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Factors Affecting Blue Catfish Populations in Texas Reservoirs

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Abstract.—The blue catfish *Ictalurus furcatus* is the largest ictalurid in the United States and is present in many reservoirs throughout Texas. While some populations are native, many fisheries are the result of introductions through stocking programs. These stockings can result in established fisheries while others fail to produce established populations. It is possible that a combination of physical, chemical, and biological variables produce an ideal environment for the successful establishment and survival of this species. The objective of this study was to identify the key factors that influence the success of blue catfish populations in Texas reservoirs. Thirty reservoirs distributed across Texas were sampled using gill nets and low-frequency electrofishing. Blue catfish abundance, condition, and natural reproduction were compared with multiple physicochemical and biological variables collected at each reservoir. Factor analysis indicated that both gill-net catch rates and low-frequency electrofishing catch rates were positively correlated to measures of primary productivity. The analysis also showed that gill-net catch rates increased with increasing reservoir surface area. The occurrence of natural reproduction showed a weak negative correlation to length of growing season. The results of this study provide further insight into the biology of blue catfish and provide managers with information that can be used to prioritize future stocking efforts.

Introduction

The blue catfish *Ictalurus furcatus* is native to many drainages of the southern United States and is a popular sport fish. In Texas, its range includes most of the state with the exclusion of the western and northwestern portions of the state (Thomas et al. 2007). It is the largest ictalurid in the United States and is generally considered a big-river species (Graham 1999). According to Ditton and Hunt (1996), catfishes ranked second in angler preference for species sought among Texas anglers. Its popularity with anglers is evidenced by the increasing presence of catfish fishing tournaments at the local, regional, and national levels. State agencies and fisheries managers are investing significant effort towards the management of this species because of its potential to provide both a harvest fishery and a trophy fishery. With increasing fishing pressure comes ever-increasing harvest, making the management of blue catfish more critical than ever. In fact, some states have already enacted harvest regulations specific to blue catfish.

In spite of its popularity, the blue catfish is the least studied of the ictalurids (Boxrucker 2007). Perhaps one reason for this is the difficulty of effectively sampling this species. Gill nets are commonly used by state agencies to sample blue catfish, however, Buckmeier and Schlechte (2009) found that catfish smaller than 250 mm were underrepresented in gill nets. This can leave managers uncertain about the status of recruitment from gill-net survey data. Low-frequency electrofishing can be used to target blue catfish with greater efficiency relative to gill nets (Buckmeier and Schlechte 2009). This is the preferred gear for sampling blue catfish and flathead catfish according to a recent survey of fisheries managers (Brown 2009). Biologists in Oklahoma have used this gear to monitor blue catfish populations in Lake Texoma since 1993 (Mauck and Boxrucker 2005). In this study, low-frequency electrofishing was used to collect juvenile size-classes in order to examine natural reproduction and recruitment.

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Although blue catfish occur naturally in a limited number of rivers and associated impoundments in Texas, many established blue catfish populations are the result of introductions through stocking programs. Blue catfish are often stocked in an impoundment to take advantage of abundant forage and to increase species diversity. According to Texas Parks and Wildlife Department (TPWD) statewide stocking records, more than 10,000,000 blue catfish fingerlings (approximately 51 mm total length) have been stocked into Texas reservoirs since 1993. Hatchery production of blue catfish fingerlings is limited and demand can exceed availability. Therefore, the allocation of fingerlings to reservoirs in need of initial or supplemental stockings is closely evaluated and prioritized. These stockings can have variable results and do not always result in populations becoming established. However, numerous reservoirs in Texas are considered to have excellent blue catfish populations. An ideal population could be described as having high abundance with a solid cohort of spawning adults and a strong juvenile constituent indicating good recruitment. While this theoretical ideal may not always be attainable, it is clear that certain reservoirs harbor the necessary attributes to produce and sustain blue catfish populations while others do not.

Many factors influence the dynamics of a fish population, ranging from meteorological phenomena to overharvest. Environmental variables likely play an important role in supporting blue catfish populations. Studies have shown that fish populations can be influenced by specific environmental variables (Mitzner 1991; Putman et al. 1995; Rutherford et al. 1995, 2001; Wildhaber et al. 2000; Paukert et al. 2002; Durham et al. 2005). These can include physical parameters such as the size and depth of a reservoir, chemical variables such as alkalinity and total phosphorus, and biological variables such as forage abundance. Understanding the factors that influence the success of blue catfish populations would help researchers and managers to make better informed decisions regarding their management. Therefore, the objective of this study was to determine the factors that allow for populations of blue catfish to exist in Texas reservoirs.

