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Aquatic macroinvertebrates of Rio Grande delta ponds

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AQUATIC MACROINVERTEBRATES OF

RIO GRANDE DELTA PONDS

A Thesis

by

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ABSTRACT

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The purpose of this study was to identify aquatic macroinvertebrates living in the vegetated margins of local ponds, to determine their relative abundances, and to construct a rapid bioassessment model. I collected macroinvertebrates seasonally from seven ponds in the Lower Rio Grande Valley. Collection sites included: Moore Airfield, Santa Ana National Wildlife Refuge, and Olmito Fish Hatchery. Twenty-eight samples were sampled and preserved at the University of Texas-Pan American. Seventy-six taxa were identified and were stored as a reference collection. Cluster analysis of the taxa and their relative abundances showed three distinct geographic patterns or regions. These patterns were verified using two additional collections, which formed a distinct primary cluster. A Lower Rio Grande Rapid Bioassessment (RBA) model was constructed using Plafkin's Environmental Protection Agency (EPA) Rapid Bioassessment Protocol III, a reference site, and eight community measures. The Rio Grande RBA can be applied across the region. Results showed eight sampling units as moderately/slightly impaired sites.

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CHAPTER I

INTRODUCTION

Rapid biological assessment (RBA) protocols and community methodologies have been developed over the past twenty years to efficiently categorize biological data used in assessing the biological integrity of freshwater environments and ecosystems. Biological integrity results from all components of an ecosystem functioning together as an integrated system. The lack of one or more components can impede an organism from establishing and maintaining itself. Biological assessment models provide quantifiable values and narrative categories for describing the integrity or quality of aquatic habitats, communities, and ecosystems.

All RBA models are calibrated from regional community data. Hughes and Larsen (1988) classified the United States by ecoregions; the Rio Grande Delta is located in parts of two ecoregions, the Southern Texas and the Gulf Coast Ecoregions. The ecoregion concept (Omernik 1987) is based on grouping regions that have similar terrain, soil texture, land use, and natural vegetation. Most federal and state regulatory and monitoring agencies have adopted this regional classification scheme. This scheme is used as a tool to provide a geographic framework to manage aquatic ecosystems and their components efficiently. All regional classifications are based on the observations that aquatic ecosystems reflect the land they drain, and the land reflects the water bodies it encompasses (Plafkin et al. 1989).

This study was located in the Tamaulipan Biotic Province and the Matamoran subprovince (Dice 1943, Blair 1950). Irrigation, agriculture, and municipal growth have affected the region's terrestrial environments and biotic communities. More than 95% of the original native brushland and plant communities have been cleared for a variety of uses that range from farmland to municipal and industrial expansion. Also, more than 90% of the riparian habitat on both sides of the Rio Grande has been cleared. In addition, large scale flood control, irrigation, and municipal projects have resulted in extensive brushland clearing (Jahrsdoerfer and Leslie 1988).

Lower Rio Grande and the Rio Grande Delta

Locally, the Lower Rio Grande is considered the river section from Laredo to the Gulf of Mexico. The section from Laredo to Falcon Reservoir has a hard, rocky bottom and alternates between a series of riffles, runs, and pools. The river between Falcon Reservoir and Roma is a natural continuation of the upstream section but has been altered in several ways. One way is by turbidity and sediment loads which have been reduced by sedimentation in Falcon Reservoir. Another way is by the natural erratic river flow. The Rio Grande enters the delta near Anzalduas Dam, south of Mission, Texas. Ninety-eight percent of the population in the Lower Rio Grande Valley receives drinking water from the river, and more than 70% of the water that enters the Delta is used for irrigation (Jahrsdoerfer and Leslie 1988).

The Rio Grande delta is flanked by plains which originated as unconsolidated sediments deposited horizontally in the Gulf of Mexico approximately 10,000 years ago (Fulton 1976). The history of the river during this period is recorded by regional sediment deposition. The elevation of the delta ranges from sea level at the Laguna Madre to between 106.7 and 114.3 meters near the western Hidalgo County line. The delta is marked with a number of resacas, which are narrow, meandering, former channels of the Rio Grande (USDA 1969). Resacas receive runoff from agricultural fields and municipalities. Most resacas are connected to irrigation systems and provide a place for municipal water storage. They also provide habitat for wildlife, as well as fishing, boating, and residential uses (Jahrsdoerfer and Leslie 1988).

Rio Grande Delta - Agriculture, Irrigation, and Drainage

The Rio Grande Delta region is semiarid with irregular rainfall and flooding. The region's climatic characteristics, physical features, and availability of river water led to the development of large scale irrigation systems that could supply large scale agriculture. Prior to the development of drainage systems in the 1900's, the delta's poor surface drainage and periodic flooding helped to maintain numerous resacas and ponds in the region. Irrigation systems were developed and financed by private interests (Jahrsdoerfer and Leslie 1988). Land developers began building large scale irrigation canals in the early 1900s. In the early 1920s, irrigation districts were organized with each district buying the irrigation system from the developers, while the water was sold to private interests for irrigation. Early irrigation systems only utilized the Rio Grande floodplain. However, through the years, these irrigation systems continued to expand (both sides of the border) beyond the floodplains. They supply water to all but the smallest municipalities (Jahrsdoerfer and Leslie 1988).

Currently, the volume of river flow and delta flooding are largely controlled by dams and the management of the reservoirs. Falcon Dam and reservoir are located on the main channel. Two of the three major tributary systems originating in the mountains of northern Mexico are also dammed: El Cuchillo Dam is on the Rio San Juan and Venustiano Carranza Dam is on the Rio Salado. The Rio Alamo is not dammed. The Rio Salado system joins the Rio Grande main channel at Falcon Reservoir, the Rio Alamo joins the main channel just upstream from Roma, and the Rio San Juan joins the main channel near Rio Grande City. Two additional dams, Anzalduas Dam and Retamal Dam, are present on the main Rio Grande channel as it meanders through the delta. These dams are designed to pool water that can then be pumped and used for agricultural irrigation, municipal drinking water, and industrial uses.

Drainage systems have been built throughout the irrigated region, including urban and rural areas. These extensive networks serve several functions: they drain poorly drained areas; they collect shallow, subsurface agricultural runoff to limit salt accumulation in the soils; and they collect municipal runoff and treated municipal waste water. In the middle and upper valley, the ditches act as tributaries which eventually form the Arroyo Colorado-North Floodway system (Jahrsdoerfer and Leslie 1988) that empties into the Lower Laguna Madre. Most drainage in the lower most part of the delta is returned to the Rio Grande or to the Brownsville Ship Channel.

Rio Grande Delta Ponds

This study concentrated on the aquatic macroinvertebrates living in local ponds. Two types of ponds were sampled in this study, a reservoir pond and modified resacas.

The reservoir pond is located at the United States Department Agricultural Center at Moore Airfield. The pond serves as the source of water for the center and is supplied by an irrigation canal. The pond is near the northwestern limits of the irrigation system. The second type of pond sampled was a modified resaca. Six ponds of this type were sampled, three in Santa Ana National Wildlife Refuge and three in Olmito Fish Hatchery, which is currently used by the Texas Parks and Wildlife Department (Fig 1). The Olmito ponds were constructed by a subdivision of the Resaca Del Rancho Viejo. Pond water levels are maintained during dry periods by controlled flow from an irrigation canal. Water levels at the three Santa Ana ponds are controlled by various methods including irrigation canals and well water.

Ponds are made up of several zones influenced by light penetration (Smith 1992). These zones include: a littoral zone, limnetic zone, profundal zone, and benthic zone. The littoral zone is the shallow water zone of rooted vegetation which provides structure and surface area for periphyton growth. These factors produce the greatest diversity of macroinvertebrates of any pond habitat (McCafferty 1981, Smith 1992) and were investigated in this study because of its diversity.

Other Delta Streams

The Arroyo Colorado is the only natural stream found within the Texas Rio Grande Delta. The arroyo has been greatly modified to form the heart of the upper and mid valley flood control and drainage system. The arroyo originates south of the Mission-McAllen area in Hidalgo County, flows eastward paralleling the Rio Grande to Harlingen, and turns northeast to the Lower Laguna Madre near the northeast corner of

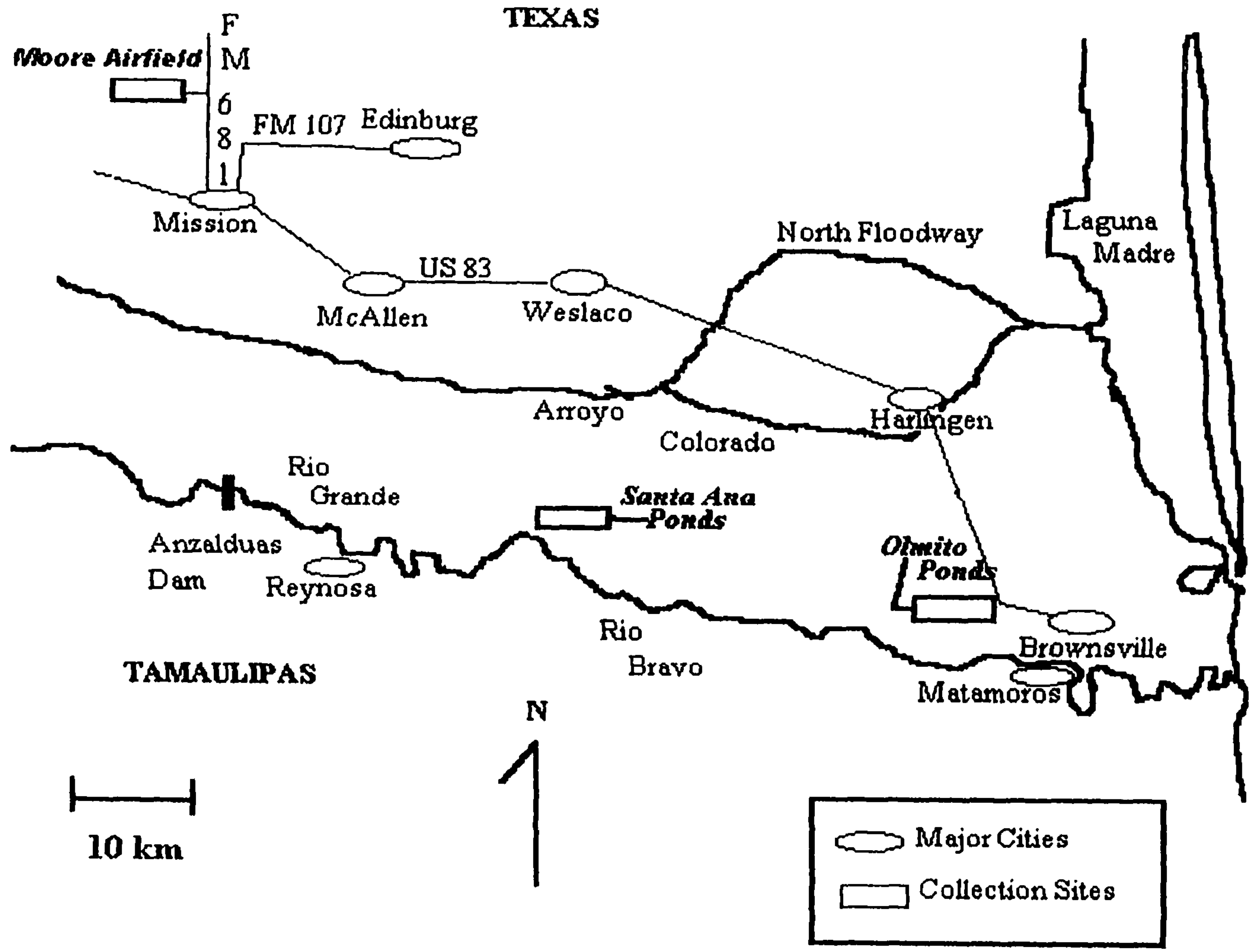


Figure 1. Map of the Rio Grande Delta Study Sites.

Cameron County. The North Floodway is a man-made channel that originates from the Arroyo Colorado about 24 km west of Harlingen near Mercedes. It flows northward about 24 km and then eastward to the Laguna Madre. In addition to excess floodwater from the Rio Grande, the Arroyo Colorado and North Floodway systems carry local storm drainage, natural seepage, agricultural runoff, and treated municipal waste water (Jahrsdoerfer and Leslie 1988).

Previous Studies

Previous studies of aquatic invertebrates in of the Rio Grande Delta are listed in Table 1. The bivalve fauna from the lower portion of the Rio Grande was surveyed by Neck and Metcalf (1988). They found nine species of unionide, two species of fingernail clams, and the introduced Asiatic clam. Neck & Metcalf (1988) concluded that the native fauna has been affected by river impoundment, agricultural redistribution of water, and water pollution.

Landry and Harper (1990) sampled soft substrate invertebrate communities along the Rio Grande between Falcon Dam and the Gulf of Mexico. They also sampled the lower Arroyo Colorado (Landry and Harper 1990).

In 1991 the Texas Water Commission (TWC) reviewed the existing database of toxic substances and suggested that it was not adequate. To correct this, the TWC broadened the spectrum of toxic substances sampled to include organic solvents and metals in water, sediment, and fish tissue (TWC 1992). Between 1992 and 1993, a more intensive study of the Rio Grande was conducted by agencies from both Mexico and the U.S. Study participants included the Texas Natural Resource Conservation Commission,

Table 1. List of studies on aquatic macroinvertebrates in the Rio Grande Delta.

Author	Year	Taxa	Locations	Habitat
Ideker	1979	Aquatic snails	Santa Ana National Wildlife Refuge	Leveed ditch
Ideker	1979	Dytiscidae	Laboratory experiments	Laboratory setting
Neck & Metcalf	1988	Freshwater Bivalves	Rio Grande below Falcon Lake as wll as distributaries of the river. Counties of Cameron, Hidalgo, Starr, and Zapata	Soft substrate, sandstone cobbles, and gravel.
Harper & Landry	1990	Macroinvertebrates	Rio Grande and between Falcon Dam and Brownsville and Arroyo Colorado.	Soft substrate Dredges
Decanini	1994	Freshwater insects	Rio Sabinas, Rio Salado, Rio Coyote, Rio Alamo, and Rio Grande between Anzalduas Dam and Brownsville's Weir, El Jardin.	Riffles
IBWC	1994	Aquatic Macroinvertebrates	Rio Grande between Del Rio and Brownsville.	Snag habitats

Texas Parks and Wildlife Department, Texas Department of Health, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. National Park Service, International Boundary and Water Commission - U.S. and Mexico Sections, Comisión Nacional del Agua, and Secretaría de Desarrollo Social (IBWC 1994). These agencies collected data for determining toxic substance concentrations in water, sediment, and fish tissue and for bioassessments using fish and benthic macroinvertebrate community data (TWC 1992). They concluded that 30 out of 48 toxic chemicals exceeded screening levels and that fish and macrobenthic communities were healthy in most locations except in 5 of 36 sites. Biotic integrity at the main stream sites indicated that if toxic impacts were occurring, the effects were relatively slight. No instances of severe aquatic life impairment were observed (IBWC 1994). The report recommended follow-up monitoring at several sites, three of which are located in the lower Rio Grande Basin. These sites are downstream from Anzalduas Dam and the Anhelo drain south of Las Milpas, downstream from Reynosa, Mexico. These sites had findings of "slight-to-moderate" or "high potential for toxic chemicals" (IBWC 1994).

