals individuals, in number of 1 or 2 and rarely 3, flying very low and searching for food. *Brotogoris jugularis* followed in abundance (254 individuals, 9.37%) in numbers up to 100 individuals overflying and screaming on a big corotú

tree (*Enterolobium cyclocarpum*) and eating fruits of palma culebra (*Elais oleifera*). In the aquatic and littoral habitat the most abundant bird was *Phalacrocorax olivaceus*, neotropic cormorant (51 individuals, 7.72%), swimming and diving in Chagres River seeking food and also resting and sunbathing in trees and trunks of the riverine coastline. *Jacana jacana*, wattled jacana (40 individuals, 6.05%) was found running along the riverine margin in search of food. See the same Table for the rest of birds observed in Tranquilla.

From the observations carried out in 2kms of each habitat (Tables N° 61 to 66, and 74) the highest richness of species was related to the forest, followed in order by the open area, the aquatic and littoral, and the marine habitat. The north entrance was the exception where the marine habitat followed the forest. On the other hand, in Pequeni, the richness of species in the forest, the open area, the aquatic and littoral habitat was higher than those recorded for each of the other sites. Furthermore, Tranquilla had the less richness of species in all of its habitat. On each habitat of each place, Emberizidae and Tyrannidae were the dominant families while the order Passeriformes prevailed, but there was a difference in the number and composition of species, families and orders.

In the habitat in some sites the trail was larger than 2 kms. The list of species and abundance is given in Tables N° 67 to 72.

In general, during this inventory it has been observed that the total number of species and individuals of birds has increased with the progress of the rainy season, reaching the highest migratory activity during the peak of this season. Toward the dry season the number of individuals decreases, perhaps influenced in part by the decrease of food and water. The decrease continues until May because there are not migratory birds and the effect of the dry season persists (Figures N° 35 and 39, Tables N° 90 and 92). The same trend was observed with the species (Table N° 92 and Figures N° 22 and 28).

The difference in the number of species during August are possibly related with tornados and/or strong winds that hited the area of sampling few days before our arrival (Cirí, North Entrance of the Panama Canal and Pequení) and due to the results from duplicate samplings (South Entrance of the Panama Canal and Gaillard Cut). During November the changes in the species are related to the migratory activity and the peak of the rainfalls (Tranquilla, Cirí, North and South Entrance of the Panama Canal and Pequení). The strong winds and storms previous to our visit to Gaillard Cut may have contributed with this variations. The presence of the dry season is perhaps the most determining factor in the observed variations during February-March (Pequení- South Entrance, Cirí, and Tranquilla). The Gaillard area, located at the continental division and the North Entrance (Caribbean slope) perhaps offers the best pluviosity, food and shelter for the species of birds which might play an important role in the increase here reported. Tranquilla has always shown less number of species probably because it was only sampled in open area and in aquatic and littoral habitat (there is not enough representative forest) and few diversity of biotopes. The decrease of species number observed during May on Gaillard Cut, North and South Entrance to the Panama Canal, and Tranquilla, coincides with the absence of migratory birds and the persistence of the dry season. In Ciri, the conditions during May and March were alike, and in Pequeni the effect of the rainy season improved the climatic conditions

and most importantly, the food. The best asymptotic species curves were those from Pequeni, South Entrance of the Panama Canal and Tranquilla (Figure N° 23 and Table N° 73). Similar results were obtained from the 2 Km trails at the sampling sites, with the difference that in this small section of 2 km the effect of the dry season persisted in Pequeni and the effect of the rainy season was started in Ciri (Figure N° 29 and Table N° 74).

The variations in the number of bird species by site and habitat (Tables N° 73 and 74, Figures N° 25 and 31) are related with the seasonal changes, specially regarding to the food, humidity, shelter, migratory season, etc... The plots from the whole trail observations and those from the 2 km sections are very similar, however it can not be ignored that the extension of trail has influence on the outcomes.

In the study area, the total number of threatened species registered was 79, while the endangered are 10, migrants 91 (transient 52 and wintering 52), locals 338, gamebirds 25, prey 28, sparrows 3, and passeriformes 222. These numbers and the corresponding to each sampling appear in Table N° 91. In this Table it is observed the same pattern of the migrants birds (transient and winter residents), locals, preying, and passeriformes, augmenting the number of species as the rainy season and the migration progress. The highest number of species usually takes place in November, as the rainfall reach its highest and the arrival of the migrants. Then, there is a decrease from February to March. These results may change by the effect of repetitions and because the migratory effect is strong from February to March due to the return of migrant birds to the north and increases the number of species in the area. Toward May the number of migrant species and individuals decreases since the migratory cycle practically is restarting. This situation is the same for locals, preying and passeriformes.

These results are similar for the number of individuals. Even more, for the trails of 2 km (Table N° 93 and Figures 28, 39, and 40) the same pattern is maintained. Possibly, the results from the 2 kms trails are not clear enough (Table N° 97), however, it most be borned in mind that both the distance and the time of observations are reduced. Although November and February-March still been the months with the highest abundance of migratory species (transient and wintering), prey and passeriformes. For local birds, there are some species with migrant population (*Cathartes aura* and others) and the number of individuals is increased during the migrations which allows to observe some of these species. The effect of migration on the abundance of birds might be expressed with sharp increases as was observed in Ciri February-March on the South Entrance to the Canal, and at Tranquilla during November (Figure N° 40). Although it is important to note that the number of local species decreases in the forest and in the marine habitat during November, probably because of the pressure from migrants birds. But it is increased on the open area and in the aquatic and littoral habitat where birds are concentrated. The same was observed during August although the local birds decreased in abundance in the aquatic habitat. During February-March the dry season condition affected all of the birds in the open area, thus decreasing the number of species. Raptors were scarced in the marine habitat and their largest number was observed in the open area during November. In May, all of the bird groups were less notorious in the forest and the same was observed in the marine habitat. The migrant birds, also, presented its lower abundance in the open area and in the aquatic and littoral, although the local birds increase in the latter. On the other hand, the

Passeriformes also decreased in the open area but increased in the aquatic and littoral habitat. Apparently there are movements from one habitat to another and the occupies those left by migrant birds. The abundance of preying birds, though very little, lowered even more (Figure N° 27). The observed situation was practically the same on the 2 kms trails, although there was not a decrease in the abundance during August for local and Passeriforme birds (Figure N° 34). The seasonal abundance of birds were also reflected in the complete trails at each habitat (Table N° 95). Some of this trends can be observed in Figures N° 24 to 27, 30 to 33, 36 to 38, and 41 to 45.

In general the higher number of species (79 and 60) and individuals (6,941 and 4,828) of migrant birds was recorded in November and February-March, respectively. During this same periods a high number of raptor's species (18 and 16 respectively) and individuals (4,934 and 3,887 respectively) was also recorded. The same was for Passeriformes, being the highest number of species 162 and 164 (respectively) whereas the individuals were 5,427 and 5,033 respectively (Table N° 91). Considering trails for each habitat (Table N° 95) it was found that the highest number of threatened species (58), local birds (264), and Passeriformes (189) were registered in the forest habitat. The highest abundance of migrant bird species (73), transient birds (43), winter residents (43), and game birds (20) was found in the aquatic and littoral habitat. The highest among the raptors (24) and sparrows (3) occurred in the open area whereas the highest number of endangered species (7) was detected both on the forest and in the aquatic and littoral habitat. Having in account the number of species counted it was observed that local birds species prevailed over the migrant birds (Figure N° 27 and 34). Also the same was observed regarding the abundance of birds (Figures N° 38 and 45).

When the 2 km trails for each habitat are considered (Tables N° 61 to 66) it was found that most of the local species belonged to Pequeni (223, 65.97%) followed by the northern entrance to the Panama Canal (207, 61.24%), the Gaillard Cut (190, 56.21%), the southern entrance to the Canal (173, 51.18%), Ciri (166, 49.11%), and Tranquilla (126, 37.27%). As for the migrant birds, the highest abundance was recorded at the southern entrance to the Panama Canal (71, 78.02%), followed by the northern entrance (50, 54.94%), Gaillard Cut (40, 43.95%), and Pequeni (31, 34.06%), Ciri and Tranquilla with 28 species (30.76%). Pequeni is the site which contains the highest number of threatened species (47, 59.49%) followed by the northern entrance (38, 48.10%), the southern entrance (36, 45.56%), Gaillard Cut (29, 36.70%), Ciri (29, 31.64%), and Tranquilla (16, 20.25%).

The northern entrance and Gaillard Cut were the areas with the higher number of game birds (15, 60%), followed by Pequeni (14, 56%), south Entrance and Tranquilla (12, 48%) and Ciri (11, 44%). Regarding the endangered species, the highest number was found in Gaillard Cut (6, 60%), followed by the southern entrance, Pequeni, and Tranquilla (5, 50%), and Ciri (4, 40%). The names of local species, migrants, threatened, game, and endangered species, and their relative abundance on each 2 kms habitat, in each place are indicated in Tables N° 61 to 66. In some places, there were habitats on which the trails were higher than 2 kms. The name of the registered species is registered in Tables N° 67 to 72.

In each site, within the categories of established habitat (forest, open area, aquatic/littoral, and marine) the birds occupied specific biotopes as water, air, antennas, streams, trees, bushes, banks, border, highway, power lines, fences, ponds, heliconian, grass, island, lagoon, mangrove, thicket, palm tree, beach, electric poles, streams, rivers, rocks, grounds, trunks, fences, and sticks. These biotopes are part of the characterization of the habitat of the bird species found which let them survive here. These observations contribute to complement on a more precise manner the description of the habitat already presented in the section on the description of the studied areas. The details of biotopes occupied by each species is presented in Tables N° 75 to 80.

The replicated census carried out during this inventory in the habitat in the southern entrance to the Panama Canal, Gaillard Cut, and the northern entrance to the Panama Canal gave more efficiency to the collections (Tables N° 73, 74, and 90 to 98). The list of species from these replications is presented in Table N° 89.

The list of species collected during this inventory is presented in Tables N° 100 to 104. Throughout the study, the use of the habitat, including the relationships plant-animal was manifested in several ways, being the must noted the feeding, resting, breeding, delousing, sunbathing, winter residency, and transit.

This detailed information for species and for habitat is presented on Tables N° 85 to 88. The habitat where these species are usually found, provides protection against weather conditions, other animals, and others.

(3.4) Mammals

A summary of the data obtained is presented in Tables N° 105 and 106 along with a comparison between the number of species observed and that probably present in the area (Eisenberg, 1989). Eisenberg lists bats as probably occurring through Panama if they have been found in Costa Rica and Colombia or elsewhere on both sides of Panama. Most bats can only be positively identified in the hand; some of those assumed to be here have not been positively identified in Panama. A total of about 53 species has been netted on Barro Colorado Island, where netting has been most intensive in Panama, over a number of years. The true number of species actually present in the study area is thus probably between 53 and 110.

It is first necessary to introduce a note of caution when considering the data presented here.

-First, most mammalogists would consider the distribution maps far too "fine grained" (Maps N° 29 to 115); mammals are mobile enough that the probability of a species that is encountered in one of the regions (Map N° 115) never entering an adjoining region is very low.

-Second, mammals can be very cryptic; it is not at all unusual to spend an entire day walking through a forest and only observe one or two species of mammal. This is

particularly true of the neotropical forests. Thus, even a trained observer will very probably fail to observe all of the mammals in a given area. An example will illustrate the point: Barro Colorado Island is a small (1,600 ha) relatively isolated sample of forest which was declared a biological reserve in 1924. Since that time there have been many thousads of man/hours of observation of the fauna there by trained observers. But it was not unitl 1966 that a student of monkey behaviour (J. R. Oppenheimer) first recorded the presence of the climbing rat *Diplomys labilis* on Barro Colorado Island. This nocturnal, arboreal rat is unlikely to have reached the island by swimming so it is probable that the species had been present there for 42 years before being observed for the first time.

-A third note of caution must be introduced in regard to the data on bats. Bat netting is essentially a "lottery" process where only those individuals that have chosen the path interrupted by the nets are recorded. Moreover, it is impossible to place nets at all altitudes and so the sample obtained will be biased toward those species that normally forage relatively low. Thus, practically all of the data presented should be viewed as being conservative.

Some species of mammals are very rarely seen because they are rare, others because they are cryptic, arboreal and/or nocturnal. The bushdog (*Speothos venaticus*) falls into the first of these categories. No specimen has ever been collected further West than the Cerro Pirre region of the Darie and there has never been even a suspicion that bushdogs exist in the study area. But one recent sighting by a pair of Smithsonian scientists and another by two ecotourist guides make it appear probable that there are at least a few (perhaps only one group of three) bushdogs in the area.

The silky or pygmy anteater (*Cyclopes didactylus*) in the order Edentata falls into the second category. It is a small animal which is totally arboreal, nocturnal and very cryptic in the daytime sleeping position, and it does not have a bright "eyeshine" in the light of a headlamp so that it is difficult to see even when it is active. Only one specimen of Cyclopes has been observed in the present study, and two others have been reliably reported. The species is probably considerably more common in the study area than the data indicate.

The following is a comparison between the number of mammals found in this inventory and those reported (Eisenberg, 1989):

Order	Number recorded in study	Number listed for area	Comments
Marsupialia	6	6	
Chiroptera	45	110	
Primates	5	5	
Edentates	5	6	

Lagomorpha	1	1	
Rodentia	12	18	
Carnivora	15	12	Includes reports on 3 species not previously known from area (1 probably an escaped captive
Perissodactyla	1	1	
Artiodactyla	3	4	1 listed species no longer occurs in area
Total	93	162	

The overall impression, one that was reinforced as the study progressed, is that the area of the Parque Nacional Soberanía, the Barro Colorado Nature Monumento and the west bank of the canal together constitute a refuge for many mammalian species which should be more widely distributed in Panama, and that hunting and habitat destruction have rendered such areas as the land around the Trinidad arm of Gatun lake and the area around Lake Alajuela practically sterile with regard to mammal species. Even in areas such as the mouth of the upper Chagres, where it enters Alajuela lake, the forest appears to be in good condition with an abundance of large fig trees (an important resource for howlers during times of general fruit scarcity) but one does not hear howler monkeys (*Allouatta palliata*) at dawn or dusk. Howler monkeys are seldom persecuted (local hunters deny that they eat them) and their total absence from what appears to be eminently suitable habitat indicates that other, more popular, game species have been entirely eliminated. Since many of these game species are important seed dispersers, their absence may be presumed to have already precipitated a decline in the diversity of tree species in the area. There is alos an unexplained absence of howlers on the Empire range canal bank (Map N° 14). The habitat there also looks ideal for howlers but, in spite of repeated dawn and dusk transects, no howlers were heard there.

For the sake of discussing the distribution of mammals in the study area, the class can be divided into two main types: the bats and the non-volant mammals.

Because of their greater mobility and nocturnality, the bats are not as restricted by human activity, habitat differences or watercourses as are the non-volant mammals. However, it is much more difficult to determine the presence or absence of bats and, except for some notable exceptions, they are almost impossible to identify to the species level unless they are held in the hand. The distribution maps for the bats should thus be regarded as highly conservative, both from the point of view of number of species that were caught, and with regard to the areas of occurrence. It is highly probable that most of the species caught occur in most of the study area, not only in the region where they are indicated.

For the purpose of this discussion, the non-volant mammals can be divided into three main types: the medium to large mammals that are hunted; the medium to large mammals that are

not hunted and the small mammals. The greatest influence on the distribution of mammals in the study area is the state of the habitat, and the state of the habitat is a reflection of human activity. A rough guide to the state of the habitat is presented in Map N° 14.

In summary, there is basically a corridor of relatively undisturbed habitat running from the Fort Sherman/Fort San Lorenzo region in the northwest, broken by Gatun lake to the south, then continuing toward the southeast through the Barro Colorado Nature Monument and the Parque Nacional Soberanía, the rear of Fort Clayton, to the Parque Metropolitano on the east side of the canal, and the Empire range bank of the canal to the Cocoli/Fort Rodman areas on the west side of the canal.

Within this corridor the inventory of mammal species is relatively complete (i.e. it is what would be expected, zoogeographically, in undisturbed habitat). The forest has been maintained, and even improved, from the days of canal construction, so that most of the forest is fairly young second growth. But control of hunting was not attempted, except on the islando of Barro Colorado, until the mid to late 1970's. "Sport", "pot" and "market" hunting resulted in the diminution of populations of *Agouti paca*, *Dasyprocta punctata*, *Tayassu tajacu*, *Mazama americana*, *Odocoileus virginanus* and *Sylvilagus brasiliensis*, and the local extinction of *Tayassu pecari*, *Ateles geoffroyi* and *Tapirus bairdiii*. Hunting for the mascot trade also reduced populations of *Cebus capucinus* and *Saguinus geoffroyi*. A combination of reduced potential prey populations and hunting was probably responsible for the reduction of carnivore populations, particularly the felids, in the area and the probable local extinction of *Felis concolor*.

There is now very little "market" or "sport" hunting in the forest corridor and, in spite of considerable "pot" hunting, the populations of game animals that were reduced are now recovering, particularly in the Parque Nacional Soberanía. Of the locally extinguished species, *Ateles* and *Tapirus* have been reintroduced to Barro Colorado and *Tapirus* may have spread to the western side of Soberanía. So *T. pecari* and *F. concolor* are the only large mammals that would naturally occur in the area but are missing.

Different species of mammals apparently differ in their adaptability to the activities of men. Thus, in the Fort Sherman area where, judging by the quantities of MRE wrappers strewn about on the forest floor, human activity is high and the resulting garbage plentiful, *Nasua narica* and *Didelphis marsupialis* (both of which are highly opportunistic foragers and facultative commensals with man), are very abundant. But neither *Eira barbara* (probably the most direct competitor with *Nasua*) nor *Philander opossum* or *Metachirus nudicaudatus* (competitors and sometimes prey of *Didelphis*) were encountered there. Similarly, the mammal fauna of the Empire Range bank of the canal appears to be species depauperate, even in areas where there is no ongoing earth moving.

Outside of the forested corridor the habitat is very disturbed. Much of it has been cleared and much of what has been cleared has been invaded by *Saccharum spontaneum*, a non-native weed grass which supports low biological diversity. Even where there is still good forest, such as the valeys of the Pequení and the Upper Chagres (those parts of the valleys within the study area)

the numbers of mammal species and individuals is low. This is probably at least partly due to the heavy hunting pressures there. The campesinos that live around the shores of Lake Alajuela hunt up these rivers, although they state that it is hardly worth their while to hunt since they seldom even see iguanas any more. It is necessary to go several kilometers up these rivers before anything like natural numbers of mammals are encountered.

In the most rural regions, the Cirí/Trinidad arm, 10 Mendoza, Tranquilla/Alajuela and Garrapata, the mammal fauna is greatly reduced. The only regularly encountered marsupial is *Didelphis marsupialis*. The edentates are well represented. *Tamandua mexicana*, *Bradypus variegatus* and *Choloepus hoffmanni* can be found wherever there are substantial patches of young forest and *Dasypus novemcinctus* occurs irregularly throughout he areas although it is persecuted as a food source. The only primates likely to occur in these areas would be *Aotus lemurinus* and *Saguinus geoffroyi*; neither were encountered during the present study. *Sylvilagus brasiliensis* probably occurs in these areas but only in scattered populations. *Sciurus variegatoides* occurs where there are substantial patches of trees with non-continuous canopy. *Liomys adspersus* and *Oryzomys* spp. should be fairly comon throughout this area. They were not trapped in this study, probably because the traps used were too large and because the trapping was concentrated more in forested areas. *Hydrochaeris hydrochaeris* is surprisingly prevalent through these areas. It is regularly hunted but small groups persist along riverside and lakeside grassy areas. The carnivore populations are greatly reduced. A few specimens of *Urocyon cinereoargentatus*, which is common to the west, have been reported in the Cirí/Trinidad arm region, but it is probably only occasional there so far. Occasional *Odocoileus virgianus* are reported, but they are rare, probably wandering in from less disturbed areas of second growth.

In the more residential outlying areas most of the species of the rural areas are also found, and are somewhat more abundant. In addition, particularly in such areas as Balboa and the military reservation housing areas, *Dasyprocta punctata*, *Agouti paca*, *Nasua narica*, *Procyon lotor* and *Odocoileus virgianus*, may be fairly abundant.

b) **FRESHWATER**

The study area is embedded in the Canal watershed-ecosystem with an approximate area of 3262 km^2. Other reservoirs like Miraflores Lake and auxiliary ponds, i.e. Caimitillo Arm, Camaron Arm, Railroad Pond, and Pedro Miguel pond were also built as part of the canal system. About 24 years later (1934) a second dam was built to control seasonal flooding, resulting in the formation of Madden Lake (Zaret, 1984), which is also used as auxiliar for a more efficient use of the water resources.

The freshwater reservoirs in the Canal area are the following:

Reservoirs	Surface (ha.)
Lake Gatun	44,430
Lake Alajuela	3,120
Lake Miraflores	161
Camaron Arm	45
Caimitillo Arm	36
Railroad Pond	17
Pedro Miguel Pond	12
Total	47,821

Maximum elevation of Gatun Lake is 26 m above sea level. Maximum depth is 29 m and the mean depth is 12.7 m. This gives a picture of a relatively shallow lake with a long shoreline, estimated in 1750 km (Zaret, 1984).

All these reservoirs brought parallell problems associated to the natural successional processes in the tropics. From 1913 on, the massive presence of aquatic macrophytes in the Gatun Lake, began to create problems to ship transits and other activities related to the canal operation (Von Chong, et.al., 1988).

The general features of the study area is as follows:

-Life zones: In a relatively small area, the Canal watershed-ecosystem displays a wide range of variations i.e., four different life zones, and mean rainfalls ranging from 1778 mm on the Pacific slope to 3300 mm on the Atlantic slope.

Based on Tosi's (1971) bioclimatic map for the Republic of Panama, a rough area estimation (Von Chong et al. 1986) of life zones comprising the Panama Canal watershed follows:

Life Zone	Hectares	Percent
Tropical Moist Forest	252,048	77.2
Premontane Wet Forest	14,052	4.3
Tropical Wet Forest	11,990	3.7
Premontane Rain Forest	585	0.2

Total Lands Areas	278,675	85.4
Total Lake Areas	47,550	14.6
Total Watershade Area	**326,225**	**100.0**

-Climate: Climatic seasons modify the structure of all communities, and seasonal phenomena are decisive for the functioning of natural communities (Krebs 1985). With the exception of macroclimate, each ecosystem component, living and not living, is influenced by others (Van Dyne 1969). At a smaller scale, climate is the most important component of the physical environment acting upon the ecosystem.

-Temperature: In general, no significant seasonal variation of temperature is observed in the study area. According to Gonzalez et al. (1975), air temperature fluctuations in the Canal region are moderate throughout the year. This is illustrated in the following table, adapted from datas of the Canal Zone Water Quality Study 1975):

	Cristobal	Madden Dam	Balboa Heights
Mean, anual	26.9°C	26.3°C	26.9°C
Maximum, anual	28.9°C	28.2°C	29.3°C
Minimum, anual	24.7°C	24.2°C	25.0°C

According to Zaret (1984), the degree of constancy in the mean ambient temperature over the year is reflected in the water temperatures of the lake.

-Precipitation: Rainfall is a very important element of the climate. Seasonality of rainfall induce a recurrent alternation of biological rhythms in the biota, as well as suspended and dissolved substances carried into the basin, which is reflected in water chemistry values of the reservoirs in the study area.

Average monthly rainfall in the Canal watershed during the period of this study is compared with the mean monthly rainfall for a 28 years period in the following table:

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Total
70	33	33	122	287	276	261	292	291	362	355	188	2570
Monthly Rainfall: 1992						290	363	372	304	277	146	
120	22	128	219	238	Monthly Rainfall: 1993							

Mean monthly rainfall in the Panama Canal watershed-ecosystem. Register of 28 years (1965-1992), and monthly rainfall during the study period (values in mm). Mean Annual rainfall for

the Atlantic slope = 3,302 mm. Mean Annual rainfall for the Pacific slope = 1,778 mm. Source Data: Meteorological & Hydrographic Branch. Panama Canal Commission.

On a broader scale there is a strong gradient of rainfall across the isthmus of Panama (Rand et al. 1982). This is also valid for the entire Panama Canal watershed, in which rainfall ranges from 1500 mm to about 4000 mm. Higher rainfall values are recorded in life zones of the upper ranges of Alajuela Lake watershed (Jonas et al. 1986).

-Winds: Seasonality of winds are clearly manifested in strenght and direction during the dry season. In general, strong trade winds blow from North and Northeast 90 percent of the time (Gonzalez et al. 1975). Wind pattern is highly seasonal with a minimum monthly mean value of 8.5 km/h during June and August. During the dry season it attains values ranging from 18 to 22 km/h (Zaret 1984).

The dry season period brings a constant seasonal factor affecting the distribution of some aquatic macrophytes. Waves induced by winds erodes lakeshores facing the predominant northern winds.

-Drawdowns: Drawdown is not a climatic phenomena, but a process associated to the Canal operation, water is managed through the reservoirs. The range of seasonal drawdowns have different values for every water reservoir serving the Canal system.

The following table, prepared with data from The Panama Canal Meteoroly and Hydrology Branch, illustrates the different dynamics of major reservoirs in the Canal system:

Elevations Lake Range				
Lake	**Period**	**Minimum Average**	**Maximum Average**	**Range Average**
Gatun	1954-1982	25.48 m.	26.64 m.	1.16 m.
Madden	1954-1982	63.86 m.	77.32 m.	13.46 m.
Miraflores	1954-1971	15.96 m.	16.85 m.	0.89 m.

Mean annual elevation of Gatun Lake is referred to 77 years of records (1915-1992) and the mean monthly elevation is based on 1992 data. The mean monthly elevation of Lake Aljuela (Madden) has been calculated on 56 years of records (1937-1992) and the mean monthly elevation is based on 1992 data. The following table shows the mean monthly variations of lake levels:

Month	Gatun Lake (1915-1992) (m)	Gatun Lake (1992) (m)	Lake Alajuela (1937-1992) (m)	Lago Alajuela (1992) (m)
January	26.4	26.5	75.4	74.7
February	26.2	26.2	74.0	72.6
March	25.9	25.9	71.8	69.5
April	25.6	25.5	68.9	65.4
May	25.6	25.6	67.4	67.7
June	25.7	26.1	67.8	70.3
July	25.8	26.3	68.7	70.0
August	25.9	26.3	70.2	71.5
September	26.0	26.4	71.6	73.2
October	26.2	26.5	73.2	73.1
November	26.3	26.5	75.1	73.9
December	26.5	26.6	76.1	75.9

Source data: Panama Canal Meteorological and Hydrographic Branch, Panama Canal Commission.

-Sedimentation: Sedimentation is another not climatic phenomena, but a very important process which usually determines the useful life of a reservoir. This process is associated to surface run-off and soil wash-out, both geared to rainfall, and thus impacted by seasonality of rains.

Changes in land uses will induce changes in fluvial sedimentation (Alvarado 1985). Unfortunately, watershed disturbances are unavoidable in these lands subject to the pressure of an evergrowing population in the terminal cities.

The rate of sedimentation processes is probably higher in those parts where the river loss the lotic character due to the damming effect by the lake. This zone recedes upstream and downstream in conjunction with lake level fluctuations, extending the zone of alluvial deposits (delta) in relation to the slope of the river when meeting the lake, and the topography of the surrounding grounds. At this point water velocity decreases drastically, accumulating heavy loads of sediments on the river bed. This can be observed in many river, but mainly in the Chagres, Trinidad, Ciri Grande and Gatun rivers.

The following table shows the contribution of the principal rivers to suspended sediments loads, according to the most recent report (April, 1993) of Panama Canal Watershed Hydrology for year 1987:

River	Drainage area (km^2)	Mean monthly discharge (m^3)	Suspended solids (tons)	Suspended solid (tons/km^2)	Annual rainfall (mm)
Chagres	414	33.79	236778	572	3258
Ciri Grande	186	8.33	31854	171	2811
Trinidad	174	5.84	16226	93	2024
Pequeni	135	15.54	113936	844	3937
Gatun	117	8.8	73580	629	5060
Boqueron	91	8.77	99393	1092	3762

Source data: Panama Canal Watershed Hydrology, 1987. Meteorological & Hydrographic Branch, Panama Canal Commission, April, 1993.

Results of previous studies (James & Barko 1991) revealed that submerged macrophytes, i.e. *Hydrilla*, play an important role in sediment accretion and composition. Marked differences were found in sediment composition between the littoral and erosional zones.

In shallow sites of the study area, it is clear in the delta formation zones of Chagres, Gatun, Ciri Grande, Trinidad an other rivers, that *Hydrilla sp.* and other submerged macrophytes, have been influential in promoting sediment accretion. Emergent macrophytes like *Typha sp.*, *Eleocharis sp.*, in the littoral zone, also contributes to increase sedimentation rates by slowing the water current velocity.

(1) **Water Quality**

The results of analysis and measurements of freshwater from the 5 quarterly samplings carried out between July 1992 to May 1993 are presented in Tables N° 107 to 116. Each table include the results from analysis and measurements at each sampling site.

Results of the monitoring during the whole project indicate, in general, the conditions normally found in the area according to particular time of the year (González et al. 1976). The most remarkable feature is the uniform distribution of the temperature in the water colum, this condition indicates the lack of thermal stratification where the difference between the surface and bottom temperature hardly exceeded 1°C. The only exception, like in the month of July and August is the station FWQ-05 located in Lake Alajuela close to the dam, where, indeed the thermal stratification is found (Figure N° 46). This thermal stratification express itself through the presence of a well defined metalimniom, located below 10 meters depth and followed by the drastic decrease in the dissolved oxygen concentration, where usually the oxygen concentration is less than 2 ppm (Figure N° 47).

(1.1) Lake Alajuela

At the beginning of the dry season Lake Alajuela (station FWQ-05) is in its maximun level and the water volume flowing out of the lake is higher than the input because of the lack of rainfall. In this way, the water level of the lake decrease and together with the effect of the prevailing winds contribute to the mixing of the water column in the lake. The mixing was observed due to the wind effect producing high dissolved oxygen concentration down to a depth of 20 m. This high concentration of dissolved oxygen makes a clear contrast with the low concentration of dissolved oxygen near the metalimniom (between 5-10 meters) during the rainy season. During March 1993, the metalimniom is not anymore well defined as it use to be during the whole rainy season (Figure N° 48). Hence, the depth distribution of the temperature is quite uniform.

During the rainy season in spite of the low concentration of dissolve oxygen in the metalimniom the deepest zone of the hypolimniom showed a higher oxygenation than the observed for the metalimnion, between 2-4 ppm (Figure N°49).

In contrast to the rainy season, the concentration of dissolved oxygen during the dry season decreased gradually with depth without any increase in the concentration of dissolved oxygen near the bottom.

Parallel to the decrease in the pluviosity and the runoff during the dry season, also the amount of organic matter and silt is diminished according to the low values of turbidity, organic nitrogen, and suspended solids. Along the entire year, this process is followed by a decrease of the BOD values, being the lowest during the dry season. This is explained because the lower amount of organic matter the less dissolved oxygen is required for the oxidation of the organic matter. It is very important that this equilibrium is mantained in order to avoid a complete consumption of the dissolved oxygen thus conducing to an anoxic conditions.

At the same time, down from the metalimnium there is a sharp increase of nutrients with depth as a result from the oxidation of organic matter originated in the upper layers. This oxidation is well developed both during the rainy and the dry season since the values of ammonia are very low, between 0.01-0.03 ppm (Figure N° 50) and the nitrates are quite high, between 0.10-0.30 ppm (Figures N° 51 to 53).

