ABSTRACT

Factors Affecting Blue Catfish Populations in Texas Reservoirs

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While some blue catfish *Ictalurus furcatus* populations are native in Texas reservoirs, many are the result of introductions through stocking programs. Some of these stockings result in established populations while others do not. Blue catfish populations were sampled in 30 Texas reservoirs and population metrics were compared with multiple physicochemical and biological variables collected at each reservoir to examine the key factors that influence their establishment and survival. 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. This study provides further insight into the biology of blue catfish and provides managers with information that can be used to prioritize future stocking efforts.

Factors Affecting Blue Catfish Populations in Texas Reservoirs

by

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A Thesis

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CHAPTER ONE

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 west and northwest 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), catfish 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.

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, over 13,000,000 blue catfish fingerlings (approximately 51 mm total length) have been stocked into Texas reservoirs since 1990. 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; Rutherford et al. 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.

CHAPTER TWO

Materials and Methods

Study Sites

Thirty reservoirs ranging in size from 1.66 km^2 to 153.29 km^2 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 (< 8.09 km^2) receiving 24,700 fish/km^2, intermediate reservoirs (8.09-40.47 km^2) receiving 12,400 fish/km^2, and large reservoirs (> 40.47 km^2) receiving 6200 fish/km^2 (TPWD, 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 (TPWD, 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 catch per unit effort (CPUE, number per net night) for blue catfish. Gillnets were set January through May in randomly selected locations. Gillnets were monofilament, 38 m long by 2.4 m deep, and

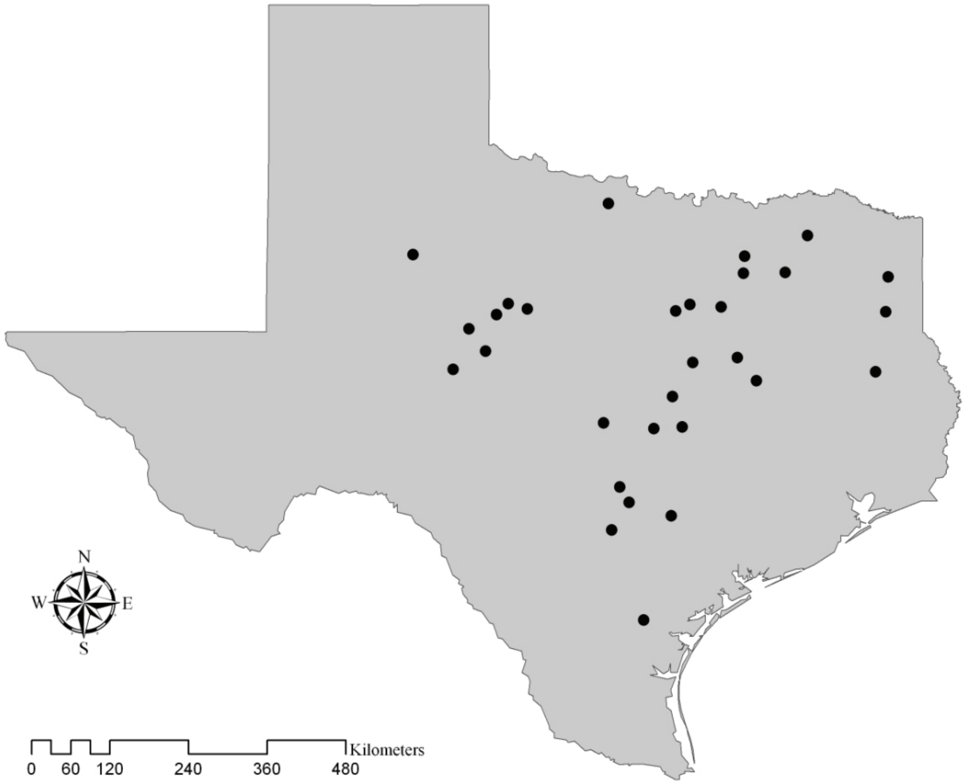


Figure 1.–Distribution of reservoirs sampled for blue catfish populations and physicochemical characteristics in Texas January 1997 through September 2008.

constructed of five 7.6 m long panels of increasing mesh sizes: 25 mm, 38 mm, 51 mm, 64 mm, and 76 mm. Reservoirs < 20.23 km^2 were sampled with five gill nets, reservoirs 20.23-40.47 km^2 were sampled with 10 nets, and reservoirs > 40.47 km^2 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 over 18ºC 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 10-5,500 µS (Smith-Root Incorporated, 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 V) DC and 15 pulses per s. Amperage was maintained at 2-4 A while sampling. Electrofishing sites were sampled for five minutes 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 (*Ws*) (Muoneke and Pope 1999) in determining relative weight (*Wr*) (Wege and Anderson 1978). In reservoirs with electrofishing catch rates > 18 fish/hr, a minimum of 50 fish were collected to make *Wr* calculations more robust. For some reservoirs, this required collection of fish at additional sampling stations. These fish were only used for *Wr* calculations. Number of sampling sites per reservoir was proportional to reservoir size for all other variables. Reservoirs < 10 km^2 were sampled with 12 stations, reservoirs 10-40 km^2 were sampled with 18 stations, and reservoirs > 40 km^2 were sampled with 24 stations. Sampling sites were generated randomly throughout the entire reservoir using the Random Point Generator extension (Jenness Enterprises) within ArcView 3.0 (ESRI).

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 < 20.23 km^2 were sampled with 12 stations, reservoirs 20.23-40.47 km^2 were sampled with 18 stations, and reservoirs > 40.47 km^2 were sampled with 24 stations (TPWD, Inland Fisheries Division, unpublished manual). Stations were sampled for five minutes. Forage catch rates were calculated as the average catch per hour (number of fish/hr) of the last three electrofishing surveys for gizzard shad *Dorosoma cepedianum*. Gizzard shad are 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 (km^2), latitude (º), longitude(º), 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 (ºC), dissolved oxygen (mg/L), total phosphorus (µg/L), alkalinity (mg $CaCO_3$/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 *Wr* 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 < 229 mm were compared across reservoirs. This length was used in an attempt to include fish produced from the previous two 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 component 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 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 < 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.

CHAPTER THREE

Results

Blue catfish population characteristics varied widely among reservoirs (Table 1). Historical gillnet 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 < 229 mm

Table 1.–Mean (SD) gill net catch per unit effort (fish/net night; GN CPUE), low frequency electrofishing catch per unit effort for all fish (fish/hr; CPUE LFE) and for fish < 229 mm total length (fish/hr; CPUE LFE<229mm), and relative weight (*Wr*) 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 *Wr*	CPUE LFE<229mm
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

Table 1.–Continued.

Name	GN CPUE	CPUE LFE	Mean *Wr*	CPUE LFE<229mm
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 two years prior to sampling and were not included in evaluation of natural reproduction.

ranged from 0/hr to 305/hr. 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 two years prior to sampling. Total catch rates for electrofishing ranged from 0/hr to 382/hr.

Physicochemical variables (mean) also varied among reservoirs (Table 2). Water temperature ranged from 26.6 ºC to 33.8 ºC. Dissolved oxygen ranged from 4.2 mg/L to 8.4 mg/L. Secchi ranged from 23.1 cm to 248.0 cm. Values for pH ranged from 7.7 to

9.3. Conductivities ranged from 183 μS to 1609 μS. Mean station depth ranged from 2.0 m to 16.6 m. Maximum reservoir depth ranged from 4.9 m to 40.2 m. Structure indices ranged from 0 to 0.6. Chlorophyll *a* ranged from 1.8 μg/L to 34.4 μg/L. Turbidity ranged from 0.0 NTU to 32.4 NTU. Total phosphorus ranged from 13.4 μg/L to 206.5 μg/L. Total dissolved solids ranged from 88.0 μg/L to 584.0 μg/L. Alkalinity ranged from 47.0 mg $CaCO_3$/L to 257.0 mg $CaCO_3$/L. Surface area ranged from 1.66 km^2 to 153.29 km^2. Growing season ranged from 220 d to 289 d. Latitude ranged from 28.039º to 33.763º. Longitude ranged from -101.037º to -94.508º. Gizzard shad catch rates ranged from 28 fish/net night to 480 fish/net night.

Factor analysis resulted in six factors having an eigenvalue > 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 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.

Table 2.–Environmental variables (mean; SD in parenthesis) measured for each reservoir. Variables measured were water temperature (ºC; WT), Secchi (cm), ph, chlorophyll *a* (µg/L; Chl *a*), turbidity (NTU), total phosphorus (µg/L; TP), total dissolved solids (µg/L; TDS), alkalinity (mg $CaCO_3$/L), surface area (km^2; SA), growing season (d; GS), Latitude (º), Longitude (º), and mean (SD) electrofishing catch rates for gizzard shad (fish/hr; G CPUE). 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	2.41	232	32.233	-99.890	399(153)
Alan Henry	28.4	244.9	8.6	2.4	0.8	13.5	584	206	11.66	223	33.058	-101.037	159(91)
Alvarado Park	29.6	51.7	8.2	26.5	10.6	80.2	288	143	1.77	240	32.373	-97.232	271(208)
Arrowhead	27.4	51.1	8.6	7.4	13.2	125.0	344	193	60.58	220	33.763	-98.355	415(194)
Belton	30.6	111.0	7.9	3.6	1.5	25.7	268	174	50.12	264	31.106	-97.475	103(105)
Buchanan	28.8	114.6	8.4	5.9	4.2	27.1	292	176	89.89	238	30.749	-98.419	221(77)
Calaveras	33.8	55.9	9.3	20.8	2.1	206.5	208	245	14.67	270	29.277	-98.311	161(170)
Canyon	29.0	172.1	8.3	1.8	2.1	13.4	396	183	33.62	261	29.864	-98.198	81(54)
Clyde	27.1	45.0	8.3	13.6	12.4	65.8	312	166	1.82	234	32.313	-99.471	480(185)
Cooper	30.1	65.0	8.5	13.8	4.6	58.5	100	104	78.13	233	33.321	-95.616	274(169)
Corpus Christi	27.6	23.5	8.4	13.3	27.5	131.8	488	238	73.88	289	28.039	-97.871	193(82)
Dunlap	26.6	125.8	8.0	9.9	4.2	35.7	272	256	1.66	267	29.654	-98.067	50(45)
Gonzalez (H-4)	28.7	42.7	8.0	5.3	16.9	78.8	296	243	2.82	277	29.468	-97.492	82(21)
Granger	29.8	36.6	8.3	9.7	17.4	37.4	236	147	16.22	259	30.688	-97.339	130(89)

Table 2.–Continued.

