Fish Assemblage and Aquatic Habitat Relationships at the Tishomingo National Wildlife Refuge, Oklahoma

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We sampled 16 water bodies on Tishomingo National Wildlife Refuge (TNWR) in south-central Oklahoma to document the occurrence of fish species, to describe habitat types, and to evaluate fish-habitat relationships. Water bodies were sampled by using electrofishing, experimental gill nets, seines, and trap nets during 1996 and 1997. We collected 52 species and report the occurrence of the American eel (*Anguilla rostrata*) upstream from Denison Dam of Lake Texoma. We used cluster analysis of the habitat features (water depth, conductivity, water clarity) to group the water bodies into three types: riverine, lacustrine, and palustrine. Similarity analysis of fish assemblages (coefficient of community) and habitat features (principal components analysis) revealed that palustrine water bodies had the highest similarity followed by lacustrine and riverine water bodies, respectively. We interpret differences in similarity to be related to variation in habitat of the water body types in the three groups. Information from this study should benefit management of fish assemblages and aquatic habitats at TNWR.

INTRODUCTION

In Oklahoma, there are few natural lakes but there are many artificial impoundments, the latter containing fishes that are adapted to both flowing (lotic) and standing (lentic) water (Miller and Robison 2004). Although the relationship between habitat characteristics and fish assemblage structure in streams and rivers of the southern Great Plains has been well studied (e.g., Matthews 1985, 1988, 1998; Taylor et al 1993; Williams et al 1996), the relationship between habitat structure and fish assemblages in lentic systems of this region has not been as thoroughly investigated (but see Summerfelt 1971, Gelwick and Matthews 1990). Impoundments and streams on the Tishomingo National Wildlife Refuge (TNWR) in southcentral Oklahoma include both lentic and lotic habitats, and some of these are periodically connected when flooding occurs. These connections affect fish assemblages by allowing obligate riverine, obligate lacustrine, and facultative riverine species to redistribute themselves along a connectivity gradient.

Fish assemblages in temperate and tropical water bodies are related to similar habitat features. In the Red River drainage of the southern Great Plains, the distribution of small fish species has been shown to be related to conductivity, stream size, woody debris, and water clarity (Taylor et al 1993). Similarly, Rodriguez and Lewis (1997) found that local differences in fish assemblage structure were related to transparency, depth, and surface area in tropical floodplain lakes during the dry season. Some of the impoundments of the TNWR may function as floodplain lakes because of their location

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along a river floodplain and periodic connection with the mainstem river channel.

Our objectives were to survey the fish assemblages of the TNWR, describe habitat types in water bodies on the refuge, and relate species occurrence to differences in habitat characteristics among the water bodies.

MATERIALS AND METHODS

Study Area

The TNWR is located in Johnston and Marshall counties in southcentral Oklahoma along the Washita River arm of Lake Texoma. The refuge was established in 1946 following completion of the Denison Dam which impounded Lake Texoma. The refuge encompasses several lakes, creeks, ponds, sloughs, and a portion of the Washita River (Fig. 1). Historical photos show that prior to creation of Lake Texoma, there were no impoundments on either side of the Washita River in the area of the TNWR. The Cumberland Pool, encompassed by the TNWR, has gradually become isolated from the main body of Lake Texoma as a result of sedimentation from the Washita River, and it is now essentially a large floodplain lake. This process also created several smaller floodplain lakes (e.g., Bell Creek, Rock Creek). These smaller lakes are separated from the Cumberland Pool by the forested embankments of the Washita River, although they are sometimes connected to one another during floods.

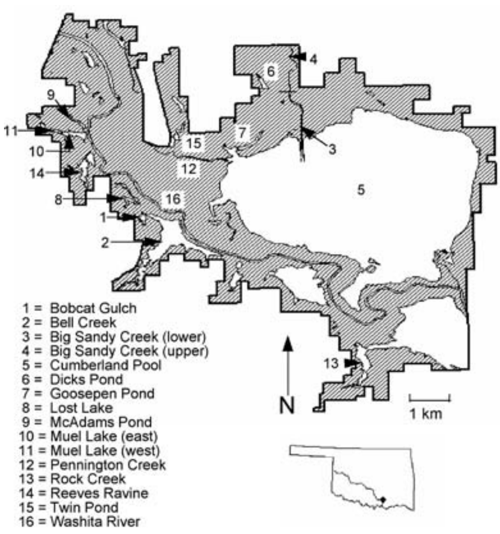

Figure 1. Location of water bodies on the Tishomingo National Wildlife Refuge, Johnston and Marshall counties, Oklahoma.

