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Seasonal distribution of the ichthyofauna of Santa Ana National Wildlife Refuge, Alamo, Texas

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SEASONAL DISTRIBUTION OF THE ICHTHYOFAUNA OF SANTA ANA NATIONAL WILDLIFE REFUGE, ALAMO, TEXAS

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SEASONAL DISTRIBUTION OF THE ICHTHYOFAUNA

OF SANTA ANA NATIONAL WILDLIFE REFUGE,

ALAMO, TEXAS

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DATE: January 27, 1989

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Matthew A. Ciomperlik, M.S.
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A study was begun in October 1985 to investigate the small aquatic ecosystems of Santa Ana National Wildlife Refuge, located in a predominantly agricultural area of the Lower Rio Grande Valley. Fishes and water quality data were collected for 13 months to determine the status of fish populations and the factors which influence their distributions on the refuge.

Sixteen fish species were collected during the study, however, more than 20 species are known to inhabit the Rio Grande in the vicinity of the refuge. It appears that with increased distance or isolation from the Rio

Grande water source there is a decrease in species richness. This is most likely due to physical limitations placed upon fish immigrants which are pumped from the river and into cement irrigation canals.

Gambusia affinis, *Cyprinodon variegatus*, *Menidia beryllina* and *Poecilia latipinna* maintained relatively high abundances throughout the study. *Gambusia affinis* was the most abundant species collected from the refuge while *C. variegatus* contributed the greatest biomass. Fish abundance patterns were closely related to changes in water temperature.

Organochlorine pesticide and trace element analysis were performed on samples of *Dorosoma cepedianum* collected from the refuge. Organochlorine residues including DDD and DDE were lower than values previously reported from the Rio Grande and surrounding areas. Trace element residues including selenium, arsenic and lead exceeded the National Academy of Sciences criteria for the safety of fish. Furthermore, mercury residues exceeded the Environmental Protection Agency criteria for the protection of aquatic life. The occurrence of these residues in fish samples from the refuge could not be linked to any one contaminant source.

Dedication

This study is respectfully dedicated to my parents,
Mr. William L. Ciomperlik and Mrs. Faith E. Ciomperlik
for their love and support
throughout my life.

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INTRODUCTION

The Lower Rio Grande Valley (LRGV) is one of only two subtropical regions of the United States and has long been known for its unique flora and fauna. This area, consisting of Cameron, Willacy, Hidalgo, and Starr Counties, Texas, has been treated as a separate Matamoran district within the Tamaulipan Biotic Province due to its lush vegetation and distinctive vertebrate fauna (Blair 1950). The dominant woody species found in the district are cedar elm (*Ulmus crassifolia*) and hackberry (*Celtis laevigata*) (Blair 1950). Vertebrate species such as the jaguarundi (*Felis yagouaroundi*) and chachalaca (*Ortalis vetula*) are limited in Texas to the Matamoran district (USFWS 1984).

Since 1943, many changes have occurred in land and water use in the LRGV. These include the widespread introduction and use of agricultural chemicals throughout the area as well as the construction of flood and irrigation control dams on the Rio Grande (Falcon in April 1954, Anzalduas in April 1960, Amistad in June 1969, and Retamal in May 1975) which have curtailed the natural seasonal flooding of woodlands adjacent to the river. An extensive floodway system, designed to rapidly drain flood waters into the Laguna Madre, was initiated in 1951 (and subsequently repaired and improved in 1959 and 1967 due to flood damage IBWC 1981).

The Texas Department of Water Resources (1981) estimated that more than 404,858 ha of brushland has been converted to irrigated cropland in the LRGV and that a similar amount has been converted on the Mexico side of the Rio Grande. Similarly, the Department of the Interior's Land Protection Plan estimated that over 90% of native brushland has been cleared in the LRGV for either agricultural or municipal uses (USFWS 1983).

Agricultural chemicals and petrochemicals have played a major role in degrading the water quality of this region. A study commissioned by the Lower Rio Grande Valley Development Council showed substances including DDT, DDD, DDE, nickel, lead, cadmium and mercury in waters of the LRGV (Black and Veatch 1982). These substances were found in greater concentrations than the Environmental Protection Agency's safety criteria for the protection of aquatic life. A study of the Arroyo Colorado (a major waterway traversing the LRGV), implemented through the National Pesticide Monitoring Program, showed DDE and toxaphene residues up to 31.5 ppm in whole fish composite samples (White et al. 1983). These authors concluded that serious pesticide contamination existed in the Arroyo Colorado.

Santa Ana National Wildlife Refuge (NWR) is one of the few relatively "natural" areas remaining in the LRGV. The refuge is located 12 km south of Alamo, Hidalgo County, Texas. The 842 ha refuge was established in 1943 in a lowland flanking a large serpentine bend of the Rio Grande. It is the largest contiguous block of Tamaulipan riparian woodland under state or federal protection in the LRGV. The refuge is approximately 27 m above sea level and vegetation is chiefly a jungle-like forest of native trees such as cedar elm (Ulmus crassifolia), Texas ebony (Pithecellobium flexicaule), and sugar hackberry (Celtis laevigata) (Fleetwood 1973). Because Santa Ana NWR is relatively undisturbed it provides the best available point of comparison for disturbed communities elsewhere in the LRGV.

In the past the natural aquatic habitats of the LRGV have included numerous pot holes, resacas and the Rio Grande. The Rio Grande was subject to a yearly flood cycle which inundated a considerable area of the flood-plain. Today, however, aquatic habitats of this area include the Rio Grande without its yearly flood cycle, an extensive irrigation canal system, man-made lakes, stock tanks, ponds and water supply reservoirs.

The fish communities of the LRGV have not been extensively studied. Treviño-Robinson (1959) found 54 species and one hybrid within the Rio Grande and its tributaries between the Pecos River and the mouth of the Rio Grande. In her study, 12 species were cosmopolitan in their distributions. In a 1982 study by Edwards and Contreras-Balderas (Pers. Comm.), 81 species were found between Falcon Reservoir and the mouth of the Rio Grande, 20 of which inhabited most sections of the lower river. Hubbs (1982) indicates a similar fish faunal makeup for the LRGV. These studies (Treviño-Robinson 1959, Edwards and Contreras-Balderas, Pers. Comm., and Hubbs 1982) showed that the lower portion of the Rio Grande is dominated by such freshwater species as Dorosoma cepedianum, D. petenense, Notropis lutrensis, Pimephales vigilax, Poecilia latipinna, P. formosa, Gambusia affinis, Lepomis macrochirus, Cichlasoma cyanoguttatum, and Oreochromis aureus. Furthermore, these studies noted that estuarine-adapted forms including, Cyprinodon variegatus, Fundulus grandis and Menidia beryllina also occur in the aquatic communities of the LRGV.

Other published fish investigations have been conducted in the LRGV. Hubbs (1964) described the reproductive biology of Poecilia latipinna and P. formosa from samples obtained near Brownsville, Texas. Atkinson and Judd (1978) compared the hematology of Lepomis microlophus and Cichlasoma cyanoguttatum from samples taken near La Joya, Texas. Edwards et al. (1986) took two specimens of Awaous tajasica from the Rio Grande below

Anzalduas dam, effectively extending the species range 250 km to the north. Two studies have been conducted on water quality parameters of the LRGV (Black and Veatch 1981, 1982; White et al. 1983).

The purpose of this study is to compare the fish species diversity and seasonal variability in diversity among the ponds of Santa Ana NWR. Measurements of selected water quality characteristics, i.e. dissolved oxygen, salinity, temperature and turbidity are correlated with fish species diversity and seasonal variability in diversity. The effect of water level manipulations on species diversity is also considered.

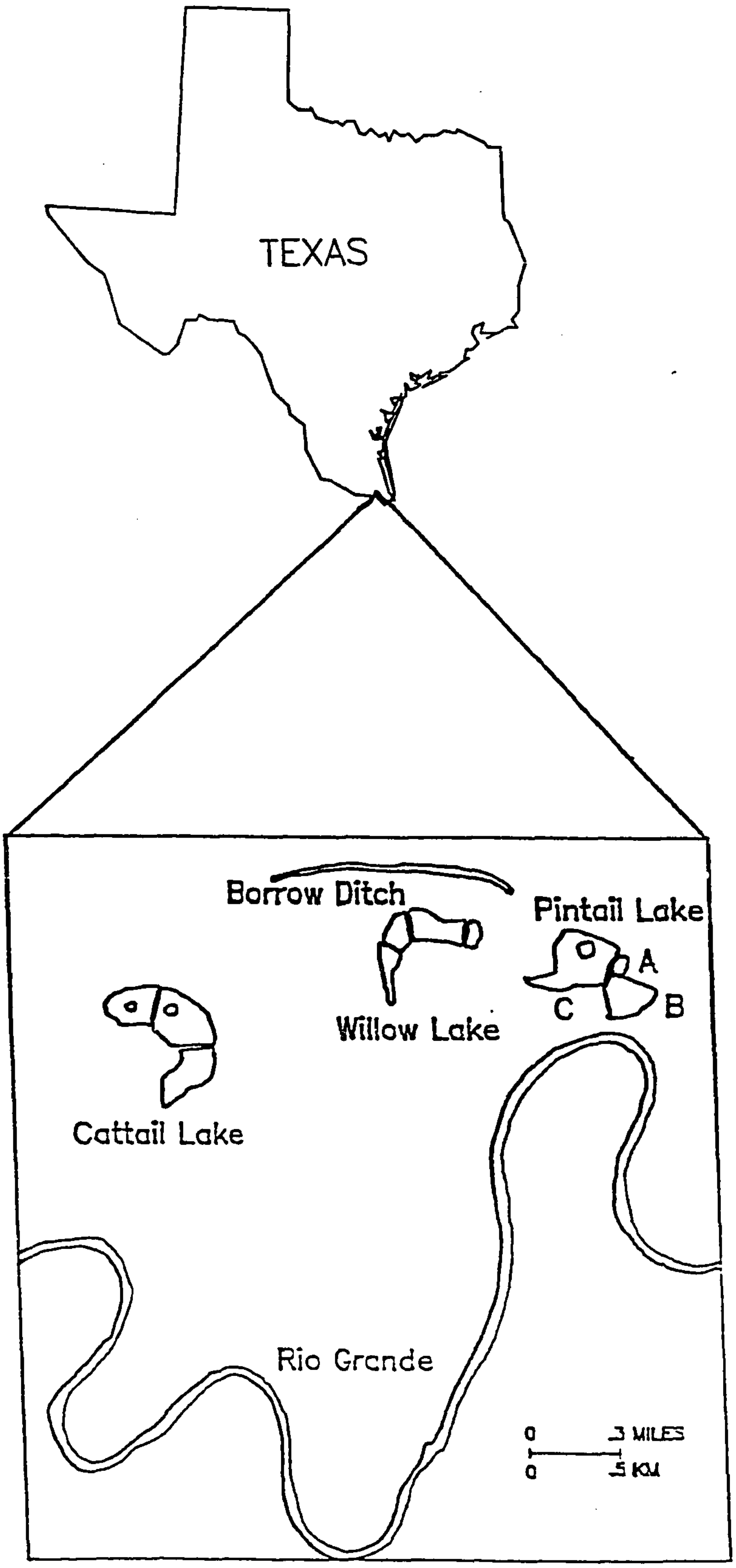
The fish communities of Santa Ana NWR were chosen because: Santa Ana NWR is located in a predominantly agricultural area of the LRGV, and a comprehensive study of fish populations on the refuge is needed for informed resource management. Four impoundments on the refuge are supplied with water from the Rio Grande while two large ponds receive water from underground sources. Hence, valuable information has been gathered for comparison of fish species diversity between water sources. Information gathered during this study will be useful to management agencies (especially the US Fish and Wildlife Service) by providing an inventory of fish species, their relative abundances and seasonal diversity in the pond ecosystems.