Name	WT	Secchi	pH	Chl *a*	Turbidity	TP	TDS	Alkalinity	SA	GS	Latitude	Longitude	G CPUE
Kirby	27.3	28.6	8.5	34.4	19.0	174.0	508	203	2.99	232	32.385	-99.730	223(48)
Kurth	29.7	248.0	8.8	3.2	0.0	19.8	108	62	2.94	247	31.448	-94.679	41(45)
Lake Georgetown	29.5	126.8	8.2	3.8	3.1	19.9	248	192	5.25	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	68.47	225	32.751	-94.508	246(73)
Lavon	28.9	62.7	8.6	20.8	9.1	56.5	272	119	86.60	235	33.034	-96.481	211(4)
Limestone	29.5	56.0	8.1	12.3	5.0	87.8	188	88	50.80	258	31.328	-96.317	264(107)
Martin Creek	31.8	67.4	8.7	7.9	3.8	39.3	212	76	20.16	239	32.270	-94.543	30(31)
Mexia	30.5	23.1	8.0	24.9	32.4	204.3	180	115	4.24	258	31.644	-96.580	377(234)
New Ballinger	28.2	55.5	8.4	11.3	12.3	36.0	572	257	2.39	225	31.730	-100.043	150(86)
O.C. Fisher	27.9	32.3	8.6	21.0	19.8	78.7	300	223	22.02	230	31.479	-100.487	236(117)
Oak Creek	28.5	154.8	8.3	7.0	1.7	23.1	452	204	9.61	230	32.041	-100.269	215(44)
Pat Cleburne	28.5	64.1	7.7	10.9	8.4	38.1	188	150	6.31	240	32.284	-97.428	211(171)
Ray Hubbard	30.7	62.7	8.4	11.1	5.8	47.9	192	94	87.70	236	32.803	-96.499	206(60)
Tawakoni	29.8	62.1	8.7	12.3	3.9	73.5	124	92	153.29	234	32.812	-95.922	239(27)
Waco	29.2	81.8	7.8	9.0	6.5	30.7	396	164	29.11	250	31.575	-97.197	272(297)
Waxahachie	29.9	74.6	8.4	14.2	7.0	25.9	164	140	2.65	248	32.340	-96.805	122(73)

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 temp., pH	0.11	1.91	
pH			0.88
Water temperature			0.69
Factor 5 - Surface area	0.08	1.40	
Surface area			0.82

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 < 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

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 (fish/net night; GN CPUE), relative weight (*Wr*), low frequency electrofishing effort for fish < 229 mm total length (fish/hr; CPUE LFE<229mm), and low frequency electrofishing effort for all fish (fish/hr; CPUE LFE).

Dependent Variable	Productivity	Watershed	Growing Season	Water temp., 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
Wr	0.08	0.21	0.13	0.16	0.12
P value	0.72	0.31	0.55	0.45	0.59
CPUE LFE<229mm	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

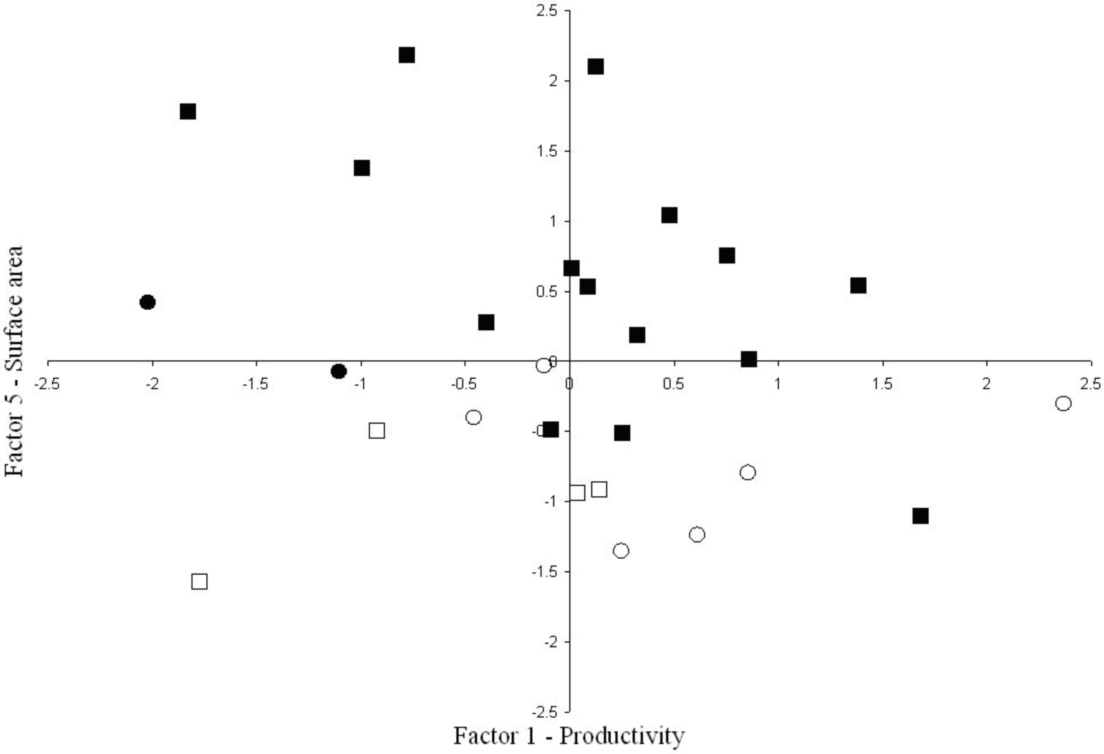


Figure 2.–Estimated factor scores for individual reservoirs for productivity factor versus surface area factor. The horizontal axis shows productivity scores while the vertical axis shows surface area scores. Squares represent reservoirs with gill net CPUE ≥ 1.0. Circles represent reservoirs with gill net CPUE < 1.0. Filled symbols indicate reservoirs having natural reproduction and open symbols indicate reservoirs with no natural reproduction.

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).

CHAPTER FOUR

Discussion and Conclusions

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 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 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 their 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 (7th 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 2.99 km^2. However, it ranked 2nd 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 is 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 < 65 cm in combination with surface areas > 14.66 km^2 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 (1.86 and 2.82 km^2) which 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.

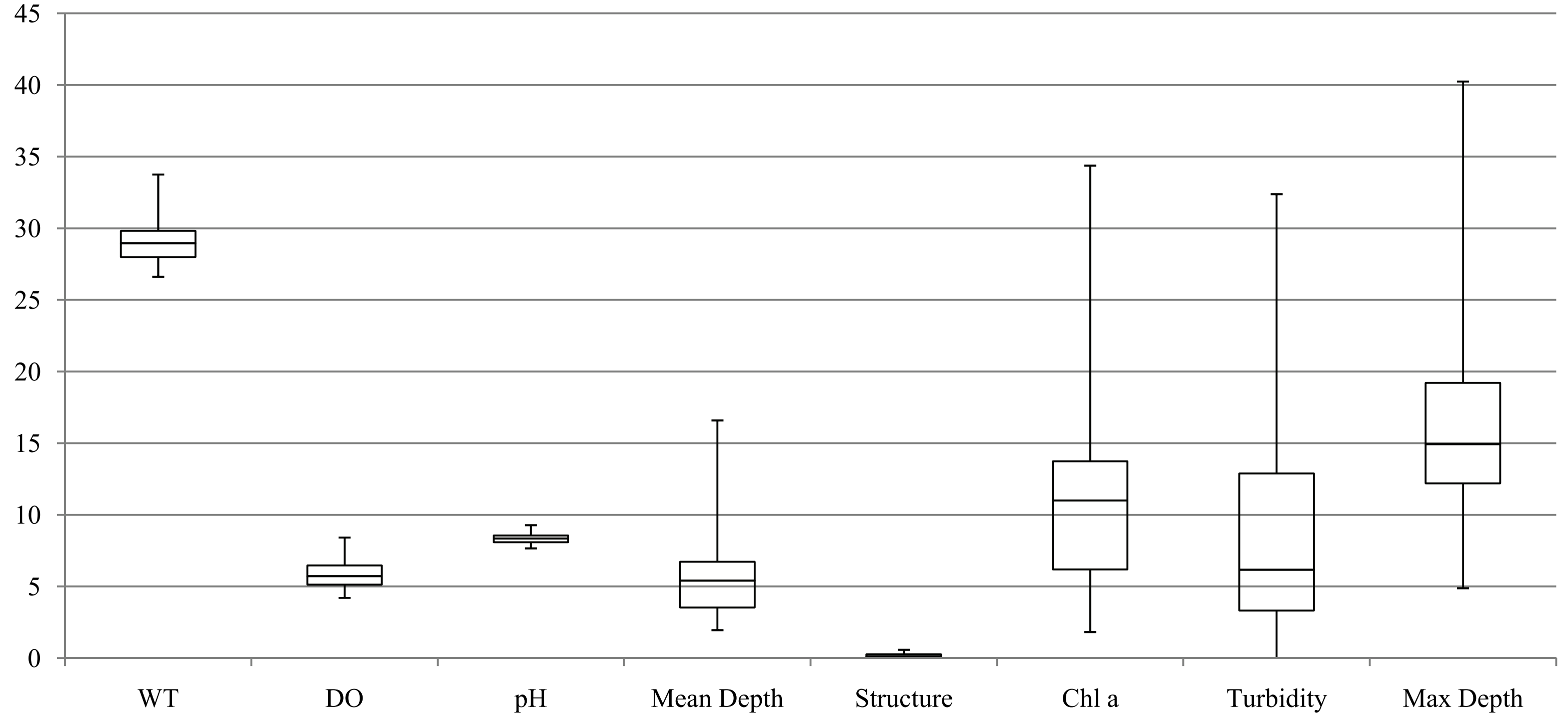
Overall, the 10 reservoirs that showed no evidence of reproduction had relatively small surface areas, ranging from 1.66 ha to 9.61 km^2 with a mean of 3.35 km^2. While superficially this might appear to be strictly an issue with surface area, the lack of correlation between surface area and electrofishing 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 their spatial and temporal foraging behaviors and their interactions with other ictalurids would also allow researchers further insight into the biology of this species.