Methods

Study Sites

Thirty reservoirs ranging in size from 166 to 15,329 ha were selected for this study based primarily on a combination of stocking history and mean gill-net catch per unit effort (CPUE) from the last three TPWD surveys. Recommended stocking rates for blue catfish fingerlings in Texas vary by reservoir size, with small reservoirs (<809 ha) receiving 247 fish/ha, intermediate reservoirs (809–4,047 ha) receiving 124 fish/ha, and large reservoirs (>4,047 ha) receiving 62 fish/ha (Texas Parks and Wildlife Department, Inland Fisheries Division, unpublished manual). Selected reservoirs had either received a full stocking, a partial stocking, or no stocking (native population). Reservoirs were selected to encompass the environmental and climatological variation across the state (Figure 1).

Gill-Net Sampling

Standardized gill net surveys were conducted by TPWD on Texas reservoirs to monitor ictalurid and moronid species according to the TPWD fisheries assessment procedures (Texas Parks and Wildlife Department, Inland Fisheries Division, unpublished manual). This information was used for relative abundance estimates that would account for long-term population trends. Data from the three most recent surveys for each reservoir (range: 1997 through 2008) were used in the current study to calculate mean CPUE (number per net night) for blue catfish. Gill nets were set January through May in randomly selected locations. Gill nets were monofilament, 38 m long by 2.4 m deep, and constructed of five 7.6-m-long panels of increasing mesh sizes: 25, 38, 51, 64, and 76 mm. Reservoirs less than 2,023 ha were sampled with five gill nets, reservoirs 2,023–4,047 ha were sampled with 10 nets, and reservoirs greater than 4,047 ha were sampled with 15 nets.

Low-Frequency Electrofishing

Low-frequency electrofishing was used to collect body condition data and to examine length frequencies of blue catfish. Sampling was conducted June through September 2008. This gear was selected because catch rates are reported to be high for blue catfish when this gear is used during the summer months (Boxrucker and Kuklinski 2008; Buckmeier and Schlechte 2009). In addition, Bodine and Shoup (2010) found that electrofishing was consistently effective in sampling blue catfish at all temperatures greater than 18°C with no length bias. A Smith-Root 5.0 Generator Powered Pulsator was used. This unit can be used in water with conductivities ranging from 10 to 5,500 μS (Smith-Root Inc., personal communication). Conductivities encountered in the selected reservoirs did not exceed this range. The pulsator was set to the high voltage range (50–1,000