This study also documents the effects of seasonal water quality differences and managed water level manipulations upon the ichthyofauna of the area. The data collected will be useful in aiding the understanding of how water quality parameters, and water supply affect fish populations inhabiting small aquatic systems.

MATERIALS AND METHODS

Fish and water samples were collected for 13 months between October 1985 and October 1986 from aquatic ecosystems within the protective confines of the Santa Ana National Wildlife Refuge. A seine (5 m long, 1.2 m tall, mesh diameter 2 mm) was used to collect fish. Each site was seined once, each month, for a distance of 15 linear meters to standardize the collection effort. Limiting seine collections to once a month minimized perturbations at the sampling sites. Eight sites were selected that characterized freshwater environments usually found in the Rio Grande flood-plain (Figure 1). Six of these sites were small to large ponds supplied with either irrigation water from the Rio Grande (Pintail Lakes (A),(B) and (C)), water pumped from underground sources (Willow and Cattail Lakes), or run-off from adjacent farmland (Vela Woods Pond). The two remaining sites included a borrow ditch and a mainstream river site (Rio Grande) to contrast fish species diversities among collection sites. Including all of the aquatic ecosystems located in the refuge has provided as complete a fish species list for the refuge as possible. Sampling within the protected confines of the refuge eliminated the possibility of outside perturbations to the collection sites.

Figure 1. Map of Texas and Santa Ana National Wildlife Refuge showing the aquatic ecosystems which were sampled.


TEXAS
Borrow Ditch
Pintail Lake
A
B
C
Willow Lake
Cattail Lake
Rio Grande
0 .3 MILES
0 .5 KM

Data on fishes were compared on a seasonal basis. Samples collected were analyzed to determine percentage biomass for each species as well as the number of individuals per species. Shannon's diversity index and Pielou's evenness index were calculated for fish species diversity and biomass diversity for each site throughout the study. Fluctuations of species diversities and abundances were expected during the course of this study. The correlation of these fluctuations with the seasonal variability of water quality characteristics was a major goal of this investigation.

Fish collected from the eight sites were preserved in a 10% formalin solution. Fish were brought into the lab, sorted by species, counted, weighed in aggregate to the nearest 0.1 g and measured (standard length) to the nearest mm. Samples of gizzard shad and sheepshead minnows were collected and forwarded for pesticide analyses to the USFW Ecological Services laboratory in Corpus Christi, Texas. Analyses were performed to determine what quantities, if any, of organochlorine pesticide or trace element residues were present in tissues of the fish.

Water samples were taken at each site immediately prior to the fish collection. Water samples of 250 ml were collected in prewashed glass containers at a depth of approximately 0.5 m. Water temperature, salinity and conductivity were measured in the field using a YSI S-C-T meter. Dissolved oxygen was measured with a YSI oxygen meter. A portable pH meter was used to determine pH. Water samples were returned to the lab (on ice) where total-hardness, total-alkalinity, and ammonia were determined using a Hach water quality kit. Turbidity was measured as a function of relative absorbance using a Bausch and Lomb Spectronic 20 spectrophotometer.

RESULTS

Fishes of Pintail Lake (A)

Pintail Lake (A) is approximately 0.06 ha in surface area and is the smallest of the impoundments within Santa Ana NWR (Figure 1). The lake is surrounded by stands of mimosa (Mimosa pigra), rattlepod (Disbania drummondii) and cattails (Typha domingensis). The substrate of the lake is mainly clay with a thick layer of gray silty mud; little or no decaying plant matter is present. Water clarity is rather poor due to suspended solids. The average turbidity is 125 Jackson Turbidity Units (JTU). River water flowed into the lake from the north from a cement irrigation canal. Water left the lake through gated pipes into either Pintail Lake (B) or (C).

Fifteen fish species were collected from this lake (Table 1). Inland silversides (Menidia beryllina) was collected throughout the study. This species accounted for more than 80% of the total fish captures during the months of December, February, April and May. Three species, sheepshead minnow (Cyprinodon variegatus), sailfin molly (Poecilia latipinna) and mosquitofish (Gambusia affinis) were also captured frequently and in large numbers. Four minnow species, red shiner (Notropis lutrensis), Tamaulipas shiner (N. braytoni), common carp (Cyprinus carpio) and bullhead minnow (Pimephales vigilax) and mexican tetra

TABLE I. Percentage of fishes collected from Pintail Lake (A) by species and month. The total fish captures (n) in a given month are shown.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	387	134	168	17	43	433	383	930	193	162	1060	515	208
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense							0.3						0.5
Dorosoma cepedianum	33.0	34.0	7.1	12.0				1.1	1.6	1.2	0.1		
Astyanax mexicanus	13.0						0.3		1.0	6.8		0.4	7.2
Cyprinus carpio	3.6								0.5				
Notropis braytoni		19.0	3.6						9.3		0.2		
Notropis lutrensis					12.0	2.5	2.1	2.3		36.0			25.0
Pimephales vigilax						0.2						2.9	
Ictalurus punctatus	0.3	0.7											
Cyprinodon variegatus	7.2	19.0	1.2	53.0		3.7		0.4	7.3	28.0	3.8	2.9	
Poecilia latipinna	33.0		3.6			10.0	2.3	0.2		3.1	54.0	49.0	2.9
Gambusia affinis	2.1		3.0			48.0	6.8	15.0	67.0	10.0	36.0	19.0	21.0
Menidia beryllina	7.2	19.0	80.0	29.0	88.0	36.0	88.0	81.0	11.0	14.0	5.8	26.0	43.0
Morone chrysops	0.3												
Lepomis macrochirus		4.5	1.8	5.9			0.3		0.5				
Cichlasoma cyanoguttatum	0.3	3.0							1.6				
	100	100	100	100	100	100	100	100	100	100	100	100	100

(Astyanax mexicanus), were collected only sporadically. A single white bass (Morone chrysops) was collected from this site in October 1985.

Table 2 shows the percent biomass collected from Pintail Lake (A) for each species by month. Gizzard shad (Dorosoma cepedianum) accounted for more than 35% of the fish biomass collected from October through January. Inland silversides accounted for more than 48% of the biomass collected during December, February, April, and May. During August and September sailfin mollies accounted for more than 70% of the fish biomass collected. Sheepshead minnows, accounted for more than 45% of the biomass collected during January and July.

Fishes of Pintail Lake (B)

Pintail Lake (B), approximately 0.47 ha in surface area, is surrounded by stands of retama (Parkinsonia aculeata), mimosa, and cattails. The substrate of the lake is similar to that of Pintail Lake (A). River water flowed into this lake from Pintail Lake (A) or from Pintail Lake (C) (Figure 1). Water clarity was poor due to a large amount of suspended clay and silt particles. Average turbidity at this site was 122 JTU.

Thirteen fish species were collected from Pintail Lake (B) (Table 3). The inland silverside was the most abundant

TABLE II. Percentage of fish biomass (g) collected from Pintail Lake (A) by species and month.

SPECIES	Oct g = 1553 %	Nov 229 %	Dec 112 %	Jan 33 %	Feb 34 %	Mar 296 %	Apr 120 %	May 169 %	Jun 153 %	Jul 112 %	Aug 367 %	Sep 259 %	Oct 111 %
<u>Dorosoma petenense</u>							0.5						2.0
<u>Dorosoma cepedianum</u>	43.0	78.0	39.0	35.0				3.3	20.0	2.1	0.1		
<u>Astyanax mexicanus</u>	7.4						3.3		1.0	17.0		1.4	27.0
<u>Cyprinus carpio</u>	4.6								26.0				
<u>Notropis braytoni</u>		2.5	1.4						4.8		0.2		
<u>Notropis lutrensis</u>					14.3	1.6	6.8	4.3		11.0			18.0
<u>Pimephales vigilax</u>						0.2						1.9	
<u>Ictalurus punctatus</u>	0.3	1.1											
<u>Cyprinodon variegatus</u>	1.3	8.6	1.2	47.0		4.3		4.5	25.0	55.0	7.5	4.7	
<u>Poecilia latipinna</u>	14.0		5.5			26.2	13.0	0.9		4.2	70.0	71.0	5.8
<u>Gambusia affinis</u>	0.9		1.3			46.7	10.0	16.0	16.0	3.8	19.0	6.7	19.0
<u>Menidia beryllina</u>	0.3	4.2	48.0	9.1	85.7	20.9	61.0	71.0	3.7	6.0	3.5	14.0	29.0
<u>Morone chrysops</u>	2.0												
<u>Lepomis macrochirus</u>		3.3	3.0	9.7			6.1		2.9				
<u>Cichlasoma cyanoguttatum</u>	26.0	2.8							0.7				
	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE III. Percentage of fishes captured from Pintail Lake (B) by species and month. The total fish captured (n) in a given month are shown. An asterisk (*) denotes a value of less than 0.1%.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	2516	306	20	154	182	721	740	996	388	327	256	842	411
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense			5.0			3.1	13.1		5.2	0.6			
Dorosoma cepedianum	9.1	9.2	50.0	1.3	0.5		20.0	2.3	4.1	13.0	43.0	31.0	12.0
Astyanax mexicanus	*	0.3		2.6		0.8			0.8		1.2	0.7	0.5
Cyprinus carpio		0.3				0.1					0.4		
Notropis braytoni											1.2		
Notropis lutrensis												0.1	0.7
Cyprinodon variegatus	1.4	0.7	5.0		1.1	0.3	0.8		2.1		0.4	2.3	
Poecilia latipinna	10.7					1.7	0.8		2.1	1.2	2.0	3.2	3.6
Gambusia affinis	73.1	2.0	15.0	1.9	13.0	1.1	5.9	22.0	23.0	1.2	37.0	41.0	68.0
Menidia beryllina	1.4	86.0		93.0	86.0	93.0	58.0	76.0	61.0	84.0	12.0	21.0	1.9
Lepomis gulosus			5.0										
Lepomis macrochirus	0.5	1.6	20.0	0.6			1.2			0.6	2.7		13.0
Cichlasoma cyanoguttatum	3.9			0.6		0.3	0.3		1.8			0.5	0.2
	100	100	100	100	100	100	100	100	100	100	100	100	100

species comprising over 80% of the total fishes captured during November, January, February, March and July. The mosquitofish was captured in all monthly collections and accounted for more than 40% of the captures during October and September 1985 and October 1986. Gizzard shad, were collected in all samples except during March, and reached a peak of 43% of the fish captures in August. Sheepshead minnows and sailfin mollies were captured frequently from Pintail Lake (B), but they never exceeded 15% of the total fish captures in any collection. Minnow species were collected infrequently and did not exceed 5% of the captures in any sample. One warmouth (Lepomis gulosus) was collected during December. This was the only collection of this species from the refuge.

Table 4 shows the percentage of fish biomass collected from Pintail Lake (B) for each species by month. Inland silversides accounted for over 70% of the total fish biomass captured during the months of January through March, May and July. Gizzard shad accounted for more than 40% of the biomass taken during November, December and September. Even though mosquitofish were collected in all samples, they did not exceed 30% of the fish biomass captured in any month.