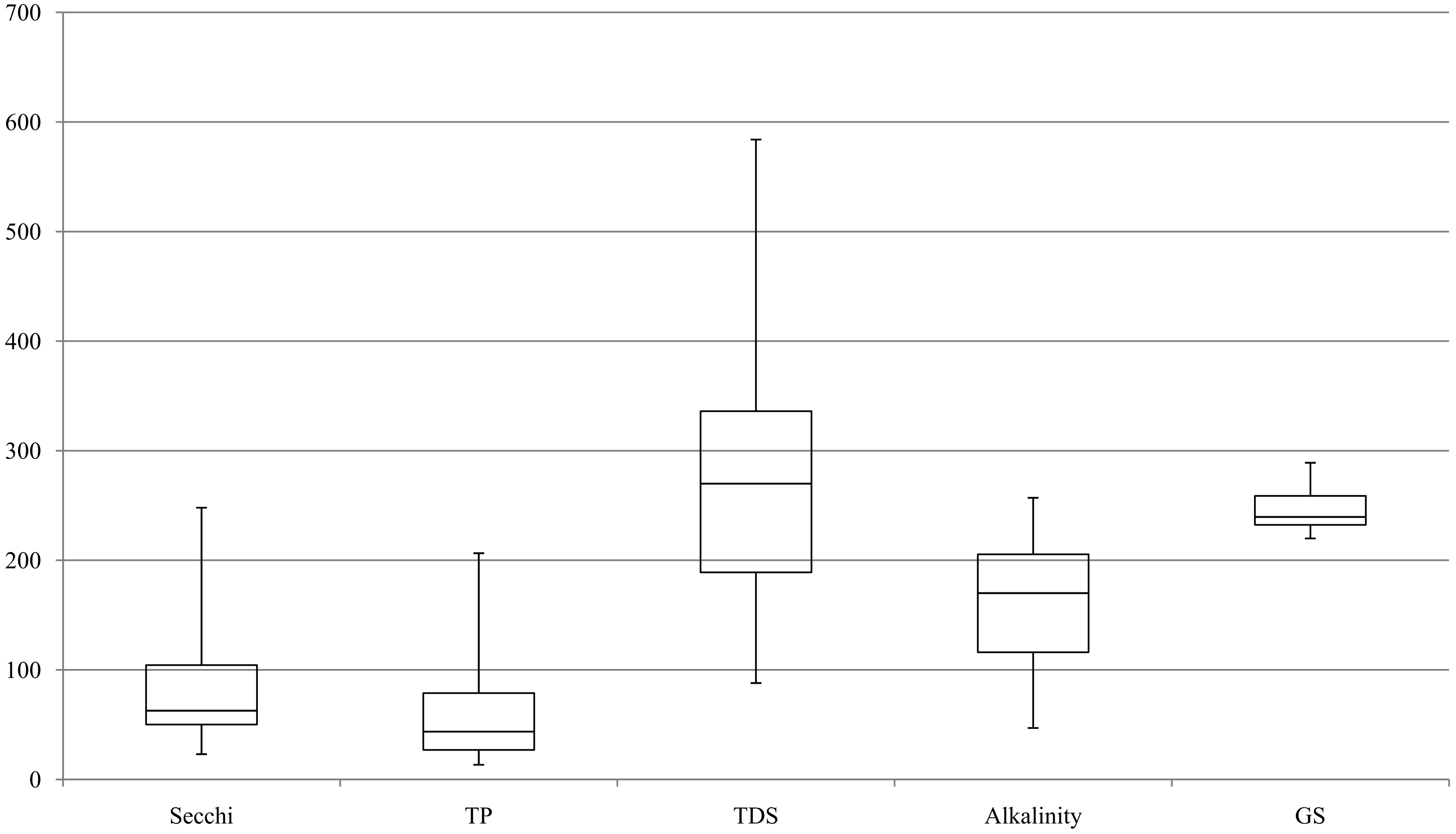
APPENDICES

APPENDIX A

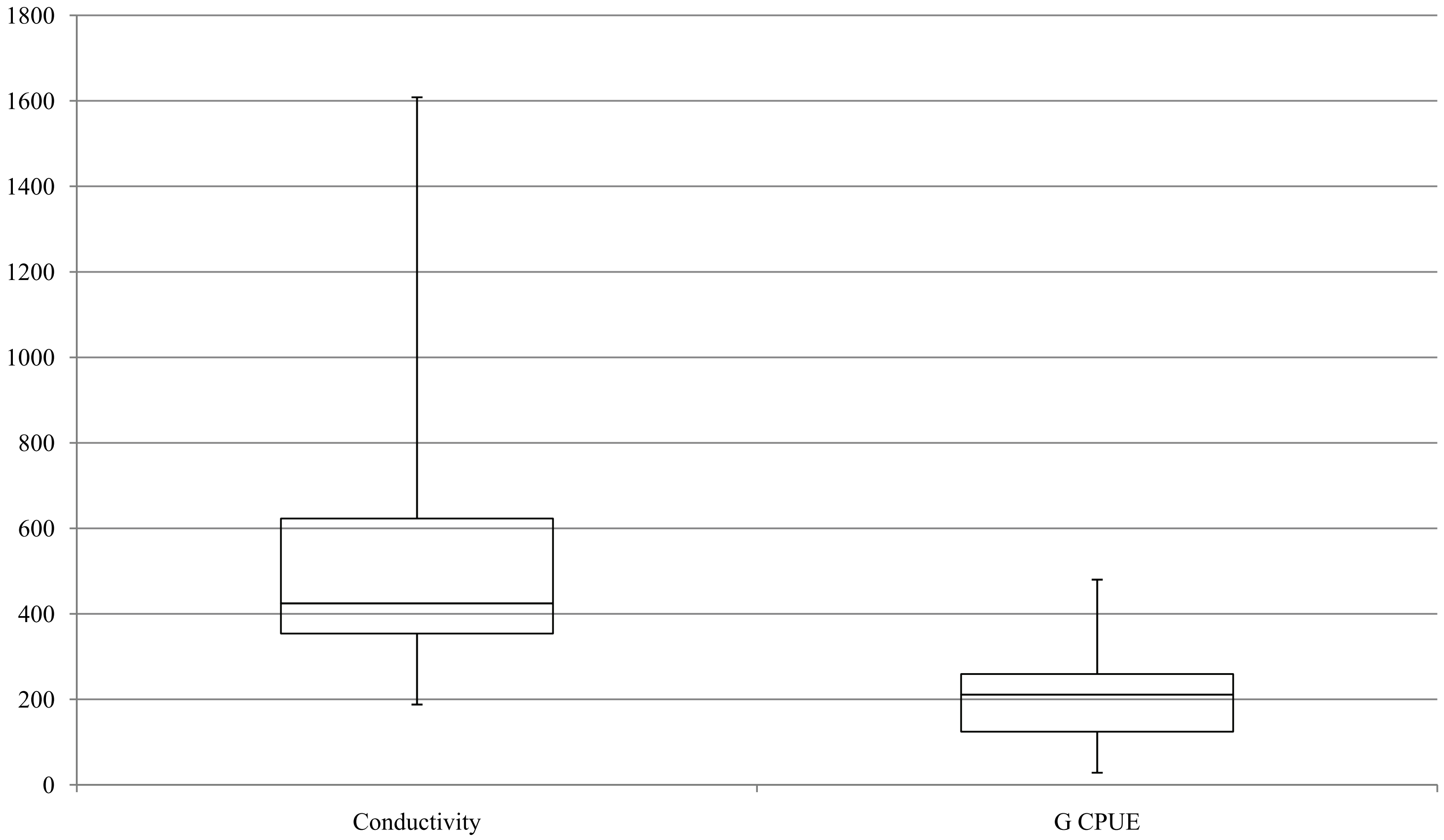
Boxplots for independent variables. This figure shows variables not included in Table 2 that were measured but did not show significant loadings in the analysis. Variables measured were water temperature (ºC; WT), Dissolved Oxygen (µg/L ; DO), ph, mean depth (m), structure (indice value), chlorophyll *a* (µg/L; Chl *a*), turbidity (NTU), maximum depth (m), Secchi (cm), total phosphorus (µg/L; TP), total dissolved solids (µg/L; TDS), alkalinity (mg $CaCO_3$/L), growing season (d; GS), conductivity (µS), mean electrofishing catch rates for gizzard shad (fish/hr; G CPUE), and surface area (km^2; SA). With the exception of historical catch rates for gizzard shad, all data were collected June-September 2008.



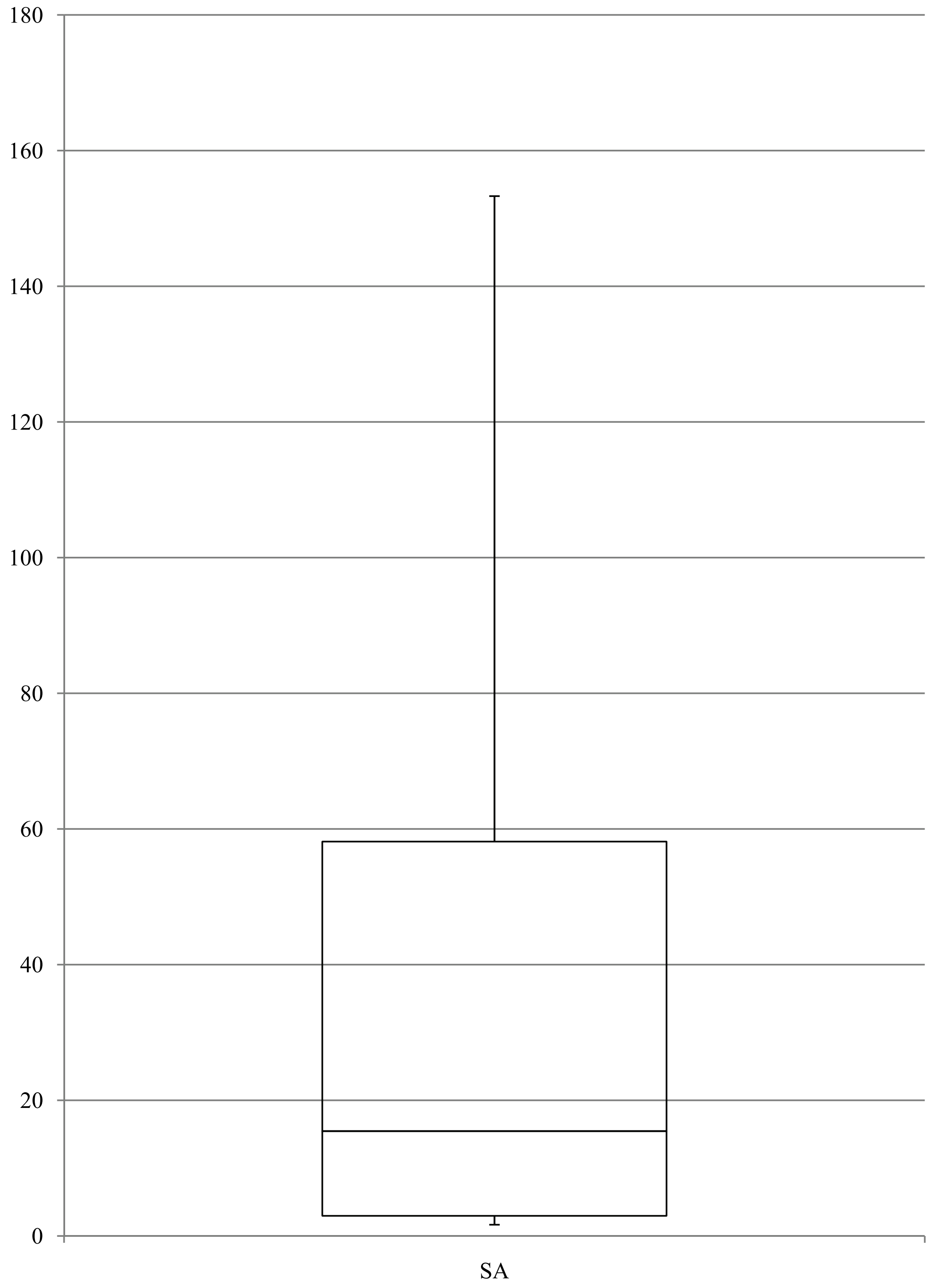
Appendix A–Continued.



Appendix A–Continued.



Appendix A–Continued.



APPENDIX B

Maps of sampling locations and numbers of fish captured at each location.