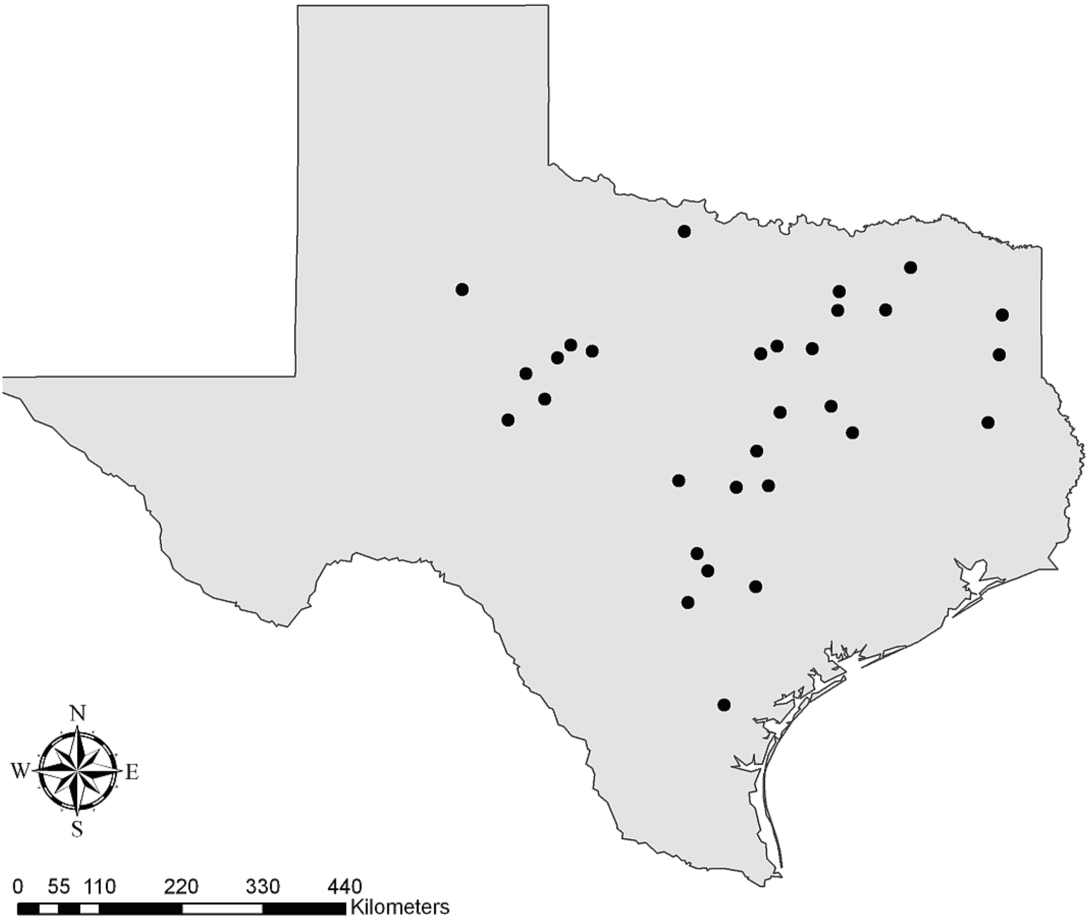

FIGURE 1. Distribution of reservoirs sampled for blue catfish populations and physicochemical characteristics in Texas, January 1997 through September 2008.

V) DC and 15 pulses/s. Amperage was maintained at 2–4 A while sampling. Electrofishing sites were sampled for 5 min to collect blue catfish. The electrofishing boat remained stationary until fish began surfacing. The electrofishing boat then moved in the direction of surfacing fish. A chase boat was also used to aid in collection of surfacing blue catfish, as suggested by Jons (1997) and used in a method similar to Buckmeier and Schlechte (2009). Total length (mm) was recorded for each fish and used for evaluating size structure. Weight (g) of each fish was also recorded and used with the standard weight equation (W_s; Muoneke and Pope 1999) in determining relative weight (W_r; Wege and Anderson 1978). In reservoirs with electrofishing catch rates greater than 18 fish/h, a minimum of 50 fish were collected to make W_r calculations more robust. For some reservoirs, this required collection of fish at additional sampling stations. These fish were only used for W_r calculations. Number of sampling sites per reservoir was proportional to reservoir size for all other variables. Reservoirs less than 1,000 ha were sampled with 12 stations, reservoirs 1,000–4,000 ha were sampled with 18 stations, and reservoirs greater than 4,000 ha were sampled with 24 stations. Sampling sites were generated randomly throughout the entire reservoir using the Random Point Generator extension (Jenness Enterprises, Flagstaff, Arizona) within ArcView 3.0 (ESRI, Redlands, California).

Biological Data

Forage data were collected independently of this study during TPWD standard electrofishing surveys.

Public reservoirs were electrofished during the fall (September through November), and sampling locations were randomly selected along shoreline/littoral habitats. Reservoirs less than 2,023 ha were sampled with 12 stations, reservoirs 2,023–4,047 ha were sampled with 18 stations, and reservoirs greater than 4,047 ha were sampled with 24 stations (Texas Parks and Wildlife Department, Inland Fisheries Division, unpublished manual). Stations were sampled for 5 min. Forage catch rates were calculated as the average catch per hour (number of fish/h) of the last three electrofishing surveys for gizzard shad *Dorosoma cepedianum*. Gizzard shad is known to be an important prey fish of blue catfish (Edds et al. 2002).

Physicochemical Data

Physical parameters were gathered from existing TPWD reservoir data. These were maximum depth (m), surface area (ha), latitude (°), longitude (°), and length of growing season (d). Length of growing season was obtained from Alvarez (2008). Variables that vary with location were taken at each site prior to electrofishing. These were water temperature (°C), dissolved oxygen (mg/L), total phosphorus (µg/L), alkalinity (mg CaCO3/L), pH, total dissolved solids (µg/L), conductivity (µS), turbidity (NTU), chlorophyll *a* (µg/L), station depth (m), Secchi depth (cm), and presence of obvious structure. Obvious structure was recorded as presence or absence of visible standing or submerged timber, vegetation, or rocks. Temperature, dissolved oxygen, chlorophyll *a*, pH, turbidity, and conductivity were measured at approximately 1 m below the surface using a YSI 6600 sonde. Total phosphorus, alkalinity, and total dissolved solids samples were collected by composite sampling in accordance with the "Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document" (EPA 2006).

Data Analysis

Sonde measurements from each sampling station were averaged to provide a single measurement for each physicochemical variable for each reservoir. Relative weights for individual fish were averaged to produce a single W_r for each reservoir. Length-frequency histograms were used to confirm natural reproduction. This was evidenced by the presence of juvenile size-classes in the length-frequency histograms that did not correspond to stocking years. In order to quantify this, catch rates of blue catfish less than 229 mm were compared across reservoirs. This length was used in an attempt to include fish produced from the previous 2 years of spawning and to exclude fish from past stockings. This length is based on blue catfish length at age studies in Texas waters (Jenkins 1956; Henderson 1972).