TABLE IV. Percentage of fish biomass (g) collected from Pintail Lake (B) by species and month.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
g =	1510	187	59	71	67	298	284	273	264	183	112	396	147
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense			2.4			2.9	18.0		11.0	0.9			
Dorosoma cepedianum	18.1	64.0	52.0	3.2	7.6		29.0	8.6	5.6	26.0	37.0	40.0	34.0
Astyanax mexicanus	0.1	1.2		17.0		5.8			1.5		5.0	1.3	1.0
Cyprinus carpio		3.8				4.0					1.0		
Notropis braytoni											2.1		
Notropis lutrensis												0.4	1.2
Cyprinodon variegatus	4.6	2.5	1.9		3.1	1.7	5.0		8.2		0.6	5.4	
Poecilia latipinna	31.7					6.9	4.4		5.1	1.6	4.6	12.0	14.0
Gambusia affinis	25.4	1.0	1.4	1.7	16.0	1.3	3.2	16.0	12.0	0.5	25.0	21.0	29.0
Menidia beryllina	0.5	25.0		72.0	73.0	74.0	30.0	75.0	47.0	70.0	14.0	20.0	1.9
Lepomis gulosus			38.0										
Lepomis macrochirus	0.8	2.8	4.1	2.0			6.5			0.6	11.0		9.5
Cichlasoma cyanoguttatum	18.7			4.1		6.1	3.2		10.0			0.4	9.0
	100	100	100	100	100	100	100	100	100	100	100	100	100

Fishes of Pintail Lake (C)

Pintail Lake (C), approximately 0.85 ha in surface area, has an island of about 0.04 ha in its middle. It is the largest lake within the refuge (Figure 1) and is surrounded by stands of mimosa, retama, willow (Salix nigra), and cattails. In addition to this vegetation the island has many large mesquite (Prosopis glandulosa) trees. The substrate of the lake was clay with a thick overlaying layer of silty mud, numerous fallen branches and decaying grasses and sedges. The fallen branches and consistency of the substrate made seining difficult at this site. River water flowed into this lake from the east through a gated pipe from Pintail Lake (A). Water clarity was poor, the average turbidity was 125 JTU.

Eleven fish species were collected from Pintail Lake (C). Sheepshead minnows and inland silversides appeared in all monthly collections (Table 5). Inland silversides accounted for more than 70% of the monthly fish captures from December through April. Sheepshead minnows accounted for approximately 60% of the monthly fish captures in November, June and July. Two poecilids, the sailfin molly and mosquitofish, were captured frequently from this site. Sailfin mollies accounted for more than 50% of the captures in September. Six species were collected only sporadically from Pintail Lake (C), they were; gizzard shad, mexican

TABLE V. Percentage of fishes collected from Pintail Lake (C) by species and month. The total fish captured (n) in a given month are shown.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	1058	123	98	60	55	311	243	327	1635	803	366	837	448
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma cepedianum	7.8	21.0	12.0	1.7			3.7				2.5		
Astyanax mexicanus	1.0		1.0				0.8		0.1				0.4
Cyprinus carpio	1.0												
Notropis braytoni	0.6	0.8	3.1										
Notropis lutrensis						0.3		0.3					
Cyprinodon variegatus	29.0	64.0	2.0	1.7	5.5	6.8	14.0	14.0	66.0	58.0	26.0	14.0	16.0
Poecilia latipinna	5.5	4.9	1.0	20.0			3.7	26.0	14.0	26.0	29.0	71.0	1.1
Gambusia affinis	2.6	4.1	7.1			4.2	7.8	18.0	19.0	7.8	35.0	11.0	29.0
Menidia beryllina	33.0	2.4	73.0	77.0	94.0	89.0	70.0	41.0	1.7	8.0	6.0	4.8	52.0
Lepomis macrochirus	9.0	2.4							0.1		1.6	0.1	
Cichlasoma cyanoguttatum	10.0								0.1				0.7
	100	100	100	100	100	100	100	100	100	100	100	100	100

tetra, Tamaulipas shiner, red shiner, bluegill (Lepomis macrochirus) and Rio Grande cichlid (Cichlasoma cyanoguttatum). The common carp was collected only once, in October 1985.

The percentage of fish biomass collected in each month from Pintail Lake (C) is shown by species in Table 6. Sheepshead minnows accounted for more than 40% of the fish biomass collected during November, June, July and October. More than 30% of the fish biomass taken during December, February, March, April, May and October was accounted for by inland silversides. These two fish species accounted for the bulk of the fish biomass collected from this site, however, gizzard shad accounted for over 44% of the biomass during November, December and August.

Fishes of Willow Lake

Willow Lake is approximately 0.40 ha in surface area (Figure 1). It is surrounded by stands of willow trees, cedar elm (Ulmus crassifolia), huisache (Acacia smallii), and cattails. The substrate of the lake was clay with an upper layer of silty mud. This lake had the greatest amount of decaying plant matter in the water and substrate. Water was pumped into Willow Lake from a deep water well, and water clarity was good despite the decaying plant matter. The average water turbidity was 89 JTU.

TABLE VI. Percentage of fish biomass (g) collected from Pintail Lake (C) by species and month.

SPECIES		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	g =	1460	285	136	43	61	68	187	158	386	838	631	426	164
		%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma cepedianum		20.0	51.0	60.0	12.0			12.0				44.0		
Astyanax mexicanus		1.8		1.7				3.9		0.6				1.5
Cyprinus carpio		3.2												
Notropis braytoni		0.1	0.1	1.0										
Notropis lutrensis							2.1		1.8					
Cyprinodon variegatus		31.0	43.0	2.8	1.4	8.0	15.0	39.0	24.0	61.0	71.0	30.0	33.0	40.0
Poecilia latipinna		7.2	3.1	0.5	13.0			11.0	9.1	24.0	23.0	14.0	52.0	2.3
Gambusia affinis		0.4	0.5	1.8	74.0		7.1	1.7	20.0	10.0	2.7	3.2	5.3	15.0
Menidia beryllina		11.0	0.8	32.0		92.0	76.0	33.0	46.0	2.2	3.7	1.5	5.7	41.0
Lepomis macrochirus		6.9	1.7							3.1		8.1	3.5	
Cichlasoma cyanoguttatum		19.0								0.3				0.4
		100	100	100	100	100	100	100	100	100	100	100	100	100

Five fish species were captured in Willow Lake prior to October 1986. Mosquitofish and sheepshead minnow were captured frequently. Sheepshead minnows accounted for more than 70% of the fish captures during November, August, September, and reached a peak of 97% in December of 1985 (Table 7). Mosquitofish accounted for over 67% of the fish captures during October, January, February, March, May, June and all of the captures in April. Sailfin mollies were captured frequently but never accounted for more than 15% of the fish captures in any one month. The Rio Grande cichlid and bluegill were also collected but in relatively low numbers.

Table 8 shows the percentage of fish biomass collected from Willow Lake for each species by month. Sheepshead minnows accounted for more than 70% of the fish biomass collected during November, December, and July through September. Mosquitofish were not quite as abundant in terms of biomass. This species accounted for over 65% of the biomass collected during October, March, June, and comprised 100% of the sample in April. Rio Grande cichlids were captured infrequently, but they accounted for over 79% of the fish biomass in February and May. Sailfin mollies accounted for more than 20% of the fish biomass during March and June.

TABLE VII. Percentage of fishes collected from Willow Lake by species and month. The total fish captured (n) in a given month are shown.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	1637	478	813	118	70	1399	509	390	1093	829	727	875	444
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Cyprinodon variegatus	4.5	71.0	97.0	27.0	4.3	5.1		0.5	5.9	48.0	91.0	88.0	0.5
Poecilia latipinna	6.4			5.9		7.2		2.8	8.6	15.0	5.4	12.0	
Gambusia affinis	89.0	29.0	3.0	67.0	94.0	83.0	100	96.0	85.0	37.0	4.0		
Menidia beryllina													1.1
Lepomis macrochirus						4.2				0.1			98.0
Cichlasoma cyanoguttatum	0.1				1.4			0.5		0.2		0.1	
	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE VIII. Percentage of fish biomass (g) collected from Willow Lake by species and month.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
g =	354	459	354	36	121	374	81	312	313	477	518	788	44
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Cyprinodon variegatus	8.5	96.0	99.0	54.0	1.0	14.0		0.4	10.0	73.0	96.0	85.0	0.2
Poecilia latipinna	16.0			7.8		20.0		0.6	22.0	13.0	2.0	15.0	
Gambusia affinis	74.0	4.0	1.0	37.0	13.0	65.0	100	20.0	68.0	11.0	2.0		
Menidia beryllina													1.8
Lepomis macrochirus						2.2				3.6			98.0
Cichlasoma cyanoguttatum	0.9				86.0			79.0		0.3		0.2	
	100	100	100	100	100	100	100	100	100	100	100	100	100

Fishes of the Borrow Ditch

The Borrow Ditch was formed by the removal of dirt for the building of a levee to hold back flood waters of the Rio Grande. The ditch was approximately 5 m wide and one km long (Figure 1). The banks of the ditch were lined with mimosa, cattails, huisache, and buffel grass (Cenchrus siliaris). The substrate of the ditch was similar to Willow Lake. River water was released into the ditch from a cement irrigation canal on top of the levee. Water clarity was good, the average turbidity was 59 JTU.

Seven fish species (gizzard shad, threadfin shad, sailfin mollies, mosquitofish, inland silversides, bluegills, and Rio Grande cichlids) were collected from the Borrow Ditch. Threadfin shad were collected in all samples except those taken in April and October 1986 (Table 9). This species accounted for more than 35% of the total number captured in June, July, September and reached a peak of 57% in August. Gizzard shad were also collected, but they were not captured as frequently nor in as large numbers. Inland silversides were collected in all samples from the Borrow Ditch except July. This species accounted for more than 60% of the total captures in seven of the 13 samples taken at this site. Mosquitofishes were taken in seven of the 13 samples and they accounted for more than 40% of the captures in November and July. Sheepshead

TABLE IX. Percentage of fishes collected from the Borrow Ditch by species and month. The total fish captured (n) in a given month are shown.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	106	92	65	34	76	13	338	518	365	265	67	290	37
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
<u>Dorosoma petenense</u>	1.9	11.0	6.2	24.0	9.2	38.0		13.0	40.0	54.0	57.0	48.0	
<u>Dorosoma cepedianum</u>	11.0			5.9		7.7	12.0						8.1
<u>Poecilia latipinna</u>		7.6								2.3	3.0	6.2	2.7
<u>Gambusia affinis</u>	1.9	63.0	7.7	5.9	20.0			20.0					
<u>Menidia beryllina</u>	85.0	11.0	78.0	47.0	67.0	54.0	88.0	67.0	60.0	40.0	37.0	45.0	73.0
<u>Lepomis macrochirus</u>		5.4	6.2	12.0	3.9					0.8	3.0	0.7	2.7
<u>Cichlasoma cyanoguttatum</u>		2.2	1.5	5.9			0.3			2.6		0.3	14.0
	100	100	100	100	100	100	100	100	100	100	100	100	100

minnows, bluegills, and Rio Grande cichlids were collected only sporadically and they never accounted for more than 15% of the total captures.

Approximately 0.08 kg of fish biomass was collected from the Borrow Ditch. The percentage of biomass collected by species and month is shown in Table 10. No individual species dominated in terms of biomass collected. Threadfin shad and inland silversides were approximately equal in their contributions to the biomass. Threadfin shad accounted for more than 45% of the biomass gathered during March, and June through September. Inland silversides accounted for more than 40% in October, and April through June. Two poecilids, mosquitofish and sailfin mollies were captured infrequently from the Borrow Ditch. Mosquitofishes were more abundant in terms of biomass collected than sailfin mollies (Table 10). Rio Grande cichlids were captured only sporadically, but they accounted for more than 38% of the fish biomass collected during December and January.

Fishes of the Rio Grande

Collections from the Rio Grande took place on a southward bend of the river where an accretion bank had formed. Samples were taken at water depths of less than 2 m. The substrate was mainly sand or clay and no decaying

TABLE X. Percentage of fish biomass (g) collected from the Borrow Ditch by species and month.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
g =	36	77	38	41	35	11	45	119	62	108	44	175	18
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense	14.0	14.0	12.0	19.0	25.0	71.0		20.0	45.0	61.0	61.0	61.0	
Dorosoma cepedianum	31.0			18.0		15.0	8.3						2.7
Poecilia latipinna		27.0								9.2	5.0	24.0	8.2
Gambusia affinis	3.1	32.0	6.5	2.7	34.0			38.0					
Menidia beryllina	52.0	4.0	26.0	16.0	37.0	14.0	83.0	42.0	55.0	17.0	9.5	11.0	24.0
Lepomis macrochirus		5.0	9.2	6.1	4.0					8.2	24.0	2.2	38.0
Cichlasoma cyanoguttatum		18.0	46.0	38.0			8.9			4.4		1.3	28.0
	100	100	100	100	100	100	100	100	100	100	100	100	100

plant matter was apparent. The bank was lined with dense stands of willow saplings. Water currents and depth made seining difficult at this site when large amounts of water were released from upriver dams. Water clarity was generally good at this site, the average turbidity was 56 JTU.