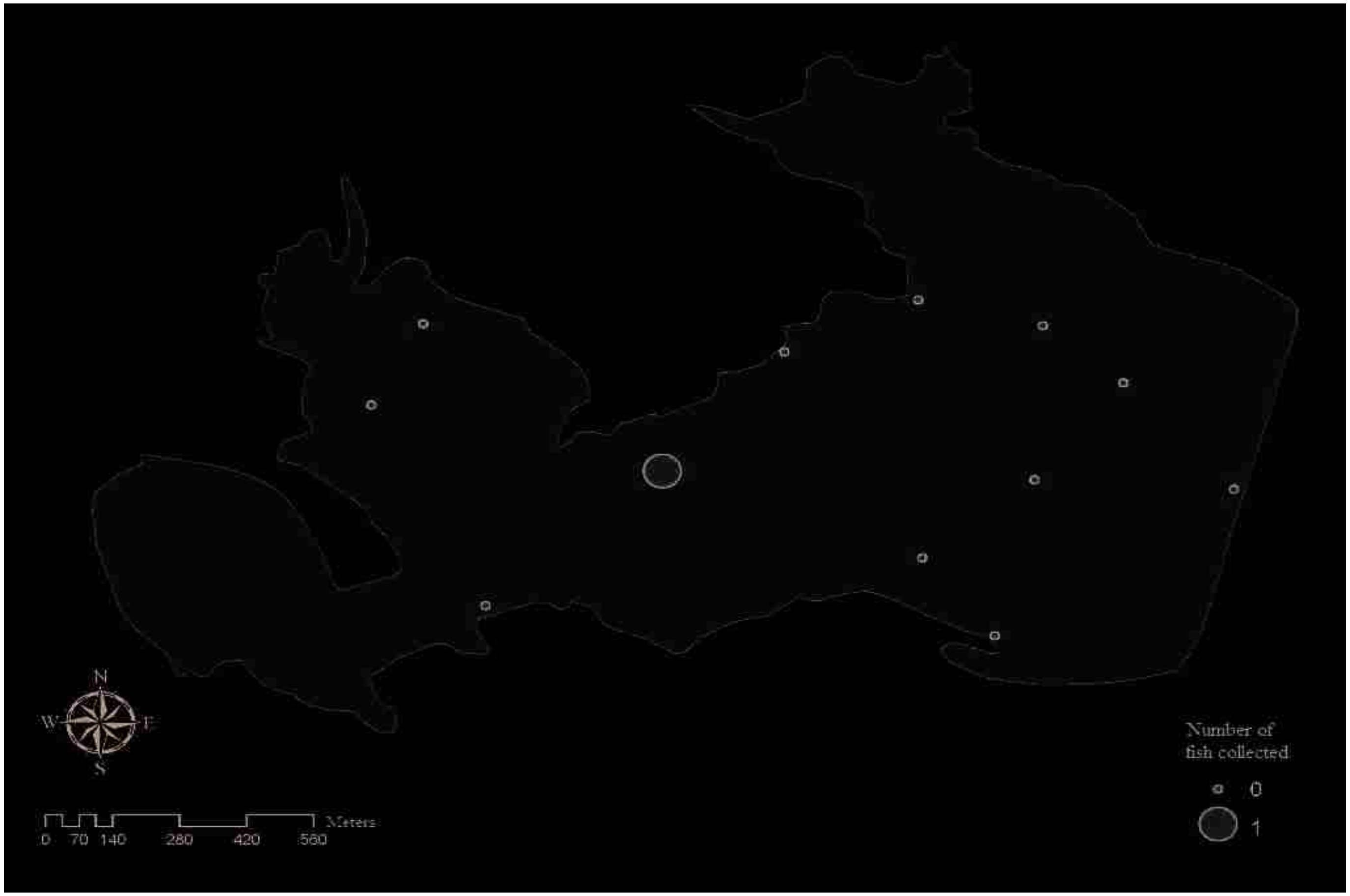


Figure B1.–Map of sampling locations and number of fish captured at each location for Abilene reservoir.

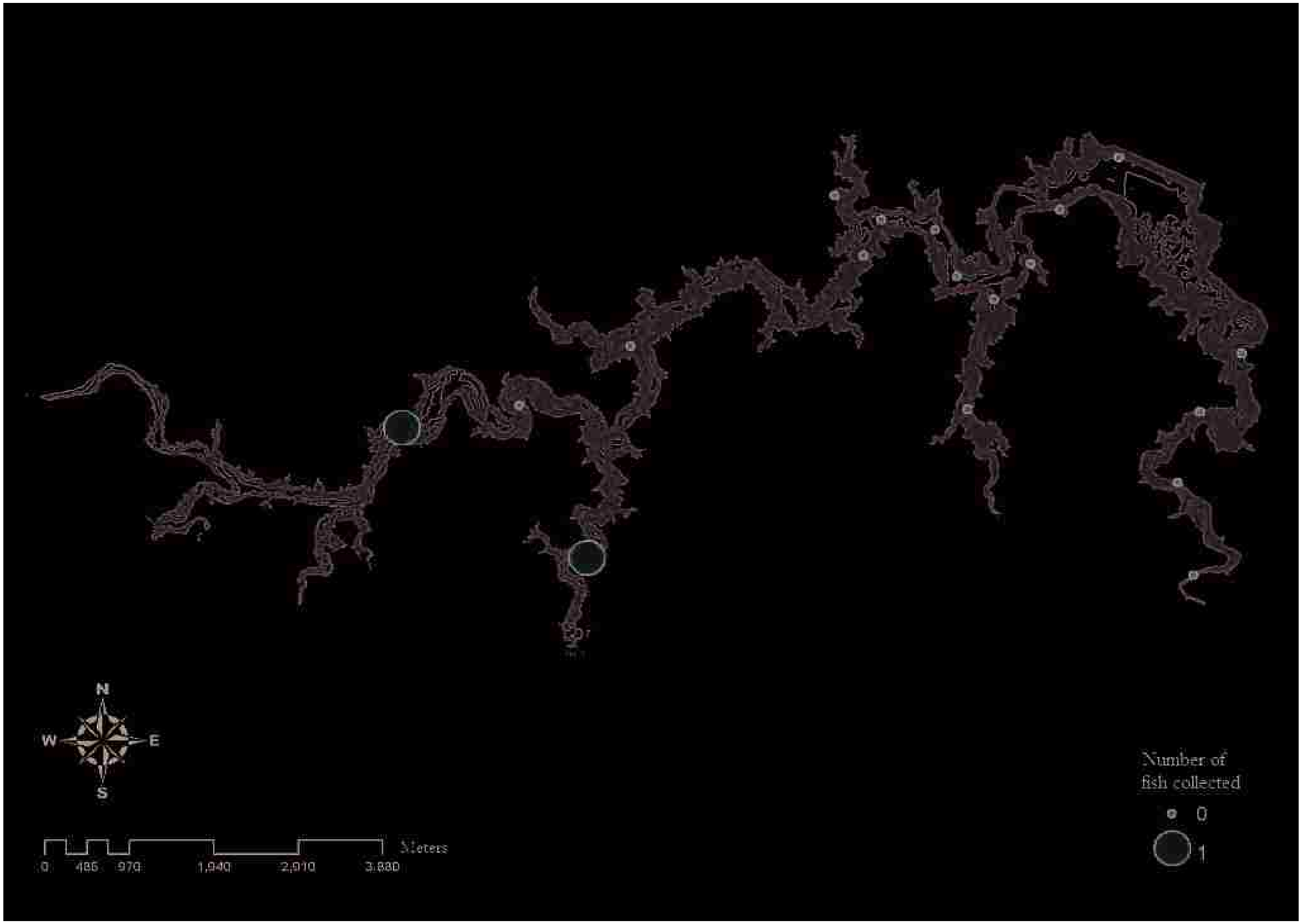


Figure B2.–Map of sampling locations and number of fish captured at each location for Alan Henry reservoir.

No fish were collected in this reservoir.

Figure B3.–Map of sampling locations and number of fish captured at each location for Alvarado Park reservoir.

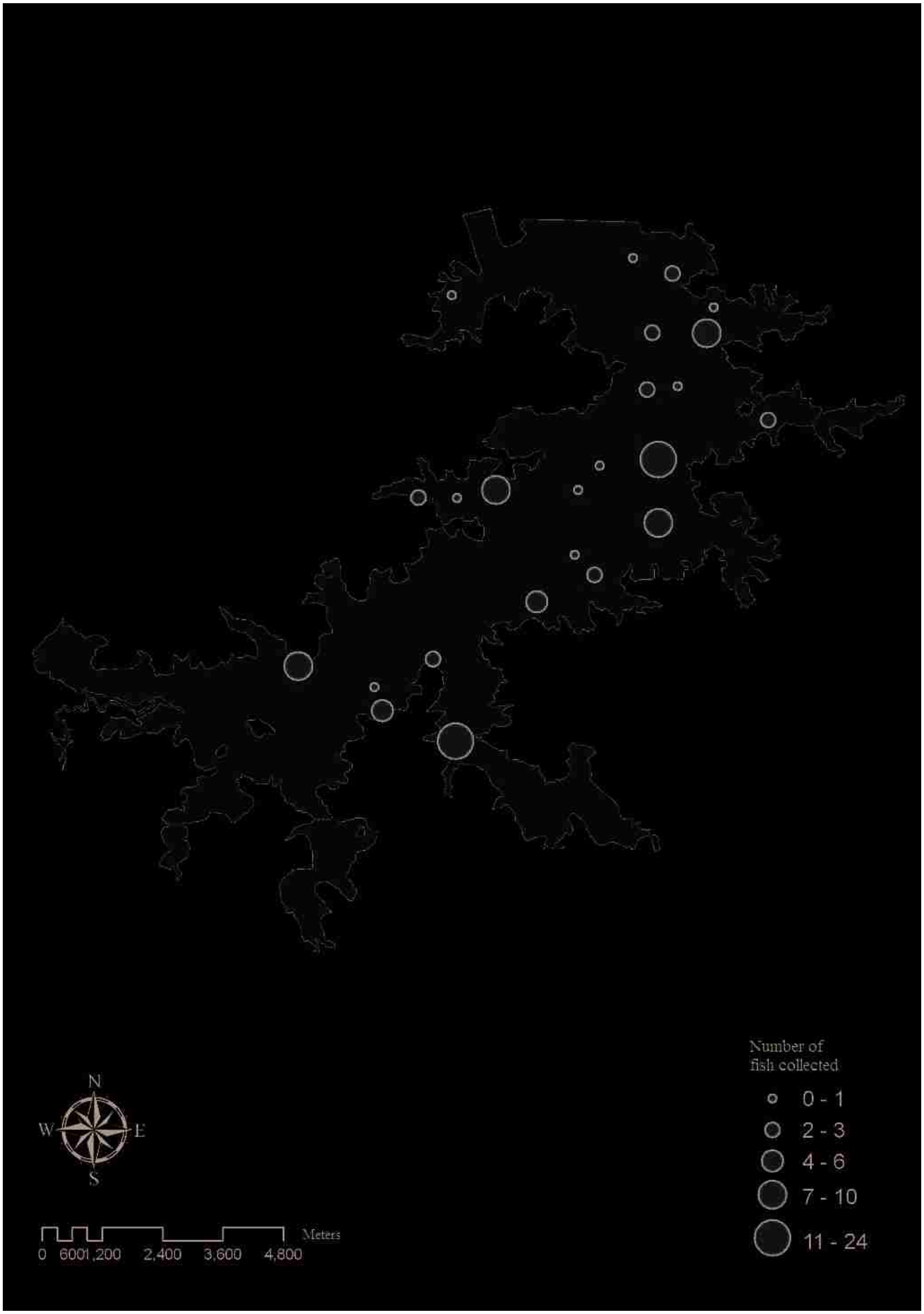


Figure B4.–Map of sampling locations and number of fish captured at each location for Arrowhead reservoir.