The FACTOR procedure in the Statistical Analysis System (SAS Institute 2006) was used to perform factor analysis to examine the number and nature of the underlying factors that were responsible for covariation within the data using the method outlined in Hatcher (1994). Independent variables included in the analysis were all measured physical, chemical, and biological variables. The factoring method used was principal components analysis. A minimum eigenvalue of 1.0 was used as a threshold for retention of factors for further analysis, prior communality estimates were set to one, and an oblique promax rotation was used to examine factor patterns to allow for correlation of factors. In interpreting the rotated factor pattern, factors having at least three significant loadings (a standardized regression coefficient > 0.40) were examined. Only variables that loaded on a single factor were considered in the interpretation of factors. Factors were then named for the construct that they were measuring. The CORR procedure was used (SAS Institute 2006) to examine Pearson correlations between the factors and the dependent variables, those being gill net catch rates, Wr, electrofishing catch rates of blue catfish less than 229 mm, and total electrofishing catch rates. Correlations were considered significant if $P < 0.10$. Total catch rates for electrofishing were also included as a dependent variable in the correlation analysis but were used only for comparison with gill-net catch rates and not as a metric of population dynamics.

Results

Blue catfish population characteristics varied widely among reservoirs (Table 1). Historical gill-net catch rates ranged from 0/net-night to 19.7/net-night. Mean relative weights ranged from 83 to 105. Electrofishing catch rates for blue catfish less than 229 mm ranged from 0/h to 305/h Length-frequency distributions showed evidence of recent natural reproduction in 17 of 27 reservoirs. Three reservoirs were excluded from examination of natural reproduction because they were stocked in the 2 years prior to sampling. Total catch rates for electrofishing ranged from 0/h to 382/h

Physicochemical variables (mean) also varied among reservoirs (Table 2). Water temperature ranged from 26.6°C to 33.8°C. Dissolved oxygen

TABLE 1. Mean (SD) gill-net catch per unit effort (GN CPUE; fish/net night), low frequency electrofishing catch per unit effort for all fish (CPUE LFE; fish/h) and for fish less than 229 mm total length (CPUE LFE < 229 mm; fish/h), and relative weight (W_r) for blue catfish in Texas reservoirs. With the exception of historical gill-net catch rates, all data was collected June–September 2008.

Name	GN CPUE	CPUE LFE	Mean W_r	CPUE LFE < 229 mm
Abilene	1.9 (2.4)	1.0	99.8	0.0
Alan Henry	0.3 (0.2)	1.3	97.8	0.7
Alvarado Park	0.2 (0.2)	0.0		0.0
Arrowhead	8.6 (4.1)	53.0	97.8	35.5
Belton	1.1 (0.6)	33.5	97.6	30.0
Buchanan	2.1 (0.6)	14.5	104.9	14.5
Calaveras	4.3 (3.3)	28.7	100.2	0.7
Canyon	1.0 (0.5)	34.7	93.4	21.3
Clyde	0.00 (0.00)	0.0		0.0
Cooper	9.1 (1.1)	99.5	96.1	76.0
Corpus Christi	19.7 (6.3)	381.5	103.5	305.0
Dunlap	0.5 (0.1)	0.0		0.0
Gonzalez (H-4)	0.1 (0.1)	2.0	91.2	0.0
Granger	1.2 (1.6)	66.7	86.6	14.0
Kirby	10.7 (3.9)	124.0	99.1	38.0
Kurth	2.1 (2.4)	0.0		0.0
Lake Georgetown	0.3 (0.6)	18.0	87.7	7.0
Lake O' the Pines	0.0 (0.0)	0.5	105.1	0.0
Lavon	13.3 (4.4)	7.5	91.4	1.0
Limestone	1.6 (1.0)	18.0	97.2	16.5
Martin Creek	1.4 (2.2)	35.3	98.1	a
Mexia	0.7 (1.0)	0.0		0.0
New Ballinger	1.2 (1.4)	0.0		0.0
O.C. Fisher	4.4 (5.4)	13.3	93.3	a
Oak Creek	5.4 (5.7)	4.0	101.6	0.0
Pat Cleburne	4.1 (1.3)	15.0	83.1	2.0
Ray Hubbard	6.3 (4.1)	22.5	95.9	9.0
Tawakoni	16.5 (3.9)	18.5	90.8	1.5
Waco	4.1 (1.1)	6.7	94.5	6.7
Waxahachie	0.0 (0.0)	69.0	95.3	[a]

[a] Reservoirs that received stockings of blue catfish fingerlings within 2 years prior to sampling and were not included in evaluation of natural reproduction.