A few parameters from Bayano Lake, in a station of 40m depth close to the dam, are compared with those from Lake Alajuela (station FWQ-05). The available data from Bayano Lake indicate a thermal stratification at a depth of 10m, and a complete absence of dissolved oxigen below 2 meters depth. The concentration of ammonia near the bottom is about 2 ppm which is one hundred times higher than measured at Lake Alajuela, while the concentration of nitrates is only 0.03 ppm, which is ten times lower than that of Lake Alajuela. In addition, the anaerobic conditions, with high levels of the sulphide ion, prevails in the Lake Bayano below the thin superficial layer.

This oxidation of the organic matter in the hypolimniom in Lake Alajuela is maintained due to the intrusion of well oxygenated and rather cold water from the Rio Indio-Rio Chagres (station

FWQ-03) and Rio Pequeni-Rio Boqueron (FWQ-04). These rivers introduces oxygen rich (7 ppm) cold waters (less than 25 °C) which penetrate into the lake controlling the conditions in most part of the hipolimnium of Lake Alajuela during the rainy season.

During the dry season, the absence of rainfall, and consequently the absence of any significant runoff eliminates the cold waters currents observed during the rainy season along the bottom of the lake, flowing along the former river beds of Chagres and Pequeni rivers. This explains the low concentration of dissolved oxygen in bottom waters of the Lake Alajuela, around 1.4 ml/l. At the same time, the dissolved nutrients, had concentrations greater than those usually found during the rainy season, this is specially valid for total phosphorus.

In contrast to the rainy season, during March 1993 the concentration of nutrients in the bottom waters of Lake Alajuela are not similar to the concentration of nutrients in the Indio and Chagres rivers (station FWQ-03) nor for Pequení and Boqueron rivers (station FWQ-04).

The most pronounced changes in the Alajuela Lake during the rainy season, were related to the increase in the concentration of chlorophyll *a* in the hypolimniom observed at the end of rainy season. This condition decreased gradually with the progress of the dry season. At the same time, there was a pronounced increase in the nitrates in the epilimniom which decreased gradually as the dry season progressed (Figure N° 54). This two parameters are inversely correlated (-0.92).

By the end of the dry season the Indio and Chagres rivers, and Pequeni and Boqueron rivers, manifested once more their influence in the bottom waters of Lake Alajuela. This is clearly indicated through the water temperature in the hypolimniom which are identical to the water temperature at the bottom of those tributary rivers.

The sampling during May 1993 indicated that it is at this time of the year when the lake exhibited the highest oxygenation in comparison to the rest of the year. Below 10m depth the concentration of dissolved oxygen was near 3.5 ppm down to the bottom. This process was followed by a decrease of ammonia concentrations while the concentration of nitrates and the chlorophyll *a* maintained themselves at a constant level in comparison to the values observed during March 1993.

(1.2) Gatun Lake

The features of the bottom water of Lake Alajuela are traceble as far as in station FWQ-06 near Gamboa. This station indicated the same values for nearly all of the measured parameters in the hypolimniom near the dam of Lake Alajuela. Consequently, this is the only sampling station which presents the lowest dissolved oxygen concentration in surface water in whole the area (below 5 ppm). The comparison of the nitrate concentration together with dissolved oxygen concentration in the bottom of stations FWQ-05 and FWQ-06 (Figure N° 55) showed a high and significant correlation (r=0.91).

There are indications that the influence of the bottom water from Lake Alajuela (station FWQ-05) are still detectable at stations FWQ-02 and FWQ-07 as indicated by the rather low concentrations of dissolved oxygen and the high concentration of nitrates. These values were quite similar to those from the bottom water of Lake Alajuela, during the entire period of this study.

Sampling stations FWQ-09, FWQ-10, FWQ-11 and FWQ-12, located approximately along the east-west axis throughout the extension of Gatun Lake, showed: the absence of thermal stratification, the presence of well oxygenated waters, low nutrient concentrations, low turbidity and suspended solids, and generally were free of total and fecal coliforms. The alkalinity decreased along this axis from near 50 ppm (station FWQ-09) tc 15 ppm (station FWQ-12).

Station FWQ-13 presented quite different picture, since this station is separated from Gatun lake by a dam but it is communicated with the Caribbean Sea. Consequently, this is an example of an estuarine area with a fresh water surface layer and sea water in the bottom. Both layers are well oxygenated and there is any trace of pollution with the exception of the low concentration of dissolved oxygen obseved during May 1993 (less than 2 ppm).

(1.3) Water quality

In general, the existing good water quality conditions in Gatun Lake is fully represented by a some selected parameters at the deepest sampling station (FWQ-10). Apparently there is: a lack of thermal stratification (Figure N° 56), high oxygen concentrations in the water column (Figure N° 57), and low concentration of nutrients both during the rainy (Figures N° 58 and 59) and the dry season (Figures N° 60 and 61).

The most significant changes from the beginning of the rainy season to the beginning of the dry season in all the aquatic system of the Panama Canal are as follow:

-There is a significant increase of the concentration of the chlorophyll in all of the station in the area. Frequently this increase of chlorophyll concentration during November is about one hundred fold of that recorded during July and August (Figure N° 62), decreasing gradually throughout the dry season.

-There is a sharp decrease of turbidity (Figure N° 63) and in the concentration of suspended solids (Figure N° 64) during the dry season with a parallel increase in the water transparency in all stations in the area (Figure N° 65). Secchi disc readings are inversely correlated with turbidity (Figure N° 66) and with concentration of suspended solids (Figure N° 67).

-There is a significant decrease in the counts of total coliforms (Figure N° 68) and fecal coliforms (Figure N° 69) in the waters of the aquatic system of the Panama Canal, with a minimun during the dry season.

-There is a high oxygenation of the water column in all of stations in the area throughout the entire year. However, during March 1993 only one station in Gatun Lake (FWQ-08) was found to have less than 4 ml/L of dissolved oxygen.

-The concentration of heavy metals in the water system of Panama Canal during the time of this study, indicates for the dry season, the concentration of iron much less (50-200 ppm) than the rainy season. With much probability this is due to the substantial decrease in the water turbidity and in the concentration of suspended solids due to the limited runoff. The same occured with the concentration of copper and zinc which presented during the dry season the lowest values. In the meantime the concentration of lead and mercury are close to the instrumental detection limits.

According to the monitoring of May 1993 everything indicates that the characteristic of the fresh water system of the Panama Canal found during the dry season (March 1993) are still present without any indications of significant changes due to the beginning of the rainy season.

(1.4) The state of eutrophication of Alajuela and Gatun lakes

From the chemical point of view, the pollution of lakes is characterized by the chemical processes in the bottom of the hypolimnion during the maximun condition of stratification (Cowgill 1975, Kwiecinski 1975). Normally, the process of eutrophication has the following stages:

-Stage I: Although the concentration is decreasing, dissolved oxygen is still quite high in the deep waters; iron and sulphide ions concentrations are absent and the dissolved phospate is quite low.

-Stage II: Dissolved oxygen is quite low in the deep waters and oxygen distribution is clinograde type. Neither iron nor sulphide ions are present and the dissolved phospate is generally in low concentration. Some lakes do not spend this stage.

-Stage III: Oxygen is very limite in deep waters; iron and dissolved phospate are quite high, but the sulphide ion is still absent.

-Stage IV: Oxygen is at very low level or absent in deep waters. Dissolved phosphate is quite high and sulphide ion is present and pull out most of the iron.

-Stage V: Oxygen is completely absent except in a very thin surface layer. The sulphide ion is present, even at the surface; water clarity is very low because of the precipitation of ferrous sulphide and pyrite; the concentration of dissolved iron is very low. The lake looses iron because of the precipitation with sulphur; there is not enough iron to precipitate the phosphate, which increases its concentration thus promoting the proliferation of aquatic weeds.

(2) **Sediments Quality**

Sheet and gully erosion, as well as landslides, increase considerably when the natural forest cover is disturbed. At present, river bank erosion is probably the main contributor of sediments, because of its steepness and instability in much of the river course.

As of December 1983, the volume of accumulated silt in Lake Alajuela since its impoundament is 37,822,014 cubic meters. The accumulated silt (approximately 37.8 x10^{-}6 cubic meters) constitutes 4.7 percent of the total storage capacity (active plus inactive) of 7.99 x10^{-}8 cubic meters.

The rate of sedimentation, based on the life of the reservoir (49 years) is 1.54 cm/year while the second is based on the last 25 years and is 3.02 cm/yr, which is a conservative index, but since the remaining uncut forest is of higly erodable land it seems an appropiate index to adopt (Alvarado 1985).

The deforestation and human settlements in the Panama Canal watershed have contributed to the increase of silting and the introduction of an extra load of organic matter which act as a pollutant.

The granulometric analysis of samples collected in 7 sampling sites in Gatun Lake showed that the sediments in the areas of Darien and Bajo Island are mostly composed by fine grained particles, such as silt and clays. In the other sampling sites sands are the prevailing particles (Table N° 117 to 121).

The results from the chemical analysis of sediments are presented in Tables N° 122 to 126. In general, the concentration of total nitrogen in the sediments of the area range between 200 to 900 ppm (0.2 to 0.9%). The ratio between the organic carbon and the organic nitrogen in the sediments varied from 10:1 to 15:1. At the same time the convertion factor from organic carbon to organic matter is around 1.8. This makes the organic nitrogen in the sediments of the area, after transformed into organic matter, to be in the range between 4 to 20%. This is a rather high concentration and match with information reported by Gonzalez et al. (1975). The highest concentration of organic nitrogen were found at stations FWQ-07 (900 ppm) and FWQ-05 (600 ppm), whereas the minimun concentration were measured at station FWQ-01 (200 ppm).

The data from March 1993 (dry season) confirmed that concentration of total nitrogen in the sediments from the aquatic system of the Panama Canal is rather constant. There are not any remarkable changes concerning this parameter during the period of this project.

Paralell to this pattern of total nitrogen, concentrations of heavy metals in the sediments of the study area, indicates a negligible change in the concentration and geographical distribution throughout the rainy season.

The samples collect during March 1993, indicated that some changes took place and the most notorious was the significantive increase in the concentration of iron, a sligth increase of zinc, whereas copper presented an erratic variation.

With regards to the heavy metals usually related to environmental pollution, the recorded concentrations were rather constant throughout the study period and within the area. The concentration of lead ranged between 15 to 30 ppm, and mercury between 0.2 to 0.5 ppm.

The analysis of high molecular hydrocarbons in sediments from Gatun Lake showed low levels (Table N° 127). However, an exception to this was the result from the analysis of May 1993 samples, when the concentration almost were four times higher than previous in the station FB-01 and almost six times more than usually recorded at station FB-07. These relatively high concentrations could be related to the transit of ships through the canal and this is clearly shown in the constantly high concentrations recorded in station FB-05, close to the Gatun Lake anchorage.

On the whole, the concentration of heavy metals in the sediments of the aquatic system of the Panama Canal, are within the ranges indicates for the igneous rocks (Green, 1959), without any indication of water pollution.

(3) **Aquatic Macrophytes**

(3.1) List of species

List of aquatic macrophyte species reported in the study area were reviewed. Included are previous reports by: Pasco (1974), Gonzalez et al. (1975), Zaret (1984), D'Arcy (1987), and the cheklist of the Flora of Panama (1980). Both in the checklist of the Missouri Botanical Garden up to 1980, and D'Arcy (1987) the submerged macrophyte *Vallisneria sp.* is not reported eventhough it was included in the list of aquatic macrophytes reported by Gonzalez et al. (1975).

Most of the listed macrophyte species were recorded at the observation stations and during the surveillance by boat. The following is the list of aquatic macrophytes within the study area:

Emergent plants

FAMILY	SPECIES
1 Araceae	*Montrichardia arborescens* (L.) Schott
2 Cyperaceae	*Eleocharis geniculata* (Rottb) Blake
3 Cyperaceae	*Eleocharis intersticta* Spreng
4 Cyperaceae	*Eleocharis elegans* (H.B.K.) R & S
5 Cyperaceae	no identificada
6 Cyperaceae	*Eleocharis sp.*
7 Gramineae	*Phragmites australis* (Cav) Trin.ex Steud.

8 Hydrocharitaceae	*Limnobium sp.*
9 Juncaceae	*Juncus sp.*
10 Marsiliaceae	*Marsilea policarpa* Hook et Grev.
11 Menyanthaceae	*Nymphoides indica* (L.) O.Kuntze.
12 Nymphaeaceae	*Nymphaea sp.*
13 Onagraceae	*Ludwigia sedioides* (humb & Bonpl)
14 Onagraceae	*Ludwigia erecta* (L.) Hara
15 Pontederiaceae	*Eichhornia azurea* (Sw.) Knuth
16 Typhaceae	*Typha angustifolia* L.
17 Umbelliferae	*Hydrocotyle umbellata* L.

Free floating macrophytes

FAMILY	SPECIES
1 Araceae	*Pistia stratiotes* L.
2 Lemnaceae	*Lemna minor* L.
3 Parkeriaceae	*Ceratopteris pteridoides* (Hook) Hieron
4 Pontederiaceae	*Eichhornia crassipes* (Mart) Solms
5 Salviniaceae	*Salvinia sp.*
6 Salviniaceae	*Azolla sp.*

Submerged macrophytes

FAMILY	SPECIES
1 Ceratophyllaceae	*Ceratophyllum demersum* L.
2 Chlorophyta	*Chara sp.*
3 Chlorophyta	*Nitella sp.*
4 Hydrocharitaceae	*Hydrilla verticillata* Royle
5 Hydrocharitaceae	*Vallisneria sp.*
6 Lentibulariaceae	*Utricularia sp.*
7 Mayacaceae	*Mayaca sp.*
8 Najadaceae	*Najas arguta* (H.B.K.)
9 Nymphaeaceae	*Cabomba piauhyensis* Garden

Shoreline macrophytes

FAMILY	SPECIES
1 Alismataceae	*Sagittaria lancifolia* L.
2 Commelinaceae	*Tripogandra c.f. elongata* (G.F.W. Meyer) 3
Commelinaceae	*Commelina elegans* H.B.K.
4 Compositae	*Ambrosia cumanensis* H.B.K.
5 Cyperaceae	*Cyperus diffusus* Vahl
6 Cyperaceae	*Cyperus giganteus* Vahl.
7 Cyperaceae	*Fuirena umbellata* Rottb

8 Cyperaceae	*Cyperus luzulae* (L.) Retz
9 Cyperaceae	*Scleria eggersiana* Boeckl
10 Deenstaedtiaceae	Helecho
11 Gramineae	*Leersia hexandra* Swartz
12 Gramineae	*Panicum grande* Hitchcock & Chase
13 Gramineae	*Echinochloa polystachya* (H.B.K.) Hiitch
14 Gramineae	*Paspalum fasciculatum* Willd
15 Gramineae	*Panicum maximum* Jacq.
16 Gramineae	*Luziola subintegra* Swallen
17 Gramineae	*Panicum purpurascens* Radd.
18 Gramineae	*Acroceras zizanioides* (H.B.K.) Dandy
19 Gramineae	*Gynerium sagittatum*
20 Gramineae	*Panicum c.f. laxum* Schwartz
21 Gramineae	*Panicum c.f. poligonatum*
22 Gramineae	*Panicum sp.*(#1)
23 Gramineae	*Paspalum repens* Berg.
24 Gramineae	*Panicum sp.*(#2)
25 Gramineae	*Panicum sp.*(#3)
26 Gramineae	*Sacharum spontaneum*
27 Gramineae	*Paspalidium geminatum* (Forsk) Stapf
28 Gramineae	*Oriza latifolia* Derv
29 Gramineae	*Homolepis aturensis* (H.B.K.) Chase
30 Gramineae	*Hymenachne amplexicaulis* (Rudge) Nees
31 Gramineae	*Sorghum vulgare* Pers.
32 Gramineae	*Paspalum nutans* Lam
33 Leguminosae	*Phaseolus c.f. coccineus* L.
34 Leguminosae	*Senna alata*
35 Leguminosae	*Mimosa pigra* L.
36 Maranthaceae	*Thalia geniculata* L.
37 Onagraceae	*Ludwigia natans* Humb & Bomp
38 Onagraceae	*Jussiaea natans* H.B.K.
39 Orchidaceae	*Habenaria petalodes* Lindley
40 Papilionaceae	*Sesbania emerus*
41 Polygonaceae	*Polygonum hyspidum* H.B.K.
42 Polygonaceae	*Polygonum acuminatum* H.B.K.
43 Polygonaceae	*Polygonum punctatum* Ell
44 Polypodiaceae	*Acrostichum aureum* L.
45 Pontederiaceae	*Pontederia rotundifolia* L.F.
46 Zyngiberaceae	*Hedychium coronarium* Koening

Relative frequency of macrophyte species are shown in Tables N° 128 to 234. Index of similitude among main rivers and between the two lakes are shown in Table N° 135.

(3.2) Species Distribution

Distribution of all types of macrophyte species is shown in Maps N° 116 to 119.

Daubenmire (1968), in considering the primary causes of plant communities, stated that "communities are fundamentally the products of interaction between two phenomena: (1) differences in the environmental tolerances (or ecologic amplitudes) of the various taxa which comprise the flora and (2) the heterogeneity of the environment".

In applying this concept to aquatic macrophytes we need to consider the particular dynamics of the Panama Canal aquatic environment, including the effects of climatic variations and also how plant communities gradually modify the environment.

These processes collectively contribute to the distribution of aquatic macrophytes, and also results in variations of the botanical structure of the macrophyte communities.

Aside from seasonal changes observed, both in main rivers, open lake, islets, and along the lakeshore, cyclic phenomena occur at a small scale, and are repeated once and again in the whole community, as part of the community internal dynamics, and not of the succession (Krebs 1985).

The most significant sources of primary production in the aquatic ecosystem of the Panama Canal, are the main rivers like Chagres, Ciri Grande, Trinidad, Gatun, Ciricito, Gatun and tributaries.

Biotic community dynamics, downstream along the river shoreline, to the alluvial deposits formed at the mouth of the river in the Gatun Lake, results from interactions among climate (especially precipitation), soils, vegetation, water level fluctuations due to water management for canal operations and, land use patterns in the watershed.

Problems caused by excessive growth of aquatic macrophytes are largely originated away from operations areas of the Canal. In part, these problems are adverse impacts resulting from the canal construction (Von Chong et al. 1986). Dredging Division reports, as early as 1913, indicate that the first aquatic weed hampering canal operations was *Eichhornia azurea*. Shortly after it was followed by the floating hyacinth, *Eichhornia crassipes*, and the water lettuce, *Pistia stratiotes*, as well as a combination of grasses and other herbaceous plants (Von Chong 1986).

The distribution of the most common aquatic macrophytes in the study area is summarized as follows:

-Gatun Lake: *Hydrilla verticillata* a native to Southeast Asia, is only one of many plant species known as submerged vegetation (Folker 1987). It *Hydrilla* is the most widely distributed macrophyte in the aquatic environment of the Panama Canal (Map N° 116).

Panama Canal records (Von Chong 1988) indicate the posibility that the sumersed macrophyte *Hydrilla* began to colonize Gatun Lake about late 20's or early 30's. Since then, the absence of natural enemies, along with its high biotic potential, greatly contributed to its explosive spread.

Results of aerial photomissions average 4,785 hectares of the Gatun Lake infested with *Hydrilla*. Fathometer tracings show *Hydrilla* thriving at depths close to 9 meter in the Gatun Lake. The area that could be potentially colonized by *Hydrilla* is about 8,600 hectares (Von Chong et al. 1986).

The following table illustrates the *Hydrilla* infestations in Gatun Lake:

Year	Month	Average Lake Level	Hydrilla (hectare)	Lake Area (hectare)
1977	**January**	25.91	4695	42299
1979	**March**	26.03	4913	42507
1984	**Dec-Jan**	26.75	4748	43742

In addition to its large biomass, estimated in 27.2 tons/acre, (1981), disseminules like apical stem sections, rhizomes, and seeds, are effective propagating and dispersing agents, and also helps *Hydrilla* to overcome environmental stress and predation.

Aquatic recreational activities contribute to the dispersion of *Hydrilla* to other locations of the freshwater ecosystem of the Panama Canal, as is presently occurring at Lake Alajuela (Map N° 117). Sedimentation due to soil erosion and washout in the Canal watershed will contribute, along with the disposal of dredge spoils, to raise the bottom to such depths accessible to *Hydrilla* colonization. In general, the open lake zones with less than 25 feet depth are colonized by *Hydrilla* with no competition. In these sites of open lake *Hydrilla* grows the year round because water clarity is usually high.

Other types of aquatic macrophytes in the Gatun Lake are mostly lakeshore and emergent (Table N° 128).

At the dredge spoil dump 4, behind Gorgona island, we observed a cove of approximately 5 hectares full of *Eichhornia crassipes* and *Pistia stratiotes* Full blooming of *Eichhornia* may have been induced by intense competition for space and nutrients with the *Pistia* (Photography N° 20). This situation could be explained by the "*in situ*" propagation because the entrance to this cove in the mouth of Carabali River was closed with a log boom to prevent floating vegetation to flush into the canal.

-Northeast section of Gatun Lake: Shorelines of land and islands, exposed to the wave sweeping action induced by the prevailing northern winds which characterize the dry season.

In general, these shorelines present an almost identical pattern in the botanical structure: windward shorelines usually colonized with *Phragmites communis* and other species best adapted to the seasonal dynamics; leeward shorelines characterized, most of the times, by *Eleocharis sp.* (Map N° 118) and other species less resistant to the environmental stress posed by wind and wind-induced waves. This pattern is well illustrated by Photographs N° 21 and 22.

This pattern may show some variation in those sites of the lake less open and protected from the winds because of a high tree canopy, or because of elevations and topographic configurations which attenuate the effect of strong winds, and/or in sites far away from passing ships.

-Southwest section of Gatun Lake: In this part the structural pattern of the emergent vegetation is similar to other sites by this section of the lake. Shorelines of land and islands are delineated in a discontinuous way by *Eleocharis sp.* (Photography N° 23), with spots of *Acrostichum aureum, Annona sp., Icacorea sp.* and *Montrichardia sp.*

Greater relative frequencies are shown by lakeshore macrophytes like *Acrostichum aureum, Montrichardia sp., Eleocharis elegans*, and the submerged macrophyte *Hydrilla* sp. (Table N° 128).

-Chagres River-Gamboa Sector: Chagres River, downstream Madden Damm has a relatively controlled flow because of the hydroelectric generation and the programmed spillages for flood control. A containment boom is laid across the river to prevent floating vegetation reach the Canal.

In addition to the chemical and mechanical weed control effected annually for about 70 years, annual spillages, which are part of the flood control system, produce a sort of purge which generally clears the regeneration of vegetation colonizing the hydrosoil exposed during the low water period.

Thus, the natural processes of succession are systematically interrupted and the Chagres River seems in this sector, and that in its outflow to the Caribbean, like an early stage of the natural succession, as opposed to what is observed in the deltas of Gatun, Trinidad, Ciri Grande and Ciricito rivers.

By the numbers, most abundant and frequent macrophyte is *Salvinia* followed by *Eichhornia crassipes, Pistia sp.* and *Ludwigia* sp., all of the free floating type (Map N° 119). This order varies according with the season, being the *Pistia* more abundant during the transition. to the rainy season, and after the onset of the season *E. crassipes* dominate the area above *Pistia sp. Hydrilla verticillata* shows more spectacular growth during the dry season and beginning of the rain season.

Table N° 128 shows the relative frequency of species along five observation periods. Photographs N° 24 to 27 illustrate the abundance of free floating macrophyte communities, and also surface matting *Hydrilla* sp.

-Section of the Chagres River downstream Gatun dam: In this section of the Chagres river flowing into the Caribean sea, the marginal vegetation with greater relative frequency recorded was the *Acrostichum aureum*. It shows in long strips on both margins, alternating with *Montrichardia arborescens*, which was second in relative frequency. These two species are frequently found associated with swampy terrains subject to seasonal flooding. Floating and emergent macrophytes were not recorded here, nor other emergent species.

-Gatun River: During the dry season the water surface in the river mouth is most of the times cleared of floating vegetation as opposed to the situation during the rainy season. This, to a larger extent, can be ascribed to the prevailing strong winds characterizing the dry season, which push to the shorelines the floating vegetation. Due to a reduced competence for the space and light in the water column, and also to a lower water level, the *Hydrilla* is topping out a large part of the water surface.

Floating vegetation is composed mainly by a mixture of *Eichhornia crassipes* and *Pistia stratiotes*. The grasses and herbaceous like *Panicum grande, P. purpurascens, Paspalum fasciculatum, Paspalum repens* and *Luziola sp.*, along with poligonaceae share the alluvial deposits; along the shoreline *E. azurea*, ciperaceae, at the lower part of the river (Photography N° 28).

By the river mouth the lakeshore presents discontinuous strips of emergent *Eleocharis sp.* (Photography N° 29). Table N° 129 shows variations in the relative frequency of macrophytes along four observation periods.

-Ciri Grande River, Trinidad River and Ciricito River: We should mention the remarkable absence of *Pistia sp.* in the southwestern part of the Gatun Lake, i.e., Ciri Grande, Trinidad and Ciricito rivers, during the reconnaissance surveys from May to June 1992, and following with observations from July 1992 to May 1993.

With the exception of *Pistia sp.* the pattern of the botanical structure is similar to that of the main rivers on the eastern part of the lake. We do not have a sound basis to explain the abscence of *Pistia* in that part of the study area.

Eichhornia azurea is very abundant in association with *Polygonum sp.*, in narrow frames almost parallel to the shoreline in the front line, along with *Sesbania emerus, Typha sp.* and *Cyperus* (Photography N° 30). *Typha* is the most abundant emergent macrophyte occupying zones near the water line and toward the succession to the hydrosere at the zone of alluvial deposits (Photography N° 31).

Quantitative differences observed in this part of the study area are related to a minor relative abundance of the free floating macrophytes *Salvinia* and *Azolla* (Tables N° 130 to

132) as compared with other tributary rivers of Gatun Lake wher these species were very abundant during the whole study period.

-Alajuela Lake (Map N° 117): One of the most widespread macrophyte on the lakeshore banks, *Ambrosia cumanensis*, in this lake, is not aquatic. Abundant aquatic macrophytes are shoreline like *Polygonum sp.*(Photography N° 33) and the most abundant *Paspalum fasciculatum* , known as "jujuca" (Photography N° 34) colonizing shoreline in the river outlet to the lake, and on the alluvial terraces of the main affluents.

Annual drawdowns and the range between maximum and minimum lake levels (about 13 meter) prevents, so far, explosive overgtowth of the few aquatic macrophytes in this reservoir. This mechanism poses an environmental pressure which controls the excesive growth of aquatic macrophytes. Submerged macrophyte *Hydrilla sp.* and *Chara sp.* are now being dispersed with the aid of trailers used in the growing boat recreation activities near the landings at Nuevo Vigia and Isla Verde.

The watershed of Alajuela Lake is relatively less disturbed than the Gatun Lake watershed. Comparatively nutrient imput is also low. List of species and their relative frequency are shown in Table N° 133.

In the rest of the water reservoirs within the canal area the present status of the aquatic macrophytes is as follows:

-Miraflores Lake: Macrophytes in this impoundment are mostly of the floating type. Overgrowth of *Pistia* sp., *Eichhornia* sp., and riverine grasses are flushed into the lake by the Cocoli river floods. For submerged vegetation the area is probably marginal for *Hydrilla* due to high chloride content caused by marine water intrusion during lockages. However, this condition seems not to affect *Ceratopyllum demersum* which is observed near the existing outfall at the NE of the lake.

-Caimitillo Arm (Red Tank Lake): This resevoir is affected by changes in water quality due to the existing sanitary landfill at the NW. Monitoring carried out in 1984 (Von Chong et al. 1986), revealed a dominance of Coontail *Ceratophyllum* sp. shared with *Chara* sp. in about 70 % of the area infested with submerged macrophytes. *Hydrilla* was dominant by the south lakeshore parallel to the causeway and the culvert connecting with the railroad pond.

At the beginning of the rainy season (May-June-July) the dominat floating macrophyte was the water lettuce *Pistia stratiotes*, in a juvenile stage, with few colonies of water hyacinth *Eichhornia crassipes* which progressively becomes dominant as the rainy season advances.

Other abundant species during the rainy season floods were, rooted hyacinth (*E. azurea*), *Azolla* sp. and *Salvinia* sp. Muddy lakeshore and adjacent areas are colonized by emergent macrophytes mainly *Montrichardia* sp. *Achrostycum aureum, Typha* sp., *Paspalum repens,*

Cyperus sp., *Eleocharis sp.*, *Phragmites sp.*, *Jussiea sp.*, *Ludwigia* sp. Not very frequent, the Alismataceae (*Echinodorus* sp.).

-Camaron Arm: Botanical structure of the aquatic communities in this reservoir is similar to that in Caimitillo Arm. No eutrophication processes are apparent. No excessive overgrowth of aquatic macrophytes are observed. Dominant submerged macrophyte is *Hydrilla*.

-Railroad Pond: Floating aquatic macrophytes are exogenous. Floating masses of vegetation from Caimitillo river, are flushed into the pond and pass the causeway culvert to accumulate here. Chemical control is effected then to reduce excessive accumulations of biomass which may serve as mosquito breeding habitat (Von Chong et al. 1986).

-Pedro Miguel Lake: Floating macrophytes propagate gradually since the onset of the rainy season and are flushed to the pond during floods of Pedro Miguel river. Most frequent and abundant floating vegetation observed was *Eichhornia crassipes*, and less abundant *Pistia sp.* Shoreline species were the fern *(Acrosticum aureum)*, Cattail *(Typha domingensis*, *Montrichardia sp.*, species of the *Polygonaceae*, and *Panicum grande*.

-Cocoli River: Cocoli river is a source of potential aquatic vegetation problems during floods, when excessive overgrowth breaks the containment boom, flushing debris, and vegetation into Miraflores Lake.

Species observed during the rainy season are *Pistia stratiotes*, *Eichhornia crassipes*, Water fern (*Azolla sp.*), and *Salvinia sp.* Shoreline and muddy shallow areas species are colonized by the *Acrostichun sp.*, *Montrichardia arborescens*, wild cane (*Gynerium sagittatum*), *Limnobium sp.*, *Jussiaea sp.*, *Ceratophyllum sp.*, *Ceratopteris sp.*, *Panicum sp.*, *Saccharum sp.*, etc.

(3.4) Species Seasonality

Some variations in the distribution of the aquatic macrophytes are related to seasonal changes in rainfall as detailed below:

-Floating macrophytes: The selective pressure exerted on each other among populations of floating macrophytes, and the aditional environmental pressure originated by the increasing amounts of dissolved nutrients and supended solids in water, initially boost the propagation of some species, in detriment of others.

Seasonality of precipitation greatly influences growth of aquatic and semiaquatic macrophytes. At the beginning of the rainy season, intense rains impact on denuded soils increasing surface run-off and soil wash-out, flushing into the rivers dissolved and suspended matters. During the low level period, surface mats of Hydrilla trap plant disseminules and plantlets, forming a bed which gradually develops a mosaic of vegetation (Photography N° 26).

-Emergent macrophytes: This type of macrophytes form a relatively more stable community very important in the ecological succession of the lake. One of the most obvious effects is the seasonal flooding due to the lake level fluctuations. Most of these macrophytes are perennial, and some i.e., *Eichhornia azurea*, and *Eleocharis sp.* have a cycle of decay or senescence late in the rainy season.

From May to July, the botanical structure of floating macrophyte communities shows little qualitative changes. The more visible changes in the main rivers of the eastern part of Gatun Lake, i.e. Chagres River (Gamboa sector), and Gatun River are quantitative. By May-June-July, *Pistia sp.*, *Salvinia sp.* and *Azolia sp.* shows more abundant than *Eichhornia crassipes*.