Decanini (1994) studied the aquatic insect riffle community of the Rio Sabinas-Salado system in Mexico. This water system ends north of Falcon Dam, which makes it a major water contributor of the lower Rio Grande. Two sites on the Rio Grande were also sampled: riffles below Anzalduas Dam and at the El Jardín weir which is south of Brownsville. A total of 9 orders, 37 families, and 60 genera of aquatic insects were identified in this study (Decanini 1994). Assessment of biological integrity included water quality based on six measures. Decanini (1994) concluded that the sites in the Rio

Sabinas-Salado system rated "excellent to good"; the Rio Grande at Anzalduas Park rated "fair"; and the Brownsville weir at El Jardín rated "poor". This study concluded that as the river flows to the Gulf of Mexico, its biological integrity deteriorates.

Ideker (1979b) studied the predation habits of the Dytiscidae Cybister fimbriolatus on the Rio Grande Leopard Frog, Rana berlandieri. In field observations the larvae preyed on medium to large tadpoles. In a laboratory setting, the adults of the Cybister were not observed preying on the tadpoles.

The objectives of this study were to systematically sample, identify, and determine the relative abundance of species living in the littoral zone of ponds and to construct a model for the rapid bioassessment of these littoral zone communities.

CHAPTER II

METHODS AND MATERIALS

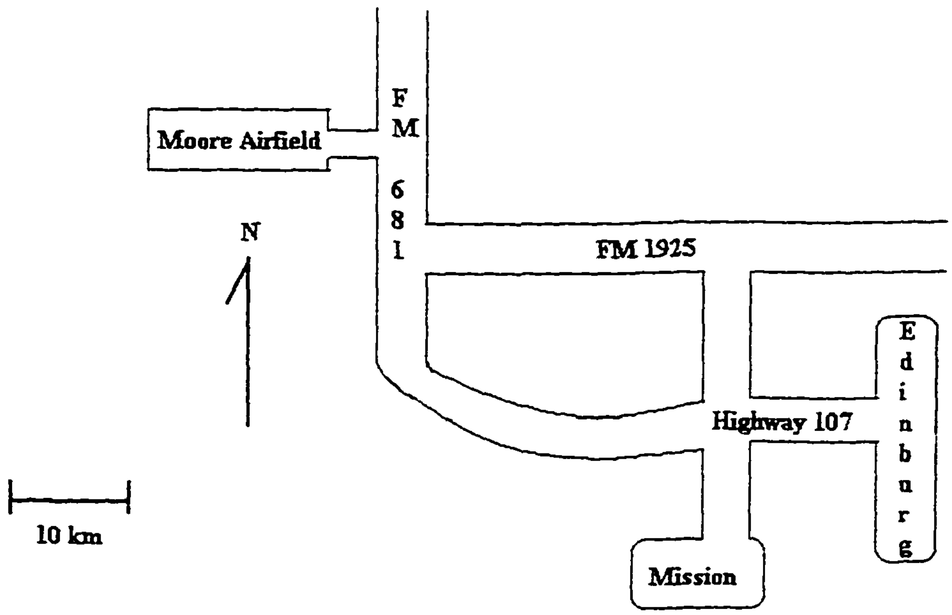
The location of the seven ponds used in this study are shown in Figure 1. Moore Airfield pond is located in the northwest corner of the region of the delta; the three Santa Ana ponds are located in the central part of the region; and the three Olmito ponds are located in the southeastern part of the region.

The ponds were selected based on community characteristics obtained from preliminary collections of January 1995 listed in the appendix (Table A1). These collections showed the following: (1) high aquatic insect diversity; (2) quality of the littoral zone habitat; (3) location for coverage of the region; and (4) accessibility. Additionally, the three ponds at Santa Ana are located in a wildlife refuge where a native terrestrial habitat has been preserved. The three Olmito ponds were chosen because of the similarity in the habitat and their proximity to each other.

POND DESCRIPTIONS - Moore Airfield Pond (Fig. 2)

Moore Airfield Pond (MOF) is located on the United States Department of Agriculture (USDA) facilities at Moore Air Base at 98°21'N 026°23'W, 20.9 km north of Mission, Texas, on FM 681. The pond had emergent cattails growing along the littoral zone, dense aquatic vegetation, and a grassy margin with no canopy. The water was clear with no sheen or odor. The substrate was soft with tree snags and detritus present.

(a)



(b)

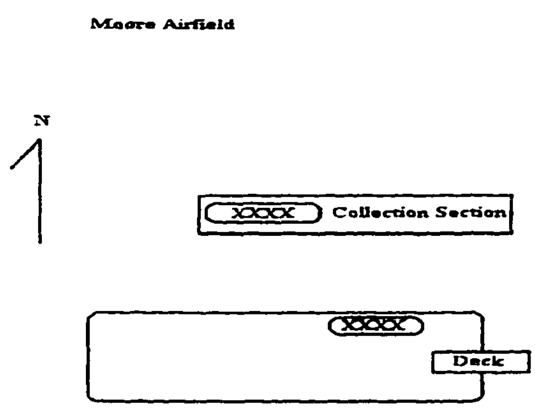


Figure 2. Moore Airfield; (a) Map to the area and (b) detailed map of the collection sites.

Hunke Ranch

Two ponds located on a privately owned ranch were chosen to test the cluster analysis results. Hunke ponds are located at 97°58'N 026°23'W, approximately 1.3 km northeast of Hargill, Texas on FM 186. These ponds were shallow with aquatic vegetation, soft substrate, grassy margins, and no riparian tree canopy cover. The water was clear with no sheen or odor. Taxonomic list and relative abundances for the two ponds are located in Table A2 of the appendix.

Santa Ana National Wildlife Refuge (Fig. 3)

Three ponds located on the United States Fish and Wildlife Service's Santa Ana National Wildlife Refuge were selected due to their diverse habitat, natural environment, and canopy cover. These ponds are located at 98°09'N 026°04'W, approximately 11.3 km south of Alamo, Texas, on US 281. The ponds selected were Pintail Lake, Willow Lake East, and Willow Lake. All three ponds are shallow but they differed in size, aquatic vegetation, and canopy. A discussion of each pond follows.

Pintail Lake (SA1) is a large pond, approximately 25 hectares (B. Hayes, pers. comm.) with bulrushes, aquatic vegetation, and soft substrate. The water was clear with no sheen or odor. Pintail Lake receives water from the Rio Grande by way of an irrigation canal. The pond has no riparian tree canopy cover. There are few small trees scattered around the margins.

Willow Lake East (SA2) is a small pond, approximately 0.72 hectares (B. Hayes, pers. comm.) with about 75% canopy. The pond had tree snags, leaf packs, soft substrate, and no rooted aquatic vegetation. The color of the water was almost black

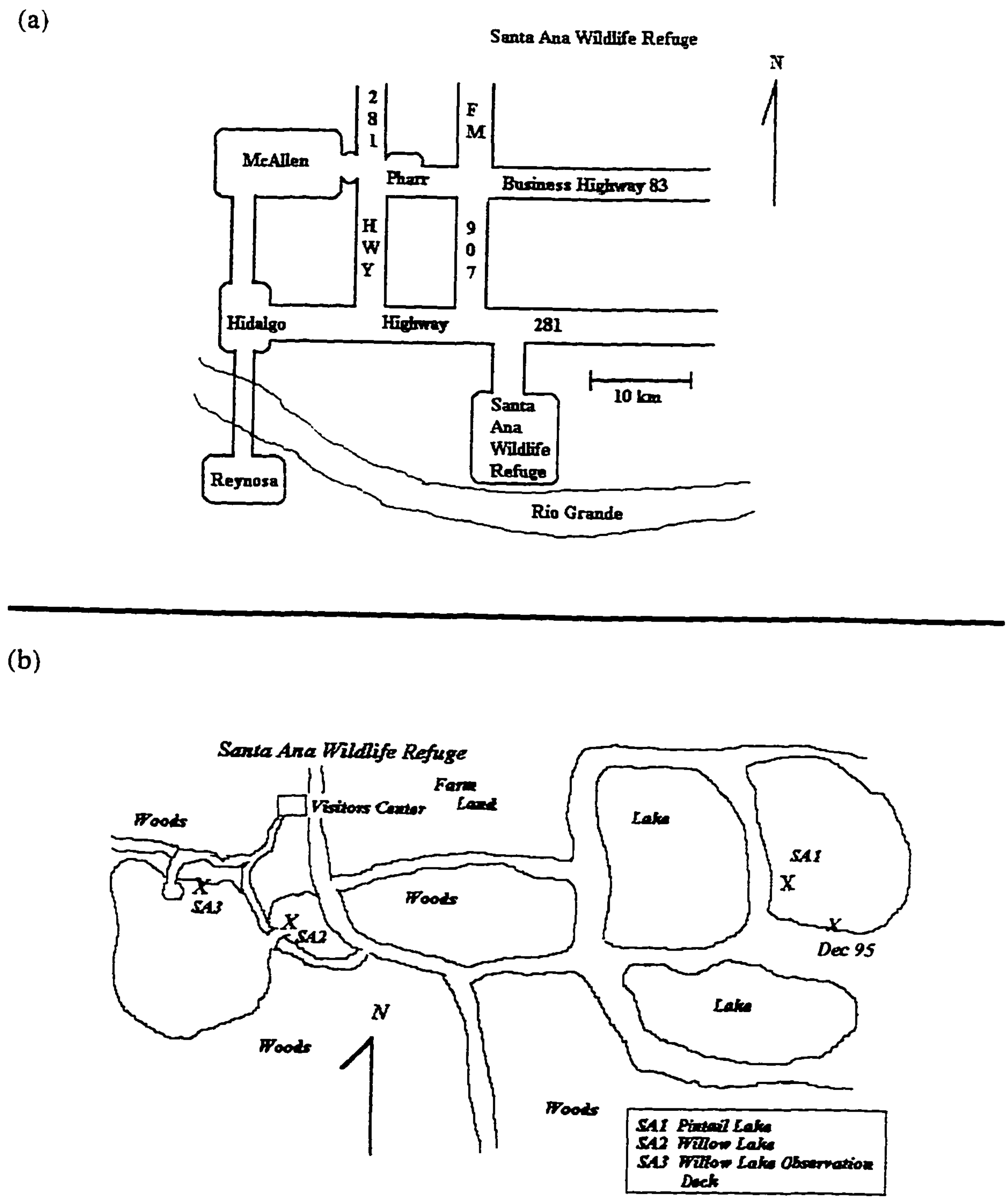


Figure 3. Santa Ana Wildlife Refuge; (a) Map to the area and (b) detailed map of the collection sites.

with a sheen and hydrogen sulfide odor. Well water was used to replenish the pond during dry periods.

Willow Lake (SA3) is a large pond, approximately 11.3 hectares (B. Hayes, pers. comm.) with bulrushes, rooted aquatic vegetation, and soft substrate. This pond has grassy margins and partial canopy with large trees. The water was clear with no sheen or odor. Water from Willow Lake East flows into this pond.

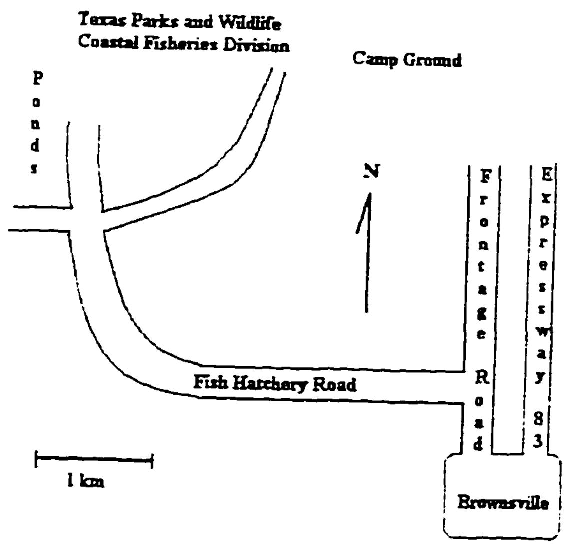
Olmito Ponds (Fig. 4)

Three ponds located at the Texas Parks and Wildlife Department's Coastal Fisheries Division, Olmito facility (97°32'N 025°58'W, 9.7 km northwest of Brownsville) were selected due to their spatial and habitat homogeneity: Olmito North (OLN), Olmito Middle (OLM), and Olmito South (OLS). These ponds had the same type of habitat, aquatic vegetation, substrate, and water source. This homogeneity was used to test the sampling technique. The ponds are open with a grassy margin, which is cut regularly, and with a few small trees. All have a dense growth of aquatic vegetation. The distance between each pond is approximately 7 meters. The water was clear with no sheen or odor. These ponds had a soft bottom substrate and were supplied from an irrigation canal. Until 1980, Olmito ponds were used as a fish hatchery. Currently these ponds are being used by the personnel to wash their marine research equipment.

Habitat Evaluation

Ball (1982) and Plafkin (1989) developed habitat assessment categories for the evaluation of streams. These habitat characteristics were modified to reflect the littoral zone found in ponds. Pond habitats were grouped according to canopy cover, aquatic

(a)



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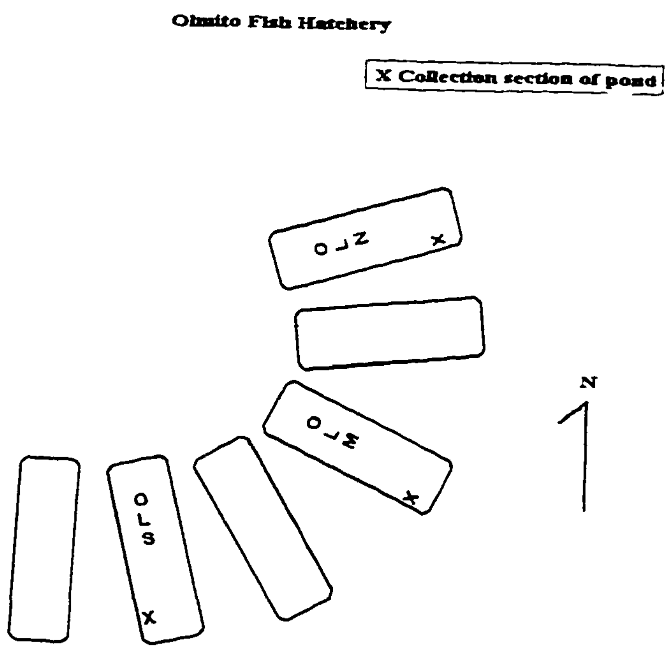

Figure 4. Olmito Fish Hatchery; (a) Map to the area and (b) detailed map of the collection sites. OLN = North pond, OLM = Middle pond, and OLS = South pond.

vegetation, clarity, sheen, and odors. Water clarity, sheen, and odor were subjectively measured. Water was considered clear when the bottom could be seen. Sheen was present if a film could be seen floating on the water and odors were recorded if present. Periodic draining or lowering of the water levels were recorded in the disturbance category. Riparian vegetation was described by the extent of the tree canopy over the littoral zone. The canopy was categorically recorded as follows: no canopy or open, 50% canopy, and 75% canopy. All other criteria were recorded as present or absent.