ranged from 4.2 to 8.4 mg/L. Secchi ranged from 23.1 to 248.0 cm. Values for pH ranged from 7.7 to 9.3. Conductivities ranged from 183 to 1,609 µS. Mean station depth ranged from 2.0 to 16.6 m. Maximum reservoir depth ranged from 4.9 to 40.2 m. Structure indices ranged from 0 to 0.6. Chlorophyll a ranged from 1.8 to 34.4 µg/L. Turbidity ranged from 0.0 to 32.4 neophelometric turbidity units. Total phosphorus ranged from 13.4 to 206.5 µg/L. Total dissolved solids ranged from 88.0 to 584.0 µg/L. Alkalinity ranged from 47.0 to 257.0 mg $CaCO_3$/L. Surface area ranged from 166 to 15,329 ha. Growing season ranged from 220 to 289 d. Latitude ranged from 28.039° to 33.763°. Longitude ranged from –101.037° to –94.508°. Gizzard shad catch rates ranged from 28 to 480 fish/net-night.

Factor analysis resulted in six factors having an eigenvalue greater than 1.0 and being retained for further analysis. These factors accounted for 82% of the common variance. However, factor 6 was disregarded as this factor had less than three significant loadings. The remaining factors all had at least three significant loadings and were retained for further analysis; however, only variables showing a clean

TABLE 2. Environmental variables (mean; SD in parenthesis) measured for each reservoir. Variables measured were water temperature (WT; ºC), Secchi (cm), ph, chlorophyll *a* (Chl *a*; µg/L), turbidity (NTU), total phosphorus (TP; µg/L), total dissolved solids (TDS; µg/L), alkalinity (mg $CaCO_3$/L), surface area (SA; ha), growing season (GS; d), Latitude (º), Longitude (º), and mean (SD) electrofishing catch rates for gizzard shad (G CPUE; fish/h). With the exception of historical catch rates for gizzard shad, all data were collected June–September 2008.

Name	WT	Secchi	pH	Chl *a*	Turbidity	TP	TDS	Alkalinity	SA	GS	Latitude	Longitude	G CPUE
Abilene	27.4	49.8	8.2	4.2	13.0	26.9	260	215	241	232	32.233	–99.890	399(153)
Alan Henry	28.4	244.9	8.6	2.4	0.8	13.5	584	206	1,166	223	33.058	–101.037	159(91)
Alvarado Park	29.6	51.7	8.2	26.5	10.6	80.2	288	143	177	240	32.373	–97.232	271(208)
Arrowhead	27.4	51.1	8.6	7.4	13.2	125.0	344	193	6,058	220	33.763	–98.355	415(194)
Belton	30.6	111.0	7.9	3.6	1.5	25.7	268	174	5,012	264	31.106	–97.475	103(105)
Buchanan	28.8	114.6	8.4	5.9	4.2	27.1	292	176	8,989	238	30.749	–98.419	221(77)
Calaveras	33.8	55.9	9.3	20.8	2.1	206.5	208	245	1,467	270	29.277	–98.311	161(170)
Canyon	29.0	172.1	8.3	1.8	2.1	13.4	396	183	3,362	261	29.864	–98.198	81(54)
Clyde	27.1	45.0	8.3	13.6	12.4	65.8	312	166	182	234	32.313	–99.471	480(185)
Cooper	30.1	65.0	8.5	13.8	4.6	58.5	100	104	7,813	233	33.321	–95.616	274(169)
Corpus Christi	27.6	23.5	8.4	13.3	27.5	131.8	488	238	7,388	289	28.039	–97.871	193(82)
Dunlap	26.6	125.8	8.0	9.9	4.2	35.7	272	256	166	267	29.654	–98.067	50(45)
Gonzalez (H-4)	28.7	42.7	8.0	5.3	16.9	78.8	296	243	282	277	29.468	–97.492	82(21)
Granger	29.8	36.6	8.3	9.7	17.4	37.4	236	147	1,622	259	30.688	–97.339	130(89)
Kirby	27.3	28.6	8.5	34.4	19.0	174.0	508	203	299	232	32.385	–99.730	223(48)
Kurth	29.7	248.0	8.8	3.2	0.0	19.8	108	62	294	247	31.448	–94.679	41(45)
Lake Georgetown	29.5	126.8	8.2	3.8	3.1	19.9	248	192	525	259	30.668	–97.727	28(21)
Lake O' the Pines	27.4	84.0	7.8	12.3	2.5	54.0	88	47	6,847	225	32.751	–94.508	246(73)
Lavon	28.9	62.7	8.6	20.8	9.1	56.5	272	119	8,660	235	33.034	–96.481	211(4)
Limestone	29.5	56.0	8.1	12.3	5.0	87.8	188	88	5,080	258	31.328	–96.317	264(107)
Martin Creek	31.8	67.4	8.7	7.9	3.8	39.3	212	76	2,016	239	32.270	–94.543	30(31)
Mexia	30.5	23.1	8.0	24.9	32.4	204.3	180	115	424	258	31.644	–96.580	377(234)
New Ballinger	28.2	55.5	8.4	11.3	12.3	36.0	572	257	239	225	31.730	–100.043	150(86)
O.C. Fisher	27.9	32.3	8.6	21.0	19.8	78.7	300	223	2,202	230	31.479	–100.487	236(117)
Oak Creek	28.5	154.8	8.3	7.0	1.7	23.1	452	204	961	230	32.041	–100.269	215(44)
Pat Cleburne	28.5	64.1	7.7	10.9	8.4	38.1	188	150	631	240	32.284	–97.428	211(171)
Ray Hubbard	30.7	62.7	8.4	11.1	5.8	47.9	192	94	8,770	236	32.803	–96.499	206(60)
Tawakoni	29.8	62.1	8.7	12.3	3.9	73.5	124	92	15,329	234	32.812	–95.922	239(27)
Waco	29.2	81.8	7.8	9.0	6.5	30.7	396	164	2,911	250	31.575	–97.197	272(297)
Waxahachie	29.9	74.6	8.4	14.2	7.0	25.9	164	140	265	248	32.340	–96.805	122(73)