After the onset of the rainy season (July), on the unstable substratums of alluvial deposits, river floods detach masses of vegetation which are moved downstream by currents and/or winds. Countless floating macrophytes plantlets reared in protected inlets or coves, initiate a rapid growth due to high levels of dissolved nutrients in water. Then, the floating hyacinth, *Eichhornia crassipes* develops a huge biomass which screens *Pistia sp.*, *Salvinia sp.*, *Azolla sp.* and other floating macrophytes (Photography N° 24).

Mid or late December is usually the beginning of a transition period to the dry season. Large masses of floating vegetation are still observed by the river mouths, and nearby lakeshores. Some floating macrophytes, like *Eichhornia crassipes* are observed in a process of decay and senescence because the high concentration of suspended solids during the last part of the rainy season, and a decrease of dissolved nutrients in water.

From January on an increased light intensity, along with a high water clarity and a decrease in lake elevation, promotes a rapid growth of *Hydrilla*, which by the months of February and March is topping-out the water surface forming extensive beds of surface matts in many rivers and also in parts of the open lake.

These beds, especially in the river mouths, trap disseminules and plantlets of floating macrophytes. The most abundant observed was *Pistia sp.*, by the end of the dry season or late April and early May, when the first rains begin to enrich waters with nutrients.

These processes of variation do not occur simultaneously in the whole aquatic environment. There is a North-South rainfall gradient as mentioned before. This variation of rainfall in the watershed produce also a difference in the occurrence of the processes of changes.

(3.5) Changes brought by the seasonality of winds

The impact that this climatic element has in the distribution of aquatic macrophytes is clearly evidenced by the *Phragmytes sp.* which is a reed growing on the winward lakeshore, or sites facing the direction from which the wind is blowing, on lakeshores eroded by waves induced by winds (Photography N° 21) and the *Eleocharis sp.*, one of the most widespread emergent macrophyte thriving preferably in the leeward lakeshores (Map N° 118), or sites protected from

the winds (Photography N° 22). There is a constancy in the association of species wherever the environmental conditions are repeated in the aquatic environment.

(3.6) Effects of temperature on aquatic macrophytes distribution

Effects, if any, of this climatic parameter on the aquatic macrophytes distribution is negligible.

(3.7) Effect of drawdowns on aquatic macrophytes distribution

Drawdown is not a climatic phenomena, but in the case of the aquatic environment of the Canal, results from a cyclic process of use and replenishment of water which is also geared to rainfall, which is a strong seasonal component.

During seasonal drawdowns from March to June, the hydrosoil between high and low water levels in shallow shorelines zones are accessible to the invasion by agressive shoreline vegetation, i.e., aquatic, semiaquatic grasses, and herbaceous plants.

Mean range of annual level fluctuation Lake Alajuela is over 13 meters (Figure N° 70). So far, this fluctuation has been sufficient to prevent overgrowth of aquatic macrophytes reach nuisance levels.

In Gatun Lake average level fluctuation is about 1.2 m. Its effect in controlling vegetation overgrowth is not considered a more limiting factor than it is Alajuela Lake.

Miraflores Lake system has a similar fluctuation value than Gatun Lake, about 0.9 m., and effects on aquatic vegetation control are almost nil. However, water transparency values are consistently low at all times in this lake. This poses an environmental stress on submerged macrophytes. Very probable this is the effect of waves induced by passing ships and/or winds in a relatively narrow section of the Canal. An additional factor can be related to Pedro Miguel lockages, which bring bottom sediments from the Gaillard Cut (Von Chong et al. 1986).

(4) **Benthos**

Samples taken from seven benthic stations scattered throughout the Gatun Lake (Map N° 15), during the period July 1992 - May 1993, indicated that at least five gastropod species inhabit the sediments (Table N° 136). Mollusk pelecypods were represented by three small body size species while anneiid oligochaetes and insects collected included only three species each.

The highest densities of benthic macroinvertebrates were recovered for the FB-4 station (mean = 2,399 individuals/m^2). Peak abundance at this station occurred in February with almost 6,000 individuals/m^2 (Table N° 137). FB-06 was the second station with high population densities. It total mean density during the study period reached 1,428 individuals/m^2, with the highest population density record in November 1992 (1,804 individuals/m^2).

The third important station was FB-03, which showed a total mean of 537 individuals/m^2 during the study period.

Peak of abundance occurred in February (1,150.60) in the profundal sediments. Samples taken from the littoral region of the benthic stations during April 1993, indicated that relatively high densities of macroinvertebrates inhabit the shallow areas of Gatun Lake.

(4.1) Bryozoans

The colonial bryozoan are rarely animals of quantitative importance in lakes. Bryozoan colonies are influenced by fish predation, colonies were branched and more productive; when exposed to fish predation, unbranched colonies persisted. A large number of invertebrate animals, from protozoans to large insect larvae, particularly chironomids, live within the colonies of bryozoans. Predators of the bryozoans consume these coinhabitants as well as the bryozoan parts.

Bushnell (1966) reported that some bryozoans species were associated with particular macrophyte substrata and that predation on actively growing colonies was often very high, especially by caddisfly (Trichoptera) larvae and snails.

In Gatun Lake, bryozoan statoblasts in relatively high densities (mean = 554/m^2) occurred in the profundal zone of five stations in August 1992 (Table N° 138). Those resistant reproductive structures were entirely absent in July 1992 and February 1993 samples from Gatun Lake.

Growth and profundal proliferation of a Bryozoan colony is a matter of simple asexual budding. Sexual reproduction might be restricted to a few weeks during the year. Statoblasts are asexual internal buds whose functional cells are enclosed by two tightly fitting sclerotized valves. Upon being released from the colony, statoblasts are distributed by currents and winds; they may float or remain on the bottom. A statoblast is highly resistant to adverse environmental conditions, but under appropriate conditions it germinates to produce a new bryozoan colony.

(4.2) Nematodes

The nematoda or roundworms constitute a significant component of the benthic fauna. The taxonomy of this group is difficult and incomplete.

Great diversity in feeding habits occurs among the nematodes. Some members are strictly detritivores, feeding solely on dead plant or animal particulate mater or both. Others are herbivorous and have specialized mouthparts for chewing living plant material or for piercing and sucking cytoplasm from plants. Among carnivorous nematodes mouthparts are more specialized, enabling them to seize, rasp, and macerate small prey animals.

Members of the Phylum Nematoda were found in relatively small numbers (overall mean = 19 individuals/m^2) in the FB-01, FB-02, and FB-05 stations in the 1992-93 survey of the benthic region of Gatun Lake (Table N° 139). Free-living nematodes are probably the most abundant benthic metazoan in lakes and may be expected from almost every benthic habitat. They are

considered a main group of the meiobenthos, organisms with body size smaller than 1 mm but larger than 50 microns. Sampling methods devised for the collection of macrobenthic animals are generally acceptable for the study of smaller animals, except that size-selective producers such as sieving must not be used in sorting organisms from the sediment (Huling & Gray 1971). The relatively low densities of nematodes found in Gatun Lake sediments are probably underestimates due to the use of 1 mm sieve in sorting these organisms.

In a detailed study of the nematode population of the sediments of a typical dimictic alpine lake, Bretschko (1973) found nematodes to be concentrated between 3 and 4 can of depth in the sediments. Analyses of the seasonal populations dynamics of the many species demonstrated 3 generations per year. Over a 2 year period, the average population density was 235,000/m^2 under ice-cover but only 60,000/m^2 during the ice-free period.

Bretschko indicated that nematode species distribution and biomass production were strongly correlated with the type of substratum. Over 80 percent of production occurred in the deeper zone of deep, fine sediments in which gravel was scarce and boulders were absent.

Nematodes of the littoral zone can reach very high densities among the attached algae of dense emergent and submersed macrophytes. In a detailed study of several lakes, Pieczynska (1964) found maxima occurred in May and June, when the populations numbered over one million individuals per square meter of substrate surface. During the other seasons of the year, the nematodes occurred in smaller, more or less constant densities. The densities of nematodes were correlated directly with the development and density of attached algae.

(4.3) Annelida

Two major groups of the annelids, or segmented worms, are represented in fresh waters. The first of these, the Oligochaeta or aquatic "earthworms", often form a major component of the benthic fauna, particularly of lakes. The other group, Hirudinea or leeches, is a diverse class of annelids of much biological interest. Although the significance of leeches as a component of total benthic animal productivity is unclear at this time, their predatory habits can materially influence the population dynamics of other benthic organisms, especially oligochaetes.

Oligochaetes are typically segmented, hermaphroditic annelids with body size ranging from less than 1 mm to about 40 cm, but much freshwater forms ar less than 5 cm in length.

Much oh the information on oligochaete populations focuses on the geographical distribution, habitat selection, and effects of organic pollution. The number of species is often greater in larger lakes, perhaps because of the greater number of different microhabitats common in larger lakes. Aquatic oligochaetes are distributed widely in lakes of greatly differing productivity, from oligotrophic to extremely eutrophic (Wetzel 1975).

Annelids are abundant and widespread in Gatun Lake sediments. They were found in almost every sample taken from the benthic region. Annelids in Gatun Lake were clearly dominated by oligochaetes which represented between 94 and 100 percent of the group (Table N° 140).

Annelids were especially abundant at the FB-04 station (mouth of Gatun River), where they were found at densities of over 40 individuals per square meter (Table N° 140). This is a shallow (11 meters) area of the lake, which undergoes continuous mixing of its water column. At this sampling station the group reached a density well over 400 individuals/m^2 in August 1992. Their densities in the littoral and the profundal were similar. Specimens of this group were found in small numbers at the FB-05 station (Puma Island). This is a deep (25 meters) an anoxic site of the lake. Annelids were found in relatively low numbers at the FB-02 (La Laguna) and FB-07 (Bajo Island) stations which are shallower than FB-05 and which also have little mixing of its waters.

Annelids mean overall abundance in Gatun Lake increased from 507/m^2 in July to 755/m^2 by August and then steadily declined during the rest of the study period (Table N° 141).

A number of studies have suggested that the particulate composition and organic matter content of the sediments are correlated with the distribution and abundance of oligochaetes (Brinkhurst 1967).

Oligochaetes ingest surperficial sediments containing organic matter of autochthonous and allochthonous origins colonized with bacteria and other microorganisms. Some species actively graze attached microorganisms growing epiphytically on macrophytic vegetation.

Several families of oligochaetes are represented in the freshwater zoobenthos. The Tubificidae and Lumbriculidae contain the large oligochaetes most frequently encountered by limnologists. The Tubificidae are especially important because their method of deposit feeding causes rapid mixing of lake sediments, a process of major importance to nutrient cycling (Strayer 1985).

As lakes and streams become organically polluted, it is common to find an abundance of tubificid oligochaetes (Brinkhurst & Cook, 1794). Associated with such organic enrichment is acute reduction or elimination of oxygen, which is lethal to a majority of benthic animals. The number of species of tubificid worms also decreases with increased organic pollution. However, the combined conditions of a rich food supply and freedom from other competing benthic animals permit rapid growth of this group.

Many oligochaetes and especially tubificids burrow headfirst into the sediments but leave their tails, containing a majority of respiratory appendages, projecting and undulating in the water above the sediment-water interface. In general tubificids are able to adapt respiration in relation to oxygen concentration down to a critical level of the range of 10 to 15 percent saturation. Hemoglobin of tubificids can tolerate anaerobic conditions for at least a month or longer, but only if they are exposed intermittently to some oxygen. Water movement is apparently an important factor in removal of toxic metabolic wastes, since anaerobic conditions can be tolerated longer in moving situations than when water is stagnant.

Branchiura sowerbyi (Annelida; Tubificidae) dominated the aquatic annelids population of Gatun Lake at all times of the year. Abundance was relatively high in February (up to 231 individuals/m^2) at the station FB-04. Samples from the littoral at the FB-07 station showed a

relatively high mean density of 204 individuals/m². Peak abundance of *Branchiura sowerbyi*, which reached 101 individuals/m², occurred in the profundal region in July in the FB-03 and FB-06 stations (Table N° 142).

The other major family of freshwater oligochaeta is the Naididae, an ecologically diverse group of worms, many of them small. Some naidids are deposit feeders, but many others eat algae or small animals. The Naididae often are overlooked by limnologists, even though they dominate the oligochaete communities of many lakes (Strayer 1985).

Oligochaete species are separate within the sediments. Naidid oligochaetes are concentrated at the sediment-water interface, rarely more than 2 to 4 cm below the surface. Tubificic oligochaetes are most dense between 2 to 4 cm of sediment depth, occasionally as deep as 15 cm. The movements of benthic organisms within the sediments are important because of the possibility that their activity can disrupt the oxidized microzone of the sediment-water interface and there by alter rates of chemical exchange between the sediments and overlying water. It appears that the intensive microbial activity at the sediment-water interface is sufficient to reestablish redox conditions almost immediately after such disturbance (Wetzel 1975).

(4.4) Hirudinea

Some leeches act as ectoparasites consuming blood and body fluids of vertebrates greatly in excess of their body weight. Other leeches are predatory on invertebrate such as oligochaetes, and entirely consume their prey (Elliot 1973).

Reproduction apparently is governed by the temperature, the density of the populations, and age. When population densities become high, size can be regulated by high mortality of the eggs, which are consumed by adult leeches (Elliot 1973).

The abundance of leeches is highly variable among different habitats of lakes. A general direct correlation exists between leech abundance and lake productivity. This relationship probably is associated with the increasing diversity of substrate types among the macrophytes and sediments, with correspondingly greater amounts of invertebrate food sources for the predaceous leeches and birds, and vertebrates for the blood-consuming leeches (Sander & Wilkialis 1992).

In Gatun Lake, scattered individuals of this group were found at the FB-03 and FB-04 stations.

(4.5) Ostracods

The ostracods, small bivalved crustacean usually less than one millimeter in size, are widespread in nearly all aquatic habitats. Their small size, benthic habits, and difficult taxonomy have all contributed to a very poor understanding of their ecology in fresh waters. Ostracods are omnivorous and feed on bacteria, algae, detritus, and other microorganisms by mean of filtration. Very little is known of the effects of ostracods on the turnover and metabolism of benthic microflora. The large population number of ostracods suggest that their role in the metabolism of surficial sediments is underestimated.

Little is known of the population dynamics of ostracod populations, although many exhibit distinct seasonal periodicity. Some species exhibit a single generation per year, others 2 or 3 per year. Predation by bottom-feeding fish and other benthic organisms are known to affect ostracod densities (Wetzel 1975).

Members of this group were found in relatively low numbers (9 ostracods/m^2 in November) in the FB-02 station of Gatun Lake.

(4.6) Mollusks

The freshwater Mollusca are separable into 2 distinct groups, the univalve snails (Gastropoda) and the bivalve clams and mussels (Pelecypoda). Respiration in the snails occurs by gills and by pulmonary cavities. The latter group can stay submersed for long periods of time, including their entire life cycle without filling their pulmonary cavities with air. Cutaneous respiration through the body membranes is common to all freshwater snails.

The food of the Pelecypoda clams consists primarily of particulate detritus and microbenthos. Large clams live as long as 15 years, while the smaller fingernail clams (Sphaeriidae) have a longevity of about a year or slightly longer. The adult population and their distribution can be modified greatly by fish predation, certain birds and a few aquatic mammals.

The bivalve mollusks of family Sphaeriidae respire and feed by filtering water through the mantle cavity. They can filter the smallest particles, down to bacteria. Considering their capacity for forming large populations, it is believe that they play a large role in water bodies as biofilters. One individual of *Sphaerium rivicola* measuring about 19 mm is capable of filtering up to 100 ml of water in one hour, while an individual of *Sphaerium corneum* measuring about 7 mm filtered about 64 ml water in one hour (Mitropolskii 1966).

According to Pennak (1978), sphaeriids feed on organic detritus, phytoplankton and zooplankton.

Mollusks were the dominant group in the sediment samples from Gatun Lake. Their highest density values occurred at the FB-04 (2,164 individuals/m^2) and FB-06 (1,253.92 individuals/m^2) stations,, which are characterized by the continuous mixing of the water column and the substrata (Table N° 143). The FB-04 station is at the Gatun River mouth and receives direct influence, in terms of organic material input, from this river catchment basin; FB-6 is adjacent to the canal route and it waters and sediment undergo a daily mixing by the mechanical action of the ships passing by.

FB-03 was the third most important mollusk station. This sample area is located in the Frijoles Bay, which is in the regular ships route and therefore, under the continuous hydraulic influence from them, which results in the mixing of their waters and sediments. The lowest total mean values for Mollusca occurred at the FB-02 and FB-05 stations. The FB-02 station is located in the area called The Laguna, a relatively shallow zone of the lake, which undergoes little mixing of its waters. FB-05 is adjacent to Puma Island and it is characterized by being relatively deep (25 meters) and quiet, with little mixing of its waters and sediments.

Littoral benthos sampled in April 1993, showed relatively high Mollusca population densities at six stations. FB-05 lacks littoral area devoid of macrophytes, so it was not possible to sample the sediments. Abundance of mollusks in the littoral region in April was over 200 individuals/m^2 at the FB-01 and FB-02 stations, while at the stations FB-04, FB-06 and FB-07 densities were well over 1,000 individuals/m^2.

Mollusks from the profundal sediments reached their maximum overall density (1,073 individuals/m^2) in February, then steadily decline during the rest of the study period.

Mollusks constituted more than 40% of the total benthic organisms in Gatun Lake. The lowest proportion of Mollusca in the profundal sediments occurred at the FB-02 station, where they represented 41% of the overall benthic population per station. The highest overall percent values were recorded at the FB-06 (95%) and FB-07 (93%) stations (Table N° 144).

Littoral benthos, sampled in April 1993, showed a clear predominance of Mollusca, which represented 91% of the total benthic population in this region. In the sediments from the profundal region, the highest proportion of Mollusca occurred in May (89%) 1993.

Snails (Gastropoda) and clams (Pelecypoda) dominated the mollusks population of Gatun Lake at all times of the study period. Gastropods dominated the Mollusca at the stations FB-1 (78%), FB-03 (69%), FB-05 (97%), FB-06 (60%) and FB-07 (56%), while pelecypoda dominates only at the FB-02 (100%) and FB-04 (84%) stations during the study period (Table N° 145).

Total Gastropod densities in the profundal sediments increased from 72.46/m^2in July to 389.84/m^2 in November, then declined to 210.78 in May. Pelecypoda did not show a clear pattern but a maximum was recorded in February (778.55 individuals/m^2).

The highest total mean per station for Gastropoda was recorded at the FB-06 (748 individuals/m^2) station while that the FB-04 station showed the highest total mean for Pelecypoda (1,816.31 individuals/m^2).

In Gatun Lake, mollusks were dominated by two pelecypod and two gastropod species: *Corbicula sp.*, *Melanoides tuberculata*, *Sphaerium sp.* and *Pyrgophorus coronatus* (Table N° 146).

Corbicula sp. dominates the Mollusca population in Gatun Lake, where it represented 38.58 percent of the overall Mollusca population density. Peaks abundance of *Corbicula sp.* occurred in February and May, when they represented 71.84 and 56.89 percent of the Mollusca population, respectively (Table N° 147).

Corbicula sp. was common at the FB-03, FB-04 and FB-06 stations, where it reached overall mean densities of 150.47, 1,168.74 and 479.77 individuals/m^2, respectively. Peaks abundance, which reached overall mean densities of 770.94/m^2 and 278.10/m^2 occurred in February and May, respectively. Highest densities of *Corbicula sp.* occurred at the FB-04 station where it reached 4,418 and 1,307 individuals/m^2 in February and May, respectively (Table N° 147).

The snail *Melanoides tuberculata* was the second most abundant mollusk in Gatun Lake sediments. It represented 24.25% of the overall Mollusca population. This species was found regularly but in relatively moderate densities in most sampling stations. It was absent in the profundal region of the FB-02 station; the littoral region of FB-02 showed *Melanoides* densities of 88.89 individuals/m^2. The overall abundance of this snail in the profundal sediments did not represent more than 33% of the mollusk population (Tables N° 146 and 148)).

Melanoides tuberculata highest mean densities occurred in the FB-03, FB-04 and FB-06 stations, where this species reached 192.20, 298.02 and 447.28 individuals/m^2, respectively. The highest overall abundance of *Melanoides tuberculata* occurred in November (227.30/m^2) and February (273.01/m^2). It is noteworthy to indicate that the overall abundance of this snail in the littoral (578.78/m^2) was higher than any profundal total mean density. In the profundal sediments, *Melanoides tuberculata* was particularly abundant in February at the station FB-04 (1,164.44 individuals/m^2).

Sphaerium sp. (Sphaeriidae) was the third most important mollusk species in Gatun Lake (Table N° 149). This fingernail clam reached its highest densities at the FB-04 station. These densities occurred in July (124.38/m^2) and November (1,244.44/m^2).

Sphaeriids are common benthic inhabitants; compared with most clams, they are tiny, smaller than a fingernail. Sphaeriids are adapted to a wide range of conditions, and occur on all types of substrate except clay and rock (Pennak 1978). They burrow into the sediment, feeding on bacteria, densities and benthic algae (Likens 1985).

Pyrgophorus coronatus was the fourth most important mollusk in the benthic region of Gatun Lake. This small snail reached its highest mean density in the profundal sediments in November (151.11/m^2). Its mean density in the littoral (22.22/m^2 in April) was lower than in the profundal in May (46.98/m^2). *Pyrgophorus coronatus* was especially abundant in the FB-06 and FB-03 stations, where it reached mean population densities of 283 and 135 individuals/m^2, respectively (Table N° 150).

(4.7) Decapods

Crayfishes are omnivorous but primarily herbivorous on algae and larger aquatic plants, and occasionally are scavengers. Their distribution is affected by predation by fish and pollutants that reduce oxygen content or alter substratum (Wetzel 1975).

Crayfish are generally inhabitants of shallow waters, seldom being found deeper than three to five feet. A few freshwater prawns were collected from the sediments in the FB-01 station (35.56/m^2) on November 14, 1992.

(4.8) Aquatic Insects

By far the most abundant and diverse group of animals of the earth is the insects, most of which are terrestrial. Of those that are aquatic, nearly all are fresh water.

The following aquatic insects were the most common among the samples:

-Odonata (Dragonflies and Damselflies): The odonata nymphs and almost entirely littoral in habitat, living among macrovegetation and littoral sediments, and burrowing into surficial sediments. The nymphs have fairly high respiratory demands and oxygen requirements.

A few Libellulidae nymphs were collected from the benthic region in the FB-01 station (8.88/m^2) on February 13, 1993.

-Diptera: The dipterans form major constituents of the benthic invertebrates of many standing waters, and the chironomid larvae are particularly ubiquitous. Adults essentially are never aquatic, but most of their life cycle is as immature forms is fresh waters. Most species have generation per year, some have 2 per year, and fewer of those known species have a 2 year life cycle. Most larvae respire cutaneously or by mean of "blood gills". Some larvae possess a type of hemoglobin that functions efficiently at low oxygen concentration.

The chironomid midges are, by most measures, the most important animals in the lacustrine zoobenthos. They are abundant in most lakes, and commonly constitute upwards of 50% of zoobenthic biomass (Strayer 1985). Because many chironomids are retained on coarse sieves (e.g. 1 mm mesh), they are often considered to be part of the macrofauna. However, small species and early instar larvae pass such coarse sieves, and are retained quantitatively only on sieves as five as about 0.1 mm mesh. In this study, we used 1 mm mesh sieve to retain the fauna collected from the sediments. It is possible that most of the chironomid larvae passed through this coarse sieve and their density records are underestimates (Table N° 151).

In Gatun Lake, chironomid larvae occurred in relatively low numbers (up to 62.22 individuals/m^2 in FB-01 in February and in FB-04 in November) in the sediment samples. FB-01 station showed the highest chironomid larvae density with a total mean of 30.62/m^2 followed by the FB-01 station (19.55/m^2). Peak abundance of chironomid larvae occurred in February (20.31 individuals/m^2). At this sapling date, they showed up at the FB-01 (62.22/m^2), FB-02 (44.44/m^2), FB-03 (8.89/m^2) and FB-04 (26.66/m^2) (Table N° 152).

-Chaoboridae: This family is represented by a single genus, *Chaoborus*, in Gatun Lake. The larvae of *Chaoborus* live in the sediments during the day and in the pelagic zone at night. They are predaceous, feeding both on zooplankton and zoobenthos such as oligochaetes.

Because of its small size, it is possible that most of the *Chaoborus* larvae passed through the sieve (1 mm) used during the study and its population densities are underestimates. *Chaoborus* occurred in August at the FB-02 (14.81/m^2) station and in November at the FB-02 (26.67/m^2) and FB-04 (8.89/m^2) stations.

(5) Fishes and Macroinvertebrates

A total of 583 fishes representing of 26 species included in 15 peripherical (marine species which occasionally penetrate rivers and some develop part of life cicle on these systems) and frehwater families were collected in 10 of yhe 11 sampling stations from july 1992 to may of 1993.

A checklist of these families and their fish species are presented in Table N° 153. Table N° 154 shows a list of species and their distribution in the 10 sampled stations.

General speaking during the sampling work period we do not observed any significant change in the number of caught individuals, but we observed the predominance of 6 freshwater fish species in all sampling periods. In other hand the rest of fish species only appeared sporadically during our inventory. The most important species were: *Cichla ocellaris, Hoplias microlepis, Cichlasoma maculicauda, Brycon chagrensis, Curimata magdalenae* and *Rhamdia guatemalensis.*

Regarding the numerical rank by species in Table N° 155 we observed that *Cichla ocellaris, Cichlasoma maculicauda, Hoplias microlepis, Rhamdia guatemalensis, Curimata magdalenae* and *Brycon chagrensis*, were the numerical dominant species having the higher values on the relative abundance of catch with 29.1, 28.3, 12, 7.7, 6.3, 6.2% respectively totaling the 89.6% of the inventory catch.

In relation to the biomass or total weight of the catch, we observed that same 6 species obtained the 87.5% of total weight having values of 33.5, 19, 14.6, 12.3, 3.5, y 3.1% for *Hoplias microlepis, Cichla ocellaris, Brycon chagrensis, Cichlasoma maculicauda, Rhamdia guatemalensis*, and *Curimatus magdalenae*, respectively (Table N° 155).

Is very important to mention that fishes as *Astronotus ocellatus, Oreochromis niloticus, Cyprinus carpio*, and *Colossoma macropomum*, are exotic fishes introduced in the recient years into the Panama Canal reservoirs.

In relation to the fishing effort employed (fishing hours) we observed an average of 15 hours per station was estimated for the sampling period in each station. In other hand in the working periods we obtained a minimum value of 14.8 and maximum value of 15.4 hours (Table N° 156).

In reference to the total number of fish collected the stations FF-04, FF-03, FF-02, FF-10, and FF-05 obtained the higher numbers with 172, 81, 67, 66 y 53 individual respectively, constrasting station FF-09 only achieved the minimum amount with 18 fishes (Table N° 157). During the sampling periods this value ranged between 131 and 98.

The fish per hour indices obtained their higher values in the stations FF-04, FF-02, FF-03, FF-10 and FF-01 with 2.4, 1.2, 1.1, 0.86 y 0.73 fish per hour, respectively. On other hand, the

minimum value of 0.26 was recorded in the stations FF-08 and FF-09 (Table N° 158). These fish per hour indices range from 0.67 and 0.88 fish/hr.

The total weight for the inventory was 226.4 kg, obtaining the higher amount in the third sampling period with 65.8 kg, while the minimum amount of was obtained in the fourth sampling period with 39.5 kg. The stations FF-04, FF-02, FF-03, FF-01, FF-05 and FF-07 showed the higher biomass values with 98.5, 34.7, 25.4, 18.4, 17.3 y 10.8 kg, respectively (Table N° 159).

Simultaneously, during the inventory of fish species we collected five species of crustacean decapods belonging to 3 families (one freshwater and 2 brackish water species). Also was caught one freshwater mollusca species. The checklist of the main macroinvertebrates species and their families are presented in Table N° 160. The distribution of these species also is detailed in Table N° 161. *Callinectes toxotes*, *Macrobrachium amazonicum*, and *Macrobrachium americanum* were the most common crustacean decapods during this inventory.

From the 5 crutacean species, 4 (or 80%) were collected in station FF-01 (Miraflores Lake) and were *Penaeus stylirostris*, *Macrobrachium americanum*, *Macrobrachium sp.* and *Callinectes toxotes*. In the other hand, *Macrobrachium amazonicum* was collected in stations FF-03 and FF-04, located at the Alajuela Lake where it was recently introduced. The freshwater snail *Pomacea sp.* of recently introduction in the Panama Canal lakes are present in stations FF-03, FF-04, FF-07, FF-08, FF-09 and FF-10 (Table N° 162).

Numerical dominance was observed in *M. americanum*, *M. amazonicum*, and *Callinectes toxotes* with 43.4, 27.3 and 24.2% of the catch respectively, totaling the 94% of the inventory catch. The other 6% was divided between *Penaeus stylirostris* and *Macrobrachium sp.* (Table N° 162).

The total weight for these macroinvertebrate was 4,924 g. showing *Callinectes toxotes* and *M. americanum* the higher values with 85 and 12.4% of the total biomass, respectively.

(6) Commercial and Sport Fisheries

(6.1) Commercial Fishery

This activity is carried out by local fishermen living in shoreline communities of Lake Gatun and Alajuela Lake. These fishermen trade fish locally or send them to the city markets in Panama and Colon.

The main type of fishing is through fishhook (N° 10) and string, baited with live bait. Generally fishermen fish for three to five hours a day, for a period of 3 to 6 days per week. As transportation they use canoes with lengths of four to 6 meters, propelled by oars or by outboard motors of 4.5 to 6 hp. (Maturell & Tapia 1991).

Usually these groups of fishermen have received some type of government counseling in cooperative organizational matters and lately, in the appropriate management of post-harvest products. Maturell & Tapia (1991) estimated that this activity represented 25% of the total capture for 1986.

Fishing grounds are identified as: Gatun River, La Represa pond, Ciricito, Cuipo, El Congal, Los Cedros, most of them located on the Trinidad Arm of the Gatun Lake. In Lake Alajuela, the most important communities are San Lorenzo, Tranquilla, and Quebrada Benítez.

It is important to stress that during the last two years, the commercial activity has taken another spin in the trade aspect, due to the production of a dry-salted product of the peacock bass, which is cured using locally produced solar dryers. This technique has opened new markets for fish products since prior to this process part of the product was lost since no coolers or freezers were used to store the catch.

Even though there are no exact or constant data on the number of captures in Lake Alajuela, it is necessary to note that native fishermen of this area, besides Sergeant fish, also capture and trade species such as *Brycon chagrensis, Hoplias microlepis, Rhamdia guatemalensis, Curimatus magdalenae*, and the recently introduced species: *Oreochromis niloticus* and *Colossoma macropomum*.

(6.2) Subsistence fishery

Without any doubt this activity is the most important in the area since it is practiced in almost every riverside community of the Panama Canal Watershed. Subsistence fishing and commercial fishing are intimately related since the same fishing methods are used for both, and in most cases the surplus captures are eaten by the fishermen and their families. This fishing activity was calculated as representing 64% of the total catch for Lake Gatun (Maturell & Tapia 1991).

(6.3) Sport fishing

In contrast with the two latter activities, this one is practiced chiefly by tourists, metropolitan residents, and U.S. military personnel stationed on bases in the Canal. These fishermen use sophisticated fish tackles like fishing poles, aluminum or fiberglass boats (most of the times rented) of 5 to 8 meters of length propelled by outboard motors of 25 to 40 hp. In most cases the boats are rented together with guides, scanners, covers, etc; there are also rental cottages available which make the activity more pleasurable.

Leisure or sport fishing is concentrated on three main points located in Lake Gatun (see map). In Gamboa, there are two places to disembark; in La Arenosa there are five points, and in Gulick only one port (Gonzalez 1993).