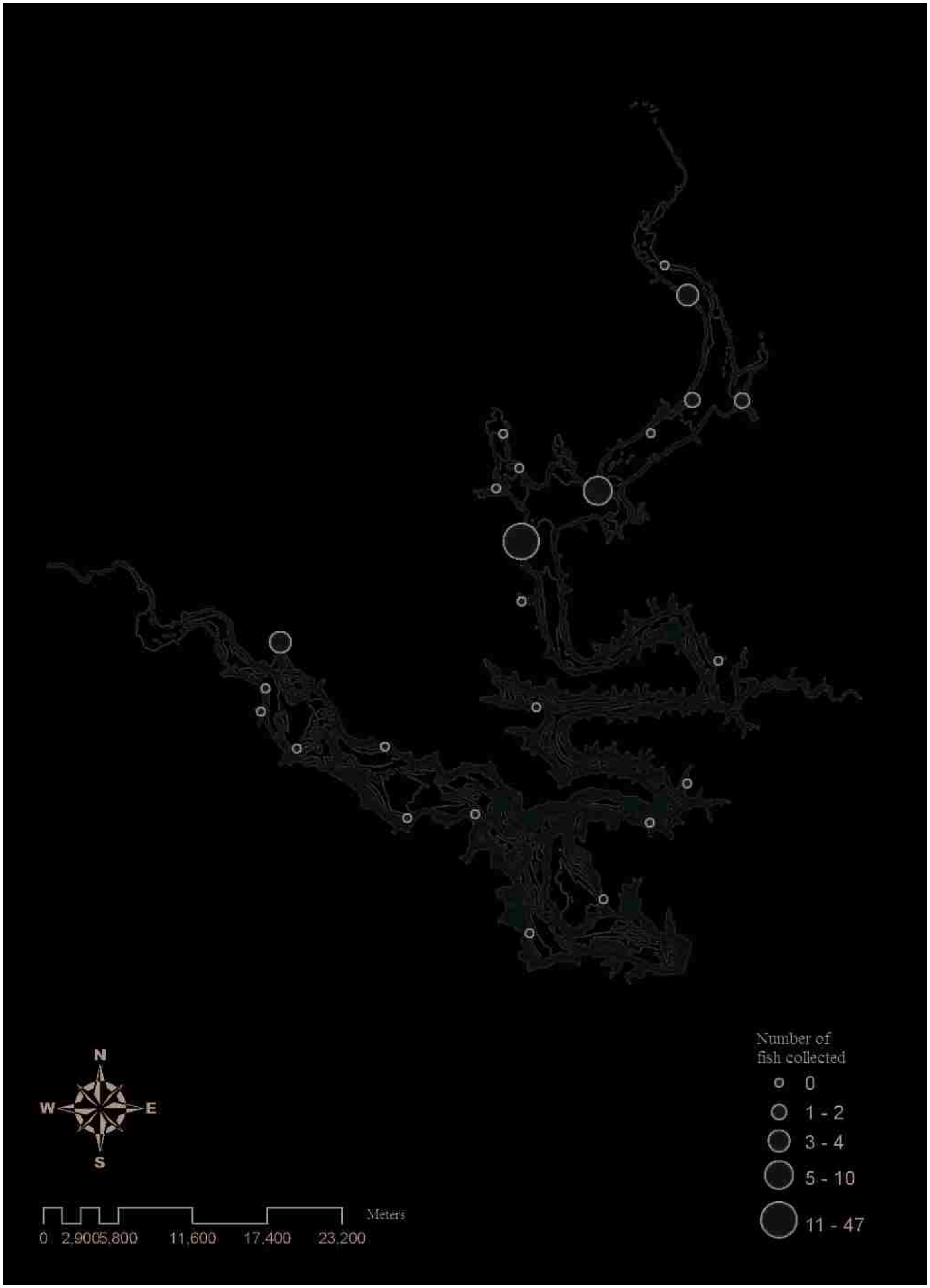


Figure B5.–Map of sampling locations and number of fish captured at each location for Belton reservoir.

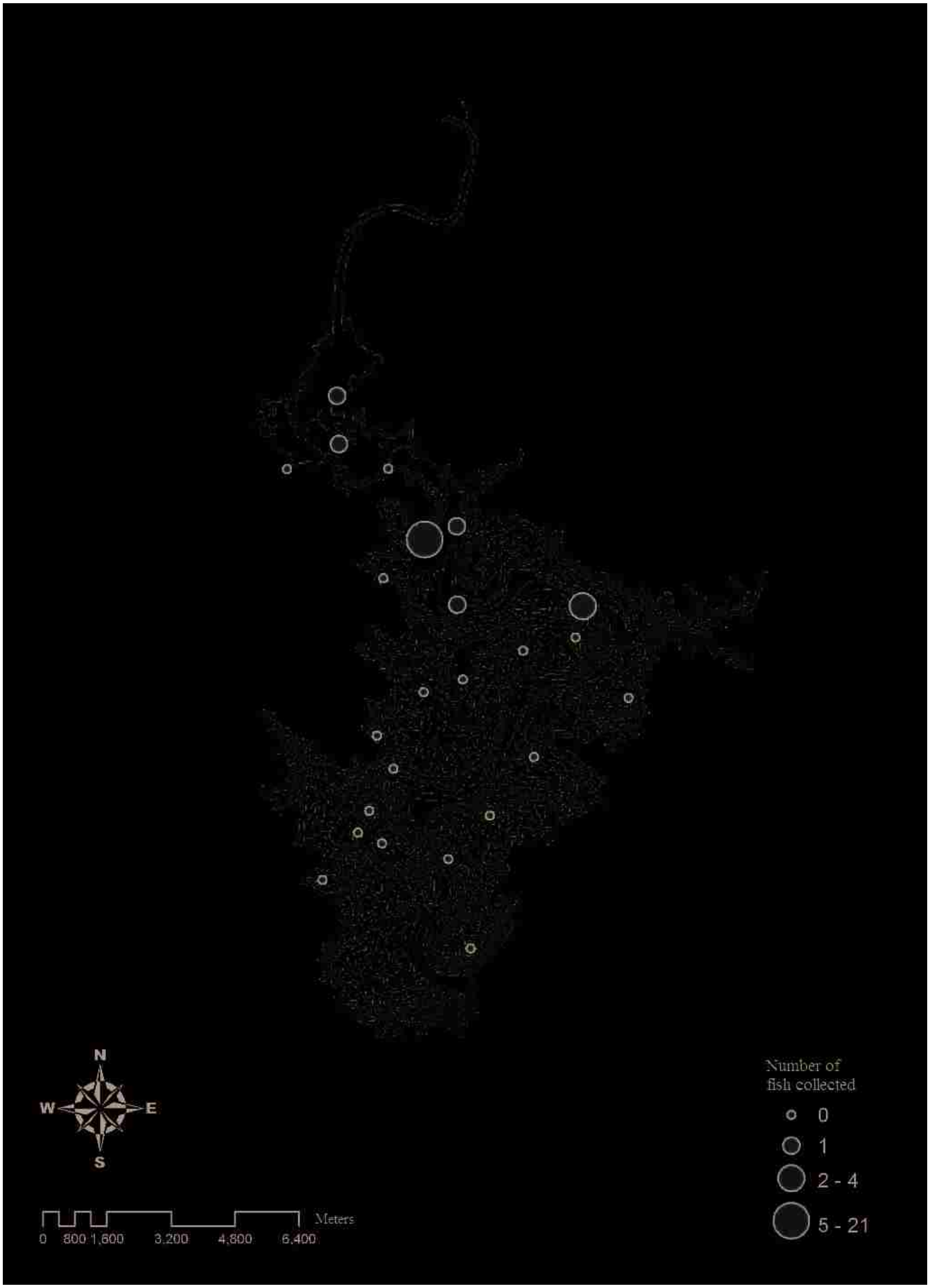
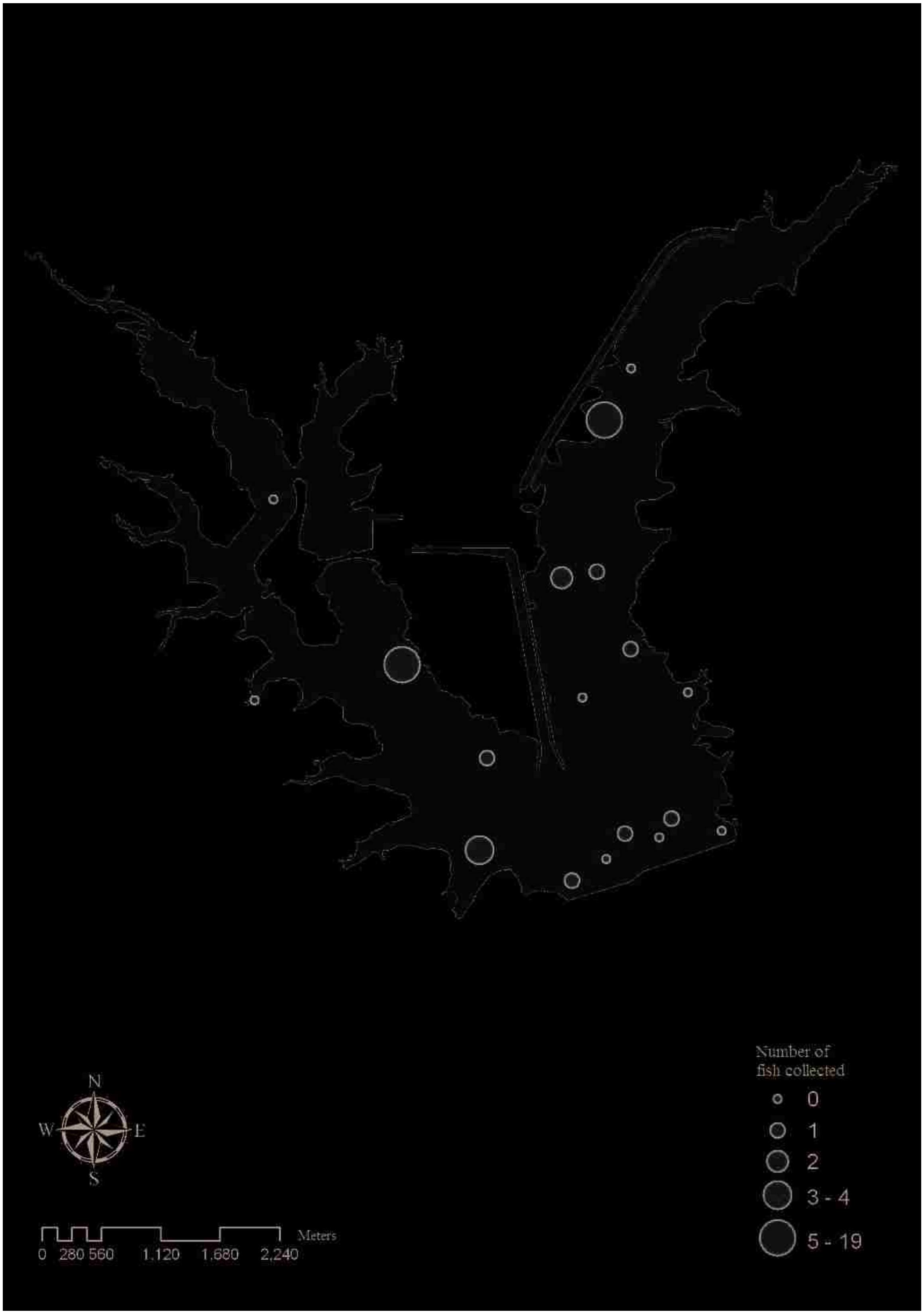


Figure B6.–Map of sampling locations and number of fish captured at each location for Buchanan reservoir.