Field Sampling

Ponds from Moore Airfield, Santa Ana, and Olmito were sampled seasonally. March, June, September, and December of 1995. A total of 28 sampling units were collected. Sampling was habitat specific for the littoral zone. One sample unit was collected each season from each site. Each sample unit consisted of a ten-meter section. A standard aquatic D-shaped dip net was used as the sampling device. Samples were washed, and large detritus was discarded at the site. Samples were preserved in 95% denatured ethanol and returned to the laboratory at the University of Texas-Pan American for identification.

Laboratory Subsampling

A white enamel pan was subdivided into six equal sections, marked, and numbered. The sample was emptied into the pan and evenly distributed. Subsamples were randomly selected from the subdivided pan by throwing a die. All organisms were removed from the corresponding numbered square rolled by the die. Removal of the organisms was conducted by visual inspection or using a dissecting microscope.

Laboratory subsampling followed the methods designed by Hilsenhoff (1987) and Bode (1988) who studied the effects of subsampling size and concluded that subsamples of 100 individuals would provide a representative estimate of local fauna (Plafkin et al. 1989). Samples were subsampled for 100 individuals or greater until redundancy had occurred. These subsampled individuals were sorted, counted, and preserved in vials containing 70% ethanol. The unused portions of the samples are stored at the University of Texas-Pan American.

Identification and Enumeration

Specimens were identified to the taxonomic level of genus with the exception of dipterans. Dipterans were identified to family or subfamily level. Organisms were identified using keys found in Wiggins (1978), Merritt and Cummins (1995), McCafferty (1981), and Needham (1955). Snails were identified to species by Dr. Robert Hershler from the National Museum of Natural History, Smithsonian Institution. Dr. Sharon Jasper, Texas A & M University College Station, identified Haliplidae. Dr. David E. Bowles from the Texas Parks and Wildlife Department identified the Trichoptera to species.

The taxa and the number of individuals per taxon were recorded. Each vial contained an identification label and locality label.

Multivariate Analysis of Abundance Data

NTSYS-pc (1995) was used to perform all possible pairwise calculations of Manhattan distances for the 28 sampling unit abundances, resulting in 378 comparisons. Manhattan distance is the sum of the absolute differences in abundance among all the taxa of any two sampling units. The Manhattan distances were evaluated by using the clustering method UPGMA (unweighted pair group method using arithmetic averages), (NTSYS-pc 1995).

Rapid Biological Assessment of Multiple Community Measures

This study used a rapid biological assessment model developed and recommended by the U.S. Environmental Protection Agency (Plafkin et al. 1989). The model was designed to apply to lotic environments and therefore was modified for the lentic pond environments. The model emphasizes the use of multiple macroinvertebrate community measures and the use of regional reference sites. Reference sites are used to establish optimum values for each of the community measures. Other ponds in a region can be compared with the reference conditions based on percent similarity.

The bioassessment model first scored each of the community measures. A measure's score was based on a comparison with the reference site. If the measure was equal to the reference site, the score was six, the maximum. If the measure was less than the reference value, it received a score of four or two or zero depending on the magnitude of the difference. These scores were then summed and compared with the reference site as percent similarity. The scoring of metrics collected and criteria for the evaluation of each site are summarized in Table 2.

Table 2. Metrics used in modified Rapid Bioassessment Protocol III (Plafkin et al. 1989).

Metric	6	4	2	0
1. Taxa Richness	≥ 18	17 - 12	11 - 6	≤ 5
2. % DS	≤ 40 %	41 - 50 %	51 - 60 %	≥ 61 %
3. EPT	> 3	2	1	0
4. % Affinity	≥ 60 %	59 - 45 %	44 - 31 %	≤ 30 %
5. Ephemeroptera richness	> 2	1	- 9	0
6. Trichoptera richness	> 2	1	- 9	0
7. Gastropoda richness	≥ 3	2	1	0
8. Predator richness	≥ 9	8 - 5	4 - 2	0

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

CHAPTER III

RESULTS AND DISCUSSION

Rio Grande Delta Pond Macroinvertebrate Taxa

Seventy-six taxa were collected and identified to the level of genus. These include sixty aquatic insects, six crustaceans, seven gastropods, two annelids, and one bivalve (Table 3). The regional abundance and absolute ranks of each taxon are listed in Table 4. A complete taxonomic list and relative abundances for the 28 samples are located in Table A3 of the appendix.

Rio Grande Delta Pond Communities - Analysis of Taxa Abundance Data

Taxa and abundance data were used to compare the pond communities. Two methods were used. Method 1 used a multivariate comparison of community similarity to search for spatial and temporal patterns. This method used pairwise comparisons of the Manhattan distances among all 28 sampling units. UPGMA clustering was used to group the most similar sampling units. Dendrograms of UPGMA results were examined for evidence of spatial and temporal patterns. Method 2 was based on EPA's Rapid Bioassessment Protocol III (Plafkin et al. 1989). This method compared multiple measures of community structure and function with reference or optimum values. A reference site was selected and reference values for eight community measures were established.

Spatial and Temporal Patterns

A distinct spatial pattern was detected. The three major clusters in Figure 5a correspond to the area of sampling unit origin in 25 of 28 cases or in 89% of the cases.

Table 3. Rio Grande Delta, littoral zone pond taxa (L) = larvae, (P) = pupa, and (A)= adult.

Ephemeroptera
- Baetidae Callibaetis
- Caenidae Caenis

Odonata
- Aeshnidae Aeshna
- Aeshnidae Anax
- Coenagrionidae Acanthagrion
- Coenagrionidae Argia
- Coenagrionidae Enallagma
- Coenagrionidae Ischnura
- Corduliidae Cordulia
- Corduliidae Macromia
- Corduliidae Neurocordulia
- Corduliidae Somatochlora
- Gomphidae Lanthus
- Gomphidae Progomphus
- Lestidae Lestes
- Libellulidae Brachymesia
- Libellulidae Erythemis
- Libellulidae Lepthemis
- Libellulidae Macrodiplax
- Libellulidae Micrathyria
- Libellulidae Orthemis
- Libellulidae Pachydiplax

Hemiptera
- Belostomatidae Belostoma
- Corixidae Corixini
- Corixidae Palmacorixa
- Corixidae sp A
- Gerridae Gerris
- Gerridae Limnogonus
- Gerridae Metrobates
- Macroveliidae Macrovelia
- Macroveliidae Oravelia
- Naucoridae Pelocoris
- Notonectidae Buenoa
- Pleidae Neoplea
- Veliidae Microvelia

Coleoptera
- Chrysomelidae Agasicles
- Chrysomelidae (L)
- Chrysomelidae (P)
- Curculionidae Steremnius
- Dytiscidae Hydroporus (L)
- Dytiscidae Matus (A)
- Dytiscidae Matus (L)
- Gyrinidae Gyrinus
- Haliplidae Haliplus tumidus (A)
- Haliplidae Haliplus tumidus (L)
- Hydrophilidae Berosus (A)
- Hydrophilidae Berosus (L)
- Hydrophilidae Derallus (L)
- Hydrophilidae Enochrus (A)
- Hydrophilidae Enochrus (L)
- Hydrophilidae Tropisternus (L)
- Hydrophilidae Tropisternus (A)
- Noteridae (A)
- Scirtidae Cyphon (A)
- Scirtidae Cyphon (L)
- Scirtidae Microcara

Trichoptera
- Hydroptilidae Oxyethira
- Leptoceridae Oecetis

Lepidoptera
- Pyralidae

Diptera
- Ceratopogonidae
- Chironomidae Chironominae
- Chironomidae Tanypodinae
- Chironomidae (P)
- Culicidae Anopheles
- Culicidae Culex
- Culicidae (P)
- Stratiomyidae Odontomyia
- Tabanidae
- Thaumaleidae
- Tipulidae

Decapoda
- Cambaridae
- Palaemonidae Palaemonetes

Cladocera Daphnia

Copepoda

Amphipoda Hyalella azteca

Ostracoda

Bivalvia
- Corbiculidae Corbicula

Annelida
- Hirudinea
- Oligochaeta

Gastropoda
- Helisoma anceps
- Melanoides tuberculata
- Physella virgata
- Pyrgophorus coronatus (smooth form)
- Pyrgophorus coronatus (spinose form)
- Snail sp D
- Snail sp F

Table 4. Taxa ranked by relative abundance for regional fauna. N = total number individual of each taxon. (L) = larvae, (P) = pupa, and (A) = adult

Rank	Taxon	N	Rank	Taxon	N
1	Chironomidae Chironominae	665	41	Dytiscidae Matus (L)	9
2	Baetidae Callibaetis	490	41	Hydrophilidae Enochrus (L)	9
3	Hyalella azteca	251	45	Cambaridae	8
4	Palaemonidae Palaemonetes	210	45	Corduliidae Cordulia	8
5	Physella virgata	204	45	Libellulidae Erythemis	8
6	Coenagrionidae Enallagma	195	45	Hydrophilidae Tropisternus (L)	8
7	Caenidae Caenis	159	49	Hydrophilidae Tropisternus (A)	7
8	Melanoides tuberculata	129	49	Culicidae (P)	7
9	Ostracoda	111	49	Hydrophilidae Derallus (L)	7
10	Pyrgophorus coronatus		52	Corduliidae Somatochlora	6
	(smooth form)	107	52	Gerridae Metrobates	6
11	Pyrgophorus coronatus		52	Lestidae Lestes	6
	(spinose form)	104	52	Corixidae sp A	6
12	Snail sp D	94	52	Libellulidae Micrathyria	6
12	Chironomidae Tanypodinae	94	57	Helisoma anceps	5
14	Coenagrionidae Acanthagrion	70	57	Libellulidae Brachymesia	5
15	Naucoridae Pelocoris	57	57	Aeshnidae Aeshna	5
16	Libellulidae Pachydiplax	55	60	Snail sp F	4
17	Aeshnidae Anax	51	60	Hydroptilidae Oxyethira	4
18	Copepoda	45	62	Libellulidae Orthemis	3
18	Ceratopogonidae	45	62	Tipulidae	3
20	Coenagrionidae Ischnura	43	62	Culicidae Culex	3
21	Belostomatidae Belostoma	41	62	Gomphidae Progomphus	3
21	Haliplidae Haliplus tumidus (L)	41	66	Dytiscidae Hydroporus (L)	2
23	Chironomidae (P)	33	66	Hydrophilidae Enochrus (A)	2
24	Stratiomyidae Odontomyia	32	66	Hydrophilidae Berosus (A)	2
25	Hydrophilidae Berosus (L)	30	66	Coenagrionidae Argia	2
26	Cladocera Daphnia	28	66	Dytiscidae Matus (A)	2
27	Leptoceridae Oecetis	27	66	Macroveliidae Oravelia	2
28	Hirudinea	19	66	Chrysomelidae Agasicles	2
29	Haliplidae Haliplus tumidus (A)	17	66	Scirtidae Cyphon (L)	2
29	Pyralidae	17	74	Chrysomelidae (L)	1
29	Oligochaeta	17	74	Gerridae Limnogonus	1
32	Corixidae Palmacorixa	16	74	Gomphidae Lanthus	1
33	Notonectidae Buenoa	15	74	Scirtidae Microcara	1
34	Pleidae Neoplea	14	74	Corduliidae Macromia	1
35	Corixidae Corixini	13	74	Thaumaleidae	1
36	Tabanidae	12	74	Chrysomelidae (P)	1
36	Macroveliidae Macrovelia	12	74	Corduliidae Neurocordulia	1
36	Gerridae Gerris	12	74	Curculionidae Steremnius	1
39	Culicidae Anopheles	11	74	Gyrinidae Gyrinus	1
40	Libellulidae Macrodiplax	10	74	Noteridae (A)	1
41	Veliidae Microvelia	9	74	Scirtidae Cyphon (A)	1
41	Libellulidae Lepthemis	9	74	Corbiculidae Corbicula	1

Two of the twelve Santa Ana sampling units clustered with the Olmito cluster and one clustered with the Moore Airfield sampling unit. No specific explanation or factors are known that would explain the characteristics of these three sample units. The dendrograms were simplified in Figure 5b to show just the major area branches. The Manhattan distances among all sampling units are shown as a similarity matrix in Table 5. If the assumption is made that pond communities have distinct geographic patterns, then the methods of sampling unit collection and analysis were accurate representations of actual pond community patterns 89% of the time. Additional support and confidence in the presence of area patterns within this region was provided by adding two sampling units from ponds on the Hunke Ranch. The results in Figure 6 show that the Hunke sampling units form a distinct cluster, which is also distinct from the Olmito, Santa Ana, and Moore Airfield area clusters.

No spatial pattern was observed within either the Olmito or Santa Ana areas where three ponds were sampled seasonally. Only two pairs of sampling units from a specific pond were more similar to each other than to any other sampling unit. These sampling units were the March and December sampling units at the Olmito Middle pond, and the June and September sampling units from the Olmito North Pond. No tertiary sampling unit clusters were present for any of the individual Olmito or Santa Ana ponds. The lack of clustering of the four seasonal samples from the individual ponds indicates that the communities were not pond specific.