Fish collections

From May to November 1996 and from March to November 1997, we used experimental gill nets, trap nets, seines, and electrofishing to sample the fish fauna of TNWR. The Cumberland Pool was sampled regularly during the entire study period; other water bodies were sampled once in the summer of 1996 or 1997. Different gear types were used to sample fish in each water body depending on habitat conditions and accessibility.

We used experimental monofilament gill nets with square mesh sizes from 1.5 to 10.2 cm, two to eight 16-m panels, and total lengths from 32 to 128 m. All gill nets were set on the bottom and fished from dusk until dawn (11-14 h sets). We set gill nets in nearshore and open water habitats in Cumberland Pool, and in other lentic habitats we set at least a single gill net in open water habitat. In streams we set a single gill net diagonal to the flow. No gill nets were set in Dicks Pond, upper Big Sandy Creek, or the Washita River because of excessive vegetation, submerged woody debris or limited access. Total effort for gill nets was reported as the total area (m^2) of netting deployed during one nocturnal set.

We used an electrofishing boat with a 3.5 gas powered pulsator electrofisher (Smith Root, Inc., Vancouver, WA) and 4,474 W generator to capture fish. All electrofishing operations used direct current at 60 pulses/s. We used single-pass, stop and go (as opposed to continuous), sampling in all water bodies. Electrofishing was not conducted in the upper Big Sandy Creek or in eastern Muel Lake because of limited access. Total effort for electrofishing is reported as the total number of minutes of pedal-on time.

Seining was conducted with a 4.0 x 0.9-m straight seine and a 12.0 x 0.9-m bag seine (both with 3.2 mm mesh). We sampled six stations around Cumberland Pool. We also seined the Washita River, Pennington Creek, Dicks Pond, and the upper Big Sandy Creek. Seine hauls were pulled 15-m to the shoreline in shallow to moderately deep water ($\leq$1 m). The upper Big Sandy Creek was sampled by using block seines and enough seine hauls ($\geq$3 hauls) to remove most of the fish in a sequence of riffle, run, and pool habitats. Effort for all seining was reported as total area (m^2) sampled.

Voucher specimens of smaller species (adult total length < 150) were preserved in 10% formalin and later transferred to 40% isopropyl alcohol. Close-up photographs were taken of the larger specimens. Voucher specimens and photos were stored in the Oklahoma State University Museum of Fishes. Scientific names follow Nelson et al (2004).

Habitat measurements

From 19 June to 2 August 1997, we collected habitat data in each water body coincident with fish sampling. Conductivity was measured by using a multiparameter-water-quality monitoring instrument (Hydrolab Scout 2, Loveland, CO). Maximum depth was measured with either a calibrated pole (± 0.1 m), sonar (± 0.3 m), or tape (± 0.05 m), and water clarity was measured by using a Secchi disk. The measurements were generally taken near the center of each water body and represent a single measurement taken during the time period.

Water bodies were classified as lacustrine, palustrine, and riverine (Cowardin et al 1979). Lacustrine systems had the following characteristics: (1) situated in a topographic depression or dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30% areal coverage; and (3) total area exceeding 8 ha. Also classified as lacustrine were smaller water bodies with a maximum depth of >2 m at low water. Palustrine systems had the following characteristics: (1) area less than 8 ha; (2) lacking active wave-formed or bedrock shoreline features; and (3) maximum depth <2 m at low water. Riverine systems included all deep-water habitats contained within a channel.

Analysis

Similarity in species composition among water bodies was compared by using the coefficient of community (CC; Whittaker 1975). This index calculates the similarity of two communities based on the presence or absence of like species by using the formula:

$$CC = \frac{2 \bullet S_{ab}}{S_a + S_b}$$

where S_a is the number of species in sample A, S_b is the number in sample B, and S_{ab} is the number in both samples. Assemblages that are completely similar have a CC of 1, and those that are completely dissimilar have a CC of 0.