Eleven fish species were captured from the Rio Grande. The percentage of total captures by species and month is shown in Table 11. Inland silverside accounted for more than 80% of the total captures in October, August and September. Red shiners were captured often, they accounted for more than 75% of the captures from February through June. The remaining eight species were captured sporadically and in relatively low numbers. No individual species was represented in all of the monthly samples.

Table 12 shows the percentage of fish biomass collected from the Rio Grande by month and species. Inland silversides accounted for more than 75% of the fish biomass collected during October and November. Red shiners accounted for 100% of the biomass collected during March, May and June. Although threadfin shad were collected sporadically, they accounted for more than 65% of the fish biomass taken during January, July and August. The remaining eight species occasionally accounted for large portions of the biomass collected but only for single samples.

TABLE XI. Percentage of fishes collected from the Rio Grande by species and month. The total fish captured (n) in a given month are shown.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	23	2	44	5	39	11	6	11	26	47	15	22	50
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense				60.0	13.0					17.0	20.0		
Dorosoma cepedianum							17.0						
Astyanax mexicanus				40.0									
Notropis braytoni		50.0										14.0	82.0
Notropis lutrensis					79.0	100	83.0	100	100	6.4			
Pimephales vigilax			75.0		2.6								
Ictalurus punctatus			2.3										
Cyprinodon variegatus			2.3		5.1								
Poecilia latipinna			2.3									4.5	
Menidia beryllina	96.0	50.0	18.0							77.0	80.0	82.0	18.0
Lepomis macrochirus	4.3												
	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE XII. Percentage of fish biomass (g) collected from the Rio Grande by species and month.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
g =	20	2	18	32	88	15	89	10	23	56	15	15	21
SPECIES	%	%	%	%	%	%	%	%	%	%	%	%	%
<u>Dorosoma</u> <u>petenense</u>				65.0	49.0					81.0	75.0		
<u>Dorosoma</u> <u>cepedianum</u>							85.0						
<u>Astyanax</u> <u>mexicanus</u>				35.0									
<u>Notropis</u> <u>braytoni</u>		21.0										10.0	80.0
<u>Notropis</u> <u>lutrensis</u>					47.0	100	15.0	100	100	3.0			
<u>Pimephales</u> <u>vigilax</u>			62.0		3.0								
<u>Ictalurus</u> <u>punctatus</u>			16.0										
<u>Cyprinodon</u> <u>variegatus</u>			2.3		1.0								
<u>Poecilia</u> <u>latipinna</u>			5.1									47.0	
<u>Menidia</u> <u>beryllina</u>	75.0	79.0	15.0							16.0	25.0	43.0	20.0
<u>Lepomis</u> <u>macrochirus</u>	25.0												
	100	100	100	100	100	100	100	100	100	100	100	100	100

Fishes of Cattail Lake

Cattail Lake is approximately 0.68 ha in surface area, making it the second largest lake within the refuge (Figure 1). The lake is appropriately named because cattails dominate the shoreline and shallow waters. Farther up on the banks are huisache, mesquite, and retama trees. The substrate of the lake is similar to Willow Lake including the abundance of decaying plant matter. The water clarity at this lake is high and the bottom can be seen quite clearly. Average turbidity was 39 JTU. Water from an electrically pumped well was channeled into Cattail Lake. No fishes were collected at this site.

Fishes of Vela Woods Pond

Vela Woods pond, approximately 0.04 ha in surface area, is surrounded by mimosa and willows. The substrate of the pond was clay with a thick overlaying layer of silty mud. A large amount of decaying plant matter was present. Water clarity was good even though the water appeared to have a red to brown tint, the average turbidity was 46 JTU. The pond received only runoff water from rainfall or excess irrigation water from nearby farmed fields. During one of the monthly collection efforts two 20 l drums of agricultural chemicals were found disposed of in water flowing into this pond. One of the empty drums had contained the broadleaf herbicide Prefar-4E (Bensulide), which is known to be toxic to fish (Stauffer 1985). The other drum contained a herbicide (Alanap-L), for which I could find no toxicity information.

A 20 l water sample taken from Vela Woods pond was returned to the laboratory for analysis. Four aquaria were setup, three with known concentrations of Bensulide (obtained from a local distributor) and one with the water sample. Thirteen Rio Grande cichlids were introduced into each aquarium, after 72 hours of exposure 10 cichlids were removed from each aquarium. Their livers were extracted and homogenized to obtain the microsomes. Microsomal detoxification of Bensulide (O,O-diisopropyl phosphorodithioate S-ester of N-(2-mercaptoethyl) benzenesulfonamide) may be accomplished by oxidative demethylation. Formaldehyde is a detoxification by-product. The extracts were measured for demethylase activity and formaldehyde formation (La Du, 1971). Concentrations were determined against a standard curve of known formaldehyde concentrations for aminopyrine. The results from this experiment showed the water from Vela Woods pond contained approximately 1600 ppm of Bensulide.

Only one fish species was collected from Vela Woods pond. Fifteen mosquitofish were taken in February, totaling 6.3 grams in biomass. It is believed that these fish were carried into the pond by irrigation runoff from an adjacent field. Due to the lack of adequate rainfall or irrigation runoff, Vela Woods pond dried up in March and remained dry throughout the rest of the study period.

All Sites

A total of sixteen species from 9 families were collected from the study sites. Mosquitofish was the most abundant species. Inland silversides, sheepshead minnow and sailfin molly were also abundant. Each species accounted for more than 10% of the total number of fishes captured (Table 13). However, sheepshead minnow had the greatest biomass followed in order by gizzard shad, sailfin molly, inland silversides and mosquitofish (Table 13).

Inland silversides was the most abundant species in Pintail Lakes A, B, C, and the Borrow Ditch. It accounted for up to 55% of the total number captured in the Borrow Ditch (Table 14). When the number of inland silversides were low in Pintail Lakes A and B, a large number of mosquitofish were collected. In the other sites, many sheepshead minnows were collected in Pintail Lake C, and many threadfin shad were present in the Borrow Ditch. sheepshead minnows accounted for 24% of the total captures in Pintail Lake C, while threadfin shad accounted for 23% of the fishes captured in the Borrow Ditch (Table 14).

TABLE XIII. Species rank by percent abundance and percent biomass for each species collected on Santa Ana NWR. (*) denotes an abundance of less than 0.01 percent. n = total number of individuals collected. g = total biomass (gms) collected.

Species	Number Collected		Biomass Collected	
	Rank	Abundance %	Rank	Abundance %
Dorosoma petenense	7	2.4	7	2.8
Dorosoma cepedianum	5	4.2	2	15.3
Astyanax mexicanus	10	0.4	9	1.5
Cyprinus carpio	13	0.1	10	1.0
Notropis braytoni	11	0.4	12	0.2
Notropis lutrensis	9	0.8	11	1.0
Pimephales vigilax	12	0.2	15	0.1
Ictalurus punctatus	14	*	16	*
Cyprinodon variegatus	3	19.0	1	26.7
Poecilia latipinna	4	11.0	3	14.7
Gambusia affinis	1	33.0	5	12.5
Menidia beryllina	2	26.0	4	13.3
Morone chrysops	15	*	14	0.1
Lepomis gulosus	16	*	13	0.1
Lepomis macrochirus	6	2.4	8	2.0
Cichlasoma cyanoguttatum	8	1.0	6	7.9
	n = 30936		g = 17622.2	

TABLE XIV. Percent abundance of species collected from each aquatic ecosystem of Santa Ana National Wildlife Refuge. The total fish captured (n) from each site is shown. An asterisk (*) denotes a value of less than 0.1 percent.

	Pintail Lake A	Pintail Lake B	Pintail Lake C	Willow Lake	Borrow Ditch	Rio Grande	Cattail Lake	Vela Woods
n =	4633	7859	6440	9382	2266	301	0	15
SPECIES	%	%	%	%	%	%	%	%
Dorosoma petenense	0.1	2.1			23.3	8.5		
Dorosoma cepedianum	6.9	15.0	3.7		3.4	1.3		
Astyanax mexicanus	2.2	0.5	0.3			3.1		
Cyprinus carpio	0.3	0.1	0.1					
Notropis braytoni	2.5	0.1	0.3			7.4		
Notropis lutrensis	6.1	0.1				40.0		
Pimephales vigilax	0.2					6.0		
Ictalurus punctatus	0.1					0.2		
Cyprinodon variegatus	9.7	1.1	24.4	34.1		0.6		
Poecilia latipinna	12.2	1.9	15.6	4.9	1.7	0.5		
Gambusia affinis	17.5	23.8	11.2	52.8	12.2			100.0
Menidia beryllina	40.6	51.8	42.5	0.1	54.8	32.0		
Morone chrysops	*							
Lepomis gulosus		*						
Lepomis macrochirus	1.0	3.1	1.0	7.9	2.7	0.3		
Cichlasoma cyanoguttatum	0.4	0.6	0.8	0.2	2.1			
	100	100	100	100	100	100	0	100

Mosquitofish was the most abundant species collected from Willow Lake. It accounted for 53% of the total number collected, while sheepshead minnow was the second most abundant fish with 34%. The bluegill reached a maximum relative abundance in this site in October of 1986. The most abundant species collected from the Rio Grande was the red shiner. This species accounted for 40% of the total number captured at this site. Inland silversides was the next most abundant species, accounting for approximately 32% by number (Table 14). In spite of 13 collection efforts at 3 different sampling locations within Cattail Lake, no fishes were collected. The Vela Woods collection site yielded only one species (15 G. affinis, collected in February 1986) after the same number of collections.

Inland silversides accounted for 27% of the fish biomass collected in Pintail Lake A, 39% in Pintail Lake B, and 30% in the Borrow Ditch (Table 15). Sheepshead minnow was the most abundant species in terms of fish biomass collected in Pintail Lake (C) and Willow Lake, where it reached 31% and 41% respectively. Threadfin shad totaled 31% of the biomass collected from the Borrow Ditch, while Rio Grande cichlid accounted for 11% (Table 15).

In the Rio Grande, threadfin shad and inland silversides appeared about equally abundant in terms of their biomass and each species accounted for 21% of the total fish biomass collected. Red shiners and mosquitofish

Table XV. Percent abundance by biomass of species collected from each aquatic ecosystem of Santa Ana National Wildlife Refuge. The total biomass (g) collected from each site is shown.

	Pintail Lake A	Pintail Lake B	Pintail Lake C	Willow Lake	Borrow Ditch	Rio Grande	Cattail Lake	Vela Woods
g =	3547	3362	4842	4231	809	402	0	6.3
SPECIES	%	%	%	%	%	%	%	%
Dorosoma petenense	0.2	2.7			31.0	20.8		
Dorosoma cepedianum	17.0	25.7	15.3		5.8	6.5		
Astyanax mexicanus	4.4	2.5	0.7			2.7		
Cyprinus carpio	2.4	0.7	0.2					
Notropis braytoni	0.7	0.2	0.1			8.5		
Notropis lutrensis	4.3	0.1	0.3			12.7		
Pimephales vigilax	0.2					5.0		
Ictalurus punctatus	0.1					1.2		
Cyprinodon variegatus	12.2	2.7	30.7	41.3		0.3		
Poecilia latipinna	16.2	5.4	12.2	7.4	5.6	4.0		
Gambusia affinis	10.7	10.0	10.9	30.4	8.9	15.4		100.0
Menidia beryllina	27.4	38.6	26.5	0.1	30.0	21.0		
Morone chrysops	0.2							
Lepomis gulosus		2.9						
Lepomis macrochirus	1.9	2.8	1.8	8.0	7.4	1.9		
Cichlasoma cyanoguttatum	2.3	5.6	1.5	12.8	11.1			
	100	100	100	100	100	100	0	100

each accounted for over 12% of the total biomass collected from the river.