Figure B7.–Map of sampling locations and number of fish captured at each location for Calaveras reservoir.



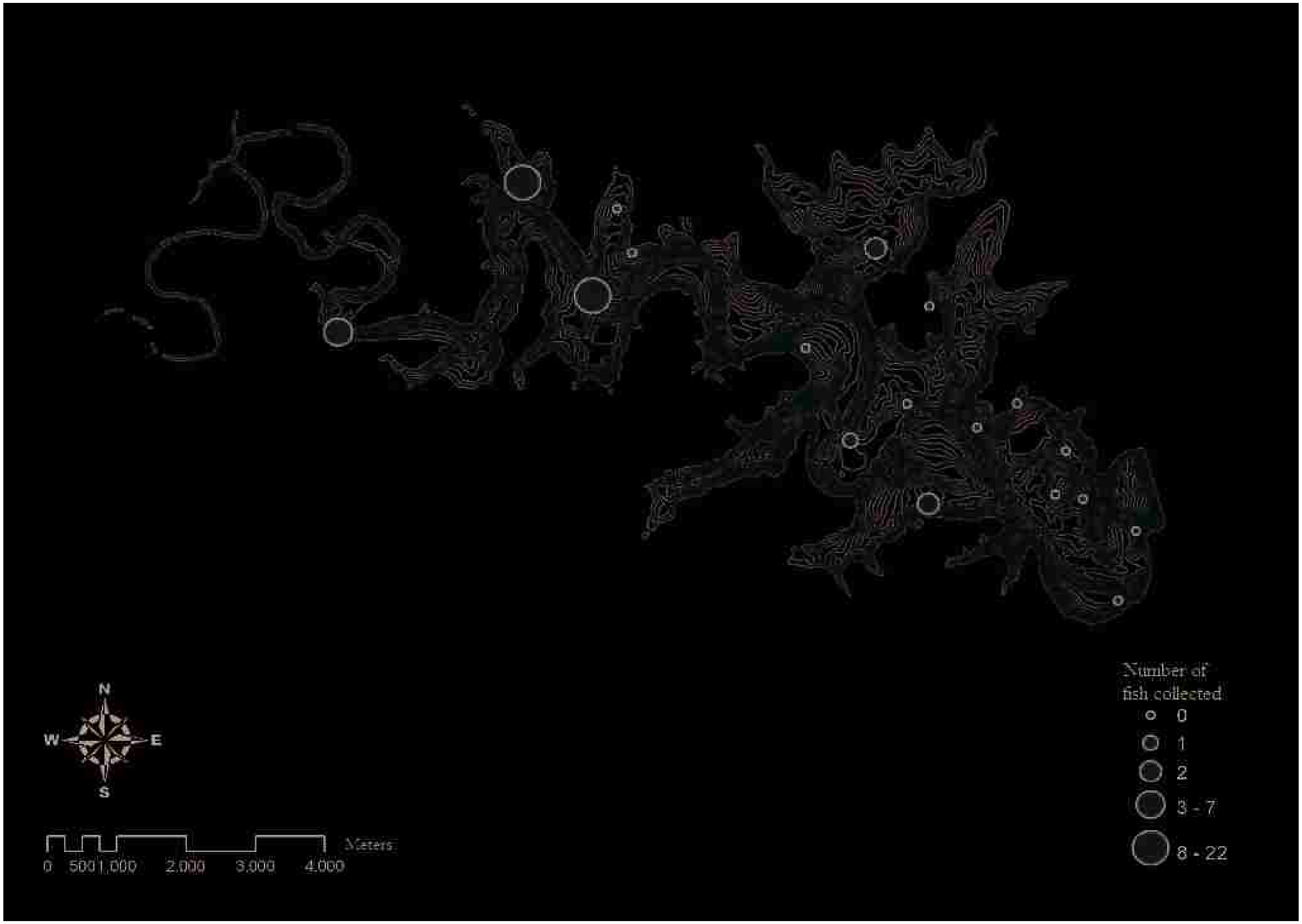


Figure B8.–Map of sampling locations and number of fish captured at each location for Canyon reservoir.

No fish were collected in this reservoir.

Figure B9.–Map of sampling locations and number of fish captured at each location for Clyde reservoir.

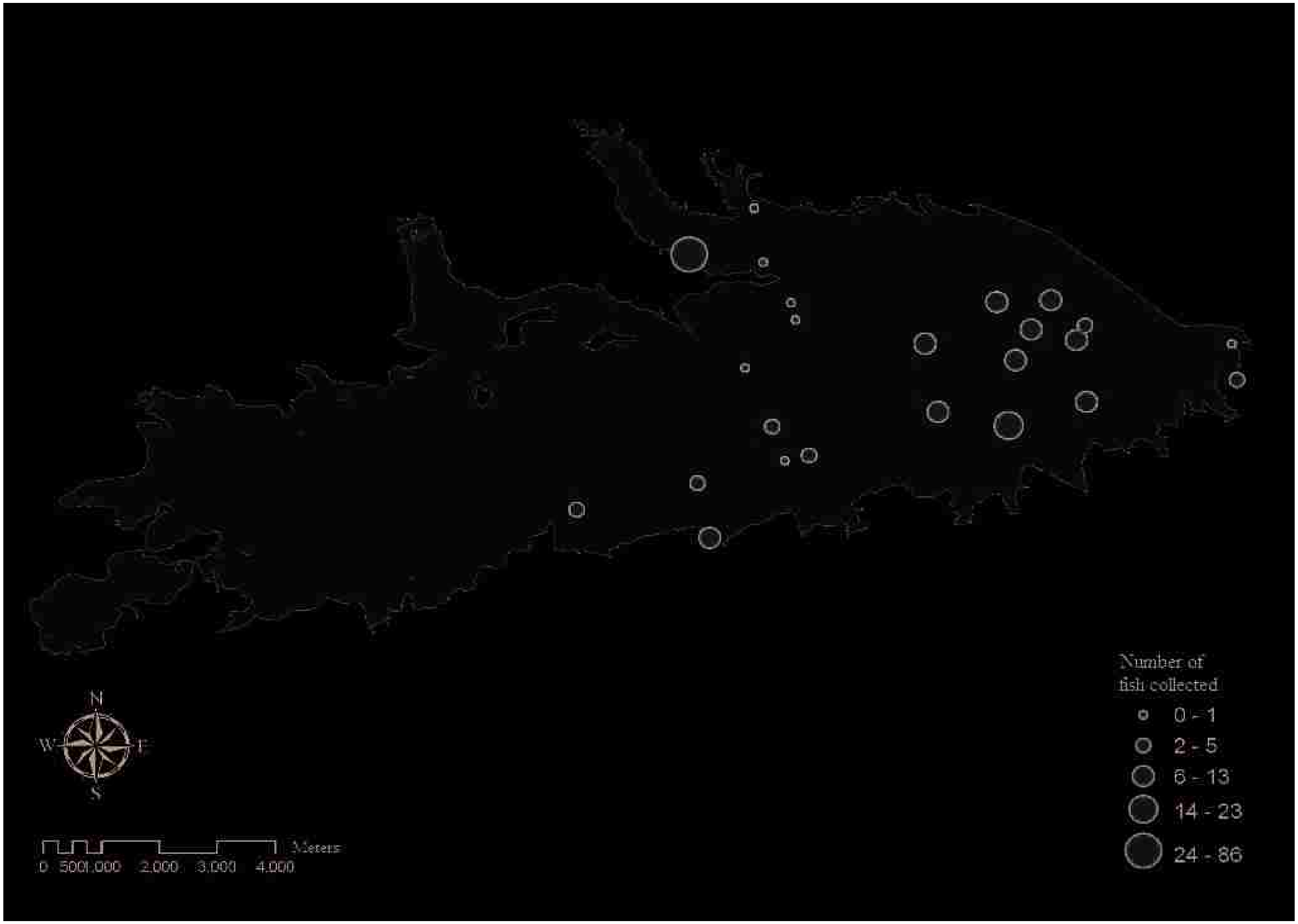


Figure B10.–Map of sampling locations and number of fish captured at each location for Cooper reservoir.

Figure B11.–Map of sampling locations and number of fish captured at each location for Corpus Christi reservoir.