There was also minimal seasonal clustering of sampling units from the two areas. Although some seasonal clustering is present between the March collections from Santa

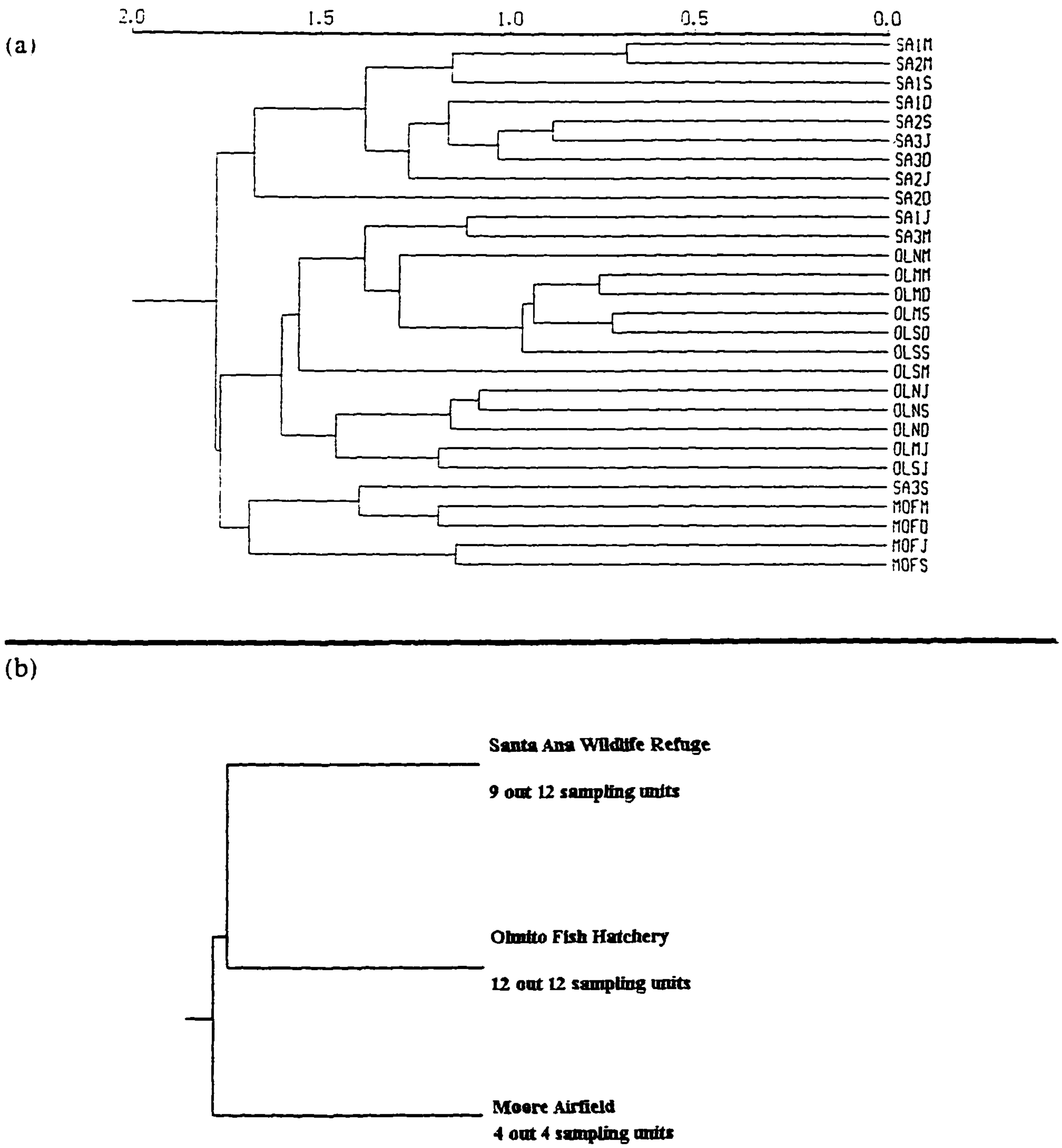

Figure 5. (a) Dendrogram of ecological distance based on taxa and taxa relative abundances and (b) Dendrogram showing "nests" of similar sites using Manhattan distance and UPGMA.

Table 5. Similarity matrix using Manhattan Distance with UPGMA. Sites 1and SA1 = Pintail Lake; 2 and SA2 = Willow Lake East; 3 and SA3 = Willow Lake; 4 and OLN = Olmito North; 5 and OLM = Olmito Middle; 6 and OLS = Olmito South; 7 and MOF = Moore Airfield. M=March, J=June, S=September, and D=December.

	1M	1J	1S	1D	2M	2J	2S	2D	3M	3J	3S	3D	4M	4J	4S	4D	5M	5J	5S	5D	6M	6J	6S	6D	7M	7J	7S	7D
SA1M	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA1J	1.5	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA1S	1.2	1.7	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA1D	1.4	2.1	1.4	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA2M	0.7	1.6	1.2	1.4	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA2J	1.6	1.9	1.7	1.5	1.7	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA2S	1.3	1.9	1.5	0.9	1.4	1.1	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA2D	1.7	2.2	2.0	1.8	1.8	1.3	1.4	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA3M	1.2	1.1	1.7	1.9	1.3	1.9	1.8	1.9	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA3J	1.2	1.7	1.4	1.3	1.1	1.4	0.9	1.6	1.6	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA3S	1.7	1.8	1.7	1.8	1.9	1.6	1.5	1.8	1.7	1.1	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SA3D	1.2	1.9	1.4	1.3	1.1	1.2	1.2	1.7	1.8	0.9	1.5	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
OLNM	1.4	1.8	1.5	1.6	1.2	1.8	1.5	1.9	1.6	0.9	1.8	1.2	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
OLNJ	1.5	1.6	1.6	1.9	1.6	1.8	1.9	1.9	1.5	1.7	1.8	1.7	1.4	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
OLNS	1.5	1.9	1.7	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.1	X	.	.	.	.	.	.	.	.	.	.	.	.	.
OLND	1.8	2.0	1.7	1.9	1.8	1.7	1.9	1.9	1.9	1.9	1.9	1.6	1.7	1.1	1.2	X	.	.	.	.	.	.	.	.	.	.	.	.
OLMM	1.5	1.4	1.7	1.9	1.5	2.0	2.0	2.1	1.1	1.7	1.6	1.9	1.1	1.3	1.5	1.6	X	.	.	.	.	.	.	.	.	.	.	.
OLMJ	1.9	1.8	1.9	2.0	2.0	1.9	2.0	2.1	1.7	1.9	2.0	2.1	1.7	1.3	1.1	1.5	1.7	X	.	.	.	.	.	.	.	.	.	.
OLMS	1.2	1.5	1.4	1.7	1.2	1.9	1.7	2.0	1.3	1.7	2.1	1.6	1.2	1.2	1.4	1.4	1.0	1.7	X	.	.	.	.	.	.	.	.	.
OLMD	1.4	1.7	1.5	1.8	1.4	2.0	1.9	2.0	1.3	1.9	2.0	1.9	1.3	1.2	1.5	1.5	0.8	1.7	1.0	X	.	.	.	.	.	.	.	.
OLSM	1.8	1.8	2.0	2.1	2.0	1.7	1.8	2.0	1.6	1.8	1.7	1.7	1.5	1.7	1.3	1.7	1.5	1.6	1.8	1.6	X	.	.	.	.	.	.	.
OLSJ	1.7	1.8	1.8	2.0	1.9	1.6	1.8	1.7	1.7	1.5	1.5	1.9	1.7	1.5	1.6	1.9	1.5	1.2	2.0	1.8	1.9	X	.	.	.	.	.	.
OLSS	1.6	1.4	1.8	2.1	1.6	2.1	2.1	2.2	1.2	2.1	2.2	2.1	1.5	1.5	1.3	1.8	0.9	1.4	1.1	1.0	1.2	1.8	X	.	.	.	.	.
OLSD	1.5	1.2	1.6	1.9	1.5	2.0	2.0	2.1	1.1	1.8	1.9	1.9	1.4	1.3	1.2	1.6	0.8	1.6	0.7	1.0	1.5	1.7	0.9	X	.	.	.	.
MOFM	1.7	1.2	2.0	2.1	1.9	1.8	1.7	2.0	1.6	1.5	1.5	1.8	1.3	1.5	1.6	1.7	1.2	1.7	1.7	1.7	1.6	1.4	1.8	1.6	X	.	.	.
MOFJ	1.6	2.0	1.7	1.7	1.7	1.7	1.6	1.9	1.9	1.5	1.9	1.6	1.4	1.5	1.6	1.5	1.8	1.7	1.4	1.9	1.9	1.9	2.1	1.8	1.6	X	.	.
MOFS	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.2	2.1	2.1	2.1	2.1	1.8	1.7	1.5	2.1	1.8	1.9	2.1	2.0	2.1	2.1	2.2	1.9	1.1	X	.
MOFD	1.9	1.8	1.9	2.0	2.0	1.7	1.8	2.0	1.8	1.5	1.3	1.6	1.7	1.6	1.6	1.4	1.5	1.6	1.8	2.0	1.7	1.6	2.0	1.9	1.2	1.4	1.3	X

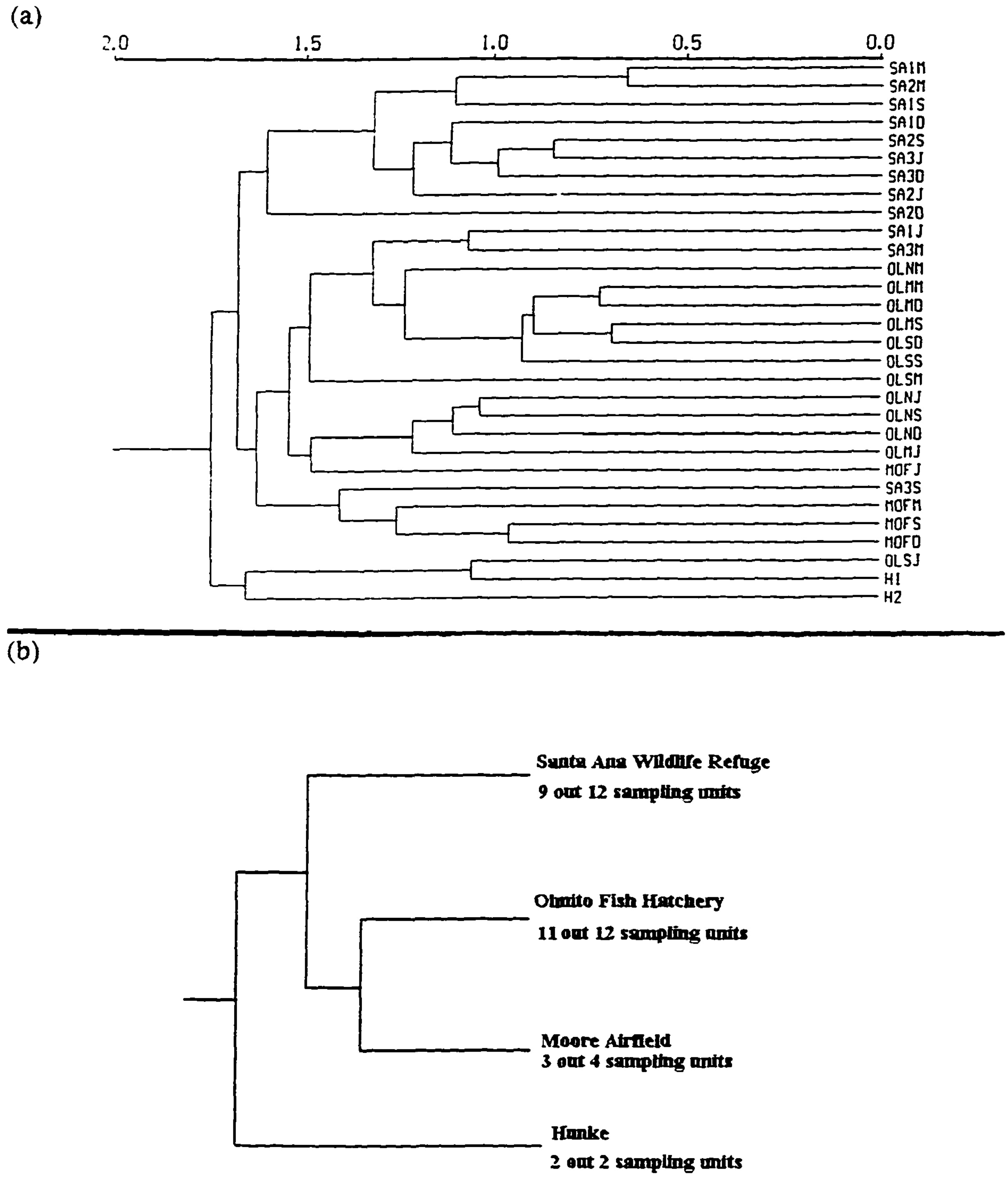

Figure 6. (a) Dendrogram of ecological distance based on the combined data set of the Rio Grande Delta ponds and (b) Dendrogram showing "nests" using Manhattan distance and UPGMA.

Ana 1 and Santa Ana 2; the June collections from Santa Ana 2 and Santa Ana 3; and the June collections from Olmito Middle and Olmito North ponds, there was no cases of a complete, three pond, seasonal clustering from either the Olmito or Santa Ana areas. A three-pond cluster would indicate that the three communities were more similar to each other than they were to any other seasonal sampling unit. This lack of temporal clustering within an area indicates that the ponds within an area were very similar year round and that seasonal change was not distinct.

POND COMMUNITY SIMILARITY - Rapid Biological Assessment

Eight community measures were used to assess the biological condition of ponds. Three of the original EPA model measures were used, taxa richness, EPT richness (Ephemeroptera, Plecoptera, Trichoptera), and Percent Dominant Species. The remaining five measures are substitutions for other original model measures. These five measures are Percent Model Affinity (Novak and Bode 1992), predator richness, gastropod richness, Ephemeroptera richness, and Trichoptera richness.

The following five measures were found useful as biomonitors of an integrated aquatic ecosystem, which include both functional and structural components. Monitoring these two components are important for they reflect the ability of the aquatic organisms to procure food, the stability of the food web, productivity of the community, and natural decomposition of organic matter (Smith 1992, Reice and Wohlenberg 1993, Merritt and Cummins 1996). Any change (positive or negative) in the composition in the community appears to alter one or more of these five measures.

Taxa Richness (TR) is the number of taxa in a sampling unit. Taxa richness increases with increasing water quality and habitat diversity. This measure is considered the best overall indicator of the biological condition of a pond (Ohio EPA 1987, Plafkin et al. 1989). Taxa richness at Santa Ana ranged from 12 to 30. Olmito the range was 15 to 27, and at Moore Airfield the range was 9 to 17. These results denote the normal seasonal variations found in any aquatic environment. Taxa richness results are listed in Table 6.

EPT richness is the total number of genera of Ephemeroptera, Plecoptera, and Trichoptera. These three orders are considered ecological barometers because they are very sensitive to pollution. The greater the EPT value, the better the water quality. The measure was used although plecopterans are not present in the Rio Grande Delta. EPT richness at Santa Ana ranged from 1 to 3; at Olmito the range was 1 to 3; and at Moore Airfield the range was 0 to 3. These results indicated that the community of the ponds to be stable. EPT richness results are listed in Table 6.