This activity increases on weekends (Friday, Saturday, and Sunday) and occurs sporadically on weekdays. This type of fishing is as important as large and important as commercial fishing. It is estimated that sport fishing totals 29% of total capture in the lake (Maturell & Tapia 1991).

Table N° 154 displays the data on the catch and fishing efforts recorded from November 1992 to March 1993, in a sport fishing landing point in La Arenosa.

During this period, a total capture of 2,326 kg was registered, with a mean value of 465 kg/month. The total fishing effort was 568 hours with a mean value of 114 hours. Finally, the total c.p.e.f. was 19.8 kg/h with an average 3.96 kg/h (Table N° 154). Without any doubt, this fishing activity involves the creation of many temporary and permanent jobs from boat rentals to cleaning of captures, etc.

(6.4) Comercial fishing analysis at the Gatun River Cooperative, Colon

During 1992 the National Directorate of Aquiculture through the Department of Lakes and Rivers, carried out a study to gather data on the catch, fishing efforts, and fishing efforts of the pre-cooperative group of Gatun River, Colon.

This particular group of fishermen is made up of ten active members that usually fish for 3 to 6 days a week and sell their catches in a small store along the Transisthmian Road, near the town of Gatun River.

It is important to stress that the data for 1992 is incomplete due to problems which appeared in the records of the pre-cooperative. In Table N° 153 are displayed the leading data for this group.

In 1992, the total capture (kg) for this group was 10,398 kg, September being the month with the most captures (1,588 kg), while the smallest kg of captures ocurred in February with 748 kg. Mean monthly capture was of 1,157 kg for that year.

The total fishing effort was 3,358 hours for 1992, with a peak value in September with 470 hours. On the other hand, the minimum fishing effort was in February, 1992 with 256 hours. The mean monthly fishing effort was 373 hours.

The captures per effort unit (c.p.e.f.)) was variable for 1992 with an average 3.07 kg/h, showing a peak c.p.e.f. in August with 3.62 kg/h, while a minimum was reported for February with 2.46 kg/h. (Gonzalez 1993).

It is important to stress that commercial fishing has a limitation, which is the lack of market which inhibits its growth. Every fishing cooperative faces this limitation.

Although the Department of Lakes and Rivers of the National Directorate of Aquiculture closely monitored the groups close to the lakeshore, official figures have not been collected regularly this may explain that the minimum annual commercial capture is close to 10 metric tons in each community.

(7) **Aquatic Mammals**

Only one species of mammals in the study area is genuinely aquatic: the manatee (*Trichechus manatus*, Trichechidae, Order: Sirenia). Manatees were introduced into Gatun lake, in the area of Gamboa mouth of the lower Chagres, in 1962. They have since spread throughout the Gatun lake area and at least one has passed through the Pedro Miguel locks into Miraflores lake.

They have been seen in the Gaillard cut, in the area where they were originally introduced, in the Gamboa Reach of the canal, and near Barro Colorado Island. There are reliable reports that the natives of Escobal hunt them and have killed at least one. At least two female manatees with small young have been observed, so it can be said with certainty that the population is breeding.

There are five species of semi-aquatic mammals, that is, mammals that principally forage in fresh water but spend much time on land, reported from the study area. These are the water opossum *Chironectes minimus* (Didelphidae; Marsupialia), the otter *Lutra longicaudis* (Mustelidae; Carnivora), the capybara *Hydrochaeris hydrochaeris* (Hydrochaeridae; Rodentia) and two small rodents: *Oryzomys couesi* and *O. alfari* (Cricetidae)

The water opssum occurs near streams and small rivers and near lakes in both forested and open areas, but is widely dispersed an seldom seen. Specimens have been observed on Barro Colorado Island and have been trapped at Limbo and in the Madden forest reserve.

The otter has steadily increased in numbers since the introduction of the peacock cichlid *(Cichla ocellaris)* into the study area in 1966. Otters now range throughout the Gatun lake area, in the middle and upper Chagres river, over Lake Alajuela, up to major tributaries of these bodies of water, and in many lakes and small ponds within the study area.

The capybara arrived in the Gatun lake area sometime in the early 60's, having spread westward from the Pacora marshes and down the upper Chagres. Capybaras are now found anywhere there are grassy patches near bodies of water on both sides of the canal. No information is presently available on the two semi-aquatic cricetids in the area.

c) **MARINE WATER**

The biota from the Pacific and the Caribbean coasts of Panama has been subjected to evolutionary changes due to the emergence of the Isthmus of Panama 3.5 million years ago (Coates et al. 1992). Hence, marine species at both sides of the isthmus has shown divergent tendency in the evolutionary sense, then allowing allopatric and sympatric conditions from a common ancestor. Accordingly, species in both coasts may be identical, totally different because of the evolutionary divergence, or geminate, morphologically similar but genetically different.

Several marine inventories have been carried out in the Isthmus of Panama among these: the Dana expedition from 1838-1842, the 1891 Albatross expedition with naturalist Alexander

Agassiz as chief scientist (Garman 1899), Meek & Hildebrandt 1911-1912 (Meek & Hildebrandt 1923, 1925, 1928), Waldo Schmitt in 1926 (Rathbun 1930, 1937), George Vanderbilt in 1941 (Fowler 1944), the Allan Hancock expedition in 1934, 1935, and 1938 (Rathbun 1937), and more recently the R/V John Pillsbury expedition carried out by the University of Miami during 1966-1967 in behalf of the Bioenvironmental and Radiological Safety Feasibility Studies Atlantic-Pacific Interoceanic Canal (Bayer et al. 1970).

(1) Oceanography and Water Quality

The Isthmus of Panama is located in a zone of low pressure that circles the globe around the Equator, known as the Equatorial Low Pressure Zone. Here, the trade winds converge in each hemisphere to form the Intertropical Convergence Zone (ITCZ) which is associated with a wide band of variable and weak winds, and strong frequent rains. Both sides of Panamanian isthmus are exposed to significant climatic changes associated with the movement of the ITCZ, which defines a dry season (January to April) and a rainy season (May to December). These seasons can vary substantially from year to year, and affect wind patterns, rainfall, and runoff from nearby rivers. Changes in runoff bring about changes in the water mass, although in very different ways near the Pacific and the Caribbean entrances to the Canal. The only feature these two areas share in terms of the seasonal changes is the increase of rainfall during the rainy season which decreases the salinity on the oceans surface. On the other hand, the intense northerly winds that blow over the isthmus during the dry season promote the upwelling in the Gulf of Panama moving deep waters to the surface (Figure N° 71). This upwelling breaks through the stratification of the water column bringing to the surface cold water, of high salinity, with higher nutrient concentrations, and poorly oxygenated (Smayda 1966, Forsbergh 1969, D'Croz et al. 1991). In addition, this seasonal upwelling is responsible for the high biological productivity in the Bay of Panamá (Kwiecinski et al. 1975). On the contrary, there is no upwelling in the Caribbean side.

Another important features affecting the properties of the sea water are the tides and the coastal currents. While in the Gulf of Panama the tides are semi-diurnal and wide ranged (6m), the tides in the Caribbean side are both semi-diurnal and diurnal, of small amplitude (<0.5m). Related to the tidal regime is the residence time of natural or anthropogenic elements in these areas (Glynn 1972). These variations might play an important role in the water quality.

The main cause of marine pollution near the entrances to the Panama Canal are: seawage effluents, fuel hydrocarbons, and industrial pollution. Seawage waters are the main source of BOD, which consequently reduce the concentration of dissolved oxygen in the water column. Because of this reason, in order to analyze the results and evaluate the quality of the sea water near the two entrances to the Canal it is necessary to take into consideration the above mentioned factors.

The results of the measurements and analysis corresponding to the quarterly samplings performed in the period from July-1992 to May-1993 are presented in Tables N° 163 to 167.

(1.1) Oceanography of the Bay of Panama

The rainy season: The results of the field measurements and the analysis of the sea water during the rainy season indicated an uniform distribution of the properties and the lack of thermal stratifications. Also, a mixed layer of warm water, around 29°C from the surface to the bottom in all of the stations in the area, was common during this season. The station MWQ-04, with the greatest depth in the studied area (25m in depth) indicated that the difference between the surface and bottom temperatures was only 1.8°C (Figure N° 72).

The same condition is valid regarding the depth distribution of the salinity. There is very little diference between the sea surface and the bottom salinity, which in any case exceeded 1.9 o/oo. A good example of this is observed at station MWQ-04 (Figure N° 73). However, an exception to this is found at station MWQ-01, located close to the Miraflores Locks, which is subjected to the constant runoff of freshwater from the operation of the Panama Canal locks. The freshwater discharge from the locks can still be traced at station MWQ-02 (in front of Farfán) according to the low salinity found in this station, ranging from about 31 o/oo in July to 27o/oo in November 1992.

In the west section of the study area there are some spots (stations MWQ-08 and MWQ-10) with relatively low sea surface salinity of about 31 o/oo in July and 28 o/oo in November (Figure N° 74). With all probability this is due to the influence of the freshwater runoff from the neighboring rivers and the proximity to the Bay of Chame. The absence of stratification is accompanied by uniform values in the concentration of dissolved oxygen in the water column. The dissolved oxygen concentration in surface waters during the rainy season varied between 6 to 8 ppm (92-123% of saturation value), while at the same time the bottom waters contained concentration of dissolved oxygen above 5 ppm (77% saturation value). A typical example of the uniform distribution of dissolved oxygen was recorded at station MWQ-04. In this station it was noted that the difference in concentration of the dissolved oxygen in a water column of 25m in depth was smaller than 2 ppm during the entire rainy season (Figure N° 75).

In summary, the sea surface temperature of the Panama Bay during the rainy season was around 28°C and the sea surface salinity was below 30 o/oo, on the average. These characteristics are quite normal for the area and the time of the year (Smayda 1966, Forsbergh 1969, D'Croz et al. 1991).

The nutrients and the chlorophyll *a* concentrations in the Panama Bay depend in great extent on the rainfall and the freshwater runoff in the area. Smayda (1966) proved that significative changes in the sea water of the Bay of Panamá are related to the high precipitation and the runoff. Besides the salinity, the most affected parameters by the freshwaters discharge are the transparency and the concentration of dissolved nutrients. The runoff decreases the transparency of the water mass because of it's high load of suspended solids. More than this, the precipitation and runoff decreased by dillution the concentration of nutrients in the sea water of the Bay of Panama.

The concentration of nutrients, between August and November 1992, was quite low and rather uniform regarding the vertical (Figure N° 76) and horizontal (Figure N° 77) distribution. The concentration of nitrates, a critical nutrient for the phytoplankton photosynthesis, seldomly exceeded 1 μg-atom/L in all of the vertical profiles in the area. Higher values were found during November at the stations MWQ-01 and MWQ-02, both located close to the entrance to the Panama Canal. The relatively high concentration of nitrates (higher than 2 μg-atom/L) with most probability is related to the contribution from the fresh water runoff from the Gatun Lake. The analysis of the water of Gatun Lake indicated extremely high concentrations of nitrates (around 10 μg-atom/L) in the vicinity of the Miraflores and Pedro Miguel locks.

The concentration of chlorophyll *a* presented a significatively increase in November, sharply pronounced at the stations MWQ-01 and MWQ-02 (Figure N° 78). With all probability the increase of chlorophyll at these stations is related to the freshwater runoff from the Miraflores and Pedro Miguel locks. Coincidencely, the analysis of freshwater samples from Gatun Lake indicated a steep increase of nitrates and chlorophyll *a* during November 1992.

The concentration of total phosphorus, which during July was higher than the average for this time of the year, returned to normal levels in August and November. Both the concentrations of the nitrates and total phosphorus during November were significatively lower than those of July. According to Smayda (1966) the amount of inorganic phosphate in the water column in Bay of Panamá is inversely correlated with the precipitation and the freshwater discharge. Thus this correlation increases with the progress of the rainy season. Also, this conclusion might be valid in regard to the observed decline in the concentration of nitrates.

The dry season: The monitoring of March 1993 indicated significant changes of the parameters in response to the development of the seasonal upwelling in the Gulf of Panama, normal to this time of the year. In general terms, there was a big change from November 1992 to March 1993, which reflected the effects of the movement of the Intertropical Convergence Zone southward of Panama.

According to the hydrometeorological data there is a strong correlationship between the annual average of the northerly wind index vs. the decrease of the average sea level in the Bay of Panama. This is followed by a simultaneous decrease in the sea water temperature and increase in the salinity of the water column.

The sea water temperature at the surface indicated a decrease from 28-29°C in November 1992 to 22-24°C in March 1993 (Figure N° 79), whereas the sea surface salinity increased from 27-28 o/oo to 34 o/oo in the same period (Figure N° 80). The mixed layer decreased to less than 10 meters and the thermocline used to be found between 5 to 10 meters in depth. Also, the stability of the water mass decreased substantially.

The temperature and the concentration of dissolved oxygen in the water column decreased (Figure N° 81) while, on the other hand, the salinity and the concentrations of the dissolved nutrients increased in all levels of the water column. The spots with the low surface concentration of phosphorus and nitrates vanished in March 1993.

The concentration of total phosphorus in March 1993 was more than doubled and the concentration of nitrates augmented by a factor of magnitude (Figure N° 82). These changes were follow by low concentration of dissolved oxygen in the bottom water. Generally, this low concentration of dissolved oxygen is located below the thermocline where the water temperature is about 20°C. This low concentration of dissolved oxygen is related with the movement of subsurface oceanic water (100-200m) toward the innermost part of the Gulf of Panama (Forsbergh 1963).

The upwelling in the Gulf of Panama affected all of the monitored stations during March 1993. The exception are the stations MWQ-01 and MWQ-02, located close to the Pacific entrance to the Panama Canal. In these station it is obvious the effect of the freshwater discharge originated from Canal locks and adjacent rivers. This makes the salinity around the Naos Island to be around 31 o/oo in comparison to the 34 o/oo normally found in the Bay of Panama during this time of the year.

The transparency of the sea water in the area is rather high during the dry season. Secchi disc measurements indicated from 7 to 8m in most of the stations during March 1993. This was true for most of the stations with the exception of stations MWQ-01 and MWQ-02 where Secchi disc reading did not exceed 2m. The Secchi disc readings of 7 to 8 meters corresponds to an euphotic zone of 16 to 18 meters in depth. This zone is well provided with nutrients making the combined concentration of NH3-N and NO3-N close to 3 μg-atom/L and the concentration of the total phosphorus about 2 μg-atom/L (Figure N° 83).

In response to the relatively deep euphotic zone and continuous provision of nutrients there is an intense photosynthetic activity evidenced by the relatively high values of chlorophyll *a* (Figure N° 84). The concentration of chorophyll *a* during this season reached the highest values measured during this project. This high values of chorophyll *a* are referred to the surface waters (1 to 2 mg/m^3), and to subsurface waters (3 to 10 mg/m^3). The highest concentrations have been found below the surface and this is probably due to the fact that the maximun photosynthetic efficiency takes place within the optimal range of light intensity for the phytoplankton species. This optimum light condition is not found on the surface in tropical oceans because of the excessive solar radiation and thus will be found in deeper levels, but always above the lower limit of the euphotic zone.

In May 1993 the oceanographic conditions returned to properties of the rainy season: sea surface temperature rose from 22-24 °C (March) to 30-31 °C; the surface salinity declined from 34 o/oo (March) to 32 o/oo, and the gradient of salinity in the water column was only 0.5 o/oo; and the dissolved oxygen increased to the normal high levels.

Water Quality of the Bay of Panamá: During the rainy season the concentration of dissolved oxygen in surface water presented a range between 6 to 8 ppm (92-123% of saturation), whereas in the bottom water the DO concentration was generally over 5ppm (77% saturation value).

The levels of BOD were rather similar from July to November decreasing toward the end of the rainy season. The trend of the BOD was followed by a sharp and paralell change in the counts

of total and fecal coliforms. The maximum counts of coliform were recorded in August when practically all of the stations indicated the presence of total coliforms (between 20-437 MPN/100ml), as well as the presence of fecal coliforms (between 4-231 MPN/100ml). The counts of total coliforms (Figure N° 85) and fecal coliforms (Figure N° 86) were at minimum in November.

The low concentration of dissolved oxygen observed during March 1993 is due to the seasonal upwelling. During this dry season it was noticeably the absolut absence of total and fecal coliforms due to the negligible runoff from the neighboring rivers and also because of the effect of the upwelling in the area. In summary, from the point of view of the water quality the Bay of Panama presented during this time of the year the optimum conditions for recreational purposes.

With the ending of the dry season (May 1993) the oceanographic conditions returned to the typical situation described for the rainy season. The dissolved oxygen returned to their normal high level in most of the sampling stations, but, exceptions to this are stations MWQ-01 and MWQ-02 where the DO was particularly low in the water column. This low concentration of oxygen might be related to a very localized pollution in this area which seems to be corroborated by the high values in turbidity, suspended solids, total phosphorus, and also by the moderate counts of coliforms.

The concentration of heavy metals during the dry season (March 1993) indicated a clear decline in comparison to the rainy season (Tables N° 168 to 172). These concentrations are within the normal range found in the ocean (Sverdrup et al. 1942). The decrease in the concentration of these metals with all probability is due to the decrease of turbidity and suspended solids which contains important quantity of heavy metals (Schaefer et al. 1958).

The analysis of volatile organics from samples collected during June and July 1992 revealed that such compounds are not found in the area in meaningful concentrations (Tables N° 173 and 174).

In summary, the data gathered through this Biological Inventory suggests that the water quality of this part of the Bay of Panama is normal and present a healthy image.

(1.2) Oceanography of the study area in the Caribbean

The rainy season: The most notable characteristic of the sea water within the study area is the homogeneous distribution of the properties in the water column. These conditions comprised the lack of thermal stratification and the presence of a mixed layer of warm water, around 28 to 29°C, from the surface to the bottom in all of the stations. Station MWQ-15 presented the typical image of the uniform distribution of the properties in the water column (Figures N° 87 and 88).

A relatively thin layer of surface water with very low salinity was observed from July to November (Figure N° 89), from the inner part of the Bay of Limon, where salinity ranged

between 25-30 o/oo, to the area outside of the jetties (32-33 o/oo). Off the Bay of Limon, oceanic water of over 35o/oo was usually found below the 20m isobath. This oceanic water intruded the Bay of Limon flowing below the surface layer of low salinity and it was gradually dilute during its movement into innermost part of the bay.

The dissolved oxygen was usually found at it minimum concentration at mid depth, below the halocline, and it increased with the depth and with the salinity related to the oceanic water (Figure N° 90). Despite this minimum, the dissolved oxygen seldomly descended below 5ppm (78% saturation value).

The concentration of dissolved nutrients and chlorophyll *a* in the Caribbean area were quite low and rather uniform from July to November. None of the nutrients analysis of surface water exceeded 1 μg-atom/L. The concentration of the nutrients increased with depth (Figure N° 91). At the same time it was found that the concentration of nutrients in the area was remarkably lower in August, but higher in November in comparison to that of July (Figure N° 92).

Simultaneously, with the slight increase of the nutrient concentration there was a significant augment in the concentration of chlorophyll *a* (Figure N° 93). As for the nutrients, this increase of the chlorophyll *a* in the Bay of Limon is related to the freshwater runoff from the Gatun Lake. Data gathered by this project indicated that the water of the Gatun Lake showed an abrupt increase in the concentration of nitrates and chlorophyll during November 1992.

The dry season: The data from March 1993 indicates a lack of thermal stratification in the water column. The gradient of temperature in the water column at the 6 sampling stations did not surpass 1.5°C.

The sea water plume of high salinity had a very limited intrusion in the Bay of Limón and it was only found in the vicinity of the jetty off the Cristobal harbor and did not reached the inner part of the bay.

The salinity of the water column in the offshore sampling stations presented the highest value in March 1993 (around 35 o/oo). This, with all probability, is due to the reduction of the freshwater runoff. In general, off the Bay of Limón the temperature and salinity are typically oceanic (35.5-36.0 o/oo). See Figures N° 94 and 95. In addition, there is an homogeneous distribution of the dissolved nutrients and chlorophyll *a* in the water column. This suggest a mixing process induced by changes in the density of the surface water. This is the possible cause for the low concentration of dissolved oxygen (2-3 ppm) in the entire water column at stations MWQ-14 and MWQ-15.

The data from May 1993 indicated the end of the dry season and a progressively return to the rainy season conditions. There was not thermal stratification in the water column and the difference between surface and bottom water was 1.0-1.5 °C. At the same time, within the Bay of Limon it was observed a pronounced increase in the surface salinity changing from 26-28 o/oo (March 1993) to 30-32 o/oo (May 1993).

Offshore the Bay of Limón the salinity is typically oceanic (35.5-36.0 o/oo). This pronounced increase of the salinity was observed from the surface to the bottom and the gradient was around 0.5 o/oo. This suggest the presence of a highly homogeneous water mass at the beginning of the rainy season.

The concentration of nutrients in the water columm was doubled, and eventually triplicated, and these were the highest values found during this project in this area (Figure N° 96). Both the concentration of total phosphorus and nitrates indicated an uniform distribution in the water column with values above 1 μg-atom/L. This stimulated a moderate photosynthetic activity in March 1993 that was higher than the observed during the rainy season of 1992. This was evidenced by the relatively high values of chlorophyll *a*, generally above 1 mg/m^3 (Figure N° 97).

The concentration of the nutrients markedly decreased at the end of the dry season (May 1993), returning to the typical conditions of the rainy season. However, the exception to this was the high concentration of total phosphorus during May 1993, being this the highest concentration recorded during this project (around 1.7 μg atom/L). These high levels of phosphorus were accompanied by increases of chlorophyll *a* in the surface (near 0.5 mg/m^3). This should mean a higher photosynthetic rate at the beginning of the rainy season.

Water quality of the study area in the Caribbean: As previously indicated, the concentration of dissolved oxygen in surface water ranged between 5.7 and 7.0 ppm (87-107% saturation value), whereas in the bottom was generally over 5 ppm (76% saturation value) during the rainy season. Low concentration of dissolved oxygen was observed offshore the jetties during the dry season (2.0-3.0 ppm). This might be caused by the inversion of the water column due the increase of the surface water density. This event brings to the surface the poorly oxygenated bottom waters.

The BOD concentration, from July to November, was rather low and quite uniform (1-2 ppm) during the period of this project. The BOD values from August were the highest and the BOD values of November were lower than those of July. These changes in BOD values were follow by: a rather striking and paralell increase in the counts of total coliforms (76-348 MPN/100ml) and fecal coliforms (34-97 MPN/100ml) during August, and a markedly absence of total and fecal coliforms in November 1992, and March 1993 (Figures N° 98 and 99). At the end of the dry season, the offshore low values of dissolved oxygen vanished and the analysis from the May 1993 samples revealed a well oxygenated water mass.

During May 1993, coliform were present at all of the sampled stations, with the exception of station MWQ-15 and MWQ-16 located offshore the jetties. However, both the counts of total and fecal coliform were below 100 NMP/100 ml.

As recorded in the Pacific, the concentration of heavy metals during the dry season (March 1993) indicated a clear decline in comparison to the rainy season (Tables N° 168 to 172). These concentrations are within the normal range found in the Caribbean coast (Lowman et al. 1970). The decrease in the concentration of these metals with all probabilities is due to the decrease of turbidity and suspended solids which contains important quantity of heavy metals.

The analysis of volatile organics from samples collected during June and July 1992 revealed that such compounds are not found in the area (Tables N° 173 and 174).

In conclusion, the sea water in the Caribbean study area did not show any symptom of significant pollution.

(2) **Sediment Quality**

(2.1) Pacific

Sediments collected in eight Pacific stations showed a higher proportion of the silts and clays fraction (< 80 microns). All of the data from the granulometry analysis are presented in Tables N° 175 to 179. The silts and clays fraction consisted of an 86 % ± 10 % for the average case of total sediments collected in the Pacific study area (N= 40). During the successive quarterly samples a higher contribution of the sand fraction was observed at station MB-02 located near the Panama Canal entrance.

The results from the analysis of total nitrogen and total organic carbon are presented in Tables N° 180 to 184. The concentration of total nitrogen in the sediments from the Pacific remained fairly constant throughout this study. Although, there was a slight decrease in the concentration of organic nitrogen in the sediments of the Bay of Panama from July 1992 to March 1993, the lowest value being found in March 1993 (<0.25% of total nitrogen). In general, the concentration of organic nitrogen ranged from 100 to 350 ppm (0.10 to 0.35%). The ratio between the total organic carbon and the organic nitrogen varied from 10:1 to 15:1. The convertion factor from organic carbon to organic matter is 1.8 and accordingly the organic matter in the sediments of the Bay of Panama should fluctuate between 2 to 4%, which is in agreement with former studies in the area (Lowman et al. 1970 and Kwiecinski et al. 1973).

The concentration of most of the heavy metals in sediments from the Bay of Panama indicated a constant and uniform distribution from July 1992 to March 1993 (Tables N° 180 to 184). Exception to this pattern is the concentration of the iron which indicates a sharp increase in March 1993 in comparison with its concentration during the rainy season. The ranges of metal concentrations are: iron between 10,000 - 60,000 ppm, copper 30 - 65 ppm, manganese 400 - 500 ppm, and zinc 80 -135 ppm. These values are similar to those reported by former studies (Lowman et al. 1970 and Kwiecinski et al. 1973).

The analysis of High of Molecular Weight (HMW) hydrocarbons in the marine sediments (Table N° 185) revealed that the area with the highest concentrations (49.30-67.84 μg/g dry sediment) are related to the channel of navigation through the Panama Canal, the docks, and the anchorage sites. The highest accumulation of HMW hydrocarbons was observed near the Panama Canal entrance (stations MB-01 and MB-04), and these values ranged from 64.60 to 56.30 μg/g of dry sediments (November 1992). But in overall, the concentration of HMW hydrocarbons in most of the studied areas were low (< 15 μg/g dry sediment) and do not suggest an important accumulation of oil in sediments.

(2.2) Caribbean

Sediments collected in the Caribbean stations showed an increased in the proportion of the silts and clays fraction (< 80 microns). All of the data from the granulometry analysis are presented in Tables N° 175 to 179. It was observed that the silts and clays fraction composed almost 70 % ± 31 % for the average case of total sediments of the Caribbean study area (Tables x-x). Caribbean stations showed a higher contribution of the sand fraction (medium to very fine sand) of the total sediment samples (N= 30).

The results from the analysis of total nitrogen and total organic carbon in marine sediments are presented in Tables N° 180 to 184. The concentration of the organic nitrogen in the sediments in the Caribbean remained nearly constant throughout this study, the same as in the Pacific. The concentration of organic matter in these marine sediments is low, in the range between 2-4%, and this were found well oxigenated without presence of sulphidric ion. The concentration of total nitrogen (0.10 to 0.20%) in sediments is about half of the value normally found in the Bay of Panama. This might be related to the smaller organic production in the Caribbean, or to the higher concentration of dissolved oxygen.

In general, the concentration of copper and zinc in sediments from the Caribbean are similar to those measured in the Bay of Panama (Tables N° 180 to 184). Although the reported concentrations of heavy metals are within the limits normally found in coastal sediments (Green, 1959), the concentrations of manganese and iron are significantly higher than those found in the sediments of the Bay of Panama. With the exception of this anomaly, the sediments of the Caribbean area do not indicate any significant symptom of metal contamination.

The highest concentrations of HMW hydrocarbons were detected within the Bay of Limon and particularly close to the navigation channel of the Canal (stations MB-09 and MB-10) ranging the values from 49.30 to 67.84 μg/g dry sediments (Table N° 185). Offshore the breakwater the hydrocarbons are found at lower concentrations, indicating clean or slightly impacted marine sediments that contained small amounts of HMW hydrocarbons, possibly from biogenic sources. On the whole, the accumulation of hydrocarbons in sediments is low and do not suggest an important pollution.

(3) Corals, Mangroves and Marine Grasses

(3.1) Corals

During the past 20 years the coral reefs in both coast of Panamá have changed notably, being evident a high and progressive decay of the community due to natural events, as El Niño, but mostly because of the anthropogenic actions such as oil spills, increased sedimentation, and dredgings (Glynn 1988, Guzmán et al. 1991). A great portion of the coral reefs close to both entrances to the Panamá Canal are affected by oil pollution (Guzmán et al. 1991, Guzmán & Holst 1993), heavy metals (Guzmán & Jiménez 1992), in addition to the overfishing of fish species associated to corals, and the extraction of corals (Guzmán, pers. observation). The most

recent studies have revealed new species of corals in both coasts of Panamá (Zlatarski 1990, Weerdt & Glynn 1991, Knowlton et al. 1992, Holst & Guzmán 1993).

There are numerous coral reefs within the area considered by this Biological Inventory. The study area include 89.4 Km and 110 Km of coastline in the Caribbean and in the Pacific, respectively.

In both coasts of the Isthmus of Panamá there are very well developed modern coral reefs with ages between 3,000 and 7,000 years (Macintyre & Glynn 1976, Glynn & Macintyre 1977). The coral reef communities in both oceans are rather differents regarding their distribution, size, and the abundance and composition of species (Glynn 1972, 1982, Porter 1972, 1974). In addition, the physical factors (i.e. distance to the mainland, sea-water temperature, and sedimentation) affecting and limiting the growth and distribution of corals are very peculiar for each ocean (Porter 1974, Glynn 1983). The seasonality in the climatology of the area are relatively similar for the whole country, however, coral reefs in both sides of the isthmus are influenced by sharp climatological changes. The Caribbean is mostly affected by the rainfall, high sedimentation, and strong winds, whereas the Pacific is affected by low sea-water temperature during the upwelling (Glynn 1972, 1982, Cubit et al. 1989).

The coral reefs in the central Caribbean coast of Panamá are characterized because they built barriers parallel to the coast, they have a wide distribution along the coast, and they are found down to 10 - 15 m in depth (Guzmán et al. 1991). The coral reefs in the Pacific coast form barriers, although are also found forming extensive reef patches (Glynn et al. 1972). The growth of the panamanian Pacific coral reefs is limited to 6 - 10 m in depth (Glynn et al. 1972, Glynn & Stewart 1973), and their distribution is poor within the Biological Inventory study area.

Historically, the coral reefs near the Caribbean entrance to the Panamá Canal have been affected by anthropogenic activities. During the conquest and colonization by the Spaniards, five hundred years ago, the corals from Bahía Limón and Bahía Portobelo were use as construction material in Portobelo. Possibly, as much as 100,000 m^3 of massive corals were extracted during this period (Guzmán & Jiménez, in prep.). However, since 1882, with beginning of the construction of the Panama Canal, the extraction of coral reached to it's highest level. From 1882 - 1885 and 1904 - 1907 the French and the American Companies excavated near 20 millions m^3 and 33 millions m^3, respectively, of coral, sand and sediments from the Bay of Limón (Noriega 1986). The Town of Cristobal, as well as the foundations for the Canal terminal were constructed upon 2 coral reefs southwest I. Manzanillo (Rousseau 1916). Between 1910 and 1916 two breakwater jetties were built in the entrance to Bahía Limón. These were 3.3 Km in length and 2 millions m^3 of coral rocks and sands from Coco Solo were excavated for this construction with a suction dredge (Rousseau 1916). During the period from 1915 - 1928 and from 1942 - 1944, World War II years, I. Margarita, Coco Solo, Largo Remo and I. Galeta were transformed into peninsulas (Copeland 1964). Several hundreds of hectares of mangrove were destroyed and filled with coral material in order to built airfields, barracks and other military installations in the area (Copeland 1964). More recently, between 1958 and 1986, five millions m^3 of coral from Payardí and Largo Remo were excavated during the construction of the oil refinery Refinería Panamá, and two large oil spills ocurred in Bahía Las Minas

affecting the coral reefs in the area (Rutzler & Sterrer 1970, Guzmán et al. 1991, Guzmán & Holst 1993).