Similarity in habitat characteristics among water bodies was determined with cluster analysis and principal components analysis (PCA). Water bodies were grouped by using cluster analysis (Ward's method, XLSTAT; Addinsoft) based on the three habitat variables: water depth, conductivity, and Secchi depth. We used an inverse distance matrix derived from a PCA of the ranked habitat variables to determine similarity of water bodies. The distance matrix was calculated from site coordinates for PCA 1 and 2. An inverse distance matrix was used to reverse the polarity of the distances such that higher values indicate greater similarity. Groups of similar water bodies from the cluster analysis were identified on the PCA plot of habitat gradients, classification centroids, and site coordinates. The occurrence of families and species in each water body group was used to assess fish-habitat relationships.

RESULTS

Fishes collections

The Cumberland Pool received the majority (35%) of total sampling effort (Table 1). The Washita River received the next highest sampling effort (9%), and all other water bodies received 2-6% of the total effort.

We collected 3,137 fish by electrofishing, 50,618 fish by seining, 2,234 fish with gill nets, and 2,016 fish with trap nets. The collections contained fishes representing 14 families and 52 species (Table 2). Forty-three species were collected in the four riverine water bodies, 42 species in the six lacustrine water bodies, and 24 species in the six palustrine water bodies. The 10 most abundant species, based on the total catch with all gear types and in all water bodies, were, in order: *Menidia beryllina, Dorosoma cepedianum, D. petenense, Pomoxis annularis, Pimephales vigilax, Notropis buchanani, Aplodinotus grunniens, Lepomis macrochirus, Cyprinella venusta*, and *Gambusia affinis*. Chappell (1999) contains information on the total catch of each species by gear type in each water body at TNWR.

Similarity of fish assemblages differed among water body types (Table 3). Fish assemblages in the six palustrine water bodies had the highest similarity (mean = 0.671, SD = 0.168, N = 15) compared with those in the six lacustrine water bodies (mean = 0.543, SD = 0.156, N = 15) and those in the four riverine water bodies, which had the lowest similarity (mean = 0.475, SD = 0.225, N = 6). Fish assemblages in riverine water bodies were less similar to one another than to those in lacustrine water bodies (mean = 0.457, SD = 0.218, N = 24) and palustrine water bodies (mean = 0.462, SD = 0.203, N = 24), although this may be an artifact of the sample size. Lacustrine water body fish assemblages were more similar to one another than to those in palustrine water bodies (mean = 0.539, SD = 0.153, N = 36).

Habitat characteristics

Water bodies on TNWR exhibited a wide range of habitat characteristics (Table 4). Secchi depths ranged from 18 (Washita

Table 1. Sampling effort by water body and gear type at Tishomingo National Wildlife Refuge, Oklahoma.

Water body	Abbreviation	Electrofishing (min)	Gill net (100 m^2 d^{-1})	Seine (10 m^2)	Trap net (net nights)
Bobcat Gulch	BCG	6.75	1.11	0.0	0
Bell Creek	BEL	9.57	2.79	0.0	0
Big Sandy Creek (lower)	BSL	14.10	1.67	0.0	5
Big Sandy Creek (upper)	BSU	0.00	0.00	*14.0	0
Cumberland Pool	CLP	35.43	69.03	830.9	111
Dicks Pond	DKP	8.33	0.00	1.1	0
Goosepen Pond	GPP	8.53	2.97	0.0	0
Lost Lake	LOL	17.50	2.97	0.0	0
McAdams Pond	MAP	12.00	2.97	0.0	0
Muel Lake (east)	MLE	0.00	1.11	0.0	0
Muel Lake (west)	MLW	6.40	1.11	0.0	0
Pennington Creek	PEN	13.22	2.51	2.1	0
Rock Creek Lake	RCA	7.15	2.79	0.0	0
Reeves Ravine	RVR	7.05	2.79	0.0	0
Twin Pond	TWP	9.05	1.11	0.0	0
Washita River	WAS	29.52	0.00	86.9	0

*Upper Big Sandy Creek was sampled by using block seines and depletion sampling.