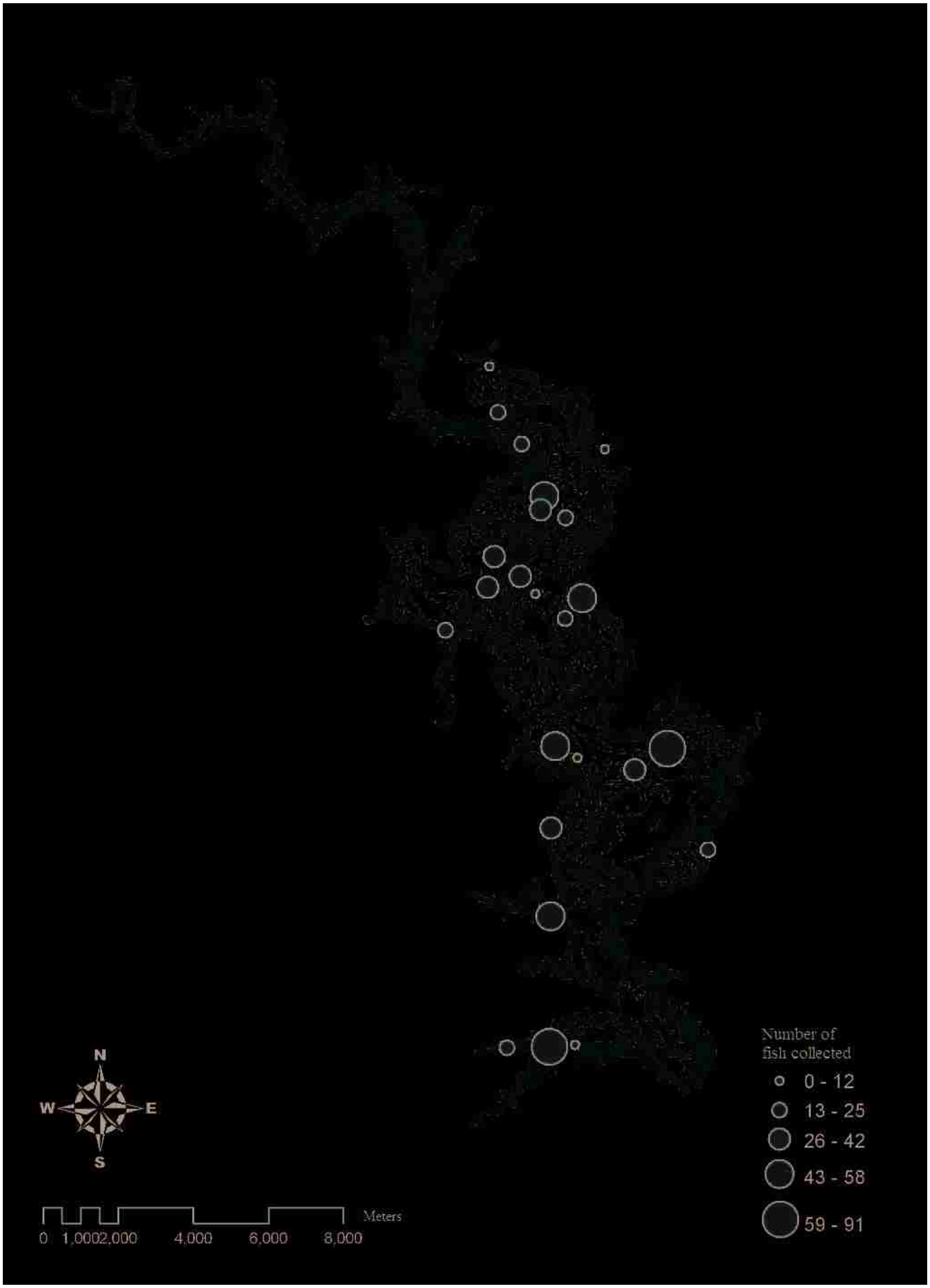


Figure B11.–Map of sampling locations and number of fish captured at each location for Corpus Christi reservoir.

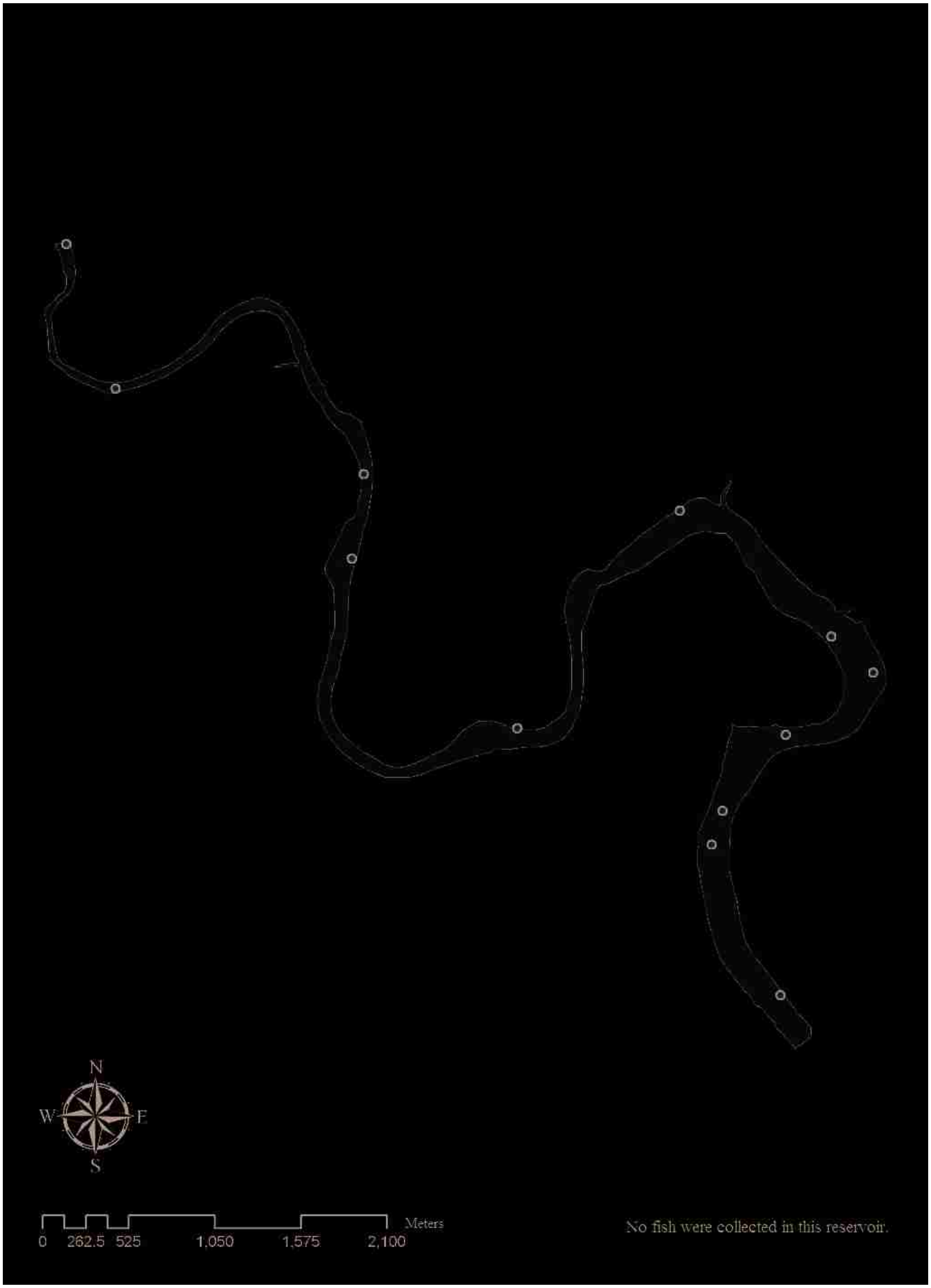


Figure B12.–Map of sampling locations and number of fish captured at each location for Dunlap reservoir.

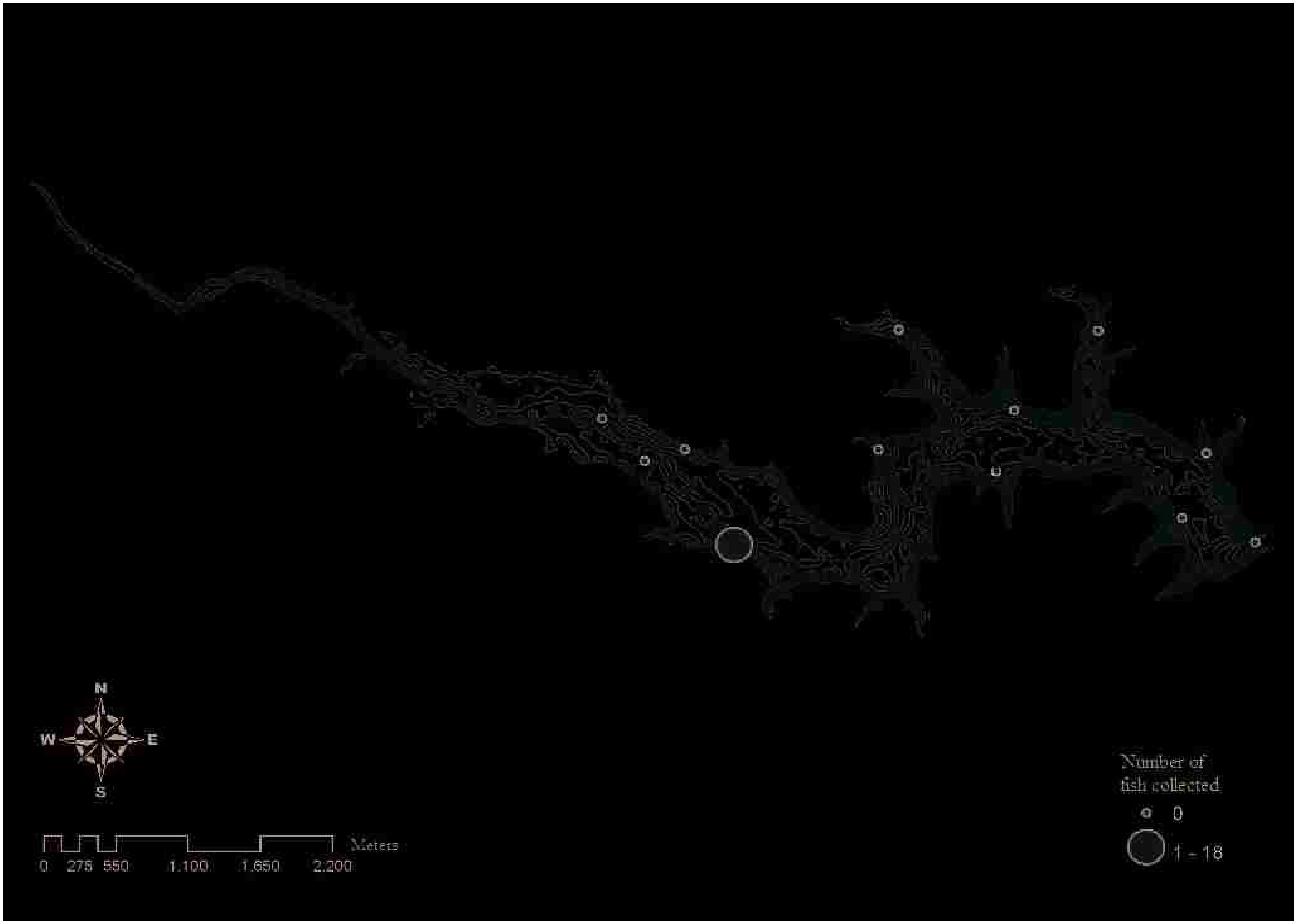


Figure B13.–Map of sampling locations and number of fish captured at each location for Georgetown reservoir.