The percent contribution of the dominant taxon (% DS) is a measure of community function. The value of this measure is obtained by dividing the number of individuals in the most abundant taxon in the subsample, by the total number of individuals in the subsample. A community dominated by a single taxon indicates environmental stress (Ohio EPA 1987, Plafkin et al. 1989). Percent dominant taxon results are listed in Table 6. These results ranged from 29 to 49 at Santa Ana; at Olmito the range was 12 to 41; and at Moore Airfield the range was 24 to 43. These results are within the normal seasonal variation found in any aquatic environment.

Percent model affinity (PMA) measures the similarity of a community to a model community (Novak and Bode 1992). The measure of similarity is percent similarity of the

Table 6. Measure results from sampled ponds in the Rio Grande Delta. List of sites are as follows: SA1 = Pintail Lake; SA2 = Willow Lake East; SA3 = Willow Lake; OLN = Olmito North; OLM = Olmito Middle; OLS = Olmito South; and MOF = Moore Airfield. TR = taxa richness; EPT = Ephemeroptera, Plecopotera, and Trichoptera; % DS = Percent Dominant taxon; % AFF = Percent Affinity; PRE = Predator richness; EPH = Ephemeroptera richness; TRI = Trichoptera richness; and GAS = Gastropod richness. M = March; J = June; S = September; and D = December.

	SA1M	SA1J	SA1S	SA1D	SA2M	SA2J	SA2S	SA2D	SA3M	SA3J	SA3S	SA3D
TR	24	16	20	22	22	16	16	12	30	17	17	14
EPT	2	3	1	1	2	2	2	1	2	3	2	3
% DS	28	35	30	29	37	26	27	34	29	40	19	49
% AFF	69	48	54	69	65	77	77	52	72	61	68	64
PRE	12	4	14	11	10	5	4	3	15	5	8	4
EPH	2	2	1	1	2	2	2	1	2	2	1	2
TRI	0	1	0	0	0	0	0	0	0	1	1	1
GAS	2	2	1	3	2	2	2	3	3	2	2	3

	OLNM	OLNJ	OLNS	OLND	OLMM	OLMJ	OLMS	OLMD	OLSM	OLSJ	OLSS	OLSD
TR	17	27	22	18	18	24	15	20	18	15	18	19
EPT	3	3	2	2	2	2	2	1	2	1	1	2
% DS	41	12	20	31	26	14	37	23	27	19	31	34
% AFF	68	78	76	78	76	70	69	51	63	70	71	65
PRE	6	12	10	6	8	11	5	8	5	7	10	8
EPH	2	2	1	1	2	2	2	1	2	1	1	1
TRI	1	1	1	1	0	0	0	0	0	0	0	1
GAS	3	5	5	5	3	4	3	4	5	2	4	3

	MOFM	MOFJ	MOFS	MOFD
TR	13	17	9	13
EPT	3	3	0	2
% DS	31	43	43	24
% AFF	66	69	51	72
PRE	3	6	4	5
EPH	2	2	0	2
TRI	1	1	0	0
GAS	3	3	3	2

sum of the absolute abundances of seven major macroinvertebrate taxa. It is intended that the model has universal application. The model is based on abundance data from a variety of stream types across the United States. The seven groups used in the original model were: Ephemeroptera, Plecoptera, Trichoptera, and Colecoptera, Chironomidae, Oligochaeta, and Other taxa. This study used four of the original PMA groups (Ephemeroptera, Trichoptera, Colecoptera, and Chironomidae) and added three groups (Crustacea, Gastropoda, and Odonata). These changes reflect the differences between stream and pond communities. The model percentages for this study were determined by averaging each measure across all 28 sample units (Novak and Bode 1992). Modified Percent Model Affinity (MPMA) was calculated and is shown in Table 7. The results for the modified percent model affinity are listed in Table 6. Santa Ana ranged from 48 to 77; at Olmito the range was 51 to 78; and at Moore Airfield the range was 51 to 72.

Predator richness is the total number of predatory taxa. Predators have a pronounced effect on the diversity of the pond. Predators at or near the top of the food web affect the abundance and the distribution of their prey, which in turn can affect the rest of the food web (Allen 1995). The number of predators should increase as the biological condition of a pond increases (Ohio EPA 1987, Plafkin et al. 1989). Predator richness in Santa Ana ranged from 3 to 15; at Olmito the range was 5 to 12; and at Moore Airfield the range was 3 to 6. These results show a correlation between the predator richness and taxa richness. If taxa richness increases there is an increase in predator richness. Predator richness results are listed in Table 6.

Table 7. Modified Percent Model Affinity (Novak and Bode 1992) divided by seasons. Santa Ana Wildlife Refuge (SA); SA1 = Pintail; SA2 = Willow Lake East; SA3 = Willow Lake; OLN = Olmito North; OLM = Olmito Middle; OLS = Olmito South; and MOF = Moore Airfield.

March	Mod %	SA1 %	DIF	SA2 %	DIF	SA3 %	DIF	OLN %	DIF	OLM %	DIF	OLS %	DIF	MOF %	DIF
Ephemeroptera	15	23	8	23	8	34	19	9	16	27	12	9	6	31	16
Odonata	10	9	11	9	11	20	10	24	14	25	15	29	19	11	1
Trichoptera	5	0	5	0	5	0	5	3	2	0	5	0	5	2	3
Coleoptera	5	14	9	8	3	5	0	0	5	2	3	8	3	0	5
Chironomidae	20	34	14	46	26	7	13	42	22	10	10	6	14	11	9
Crustaceans	15	4	11	2	13	11	4	16	1	21	6	3	12	33	18
Gastropoda	20	6	14	4	16	5	15	4	16	9	11	38	18	11	9
Other	10	10	0	8	2	18	8	2	8	6	4	7	3	1	9
sum of diff			72		84		74		74		66		80		70
sum of diff x 0.5			36		42		37		37		33		40		35
100-(sum of diff x 0.5)			64		58		63		63		67		60		65
% model affin	100		64		58		63		63		67		60		65

June	Mod %	SA1 %	DIF	SA2 %	DIF	SA3 %	DIF	OLN %	DIF	OLM %	DIF	OLS %	DIF	MOF %	DIF
Ephemeroptera	15	67	52	6	9	9	6	13	2	11	4	6	9	4	11
Odonata	10	2	8	1	9	2	8	23	13	17	7	14	4	4	6
Trichoptera	5	1	4	0	5	1	4	10	5	0	5	0	5	1	4
Coleoptera	5	1	4	9	4	2	3	0	5	4	1	3	2	3	2
Chironomidae	20	7	13	19	1	54	34	12	8	3	17	10	10	25	5
Crustaceans	15	9	6	27	12	21	6	16	1	17	2	37	22	46	31
Gastropoda	20	3	17	25	5	9	11	12	8	26	6	6	14	15	5
Other	10	10	0	13	3	2	8	14	4	22	12	24	14	2	8
sum of diff			104		48		80		46		54		80		72
sum of diff x 0.5			52		24		40		23		27		40		36
100-(sum of diff x 0.5)			48		76		60		77		73		60		64
% model affin	100		48		76		60		77		73		60		64

Table 7. Continued

September	Mod %	SA1 %	DIF	SA2 %	DIF	SA3 %	DIF	OLN %	DIF	OLM %	DIF	OLS %	DIF	MOF %	DIF
Ephemeroptera	15	14	1	10	5	1	14	10	5	38	23	31	16	0	15
Odonata	10	5	5	7	3	10	0	8	2	14	4	22	12	4	6
Trichoptera	5	0	5	0	5	1	4	1	4	0	5	0	5	0	5
Coleoptera	5	27	22	1	4	1	4	1	4	0	5	4	1	0	5
Chironomidae	20	33	13	35	15	23	3	12	8	24	4	5	15	4	16
Crustaceans	15	1	14	18	3	22	7	12	3	10	5	2	13	33	18
Gastropoda	20	1	19	25	5	16	9	47	27	7	13	26	6	51	31
Other	10	19	9	4	6	26	16	9	1	7	3	10	0	8	2
sum of diff			88		46		57		54		62		68		98
sum of diff x 0.5			46		23		29		27		31		34		49
100-(sum of diff x 0.5)			56		77		71		73		69		66		51
% model affin	100		56		77		71		73		69		66		51

December	Mod %	SA1 %	DIF	SA2 %	DIF	SA3 %	DIF	OLN %	DIF	OLM %	DIF	OLS %	DIF	MOF %	DIF
Ephemeroptera	15	2	13	2	13	5	10	9	6	22	7	33	18	4	11
Odonata	10	15	5	3	7	6	4	7	3	39	29	14	4	2	8
Trichoptera	5	0	5	0	5	2	3	1	4	0	5	1	4	0	5
Coleoptera	5	13	8	6	1	2	3	2	3	0	5	0	5	2	3
Chironomidae	20	33	13	12	8	53	33	9	11	14	6	13	7	16	4
Crustaceans	15	4	11	67	52	3	17	21	6	5	10	8	7	33	18
Gastropoda	20	23	3	10	15	28	3	44	24	7	13	18	2	40	20
Other	10	11	1	0	5	4	1	7	3	13	3	13	3	3	7
sum of diff			59		106		82		60		78		50		76
sum of diff x 0.5			30		53		41		30		39		25		38
100-(sum of diff x 0.5)			70		47		59		70		61		75		62
% model affin	100		69		47		59		70		61		75		62

The following three measures showed little to no variation and were not evaluated further. Ephemeroptera and Trichoptera richness are the total number of genera found in the orders Ephemeroptera and Trichoptera. These two measures were used individually because their richness distinguishes between unimpaired and minimally impaired communities. Two of the biological condition categories are not expected to have individuals in the orders. Because of this a missing value code, -9, is present in the criteria scoring table (Ohio EPA 1987, Plafkin et al. 1989).

Six species of gastropods were present in the delta region (Table 3). Snails were often the most abundant macroinvertebrate found in the ponds. As seen in Table 4, four of the six species were in the top twelve in regional abundance which included the exotic species Melanoides tuberculata. Snails can have a profound influence on periphyton and the periphyton-based food web. A study conduced by Steinman (1992) on effects of light on periphyton observed an increase in periphyton biomass only when snail populations were drastically reduced (Allen 1995). The measure is difficult to score in that some snails should be present in even unimpaired ponds. Results are listed in Table 6.

Four of the EPA measures or criteria were not used: 1) Hilsenhoff's biotic index, 2) ratio of scrapers to filter collectors, 3) community loss index, and 4) ratio of shredders to the total collection. Hilsenhoff Biotic Index is based on tolerance values of individual taxa. These tolerance values are calibrated from specific taxon abundance across the range of biological conditions. Only good to excellent ponds were sampled during this study. Moderately and seriously impacted ponds were not part of this study. The ratio of scrapers to filter collectors is based on a functional feeding group ratio characteristic of lotic environments. The measure was not used in this study because few filter collectors were present in the ponds due to the lack of current. The community loss index was not used because the results of cluster analysis indicated that communities differ across the region. This method reflects the similarities or dissimilarities in relative abundances between sampling units. Pairwise comparisons of equal but different community composition would be misleading. The ratio of shredders to the total collection was of little value in the ponds because few delta taxa are members of the shredder functional feeding group.

Reference Site

The Olmito North pond was selected as the reference site for this study. Eight community measures were calculated from the pond's four seasonal sampling units. Variations among these four seasonal collections were used to define the reference conditions of each of the eight measures. Three steps were necessary to determine the biological condition category of other sampling units or seasonal pond collections. The first step was to scale the values of each measure, Table 8 shows how the numerical value of each metric was scored on a scale from 6 to 0. A score of a 6 indicates the sample is equivalent to the reference for that metric. The second step is to sum the eight scores. The total is referred to as the "Criteria Score". The third step was to compare the criteria score with the reference criteria score by percent similarity. The resulting percent similarity determines the Biological Condition Category of the sampling unit which is referred to as the bioassessment value. Attributes of each of the four biological condition categories are listed in Table 9.

Table 8. Rapid Bioassessment criteria for the Rio Grande Delta Model. TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; and % DS = Percent Dominant Taxon.

Criteria	6	4	2	0
TR	≥ 18	17 - 12	11 - 6	≤ 5
EPT	> 3	2	1	0
% D S	≤ 40%	41 - 50	51 - 60	≥ 61%
% Affinity	≥ 60%	59 - 45	44 - 31	≤ 30%
Ephemeroptera	> 2	1	-9	0
Trichoptera	> 2	1	-9	0
Gastropoda	≥ 3	2	1	0
Predator	≥ 9	8 - 5	4 - 2	0

Table 9. Narrative and Numerical Criteria for EPA's Bioassessment Protocol III (Plafkin et al. 1989) including the modified Percent Comparison to Reference Score for the Rio Grande Delta.

Percent Comparison to Reference Score Rio Grande Delta (modified)	Percent Comparison to Reference Score EPA (unmodified)	Biological Condition Category	Attributes
>75%	>83%	Non-impaired	Comparable to the best situation to be expected within an ecoregion. Balanced tropic structure. Optimum community structure (composition and dominance) habitat quality.
56 - 74%	54 - 79%	Slightly-impaired	Community structures less than expected. Composition (species richness) lower then expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36 - 55%	21 - 50%	Moderately-impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	<17%	Severely-impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

All of the 28 sampling units were compared or assessed by this method. Table 10 shows these results in both numerical, criteria score, and narrative form and Figure 7 is a graph of the results with the 75% line showing the results of the rapid bioassessment for the three areas. Sites on or above the 75% line (a criterion score of 36) were considered comparable to the best conditions within the region, and the biological condition is assessed as non-impaired. Twenty of the sampling units were assessed as non-impaired, seven as slightly impaired and one as moderately impaired. Three (MOFS, SA2J, and SA1S) of the eight less than optimum sampling units were from ponds where water level lowering occurred during the study period. The results of the five site may have impacted due to sampling error. No other disturbances were noticed at these ponds during the study period.

Two of the biological criteria categories, scores 6 and 4, are based on this study. The two other criteria categories, scores 2 and 0, were inferred and extrapolated from Plafkin et al. (1989) EPA recommendations and Novak and Bode (1992) percent similarity model.

Habitat Evaluation

Habitat descriptions are based upon readily observable general characteristics of the riparian vegetation, the aquatic vegetation, and physical characteristics of the water. Specific details about the riparian or aquatic vegetation were beyond the scope of this study. Table 11 is a summary of the habitat features at each pond including the Hunke Ranch ponds indicating the similarity of the three Olmito and the two Hunke Ranch

Table 10. Bioassessment results for each pond per season.