loading (loading on a single factor) were included in the final factor interpretation (Table 3). Factor 1 exhibited significant loadings from Secchi, total phosphorus, chlorophyll *a*, and turbidity, which are all related to productivity. Factor 2 showed significant loadings from longitude, total dissolved solids, and alkalinity, which all relate to watershed attributes. Factor 3 showed significant loadings from growing season and latitude. Factor 4 loadings included water temperature and pH. Factor 5 was most heavily loaded by surface area. Factors were named according to the loading variables (Table 3) and are referred to by name for the remainder of the text.

Pearson correlation showed the relationships between the factors and the dependent variables (Table 4). Gill-net catch rates for blue catfish were significantly and positively correlated with productivity (r = 0.36; P = 0.05) and surface area (r = 0.38; P = 0.04). Estimated factor scores of individual reservoirs relative to productivity and surface area clearly demonstrate this relationship (Figure 2). Relative weight was not correlated with any factor. Electrofishing catch rates for blue catfish less than 229 mm were correlated with growing season (r = –0.33; P = 0.09). Latitude showed a positive loading while growing season showed a negative loading, indicating that juvenile blue catfish catch rates were higher in northern reservoirs than in southern reservoirs. Total catch rates for electrofishing were correlated with productivity (r = 0.33; P = 0.08) and growing season (r = –0.32; P = 0.08).

Discussion

The fact that many reservoirs in Texas have established blue catfish populations many years after stocking indicates that this big-river species can thrive in a lacustrine environment. However, it is clear that certain reservoirs produce better blue catfish populations than others. This study shows that environmental factors do indeed influence blue catfish populations in Texas. The results of the analysis show that surface area, productivity, and growing season had the greatest influence on blue catfish populations in the study reservoirs.

Many attributes of large reservoirs could contribute to the positive correlation between surface area and gill-net catch rates. In Texas, large reservoirs are usually impoundments of large rivers while small reservoirs are often impoundments of creeks and tributaries. These large reservoirs may possess many morphometric and bathymetric features that are similar to habitats found in large rivers. Large rivers feeding these reservoirs may also offer easier

TABLE 3. Factor analysis for independent variables. Individual factors were given thematic titles according to the variables showing significant loadings on that factor. Insignificant and dual loadings are not shown. % variance = percentage of common variance. Loadings show standardized regression coefficients from the rotated factor pattern matrix.

Factor	% variance	Eigenvalues	Loadings
Factor 1 – Productivity	0.24	4.32	
Secchi			–0.91
Total phosphorus			0.81
Chlorophyll *a*			0.78
Turbidity			0.78
Factor 2 – Watershed	0.20	3.62	
Total dissolved solids			0.94
Longitude			–0.93
Alkalinity			0.85
Factor 3 – Growing season	0.14	2.51	
Growing season			–0.96
Latitude			0.91
Factor 4 – Water temperature, pH	0.11	1.91	
pH			0.88
Water temperature			0.69
Factor 5 – Surface area	0.08	1.40	
Surface area			0.82

TABLE 4. Pearson correlation coefficients for relationships between blue catfish population characteristics and environmental factors (from factor analysis). Blue catfish variables are mean gill net catch per unit effort (GN CPUE; fish/net night), relative weight (W_r), low frequency electrofishing effort for fish < 229 mm total length (CPUE LFE < 229 mm; fish/h), and low frequency electrofishing effort for all fish (CPUE LFE; fish/h).