Seasonal Variation

Threadfin shad was collected in greater abundance during the months of April, May, June and July than other months in the year. This species reached a peak abundance of 6.3% of the total fishes collected in July (Table 16). Another clupeid, gizzard shad showed its greatest abundance during October and November of 1985 and August through October of 1986.

Four species maintained a relatively high abundance throughout this study. Sheepshead minnow was collected in abundance from June to September 1985. However, this species reached a peak of 66% of the total fishes collected in December (Table 16). The sailfin molly was most abundant during the same months but reached a peak of 30% in September of 1986. Mosquitofish maintained an abundance of greater than 16% except in December when it dropped to 3.6% of the total fishes collected. A total of 7958 inland silversides were collected between October 1985 and October 1986. Most individuals of this species were collected from January through May 1986.

Several species were collected in relatively small numbers throughout the study period. Bluegill usually maintained an abundance of less than 3%, although in

TABLE XVI. Percentage of fish species collected by month. The total number of individuals (n) collected each month are shown. An * denotes an abundance of less than 0.1%.

SPECIES	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
n =	5843	1135	1208	388	480	2888	2219	3172	3700	2433	2491	3381	1598
	%	%	%	%	%	%	%	%	%	%	%	%	%
Dorosoma petenense	*	0.9	0.4	2.8	2.5	0.9	4.4	2.1	4.5	6.3	1.6	4.1	0.3
Dorosoma cepedianum	7.7	8.7	2.8	1.8	0.2	*	8.7	1.0	0.5	1.8	4.9	7.6	3.2
Astyanax mexicanus	1.1	0.1	*	1.5		0.2	0.1		0.2	0.5	0.1	0.2	1.2
Cyprinus carpio	0.4	*				*			*		*		
Notropis braytoni	0.1	2.5	0.7						0.5		0.2	*	2.6
Notropis lutrensis	*				7.5	0.8	0.6	1.0	0.7	2.5		*	3.5
Pimephales vigilax	*		2.7		0.2	*						0.4	
Ictalurus punctatus	*	0.1	*										
Cyprinodon variegatus	7.7	39.0	66.0	11.0	2.1	3.8	1.8	1.6	31.0	37.0	32.0	27.0	4.6
Poecilia latipinna	9.5	1.1	0.7	4.9		5.4	1.1	3.1	8.8	14.0	29.0	30.0	1.7
Gambusia affinis	58.0	18.0	3.6	22.0	25.0	48.0	27.0	28.0	39.0	16.0	25.0	16.0	28.0
Menidia beryllina	8.9	27.0	22.0	54.0	62.0	38.0	56.0	63.0	14.0	21.0	6.1	15.0	23.0
Morone chrysops	*												
Lepomis gulosus			*										
Lepomis macrochirus	1.8	1.7	0.9	1.5	0.6	2.0	0.5		*	0.2	0.6	*	31.0
Cichlasoma cyanoguttatum	4.2	0.5	*	0.8	0.2	*	0.1	*	0.3	0.4		0.2	0.6
	100	100	100	100	100	100	100	100	100	100	100	100	100

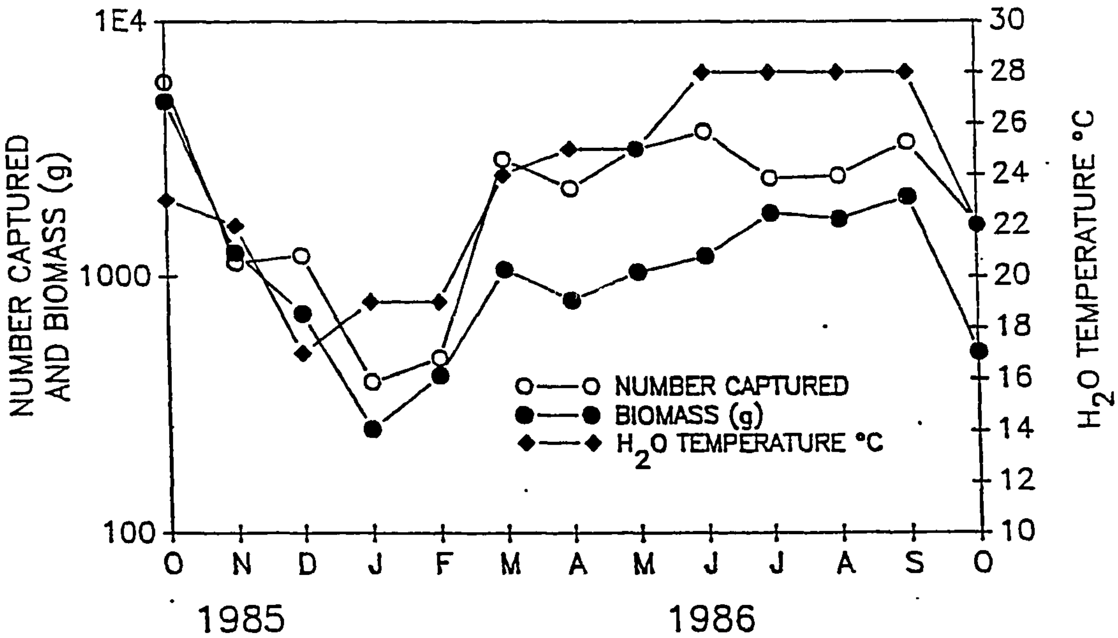
October 1986 it accounted for 31% of the total fishes collected. Rio Grande cichlid was also collected in small numbers. In all months this species' abundance was less than 5.0% of the total fishes collected.

Water Parameters

Fluctuations of species diversity, abundance, biomass and capture size were expected during the course of this study. The number of individuals captured from the refuge as well as their biomass closely followed the seasonal fluctuation of water temperature (Figure 2). During the winter months the total number of captured fishes dropped to 388 individuals and fish biomass showed a sharp decrease as well. An increase in the number of individuals captured began in February and continued through June. When water temperature dropped to 21 °C in October a decline in the number captured and biomass was observed.

Correlation coefficients were calculated between number captured, biomass and all water quality parameters measured. The total number captured and total biomass collected from all sites were strongly correlated ($r = 0.84$, $df = 12$, $p < 0.001$) as was expected. The total number of fishes captured was correlated with water temperature ($r = 0.56$, $df = 12$, $p < 0.05$) while biomass and

Figure 2. Relation among water temperature, fishes collected and their biomass from ponds within Santa Ana National Wildlife Refuge.

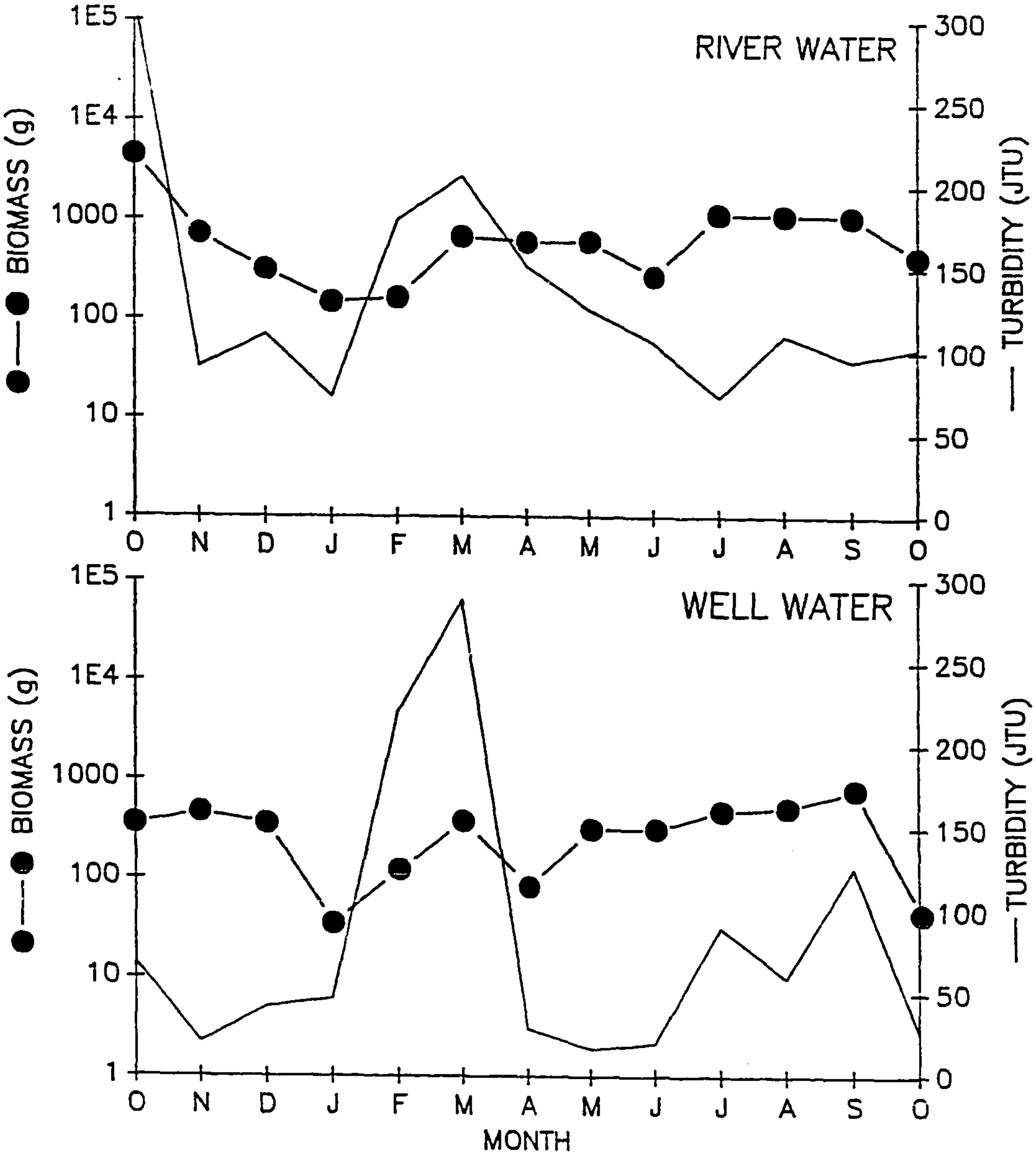


1E4
1000
100
NUMBER CAPTURED AND BIOMASS (g)
30
28
26
24
22
20
18
16
14
12
10
H2O TEMPERATURE °C
NUMBER CAPTURED
BIOMASS (g)
H2O TEMPERATURE °C
O N D J F M A M J J A S O
1985
1986

water temperature showed no correlation ($r = 0.27$, $df = 12$, $p > 0.4$). Biomass was correlated with turbidity at sites which received river water ($r = 0.59$, $df = 12$, $p < 0.05$), while well water sites showed no correlation. Figure 3 shows the relation between water turbidity (JTU) and biomass (g) for river water and well water.