Sites	Mar		Jun		Sep		Dec	
	Biological Condition Category	Criteria Score	Biological Condition Category	Criteria Score	Biological Condition Category	Criteria Score	Biological Condition Category	Criteria Score
Moore Airfield (MOF)	Non-impaired	(40)	Non-impaired	(40)	Moderately impaired	(18)	Slightly impaired	(34)
Pintail Lake (SA1)	Non-impaired	(38)	Non-impaired	(36)	Slightly impaired	(30)	Non-impaired	(36)
Willow Lake East (SA2)	Non-impaired	(36)	Slightly impaired	(34)	Slightly impaired	(32)	Slightly impaired	(28)
Willow Lake (SA3)	Non-impaired	(40)	Non-impaired	(40)	Non-impaired	(36)	Non-impaired	(36)
Olmito North (OLN)	Non-impaired	(40)	Non-impaired	(44)	Non-impaired	(42)	Non-impaired	(40)
Olmito Middle (OLM)	Non-impaired	(38)	Non-impaired	(36)	Non-impaired	(36)	Slightly impaired	(34)
Olmito South (OLS)	Non-impaired	(38)	Slightly impaired	(30)	Non-impaired	(36)	Non-impaired	(40)

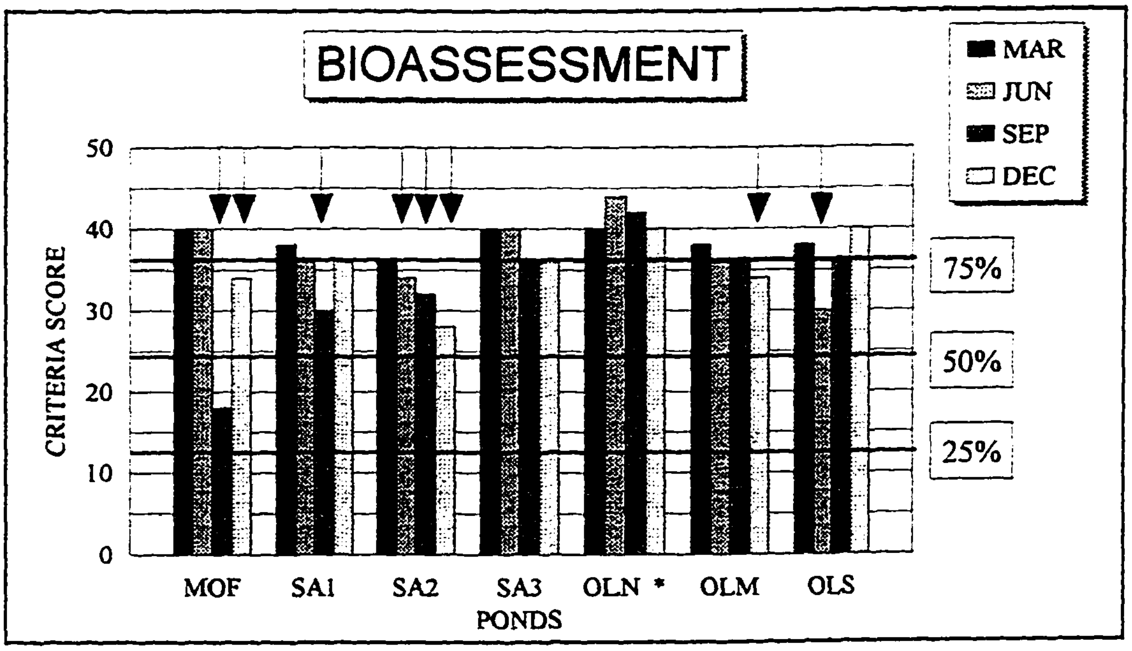

Figure 7. Graph of the bioassessment results for each season in the 7 ponds. Ponds at or above the 75% line are non-impaired sites. * denotes the reference site (OLN) and arrows denote sampling units that were moderately and/or slightly impaired.

Table 11. Habitat Classification. Santa Ana ponds, Pintail (SA1), Willow Lake East (SA2) and Willow Lake (SA3); Olmito ponds, Olmito North (OLN), Olmito Middle (OLM), and Olmito South (OLS); Moore Airfield (MOF); H1=Hunke pond #1 and H2=Hunke pond #2. 0 = not present and X = present.

	Sites								
Pond habitat	SA1	SA2	SA3	MOF	OLN	OLM	OLS	H1	H2
Riparian Canopy Cover									
Open	X	0	0	X	X	X	X	X	X
Partial 50%	0	0	X	0	0	0	0	0	0
75%	0	X	0	0	0	0	0	0	0
Littoral Zone Vegetation									
Rushes	X	0	X	0	0	0	0	0	0
Cattails	X	0	0	X	0	0	0	0	0
Grasses	X	0	0	X	X	X	X	X	X
Aquatic Vegetation	X	0	X	X	X	X	X	X	X
Leaf Detritus	0	X	0	0	0	0	0	0	0
Physical									
Sheen	0	X	0	0	0	0	0	0	0
Odor	0	X	0	0	0	0	0	0	0
Disturbances - other	X	X	0	X	0	0	0	0	0

habitats. It also indicates the variation in habitats at the three Santa Ana ponds. The important factor seems to be the structures or substrates found within the ponds, such as leaf packs, tree snags, and aquatic vegetation which provide substrates for periphyton growth.

Pond Results

Moore Airfield

Five hundred twenty-six individuals in 26 taxa were identified (Table 12) from the Moore Airfield collections. This number is less than one-half the numbers from the Santa Ana (59) and Olmito (56) sites. Three possible explanations for differences in the species per area are: the relatively few collections at Moore Airfield where only one pond was sampled, fewer species actually present in the area, and sampling error. Four collections were taken at Moore Airfield compared with 12 from Santa Ana and 12 from Olmito. Moore Airfield is more isolated than either Olmito or Santa Ana from other ponds in their vicinities. It is at the end of the Hidalgo County Irrigation District # 6 system, approximately 24 km from the river (O. Garza, pers. comm.). Moore Airfield pond was lowered for water pump maintenance in September 1995. Only 0.5 meters of water remained. September and December biological conditions were lower than the two previous assessments. Measure values for the Moore Airfield seasonal collections are listed in Table 13. Five measures decreased in September: Taxa Richness, EPT, % Affinity, Ephemeroptera richness, and Trichoptera richness. December's collection shows an improvement in four of the measures. Gastropod richness and % DS were not effected. The cluster patterns were not affected by water lowering indicating that the relative taxa

Table 12. List of taxa collected from Moore Airfield, collected per season. Higher taxanomic classifications (after Thorp and Covich 1991) are identified in bold. (L) = larvae, (P) = pupa, and (A) = adult.

	Mar	Jun	Sep	Dec
Ephemeroptera				
Baetidae Callibaetis	8	1	0	2
Caenidae Caenis	37	5	0	2
Odonata				
Coenagrionidae Acanthagrion	4	0	2	0
Coenagrionidae Enallagma	12	1	1	3
Corduliidae Macromia	0	0	1	0
Gomphidae Lanthus	0	1	0	0
Libellulidae Brachymesia	0	1	0	0
Libellulidae Macrodiplax	0	1	0	0
Hemiptera				
Belostomatidae Belostoma	0	0	0	2
Gerridae Gerris	0	0	8	0
Macroveliidae Oravelia	0	0	0	1
Coleoptera				
Hydrophilidae Berosus (L)	0	4	0	2
Trichoptera				
Leptoceridae Oecetis	2	1	0	0
Lepidoptera				
Pyralidae	0	0	0	1
Diptera				
Ceratopogonidae	1	0	0	0
Chironomidae Chironominae	13	38	4	8
Chironomidae Tanypodinae	1	1	0	12
Chironomidae (P)	1	0	0	0
Tabanidae	0	1	0	0
Decapoda				
Palaemonidae Palaemonetes	5	67	33	13
Amphipoda Hyalella azteca	44	8	0	30
Bivalvia				
Corbiculidae Corbicula	0	1	0	0
Gastropoda				
Pyrgophorus coronatus (spinose form)	1	1	0	0
Physella virgata	8	6	7	20
Pyrgophorus coronatus (smooth form)	0	0	1	0
Melanoides tuberculata	7	17	43	31
TOTALS	144	155	100	127
TR	13	17	9	13

Table 13. Seasonal Bioassessment of Moore Airfield. TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	13	17	9	13	6	4	4	2	4
EPT	> 3	3	3	0	2	6	6	6	0	4
% DS	≤ 40	31	43	43	24	6	6	4	4	6
% Affinity	≥ 60	65	64	51	62	6	6	6	4	6
EPH	> 2	2	2	0	2	6	6	6	0	6
TRI	> 2	1	1	0	0	6	4	4	0	0
Gastropoda	≥ 3	3	3	3	2	6	6	6	6	4
Predators	≥ 9	3	6	4	5	6	2	4	2	4
Total Score						48	40	40	18	34
Criteria Score							83%	83%	38%	71%
Biological Condition							Non	Non	Mod	SI

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

abundance remained similar (Fig. 5).

Santa Ana National Wildlife Refuge

One thousand six hundred and nineteen individuals in fifty-nine taxa were identified from three different ponds. Taxanomic data and their relative abundances are listed in Table 14. The habitat surrounding the three ponds ranged from several trees to few trees and dense aquatic vegetation to no vegetation. These variations did not produce any distinct clustering patterns.

Rapid bioassessments of the biological conditions at the three ponds reflect the observed changes in water levels at Pintail Lake and Willow Lake East (Table 10 and Fig. 7). June, September, and December collections from Willow Lake East were categorized as slightly impaired. Taxa richness and predator richness decreased in all three seasonal collections following the drying and filling of Willow Lake East. Cluster analysis taxa abundance did not detect changes in taxa abundance after the drying and filling events. The three sampling units from this period continued to cluster with the other Santa Ana sampling units.

Forty-six taxa were identified in Pintail Lake (SA1). Pintail Lake was drained in September to permit the annual mowing of cattails. The September collection preceded the lowering and mowing. The December collection location was moved about 20 meters east of the three previous collections in order to find water (Fig. 2b). Results of the biological condition showed only September as slightly impaired (Fig. 7). The following measures effected the criteria score: EPT, % Affinity, Ephemeroptera richness, Trichoptera richness, and gastropoda richness. This slight impairment may be due to

Table 14. List of taxa collected from Santa Ana National Wildlife Refuge collected per season. 1 = Pintail Lake (SA1), 2 = Willow Lake East (SA2), and 3 = Willow Lake (SA3). M = Mar, J = Jun, S = Sep, and D = Dec. Higher taxonomic classifications (after Thorp and Covich 1991) are identified in bold letters. (L) = larvae, (P) = pupa, and (A)= adult.

	1	1	1	1	2	2	2	2	3	3	3	3
	M	J	S	D	M	J	S	D	M	J	S	D
Ephemeroptera												
Baetidae Callibaetis	35	46	20	3	36	1	2	0	52	3	0	4
Caenidae Caenis	3	51	0	0	3	5	8	2	9	10	1	2
Odonata												
Aeshnidae Aeshna	0	0	0	0	0	0	0	0	1	0	0	0
Aeshnidae Anax	2	0	0	19	3	0	1	0	7	0	0	0
Coenagrionidae Acanthagrion	3	1	0	0	0	1	0	0	0	1	0	0
Coenagrionidae Enallagma	0	0	1	0	0	0	0	1	9	0	0	0
Coenagrionidae Ischnura	0	0	1	0	0	0	0	0	0	0	0	2
Corduliidae Cordulia	0	0	0	0	0	0	0	0	8	0	0	0
Corduliidae Somatochlora	0	0	0	0	0	0	5	0	0	0	0	0
Lestidae Lestes	1	0	0	0	0	0	0	0	5	0	0	0
Libellulidae Erythemis	0	0	0	0	2	0	0	0	0	0	0	0
Libellulidae Lepthemis	0	0	0	0	0	0	1	0	0	0	8	0
Libellulidae Micrathyria	0	0	0	0	6	0	0	0	0	0	0	0
Libellulidae Orthemis	0	2	0	0	1	0	0	0	0	0	0	0
Libellulidae Pachydiplax	9	0	5	0	10	0	0	2	8	1	3	5
Hemiptera												
Belostomatidae Belostoma	0	0	4	1	0	0	0	0	1	0	0	0
Corixidae Corixini	3	0	0	0	0	0	0	0	2	0	0	0
Corixidae Palmacorixa	0	11	3	0	0	0	0	0	0	0	0	0
Corixidae sp A	3	0	0	0	1	0	0	0	2	0	0	0
Gerridae Limnogonus	0	0	0	1	0	0	0	0	0	0	0	0
Naucoridae Pelocoris	2	2	1	0	1	0	0	0	5	1	1	0
Notonectidae Buenoa	5	0	0	1	4	0	0	0	0	0	0	0
Gerridae Gerris	0	0	0	0	0	0	0	0	0	0	1	0
Gerridae Metrobates	0	0	0	0	0	0	0	0	0	0	6	0
Macroveliidae Macrovelia	0	0	0	0	0	0	0	0	4	0	1	0
Pleidae Neoplea	0	0	0	0	0	0	0	0	4	0	0	0
Veliidae Microvelia	0	0	0	0	0	0	0	0	7	0	1	0
Coleoptera												
Chrysomelidae Agasicles	0	0	0	0	1	0	0	0	0	1	0	0
Chrysomelidae (L)	1	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae (P)	1	0	0	0	0	0	0	0	0	0	0	0
Curculionidae Steremnius	0	0	1	0	0	0	0	0	0	0	0	0
Dytiscidae Hydroporus (L)	0	0	1	0	0	0	0	0	0	0	0	0
Dytiscidae Matus (A)	0	0	1	0	0	0	0	0	0	0	0	0
Dytiscidae Matus (L)	0	0	4	0	0	0	0	0	0	0	0	0
Gyrinidae Gyrinus	0	0	0	0	11	0	0	0	1	0	0	0
Haliplidae Haliplus tumidus (A)	1	0	15	1	0	0	0	0	0	0	0	0
Haliplidae Haliplus tumidus (L)	13	0	0	0	1	1	1	7	4	1	0	1

Table 14. Continued.