Table 2. Total catch and occurrence of fish species grouped by habitat type of water bodies on Tishomingo National Wildlife Refuge, Oklahoma. Habitat clusters are illustrated in Fig. 2. Abbreviations for water bodies are described in Table 1.

		Cluster 1 — Riverine				Cluster 2 — Lacustrine						Cluster 3 — Palustrine					
Family Scientific name	Total catch (%)	BSL	BSU	PEN	WAS	BEL	CLP	MAP	MLE	RCA	RVR	BCG	DKP	GPP	LOL	MLW	TWP
Anguillidae																	
Anguilla rostrata	<0.01						X										
Atherinopsidae																	
Labidesthes sicculus	<0.01							X									
Menidia beryllina	65.25	X		X	X	X	X	X		X	X	X		X	X		X
Catostomidae																	
Carpiodes carpio	0.56	X		X	X	X	X	X		X			X	X		X	X
Ictiobus bubalus	0.77	X		X		X	X	X	X	X	X	X		X	X	X	X
Ictiobus cyprinella	0.17					X	X	X	X		X			X	X	X	
Ictiobus niger	<0.01	X															
Minytrema melanops	0.01			X													
Moxostoma erythrurum	<0.01		X										X				
Centrarchidae																	
Lepomis cyanellus	0.01	X	X								X						
Lepomis gulosus	0.25	X	X	X		X		X		X	X		X		X	X	X
Lepomis humilis	0.64	X		X	X		X					X		X		X	X
Lepomis macrochirus	1.04	X	X	X		X	X	X		X	X	X	X	X	X	X	X
Lepomis megalotis	0.16	X	X	X		X		X		X	X	X				X	
Lepomis microlophus	0.04	X		X		X		X		X	X						
Micropterus punctulatus	0.04	X	X														
Micropterus salmoides	0.11	X		X		X		X		X	X	X	X	X	X	X	X
Pomoxis annularis	1.91	X		X		X	X	X		X	X	X	X	X	X	X	X
Clupeidae																	
Dorosoma cepedianum	11.23	X		X	X	X	X	X	X	X	X	X		X	X	X	X
Dorosoma petenense	5.99	X			X			X									
Cyprinidae																	
Campostoma anomalum	0.11		X				X										
Cyprinella lutrensis	0.76	X		X	X		X										
Cyprinella venusta	0.97	X	X	X	X		X			X							
Cyprinus carpio	0.13	X		X	X		X	X	X	X		X		X	X		X

Table 2. (continued)

Family Scientific name	Total catch (%)	Cluster 1 — Riverine				Cluster 2 — Lacustrine						Cluster 3 — Palustrine					
		BSL	BSU	PEN	WAS	BEL	CLP	MAP	MLE	RCA	RVR	BCG	DKP	GPP	LOL	MLW	TWP
Macrhybopsis hyostoma	0.18				X		X										
Macrhybopsis storeriana	0.01				X		X										
Notemigonus crysoleucas	0.01							X			X		X				X
Notropis atherinoides	0.01				X												
Notropis buchanani	1.57			X	X		X			X				X			
Notropis stramineus	0.12		X		X		X										
Notropis volucellus	0.76						X										
Phenacobius mirabilis	0.01		X				X										
Pimephales notatus	<0.01						X										
Pimephales promelas	<0.01						X										
Pimephales vigilax	1.61	X		X	X		X					X		X	X		X
Fundulidae																	
Fundulus zebrinus	0.01		X														
Hiodontidae																	
Hiodon alosoides	0.07						X		X								
Ictaluridae																	
Ameiurus natalis	0.01		X	X													
Ictalurus furcatus	0.29			X	X	X	X		X	X				X			
Ictalurus punctatus	0.33	X		X	X	X	X		X	X	X	X		X	X	X	X
Pylodictis olivaris	0.02				X	X	X			X							
Lepisosteidae																	
Lepisosteus oculatus	0.22	X		X			X	X		X		X	X	X	X	X	X
Lepisosteus osseus	0.34	X		X	X		X	X		X							
Lepisosteus platostomus	0.74	X				X	X				X						
Moronidae																	
Morone chrysops	0.76	X		X		X	X		X	X	X			X			
Morone saxatilis	0.09	X		X			X										