The history of the coral reefs in the Pacific entrance of the Panamá Canal has been less dramatic than described for the Caribbean, since there were more construction material available from large land excavations in Gaillard Cut and some other areas (Rousseau 1916). Notwithstanding that, both entrances to the Canal are constantly subjected to a high silting derived from the dredging of 2 million m^3 of sediments as required for the functioning of the Canal (Noriega 1986). In addition, the locks operations produces a constant discharge to the coastal zone of millions of gallons of water loaded with suspended solids due to the deforestation of the Canal watershed (Bethancourt 1988). In spite of the high sedimentation in the area and the history of adverse environmental impacts since the beginning of this century, the mean coverage of coral in the Caribbean side was near 27% in 1985 (Guzmán et al. 1991), and possibly higher than this in the Pacific (Glynn 1984).

Currently, two third of this coverage has disappeared (Guzmán et al. 1991).

Location and coverage of the coral reefs: Thirteen (13) reef's flats with different sizes are present in the Caribbean study area and none in the Pacific area (Maps N° 20 and 21). The total area of the reef's flats in the Caribbean is 134.4 Ha (Table N° 186). The reef's flats of Largo Remo Is., Galeta Is., Fort Sherman and Bruja Is. are the largest within the study area (Table N° 186).

The number of coral reefs within the Caribbean study area is similar to that of the reef's flats (Map N° 20, Table N° 186). Many of these coral reefs are separated by channels into small patches distributed across the flats. The total area of the coral reefs in the Caribbean was 204.6 Ha, whereas in the Pacific these were just 3.9 Ha . The most important reefs in the Caribbean, regarding their size, were those of Payardí Is., Largo Remo Is., Galeta Is., Media Palma, and Brujas. The coral reefs at Payardí Is., was possibly twice as big as it has been observed during this study, due to the 5 millions of cubic meters of corals that were extracted in the excavations that took place during the construction of Refinería Panamá (the oil refinery).

The coral reefs in the Pacific area (Map N° 21) were only found in the surroundings of Taboga, Urabá, and Taboguilla Islands. The coral reef northeast to Taboga (in front to the town) is the largest and best developed of the area and has almost 2 Ha. However, this coral reef is completely dead. Some coral communities, formed by few coral colonies growing on the rocky bottom, were observed in all of the surroundings of these islands, including Farallón Is., Chamá, Tórtola, and Melones. No corals were observed in the surroundings of islands very close to the mainland (i.e. Venado, Gato, and the group of small islands south to the Río Perequeté) in spite of the presence of rocky bottoms which might provide a suitable substrata for coral development. Possibly, the high siltation produced by the tides might be a limiting factor for the normal development of coral reefs in this area.

Preliminary reconnaissance of the coral reefs: In this section are presented the lists of species observed in the coral reefs in both sides of the isthmus, within the study area and although this inventory only emphasizes the coral species (Tables N° 187 and 188), some preliminary lists of specie of sessile organisms associated to the reefs (plants and animals) are also included (Tables N° 189 to 191).

The diversity of coral species observed in the Caribbean coast is three times greater to that observed in the Pacific. There are 48 species of hermatypic corals and 3 species of hydrocorals in the coral reefs of the Caribbean coast (Table N° 187), whereas only 14 species of corals have been observed in the Pacific side (Table N° 188). Only 11 species of corals were observed in the reef's flats in the Caribbean (Table N° 187). For the first time the genus *Siderastrea* is reported for the eastern and western Pacific, and in addition, a new species of coral is reported. There is the possibility that other two new species of *Siderastrea*, which are very similar to *Siderastrea siderea*, could be reported for the Caribbean. In general, there have been collected many species of corals that are alike species already described (i.e. *Pavona, Porites*, and *Siderastrea*), but some additional studies might reveal additional new species, and this will have to be confirmed. Some specimens from these species have been already sent to taxonomists in Iowa and Washington.

Anhermatypic corals were observed in both sides of the canal (Table N° 189). These are cryptic corals growing beneath stones and corals, and in crevices, and possibly there are more species than presently reported. In general, this group of corals is the less studied of all because their relatively limited importance as coral reefs builders. The list of such species herein presented is prelimary, and it might suggest that the diversity of these corals is pretty much similar for both oceans. *Tubastrea coccinea* was found actively growing in the rocky shores of the islands in the Pacific side.

The diversity of octocorals (soft corals) is pretty low for this area of the Caribbean coast of Panamá (Table N° 190). There is not any previous list of species from this area that could be use for comparative purpose, however, at least some 30 species of corals have been reported in San Blas and Bocas del Toro (Guzmán & Holst in preparation). The species Erythropodium caribaeorum is abundant and widely distributed in the coral reefs. In the Pacific side, the whole picture is more complicated because the taxonomy of corals has never being studied. This pose difficulties for the correct identification of the species. At least 9 species of octocorals are preliminary reported for the Pacific side (Table N° 190). In general, the octocorals in the Pacific do not grow in the reef but on the rocky shores.

The reefs in the Caribbean are very diverse in algae. Most of the algae herein reported are distributed both in the reef flat as well as in the coral reef. Table N° 191 show a preliminary list of species observed growing in the Caribbean coral reefs. A total amount of 41 species of macroalgae and 6 species of crustose coralline algae were identified (Table N° 191). However, a reduced group of species dominated the different habitats. The reef's flat are dominated by *Laurencia papillosa*, *Acanthophora spicifera* and the calcareous algae *Halimeda opuntia*; coral reefs showed a high coverage of *Dictyota spp.*, *Caulerpa racemosa*, *Amphiroa spp.*, and *Halimeda spp.* *Halimeda* dominate extensive areas of the reef at Bahía Las Minas. In the

however, since these were just a few colonies within a large area (0.9 and 1.8 Ha respectively; see Table N° 186), none of these were detected within the transects recorded at each of the reefs. The crustose coralline algae covered 100% of the area within the transects at these sites. Regarding the Urabá reef, with intermediate size when compared to the other two reefs, *P. damicornis* cover more than 20% of the reef area, whereas coverage by *P. clavus* and *Psammocora spp.* is less than 2% (Figure N° 108). It is important to mention that this small reef patch is beside the unique population (6 individuals) of *Siderastrea sp.* reported for the eastern and western Pacific Ocean.

In general, the main reef builder species of the Caribbean Sea were recorded within the studied area. The absence of some of the Caribbean species (47%) within the studied area could be explained as follow: 1) these reefs are not found in depth greater than 10-12m, whereas in other areas of Panamá (i.e. San Blas) reefs are distributed down to 40m in depth; 2) the environmental impact that have occurred since almost a century, has been mostly concentrated in the Colón area; 3) the reefs within the study area are under a chronical environmental pressure as a consequence of the dredging, silting and oill pollution (see Guzmán et al. 1991, Guzmán & Holst 1993). Although the first explanation could answer the absence of some species that are associate to specific habitats, although these are not the majority of the species; the two other explanations seem to be a more valid explanation for the decreased number of species. For instance, *Acropora palmata* disappeared from Bahía Las Minas after the 1986 oil spill (Guzmán et al. 1991). *Porites furcata*, a very active reef builder coral species in Bahía Las Minas, was found in healthy conditions only at the Largo Remo west reef (LRRW). Additionally, all of the reefs within the Bahía Limón were killed because of the construction and operation of the Panamá Canal, also being affected extensive areas of coral reefs located several miles away (H.M. Guzmán unpublished data). The reduced area cover by life coral (<6%), and the high coverage by macroalgae (>80%) found at all of the reefs (Figure N° 105) clearly evidence the magnitude of the damage suffered by the corals of the area since time ago.

In the Pacific, the species diversity is comparable to what has been reported for the rest of the isthmus and the eastern Pacific. Although not documented from the quantitative side, the coral reefs at Taboga-Taboguilla were affected by the 1982-1983 El Niño event, causing massive mortality of corals that reached 90% in some of the reefs at Las Perlas Is. and in the Gulf of Chiriquí (Glynn 1984). Besides this, these reefs have recently been subjected to large extraction of coral heads to be sold abroad. It is understand that this activity has been stopped. The only coral reef within the area that still alive is at Urabá Is. In this reef was discovered the unique alive population of *Siderastrea* that exist in the eastern and western Pacific ocean. This discovery has promoted an intense scientific interest in the area. Until know this genera was exclusively reported for the Caribbean Sea, the Red Sea, and the Indian Ocean (Veron 1986).

It is necessary to understand the value of coral reefs for the society. The benefits derived from these reefs are beyond their importance for the coastal protection, the fisheries yields, and the reacreational value, because of the current researchs on the reef's natural products that are being tested against many human diseases. Whatever is the selected alternative for the Panamá Canal, it should consider the current health of the coral reefs in the area. If the salinity, or the rate of silting, are changed due to the deforestation of the Canal watershed, the widening of the canal,

and the construction of a new canal, then it could be expected a critical decline of the coral reef area, and even the death of these reefs. The effects derived from any of the alternatives should not be exclusively weighted in view of the study area of this inventory, but as a source of larvae that will disperse corals into the adjacent areas.

(3.2) Mangroves

The mangrove forests within the study area are described regarding the extent and location, the species presence and distribution, and the forest structure (Table N° 197).

Pacific coast

-Perequeté: This section of the coast is situated toward the southern limit of the Pacific study area (Map N° 23). It includes four general groupings of mangrove forest communities, notably those around the Río Perequeté system, Playa El Coco, Los Hatillos, and Quebrada La Mula (Map N° 120). The country-side surrounding these mangroves is generally hilly grasslands with some scattered small stands of natural trees. Human activity is rural with small villages along the coast. Rainfall, tidal range and wind conditions are notably similar to those shown in Map N° 24.

The Río Perequeté system is the largest area of mangrove in this section. There are around 2.84 km^2 (=284 ha) of surrounding mangrove forests in this small, but well-developed estuary. The main channel is relatively narrow, around 10-20m, but it is navigable by small craft for three to four kilometres upstream. This course meanders and the actual distance inland accessible by boat is less than two kilometres.

Eight mangrove species, and the hybrid *Rhizophora*, were observed in this system. These are listed in Table N° 198 along with their presence at six sites upstream. Note the differing ranges upstream of each of these taxa. *Laguncularia racemosa*, *Avicennia germinans*, *A. bicolor* and *Pelliciera rhizophorae* "red" each range widely upstream from the mouth. It was notable that *Rhizophora mangle* was limited to downstream parts while *R. racemosa* was common upstream, although these trees were scattered and often quite tall (~30 m). Also in the upstream parts (3 km and more), there were extensive thickets of lianes forming undercanopies with *Acrostichum* and *Tabebuia* under larger trees of mostly *Avicennia bicolor*.

In general, there were several major species associations which characterize the system. Two major ones were associated with either accreting or undercut banks along the meandering channel. On the accreting banks, *Laguncularia* was present along the front in dense, low (2-4 m), monotypic thickets. Behind these, and along undercut banks were tall Avicennias and Rhizophoras. And, on stream margins in-between, *Rhizophora mangle* was notably in frontal stands with some larger individuals behind. In the mid to high intertidal zone, one very characteristic association was tall *Avicennia bicolor* forests (25-30 m) with an undercanopy of *Pelliciera* (8-10 m tall). This type of stand was assessed for structural

composition (Table N° 199), and it had a basal area of 48.2 m^2/ha. Also note the 19% presence of tall *Rhizophora racemosa* (17-18 m).

During the survey, the stream flow was notably freshwater outflow with many drift logs and flotsam being swept downstream. This was reflected in low mid-stream salinities (Table N° 198) and temperatures (mean of 24.8 °C). It was also observed that several species were flowering and/or fruiting. Some notable ones were: *Rhizophora mangle* with mature fruits; *Avicennia germinans* with immature and mature fruits; and, *A. bicolor* with mature buds and flowers.

The mouth of the river and the surrounding rocky headland shores were notably dominated by scrubby *Laguncularia* trees (3-8 m tall). There were no Rhizophoras observed in this habitat. The small rocky island (called Isla Peligro in this study), 4 km east of Río Perequeté, also had many scrubby trees of *Laguncularia racemosa* (3-4 m tall) on the north-western rocky-spit beach. These were on the low to mid intertidal. Behind them (mid to high intertidal) was a small number of other trees (~8 m tall), including several *Avicennia germinans*, and two *A. bicolor*. There were no Rhizophoras.

-Caimito: This section of the coast is situated in the southern part of the Pacific study area (Map N° 93). It includes four general groupings of mangrove forest communities, notably those around the Río Caimito system, southern Bahía Chorrera and Isla Gato, Quebrada Copé and Punta Salazar, and Bahía Vacamonte (Map N° 121). The country-side surrounding these mangroves is generally hilly grasslands with some scattered small stands of natural trees. There is a busy village at Puerto Caimito. Rainfall, tidal range and wind conditions are notably similar to those shown in Map N° 24.

The Río Caimito system is the largest area of mangrove in this section. There are around 3.50 km^2 (=350 ha) of surrounding mangrove forests in this well-developed estuary. The main channel is navigable by small craft for 8 to 9 km upstream. This course meanders and the actual distance inland accessible by boat is less than 4 km.

Nine mangrove species, and the white form of *Pelliciera*, were observed in this system. The most outstanding finding was *Mora oleifera* since this was the only site where this species was observed in the study area. All taxa are listed in Table N° 200, along with their presence at eleven sites upstream. Note the differing ranges upstream of each. *Laguncularia racemosa* and *Avicennia germinans* extend virtually throughout the estuary. *Avicennia bicolor* and *Pelliciera rhizophorae* "red" range from the mid to upper estuarine parts, while the white *Pelliciera* was notably seen upstream only. The pattern with Rhizophoras noted in the Perequeté was also seen in this river, namely with *Rhizophora mangle* limited to downstream parts and *R. racemosa* upstream. These latter trees upstream were around 40 m tall. Upstream parts (~4.5 km and more), where characterized by the presence of *Mora oleifera*. These trees were around 30-40 m tall and often formed a continuous monotypic canopy with an undercanopy of *Mora* seedlings, as well as, *Acrostichum* and *Tabebuia*. (~2-3 m tall).

Some structural characteristics of this kind of forest are shown in Table N° 201. Two other forest types downstream were also studied. One was a *Rhizophora racemosa* stand with a sparse undercanopy of *Pelliciera*, plus seedlings of *Mora* and *Avicennia bicolor*. The other was a monotypic stand of *Avicennia germinans*. These forests were those of essentially the mid intertidal range. As noted for the Perequeté, *Laguncularia* dominated the accreting banks of channel meanders, in dense thickets 3-8 m tall.

The Caimito system was characterized by a wide range of species associations and forest types. Only three are covered by the structural assessments, but they include the *Avicennia bicolor* and *Pelliciera* stands like those in the Perequete.

During the survey, the stream flow was notably freshwater outflow with many drift logs and flotsam. However, the flow was considerably less than that observed in the Perequeté. This was reflected in the upstream record of salinities (Table N° 200) and temperatures (mean of 27.6 °C). It was also observed that several species were flowering and/or fruiting. Some notable ones were: *Tabebuia* with flowers and fruits; *Rhizophora mangle* with mature fruits; *Avicennia germinans* with immature and mature fruits; and, *A. bicolor* with mature buds and flowers.

The mouth of the river and the surrounding rocky headland shores were notably dominated by scrubby *Laguncularia* trees (3-8 m tall). There were no Rhizophoras observed in this habitat.

-Veracruz: This section of the coast is situated in the central part of the Pacific study area (Map N° 23). It includes four general groupings of mostly fringing mangrove forest communities, notably those around the Río Biqué and La Playita, Punta Biqué and Veracruz, and Río Venado (Map N° 122). The country-side surrounding these mangroves is generally hilly grasslands with some scattered small stands of natural trees. There is a large town at Veracruz and the beaches here are popular for bathing. Rainfall, tidal range and wind conditions are notably similar to those shown in Map N° 24.

There are no major systems of mangrove forests along this section. Four species were found here, *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Acrostichum*. The associations were relatively simple with Laguncularia dominating the shoreline communities, and mixtures of the others in the small streams, notably Río Venado.

-Balboa: This section of the coast is situated in the central part of the Pacific study area (Map N° 23). It is dominated by the activities and port facilities of the Pacific entrance to the Panama Canal. There are five areas of mangrove forests in this section, notably Río Farfán, Rodman, Cocoli, Altos de Diablo, and Clayton (Map N° 123). The country-side surrounding these mangroves is generally hilly and built over, although there are several scattered stands of natural trees. Rainfall, tidal range and wind conditions are those shown in Map N° 24.

parts. Only one *Rhizophora* species, *R. racemosa*, apparently occurs in this system, and this is from mid to further upstream. These latter trees upstream were around 20 m tall. *Hibiscus tiliaceus* was found in upstream locations beyond 2.8 km (Table N° 205).

The Juan Diaz system was characterized by the dominance of *Avicennia bicolor* in many species associations, or in monotypic stands. The stand surveyed included a even mix of both *Avicennia bicolor* and *Rhizophora racemosa*. These were of moreorless equal height and number. Generally trees were around 20 m tall. *Tabebuia* was notable again as an undercanopy to *Avicennia bicolor* in upstream locations.

During the survey, the stream flow was notably freshwater outflow with drift logs and flotsam. This was reflected in the upstream record of salinities (Table N° 204) and temperatures (mean of 26.7°C). It was also observed that several species were flowering and/or fruiting. Some notable ones were: *Pelliciera* with flowers, *Tabebuia* with flowers and fruits; *Rhizophora mangle* with mature fruits; *Avicennia germinans* with immature and mature fruits; and, *A. bicolor* with mature buds and flowers.

Atlantic coast

-Chagres: This section of the coast is situated in the western part of the Atlantic study area (Map N° 23). It is partly influenced by the activities and port facilities of the Atlantic entrance to the Panama Canal. There are five areas of mangrove forests in this section, notably Río Chagres, Punta Toro, Río Aguadulce, Río Petitpie and Quebrada Morito (Map N° 125). The country-side surrounding these mangroves is generally hilly and densely vegetated in natural rainforest. Rainfall, tidal range and wind conditions are similar to those shown in Map N° 24.

There are no major stands in this section. The mouth of the Chagres has few mangroves, possibly because of the step terrain and the high freshwater flow. One association of species with *Acrosticum* and *Pachira aquatica* trees needs further investigation. They consisted of a broken canopy of *Pachira* trees, around 8-10 m tall, with a dense thicket of *Acrostichum* underneath, around 2 m tall. These characteristic stands border the river banks downstream. The stands along the exposed coastal margin to Punta Toro are mostly scrubby thickets tucked behind rocky outcrops and reef flats.

Five mangrove species were observed in this section. All taxa are listed in Table N° 206, along with their presence at seven sites around the coastline. There were no situations where consideration of upstream ranges were appropriate. The diversity was greatest in the small Río Petitpie in the south-west corner of Bahía Limón. Here was found one of the few occurrences of *Pelliciera* on the Atlantic coastline. This was the white form. Generally, most stands are dominated by *Rhizophora mangle*. And, unlike the Pacific coast these trees fringe the lower intertidal zone. Heights vary, but in exposed coastal sites like those near Punta Toro, these were between 2-3 m and reaching 8-10 m behind. In the protected areas of the smaller rivers, Rhizophoras were notably between 10-12 m tall. *Laguncularia* trees

This estuary extends to around 10 km upstream, approaching the locks and dam of Miraflores, near Clayton. This course is reasonably direct and much is along the Canal waterway. The biggest stand of mangroves were found near Cocoli (~25 ha), and is part of the old French Canal.

Seven mangrove species, and the white form of *Pelliciera*, were observed in this system. All taxa are listed in Table N° 202, along with their presence at nine sites upstream. Note that ranges of distribution in this system are relatively uniform, although *Rhizophora racemosa* is found more downstream compared with the riverine estuaries of the Perequeté and Caimito. Again, *Laguncularia racemosa* and *Avicennia germinans* extend virtually throughout the estuary. *Pelliciera rhizophorae* "red" is relatively wide ranging, especially compared with the white form.

During the survey, the stream flow was minimal freshwater outflow in this large estuary. This was reflected in the upstream record of salinities (Table N° 203) and temperatures (mean of 28.6 °C). It was also observed that several species were flowering and/or fruiting. Some notable ones were: *Pelliciera* with flowers, *Tabebuia* with flowers and fruits; and *Rhizophora mangle* with mature fruits.

The mouth of the Canal and the surrounding rocky headland shores were notably dominated by scrubby *Laguncularia* trees (3-8 m tall). This includes the offshore Culebra site, near Naos Island.

-Juan Díaz: This section of the coast is situated in the north-eastern part of the Pacific study area (Map N° 23). It includes three general groupings of mangrove forest communities, notably those around the Río Juan Díaz system, the Río Tocumen, and Panamá Viejo (Map N° 124). The country-side surrounding these mangroves is generally flat grasslands with some scattered small stands of natural trees. It is surrounded by the urban development and light industrial areas of Panama City. Rainfall, tidal range and wind conditions are those shown in Map N° 24.

The Río Juan Díaz system is at the western end of an extensive low lying mud-flat shoreline, extending for many kilometres east around the northern margin of Panama Bay. There are around 4.41 km^2 (=441 ha) of surrounding mangrove forests in this estuary. The main channel is navigable by small craft for at least 3 km upstream. There were some marine industrial facilities, piers and moored (and sunken) vessels along the banks between one and two kilometres upstream. Generally the waterway was heavily polluted with pungent smelling water, and piles of garbage caught on branches on the water's edge. There was also a lot of cutting of trees, particularly *Pelliciera*. Upstream much of the shoreline vegetation was absent and the banks were open fields.

Eight mangrove species were observed in this system. All are listed in Table N° 204, along with their presence at seven sites upstream. Note the differing ranges upstream of each. *Laguncularia racemosa* and *Avicennia germinans* extend virtually throughout the estuary. *Avicennia bicolor* and *Pelliciera rhizophorae* "red" range from the mid to upper estuarine

were present also in most locations, including exposed and sheltered sites, they were mostly behind *Rhizophora*. *Avicennia* was uncommon, and *Pelliciera* was moreso.

-Colón: This section of the coast is situated in the central part of the Atlantic study area (Map N° 23). It is dominated by the activities and port facilities of the Atlantic entrance to the Panama Canal. There are seven areas of mangrove forests in this section, notably Río Folk, Cristobál - French Canal, Telfers Island, Río Aguaclaro, Gatún - Fort Davis, The Basin - French Canal, and Bahía Limón east (Map N° 126). The country-side surrounding these mangroves is generally flat and there are many areas of filled and reclaimed mangrove forests. These have been built on as part of the Canal operations, but also for the Port of Cristobál and the city of Colón. Rainfall, tidal range and wind conditions are those shown in Map N° 24.

This estuary extends to around 6 km upstream from Bahía Limón, to both the locks near Gatún and along the old French Canal to The Basin. The biggest stand of mangroves were found on Telfers Island (~208 ha), and includes filled sections of the old French Canal.

Six mangrove species were observed in this system. One species, *Nypa fruticans*, the mangrove palm was apparently introduced from the eastern hemisphere (Duke 1991). All taxa are listed in Table N° 207, along with their presence at five sites upstream in the Canal. Note that ranges of distribution in this system are relatively mixed, although *Avicennia germinans* was not found in the upstream parts. It was generally uncommon. *Rhizophora mangle* and *Laguncularia racemosa* dominated most sites. The trees were generally straight and erect, with heights around 30 m in areas like The Basin, and up to 35 m in the Río Aguaclaro.

During the survey, the stream flow was minimal freshwater outflow in this large estuary. This was reflected in the upstream record of salinities (Table N° 207) and temperatures (mean of 28.9 °C). The Río Aguaclaro apparently had greater freshwater flow.

There were also large mangrove areas (~25 ha) destroyed after the photos were taken in 1990, along the north-east margin of the Río Folk estuary. This area was being converted to commercial and business facilities. There are recent reports that the destruction of large areas of mangrove forests continues in this area, notably toward the airport at Frances Field (Map N° 127).

-Bahía Las Minas: This section of the coast is situated in the eastern part of the Atlantic study area (Map N° 23). It is dominated by Bahía Las Minas (BLM) which is a large northward-facing bay, around five kilometres across the mouth. The margin of the bay is convoluted, and densely fringed with mangrove forests growing in a variety of habitats from exposed coastal sites behind reef flats, to those bordering tidal channels, and those further upstream alongside freshwater dominated estuarine reaches. Parts of these forests have been altered and removed with some urban development, a port, a refinery and a power plant (notably around Isla Payardi), but apart from this, their chief use includes fishing, scavenging and cutting of mangrove saplings at a subsistence level by local fishermen.

There are five areas of mangrove forests in this section, notably Coco Sol, Margarita, western BLM, central BLM, and eastern BLM (Map N° 127). The country-side surrounding these mangroves is generally with low hills. Rainfall, tidal range and wind conditions are similar to those shown in Map N° 24.

Six mangrove species were observed in this system. All taxa are listed in Table N° 208, along with their presence at 5 sites upstream in the Río Las Mercedes. This river is located just north-east of BLM and is included as an example of upstream distribution in this section. Note that ranges of distribution in this river are relatively uniform, although *Rhizophora mangle* is found over the full range.

Forests in this notably riverine estuary form tall (~30 m tall) mixed stands of varying proportions with the four main tree species, *Rhizophora mangle*, *Laguncularia racemosa*, *Pelliciera rhizophorae* and *Avicennia germinans*. However, most forests in BLM are less tall, and they have less species. These forests are defined by three major habitat types, exposed coast, sheltered channels, and riverine estuaries. In Table N° 209, data collected by Duke & Pinzón (in press) shows how these habitats vary in structural character and species composition. Generally, the exposed fringing stands are all *Rhizophora mangle*, although behind them on higher intertidal sites there are *Laguncularia racemosa* trees. Canopy height is usually restricted to around 3-4 m. Along the more protected tidal channels, *Rhizophora* still dominate the fringing forests but this fringe is narrower and there are more *Laguncularia* trees. These trees are also taller, around 5-8 m. Thus by degree, the total above ground biomass increases where there is more shelter and more freshwater influence.

During the survey, the stream flow of the Río Las Mercedes showed freshwater outflow in this small estuary. This was reflected in the upstream record of salinities (Table N° 208) and temperatures (mean of 27.1 °C).

Summary of area estimates & species checklists: Tables N° 210 and 211 present a summary of area estimates of mangrove communities on Pacific and Atlantic coasts of the study area. These are grouped according to the sections of coast shown in Map N° 23.

There are a total of 36.08 km^2 (=3,608 ha) of mangrove forests in the study area. Note that there is a slightly smaller area on the Atlantic coast (17.11 km^2), compared to the Pacific (18.97 km^2). The Atlantic estimate however is still greater than an earlier estimate for the much larger Costa Arriba de Colón (13.41 km^2) (Instituto Geográfico Nacional "Tommy Guardia", 1988a). This was apparently caused by the different definition of mangrove forests, and possibly the different interpretations using satellite photography, compared with aerial photography.

Eleven mangrove species, including the putative hybrid *Rhizophora* and two forms of *Pelliciera rhizophorae*, were observed in the study area. Species checklists for all sections of the study area are summarized in Table N° 212.

(3.3) Marine Grass

Table N° 213 lists the names and locations of all large seagrass beds located during this survey of the Panama Canal alternatives area. Bottom cover characterizations (Table N° 214), as percentages of the study site areas, show what types of plants, sessile animals, and non-living substrata were seen at each site. Other seagrass beds, that were studied during a 3-year oil spill effects study (Marshall et al., in review) were revisited. Profiles from the additional sites are also included in this report. Profiles from all of the surveyed seagrass beds are shown in Figures N° 109 to 118. Labeled aerial photographs (Aerial photographs N° 35 to 48) show the locations of seagrass beds that were not profiled but which were examined. These photographs show the major seagrass species that were observed at each site. Reef flat seagrass beds such as those at Punta Brujas (Figure N° 112 and Aerial photograph 46) consisted of very short bladed beds of *Thalassia* mixed with algae on a substratum of rocky rubble.

The profiles show that each seagrass bed, with the exception of Punta Brujas' seagrass bed (Figure 43), have a characteristic form. The first and the last profiles at each site slope steeply into deeper water. In most cases the mid-area profiles have a more gentle slope. The Punta Brujas seagrass bed is located on a reef flat area behind an extensive barrier of living coral and reef rock. Seagrass growth at Punta Brujas is limited to the protected area within this otherwise exposed location. The coral and rock seaward barrier protect this shallow seagrass bed from ocean waves. Seagrasses at this site were patchily distributed and grew into a bed of rocky rubble.

All of the other sites in this set of figures are located in small shallow bays in Bahia Las Minas or within coves in Bahia Limon (Figure N° 116). The seagrass bed form is determined, in each of these cases, by the shape of the shallow bay or cove. Currents flowing along the seaward-most border of each seagrass bed have apparently dug channels that are too deep for seagrass penetration. These channel walls are often colonized by corals. At some sites the corals form a seaward barrier which protects seagrasses during the annual periods of large surf that are characteristic of this coast. The maximum penetration depth of the seagrass *Thalassia testudinum* is shown in each figure (Figure N° 109 to 118).

Thalassia reached its greatest depth in Bahia Limon (Figure N° 116). It reached similar depths at Pena Guapa (Figure N° 109). Densities of *Thalassia*, *Syringodium filiforme*, *Halodule wrightii*, and algae varied from site to site (Table N° 213). *H. wrigthii* was typically found in very shallow water adjacent to shorelines or on tidally exposed sand bars. *T. testudinum*, by far the most abundant seagrass, covers most shallow bottoms in areas where water clarity is adequate. *S. filiforme* was usually mixed with *T. testudinum* along the deeper edges of grassbeds or it occurred in monospecific seagrass stands at depths past of the point of penetration of *T. testudinum*. A fourth seagrass species, *Halophila decipiens* was found mixed in with dense beds of algae along the deep fringes of seagrass beds.

Table N° 215 reports the densities of seagrass shoots that were observed at the profiled sites. Seagrass mean densities were greatest for *Thalassia* at the northwest corner of Isla Largo Remo. *Syringodium* was most abundant at Pena Guapa. It occurred at 4 of 8 sites while *Thalassia* was

found at all sites. In several areas these two seagrass species were present in mixed beds. Blade biomass was greatest for *Thalassia* at Isla Mina North and least at Isla Cocovi (Table N° 216). *Syringodium* biomass was greatest at Isla Pena Guapa. Algal biomass was greatest at Pulpit Point within Bahia Limon. Macroalgae were absent from the seagrass bed at Isla Cocovi.

Thirty two species of fish were collected over seagrass beds within the study area (Table N° 217). Several species in this collection are sought by local fishermen. They are present as juveniles in seagrass beds because of the protective covering provided by the seagrass leaf canopy. They also feed on many of the invertebrates and fish that are abundant in Panama's seagrass beds (Marshall et al., in review).

The seagrass community in the entire project area proved to be similar to that described, in the vicinity of Bahia Las Minas, by Heck (1977), Vasquez-Montoya (1979), and Marshall et al. (*in review*). The zonation pattern throughout this area is also typical of many other areas in the Caribbean (Zieman, 1982). Extensive seagrass meadows were found at locations wherever gradual coastal slopes prevailed and where water clarity was adequate.

Very small patches of *Thalassia* were found in the back reaches of Bahia Las Minas. Coastal development and non-point pollution sources have undoubtably combined to push the area where seagrasses can thrive to more seaward locations within much of the Bahia Las Minas area. Further upland development, upland deforestation and coastal dredging will undoubtably combine to limit seagrass growth to very shallow areas where water clarity remains above critical limits. A recent literature review of 27 studies of human impact on seagrass meadows along the Florida coast cites numerous cases where dredge and fill operations have caused large declines in seagrass bottom coverage (Livingston 1987).