Dependent variable	Productivity	Watershed	Growing season	Water temperature, pH	Surface area
GN CPUE	0.36	0.03	0.09	0.16	0.38
P value	0.05	0.87	0.64	0.40	0.04
W_r	0.08	0.21	0.13	0.16	0.12
P value	0.72	0.31	0.55	0.45	0.59
CPUE LFE < 229 mm	0.28	0.17	–0.33	–0.08	0.17
P value	0.16	0.39	0.09	0.70	0.39
CPUE LFE	0.33	0.17	-0.32	0.00	0.12
P value	0.08	0.38	0.08	0.98	0.51

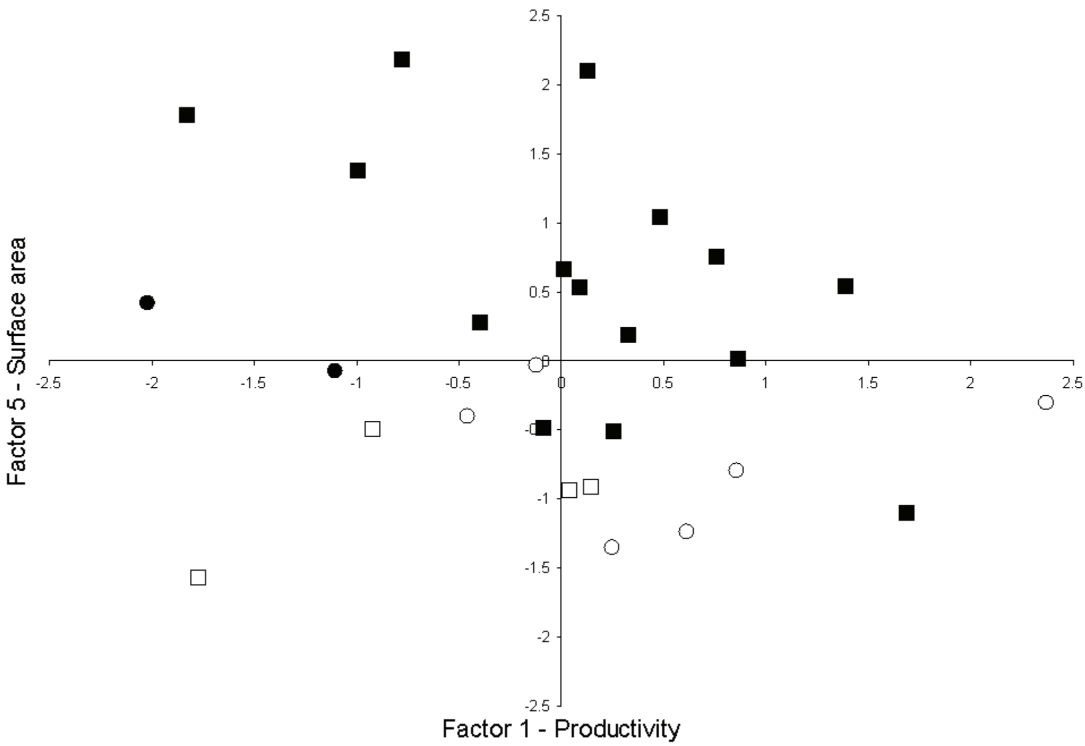

FIGURE 2. Estimated factor scores for individual reservoirs for productivity factor versus surface area factor. The horizontal axis shows productivity scores while the vertical axis shows surface area scores. Squares represent reservoirs with gill-net catch per unit effort (CPUE) ≥ 1.0. Circles represent reservoirs with gill-net CPUE less than 1.0. Filled symbols indicate reservoirs having natural reproduction and open symbols indicate reservoirs with no natural reproduction.

access to spawning habitats during spawning migrations. Blue catfish are known to prefer the main-stem habitats of big rivers rather than smaller creeks and tributaries (Graham 1999). This might also explain their success in lacustrine environments. Large reservoirs have a large geographic footprint that likely encompasses a wide variety of habitat types (foraging, spawning) and have complex bathymetry. Blue catfish preferred deep, inundated river channel habitats over coves and shallow water habitats in Lake Texoma (Edds et al. 2002). In smaller reservoirs where deep open-water habitat may be limited, other species that forage in littoral habitats may have a decided advantage. Large reservoirs may offer optimal conditions for multiple ictalurid species, as channel catfish length at age was found to be positively related to reservoir surface area in Texas reservoirs (Durham et al. 2005).