Table 2. (continued)

Family / Scientific name	Total catch (%)	Cluster 1 — Riverine				Cluster 2 — Lacustrine						Cluster 3 — Palustrine					
		BSL	BSU	PEN	WAS	BEL	CLP	MAP	MLE	RCA	RVR	BCG	DKP	GPP	LOL	MLW	TWP
Percidae																	
Etheostoma gracile	0.01												X				
Etheostoma spectabile	0.07		X														
Percina macrolepida	0.18	X	X	X	X		X				X	X		X	X	X	X
Percina sciera	0.04		X														
Poeciliidae																	
Gambusia affinis	0.91		X	X	X	X	X				X		X	X		X	
Sciaenidae																	
Aplodinotus grunniens	1.49	X		X	X	X	X			X		X		X			X
TOTAL	100.00	27	16	27	21	18	35	16	8	20	17	14	10	19	13	14	16

Table 3. Similarity of fish assemblages (i.e., coefficient of community) grouped by habitat type of water bodies on Tishomingo National Wildlife Refuge, Oklahoma. Habitat clusters are illustrated in Fig. 2. Similarity within habitat types is indicated in bold italics. Abbreviations for water bodies are described in Table 1.

	Cluster 1 — Riverine				Cluster 2 — Lacustrine						Cluster 3 — Palustrine					
Site	BSL	BSU	PEN	WAS	BEL	CLP	MAP	MLE	RCA	RVR	BCG	DKP	GPP	LOL	MLW	TWP
BSL	***1.000***	***0.326***	***0.815***	***0.542***	0.622	0.645	0.605	0.286	0.723	0.636	0.683	0.324	0.652	0.600	0.585	0.698
BSU		***1.000***	***0.326***	***0.216***	0.235	0.275	0.188	0.000	0.222	0.364	0.200	0.308	0.171	0.207	0.333	0.188
PEN			***1.000***	***0.626***	0.667	0.677	0.605	0.343	0.809	0.591	0.683	0.378	0.783	0.600	0.634	0.698
WAS				***1.000***	0.410	0.714	0.270	0.276	0.537	0.263	0.457	0.129	0.600	0.353	0.343	0.486
BEL					***1.000***	***0.528***	***0.647***	***0.462***	***0.789***	***0.800***	0.563	0.429	0.703	0.581	0.688	0.588
CLP						***1.000***	***0.392***	***0.372***	***0.582***	***0.423***	0.490	0.222	0.667	0.458	0.449	0.510
MAP							***1.000***	***0.333***	***0.722***	***0.667***	0.600	0.538	0.571	0.690	0.667	0.688
MLE								***1.000***	***0.429***	***0.400***	0.364	0.000	0.519	0.476	0.364	0.333
RCA									***1.000***	***0.595***	0.647	0.400	0.718	0.606	0.588	0.667
RVR										***1.000***	0.581	0.444	0.611	0.667	0.710	0.606
BCG											***1.000***	***0.333***	***0.788***	***0.815***	***0.714***	***0.867***
DKP												***1.000***	***0.414***	***0.435***	***0.583***	***0.538***
GPP													***1.000***	***0.750***	***0.727***	***0.800***
LOL														***1.000***	***0.741***	***0.828***
MLW															***1.000***	***0.733***
TWP																***1.000***

River) to 200 cm (estimated; upper Big Sandy Creek). Conductivity ranged from 243 (Dicks Pond) to 1370 mS cm^{-1} (Washita River). Maximum water depth ranged from 43 (upper Big Sandy Creek) to 440 cm (Cumberland Pool).

We identified three groups of water bodies from the cluster analysis that aligned along gradients defined by the PCA. Cluster 1 was composed of riverine water bodies (BSL, BSU, PEN, WAS; see Table 1 for definitions) that had the highest conductivity and lowest water clarity (Fig. 2). Cluster 2 was composed of lacustrine water bodies (BEL, CLP, MAP, MLE, RCA, RVR) with intermediate conductivity and water clarity (Fig. 2). Cluster 3 was composed of palustrine water bodies (BCG, DKP, GPP, LOL, MLW, TWP) with the least depth, highest water clarity, and lowest conductivity (Fig. 2). Principal Component 1 was a gradient of maximum water depth, and PC 2 was a gradient of increasing conductivity and decreasing water clarity (Fig. 3).