The major shallow water seagrass species found in the study area included *Halodule decipiens*, *Syringodium filiforme*, and *Thalassia testudinum*. In certain areas species of *Halophila* were located in deep water beyond the edges of the coastal seagrass beds and coral reefs. *Halophila* has lower light tolerance limits than do the other three species of Panamanian seagrasses (Judson and Haunert 1991).

The maximum depth reached by the seagrass *Thalassia testudinum* on this part of Panama's Caribbean coast is indicative of areas with low water clarity. *Thalassia* penetrates to much greater depths ($\approx$ 12 m) near St. Croix (Zieman 1987). On Nicaragua's Miskito Bank *Thalassia* and *Syringodium* can be found at depths approaching the limits described for St. Croix (Marshall et al. 1992).

The coastal area within the canal alternatives study boundaries is a high energy coast that is subject to large surf from the open sea. It also receives tremendous loads of suspended sediment from coastal rivers during the annual rainy season. Upland deforestation undoubtably increases erosion and increases sediment loads in coastal rivers. Sediments that accumulate near and within seagrass meadows during the rainy season are undoubtably resuspended by waves during the dry, windy season. The total effect is to limit seagrass to shallow water. Perhaps the slight

increase in depth penetration of seagrasses seen within Bahia Limon is due to the protection provided to the tropical forests along the route of the Panama Canal.

Despite the fact that seagrass total acreages are relatively small within the study area the ecological importance of the grasses should not be overlooked. Seagrasses provide juvenile and adult habitat for many species as demonstrated by the numerous fish species collected in this study. Abundant populations of invertebrates are described (Marshall et al. in review, Heck 1979) from collections made in a partial subset of the listing of seagrass beds shown in Table 52. The loss of any significant part of the seagrass community on this coast may result in decreased stocks of the fishes that are commonly eaten by local inhabitants.

It is also well known (Clark 1977) that seagrass beds decrease current flow rates and thereby increase sediment deposition. The roots and rhizomes of seagrasses work together to anchor fine sediments that would otherwise be washed away. The death of intertidal seagrasses following the 1986 Bahia Las Minas oil spill resulted in the complete erosion and resuspension of fine sediments from several shallow rocky platforms (Caldwell & Steger, in review). After the seagrass plants died their roots and rhizomes rotted. At present a bare rocky platform exists where shallow beds of seagrass existed before the spill.

Any decrease in seagrass acreage within the study area would result in sediment resuspension and create additional problems for the remaining seagrasses, algae, and coral populations. It might be possible to use canal derived dredge spoils to create additonal shallow banks, within Bahia Limon, where seagrasses could grow. The banks should, as indicated by the results of this study, not exceed 2 m in depth. Sediment characteristics (type and grain size) also need to be considered prior to creating seagrass habitat. Seagrasses could then be planted across the bank tops in order to speed up revegetation rates. The overall effect of this effort would benefit the canal builders by stabilizing banks of dredge spoil and it would benefit local fishermen by providing increased nursery grounds for many commercially important fish species. Seagrass sediment requirements and planting techniques have been established for some species but the success of seagrass bed creation and replantings has been sporadic (Lewis, 1987).

(4) Benthos

Results of the counting of benthic organisms were expressed in terms of mean abundance per square meter (org./m^2) (Tables N° 218 to 227). A total of 3,388 benthic organisms were found (using a 1.00 mm mesh size) of a total of 210 replicates (21.0 m^2 of total sediment). From the total of organisms found 55 % corresponded to the 6 Caribbean stations (1,855 organisms). A total of 171 species or taxa of benthic organisms were found in five cruises. However, a few incidental species were collected in benthic samples, and among these: two truly planktonic hydromedusae, two *Sagitta sp.*, an hemichordate larvae, and a carangid fish larvae. Although, these only accounted for less than 1% of the taxa here reported. From the identification of the benthic community two new species were found in the Caribbean: a *Cyathura* isopod (Dr. T. Bowman USNHM, com. pers.) and a *Stylopoma* bryozoan (Dr. J.C.B. Jackson STRI, pers. com.). For the Pacific study area 19 taxa were added to the existing records of benthic species

reported for Panama, whereas 41 taxa more have been added to the list of species for the Caribbean study area.

The cumulative number of species from the 5 quarterly samplings, both in the Pacific and the Caribbean, showed a tendency of an asymptotic curve (Figure N° 119), therefore suggesting that the benthic community was adequately sampled.

Mean abundance of benthic organisms was higher in the Caribbean with 226 org./m2 (N= 30, S.D.: 147) than in the Pacific with 147 org./m2 (N= 40, S.D.: 125). In the Pacific study area there was a seasonal pattern with two peaks of abundance in July 1992 and March 1993. In the Caribbean the seasonal fluctuation in abundance had a maximum peak in July 1992. In general, the Pacific stations showed a pattern where the abundance gradually decreased from the nearshore to offshore the Panama Canal entrance (MB-01 to MB-02: 172, MB-03 to MB-05: 151 and MB-06 to MB-08: 126 org./m2). In the Caribbean, stations located offshore Limon Bay (MB-12 to MB-14) almost doubled the abundance (277 versus 176) observed within the Bay of Limon.

Polychaeta, Crustacea, Sipuncula, Nemertinea and Mollusca taxa dominated the counts of benthic fauna making up to 81 % of total organisms. In the Caribbean, Polychaeta, Crustacea, Mollusca and Bryozoa were the dominant groups accounting for 90 % of total organisms counted. In the Pacific some taxa happened to occur rarely but were highly abundant in a single collection, among these the Cnidarians (12 % in Cruise I). In the Caribbean, Sipuncula and Echinodermata occurred in all cruises comprising not more than 2 % of total organisms. Others groups that occurred rarely being 1-2 % of total organisms in the Caribbean were Cnidaria and Porifera. In the collections, some others nine groups occurred sporadically in the Pacific and five in the Caribbean of which each accounted for less than 1 % of total organisms. A total of 56 Crustacean species were reported being the peracarids the most abundant subgroup with 35 % of total crustaceans found and represented by five orders and 20 species: Mysidacea (2), Cumacea (2), Tanaidacea (1), Isopoda (7), and Amphipoda (8). The Peracarida superorder dominate the benthic community in general in terms of abundance being the isopods and gammaridean amphipods the most conspicuous found in the samples. With respect to Mollusca, a total of 57 species were identified of which 15 species are Gastropoda (14 genera in 12 families) and 42 species were Bivalves (24 genera in 13 families). Bivalves belonging to the Nuculanidae, Solecurtidae and Tellinidae families were the dominant molluscs found in the samples.

The distribution and composition of species or taxa of benthic organisms in the Pacific and the Caribbean was fairly homogenous disregard water depth. However, mean abundance and number of taxa was higher for those stations located offshore Limon Bay (MB-12 to MB-14) compared to those located within Bay of Limon.

Although some other benthic studies have been carried out in this area (Tables N° 228 and 229), these have mostly covered the tidal zone (Dexter 1979, Brusca & Weinberg 1987, Kensley & Kaufman 1988). Also, some few benthic collections were done by the University of Miami during the late 60's in relation to the study of feasibility of a sea-level canal (Bayer et al. 1970).

On the whole, including the data from this inventory, 298 benthic taxa are reported for the Isthmus of Panama (172 in the Pacific, and 126 in the Caribbean). Among these, only 60% have been identified to species (114 in the Pacific, and 64 in the Caribbean). This Biological Inventory have added to the species list 62 taxa in the Pacific and 42 taxa in the Caribbean. Only 5 identical species have been found both for the Pacific and the Caribbean (1 polychaeta, 2 crustaceans, and two sipunculids). However, some 21 sibling species are within the study area, 10 of these species are mollusks, 10 crustaceans, and 1 echinoderm.

(5) Meroplankton

The general information on the meroplankton collections is presented in Tables N° 230 to 234. The data on the abundance of the fish's eggs is presented in Tables N° 235 to 239. The highest abundance was observed in samples from November 1992 collected at stations MM-02 (Pacific) and MM-08 in the Caribbean, both of these sites located near the entrances to the Panama Canal. The eggs from clupeid and engraulid fish were the most abundant among the commercially important species, specially at station MM-02 (3,503 and 2,861 eggs/100m^3 respectively). A high number of fish eggs from other taxa were counted in samples from station MM-06 (21,016 eggs/100m^3). In the Caribbean, the highest abundance was recorded at station MM-08, where engraulid fish eggs were predominant (17,560 eggs/100m^3), followed by clupeid fish eggs (9,091 eggs/100m^3). This station also showed a high number of fish eggs from other taxa (4,007 eggs/100m^3). The high abundance of fish eggs during November 1992, particularly at stations MM-02 and MM-08, seem to be related to the low salinity in these areas as a consequence of the discharge of freshwater from the operation of the Canal locks (27.2 o/oo in the Pacific and 27.8 o/oo in the Caribbean side). According to Simpson (1959) an engraulid fish, the anchoveta *Cetengraulis mysticetus*, spawns in low salinity areas close to the Pacific entrance to the Canal. D'Croz & Kwiecinski (1980) reported the anchoveta to intensively spawn in the coastal area near the mouth of River Juan Diaz.

The eggs from this spawning are dispersed into deeper areas by the tides and the ocean currents. The results from this Biological Inventory indicates that the maximum peak in the spawning of the anchoveta took place in November 1992, which is in complete agreement with previous reports from Howard & Landa (1958). Similarly, the highest intensity in the fish spawning in the Caribbean also occurred during the end of year. Some other studies in the Caribbean Sea (Venezuela) have reported this same pattern (Lopez 1972). But despite this well defined peak in the fish eggs abundance, there was evidence that some fair abundance of fish eggs occurred throughout the year, which indicates that there is some spawning activity all year round.

The stage of development of the fish eggs during this study is reported in Tables N° 240 to 244. Both for the Pacific and the Caribbean, the middle stage eggs from engraulid and clupeid fish were the most common in the meroplankton samples. Early and late stages eggs from these fish were very rare, although some from other taxa were observed among the samples.

The larvae of marine invertebrates collected during this inventory are presented in Tables N° 245 to 254. The crustacean Zoea larvae was the most common in the samples, specially at station MM-02 (Pacific) and MM-08 (Caribbean) where the highest density (45,793

larvae/100m^3) was observed during this study. Postlarvae of penaeid shrimps were also abundant in these two stations during November 1992 (16,911 and 12,576 p.l./100m^3 respectively). During the collection on February 1993, penaeid postlarvae continued to be abundant in the Pacific (5,625 p.l./100m^3). This pattern in the presence of penaeid shrimp postlarvae, from November to February, coincides with the description of the life history of most of the penaeids in the Bay of Panama (D'Croz & Kwiecinski 1980). The penaeid shrimps locally known as white shrimps, *Penaeus occidentalis*, *P. vannamei*, and *P. stylirostris*, have this trend and these species are the most important for the local shrimp industry. Postlarvae of these species enters into to the shallow, brackish, mangrove bordered, estuaries of the Bay of Panama, where they stay for several weeks. These nursery grounds concentrates postlarvae of shrimps, as well as larvae of marine fish, during the whole year, but particularly during the dry season. This nursering role of the mangrove bordered estuaries is also important for the Caribbean fish and invertebrate larvae. Gastropod and pteropod larvae were also abundant in both coasts during November 1992. Numerous larvae from bivalves were present in samples from station MM-05 (Pacific) during February 1993, and in samples from station MM-08 (Caribbean) in November 1992 (8,498 and 3,836 larvae/100m^3 respectively). These peaks of abundance of bivalve larvae might be related to the increased runoff in the Caribbean, and to the upwelling in the Pacific.

The data on the abundance of fish larvae is presented in Table N° 255 to 264. In the Pacific, most of the fish larvae were collected at the end of the rainy season (November 1992) near the Canal entrance. These larvae were mostly at the preflexion stage. The most common were larvae from engraulid (15,451 larvae/100m^3), carangid (2,113 larvae/100m^3), mugilid (532 larvae/100m^3), and sciaenid fish (436 larvae/100m^3). Although, it was observed a smaller peak of engraulid larvae abundance during the first months of the rainy season (July 1992) revealing a bimodal distribution of the spawning. This same bimodal pattern was observed for the sciaenid fish larvae (November 1992 and February 1993).

The most common fish larvae in the Caribbean were the engraulid (1,667 larvae/100m^3), carangid (1,151 larvae/100m^3), and sciaenid fish (566 larvae/100m^3). The highest abundance of these larvae was recorded at the end of the rainy season, the same as in the Pacific. This concurrence is probably related to the increased runoff that usually occurred from October to November.

A few fish juveniles were collected within the meroplankton samples (Tables N° 265 and 266). In the Pacific, most of these juveniles were engraulid fish collected during the February 1993 sampling. This finding is in accordance to what have been reported by Bayliff (1956) who found abundant engraulid juveniles during the dry season. Other fish juveniles are reported to move into the estuarine habitat, as observed with the carangid and the mugilid fish.

In general, the overall abundance of meroplankton is higher in the Caribbean than in the Pacific. This might be related to the role of coral reefs, seagrass meadows, mangrove forests and estuaries as spawning and breeding areas for many marine species.

(6) Fishes and Macroinvertebrates

(6.1) Fish

The work "The Marine Fishes of Panama" by Meek & Hildebrand (1923, 1925, 1928) has been traditionally the most important on the panamanian marine ichthyofauna and because of the geographic position of the Isthmus of Panama its influence extends beyond this country. This outstanding work was based on samplings from both coasts of Panama carried out in 1911 and 1912, as well as other species reported for Panama by several taxonomists that made collections in Panama. As a consequence of the geographic position of Panama, some facts need to be mention: first, the Atlantic coast of Panama is part of the Caribbean and therefore most of the species found along this coast are typically Caribbean; secondly, Panama is the northernmost and southernmost distribution species of marine fish from North-America and South-America, respectively, turning the isthmus into a point of convergence of species from both hemispheres.

The fishes of the Pacific of Panama belong to the biogeographic region known as the Panamic Province, which extends from the Gulf of California to Ecuador. This biogeographic province features a high diversity of species and it is the second richest in fish species after the Indo-Pacific, to whom share some species (Amezcua Linares 1985). On the other hand, the Caribbean fish belong to the West Indies Province that extends from Florida to Brazil.

The parallelism between the fishes on both coasts of the isthmus has been under discussion by many authors. In general, most of them agree with the existence of a connection between both oceans after which it closed some 3.5 millions years ago (Coates et al. 1992) leading into the species differentiation in both oceans. For instance, from the 72 species reported as common for both oceans by Meek & Hildebrand only 24 identical species were collected in both oceans and the remaining 48 species are cosmopolitan in their distribution. Subsequent studies reduced the number of shared species from 24 to 12 (Briggs 1967) thus indicating a more accurate comparison between the common ichtyofauna for these oceans.

This Biological Inventory has recorded in total 197 species, 113 in the Pacific and 84 in the Caribbean (Tables N° 267 to 271). The cumulative diversity of the species, both in the Pacific and in the Caribbean, do not show a tendency toward stabilization which seems to suggest the sampling program established by the TOR was not intense enough for this studied area (Figures N° 120 to 122; Table N° 272). However, when these results are separated into littoral and sublittoral the cumulative diversity of the littoral fish stabilized indicating this population was completely covered by the samplings

In the study, all of the data on the mean abundance is presented in Tables N° 273 to 277. The mean abundance (ind./collection) in the Pacific was particularly high at the beginning of the rainy season (July 1992 and May 1993) suggesting a relationship with the period that follows the upwelling during the dry season. The low sea temperature related to this upwelling displace many species of fish and invertebrates to warmer and shallow waters (Smayda 1969, Forsbergh 1969, D'Croz et al. 1991). The increase of the mean abundance after the upwelling suggest an intense recruitment of fish juveniles from the neighboring estuaries and mangrove bordered

coast. This is supported by the high incidence of small sized juvenile fish collected after the dry season in the Pacific (Tables N° 273 and 277). In the Caribbean the mean abundance of fish was fairly uniform throughout the rainy season, but diminished during the dry season as can be observed as follow:

Area	Quarterly Samplings				
	I	II	III	IV	V
Pacific	376.00	133.00	154.04	321.96	532.50
Caribbean	68.29	67.79	72.36	49.86	77.64

In general, the number of fish families ranged from 37 to 40 and the species from 77 to 111 with a sharp increase at the beginning of the rainy season. In the Pacific, the species diversity was higher at the beginning of the rainy season decreasing gradually toward the end of the year. The fish diversity in the Caribbean was fairly constant throughout the year Tables N° 267 to 271. In summary the specie diversity of fish in the area was the following:

Quarterly samplings	I	II	III	IV	V
Pacific species	70	59	65	45	75
Caribbean species	35	35	34	32	30
Total of Families	40	37	40	37	61
Total of Species	111	101	96	77	106

Also, a total of nine (9) identical species for both oceans were collected throughout the study in contrast to twelve (12) reported by Briggs in 1967, and *Gerres cinereus* was the only of such species to show up in four samplings as follow:

Quarterly Samplings				
I	II	III	IV	V
A. vulpes	*G. cinereus*	*S. crumenophtalmus*	*G. cinereus*	*C. hippos*
G. cinereus		*E. crossotus*		*A. lamprotaenia*
T. lepturus		*G. cinereus*		
C. hippos				
D. holacanthus				

The species with the highest mean abundances (ind./collection) in both oceans were related to their position in the food web and most of them are ranked as secondary consumers (**) that eats on animals and plants (carangid and bothid fish in the Pacific and Caribbean, respectively), followed by primary consumers (*) which feed on plankton and detritus as the gerreid fish (Yañez-Arancibia & Nugent 1997). In short, we found the following structure in the fish population:

Quarterly samplings	Pacific species ranked by abundance		
I	*P. woolmani* (37.88)**	*V. declivifrons* (35.75)**	*G. cinereus* (33.50)*
II	*P. woolmani* (19.83)**	*B. chrysoleuca* (14.71)*	*V. declivifrons* (9.96)**
III	*D. peruvianus* (29.13)*	*F. panamensis* (18.33)**	
IV	*G. cinereus* (318.48)*	*M. curema* (155.08)*	
V	*C. orqueta* (50.83)**	*G. formosa* (47.67)**	
	Caribbean species ranked by abundance		
I	*E. jonesii* (12.64)*	*S. micrurum* (9.50)**	
II	*E. jonesii* (20.64)*	*S. micrurum* (13.00)**	
III	*G. cinereus* (17.21)*	*E. crossotus* (14.86)**	
IV	*P. oligodon* (27.72)**	*S. micrurum* (22.29)**	
V	*C. evermanni* (23.14)**	*D. rhombeus* (11.43)*	

In the Pacific, the sampling stations with the highest mean abundances (ind./collection) were those located in the western side of the study area, in the vicinity of the estuary of Chame (stations MF-12, MF-11, and MF-10). In the Caribbean, the most abundant stations are located near Bahía Las Minas, in the eastern side of the study area (stations MF-18 and MF-19). The distribution per sampling and station of the highest abundance during the study has been summarized as follow:

Area	Quarterly Samplings				
Pacific	I	II	III	IV	V
	MF-09(998.00)	MF-07 (334.50)	MF-03 & 05 (47.00)	MF-03 (636.00)	MF-08 (1721.00)
	MF-12 (770.00)	MF-10 (289.00)	MF-11 (468.00)	MF-11 (1609.50)	MF-12 (1368.50)
		MF-12 (261.00)			

Caribbean	I	II	III	IV	V
	MF-18 (147.00)	MF-18 (164.00)	MF-14 (41.50)	MF-15 (81.50)	MF-18 (219.00)
	MF-19 (95)	MF-19 (119.00)	MF-19 (160.00)	MF-19 (96.00)	MF-19 (166.50)

On the other hand, the stations with the highest diversity of fish in the Pacific sublittoral follow the same pattern described in the preceding paragraph but the lowest diversity is located at the station MF-06 in front of the Panama Canal Pacific entrance. In the Caribbean, the highest diversity is found to be in the vicinity of Bahía Las Minas at station MF-18 and the lowest at station MF-19, as can be seen in the following summary:

Area	Quarterly Samplings				
	I	II	III	IV	V
Pacific	MF-12(32)	MF-10 (30)	MF-08 (31)	MF-11 (27)	MF-07 (38)
		MF-12 (29)			MF-08 (40)
Caribbean	MF-18(20)	MF-18 (20)	MF-17 (17)	MF-17 (15)	MF-18 (18)
				MF-18 (15)	

The overall picture of the stations with the lowest fish diversity was as follows:

Area	Quarterly Samplings				
	I	II	III	IV	V
Pacific	MF-06 (18)	MF-07 (23)	MF-06 (20)	MF-06 (4)	MF-11 (23)
		MF-11 (23)			
Caribbean	MF-17 (17)	MF-17 (11)	MF-19 (11)	MF-19 (8)	MF-17 (13)
		MF-19 (11)			

The samplings in the littoral zone in the Pacific were characterized by fish ranging in size between 2.00 to 31.00cm and weighting from 0.01 to 265.00g. These are typical juvenile fish collected in the vicinity of estuaries and mangrove forests known to be breeding and nursering grounds for many marine species. The most abundant samples were collected at the end of the dry season and the beginning of the rainy season (May 1993) possibly as a consequence of the upwelling. The Engraulidae (anchovies) were the dominant fish family. In the Caribbean littoral, the fish size fluctuated from 2.00 to 67.00cm and their weight range was between 0.10 and 500.00g. The most common littoral fish in the Caribbean were the Gerreidae (mojarras).

The fish from the sublittoral zone in the Pacific had a range in size from 5.00 to 135.20cm and the weight was from 0.06 to 2,969.00g. The Carangidae (jacks) and Sciaenidae (croakers and drums) were the most frequent fish among the samples. The stations with the highest abundances were those in the neighborhood of the estuary and mangrove forest of the Bay of Chame. In the Caribbean, the size varied from 3.60 to 47.50cm and the weight between 0.50 and 320.00g. Gerreidae and Bothidae (left-eyed flounders) were the most common fish.

Regarding the mean abundance of the species monitored for gonad maturation and gut content, the Pacific snappers *Lutjanus guttatus* and *Diplectrum euryplectrum* observed a steady decline as the rainy season progressed. During the dry season there was an absence of specimens from these species, possibly as the result from the upwelling. On the contrary, in the Caribbean the abundance of the red snapper *L. synagris* followed an unimodal distribution with a peak in August, whereas the abundance of the sand perch *D. formosum* gradually decreased in the rainy season. The summarized data on the abundance of these selected species is as follows:

Species	Area	Quarterly Samplings				
		I	II	III	IV	V
L. guttatus	Pacific	11.81	1.58	1.29	0.00	1.71
D. euryplectrum	Pacific	23.51	6.38	5.92	4.75	12.96
L. synagris	Caribbean	6.00	9.21	3.43	1.93	3.07
D. formosum	Caribbean	2.43	0.57	0.79	2.36	4.36

The gut content in these marine fish species showed a diet compose mostly by crustaceans (penaeid shrimps, stomatopods, and crabs) and small fish (Tables N° 278 to 282). Thus these fish species are considered as third level consumers (exclusively carnivorous). Furthermore, there is no variation in the food habit of these fish regarding the climate and the oceanographical seasonality of this area (dry season vs. rainy season).

According to the study of the gonad maturation, both in the Pacific and the Caribbean, the snapper *Lutjanus* and the sand perch *Diplectrum* spawned several times throughout the study period: at the beginning of August 1992, in October 1992, and possibly in April 1993 at the end of the dry season. This way these species are constantly recruiting juvenile fish to the stock throughout the year. The species of *Diplectrum*, in both oceans, presented a protandric hermaphroditism or sexual inversion (males changed into females) which explained the predominance of a single sex, mostly females, during the November 1992, February and May 1993 collections. In general, the stages of gonad maturation were observed to occur almost simultaneously in both oceans which is probably related to the seasonality of the climate (Tables N° 283 to 301).

Comparison to other studies: In addition to the list of species from Meek & Hildebrand (1923, 1925, 1928), important biological information was gathered by the University of Miami (Bayer

et al. 1970) during the Bioenvironmental and Radiological Safety Feasibility Studies Atlantic-Pacific Interoceanic Canal. The study from the University of Miami was mostly concentrated in relatively deep water (from 50m to 3,000m), covering the whole range from the continental shelf down to the abyssal plain. In fact, the sampling effort within the 50m isobath was very limited. On the contrary, the sampling effort of the Biological Inventory has been exclusively concentrated in the shallow area, within the 50m isobath. When the results of this Biological Inventory are compared with the findings of the University of Miami it emerges that the cumulative number of species recorded by both studies is 566 and from this, 220 (39%) species are from the Biological Inventory and 346 (62%) from the study of the University of Miami (based on the catches from bottom trawling nets). Among the fish species only 37 species have been commonly found by both inventories and represent 7% of the total. Also, comes out that the Biological Inventory surpass the number of species from both oceans within the 50m isobath, with 117 species from the Pacific and 103 species from the Caribbean, in contrast to 90 and 68 species recorded by the University of Miami, respectively. However, the Caribbean list of species from the University of Miami is much larger than that from the Inventory when are considered the collections below the 50m isobath. The cumulative list of fish species, including all of the species collected both by the University of Miami and the Biological Inventory is presented in Tables N° 302 and 303.

(6.2) Macroinvertebrates

The total abundance of invertebrates (Tables N° 304 to 308) collected was 13,407, it represented 7,955 (60%) individuals from the Pacific Ocean and 5452 (40%) individuals from the Caribbean stations. The total collected biomass was 239.08 kg, and it divided among the Pacific stations as 171.10 kg (72%) and 67.98 kg (28%) at the Caribbean stations.

The most abundant species were: *Callinectes arcuatus*, *Renilla amethystina*, *Lolliguncula panamensis*, *Portunus xanthussi xanthussi*, *Xiphopenaeus riveti*, *Squilla aculeata aculeata*, *Sycionia disdorsalis*, *Euphylax robustus*, *Astropecten armatus* and *Ptylosarcus sinosus*. These ten species represented 75% of the total number of individuals from the Pacific collections. The most abundant species was *Callinectes arcuatus* with 17% of the total, while *Renilla amethystina* was the second most abundant species with 15% of the total collected.

In the Pacific Ocean, *Callinectes arcuatus* was the most abundant species with 35% of occurrence in July, 34% in August, but in December it was displace to a third rank with an abundance of 11%, finally in February it had the fifth rank with 4%. However, *Renilla amethystina* accounted as the most abundant species in December and February with 34% and 29% of the total, respectively. Finally, in May 1993, the shrimp *Xiphopenaeus riveti* was the most abundant organism with 25%.

The total biomass collected from the Pacific stations was 171.10 kg. The dominant species in term of the biomass were: *Callinectes arcuatus*, *Euphylax robustus*, *Lolliguncula panamensis*, *Portunus xanthussi xanthussi*, *Renilla amethystina*, *Ptylosarcus sinosus*, *Squilla aculeata aculeata*, *Xiphopenaeus riveti*, *Hepatus kossmani* and *Penaeus occidentalis*, and these represented 83% of the total biomass reported for the Pacific Ocean. *Callinectes arcuatus* was

the species with the highest abundance with 31% of the total, and *Euphylax robustus* was the second most abundant with 15%.

The highest biomass among the invertebrates at the Pacific was recorded by *Callinectes arcuatus* in July, August, December and May, but *Lolliguncula panamensis* provided the highest biomass in February with 51%.

The total number of individuals collected at the Caribbean stations was 5,452, and it represented 40% of the total reported for both oceans. The most abundant species were: *Arenaeus cribarius*, *Lupella forceps*, *Penaeus braziliensis*, *Amusium papiraceum*, *Portunus anceps*, *Penaeus duorarum*, *Portunus spinicarpus*, *Astropecten articulatus* and *Hepatus princeps*, and they represented 90% of the total collected. The most abundant species was *Arenaeus cribarius* with 37% of the total and the crab *Lupella forceps* was in the second rank of abundance with 14%.

At the Caribbean, in July, August, December and May, *Arenaeus cribarius* was the most abundant species with 33%, 55%, 29% and 21% respectively. However, in February *P. braziliensis* was the most abundant invertebrate representing 33% of the collection, and in the second rank of abundance was *Arenaeus cribarius* with 12%.

The total biomass at the Caribbean stations was 67.98 kg., and it represented 28% of the total reported. The highest biomass was provided by: *Arenaeus cribarius*, *Penaeus braziliensis*, *Penaeus duorarum*, *Lupella forceps*, *Turbinella angulata*, *Portunus anceps*, *Hepatus princeps*, *Halycomites* sp. and *Amusium papiraceum*, these species represented 77% of the total collected. The highest rank in biomass was provided by *Arenaeus cribarius* with 16%, while *Penaeus braziliensis* was the species with the second rank in abundance with 13%.

In August, *Penaeus duorarum* provided most of the total biomass with 34%, but in November, *Portunus anceps* had the highest rank of the total biomass with 19%. However in July, February and May *Penaeus braziliensis* accounted for most of the biomass at the Caribbean with 22%, 40% and 27%.

In overall, the amount of invertebrates collected during July and August were quite similar (2,923 and 2,943 respectively), but in December this abundance declined to 2,035, in March these organisms reached 2,589, and finally in May this amount was 2917. Also, a significant turnover was observed between both oceans. In July, the Caribbean stations contributed with 33% of collected invertebrates, but in August and December this was increased up to 66% of the total collection, and in March and May it declined to 16% and 27% respectively. In the Pacific Ocean an inverse situation was observed, being 66% in July collections, 33% in August and December, 84% in March and 73% in May.

The total number of species reported in this study was 106, from this 56 species are from the Pacific Ocean and 50 from the Caribbean (Table N° 309). Bayer et al. (1970) reported 1380 species of invertebrates in both oceans, but species collected in bottoms less than 50m in depth were 423. The analysis of the lists provided by Bayer et al. (1970) found 35 species shared with our study, and it represented 71 new species summed to the work of Bayer et al. The

cumulative number of species from the quarterly samplings might suggest a tendency toward the stabilization, although some additional sampling effort would provide a few species more (Figures N° 123 to 125).

(7) Sport and Commercial Fisheries

(7.1) Resources from the Gulf of Panamá

The most important fishery resources of the country are within the Gulf of Panamá. The community of coastal pelagic fish located above the thermocline is dominated by species such as: the anchoveta *Cetengraulis mysticetus*, the herring *Opisthonema libertate* and several species of anchovy (*Anchoa spp.*). Related to these species are some important predators as the mackerel (*Scomberomerus maculatus*), barracudas, and sharks. Below the thermocline some other species might be found at high densities, such as the mackerel (*Decapterus macrosoma*), deep water sardines (*Etrumeus tere*), and other less abundant species. The yearly available biomass of pelagic fish (anchoveta and herring) in the Gulf of Panamá usually vary between 70,000 and 160,000 metric tons (m.t.) as can be inferred from the historical records of yields from the fishing fleet of the gulf (Table N° 310). Possibly, as much as 50,000 m.t. of jacks and deep water sardines, that according to the prospections of the r/v "Fridtjof Nansen"are available in the gulf, are fished altogether with the catches from the anchoveta fishing fleet. Moreover, the report from the r/v "Fridtjof Nansen" suggest that some 80,000 m.t. of carangid fish could exist at greater depths. This stock is not currently under exploitation.

Among the pelagic oceanic stocks are the yellowfin tuna *Thunnus albacares* and the skipjack tuna *Katsuwonus pelamis*, usually located off the 100 fathom isobath. These species are frequently concentrated south to Bahía de Piñas, Darién, and in the proximity to Punta Mala, Azuero (Bullis & Klima 1972). Being these fish oceanic species they are not related to the study area of this Biological Inventory.

The demersal fish stock is estimated in the vicinity of 200,000 m.t. and it is mostly comprised by stromateid fish (dollar fish), some species of serranids, and snappers. This resource is barely utilized by the panamanian fishing industry. Snappers and serranids, the most commercially important among the fish of this stock, might represent 7,000 and 12,000 m.t., respectively, according to the r/v "Fridtjof Nansen". Despite the fact that there exist a fishery of demersal fish, mostly snappers, the current fish landings might suggest this stock is under-utilized.