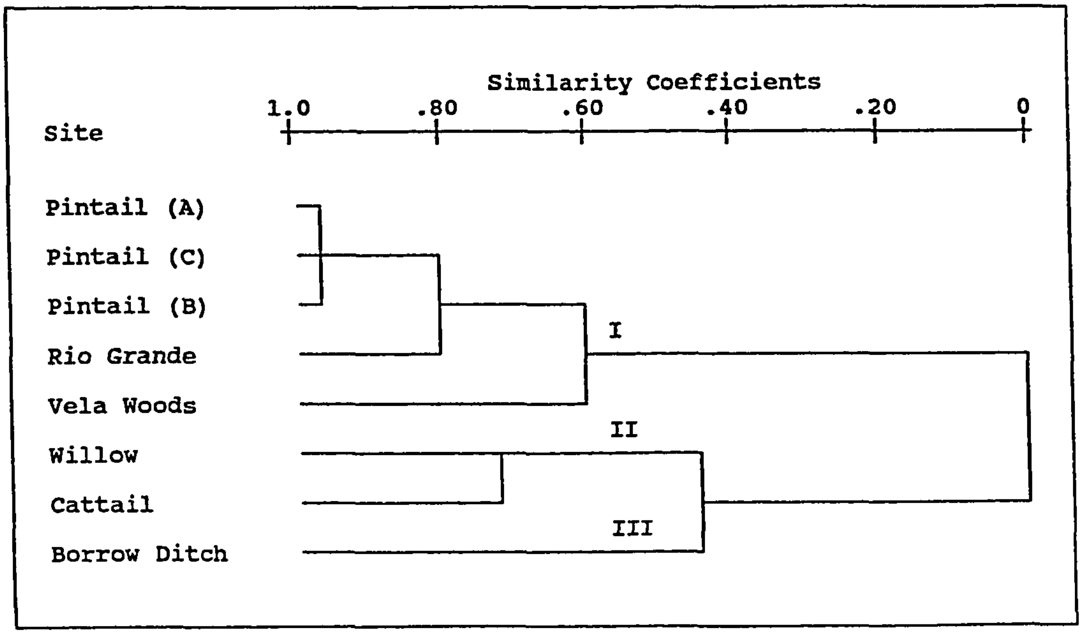
The results of a cluster analysis of water quality parameters including temperature, dissolved oxygen, pH, salinity, conductivity, hardness and turbidity are presented in Figure 4. A subjective decision was made to designate separate groups at 0.6 units of similarity. At this level water source between collection sites seems to provide the best fit to the data. Three groups were distinguished. Group I includes the Pintail Lakes, Rio Grande, and Vela Woods. Group II includes Willow and Cattail Lakes. Group III includes the Borrow Ditch. Collection sites which received either river water or runoff are characterized in group I. The lakes which were clustered into group II received well water as their source. The Borrow Ditch clustered into a group by itself even though it received river water as its source. Consistently higher conductivities and salinities obtained at this site appear to have caused this grouping.

Figure 3. Relation of water turbidity and fish biomass collected in river water source ponds and well water source ponds within Santa Ana NWR.



RIVER WATER
BIOMASS (g)
TURBIDITY (JTU)
1E5
1E4
1000
100
10
1
300
250
200
150
100
50
0
O N D J F M A M J J A S O
WELL WATER
BIOMASS (g)
TURBIDITY (JTU)
1E5
1E4
1000
100
10
1
300
250
200
150
100
50
0
O N D J F M A M J J A S O
MONTH

Figure 4. Similarity coefficient dendrogram of collection sites based on cluster analysis of water quality parameters. Linkage at coefficient = .60 was selected to illustrate community types.


Similarity Coefficients
Site
1.0
.80
.60
.40
.20
0
Pintail (A)
Pintail (C)
Pintail (B)
Rio Grande
Vela Woods
Willow
Cattail
Borrow Ditch
I
II
III

Water Source

Ponds using river water as their source appeared to vary little in their community structure. A maximum of 15 species were found in Pintail Lake (A). Thirteen species were collected in Pintail Lake (B) and 11 species in Pintail Lake (C). Well water source ponds maintained fewer species than the river water source ponds. Five species were collected at Willow Lake while no species were collected at Cattail Lake. Species richness in river water source ponds closely approximated that found in the Rio Grande (Table 13) where 11 species were collected.

Ponds maintained with river water accounted for 69% of the total biomass collected. Pintail Lake (C) accounted for 27% of the total fish biomass collected while Pintail Lake (A) and (B) accounted for 20% and 22% respectively. Willow Lake, a well water source pond, totaled 24% of the biomass collected. All other sites combined (Rio Grande, borrow ditch and Vela Woods pond) contributed only 7%. Biomass of collected fishes from the Rio Grande were considerably lower than those obtained from other collection sites in this study. This was likely due to sampling bias as site accessibility and sampling in the deep river channel challenged collection efficiency at this site.

Cluster analysis of collection sites based on species similarity indices are presented in Figure 5 following Sorensen's index of similarity (Krebs, 1985). A subjective decision was made to designate groups at 0.6 units of similarity. Beyond this point, cluster analysis grouped river water communities and well water communities. At the 0.6 level, field observations, species composition, and diversity indices of collection sites appeared to provide the best fit to the data. Four groups were distinquished. Group I included Pintail Lakes (A), (B) and (C) as well as the Borrow Ditch. This group shared several species in common. Group II included Willow Lake which only shared four species in common with group I. Vela Woods pond was included in group III, this pond shared only one species in common with groups I and II. Cattail Lake, with no fishes, clustered farthest from other aquatic systems of the refuge.

Species Diversity

Species diversity indices were calculated on a monthly basis throughout this study. No discernable patterns were observed from the monthly diversity data. The combination of all monthly samples were used to calculate Shannon's diversity index and Pielou's evenness index (Table 17). Species diversity was greater in ponds

Figure 5. Similarity coefficient dendrogram of collection sites based on cluster analysis of Sorensen's index of community similarity. Linkage at coefficient = .60 was selected to illustrate community types.

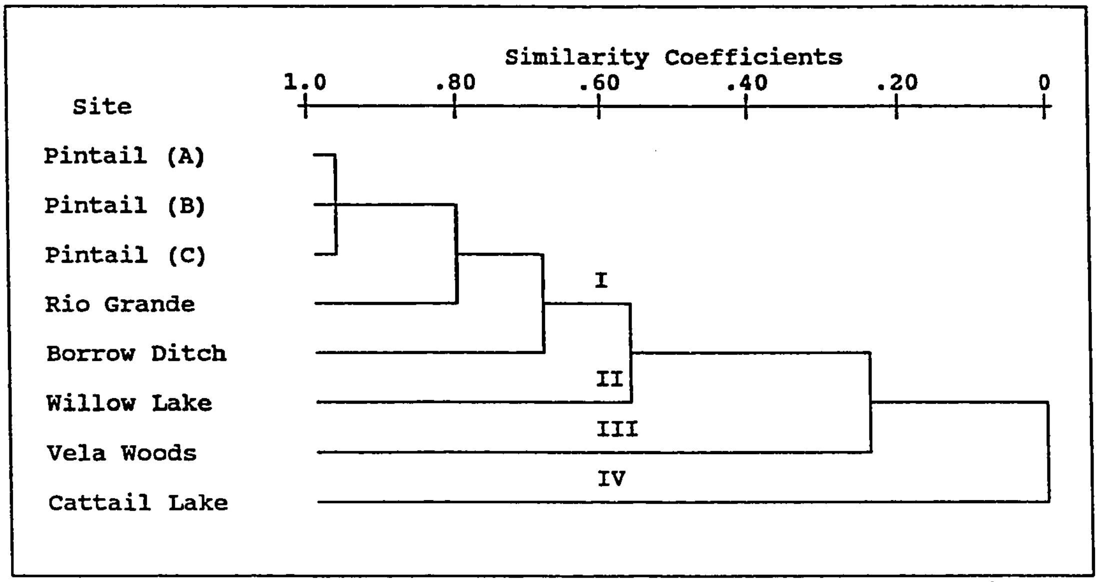

Similarity Coefficients
1.0
.80
.60
.40
.20
0
Site
Pintail (A)
Pintail (B)
Pintail (C)
Rio Grande
Borrow Ditch
Willow Lake
Vela Woods
Cattail Lake
I
II
III
IV

TABLE XVII. Comparison of Shannon's species diversity Index (H') and Pielou's evenness index (J), between collection sites. Indices were calculated by combining all monthly samples. The number of species and individuals collected (N) are shown.

Site	Species	N	H'	J
Pintail Lake (A)	15	4672	2.38	0.61
Pintail Lake (B)	13	7859	2.00	0.54
Pintail Lake (C)	11	6364	2.26	0.65
Willow Lake	6	9382	1.50	0.58
Borrow Ditch	7	2266	1.58	0.56
Rio Grande	11	301	2.31	0.67
Cattail Lake	0	0	0	0
Vela Woods	1	15	0	0

supplied with river water than those supplied with well water. Biomass diversity indices in river water source ponds were similarly higher than well water source ponds. The maximum biomass diversity was found from the Pintail Lakes (Table 18). Biomass diversity indices from the Rio Grande and Borrow Ditch collection sites were greater than the indices calculated for Willow Lake. The diversity index for biomass and the evenness index calculated for the Rio Grande closely approximated those observed from Pintail Lakes (A) and (B) (Table 18).

Organochlorine Pesticide Analysis

Fish samples collected for pesticide analysis are shown in Table 19. Gizzard shad were collected from Pintail Lakes (A), (B), and (C). Shad species were unavailable from Willow Lake so sheepshead minnows were collected instead. Organochlorine pesticide analyses of whole fish composite samples collected are also shown. The gizzard shad sample from Pintail Lake (A) showed a concentration of 0.75 ppm (wet weight) of DDE, a breakdown product of DDT. Samples from Pintail Lakes (B) and (C) were slightly lower; 0.54 and 0.66 ppm respectively. The sheepshead minnow sample from Willow Lake, although not directly comparable to the samples from the Pintail Lakes, showed a DDE concentration of 0.33 ppm. All of the samples

TABLE XVIII. Comparison of biomass using Shannon's diversity index (H') and Pielou's evenness index (J), between collection sites. Indices were calculated by combining all monthly samples. The number of species and biomass collected (g) are shown.

Site	Species	g	H'	J
Pintail Lake (A)	15	3548.2	2.94	0.75
Pintail Lake (B)	13	3852.5	2.73	0.74
Pintail Lake (C)	11	4775.6	2.47	0.71
Willow Lake	6	4230.1	1.66	0.64
Borrow Ditch	7	808.3	2.37	0.84
Rio Grande	11	401.3	2.59	0.75
Cattail Lake	0	0	0	0
Vela Woods	1	6.3	0	0

Table XIX. Organochlorine residue analyses performed by USFW Ecological Services. Values are in parts per million (ppm = mg/kg). An asterisk (*) denotes a value below the detection limit. Sample sizes (N) and Total mass (g) of samples are indicated.

Site	Species	N	g	p,p' - DDE	p,p' - DDD	ENDRIN	DIELDRIN	OXY-CHLOR-DANE
Pintail Lake (A)	Dorosoma cepedianum	35	141.0	0.750	0.005	*	0.010	*
Pintail Lake (B)	Dorosoma cepedianum	25	84.4	0.540	0.005	*	0.012	*
Pintail Lake (C)	Dorosoma cepedianum	25	142.7	0.660	0.005	0.011	0.012	*
Willow Lake	Cyprinodon variegatus	35	75.3	0.330	0.005	*	*	0.013

(gizzard shad and sheepshead minnows) show only a trace (0.005 ppm) of DDD, another degradation product of DDT.

Trace amounts of three cyclodiene insecticides were detected in the fish samples. Dieldrin was found in concentrations not greater than 0.01 ppm from gizzard shad in the Pintail Lakes, eldrin (0.01 ppm) in gizzard shad from Pintail Lake (C), and oxychlordane (0.01 ppm) in sheepshead minnows from Willow Lake.

Trace Element Analysis

Trace element analyses of whole fish composite samples collected from the refuge are shown in Table 20. Several elements including arsenic, cadmium, mercury, lead and selenium were considered for their toxicity to fish species. All other elements shown are provided as baseline data for future reference. Trace element residues from Pintail Lakes (A) and (B) were generally lower than values obtained from Pintail Lake (C). Gizzard shad from Pintail Lake (C) exceeded 0.5 mg/kg of selenium, arsenic and lead. Cadmium and mercury residues were less than 0.5 mg/kg in all samples analyzed but the highest values for these two elements were found in Pintail Lake (C). Three elements including aluminum, iron and magnesium had residues greater than 200 mg/kg in all fish samples.

TABLE XX. Trace element residue analyses performed by USFW Ecological Services. Values are in parts per million (ppm = mg/kg). An asterisk (*) denotes a value below the detection limit.