Fish-habitat relationships

Each group of water bodies had some distinct fish species associations (Table 2). Riverine systems had the greatest number of water bodies with percid species, including typically river-dependent species *Etheostoma spectabile* and *Percina sciera,* which occurred in the shallow riffle habitats of the upper Big Sandy Creek. Riverine cyprinid species, such as *Campostoma anomalum* and *Notropis atherinoides,* and the catastomids *Moxostoma erythrurum* and *Minytrema melanops* were found only in this group of water bodies.

Lacustrine systems contained several fish species that are commonly associated with deepwater, turbid habitats (Table 2). Several catastomids (*Carpoides carpio, Ictiobus bubalus, Ictiobus cyprinella*), centrarchids (*Lepomis gulosus, L. macrochirus, L. megalotis, L. microlophus, Micropterus salmoides, Pomoxis annularis*), and ictalurids (*Ictalurus furcatus, I. punctatus, Pylodictus olivaris*) and a cyprinid (*Cyprinus carpio*) and a moronid (*Morone chrysops*), occurred in most of the lacustrine

Table 4. Classification and mean habitat characteristics of water bodies at Tishomingo National Wildlife Refuge, Oklahoma.

Water body	Classification	Max. depth (meters)	Secchi depth (meters)	Conductivity (mS cm^{-1})
Muel Lake (east)	Lacustrine	1.40	0.18	804
Rock Creek Lake	Lacustrine	1.50	0.20	545
Bell Creek	Lacustrine	2.10	0.45	583
Reeves Ravine	Lacustrine	2.90	1.20	413
McAdams Pond	Lacustrine	3.70	1.10	428
Cumberland Pool	Lacustrine	4.40	0.50	710
Goosepen Pond	Palustrine	0.60	0.50	683
Dicks Pond	Palustrine	1.00	0.90	243
Twin Pond	Palustrine	1.25	0.40	519
Muel Lake (west)	Palustrine	1.40	0.25	450
Bobcat Gulch	Palustrine	1.50	0.40	455
Lost Lake	Palustrine	2.40	0.80	581
Big Sandy Creek (upper)	Riverine	0.43	2.00	560
Pennington Creek	Riverine	1.75	0.35	448
Big Sandy Creek (lower)	Riverine	2.20	0.55	588
Washita River	Riverine	3.50	0.20	1370

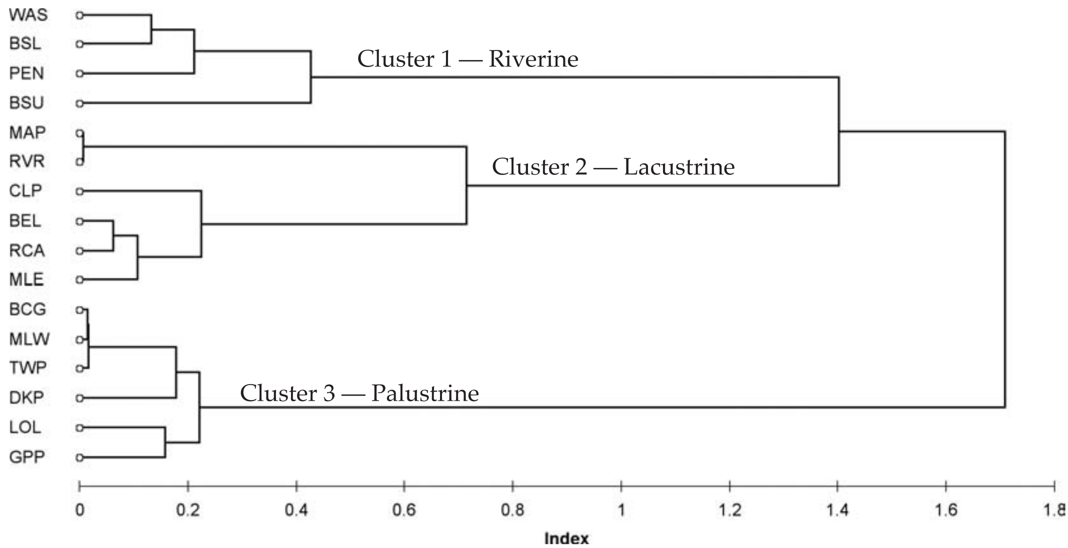

Figure 2. Dendogram water bodies on the Tishomingo National Wildlife Refuge, Oklahoma. Groupings of water bodies are based on cluster analysis of habitat characteristics. Abbreviations for water bodies are described in Table 1.