The annual catch of penaeid shrimps suggest that the available biomass vary from 5,000 to 6,000 m.t. per year. The fishery statistics from the Ministry of Industries and Commerce of the Republic of Panama (MICI) indicate that possibly just 10 to 15% of this catch is from the Gulf of Chiriquí. The species of this stock are: the white shrimps (*Penaeus occidentalis, P. stylirostris*, and *P. vannamei*), the red shrimp *P. brevirostris*, the zebra shrimp *Trachypenaeus byrdi*, and the seabobs (*Xiphopenaeus riveti, X. kroyeri*, and *X. precipua*). In addition to this, there is an important stock of deep water shrimps (from 70 to 200 fathoms). This resource is composed by: a pandalid shrimp (*Heterocarpus vicarius*), locally known as bighead shrimp; a

the species with the highest abundance with 31% of the total, and *Euphylax robustus* was the second most abundant with 15%.

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penaeid shrimp known as Fidel (*Solenocera agassizii*), and a galatheid of the species *Pleuroncodes planipes*. All of these deep water fishing resources were discovered by the FAO regional fishery project betweeen 1967 and 1970. Up to this time, the annual catch of deep water shrimps is close to 1,000 m.t.

The scallop *Argopecten circularis* has been gaining the interest from the fishermen as an important fishery stock in the Gulf of Panamá. The size of the stock seems to fluctuate within a 6-8 years cycle. From 1985 to 1986 the annual landings of scallops from the Gulf of Panamá jumped from 2 to 2,000 m.t. (Anonymous 1987). After this high yield the scallop landings have decreased to a very small amount because unknown reasons. In addition to scallops, some other bivalves are exploited by the artisanal fishermen and most of these are clams (*Donax spp.* and *Protothaca asperrima*). It is not possible to determine the size of the stock based on the existing fishery statistics, but anyway this biomass is probably small.

The prospections of the r/v "Fridtjof Nansen" revealed an important stock of squids. This stock might represent up to 30,000 t.m. of the squids *Loliolopsis diomedae* and *Lolliguncula panamensis*. This stock is not being fished.

In summary, the most recent fishery prospections suggest that the extractable biomass in the Gulf of Panamá might be around the 400,000 m.t. per year. Most of this fish stock is comprised by demersal fish and squids which are not fished (more than 100,000 m.t.).

(7.2) Resources from the Caribbean

According to the fishery prospections carried out by the FAO regional fishery project and most recently from the Japan International Cooperation Agency (JICA, 1984), the most important resources are the demersal species. Among these are: the snappers *Lutjanus vivanus, L. synagris*, and *Rhomboplites aurorubens*, sharks as *Rhizoprionodon sp.* and *Squalus cubensis*, some carangid fish (jacks), and the pink shrimp *Penaeus duorarum*. Bottom trawling is the best fishing gear for the snappers and the shrimps and there is 1,000 Km^2 of marine bottom suitable for this type of fishing. The stock of pelagic fish is very limited in the area, although some commercially important species are in small quantity (including some tunid fish as the albacore and the yellowfin tuna). Some other fish stocks, although not too big, are important for the inhabitants of the coastal area as the octopus, mangrove oysters, the king crab *Mithrax spinosissimus*, and the spiny lobster *Panulirus argus, P. guttatus*, and *P. laevicauda*. The fishery records from the area suggest that the lobster stock is around 200 to 400 m.t. a year.

(7.3) Commercial and sport fisheries

Most of the fishing effort is devoted to: the penaeid shrimps stock, the anchovetas and herring for the production of fish meal, and fish (mostly demersals) for the human consumption. This fishing activity involves some 10,000 peoples and it is mostly concentrated in the Pacific coast

of Panamá. In the Caribbean, the fishing activity is of low intensity and mostly of the subsistence type. According to the Ministry of Commerce and Industry of the Republic of Panamá (MICI 1990), some 2,000 peoples are working for the fishing industry, 6,500 are artisanal fishermen, and around 1,500 persons are involved in the processing and marketing of sea products. The annual revenue from the exportation of the panamanian marine products is about $ 100,000,000, and within this shrimps represent from $ 65,000,000 to 70,000,000.

The shrimp fishery has observed a steady decline of the total catch during the past 10 years (1981-1990). The overfishing of the stock has been indicated as the main cause of this decline. The yearly total catch during the first half of the 80's was between 7,000 and 8,000 m.t. But since 1987, the catch has decreased to some 5,000 t.m. To some extent, this decline could also be related to natural oscillations of the population of shrimps and/or in the environment.

The yields from the anchovy and herring fishery usually show amply oscillations that are related to the oceanographic conditions in the Gulf of Panamá. Annual total catch have varied from 40,000 to almost 200,000 m.t.. According to the Ministry of Commerce and Industry of the Republic of Panamá the stock might has 250,000 m.t.

The artisanal fishery has showed the highest growing rate among the fishery activities in Panamá during the past 10 years. By the beginning of the 80's the annual total catch was below 2,000 m.t., but during the early 90's the yearly catch reached 7,000 m.t. The most common species in the artisanal landings are: snappers, spanish mackerel (scombrid), jacks (carangid), corvinas (scianid), and lobsters. From 1986 to 1987 the catch of scallops (*Argopecten circularis*) were unusually high (5,000 m.t.).

There is some development of mariculture of white shrimps in the Pacific coast. Some 5,000 Ha. of shrimp ponds are located mostly at Coclé, Herrera, and Los Santos. However, some mariculture operations are being held in the area of Bayano, east to Panamá City, and closer to the study area of this inventory. The production of shrimp in ponds has reached up to 1,600 m.t. in 1988. This production overcomed the catch of white shrimps from the shrimp trawlers. There is some controversy regarding the relationship between the devolopment of the coastal mariculture vs. mangrove forest.

The sport fishery in Panama is based on a few species, among are the following:

Species	Common name	Distribution
Tylosurus fodiator	needle fish	P
Thunnus albacares	yellowfin tuna	P
Thunnus alalunga	albacore	P
Katsuwonus pelamis	skipjack tuna	P - C
Cynoscion phoxocephalus	corvina	P
Macrodon mordax	corvina	P
Coryphaena hippurus	dolphin	P
Centropomus robalito	snook	P

Centropomus unionensis	snook	P
Caranx chrysos	blue runner	C
Seriola dumerilii	amberjack	C
Caranx hippos	crevelle jack	P - C
Trachinotus kennedyi	pompano	P
Megalops atlanticus	tarpon	P - C
Lutjanus guttatus	red snapper	P
Lutjanus colorado	red snapper	P
Lutjanus cyanopterus	red snapper	C
Acanthocybium solanderi	wahoo	C
Scomberomorus maculatus	spanish mackerel	P - C
Istiophorus spp.	sail fish	P
Xiphias gladius	swordfish	P - C
Makaira indica	black marlin	P - C
Nematistius pectorilis	rooster fish	P

There is no regulation of the sport fishery in Panamá, thus it is impossible to assess the fishing effort and the volume of the catch. In general, sport fishery is considered a low intensity activity and the catch are believed to be small. The most atractive sites for the sport fishing that are within the Biological Inventory study area in the Pacific are: the Fort Amador Causeway, Taboga, Taboguilla, and Urabá Islands, and the small rocky islands spreaded from the Panamá Canal entrance and Punta Chame. In the Caribbean, the favorite area for sport fishermen range from the mouth of the Chagres river to Isla Grande.

d) RARE AND ENDANGERED SPECIES

Local endangered species are protected by panamanian laws. Some of these species might be abundant in some places and not necessarily threatened, or on the contrary, they might be rare and extremely threatened in the study area. Among the recorded species in this inventory, the following are considered as endangered or rare species:

(1) Flora (Terrestrial)

Table N° 24 displays the general information from all identified species as to their distribution. This list is an addition to the species list for the area of the Canal Zone published by D'Arcy (Missouri Botanical Garden, 1987). It is also included a value given by CITES and IUCN regarding to the survival possibilities and world range for each species. From the IUCN species list the following were found during this inventory:

Gnetum leyboldii: extinct species according to IUCN.

Amphitecna isthmica: threatened species.

Amphitecna spathicalyx: threatened species

Bombacopsis quinata: threatened species

Brosimum costaricanum: threatened and vulnerable species

Eschweilera pittieri: threatened species

* *Oenocarpus mapora*: threatened species

Vantanea occidentalis: threatened and vulnerable species

* *Astrocaryum standleyanum*: vulnerable

Clarisia racemosa: threatened and vulnerable species

Geonoma deversa: threatened and vulnerable

* *Scheelea zonensis*: vulnerable

Synechantus warscewiczianus: threatened species

Symphonia globulifera: vulnerable

* *Annona spraguei*: rare species

Capparis panamensis: rare species

* *Clidemia gracilis*: rare species

Croton billbergianus: rare species

Piper polytrichum: rare species

Ruellia tubiflora: rare species

* *Vismia jefensis*: rare species

(2) Fauna (Terrestrial)

(2.1) <u>Insects</u>

Although there is no record on threatened insect species, some insect families collected during this inventory are considered to be very scarce as: Masaridae, Ropronidae (Hymenoptera), Dilaridae (Neuroptera), Othniidae (Coleoptera), and Strongylophthalmiidae (Diptera).

(2.2) Amphibians and reptiles

The threatened and endangered species of amphibians and reptiles recorded for the study area are listed in Table N° 57. In this list are considered as threatened those species classified as vulnerable by the IUCN (1982) and those appearing in the appendix II of CITES (1991). In addition, are included in this list, those endemic species of the Republic of Panamá; which due to their reduced geographic distribution could be considered as threatened.

Family Caeciliaidae

Oscaecilia ochrocephala: This cecilian is a species with a fossorial habit, which make difficult to determine its distribution and abundance; therefore, it was not included in this list.

Family Dendrobatidae

Dendrobates auratus: This frog was observed in several study sites (Table N° 54), being the most common species within the forests of Ciri (Figure N° 2).

Phyllobates lugubris: was only found in Ciri, eastern extreme of its distribution range, where was usually found along the margins of forest streams.

Family Alligatoridae

Caiman crocodilus: The caiman is usually common in the Canal Area, being particularly visible at nighttime. It was commonly found in the slow moving streams and lagoons of Ciri, Corte Culebra and Cocoli. Numerous individuals of this species were seen in the Alajuela Lake in the surroundings of the Tranquilla town. In Pequení it was not observed, but according to the information provided by local residents, this species is found in the slow moving sections of the river, mainly at its mouth in the Alajuela Lake. Its absence in Sherman, probably was because of the minimal and fruitless searchers made from the shore of Gatun Lake.

Family Crocodilidae

Crocodilus acutus: In contrast to the caiman, the crocodile was observed infrequently in those sites having suitable habitat for their existence. We only observed one adult individual of this species in the Alajuela Lake nearby the town of Tranquilla. However, the locals mentioned that they were seen with moderate frequency. According to local residents from Ciri, this species is usually observed along the slow moving course of the Ciri River

in the mouth in the Gatun Lake. We could not obtain information about this species from the locals of Pequeni.

Family Iguanidae

Iguana iguana: The green iguana is present in all of the study sites (Table N° 55). All these sites have appropriate sites for the survival of this species; having forested zones were the iguanas can live, and suitable areas for nesting. Nevertheless, the extension of the forest, mainly along the margins of rivers and lakes, could be a factor that limits the population size of the green iguana at some sites. For nesting, the green iguanas need areas with dispersed vegetation or open areas with a layer of soil suitable for digging burrows. There are many areas with such characteristics in all the study sites, most of them created by human deforestation or naturally when the water level of the rivers and lakes decreases during the dry season. Is during the dry season, in the period from January to March, when the female iguanas descent to the ground to lay their eggs (Werner & Rey 1987).

We found juvenile iguanas in Sherman, Cocolí y Corte Culebra, which are restricted areas without or a few settlers. Corte Culebra was the only site where we saw an adult iguana on the ground, at the end of the nesting period. These observations indicate that in these sites a viable and reproductive population seems to exist. Whereas, in the populated sites of Cirí, Pequení and Tranquilla, we did not observe iguanas. The local residents in these sites assured to us that the green iguana occurs in such areas, being observed infrequently. Furthermore, they mentioned the iguanas are been very tempting, that they are hunted indiscriminately even during the nesting season. Not having observed juveniles in these populated sites, maybe an additional indication that a reduced iguana population with low opportunities for a successful nesting is present in these sites, because of the strong human pressure.

Family Colubridae

Tantilla albiceps: The snakes, as previously mentioned, are observed infrequently; therefore, these species are difficult to sample. An extreme example is this species known only from a single specimen collected at Barro Colorado Island in 1925 (Rand and Myers, 1990).

Family Boidae

Boa constrictor and *Corallus annulatus*: During this inventory there were observed a single individual of each of these species.

Family Elapidae

Micrurus stewarti: A few individuals were observed at Ciri.

(2.3) Birds

There were found within the study area 10 endangered bird species according to the Institute of Natural Renewable Resources of the Republic of Panama. However, 79 bird species are considered as threatened species according to CITES and IUCN. The deforestation and intensive hunting are considered as the main factors affecting these birds. Among the records from this inventory the following bird species are considered as endangered species:

Family Tinamidae

Tinamus major: Great tinamu, two individuals were registered in the Gaillard Cut forest.

Crypturellus soui: Small tinamu, was registered in all of the sampling sites and as much as 18 individuals were recorded at the same time at Pequeni.

Family Anatidae

Dendrocygna autumnalis: Black belly guichichi. It is a common bird in the southern entrance to the Canal, Tranquilla, and Pequeni. As much as 162 individuals were recorded at the Farfan pond.

Cairina moschata: Common duck. A single individual was registered near the mouth of Ciri Grande River.

Oxyuna dominica: Duck. Some 26 individuals were observed near the mouth of Ciri Grande River.

Family Cracidae

Ortalis cinereiceps: Paisana. This bird was common in all of the sampling sites, however the highest concentration was recorde at Gaillard Cut.

Family Phasianidae

Odontophorus gujanensis: Mountain patridge. This is a very rare species and only a single individual was heard near the margin of Pequeni forest.

Family Columbidae

Columba cayennensis: Torcaza. This pidgeon was very frequent in all of the studied area. In the southern entrance to the Canal it was recorded the highest concentration.

Columba nigrirostris: Pidgeon. This bird was observed in all sites within the study area buth a very low densities.

Columba speciosa: Pidgeon. Only one individual was observed in the Gaillard Cut.

(2.4) Mammals

Order Xenarthra (=Edentata)

Family Myrmecophagidae: This family is represented by the anteaters, a group represented almost throughout the country; some of the species registered are the following:

Cyclopes didactylus: During the studies carried out, it was found in Barro Colorado Island and the Metropolitan Natural Park. This is a very rare species, strictly arboreal and susceptible to fragmentations of the forests where it lives; it is frequently found in riverside forests and secondary forest areas, mainly in lowland rain forest. It is chiefly a nocturnal animal and feeds exclusive on ants. There are no data on the gestation period of this species.

Tamandua mexicana: This species is very common throughout the canal area; during the studies carried out, it was found in Fort Sherman, Río Limbo, Summit, Pita Road, Parque Natural Metropolitano, and Cocolí. This species has been included in the III Appendix of CITES, considering it as a very rare species; it is eaten by some of the local indians. This species has nocturnal, twilight and diurnal habits. It is both an arboreal and terrestrial animal and feeds on ants and termites.

Family Dasypodidae: This Family is represented in Panama by two species, both are included in the list of endangered species, however, during the present study only one of them was registered.

Daypus novemcinctus: This species is very common throughout the canal area; during the studies carried out, it was registered in Fort Sherman, Gigante Peninsula (Natural Monument Barro Colorado Island), Río Limbo, Pita Road (Soberanía National Park), Cocolí (Area of Military Coordination), and Cirí on the west bank of the Canal. The latter zone is characterized by a zone of pastureland where riversida forest predominate and grazing zones. This species in hunted throughout its area of distribution, but is neverthelesess considered as very abundant.

It is a species of nocturnal and solitary habits and is found in diverse habitats; it is primarily an insectivore, with a tendency to specialize in ants termites. This species is a natural carrier of the Chagas illness.

Order Primates

Family Callitrichidae: In Panama this Family is represented by only one species; it is often kept as a pet.

Sauinus geoffroyi: In the Canal area there are several healthy populations; it is however considered a very endangered or almost extinct species and has been included in the Appendix I of CITES. The populations are restricted to isolated fragments of forest. It is usually found in zones of nature, secondary evergreen and decidous forest; the density of population is considered to bary between 30-180 individuals/km2, at times groups are composed of 3-13 individuals (Emmons & Feer, 1990).

In the area of study it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Limbo River, Summit, Plantation Road, the Metropolitan Natural Park and Cocoli. It is a species of diurnal habits; its diet consists of 60% friuts, 30% insects and 10% vegetable matters (Eisenber 1989).

Family Cebidae: In Panama this family is represented by five species of four genus. One of the species (*Alouta coibensis*) is not found in the area of study and is restricted to Coiba Island and the Azuero peninsula (Wilson & Reeder 1993).

Alouta palliata: This species has been included in the Appendix I of CITES. In the area of study it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Syristes River, Limbo River, Summit, Pita Road, the Metropolitan Natural Park, Cocoli and Plantation Road. This is an abundant species throughout the forests in the Canal area; but it is declining rapidly due to the deforestation over a large part of its range and also due to being hunted in some areas as a source of protein.

It inhabits nature, old secondary, evergreen, semi-deciduous and riverside forests; groups are formed with 2-45 individuals but generally 10-20 individuals will formed a group composed of 2-4 males and 5-10 females. Its diet consists of 50% young leaves and 50% friuts; it is a strictly diurnal species.

Aotus lemurinus: This species has been included in the Appendix I of CITES. In the area of study it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Limbo River, Syristes River, Pita Road and Cocoli. The nocturnal monkey or jujuná as this species is Know, is moderately distributed and is considered a fairly common species, it is affected by deforestation and hunting.

This species inhabits a wide range of nature, secondary and altered forests; these areas vary from humid to arid. It is principally a frutarian but on occasion supplements this with insects; a normally monogamous species, however during mating season four or five males may aggregate to dispute a female. It inhabits holes in treetrunks or raft-like structures it builds in the treetops.

Ateles geoffroyi: This species has been included in the Appendix I of the CITES. In the area of study it was only found on Barro Colorado Island and Plantation Road. It is a species locally extinct in many areas and common in very few places, it requires large areas of unfragmented forests. On Barro Colorado Island exists a population of 25-30 individuals,

this population is greatly endangered due to the destruction of this habitat and hunting. The spider monkey is strictly frutarian, but on occasion will eat new leaves.

Cebus capinus: the white-face monkey has a relatively wide range of distribution, with gradually declining populations due to destruction of habitats, being hunted as a source of protein or being kept as pets. The species is included in the Appendix I of CITES. In the areas of study it has been found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, and Plantation Road. It is a species locally extinct in many areas and common in very few places; it requires large areas of unfragmented forests.

Order Rodentia

Family Hydrochaeridae: This Family is considered monotypical since it is represented by only one genus with one species.

Hydrochareris hydrochaeris: The poncho or capybara is a species not common in Panama; in some sites however it is relatively abundant. It has been found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Limbo River, Summit, Pita Road, Cocoli, the southern part of Alajuela Lake, Tranquilla and Ciri. The capybara is a nocturnal species, it is severely sought out in some areas, but where human hunting is absent it can be observed during the morning and afternoon; associated with bodies of water, mainly marsh and floodlands; it has a gestation period of 150 days which is partially controlled by the rainy season. It is found in groups of 2-27 individuals with one dominant male; it is an herbivore.

Family Dasyproctidae: In Panama, this Family is represented by two species, one of which is endemic to the Island of Coiba (*Dasyprocta coibae*).

Dasyprocta punctata: The ñeque is one of the larger mammals that has been submitted to great pressure by man; it is extinct in some sites due to hunting; it is endangered due conversion of forest into grazelands. It inhabits nature and secondary lowland forest, mountainous rainforest and deciduous forest. This is a monogamous species, where the same pair lives together until the death of one of the mates.

This individual is a seed disperser due to the fact that it gathers seeds and buries them in areas far from the originating tree. The gestation period is approximately 120 days.

Family Agoutidae: The rodents that belong to this Family have large bodies of regular proportions; some of these mammals indigenous to the tropical regions of America are objects of the greater part of hunts and are famous for their delicious meat.

Agouti paca: This species is very common throughout the Canal Area, but is extinct in many areas within its range due to hunting; ecologically it it covers a wide range of distribution; it is mainly associated with forest and is very common in the underbrush and around fallen trees. During the studies carried out it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Syristes River, Limbo River, Summit, Pita Road and

Plantation Road. The greatest threat to this species is the indiscriminate hunting to which it is subject throughout almost all Central America and Panama.

The painted rabbit, as this species is also known, is completely vegetarian and consumes a great variety of fruits and vegetables, including roots and tubers. It is estimated that it can live upto 18 years in captivility, the especies is nocturnal, monogamous with a gestation period averaging 157 days in captivity. (Mendez 1970).

ORDER CARNIVORA

Family Canidae: In this family are grouped carnivores whose general typical formation is that of the domestic dog; these animals have the tendency to hunt in packs. In Panama, this family is represented by the following species.

Speothos venaticus: The Mountain Dog is a rare species and difficult to observe; in the area of study it has been observed on Limbo River and Pita Road; it has been included in the Appendix I of CITES and is considered a vulnerable species by UICN. Generally, little is known of the habits of this species; it is known as a nocturnal carnivore that lives in rainforests and uses burrows in order to protect itself. (Mendez, 1970).

Studies realized with individuals kept in captivility indicate that this is a highly carnivorous species, which attacks other small mammals and birds. The reproductive period is a 65 days, resulting in 3-5 offspringam, capable of having two reproductive cycles in one years. (Eisenberg, 1989). At presente, it is considered that the main threat to this species is the destruction of its habitat and the reduction of food availability due to habitat destruction.

Urocyon cinereoargenteus: This species is very rare and difficult to observe; in the area of study it had been found in Pita Road and Ciri. Generally it is widely distributed and mostly unthreatened, however the destruction of the forests it inhabits is endangering the species; as is the case of many other mammals, the meat of this canide is used by the some of the rural natives. (Mendez, 1970). The period of gestation is 63 days with an average of three to seven offspring, it feeds on friut, invertebrates and small vertebrates (Eisenberg, 1989).

Family Felidae: This is without doubt one of the best known groups of mammals in the entire globe, since cats or felines are found almost throughout the planet with few exceptions. They are carnivores, with retractible claws which are used for climbing or capturing their prey; in Panama this group is represented by six species of cats, of which, in the Canal area only four species are represented and one has become extinct in the area Puma concolor (Felis concolor).

Herpailurus yaguarondi (=Felis yagouaroundi): The congo wildcat is rare or slightly common in some areas of the Canal Basin; it is considered an undetermined species by IUCN (jack of information) and is included in the Appendix I of CITES; during the studies carried out it was found in Fort Sherman, Barro Colorado Island, Syristes River, Limbo River, Summit, Pita Road, the Metropolitan Natural Park, San Juan of Pequeni and

Plantation Road. The main threat to this species is the destruction of its habitat, but is one of the species of cats with the greatest capacity to adapt in disturbed zones.

It inhabits tropical forest, subtropical, secondary forests and bushlands including flood zones, this species has nocturnal and diurnal habits, is terrestrial and solitary though it may be found in pairs; the jaguarundi is totally carnivorous, feeding on snakes, lizards, birds and other small mammals (Emmons & Feer, 1990); the period of gestation is 78 days (Eisenberg, 1989).

Leopardus pardalis (=*Felis pardalis*): The ocelot or manigordo as it is also known is rare in some areas of the Canal Basin, but in other areas it may be considered relatively common; during the studies carried out it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Syristes River and Summit, it is considered a vulnerable species by IUCN and is included in the Appendix I of CITES. The main threats to this species are the destruction of its habitat, being hunted for the commercial use of its skin and being kept as pets.

It inhabits tropical and subtropical forests, including flood zones and cedar forests, the species has nocturnal habits and is terrestrial and solitary through tending to share territories it does not hunt in pairs; it is totally carnivorous, feeding mainly on rodents, this diet is supplemented with snakes, lizards, birds and other small vertebrates (Emmons & Feer, 1990); the period of gestation is approximately 75 days (Eisenberg, 1989).

Leopardus wiedii (=*Felis wiedii*): The wildcat or margayis a very rare specie in the Canal Basin; during the studies carried it was found in Fort Sherman, Barro Colorado Island, Syristes River, Limbo River, Summit, Pita Road, The Metropolitan Natural Park, San Juan of Pequeni and Plantation Road; it is a considered a vulnerable species by IUCN and is included in the Appendix I of CITES. The main threats are the destruction of its habitat and being hunted for commercial use of its skin; it is one of the cats most sensitive to disturbance by human activity.

It inhabits evergreen and deciduous forests, its habits are nocturnal and diurnal, arboreal and terrestrial; the margay is totally carnivorous, feeding on snakes, lizards, birds and others small arboreal or terrestrial mammals (Emmons & Feer, 1990); the period of gestation is approximately 75 days (Eisenberg, 1989).

Panthera onca: The jaguar or tiger as this species is known is one of the largest felines in the world, distributed almost throughout the American continent; curing the studies carried out it was found on the Syristes and Limbo River; it is considered a vulnerable species by IUCN and is included in the Appendix I of CITES. The main threat to this species are the destruction of its habitats and being hunted for commercial use of its skins; it is one of the cats most sensitive to disturbances due to human activity, it is also in imminent danger of extinction.

It inhabits tropical forests, areas of swampy grasslands and arid zones; it is a species of nocturnal and diurnal habits and is terrestrial; the jaguar is totally carnivorous, feeding on larger mammals such as deer, rabbits, ponchos, tapirs, peccaries; it also feeds on turtles, caymans, birds and even fish; the jaguar can survive where its habitat has been destroyed and substituted by cattle and horses (Emmons & Feer, 1990); the period of gestation is approximately 101 days (Eisenberg, 1989); due to its large size, this species requires extensive territory in order to subsist, this area is estimated at 25 km^2.

Family Mustelidae: The mustelids are a select group of mammals that are not only famous for the bloodthirsty habits associated with their natural instincts as excellent hunters, but also because some of their representatives provide some of the most valuable skins used in the fur industry. This family include the true otter, the skunk, the ferret, the true weasel and other similar species (Méndez, 1970); this group is represented in Panama by five species, three of which have been reported on various occasions in the study area.

Eira barbara: The tayra or black cat is a uncommon and even rare species in some areas of the distribution and due to its habits it is rarely observed, it can hide in the highest treetops or in the densest underbrush of the forest; in the area of study it was only found on Barro Colorado Island, Gigante Peninsula, Syristes River and Limbo River. It is a species that lives far removed from human activity, the main threat to this species is the destruction of the forests where it finds food.

It inhabits tropical, deciduous and evergreen forests, it is species of diurnal habits except when close to human habitation, it then becomes a twilight species, it is arboreal and terrestrial and usually travels in pairs. It is considered an omnivorous species, since, beside feeding on small mammals and other vertebrates, it also feeds on insects and fruits (Emmons & Feer, 1990); the period of gestation is approximately 70 days (Eisenberg, 1989).

Lontra longicaudis (=Lutra longicaudis): The otter or water cat, as it is known, it is one of the most common species in the area of study, associated mainly with bodies of water, rivers and creeks; in the study area it was found in Barro Colorado Island, Gigante Peninsula, southern part of Alajuela Lake, Tranquilla and Ciri; it is considered a vulnerable species by IUCN and is included in the Appendix I of CITES. The main threats to this species are water pollution and deforestation.

It inhabits tropical, deciduous and evergreen forests, it generally establishes itself along riverside areas of fast moving rivers and creeks it is species of diurnal habits and probably nocturnal and semi-aquatic; it is solitary though at times it may be observed in pairs. It feeds on fish, crustaceans (Emmons & Feer, 1990) and occasionally on lizards and birds (F. A. Arosemena, pers. obs.); the gestation period is approximately 75 days (Eisenberg, 1989).

Family Procyonidae: The main characteristics common to all members of this family is a somewhat long tail, marked with light and dark rings; its habits are similar to those of the bear

with the exception of two species of pandas that belong to southeast Asia, the rest of the procyonids are americans; in Panama we find six of these species, all of these are represented in the study area.

Procyon cancrivorous: The mangrove cat or racoon is one of the most common species, in many of the study sites it is considered as uncommon or scarce; in the area of study it was found only in Fort Sherman, lower part of the Chagres River, between Gatun Lake and Fort San Lorenzo. The main threats to this species are water pollution and deforestation.

It inhabits humid tropical forest and mangrove areas, wooded regions and lagoons, it is a species of nocturnal habits and is semiaquatic; it is solitary species though at times it may be observed in pairs. It feeds on fish, crustaceans, mollusks and some amphibians and insects (Emmons & Feer, 1990); the gestation period is approximately 73 days.

Procyon lotor: This species of mangrove cat or racoon is more common than previos species in many sites in the study area; in the area of study it was found only on Limbo River, Pita Road and the Metropolitan Natural Park. This species has similar habits and ecology to the previously mentioned species.

Nasua narica: The gato solo or coati is one the most common and most frequently observed species in all the Canal Area; in the study area it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Syristes River, Limbo River, Summit, Pita Road, the Metropolitan Natural Park, Cocoli, Plantation Road, San Juan de Pequeni, and the lower part of the Chagres River between Gatun Lake and Fort San Lorenzo. The main threats to this species are its being hunted for its meat and being kept as a pet; also the deforestation is one of the influential factors regarding the distribution of this species.

It inhabits humid tropical forest, underbrush and secondary forests zones; it is a species of diurnal habits and is terrestrial and arboreal; it is a solitary or gregarious species, usually observed in groups of 5 - 30 individuals, generally juveniles or subadults. It is an omnivorous species and feeds on fruits, invertebrates and other small vertebrates (Emmons & Feer, 1990); The gestation period is approximately 77 days (Eisenberg, 1989).

Order Perissodactyla

Family Tapiridae: The tapirs are coarse, corpulent animals which represent the only perisodactyls indigenous to the western hemisphere; its small trunk seems to it to the elephant to which it has no phylogenetic ties. Only four species of tapirs exist in the world, one is the asiatic and the rest are american; only of these species is represented in Panama.

Tapirus bairdii: The tapir was extinct in the study area and was later reintroduced; individuals found on Barro Colorado Island are descendants of the reintroduced animals and the lone tapir in Fort Sherman area probably escaped from an existing zoo in the area. Due to the strong threat existing to this species, CITES includes it in the Appendix I and IUCN

considers it an endangered species; the main threat to this species is hunting and destruction of its habitat.

This species has nocturnal and diurnal habits, is solitary is occasionally observed in the same area in family groups (parents and offspring); it lives mainly associated to swamplands, lagoons, rivers and creeks. It feeds on grasses, new leaves, fruits and occasionally the bark of some trees. (F. A. Arosemena, pers. obs.); it inhabits humid tropical forests, mainly in places devoid of human activity; it produces only one offspring after three months os gestation (Eisenberg, 1989).

Order Artiodactyla

Family Tayassuidae: The wild boars are the only members of this family; they are very similar to the pig to whom they are related; but its most important features are a more bristly skin and more compact body than its Old World forebears (Méndez, 1970). In Panama, the family is represented by two species, one of which, the mountain pig (Tayassu pecari), is extinct in the study area.

Pecari tajacu (=Tayassu tajacu): The wild boar is one of the large mammals represented in the wooded zones of the study area; in the area study it was found in Fort Sherman, Barro Colorado Island, Gigante Peninsula, Syristes River, Limbo River. The main threat to this species is being hunted for its meat and the destruction of its habitat; both of the Panama species belonging to this family are included in the Appendix II of CITES.