	1	1	1	1	2	2	2	2	3	3	3	3
	M	J	S	D	M	J	S	D	M	J	S	D
Hydrophilidae Berosus (A)	0	0	1	0	0	0	0	0	0	0	0	0
Hydrophilidae Berosus (L)	3	1	4	0	0	0	0	0	2	0	1	1
Hydrophilidae Derallus (L)	0	0	0	6	0	0	0	0	1	0	0	0
Hydrophilidae Enochrus (A)	0	0	0	2	0	0	0	0	0	0	0	0
Hydrophilidae Enochrus (L)	1	0	0	1	0	5	0	0	0	0	0	0
Hydrophilidae Tropisternus (A)	0	0	4	0	0	2	0	0	0	0	0	0
Hydrophilidae Tropisternus (L)	0	0	7	0	0	1	0	0	0	0	0	0
Noteridae (A)	0	0	0	1	0	0	0	0	0	0	0	0
Scirtidae Cyphon (A)	0	0	0	1	0	0	0	0	0	0	0	0
Scirtidae Cyphon (L)	0	0	0	2	0	0	0	0	0	0	0	0
Trichoptera												
Hydroptilidae Oxyethira	0	0	0	0	0	0	0	0	0	1	1	2
Leptoceridae Oecetis	0	2	0	0	0	0	0	0	0	0	0	0
Diptera												
Ceratopogonidae	1	1	12	0	0	2	1	0	0	0	21	2
Chironomidae Chironominae	47	6	43	36	63	17	27	13	8	53	11	57
Chironomidae Tanypodinae	4	4	7	5	3	2	8	0	4	18	16	4
Chironomidae (P)	8	0	0	0	13	0	0	0	1	2	0	2
Culicidae (L)	0	0	1	0	0	0	0	0	0	0	0	0
Culicidae Anopheles	0	0	0	1	0	0	0	0	0	0	0	0
Culicidae Culex	1	0	0	0	0	0	0	0	0	0	0	0
Culicidae (P)	0	0	2	0	1	0	0	0	0	0	0	0
Stratiomyidae Odontomyia	0	1	5	4	0	1	0	0	0	0	0	0
Tabanidae	0	1	0	0	0	3	0	0	1	0	0	0
Tipulidae	0	0	0	1	1	0	0	0	0	0	0	0
Decapoda												
Cambaridae	0	0	0	0	0	1	3	2	2	0	0	0
Palaemonidae Palaemonetes	1	0	0	0	0	0	0	0	0	0	0	0
Cladocera Daphnia	0	0	0	2	0	0	5	15	1	1	0	0
Copepoda	0	0	1	1	2	0	1	38	0	2	0	0
Amphipoda Hyalella azteca	1	13	0	0	0	0	0	0	15	19	22	2
Ostracoda	4	0	0	1	2	26	9	20	2	7	3	0
Annelida												
Hirudinea	2	0	0	0	6	0	0	0	7	0	0	0
Oligochaeta	0	0	0	4	0	7	3	0	0	1	0	0
Gastropoda												
Physella virgata	8	3	1	3	6	17	7	7	4	5	12	23
Helisoma anceps	0	0	0	3	0	0	0	1	0	0	0	1
Melanoides tuberculata	0	0	0	0	0	0	0	0	1	0	0	0
Snail sp D	3	1	0	24	2	8	18	3	3	7	7	9
TOTALS	166	146	145	124	179	100	100	111	181	134	116	117
TR	24	16	20	22	22	16	16	12	30	17	17	14

sampling error. The cluster patterns were not affected by the reduction of water levels. Pintail Lake is surrounded by other ponds with similar habitats. These ponds are drained periodically. Pintail Lake's bioassessment values and scores are listed in Table 15.

Thirty-five taxa were identified in Willow Lake East (SA2). In June Willow Lake East was intentionally allowed to dry completely for approximately three days (E. Hopson, pers. comm.). The pond was flooded at 0930 and sampled at 1630 on the same day. Well water was used to replenish this pond during dry periods. The water flows through the pond and helps to maintain the water level in Willow Lake. The three collections appeared to be slightly impaired due to the loss of the habitat. The following measures were affected in June and September: Taxa richness, EPT, Trichoptera, Gastropoda, and predator richness. In December's collection the following measures were affected: taxa richness, EPT, % Affinity, Ephemeroptera, Trichoptera, and predator richness. The rapid bioassessment reflected the management system. Willow Lake East's bioassessment values and scores are listed in Table 16. In Willow Lake (SA3) a total of 41 taxa were identified. No unusual events were noticed at this pond. Results of the biological conditions showed that Willow Lake had no impaired collections. Willow Lake's bioassessment values and scores are listed in Table 17.

The three events, at Moore Airfield, Pintail Lake, and Willow Lake East, did not seem to affect the cluster patterns. These aquatic communities displayed resilience and stability in their ability to absorb a disturbance without any changes, to resist change, and to recover quickly without large changes in composition (Krebs 1994, Smith 1996).

Table 15. Seasonal Bioassessment of Pintail Lake (SA1). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	24	16	20	22	6	6	4	6	6
EPT	> 3	2	3	1	1	6	4	6	2	2
% DS	≤ 40	28	35	30	29	6	6	6	6	6
% Affinity	≥ 60	64	48	56	69	6	6	4	4	6
EPH	> 2	2	2	1	1	6	6	6	4	4
TRI	> 2	0	1	0	0	6	0	4	0	0
Gastropoda	≥ 3	2	2	1	3	6	4	4	2	6
Predators	≥ 9	12	4	14	11	6	6	2	6	6
Total Score						48	38	36	30	36
Criteria Score							79%	75%	63%	75%
Biological Condition							Non	Non	SI	Non

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

Table 16. Seasonal Bioassessment of Willow Lake East (SA2). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	22	16	16	12	6	6	4	4	4
EPT	> 3	2	2	2	1	6	4	4	4	2
% DS	≤ 40	37	26	27	34	6	6	6	6	6
% Affinity	≥ 60	58	76	77	47	6	4	6	6	4
EPH	> 2	2	2	2	1	6	6	6	6	4
TRI	> 2	0	0	0	0	6	0	0	0	0
Gastropoda	≥ 3	2	2	2	3	6	4	4	4	6
Predators	≥ 9	10	5	4	3	6	6	4	2	2
Total Score						48	36	34	32	28
Criteria Score							75%	71%	67%	58%
Biological Condition							Non	SI	SI	SI

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

Table 17. Seasonal Bioassessment of Willow Lake (SA3). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	30	17	17	14	6	6	4	4	4
EPT	> 3	2	3	2	3	6	4	6	4	6
% DS	≤ 40	29	40	19	49	6	6	6	6	4
% Affinity	≥ 60	63	60	71	59	6	6	6	6	4
EPH	> 2	2	2	1	2	6	6	6	4	6
TRI	> 2	0	1	1	1	6	0	4	4	4
Gastropoda	≥ 3	3	2	2	3	6	6	4	4	6
Predators	≥ 9	15	5	8	4	6	6	4	4	2
Total Score						48	40	40	36	36
Criteria Score							83%	83%	75%	75%
Biological Condition							Non	Non	Non	Non

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

Olmito Fish Hatchery

A total of fifty-six taxa and 1,634 individuals were identified from the Olmito ponds (Table 18). Cluster analysis grouped all of the 12 Olmito sampling units together. This was expected due to the close proximity and habitat similarity (Table 11) of the three ponds. The results of the cluster analysis are interpreted as indicating little seasonal variation and a lack of pond specific communities. The biological condition of the twelve sampling units showed only two slightly impaired samples. These impaired samples may be due to sampling error. The remaining ten samples were assessed as unimpaired (Table 10). There were no observed habitat modifications during the study.

A total of forty-two taxa were identified at Olmito North. All four collections were non-impaired. Olmito North's bioassessment values and scores are listed in Table 19. Thirty-nine taxa were identified at Olmito Middle. Only December's collection was slightly impaired. The following measures were affected: EPT, % Affinity, Ephemeroptera, Trichoptera, and predator richness. Olmito Middle's bioassessment values and scores are listed in Table 20. Thirty-five taxa were identified at Olmito South. Only June's collection was slightly impaired with all of the measures being effected except for % DS. Olmito South's bioassessment values and scores are listed in Table 21.

Table 18. List of taxa collected from Olmito Fish Hatchery, collected per season. N = North pond, M = Middle pond, and S = South pond. Higher taxonomic classifications (after Thorp and Covich 1991) are identified in bold letters. (L) = larvae, (P) = pupa, and (A) = adult.

	N	N	N	N	M	M	M	M	S	S	S	S
	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC
Ephemeroptera												
Baetidae Callibaetis	11	17	14	10	31	10	47	36	2	8	39	52
Caenidae Caenis	5	2	0	0	1	5	1	0	7	0	0	0
Odonata												
Aeshnidae Aeshna	1	0	0	0	0	1	0	0	2	0	0	0
Aeshnidae Anax	0	0	0	1	6	0	1	6	0	0	0	5
Coenagrionidae Acanthagrion	2	10	6	0	0	19	0	0	0	20	1	0
Coenagrionidae Argia	0	2	0	0	0	0	0	0	0	0	0	0
Coenagrionidae Enallagma	33	3	2	0	23	0	13	30	27	0	24	12
Coenagrionidae Ischnura	0	8	1	6	0	0	1	21	0	0	0	3
Corduliidae Neurocordulia	0	0	1	0	0	0	0	0	0	0	0	0
Corduliidae Somatochlora	0	0	0	0	0	1	0	0	0	0	0	0
Gomphidae Progomphus	0	2	1	0	0	0	0	0	0	0	0	0
Libellulidae Brachymesia	0	3	0	0	0	0	0	1	0	0	0	0
Libellulidae Erythemis	0	6	0	0	0	0	0	0	0	0	0	0
Libellulidae Macrodiplax	3	0	0	0	0	1	0	0	0	0	3	2
Libellulidae Pachydiplax	2	1	0	1	2	0	2	4	0	0	0	0
Hemiptera												
Belostomatidae Belostoma	0	2	3	0	2	5	0	7	0	10	3	1
Corixidae Corixini	0	0	0	0	0	0	0	0	2	6	0	0
Corixidae Palmacorixa	0	2	0	0	0	0	0	0	0	0	0	0
Gerridae Gerris	0	0	0	0	1	0	0	0	0	0	0	2
Macroveliidae Macrovelia	0	1	0	0	0	0	1	1	1	0	0	3
Macroveliidae Oravelia	0	0	0	0	0	0	0	0	0	0	1	0
Naucoridae Pelocoris	0	5	2	0	1	11	0	4	0	15	5	1
Notonectidae Buenoa	0	0	0	0	0	0	0	0	1	2	2	0
Pleidae Neoplea	2	3	2	1	0	1	0	0	0	0	1	0
Veliidae Microvelia	0	0	1	0	0	0	0	0	0	0	0	0
Coleoptera												
Dytiscidae Hydroporus (L)	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae Matus (A)	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae Matus (L)	0	0	0	0	0	1	0	0	0	1	3	0
Haliplidae Haliplus tumidus (L)	0	0	0	0	0	0	0	0	0	0	2	0
Hydrophilidae Berosus (A)	0	0	0	0	0	0	0	0	0	1	0	0
Hydrophilidae Berosus (L)	0	0	1	0	0	1	0	0	8	1	0	0
Hydrophilidae Derallus (L)	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae Enochrus (L)	0	0	0	0	1	1	0	0	0	0	0	0
Hydrophilidae Tropisternus (A)	0	0	0	0	0	1	0	0	0	0	0	0

Table 18. Continued.

	N	N	N	N	M	M	M	M	S	S	S	S
	M	J	S	D	M	J	S	D	M	J	S	D
	A	U	E	E	A	U	E	E	A	U	E	E
	R	N	P	C	R	N	P	C	R	N	P	C
Scirtidae Microcara	0	0	0	0	1	0	0	0	0	0	0	0
Trichoptera												
Leptoceridae Oecetis	5	14	1	1	0	0	0	0	0	0	0	1
Lepidoptera												
Pyralidae	0	0	2	0	0	0	6	0	0	0	0	8
Diptera												
Ceratopogonidae	0	1	0	0	1	0	0	0	2	0	0	0
Chironomidae Chironominae	71	17	18	10	11	3	30	22	4	11	5	19
Chironomidae Tanypodinae	0	0	0	0	0	1	0	0	2	1	1	0
Chironomidae (P)	3	0	0	0	1	0	0	0	0	2	0	0
Culicidae (L)	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae Anopheles	0	0	3	2	0	1	0	2	0	0	0	1
Culicidae Culex	0	0	2	0	0	0	0	0	0	0	0	0
Culicidae (P)	0	0	0	0	0	0	0	3	0	0	0	1
Stratiomyidae Odontomyia	0	3	0	4	0	10	1	0	0	2	0	1
Tabanidae	0	1	0	0	2	0	1	0	1	0	0	1
Thaumaleidae	0	0	0	0	0	0	0	1	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	1	0	0	0	0
Decapoda												
Palaemonidae Palaemonetes	7	17	12	21	3	12	13	4	0	0	2	0
Cladocera Daphnia	1	0	0	2	0	0	0	1	0	0	0	0
Amphipoda Hyalella azteca	20	6	0	0	22	6	0	1	3	26	0	13
Ostracoda	0	0	6	0	0	5	0	0	0	26	0	0
Annelida												
Hirudinea	2	2	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	2	0	0	0	0	0	0
Gastropoda												
Pyrgophorus coronatus												
(spinose form)	4	4	19	3	5	18	4	4	11	0	19	11
Physella virgata	1	5	12	31	0	1	0	1	12	4	0	0
Pyrgophorus coronatus												
(smooth form)	2	6	29	6	4	8	3	4	13	4	11	16
Melanoides tuberculata	0	2	5	5	2	9	3	1	1	0	1	1
Snail sp D	0	2	4	0	0	0	0	0	2	0	1	0
Snail sp F	0	0	0	4	0	0	0	0	0	0	0	0
TOTALS	175	147	147	110	120	134	127	155	101	140	124	154
TR	17	27	22	18	18	24	15	20	18	15	18	19

Table 19. Seasonal Bioassessment of Olmito North (OLN). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	17	27	22	18	6	4	6	6	6
EPT	> 3	3	3	2	2	6	6	6	4	4
% DS	≤ 40	41	12	20	28	6	4	6	6	6
% Affinity	≥ 60	63	77	73	70	6	6	6	6	6
EPH	> 2	2	2	1	1	6	6	6	4	4
TRI	> 2	1	1	1	1	6	4	4	4	4
Gastropoda	≥ 3	3	5	5	5	6	6	4	6	6
Predators	≥ 9	6	12	10	6	6	4	6	6	4
Total Score						48	40	44	42	40
Criteria Score							83%	92%	88%	83%
Biological Condition							Non	Non	Non	Non

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

Table 20. Seasonal Bioassessment of Olmito Middle (OLM). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, Sl = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value				Ref Model Scores	Bioassessment Scores			
		Mar	Jun	Sep	Dec		Mar	Jun	Sep	Dec
TR	≥ 18	18	24	15	20	6	6	6	4	6
EPT	> 3	2	2	2	1	6	4	4	4	2
% DS	≤ 40	26	14	37	23	6	6	6	6	6
% Affinity	≥ 60	67	73	69	61	6	6	6	6	6
EPH	> 2	2	2	2	1	6	6	6	6	4
TRI	> 2	0	0	0	0	6	0	0	0	0
Gastropoda	≥ 3	3	4	3	4	6	6	2	6	6
Predators	≥ 9	8	11	5	8	6	4	6	4	4
Total Score						48	38	36	36	32
Criteria Score							79%	75%	75%	71%
Biological Condition							Non	Non	Non	Sl

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

Table 21. Seasonal Bioassessment of Olmito South (OLS). TR = Taxa Richness; EPT = Ephemeroptera, Plecoptera, Trichoptera; % DS = Percent Dominant Taxon; EPH = Ephemeroptera richness; and TRI = Trichoptera richness. Non = non-impaired, SI = slightly impaired, and Mod = moderately impaired.