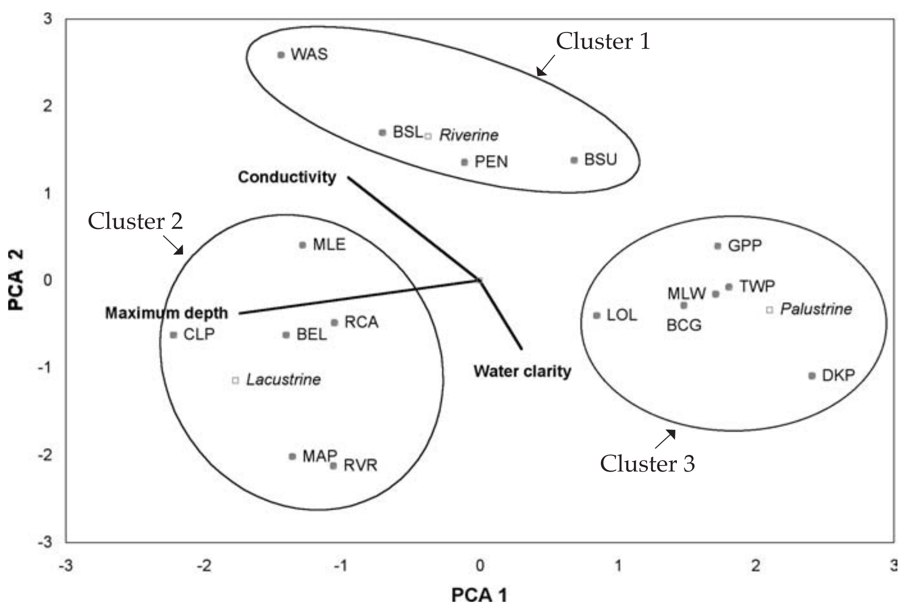

Figure 3. Plot of principal components showing habitat gradients, centroids, and cluster analysis grouping of water bodies on Tishomingo National Wildlife Refuge, Oklahoma.

water bodies. *Anguilla rostrata, Labidesthes sicculus,* and *Hiodon alosoides* were found only in lacustrine water bodies.

Palustrine systems were shallow water bodies and had the lowest fish species richness, but the highest assemblage similarity (Tables 2 and 3). Fish species that occurred in at least five of the six palustrine water bodies were *Ictiobus bubalus, Lepomis macrochirus, Micropterus salmoides, Pomoxis annularis, Dorosoma cepediamum, Ictalurus punctatus, Lepisosteus oculatus,* and *Percina macrolepida*. The slough darter (*Etheostoma gracile*) was collected only from Dicks Pond, a clear, shallow water body with the lowest conductivity.

DISCUSSION

Of the 52 fish species collected on the TNWR, we did not collect any state or federally listed endangered or threatened species. However, we did collect two adult American eel (*Anguilla rostrata*), which were unexpected because of its catadromous life history and the presence of Denison Dam for more than 50 years. Binderim (1977) collected 46 species in Mill Creek, a tributary of the Washita River 25 km west of the TNWR, and reported 36 more species that occur in nearby lakes and streams of the drainage. Several large river and lake fishes we collected (*Anguilla rostrata, Ictiobus cyprinella, I. niger, Minytrema melanops, Macrhybopsis hyostoma, Notropis atherinoides, N. buchanani, Fundulus zebrinus, Hiodon alosoides, Ictalurus furcatus, Morone saxatilis*) were not collected in Mill Creek (Binderim 1977). However, we did not collect 30 of the 82 species listed in Binderim (1977). These species and other locally abundant species in the Red River drainage (Taylor et al 1993, Miller and Robison 2004) were probably not collected because of a lack of suitable habitat or inadequate sampling effort in suitable habitats. Further collections in the TNWR may reveal the presence of additional species found by Binderim (1977) and others.