It inhabits humid tropical forests, it is a species of diurnal, and nocturnal habits and is terrestrial; generally the males are solitary but the females, juveniles and subadults are gregarious, they may be observed in groups of 1 - 20 individuals, it is however normal to see groups of 6 - 9 individuals. It is an omnivorous species feeding on fruits, palm seeds, roots, tubers, invertebrates and other small vertebrates (Emmon & Feer, 1990); The gestation period is approximately 116 days (Eisenberg, 1989).

Family Cervidae: This family demostrates the most outstanding features of the Artiodactyla Order, such as being absolute ruminants and having a complex four-chambered stomach; with few exceptions they grow simple or branched frontal horns which are almost always characteristic of the males who periodically shed them.

Mazama americana: The corzo deer is observed occasionally and is considered relatively scarce in the study area; it has been found in the area of Fort Sherman, Gigante Peninsula and Syristes River. The main threat to this species is hunting and the destruction of its habitat.

It inhabits mainly wooded areas, semideciduous tropical forests, although it can adapt easily to open zones close to plantations and gardens; it is solitary diurnal and small groups nocturnal. It feeds on grasses and tender leaves, fruits and flowers, during the dry season

it includes fruits and mushrooms in its diet; its gestation period lasts seven months (Eisenberg, 1989; Emmons, 1990).

Odocoileus virginianus: The white-tailed deer is observed with relative frequency in the study area; it has been found mainly on Gigante Peninsula, Limbo River, Pita Road and in the area of Cocoli. The main threat to this species is hunting and destruction of its habitat.

It inhabits open areas and secondary forests that border old forests, mainly in zones of lower elevations; they are solitary individuals though at times may be observed in small groups, with diurnal and nocturnal habits. It feeds and tender leaves, fruits and flowers; its gestation period is seven and half months (Eisenberg, 1989; Emmons, 1990).

(3) Freshwater

Order Sirenia

Familia Trichechidae: In this family are the only strictly aquatic mammals existing in the Canal Area; three species represent this family, two of which live in America and the third which is exclusive to Africa.

Trichechus manatus: The manati is a species that was introduced to the Canal Area at Gamboa on Lake Gatun in 1962; it is a species included in the Appendix I of CITES. As pointed out by Dr. Smythe, it has extended is distribution to Miraflores Lake, passing through the locks. It has also been observed in the areas surrounding Barro Colorado Island; the present population may be the descendants of the introduced individuals.

This species is totally herbivorous, including in its diet marine grasses, water hyacinths and mangroves. Only one offspring is produced after three months of gestation.

(4) Marine Waters

Order Scleratinia

Siderastrea sp. nova: This marine inventory found that the only rare, unique and possibly endangered marine species in the study area is related to the discovering of the genus *Siderastrea* in the Pacific. As been pointed out, this is the first report of this genus in the eastern, central and western Pacific, and up to this moment the species has not been already described. This small colony of *Siderastrea* was observed at Uraba Island, near the Pacific entrance to the Panama Canal, forming a fragile population.

Order Testudines

Although the sea turtles were not observed during the samplings, their distribution includes the study area. The endangered species of turttle that are more frequent in the panamanian coasts are the following:

Chelonia mydas: Green turtle, is distributed in all tropical seas with the exception of the eastern Pacific Ocean. They feed on marine grass and seaweeds.

Chelonia agassizi: East Pacific green turtle it is found from Mexico to Peru and the Galapagos Islands. Eats seaweeds.

Eretmochelys imbricata: Hawksbill. Tropical oceans near coral or rocky reefs.

Caretta caretta: Loggerhead. Subtropical, all oceans. Eats molluscs and crabs.

Lepidochelys olivacea: Olive ridley. Tropical, mainly East Pacific, northern Indian and South Atlantic Ocean. Eats crustaceans, fish eggs and some vegetation.

Dermochelys coriacea: Leatherback turtle. Nest in tropics but wanders to temperate, even sub-artic waters. Eats jellyfish.

e) UNIQUE COMMUNITIES

This inventory did not find unique community within the study area. All of the observed biological communities, including those with great biodiversity and high ecological sensitivity, as climax tropical forest, mangroves and coral reefs are repeated along the Republic of Panama. However, some of these communities in the study area are under great pressure from agriculture, cattle raising, urban expansion, and even in some cases affected by pollution. Although, these communities are not uniques, they have an important biodiversity that should be kept and preserved, for instance:

-climax forests within the Panama Canal watershed have been altered in almost 70% due to the previously described processes within this report. Among the consequences from this loss are the erosion of soils, an increase in the silting of the Canal lakes, impoverishing of the water quality in rivers and lakes, decrease of habitats for numerous wildlife species, and in general, the loss of the biodiversity.

-mangrove forests are a permanent victim of aggression due to the reclaimation of coastal lands for the agriculture, cattle raising, urban development, harbor constructions and pollution. Their ecological role for the tropical coastal zone has been remarked in this report, specially regarding to their function as nursering ground for many aquatic and marine species, and also as an important primary producer.

-coral reefs are very fragile biological communities. The coral reefs within the study area in the Caribbean were highly impacted during the construction of the Panama Canal and more recently by the development of the oil refinery. At present, the major threats for the coral reefs in this area are the oil pollution and the increase of silting due to the deforestation of coastal lands. In the Pacific area, the few coral reefs that still alive are in a very precarious condition with a reduced living coverage that represent less than 10%. The disturbance from natural events such as El Niño 1982-1983 together with some

particularly intense upwellings in the Gulf of Panama have been responsible for massive coral mortalities. This community, already subjected to stress, could collapse in front of a new pressure as the sewage and oil pollutions.

5) CONCLUSIONS

a) TERRESTRIAL

(1) Flora

-Original plant cover (tall forest) has been reduced to aproximately 30% of the area and on cleaared land a mixture of extensive grazing lands, secondary forest (pioneer, early secondary and late secondary) and abundant but small food cultivation patches that were established by a slow but continuous process of colonizaton. This deforested area also includes all land occupied by lakes, engineering structures (Canal, roads, buildings and different types of instalation for the operation and maintenance of the Canal), human dwelling places of the settlers are included.

-The reduction of natural plant cover increases erosion and silting rates and threatens the expected operational life of the canal. This condition is not very serious in the lower wartershed due to a relatively gentle topography of the area but on the high watershed with rough and step topography and higher rainfall the situation requires inmediate attention to protect the Canal operation.

-We did not find important volumes of commercial timbers in the area as to support a reasonable yield felling operation. Extraction of valuable timbers has been in progress at artisanal level for long years even before the construction of the Canal and even this is not recommended activity for the area it is a low scale damage and offers no significative threat.

-The study area is located in the "tropical humid", the most extensive life zone of the Republic of Panama and practically all the species collected are also present in sites adyacent to the study area.

-Protected areas quickly return by natural succesions to a forest type cover. This procees should be complemented with forest plantation with native species on those sites so deteriorated that the natural regeneration becomes difficult.

(2) Fauna

(2.1) Entomology

-Insect groups of medical importance such as the Culicidae and Ceratopogonidae Families (Diptera), including species of *Culicoides* were collected in high numbers and found in relatively stable populations, especially at Arenosa. The sampling period, although short, produced a good number of species as was also the case of *Lutzomyia* (Psychodidae), collected in smaller numbers. It is possible that this situation is due to the stability derived from the presence of permanent aquatic environments and the humidity which was typical in the sampling areas.

-Other groups, although of lesser importance, but found in relatively high numbers were the Calliphoridae, Muscidae, and Sarcophagidae (Diptera), Formicidae (Hymenoptera); Staphylinidae (Coleoptera), and Acari.

-*Culex* was the predominant genus found in al the localities; it is capable of transmitting filariasis and the encephalitis virus. *Anopheles* was particularly abundant at Gamboa and Arenosa. *A. albimanus* which was collected throughout this study is the principal vector of malaria in the region. *Aedes and Mansonia* were more abundant in Gamboa and are potential vectors of the Venezuelan equine encephalitis.

-Forty three species of the *Culicoides* were obtained and the group was particularly abundant and diverse at Arenosa. Among the collected species it is worth mentioning *Culicoides furens, C. guyanensis, C. reticulatus, C. iriartei, C. camposi* and *C. paraensis*, wich are the mosrt important because of their anthropophilic habit.

-Six out of seven anthropophilic species of *Lutzomyia* known as vectors of leishmaniasis in the region were also collected. These were: *L. gomezi, L. olmeca, L. panamensis, L. pessoana, L. trapidoi*, and *L. ylephiletor.*

-Four species of *Chrysomya* (Diptera:Calliphoridae) introduced from Africa through South America were found practically displacing *Cochliomyia macellaria*, a necrophagous species in the area.

-Although Arenosa was the locality with less diversity, the general abundance and diversity of insects found indicate that there was not a marked predominance of any major taxonomic group or species, as it usually happens in more disturbed environments.

-A total of 56 Families of beneficial insects that act as natural enemies of pests were collected. Thirty one of these belong in the Hymenoptera.

-The presence of insects important to forestry or agriculture was of little significance. However, the following groups found are worth mentioning: Cerambycidae, Buprestidae, Curculionidae, Scolytidae, Chrysomelidae (Coleoptera); Noctuidae, Pyralidae, and Gelechiidae (Lepidoptera); Aphididae, Cicadellidae, Delphacidae, Cercopidae (Homoptera); Tephritidae, Agromyzidae, Cecidomyiidae (Diptera); Pentatomidae, Miridae, Tingidae (Hemiptera); Acrididae (Orthoptera).

(2.2) Herpetology

-The herpetofauna of the Canal Area has been surveyed since the last century, knowledge that has been increasing through the years, and at present been the better known of the whole country. We concentrated our studies to several sites that had a limited extension; which were visited regularly for a period of about one year, according to preestablished conditions. Considering these limitations, we have estimated that most of the common species present in the study sites have been sampled.

-The anurans are relatively better represented in the study, since they were detected by their vocalizations or found in places were they tend to concentrate. In the opposite extreme, are the snakes, which are observed sporadicly.

-During this study a total of 60 amphibians and 58 reptiles were found. Of all the study sites, Cirí had the least species diversity; whereas Pequení and Corte Culebra had highest diversity. This could, in part, be related to the habitat diversity present in the latter two sites; while, Cirí is mostly pasture land with very reduced forested areas.

-The species composition and abundance varied according to the study site. The frogs *Centrolenella fleischmanni*, *Eleutherodactylus fitzingeri* and *Hyla microcephala*, and the lizard *Anolis limifrons* are considered as common in all the study sites. The species found in the study sites were observed in different types of habitats and specific sites within them. Some species only live in the open areas, other exclusively inhabit the forest.

-The walks along the transects show the existence of seasonal changes in some anuran species. The frogs living in the forest floor tend to concentrate in moist areas along the margins of streams during the dry season, but with the beginning of the rains they disperse throughout the humid forest floor. Some anuran species aggregate in the margins of ponds or streams to reproduce during the wet season, being absent during the dry season. This seasonality in the reproductive behavior of many anurans is evident at the beginning of the rains with the formation of choruses within the surroundings of suitable sites for breeding.

-The threatened or endangered species, specifically the caiman (*Caiman crocodilus*), the crocodile (*Crocodylus acutus*) and the green iguana (*Iguana iguana*), with exception of the first one, are observed infrequently in the study sites. In the sites were caimans were observed they were numerous, this was not the case for the crocodiles. In those sites inhabited by humans, the green iguana is observed infrequently, because it is hunted indiscriminately even during the close season.

(2.3) Ornithology

-For the surveyed habitats on selected sites 386 species were registered.
The place with the greatest number of species was Gaillard Cut, followed by Pequení, North Entrance, South Entrance, Cirí, and Tranquilla. The first four contain more species since they keep some of their forest cover, whereas Cirí and Tranquilla are much disturbed, pasture lands are dominant. Gaillard Cut since located on the continental divide presents species from both slopes which favors the increase in species.

-The forest was the habitat with the greatest number of species, followed by the aquatic and littoral, and the open area. The least abundance of species always corresponded to the marine habitat. Passeriformes and Emberizidae constituted the most representative taxa and *Cathartes aura* the species with the greatest number of individuals.

clear shift only in the increase of snail density in the littoral This fact may be related to the well known association of snail species with macrophyte grows.

-The mollusks and annelids contribute greatly on the numerical density of the zoobenthos in Gatun Lake, constituting approximately 40% of the total benthic population. These figures are not comparable with other lakes, where chironomid larvae and nematodes made the bulk (up to 90%) of the benthic macroinvertebrate fauna.

-There are not great changes in the structure of the zoobenthos between different water depths in a particular region of Gatun Lake. The common pattern of distribution is that most species are present throughout a region extending from the shoreline down to the profundal changes in the structure of zoobenthos in Gatun Lake can be seen is a shallow one and subject to constant mixing of its waters, benthic productivity increases notably. However, relatively deep stations, which undergoes continuous mixing of its waters has population densities of benthos comparables to shallow well-mixed stations. It is likely that dissolved oxygen is of prime importance in the depth distribution of benthic animals in Gatun Lake.

(5) Fishes and Macroinvertebrates

-Excluding the recently introduced species *Colossoma macropomum, Cyprinus carpio, Oreochromis niloticus*, and *Astronotus ocellatus*, from the 26 freshwater and peripherical fish species collected during this inventory, all had been reported previously in rivers and creeks near the area of study. It is important to note that many of the peripheric and freshwater species have been reported particularly in creeks and rivers out of the study area.

-The outstanding fish species *Cichla ocellaris*, fish accidentally introduced into the Gatun Lake by 1967, represented the most abundant and predominant fish specie. There is evidence that suggests this fish reduced the populations and eliminated by predation 6 of the 14 species of native fish (mainly characids and poecilids) that inhabited the reservoir. The most important species of macroinvertebrates collected during this inventory had been reported in previous studies.

(6) Commercial and Sport Fisheries

-At present, the fishing activities involving the peacock cichlid fish (*Cichla ocellaris*), are defined in three categories: commercial, subsistence, and sport. These activities are of great importance to the inhabitants of the Panama Canal watershed since they provide sources of direct and indirect employment, as well as a steady food supply.

-There is a fish production estimate of 150 to 300 metric tons per year in Lake Gatun, while for Lake Alajuela this figure may vary between 20 to 50 metric tons.

weed control). As in many other reservoirs in the tropics, species diversity is very low as compared with terrestrial ecosystems.

-The dynamic processes of the Panama Canal Aquatic environment, associated to the canal operations, to the climate, principal land use pattern in the watershed, development in forested areas, greatly contribute to maintain optimum conditions for aquatic vegetation growth.

-The plant community displaying greater variability in its abundance in response to seasonal changes, are the free floating macrophytes. Spatial and/or temporal distribution of some free floating macrophytes, i.e. *Pistia sp.*, as well as their abundance, seem to be associated with more long lasting cycles other than seasonal climatic changes.

-Relatively more stability is displayed by emergent and lakeshore macrophytes, especially in areas protected from the winds and not subject to the influence of great rivers.

-Macrophytes distribution is subject, in a large extent, to the gradient of natural and cultural factors posing selective stress at each phase in the process of natural succesion.

(4) Benthos

-Ecologists make use of certain index organisms to distinguish the various natural benthic assemblages known as communities. Bottom faunas differ greatly in various kind of lakes and the differences are often numerous and complicated. The numerical dominance of a certain species or group of species does seem to be characteristic of certain kind of lakes. It is very likely that the zoobenthos of most lakes containing several hundreds species and at least ten phyla.

-The zoobenthic community of Gatun Lake is not diverse and consists of a few species belonging to at least six phyla: Mollusca, Annelida, Arthropoda, Crustacea and Bryozoa. Thus, this small artificial lake in the tropical zone, a lake that does not possess a particularly wide range of benthic habitats, probably contain only a half a dozen phyla of macroinvertebrate on its sediments.

-Important relationships among the benthic organisms can be seen by a comparison of the littoral and profundal fauna. In very productive or relatively deep tropical lakes which do not undergo seasonal mixing, the hypolimnetic water strata undergo a severe oxygen reduction and increases in the metabolic products of microbial decomposition; the benthic fauna adapted to these harsh conditions decreases markedly. Therefore, a commonly observed community structure consists of a rich fauna with high oxygen demands in the littoral and a more homogeneous with lower species diversity fauna in the profundal.

-There is little variation in the specie richness between the littoral and profundal regions in Gatun lake. The benthic macrofauna of those two regions are basically the same, with a

b) FRESHWATER

(1) Water Quality

-To evaluate and define the stage of eutrophication of Alajuela and Gatun lakes, available data on dissolved oxygen, phosphate, and iron for both lakes has been compared with the typical concentrations that characterizes each of the stages of eutrophication, according to Cowgill (1975).

-As typical for the bottom waters of Lake Alajuela, the following concentrations has been taken for comparison: dissolved oxygen (2 ppm), phosphate (0.001-0.030 ppm) and iron (0.060-0.150 ppm). These values indicate low concentration of oxygen, the absence of sulphide ion, and a quite low concentration of phosphate and iron. These datas portray conditions to classify the Lake Alajuela in the meso-eutrophic stage III.

-Concerning the bottom waters of Gatun Lake, concentrations taken for comparison follow: dissolved oxygen 5-6 ppm; phosphate 0.010-0.040 ppm; and iron 0.030-0.300 ppm. These values indicate good oxygenation and quite low concentrations of phosphate and iron, and portray conditions to classify Lake Gatun in a meso-eutrophic stage II of eutrophication.

-Altogether, it seems that waters of lakes Alajuela and Gatun, are in good conditions. However, bottom waters of the Chagres River, down Lake Alajuela, constantly revealed an oxygen deficiency.

(2) Sediments Quality

-Granulometric analysis of samples collected showed that the sediments of Gatun Lake are dominated by fine grained particles such as silt and clays.

-In general, there is a constancy in the concentration of organic matter in the sediments from the aquatic system of the Panama Canal. There was not detected any seasonal trend.

-As with the total nitrogen, the level of heavy metals in the sediments of the study area indicate no significant changes in their concentration and geographical distribution during the year. However, a few changes take place during the rainy season, during which a significant increase in the iron concentration, and a sligth increase of zinc was observed.

-On the whole, the concentration of heavy metals in the sediments of the aquatic system of the Panama Canal are generally within the normal range and there is no evidence of water pollution.

(3) Aquatic Macrophytes

-Information collected during distribution studies of floating aquatic macrophytes, reflects a clear temporal and/or seasonal situation and, in some areas as well as cultural (aquatic

-In the surveyed area species threatened, endangered, game, raptors, and sparrows dwell. The work area is part of the migratory route followed by many birds. Here, a total of 82 species arrived, of which 47 are wintering and 46 are just transient. There are 326 local species. At each habitat of each site, the number of local birds species and individuals was always dominant over the migratory, although sometimes there could be displacement by the latter.

-In general, and for each site and for each habitat, a seasonal characteristic was evident, where the number of species and of individuals increases as the rainy and migratory season progress, reaching its highest amounts toward the climax of the rains and zenith of the North-South migration in November, to then decrease to the dry season. This is evident for the migratory for which huge groups can be observed returning from the South to the North in February-March. Birds located in each of the habitats and sites studied utilize the area carrying out all the activities that allow them to live there in the present conditions.

(2.4) Mammals

-The overall impression is that the area of the Parque Nacional Soberanía, the Barro Colorado Nature Monument and the west bank of the canal opposite Gamboa together constitute a refuge for many mammalian species which should be more widely distributed in Panama, and that hunting and habitat destruction have rendered such areas as the land around the Trinidad arm of Gatun Lake and the area around Alajuela Lake practically sterile with regard to non-volant mammal species.

-"Sport", "pot" and "market" hunting have resulted in the disminution of populations of mammals including: the paca *Dasyprocta punctata*, zaino *Tayassu tajacu*, the corzo deer *Mazama americana*, white tailed deer *Odocoileus virginanus*, the rabbit *Sylvilagus brasiliensis*, and the local extinction of the wild boards *Tayassu pecari*, the spider monkey *Ateles geoffroyi* and tapir *Tapirus bairdiii*. Hunting for the mascot trade also reduced populations of *Cebus capucinus* and *Saguinus geoffroyi*. A combination of reduced potential prey populations and hunting was probably responsible for the reduction of carnivore populations, particularly the felids, in the area and the probable local extinction of the cougar *Felis concolor*.

-In the most rural regions the mammal fauna is greatly reduced. Some marsupial and edentates can be found wherever there are substantial patches of young forest. In the more residential outlying areas most of the species of the rural areas are also found, and are somewhat more abundant. In addition, particularly in such areas as Balboa and the military reservation housing areas, *Dasyprocta punctata*, *Agouti paca*, *Nasua narica*, *Procyon lotor* and *Odocoileus virgianus*, may be fairly abundant.

(7) Aquatic Mammals

-Only one species of mammals in the study area was genuinely aquatic: the manatee *Trichechus manatus*. Manatees were introduced in Gatun Lake in 1962. There are also five species of semi-aquatic mammals: the water opossum, the otter, the capybara, and two small rodents of the genus *Oryzomys*.

-The otter has steadily increased in numbers since the introduction of the peacock cichlid (*Cichla ocellaris*) into the study area in 1967 and it now found throughout the Gatun Lake, in the middle and upper Chagres River, over Lake Alajuela, up to major tributaries of these water bodies, and in many lakes and small ponds within the study area.

-The capybara arrived in the Gatun Lake area sometime in the early 60's, having spread westward from the Pacora marshes and down the upper Chagres. Capybaras are now found anywhere where there are grassy patches near bodies of water on both sides of the canal.

c) MARINE WATERS

(1) Oceanography and Water Quality

-The water mass in the Bay of Panama presented sharp differences between the rainy and the dry season. During the rainy season (May to December) there is an uniform distribution of properties in the water column, including the lack of thermal stratification. The mixed layer is characterized by: warm temperature, low salinity, low nutrient concentration, and low levels of chlorophyll *a*. During the dry season (January to April) takes place the upwelling event with low sea temperature, pronounced increase in the salinity, augment of dissolved nutrients and high concentration of chlorophyll *a*.

-The oceanography conditions in the Caribbean showed an annual cycle similar to that of the Bay of Panama. During the rainy season the sea water properties are uniformly distributed in the water column. The sea temperature is high, the salinity low, the dissolved oxygen high, low the concentration of nutrients, and low the chlorophyll *a*. During the dry season the salinity is increased, suggesting the presence of oceanic water within the area. However, the concentration of nutrients and chlorophyll *a* is relatively lower than observed in the Pacific.

-The water quality observed very small symptoms of pollution in both oceans and most of this is related to sewage. In general, the water quality in the project area is considered as good.

(2) Sediment Quality

-The sediments from the sampling station in the Pacific study are mostly muddy.

-The sediments from the Caribbean sampling stations was composed of a mixture of medium and fine sands, and silts and clays.

-The concentration of total nitrogen in the sediments from the Pacific and the Caribbean remained fairly constant throughout this study. In general, the concentration of organic nitrogen ranged from 100 to 350 ppm (0.10 to 0.35%). The ratio between the total organic carbon and the organic nitrogen varied from 10:1 to 15:1.

-The concentration of heavy metals, both at the Bay of Panama and in the Caribbean, are within the normal range reported for coastal areas. However, the concentrations of iron and manganese in the Caribbean are higher than the reported for the Bay of Panama.

-The hydrocarbons were at low levels of concentrations in most of the sampling sites, and do not suggest an important accumulation of oil. However, some moderate concentrations were observed in some points within the navigation channel and in the anchorage sites of the Panama Canal.

(3) Corals, Mangroves, and Marine Grass

(3.1) Corals

-The diversity of the corals within the study area represents 53% and 82% of the diversity reported for the Caribbean and Pacific coast of Panamá, respectively (Holst & Guzmán 1993). The diversity of octocorals is less than 30% of the species reported for the rest of the country.

-In summary, the coral reefs at both ends of the Panamá Canal are not in good conditions. It is evident that the lack of management and protection in this part of the panamanian coastal zona has lead into an irreversible impact on the reef. The recovery of these reefs is conditioned to the recruitment of new organisms in the area (*sensu* Guzmán et al. 1991). In order to achieve this it is necessary that, at least, some of the chronic environmental stressors affecting the area should be controlled, or cutted off. This central part of the coastline of Panamá hold most of the industrial and urban development, thus making this area succeptible of future environmental impacts. The extended lack of management and protection of this resource, here and in other part of the country (i.e. Gulf of Chiriquí, Bocas del Toro, and San Blas), could impede the natural recovery of these reefs.

(3.2) Mangroves

-The occurrence of species within all sections, namely *Laguncularia racemosa*, *Avicennia germinans* and *Acrostichum* sp.

-The unique occurrence of *Mora oleifera* in the Río Caimito (Note: this site represents the northern extent of this unusal and uncommon tree; notable, since it has the largest cotyledons of any plant), and the putative *Rhizophora* hybrid, *R. harrisonii*, in the Río Perequeté (Note: there are, however, problems with diagnostic characters for this taxon, and its occurrence is likely to be more widespread).

-The occurrence of both forms of *Pelliciera rhizophorae* on both Pacific and Atlantic coasts (Note: the distinction between forms has not been noted prior to this report, indicating that occurrences of *Pelliciera* elsewhere need to be revised).

-The introduced mangrove palm, *Nypa fruticans*, in the Río Folk in Colón and Bahía Las Minas sections. (Note: these are under immediate threat by recent and on-going reclammation of mangrove forests around France Field and Colón); and,

-The different zonation patterns of species and their associations with each other, particularly noting the occurrence of *Laguncularia racemosa* in low intertidal positions and along rocky exposed shorelines of the Pacific coast, while this habitat on the Atlantic coast is occupied by *Rhizophora mangle*.

(3.3) Marine Grass

-The studied seagrass meadows proved to be similar to that described, in the vicinity of Bahia Las Minas.

-The zonation pattern throughout this area is also typical of many other areas in the Caribbean. Extensive seagrass meadows were found at locations wherever gradual coastal slopes prevailed and where water clarity was adequate.

-Despite the fact that seagrass total acreages are relatively small within the study area the ecological importance of the grasses should not be overlooked. Seagrasses provide juvenile and adult habitat for many species as demonstrated by the numerous fish and invertebrate species collected in this study.

-The loss of any significant part or the seagrass community on this coast may result in decreased stocks of the fishes that are commonly eaten by local inhabitants.

(4) Benthos

-Mean abundances and number of species was higher in the Caribbean stations than those of the Pacific.

-Mean abundances and number of species was higher for the offshore stations in the Caribbean than those within Limon Bay.

-Polychaeta, Crustacea and Mollusca predominated in the counting and mean abundances of benthic samples.

-Peracarids were the most abundant group in benthic collections. Isopods and gammaridean amphipods dominated.

-Species composition was relatively homogenous disregard water depth.

-Seasonal abundance fluctuation follows a typical one peak pattern in the Caribbean with a maximum density on July. In the Pacific, the seasonal abundance pattern showed two peaks of abundances in July 1992 and March 1993.

-A total of 171 species or taxa of benthic organisms were found in five cruises. Two new species were found in the Caribbean: a *Cyathura* isopod and a *Stylopoma* bryozoan.

-A total of 19 new records of benthic species were found including 8 species with extension of its know range to that of the Pacific study area. On the Caribbean, a total of 41 new records of benthic species were found including 23 species with extension of its known range to that of the Caribbean study area.

(5) **Meroplankton**

-Results showed a peak of abundance of meroplankton during November 1992, especially at station MM-02 (Pacific) and MM-08 (Caribbean), both located at the entrances to the Panamá Canal.

-The highest abundance of eggs of engraulid and clupeid fish was observed in the Caribbean area.

-The most common larvae of invertebrates at both sides were the Zoea, postlarvae of penaeid shrimps, and pteropod, gastropod, and bivalve larvae.

-Larvae of engraulid, carangid, mugilid, and sciaenid fish were common in samples collected during November 1992 at both entrances to the Panamá Canal. In general, the overall abundance of meroplankton is higher in the Caribbean than in the Pacific. This might be related to the role of coral reefs, seagrass meadows, mangrove forests and estuaries as spawning and breeding areas for many marine species.

(6) **Fish and Macroinvertebrates**

(6.1) Fish

-A total of 197 species of marine fish were collected during this inventory, 113 from the Pacific and 84 in the Caribbean. Among these, only 9 identical species were found in both oceans in contrast to the 12 reported by Briggs (1967). These results in comparison with those reported in 1970 by the University of Miami on behalf of the "Bioenvironmental and Radiological Safety Feasibility Studies Atlantic-Pacific Interoceanic Canal" shows that this Inventory has enriched the list of species reported for both the Pacific and the Caribbean, within the 50m isobath. However, the list of Caribbean species from the University of Miami is much higher than ours when considered the collection below the 50m isobath.

-The highest abundance and diversity of sublittoral marine fish was related to the proximity to estuarine areas and mangrove forests, that are nursering and breeding grounds to many

marine fish and invertebrates, specially in the vicinity of Chame (Pacific) and Bahía Las Minas (Caribbean). Fish were abundant in the Pacific at the beginning of the rainy season and this is believed to be related to the period that follows the dry season upwelling. The most frequent species in both oceans are ranked as secondary consumers (carangid and bothid fish) followed by primary consumers (gerreid fish).

-The species of *Lutjanus* and *Diplectrum* showed a gut content mostly comprised by crustaceans and small fish and they are ranked as third level consumers. The study of the gonad maturation revealed that these species had several spawnings: in August and October 1992, and in April 1993.

-The gonad maturation was observed to occur almost simultaneously in both oceans. The species of the sand perch *Diplectrum* showed sexual inversion or protandric hermaphroditism (males changed into females) in both oceans.

(6.2) Macroinvertebrates

-*Callinectes arcuatus* and *Arenaeus cribarius*, active predators, were the dominant taxa during the rainy season (August, July and December); but in dry season they were displaced by *Renilla amethystina* and *Penaeus braziliensis*. In May 1993, *Xiphopenaeus riveti* and *Arenaeus cribarius* were the dominant species.

-Most recorded species were located in the sublittoral zone both at the Pacific and in the Caribbean.

(7) Sport and Commercial Fisheries

-Most of the fishery resources of Panama are located in the Pacific. The most recent fishery prospections suggest that the extractable biomass in the Gulf of Panamá might be around the 400,000 m.t. per year.

-In the Caribbean, the most important resources are the demersal species. Among these are: the snappers, sharks, some carangid fish (jacks), and the pink shrimp.

-Most of the fishing effort is devoted to: the penaeid shrimps stock, the anchovetas and herring for the production of fish meal, and fish (mostly demersals) for the human consumption. This fishing activity involves some 10,000 peoples and it is mostly concentrated in the Pacific coast of Panamá. In the Caribbean, the fishing activity is of low intensity and mostly of the subsistence type.

-The sport fishery in Panamá is based on a few species and in general, sport fishery is considered a low intensity activity and the catch is believed to be small.

d) RARE AND ENDANGERED SPECIES

Within the study area many rare and endangered species were observed. Among these are included: 10 threatened plant species, 7 species which are considered rare, and 7 vulnerable. There was also found one plant species believed to be extinct in the area. Regarding the terrestrial fauna, 10 species of amphibians and reptiles considered as threatened species or endangered, were registered. Also, 10 bird species and 29 terrestrial mammals. An species of aquatic mammal and 6 species of marine turtles considered as endangered are reported for the area. Although no insect species considered as threatened or endangered were collected, 5 rare families of insects were found in the study area. The deforestation, the slash and burn agriculture, and the excessive hunting are the principal cause for this situation.

e) UNIQUE COMMUNITIES

Although no unique communities were found throughout the study, communities that are considered to have high biodiversity, ecologically fragile, were found. Examples of these are: climax forests, mangroves, and coral reefs.

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