Criteria Measures	Ref Model Values	Metric Value Mar	Jun	Sep	Dec	Ref Model Scores	Bioassessment Scores Mar	Jun	Sep	Dec
TR	≥ 18	18	15	18	19	6	6	4	6	6
EPT	> 3	2	1	1	2	6	4	2	2	4
% DS	≤ 40	27	19	31	34	6	6	6	6	6
% Affinity	≥ 60	60	60	66	75	6	6	6	6	6
EPH	> 2	2	1	1	1	6	6	4	4	4
TRI	> 2	0	0	0	1	6	0	0	0	4
Gastropoda	≥ 3	5	2	4	3	6	6	4	6	6
Predators	≥ 9	5	7	10	8	6	4	4	6	4
Total Score						48	38	30	36	40
Criteria Score							79%	63%	75%	83%
Biological Condition							Non	SI	Non	Non

% Comp. to Ref. Score	Bioassessment Biological Condition Category	Attributes
>75%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for habitat quality.
56-74%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
36-55%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<35%	Severely impaired	Very few species present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.

CHAPTER IV

CONCLUSIONS

Delta ponds displayed strong geographic patterns within the region. Cluster analysis showed three distinct areas. Seasonal changes in pond communities were not distinct. These ponds remained similar to each other year round. Gross differences in riparian habitat did not explain the differences found in the pond communities. Finally, the Lower Rio Grande Delta Rapid Bioassessment model can be applied across the region without seasonal or regional modifications. This model seems to be sensitive enough to detect severe water loss cycles.

The Rio Grande Rapid Bioassessment (RBA) Model should be refined and evaluated by sampling less favorable sites in the future. This study only concentrated on good to excellent sites. This information could be used to develop tolerance values for aquatic macroinvertebrates found in this ecoregion, using methods set forth by Hilsenhoff (1982) and Lenat (1993). Also, another study could be conducted on the periphyton community. This study should include type and location of the colony, type of substrate, and source of nutrients. Another segment of this study could be gut analysis on the macroinvertebrates sampled to determine what they are feeding on.

CHAPTER V

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CHAPTER VI

APPENDIX

Table A1. Results of Preliminary Collection of January 1995. Sites 1 = Santa Ana Refuge; 2 = Milano Rd Irrigation Canal; 3 = Olmito Fish Hatchery; 4 = Nelson Rd Irrigation Canal; 5 = Moorefield; 6 = Rooth Rd Irrigation Canal. Higher taxanomic classification (after Thorp and Covich 1991) are identified in bold.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Ephemeroptera						
Baetidae Callibaetis	61	23	86	7	15	8
Caenidae Caenis	3	4	59	28	148	0
Odonata						
Aeshnidae Aeshna	3	0	0	0	0	0
Aeshnidae Anax	2	0	8	0	0	2
Coenagrionidae Acanthagrion	2	6	43	0	0	1
Coenagrionidae Argia	0	2	0	0	0	3
Coenagrionidae Enallagma	0	8	6	15	15	26
Coenagrionidae Ischnura	0	1	2	0	0	0
Corduliidae Epitheca	0	0	0	0	1	0
Corduliidae Somatochlora	1	0	0	0	2	0
Corduliidae Williamsonia	0	0	1	0	0	0
Gomphidae Lanthus	0	0	0	0	0	1
Gomphidae Progomphus	0	0	0	0	1	0
Lestidae Lestes	4	0	1	0	0	0
Libellulidae Erythemis	0	0	1	0	0	5
Libellulidae Macrodiplax	0	0	6	0	5	0
Libellulidae Micrathyria	3	0	0	0	0	0
Libellulidae Orthemis	1	0	0	0	0	0
Libellulidae Pachydiplax	24	0	4	0	0	0
Protoneuridae Protoneura	0	0	0	0	2	6
Lepidoptera						
Pyralidae	0	0	1	0	0	0
Hemiptera						
Corixidae Corixini	0	1	0	0	0	0
Corixidae sp A	2	0	0	0	0	0
Gerridae Gerris	0	6	0	0	0	0
Gerridae Metrobates	0	0	0	0	0	1
Gerridae Rheumatobates	0	1	0	0	0	0
Macroveliidae Macrovelia	0	0	2	0	0	0
Macroveliidae Oravelia	0	0	1	0	0	0
Naucoridae Pelocoris	1	1	0	0	0	0
Nepidae	0	0	1	0	0	0
Notonectidae Buenoa	5	0	2	0	0	0
Pleidae Neoplea	5	0	5	0	0	0
Veliidae Microvelia	1	0	0	0	0	0
Coleoptera						
Dytiscidae Matus	1	0	0	0	0	0
Elmidae Stenelmis	0	0	0	0	0	1
Haliplidae Haliplus tumidus (L)	8	0	0	0	0	0

Table A1. Continued

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Hydrophilidae Berosus (A)	0	0	0	0	0	1
Hydrophilidae Berosus (L)	1	0	2	0	4	4
Hydrophilidae Enochrus	0	0	1	0	0	0
Scirtidae Microcara	0	2	16	0	1	0
Neuroptera						
Sisyridae Sisyra	1	0	0	0	0	0
Trichoptera						
Leptoceridae Oecetis	0	0	1	0	1	0
Diptera						
Ceratopogonidae	0	0	0	0	3	1
Chironomidae Chironominae	25	10	51	8	37	15
Chironomidae Tanypodinae	23	1	3	1	8	0
Chironomidae (P)	6	0	1	0	2	0
Culicidae Anopheles	0	0	8	0	0	0
Tabanidae	0	0	7	0	0	0
Cladocera Daphnia	0	0	0	0	1	0
Amphipoda Hyalella azteca	0	15	9	38	41	11
Decapoda						
Palaemonidae Palaemonetes	0	220	3	97	2	131
Bivalvia						
Corbiculidae Corbicula	0	0	0	0	2	0
Annelida						
Oligochaeta	0	0	0	0	2	0
Gastropoda						
Pyrgophorus coronatus (spinose form)	0	0	2	0	0	0
Pyrgophorus coronatus (smooth form)	2	4	1	2	1	5
Snail sp D	1	0	3	0	0	0
Melanoides tuberculata	0	1	1	0	5	4
Total	186	306	348	196	299	226
TR	23	17	32	8	21	18

Table A2. Results of Hunke ponds, June 1996. Higher taxanomic classification (after Thorp and Covich 1991) are identified in bold.

	H 1	H 2
Ephemeroptera		
Baetidae Callibaetis	5	20
Odonata		
Coenagrionidae Acanthagrion	14	3
Lestidae Lestes	2	0
Libellulidae Pachydiplax	18	4
Hemiptera		
Belostomatidae Belostoma	1	2
Corixidae Centrocorisa	1	0
Naucoridae Pelocoris	7	7
Nepidae	1	0
Notonectidae Buenoa	2	0
Notonectidae Notonecta	0	7
Pleidae Neoplea	0	1
Coleoptera		
Curculionidae Steremnius	0	2
Dytiscidae Matus (A)	1	3
Haliplidae Haliplus tumidus (A)	1	0
Hydrophilidae Tropisternus (A)	2	42
Amphipoda Hyalella azteca	11	5
Ostracoda	28	4
Gastropoda		
Physella virgata	6	4
Snail sp D	0	4
Total	100	108
TR	15	14

Table A3. Rio Grande Delta taxa and abundance by site and seasons. Sites: 1 = Moore Air Field; 2 = Pintail Lake; 3 = Willow Lake East; 4 = Willow Lake; 5 = Olmito North; 6 = Olmito Middle; and 7 = Olmito South M = March, J = June, S = September, and D = December. Taxanomic classifications (after Thorp and Covich 1991) in bold letters.

	Sites and Collection Dates																											
	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Ephemeroptera																												
Baetidae Callibaetis	6	1	0	2	21	32	14	2	21	1	2	0	29	2	0	3	6	12	10	9	26	7	37	23	2	6	31	34
Caenidae Caenis	26	3	0	2	2	35	0	0	2	5	8	2	5	7	1	2	3	1	0	0	1	4	1	0	7	0	0	0
Odonata																												
Aeshnidae Aeshna	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	2	0	0	0
Aeshnidae Anax	0	0	0	0	1	0	0	15	2	0	1	0	4	0	0	0	0	0	0	1	5	0	1	4	0	0	0	3
Coenagrionidae Acanthagrion	3	0	2	0	2	1	0	0	0	1	0	0	0	1	0	0	1	7	4	0	0	14	0	0	0	14	1	0
Coenagrionidae Argia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Coenagrionidae Enallagma	8	1	1	2	0	0	1	0	0	0	0	1	5	0	0	0	19	2	1	0	19	0	10	19	27	0	19	8
Coenagrionidae Ischnura	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	5	1	5	0	0	1	14	0	0	0	2
Corduliidae Cordulia	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corduliidae Macromia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corduliidae Neurocordulia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Corduliidae Somatochlora	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gomphidae Lanthus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae Progomphus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Lestidae Lestes	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae Brachymesia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0
Libellulidae Erythemis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Libellulidae Lepthemis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A3. Continued.

	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Libellulidae Macrodiplax	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	2	1
Libellulidae Micrathyria	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae Orthemis	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae Pachydiplax	0	0	0	0	5	0	3	0	3	0	0	2	4	1	3	4	1	1	0	1	2	0	2	3	0	0	0	0
Hemiptera																												
Belostomatidae Belostoma	0	0	0	2	0	0	3	1	0	0	0	0	1	0	0	0	0	1	2	0	2	4	0	5	0	7	2	1
Corixidae Corixini	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0
Corixidae Palmacorixa	0	0	0	0	0	8	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Corixidae sp A	0	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae Gerris	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae Limnogonus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae Metrobates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroveliidae Macrovelia	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	0	0	0	1	1	1	0	0	2
Macroveliidae Oravelia	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Naucoridae Pelocoris	0	0	0	0	1	1	1	0	1	0	0	0	3	1	1	0	0	3	1	0	1	8	0	3	0	11	4	1
Notonectidae Buenoa	0	0	0	0	3	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0
Pleidae Neoplea	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	2	1	1	0	1	0	0	0	0	1	0
Veliidae Microvelia	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Coleoptera																												
Chrysomelidae Agasicles	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae (L)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae (P)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Curculionidae Steremnius	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A3. Continued.

	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Dytiscidae Hydroporus (L)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae Matus (A)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae Matus (L)	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0
Gyrinidae Gyrinus	0	0	0	0	0	0	0	0	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliplidae Haliplus tumidus (A)	0	0	0	0	1	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliplidae Haliplus tumidus (L)	0	0	0	0	8	0	0	0	1	1	1	6	2	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0
Hydrophilidae Berosus (A)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hydrophilidae Berosus (L)	0	3	0	2	2	1	3	0	0	0	0	0	1	0	1	1	0	0	1	0	0	1	0	0	8	1	0	0
Hydrophilidae Derallus (L)	0	0	0	0	0	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae Enochrus (A)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae Enochrus (L)	0	0	0	0	1	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Hydrophilidae Tropisternus (A)	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Hydrophilidae Tropisternus (L)	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noteridae (A)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae Cyphon (A)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae Cyphon (L)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae Microcara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Trichoptera																												
Hydroptilidae Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae Oecetis	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	10	1	1	0	0	0	0	0	0	0	1
Lepidoptera																												
Pyralidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	5
Diptera																												
Ceratopogonidae	1	0	0	0	1	1	8	0	0	2	1	0	0	0	18	2	0	1	0	0	1	0	0	0	2	0	0	0

Table A3. Continued.

	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Chironomidae Chironominae	28	4	30	29	37	17	27	12	4	40	9	49	41	12	12	9	9	2	24	14	4	8	4	12	9	25	4	6
Chironomidae Tanypodinae	1	1	0	9	2	3	5	4	2	2	8	0	2	13	14	3	0	0	0	0	0	1	0	0	2	1	1	0
Chironomidae (P)	1	0	0	0	5	0	0	0	8	0	0	0	1	1	0	2	2	0	0	0	1	0	0	0	0	1	0	0
Culicidae Anopheles	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	2	0	1	0	1	0	0	0	1	0	0	0	0
Culicidae Culex	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Culicidae (P)	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1
Stratiomyidae Odontomyia	0	0	0	0	0	1	3	3	0	1	0	0	0	0	0	0	0	2	0	4	0	7	1	0	0	1	0	1
Tabanidae	0	1	0	0	0	1	0	0	0	3	0	0	1	0	0	0	0	1	0	0	2	0	1	0	1	0	0	1
Thaumaleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Decapoda																												
Cambaridae	0	0	0	0	0	0	0	0	0	1	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palaemonidae Palaemonetes	3	43	33	10	1	0	0	0	0	0	0	0	0	0	0	0	4	12	8	19	3	9	10	3	0	0	2	0
Cladocera Daphnia	0	0	0	0	0	0	0	2	0	0	5	14	1	1	0	0	1	0	0	2	0	0	0	1	0	0	0	0
Copepoda	0	0	0	0	0	0	1	1	1	0	1	34	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda Hyalella azteca	31	5	0	24	1	9	0	0	0	0	0	0	8	14	19	2	11	4	0	0	18	4	0	1	3	19	0	8
Ostracoda	0	0	0	0	2	0	0	1	1	26	9	18	1	5	3	0	0	0	4	0	0	4	0	0	0	19	0	0
Bivalvia																												
Corbiculidae Corbicula	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annelida																												
Hirudinea	0	0	0	0	1	0	0	0	3	0	0	0	4	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	3	0	7	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Table A3. Continued.

	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Gastropoda																												
Pyrgophorus coronatus (spinose form)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	13	3	4	13	3	3	11	0	15	7
Physella virgata	6	4	7	16	5	2	1	2	3	17	7	6	2	4	10	20	1	3	8	28	0	1	0	1	12	3	0	0
Pyrgophorus coronatus (smooth form)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	20	5	3	6	2	3	13	3	9	10
Snail sp D	0	0	0	0	2	1	0	19	1	8	18	3	2	5	6	8	0	1	3	0	0	0	0	0	2	0	1	0
Helisoma anceps	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Snail sp F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Melanoides tuberculata	5	11	43	24	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3	5	2	7	2	1	1	0	1	1

CHAPTER VII

VITA

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