Site	Species	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mg
Pintail Lake (A)	Dorosoma cepedianum	328.90	0.40	1.20	4.72	0.01	0.01	0.50	1.03	215.80	0.08	342.80
Pintail Lake (B)	Dorosoma cepedianum	878.80	0.48	1.90	8.41	0.03	0.02	0.94	1.42	520.70	0.07	548.60
Pintail Lake (C)	Dorosoma cepedianum	1164.80	0.91	1.40	13.10	0.04	0.03	2.00	1.64	777.40	0.14	624.00
Willow Lake	Cyprinodon variegatus	262.00	1.19	2.30	11.80	0.01	*	0.76	5.09	176.60	0.04	631.40

Mn	Mo	Ni	Pb	Se	V	Zn
6.00	*	0.31	0.35	0.30	0.83	19.30
18.10	*	0.56	0.76	0.43	1.67	28.70
24.10	*	1.25	1.01	0.52	2.89	24.60
33.20	0.16	0.27	0.40	0.22	0.82	18.10

DISCUSSION

Pintail Lake (A)

Pintail Lake (A) was the first lake in a series of three to receive irrigated river water. While having a smaller surface area than the other lakes it maintains a greater number of fish species. This is most likely due to the lake's greater chance of receiving and maintaining fish species immigrants from the Rio Grande water source. Two estuarine adapted species (inland silversides and sheepshead minnow) were captured frequently and in large numbers. Minnow species were captured only sporadically but were better represented at this site than other lakes on the refuge. Gizzard shad and inland silversides contributed the majority of fish biomass collected from Pintail Lake (A).

Approximately 44% of the fish biomass collected from Pintail Lake (A) was taken in October 1985 when the water level was low. Records from the refuge (USFWS Annual Narrative 1985) show that only 6.2 acre-feet of irrigation water was purchased for use in the Pintail Lakes during September and October. In November an additional 78.7 acre-feet were released into the Pintail Lakes. Seining efforts following the addition of water showed a decrease in species richness and overall abundance. The decrease in abundance was most likely due to the increase in water volume. The absence of an increase in species richness was probably related to seasonal factors which were unfavorable for fish species immigrants.

Pintail Lake (B)

Pintail Lake (B) differs mainly from the other Pintail Lakes in fish species composition. Inland silversides, mosquitofish and gizzard shad comprised the bulk of the total fish captures from Pintail Lake (B). Sheepshead minnow were not as abundant in this lake as they were in Pintail Lake (A) or (C). Minnow species were not as abundant and bullhead minnows were completely absent. The scarcity of minnow species in Pintail Lake (B) appears due to its distance from the river water source.

Inland silversides were clearly the most abundant species in terms of total biomass collected. The greatest fish biomass (approximately 30% of the total) was collected in October 1985 when the lake's water level was low. Pintail Lake (B) experienced the same water level manipulations as did Pintail Lakes (A) and (C), with the same result of no net increase in species richness.

Pintail Lake (C)

Pintail Lake (C) was the largest of the three Pintail Lakes. Likewise, this lake was the most productive lake (in terms of fish biomass) within Santa Ana NWR. Approximately 4.8 kg of fish were taken from the lake during the study. The lakes species composition was very similar to that of the other Pintail Lakes. Seining efforts yielded large numbers of sheepshead minnows and inland silversides. These two species were present in all of the thirteen monthly samples. Poecilids were well represented in Pintail Lake (C); sailfin molly and mosquitofish were collected in the majority of the samples.

Willow Lake

Willow Lake receives a larger number of human visitors due to its ease of accessability and because of the abundant waterfowl that are found there. Water clarity was so good that fishes could be seen quite clearly also. Willow Lake was supplied with well water pumped from underground sources. Unfortunately well water does not provide a source of fish species immigrants. Five fish species were collected from this lake before October 1986. Mosquitofish were the most abundant numerically while sheepshead minnows were the most abundant in terms of total biomass collected.

In September and October 1986 Willow Lake underwent a managed turnover in water supply. The lake was allowed to draw down in September and river water was released into the lake in October. The seine sample during October yielded a large number of larval bluegills, a few inland silversides and sheepshead minnows. Sailfin mollies, mosquitofish and Rio Grande cichlids which were previously captured were absent from this sample. An additional seine sample was taken from Willow Lake in April 1987. Six fish species were collected at this time. Inland silversides and red shiners were two notable additions to the ichthyofauna of the lake. However, the Rio Grande cichlid was still absent.

Records from the refuge (USFWS Annual Narratives) indicate that Willow Lake was isolated from the river water source for over five years. During this time the lake managed to support five fish species. The re-introduction of river water to Willow Lake supplied two additional species within six months time. It appears that with the continued use of river water, this lake will approach a species richness similar to the Pintail Lakes.

Borrow Ditch

The Borrow Ditch was one of the smaller aquatic ecosystems sampled. This site offered a chance to compare fish species composition in a drainage ditch ecosystem to the lake ecosystems on the refuge. The Borrow Ditch had considerably less surface area than any of the lakes sampled. It received much less water from the Rio Grande and subsequently fewer fish species. Seven species were collected, all were a subset of those species found in the Pintail Lakes or Willow Lake.

The ditch ecosystem was somewhat similar to the Pintail Lakes in species composition. Inland silversides and threadfin shad accounted for the largest portion of the seine captures. Threadfin shad were better established in the Borrow Ditch than in all three of the Pintail Lakes combined. Poecilids were less abundant in this site than either Willow or the Pintail Lakes.

Rio Grande

The Rio Grande was sampled in order to contrast fish species composition between the river and lakes of the refuge. More than 20 species have been reported from the Rio Grande in the vicinity of Santa Ana NWR (Treviño-Robinson, 1959, Edwards and Contreras-Balderas, unpubl. data, and Wood, 1986). Seine samples were difficult to obtain from the river because of water depth and swift currents. Because of physical limitations placed on seine sampling I felt that my collections clearly under estimated species richness and abundance. Collections from the Rio Grande yielded only eleven fish species. All species were collected sporadically, in low numbers, and only 2 species were present in more than 3 months. The most often captured species were inland silversides and red shiners.

Threadfin shad and several minnow species were captured less frequently.

The Rio Grande is the only source of fish species immigrants into the small aquatic ecosystems of the refuge and others in the region. Water is pumped up from the river into irrigation canals which distribute the water throughout the Lower Rio Grande Valley. Fish which are transported in this manner are subject to size limitations due to pumping machinery and to physical stress. It is apparent that the river will always maintain greater fish species richness and abundance than the refuge.

Cattail Lake

Preliminary observations of Cattail Lake revealed no visible fish species. Thirteen seine samples amongst three different locations within the lake yielded no fish. My reviews of USFWS Annual Narratives indicated two factors which clarify the absence of fish. Past management strategies aimed at controlling cattails called for drying up the bed of the lake, with burning of the tenacious vegetation. In addition, the water source used to refill Cattail Lake was well water. Water chemistry data showed no great variation from Willow Lake water except for dissolved oxygen. It is possible that Cattail Lake could support fish species if given a source of fish species immigrants.

Vela Woods Pond

Water source was the controlling factor influencing fish species within Vela Woods Pond. Run off from rain and adjacent irrigated farm land was minimal and the pond dried up in March 1986. This type of water source was poor in comparision to irrigation water supplied directly to a lake. Run off characteristically carries large amounts of silt and possibly agricultural chemicals. The pond yielded only one fish species (mosquitofish) as a single occurrence during February 1986. It was thought that these fish were carried into the pond by irrigation run off from a near by field. The sporadic nature of the water supply coupled with agricultural chemicals have apparently kept fish species from colonizing Vela Woods Pond.

Agricultural chemicals pose a serious threat to aquatic life in the Lower Rio Grande Valley. The protected areas of Santa Ana NWR are no exception. The careless disposal of chemical drums in water effluence flowing into Vela Woods Pond is witness to this fact. One of the empty drums contained a broadleaf herbicide known to be toxic to fish species. An experiment aimed at measuring this chemicals concentration in fish livers showed the water from the pond to be heavily contaminated.

All Sites

Sixteen fish species were collected from the aquatic ecosystems of Santa Ana NWR. Mosquitofish was the most abundant species captured followed in order by inland silversides, sheepshead minnow and sailfin molly. Although these species were collected in large numbers they did not rank in the same order with respect to biomass abundance. Sheepshead minnow had the greatest biomass collected from the refuge followed in order by gizzard shad, sailfin molly, inland silversides and mosquitofish.

Inland silversides was a dominant component of the ichthyofauna of the refuge. It was the most abundant species collected (numerically and in biomass) from the Pintail Lakes and Borrow Ditch. It seems that this species was the most adaptive colonizer of the fishes in river water ecosystems of the refuge. Other species which established themselves in great numbers were mosquitofish, sheepshead minnows, sailfin molly, gizzard and threadfin shad, all species with good colonizing abilities.

Willow Lake received river water approximately five years prior to this study (USFWS Annual Narratives). Consequently, Willow Lake shared several species in common with the Pintail Lakes even though it received well water during this study. Apparently the fish species which were introduced with river water underwent selection pressures that favored the pond's current community structure.

Mosquitofish and sheepshead minnows may have been selected for their reproductive aggressiveness and hardiness. This would explain the abundances in which these species were collected.

The Rio Grande did not yield as many fish species as were anticipated. Likewise, individual abundances in seine attempts were considered to be rather low. The most abundant species collected from the river were inland silversides and red shiner. Inland silversides populations were not as well represented at this site as they were in the river water ponds of the refuge. Sampling difficulty in the river was the most likely cause for the low number of individual captures.

Seasonal Variation

Data from the collections were pooled in order to assess seasonal variations of species abundance. Large variations in abundance did not occur within a given season. Species abundance trends generally spanned more than one season. The subtropical climate of the region causes a blending of seasons which enables fishes to thrive well into winter months.

Four species maintained relatively high abundances throughout the study. Sheepshead minnow and sailfin molly showed their greatest abundance during the summer and early fall months. Mosquitofish and inland silversides were collected in abundance in late winter and early spring. Two clupeids collected from the refuge appeared to have staggered abundance peaks. Threadfin shad were captured in large numbers in late spring and early summer while gizzard shad peaked in late summer and fall seasons.

Seven species were collected only sporadically throughout this study. Five of these species: carp, Tamaulipas shiner, red shiner, bullhead minnow, and channel catfish (Ictalurus punctatus) were collected so infrequently that their abundance patterns are difficult to assess. White bass and warmouth were each collected only once and their abundances were less than 0.1% of the total fishes collected.

All but one of the species collected during this study were previously noted by Edwards and Contreras-Balderas (unpubl. data) as inhabiting the segment of the Rio Grande between Anzalduas Dam and Brownsville. One specimen collected from Santa Ana, white bass, was previously reported from the Rio Grande only between Falcon and Anzalduas Dams. An additional 15 species known from the Rio Grande in the vicinity of the Santa Ana NWR were not collected from the refuge itself. Many sailfin mollies were collected from the refuge while no amazon mollies (P. formosa) were collected. The absence of amazon mollies from the refuge is not understood since its range overlaps that of the sailfin molly (Hubbs 1964). Likewise, this species was collected by Edwards and Contreras-Balderas from the Rio Grande.

Water Parameters

Santa Ana NWR is located in a subtropical region which generally experiences mild winters and hot summers. Seasonal variation of water temperatures is moderate compared to more temperate regions of the United States. Water temperatures on the refuge from October 1985 to October 1986 varied only by 12 °C.

The seasonal fluctuation of water temperatures within the ponds of the refuge brought about similar changes in fish abundance and biomass. A decline in the total number of fishes captured and their biomass was observed as water temperatures dropped in winter. When water temperatures increased in early spring both captures and biomass increased. A plateau for individual captures and their biomass was realized at approximately 28 °C.

Correlation coefficients were calculated between the total fish captures, total fish biomass and selected water quality parameters. Fish captures were correlated with biomass as was expected. The total monthly fish captures from the refuge were correlated to water temperature. This correlation supplies evidence that although the seasonal variation of water temperature in this region is moderate, it still plays a role in controlling fish populations.