Productivity was also influential with regard to blue catfish abundance. Highly productive reservoirs generally support abundant populations of many species and have high forage densities, so it makes sense that blue catfish populations would also thrive in these reservoirs. Winemiller et al. (2000) found that chlorophyll a was positively correlated with fish abundance in Brazos River oxbow lakes. In the trophic state model, production and biomass at each trophic level is controlled by nutrients and primary production (Hayes et al. 1993). This model infers that the population dynamics of lower trophic levels would influence the success of blue catfish. Michaletz (1998) showed that gizzard shad CPUE increased with increasing reservoir productivity in Missouri reservoirs. Gizzard shad catch rates did show a significant loading on productivity (not shown on Table 3); however, it also loaded on growing season and was therefore excluded from interpretation of the factors. While the influence of gizzard shad abundance may not be implicitly clear from the results of this study, it is likely its abundance does have some effect on blue catfish populations.

While surface area and productivity showed the most influence on blue catfish populations, it is the correct combination of the two that seems to provide the optimal conditions for blue catfish to thrive (Figure 2). Some of the study reservoirs showed above average productivity but were very small in surface area, and many of these were reservoirs in which blue catfish stockings have yielded poor results. Other study reservoirs had average to above average surface areas but relatively low productivity, and many also yielded little returns from blue catfish stockings. The combination of high productivity within large reservoirs seemed to provide the optimum reservoir conditions to support blue catfish populations. At this point, a couple of the exceptions to the observed trends merit discussion. Lake O' the Pines, a large reservoir (seventh largest surface area) that also received a full stocking has one of the poorest blue catfish populations in the state. However, it ranked 19th in terms of productivity, suggesting that large surface area alone is not enough to produce abundant blue catfish populations. Another exception is Lake Kirby. This small reservoir has a robust blue catfish fishery, yet is diminutive in size at only 299 ha. However, it ranked second with regard to productivity. This may be due in part to the fact that water levels are maintained by effluent outflow from a nearby water treatment plant. Spawning habitat seems to be available as strong juvenile size-classes are present and the last stocking occurred in 2001. The high levels of primary productivity likely provide an excellent forage base at the lower trophic levels for juvenile blue catfish. Lake Kirby's blue catfish population is a marked exception among the small reservoirs sampled.

Surface area data are readily available to managers; however, the same may not be true for all variables relating to productivity. Secchi depth is easily obtained and could be used as a surrogate measure of productivity (Carlson 1977; Michaletz 1999). Reservoirs with a mean Secchi depth less than 65 cm in combination with surface areas greater than 1,466 ha had the most robust blue catfish populations (Figure 2). While these numbers are not absolute thresholds, these values can provide guidance for managers to more closely evaluate the potential of Texas reservoirs to sustain blue catfish populations. This, in combination with results from past stockings, will help managers to better prioritize their stocking efforts for blue catfish.

While it seemed that natural reproduction increased in the northern regions of the state, this may simply be a product of geography and reservoir distribution in Texas. For this study, there were simply a greater number of reservoirs sampled in the central and northern parts of the state, which may have contributed to these results. With the exception of the very large and productive southernmost reservoir sampled, which had a very high juvenile catch rate, the other southerly reservoirs that were sampled had relatively poor juvenile catch rates. Included in these were two small reservoirs (186 and 282 ha) that are very riverine in nature and are small impounded sections of river. Although these two impoundments received full stockings, both failed to establish blue catfish fisheries. Five of the seven northernmost reservoirs had high juvenile catch rates. All of these reservoirs also had relatively large surface areas and above-average productivity.

Overall, the 10 reservoirs that showed no evidence of reproduction had relatively small surface areas, ranging from 166 to 961 ha with a mean of 335 ha. While, superficially, this might appear to be strictly an issue with surface area, the lack of correlation between surface area and electrofishing catch rates of juveniles may elucidate a deeper issue. Examining Table 4, there is an inconsistency between the correlation coefficient for that of electrofishing (juvenile) catch rates and surface area and the coefficient for that of gill-net (adult) catch rates and surface area. There appears to be a disconnect between young juveniles and adults in small reservoirs, suggesting inadequate recruitment. This issue may be habitat-related and may be indirectly related to surface area. Reservoirs with small surface areas have a small geographic footprint, encompassing fewer habitat types and exhibiting monotypic bathymetry, and may not provide suitable foraging habitat for adult blue catfish.

While this research suggests that reservoir attributes and environmental variables play a role in the establishment and survival of blue catfish, researchers would benefit from a thorough knowledge of habitat use throughout all life stages of this species. Nesting habits are said to be similar to channel catfish (Pflieger 1997), but perhaps blue catfish may prefer specific conditions not needed by other ictalurid species to initiate spawning. A better understanding of its spatial and temporal foraging behavior and its interactions with other ictalurids would also allow researchers further insight into the biology of this species.

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