We identified variation in the extent of similarity between fish assemblages and water body type on the TNWR. The greatest similarity, based on fish assemblage and habitat similarity, occurred in palustrine water bodies. Fish assemblages in these small, upland, low conductivity, and clear water bodies differed from those in the lacustrine and riverine water bodies. Palustrine fish assemblages were similar to upland streams in that they had a greater number of centrarchid species, although they lacked stream residents such as *Etheostoma spectabile* and *Campostoma anomalum*. They also contained lowland stream, large-bodied species, such as *Cyprinus carpio, Micropterus salmoides, Pomoxis annularis,* and *Ictiobus* species, but they lacked other lowland species, such *Aplodinotus grunniens* and *Morone chrysops*. There was a unique fish assemblage associated with vegetated backwaters of Dicks Pond that was dominated by *Lepomis gulosus* and included *Etheostoma gracile;* both species are associated with dense aquatic macrophyte beds (Miller and Robison 2004).

Lacustrine water bodies on the TNWR are permanent but variable lentic habitats that are colonized by both native and exotic fish species. These habitats differed widely in size, water clarity, maximum depth, macrophyte development, flow regime, and connectivity with riverine habitats. Several species (*Anguilla rostrata, Notropis volucellus, Hiodon alosoides, and Pimephales promelas*) were found exclusively in lacustrine water bodies. Most of these water bodies occurred in the lowlands of the TNWR and were connected with the Washita River during large flood events. Flood pulses connect rivers with their floodplains and inclusive water bodies (Junk et al 1989). Several large-bodied species, such as *Lepisosteus platostomus, Cyprinus carpio,* and *Ictiobus bubalus,* are well known to use flooded areas as spawning, nursery and foraging habitat (Cone et al 1986, Ploskey 1986).

Similarity among fish assemblages in riverine water bodies at the TNWR was relatively low, probably because of the wide variation in the size and types of rivers and streams on the refuge. Riverine water bodies ranged from a small, clear headwater stream (upper Big Sandy Creek) to a large, turbid prairie river (Washita River), which were aligned at opposite ends of the cluster analysis (Fig. 2) and PCA axis 1 (Fig. 3) for riverine water bodies. Correspondingly, fish assemblages differed in these streams and rivers. Species frequently associated with clear, upstream habitats (Binderim 1977, Taylor et al 1993, Williams et al 1996) included *Campostoma anomalum, Labidesthes sicculus, Ameiurus natalis, Lepomis megalotis, L. cyanellus, Micropterus punctulatus, Etheostoma spectabile,* and *Percina caprodes.* Species frequently associated with turbid downstream habitats (Binderim 1977, Taylor et al 1993, Ashbaugh et al 1996, Luttrell 1996, Cantu and Winemiller 1997) included *Macrhybopsis hyostoma, Menidia beryllina, Aplodinotus grunniens, Morone chrysops, Ictalurus punctatus, Dorosoma cepedianum, D. petenense, Ictiobus spp., Notropis atherinoides, cyprinus carpio, Carpiodes carpio,* and *Pomoxis annularis.* Variation in fish assemblage structure in streams and rivers of the southern Great Plains has largely been attributed to a combination of biotic interactions, physicochemical conditions, and longitudinal changes in stream size and habitat type (Binderim 1977, Matthews 1988, Taylor et al 1993, Ashbaugh et al 1996, Luttrell 1996, Williams et al 1996, Cantu and Winemiller 1997). Across these studies, some species exhibit associations with either clear upstream or turbid downstream habitats, which were clearly distinguishable in the riverine water bodies of the TNWR.

The TNWR contains a variety of water bodies, including several that we did not sample. Management of fishes in the TNWR water bodies occurs almost exclusively in the Cumberland Pool, where sport fishing for *Pomoxis annualis* and ictalurids is common. Our inventory of fishes in other water bodies, as well as an inventory of terrestrial habitats and vertebrates (Fisher et al 1998) should aid TNWR managers by providing baseline information for conservation planning of the biological resources and habitats on the refuge.

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