Fish biomass showed no mathematical correlation to the seasonal variation of water temperature, although seasonal trends appeared similar to those for fish captures. It seems that feeding behaviors of these fish were not temperature controlled.

Fish biomass captures were correlated with turbidity at sites which received river water as their source, while well water sites were not. The correlation between biomass collected and turbidity is somewhat tenuous since turbidity is a combined measure of plankton, detritus and suspended solids. Unfortunately measurements were not taken to evaluate the plankton and detritus components of turbidity. Matthews (1984) showed that the abundance of larval shad as well as their biomass decreased during or immediately following periods of high water turbidity. This phenomenon was related to the decline in zooplankton abundance. The phenomenon noted by Matthews did not appear to take place in the river water ponds of the refuge because fish biomass actually increased during periods of elevated water turbidity. Other water parameters including dissolved oxygen, pH, salinity, conductivity and alkalinity showed no correlation to the numbers captured or their biomass.

Cluster analysis of water quality parameters from the aquatic ecosystems of the refuge yielded three distinct groups. The first group included Pintail Lakes (A), (B), (C), Rio Grande and Vela Woods pond. The second group included Willow Lake and Cattail Lake. The Borrow Ditch was the only site in the third group. Collection sites which received either river water or runoff were characterized in the first group, while those in the second group received a well water source. The Borrow Ditch was placed in a third group, being more similar to well water communities, even though it received river water as its source. The Borrow Ditch is a very simplified, man-made environment and this attribute combined with consistently higher salinities and conductivities may be responsible for this grouping.

Water Source

Water source has played a major role in influencing the species composition of the ponds within Santa Ana NWR. Willow and Pintail Lakes are supplied with well water and river water respectively. The Pintail Lakes held 16 species while Willow Lake maintained only five species. All of the fish species collected from Willow Lake were a subset of those collected from the Pintail Lakes. The species that both these impoundments had were: sheepshead minnow, sailfin molly, mosquitofish, bluegill, and Rio Grande cichlid. The Pintail Lakes had the same water source (river water) and share 11 species in common. Furthermore, 11 species which were collected from the Rio Grande were present in collections from the Pintail Lakes.

The species they had in common were: threadfin shad, gizzard shad, mexican tetra, Tamaulipas shiner, red shiner, bullhead minnow, channel catfish, sheepshead minnow, sailfin molly, inland silversides, and bluegill.

Cluster analysis of collection sites based on Sorensen's index of community similarity indicated four separate groups. The first group included Pintail Lakes (A), (B), (C), and Rio Grande as well as the Borrow Ditch. This group shared 11 fish species in common. The second group included Willow Lake only, which shared four species in common with the first group. Vela Woods pond was included in the third group, this pond had only one species in common with the first and second groups. Cattail Lake was placed into the fourth group by itself. This site was included into the cluster analysis, even though it had no fish species, to show its similarity to the other aquatic ecosystems of the refuge.

More than 20 species are known to inhabit the Rio Grande in the vicinity of Santa Ana NWR (Treviño-Robinson, 1959; Edwards and Contreras-Balderas, unpubl. data; Wood, 1986), however, only 16 species have dispersed into or have colonized the aquatic ecosystems of the refuge. It appears that with increased distance or isolation from the Rio Grande water source there is a decrease in fish species abundance. This would account for the decline in species abundance between the Rio Grande and Pintail Lake (A).

There is also a drop in the number of species captured between the Pintail Lakes with increasing distance from river water.

Willow Lake was isolated from the river water source since 1980 and only five species were collected at this site. A managed water source turnover from well water to river water occurred at Willow Lake in September 1986. The fish community structure of the lake changed following the alteration of water source. In subsequent samples species richness increased to seven species and the dominant species changed from sheepshead minnow to inland silversides. Red shiner was also collected in much higher abundance after the change in water source.

Overall, sites which utilize river water as their source support a greater number of species than those supplied with well water. River water offers the advantage of a good source of fish species immigrants while maintaining adequate water levels within the impoundments of the refuge. Unfortunately, this source is not without its drawbacks as undesirable species may find their way into the refuge as well. Introduced fish species such as the common carp and blue tilapia (Oreochromis aureus) have colonized the aquatic habitats of the refuge, competing with native species. Carp populations on the refuge had grown to such a high level in 1978 that expensive control efforts had to be implemented. In August 1978, six 55 gallon drums of carp ranging in size from a few cm to ten kg were removed from Willow Lake (USFWS Annual Narrative 1978). This event occurred during a planned water drawdown of the pond.

Blue tilapia is another introduced species which has received a great deal of attention. In less than 10 years this species has become a dominant component of the ichthyofauna of the lower Rio Grande and at times is more abundant than the native Rio Grande cichlid (Wood 1986). The blue tilapia was well established in the aquatic ecosystems of Santa Ana NWR several years prior to 1983 (USFWS Annual Narrative 1983). Managed water drawdowns to control "rough fish" along with a severe winter freeze in late 1983 have essentially eradicated this species from the refuge. No tilapia were collected during this study. The potential, however, for recolonization of the aquatic habitats of the refuge by this species increases with the continued use of the river water source. Wood (1986) showed that blue tilapia had recolonized the Rio Grande within 5 months following the 1983 freeze.

Species Diversity

The combination of all monthly samples were used to calculate Shannon's diversity index and Pielou's evenness index. Shannon's index showed that species diversity and biomass diversity was greater in the river water ecosystems than those which utilized well water. Pintail Lake (A) had the greatest species diversity of all the ponds within the refuge. This site was the first impoundment of the Pintail Lakes to receive irrigation water, which was then released into the two remaining impoundments. Hence, Pintail Lake (A) stands a greater chance of receiving and possibly maintaining a larger number of individuals of a given species. This might also explain the slight difference in diversity indices between these impoundments.

Species diversity and biomass diversity in Willow Lake was comparitively low. It yielded low diversity indices because a large number of individuals were captured that represented only a few (5) species. Isolation from the river water source and a relatively stable environment has apparently fashioned Willow Lake into a climax community. The community has two fishes, sheepshead minnows and mosquitofish, that account for more than 85% of the total captures.

Organochlorine Pesticide Analysis

Several studies have documented organochlorine residues in fishes from the Rio Grande (White et. al. 1983, Schmitt et. al. 1981, Henderson et. al. 1971). These studies indicate that DDE residues have not declined appreciably in this area since the use of DDT was banned in the United States in 1972. However, DDT is still used in

Mexico and contaminated runoff from crop lands into the Rio Grande has not been considered. The extensive irrigation system in the Lower Rio Grande Valley may act as a distribution mechanism for contaminated river water throughout the area.

Organochlorine pesticide analyses of whole fish composite samples from the refuge showed trace amounts of DDE and DDD. Both of these compounds are degradation products of DDT. Trace amounts of three cyclodiene insecticides were also detected in the fish samples. These chemicals were identified as dieldrin, endrin and oxychlordane.

Organochlorine residues reported in previous studies were generally higher than those found from the refuge. This is most likely due to the difference in size (or life stage) of gizzard shad collected. Gizzard shad from the refuge ranged from 4 to 7 cm (SL) as compared with 26 to 41 cm from the other studies. Even though larger gizzard shad were not available from the refuge and all together unavailable from Willow Lake, this information will serve as baseline data for future pesticide monitoring.

Trace Element Analysis

Whole fish composite samples collected from Santa Ana NWR were analyzed for trace element residues. The National Academy of Sciences (1972) and Walsh et. al.

(1977) consider that any residue level exceeding 0.5 mg/kg net weight of mercury, arsenic, lead, cadmium or selenium would harm fish. Several incidences of residue levels greater than 0.5 mg/kg of these elements were detected in samples from the refuge. Gizzard shad collected from Pintail Lake (C) exceeded the limits for selenium, arsenic and lead residues. The sheepshead minnow sample from Willow Lake showed a concentration of arsenic which was more than twice the proscribed limit. Cadmium and mercury residues were less than 0.5 mg/kg in all samples. However, mercury levels exceeded the Environmental Protection Agency criteria of 4.1 ug/kg for the protection of freshwater aquatic life. Several elements including aluminum, iron and magnesium seemed to have elevated residue levels in these samples but I could find no data for comparison.

The occurence of organochlorine and trace element residues within Santa Ana NWR is distressing. There are several possible sources of contamination in the area where the refuge is located. Aerial application of agricultural chemicals to nearby farmlands and the use of organochlorine insecticides in Mexico are two possible sources. Likewise, the possibility of persistent contamination by chemicals applied 10 to 20 years ago cannot be ruled out. Irrigation water drawn from the Rio Grande may carry agricultural chemicals from great distances. Chemical runoff from farmlands and improper disposal of containers are possible sources as observed at Vela Woods. The refuge is located in a "high risk" area and future monitoring of these pesticides for long term changes is advisable.

CONCLUSIONS

Sixteen fish species were collected from the small aquatic ecosystems of Santa Ana National Wildlife Refuge. Four of these species maintained relatively high abundances throughout the study, they were the mosquitofish, sheepshead minnow, inland silverside and sailfin molly. The mosquitofish was the most abundant fish species in terms of the total number captured, while the sheepshead minnow was most abundant in terms of total biomass collected.

More than twenty fish species are known to inhabit the Rio Grande in the vicinity of the refuge (Treviño-Robinson, 1959; Edwards and Contreras-Balderas, unpubl. data), however, only sixteen species have dispersed into or have colonized the refuge. Since annual floods from the Rio Grande no longer occur the only source of fish species immigrants is found in diverted river water. This water source is less than optimum since size constraints are placed on fish immigrants which must pass through pumps lifting water from the Rio Grande. Immature or smaller individuals are more likely to survive. This may be a reason for the lack of larger or predatory fishes in the ponds of the refuge.

Water source has played a major role in influencing the species composition of the ponds within the refuge.

Pintail Lake (A) which received river water as its source maintained up to 15 fish species while Willow Lake which received well water had only five species. Willow Lake experienced an increase in species abundance from five to seven species following a change in water source to river water. The continued supply of river water to Willow Lake will probably further increase the lake's fish species diversity. It appears that with increased distance or isolation from the Rio Grande water source there is a decrease in fish species abundance. This would also account for the decline in species abundance between the Pintail Lakes which share a common river water source.

The river water source is not without its drawbacks. Introduced fish species like the common carp and blue tilapia in the past have colonized the ponds of the refuge. Several carp were collected during the study while blue tilapia appear to have been erradicated due to control efforts and a severe freeze in 1983. The potential for recolonization of the ponds by the blue tilapia increases with the continued use of river water.

Organochlorine pesticide and trace element analyses were performed on whole fish composite samples from the refuge. Organochlorine residues including DDD and DDE were lower than values previously reported from the Rio Grande and surrounding areas. This is possibly due to the difference in size (or lifestage) of gizzard shad used for analyses between studies. Trace element residues including selenium, arsenic and lead exceeded the National Academy of Sciences criteria of 0.5 mg/kg for the safety of fish. Furthermore, mercury residues exceeded the Environmental Protection Agency criteria of 4.1 ug/kg for the protection of aquatic life. The occurence of these residues in fish samples from the refuge could not be linked to any one contaminant source.

This study has provided information which is important for fish resource management on Santa Ana National Wildlife Refuge. Data gathered with respect to the fish species abundance and biomass may be helpful to manage fish species and help to ultimately determine their importance to piscivorous bird species which often feed from the waters of the refuge. The information gathered on water quality parameters and differences in water source may be helpful in determining water resource management strategies.

This was the first investigation of fish species which included all of the aquatic ecosystems of the refuge. Additional studies are needed which utilize different collection techniques such as gill nets or large bag seines. Further samples need to be taken from Willow Lake to determine the present fish species composition. Transplant studies might be useful to determine if Cattail Lake and Vela Woods Pond are capable of supporting native fish species. Studies which compare the fish species in the refuge and those from other oxbow lakes or resacas in the LRGV might also yield interesting data.

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