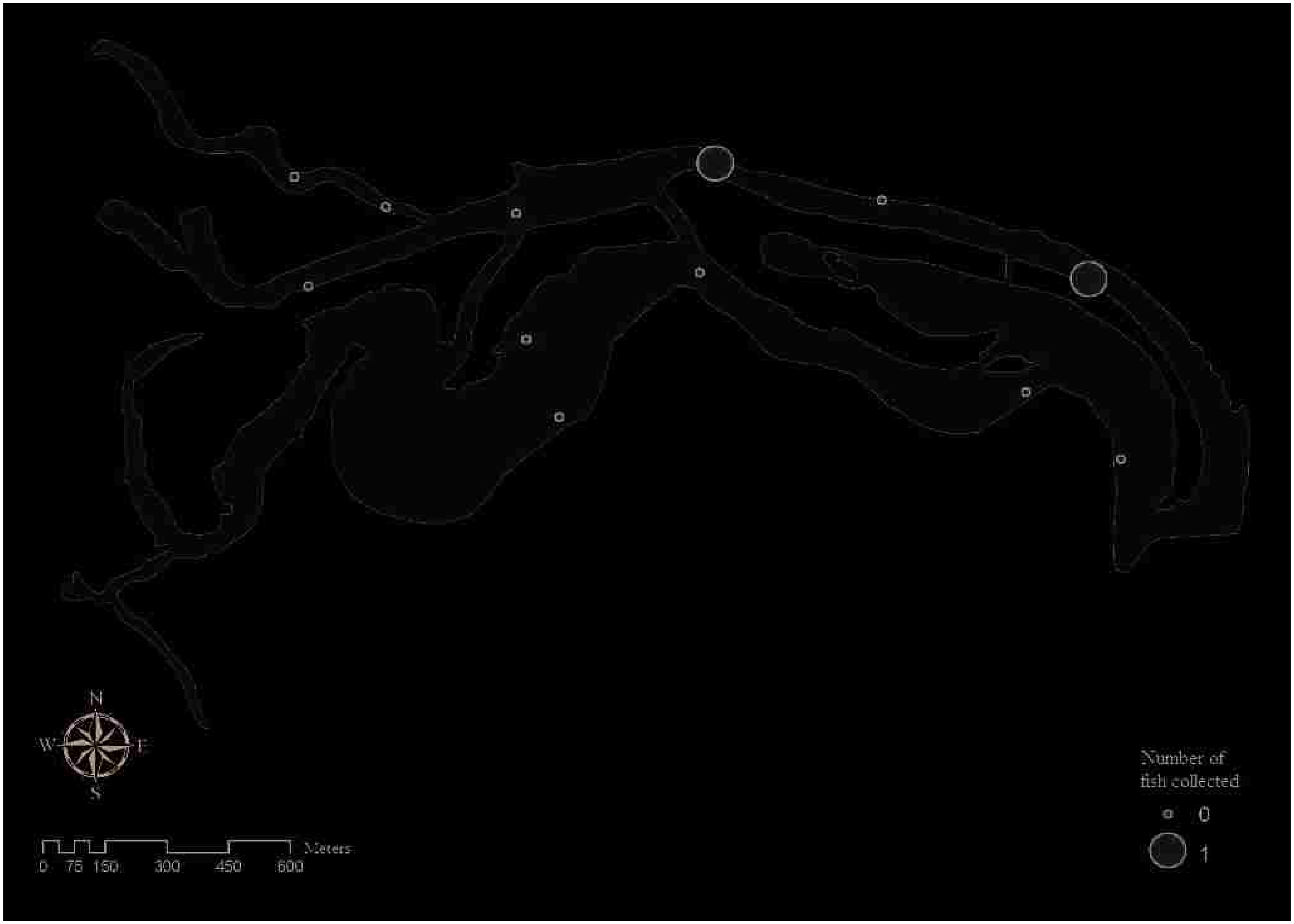


Figure B14.–Map of sampling locations and number of fish captured at each location for Gonzalez (H-4) reservoir.

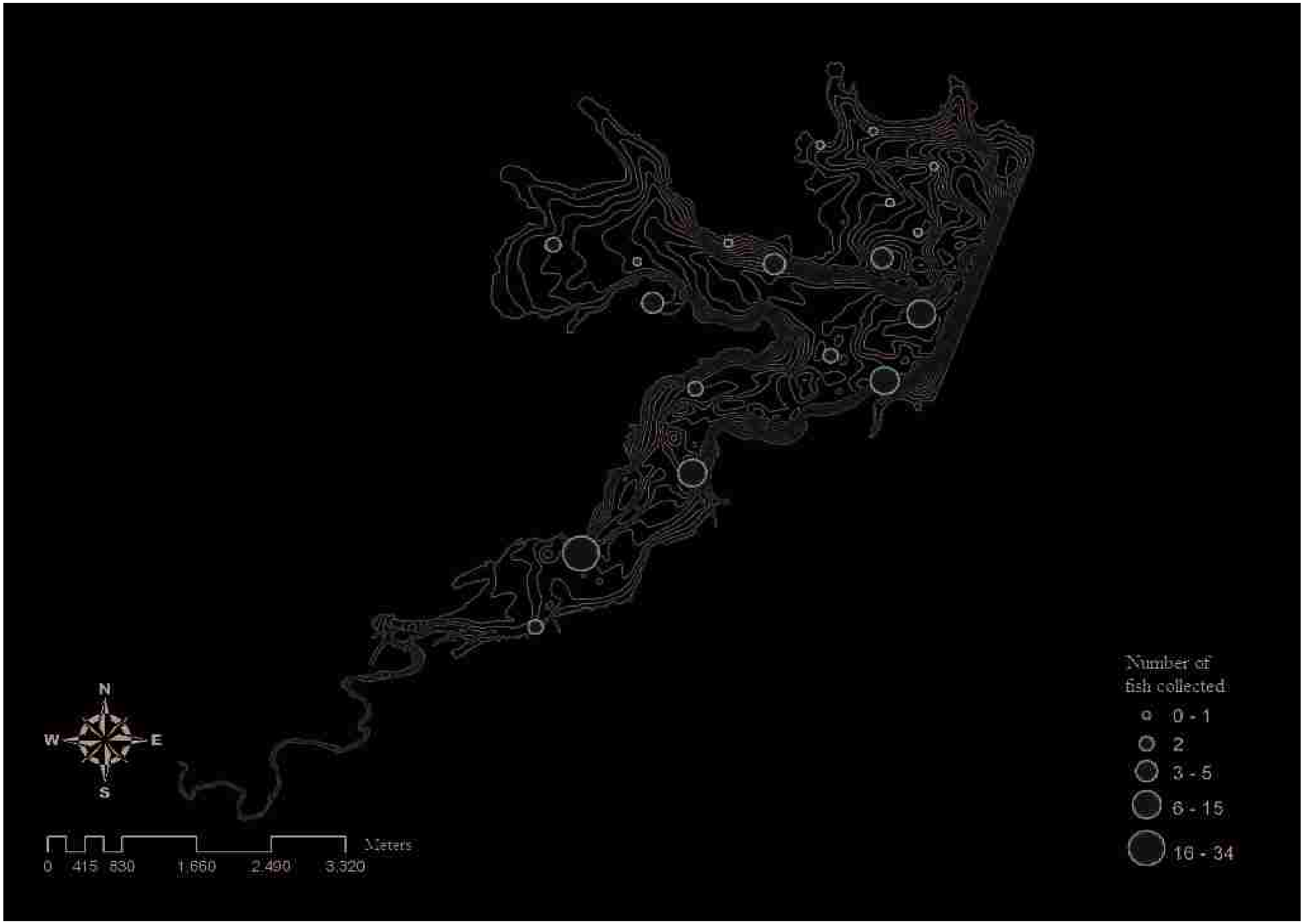


Figure B15.–Map of sampling locations and number of fish captured at each location for Granger reservoir.

Figure B16.–Map of sampling locations and number of fish captured at each location for Kirby reservoir.

No fish were collected at this reservoir.

Figure B17.–Map of sampling locations and number of fish captured at each location for Kurth reservoir.

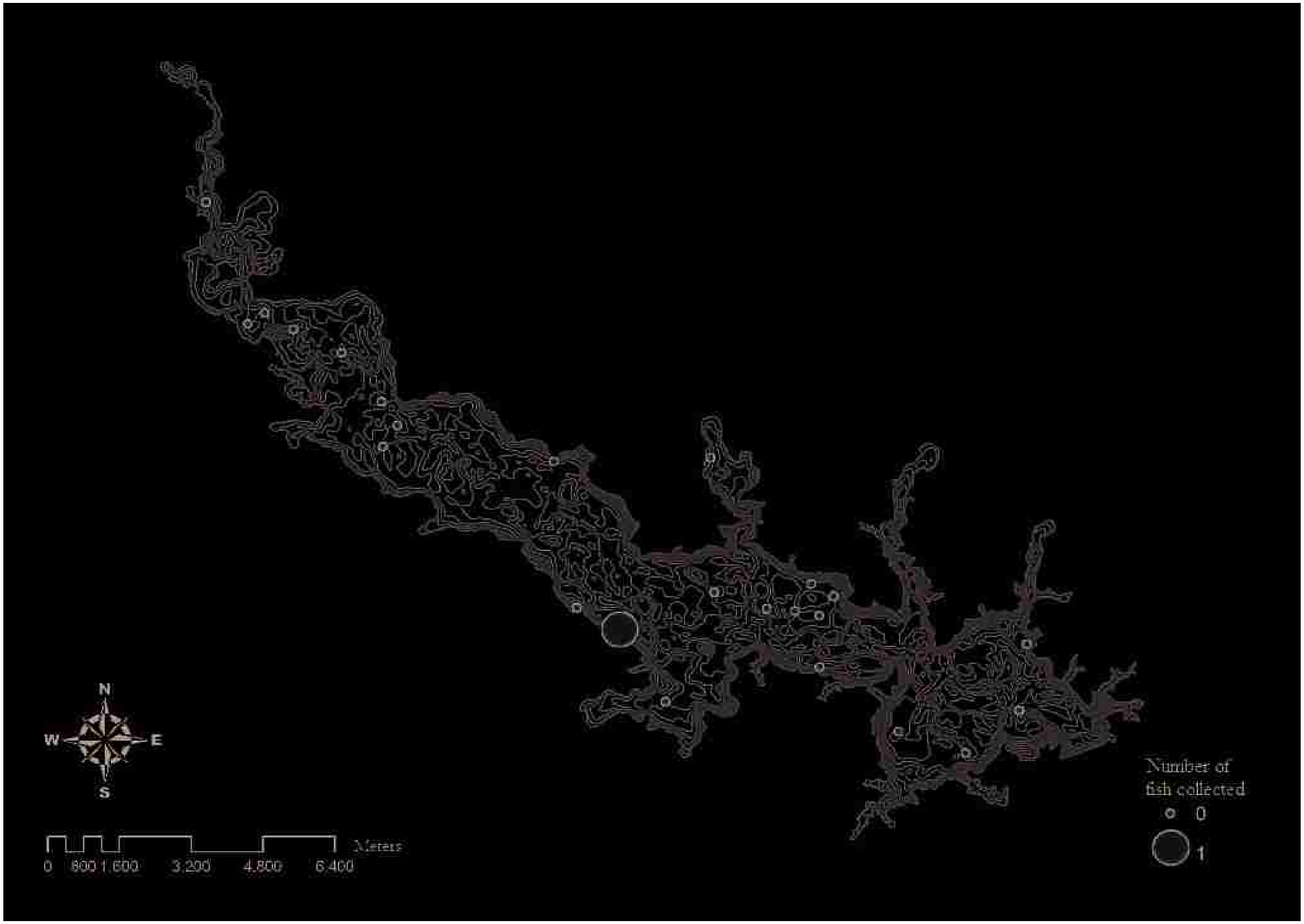


Figure B18.–Map of sampling locations and number of fish captured at each location for Lake O’ the Pines reservoir.

Figure B19.–Map of sampling locations and number of fish captured at each location for Lavon reservoir.

Figure B20.–Map of sampling locations and number of fish captured at each location for Limestone reservoir.

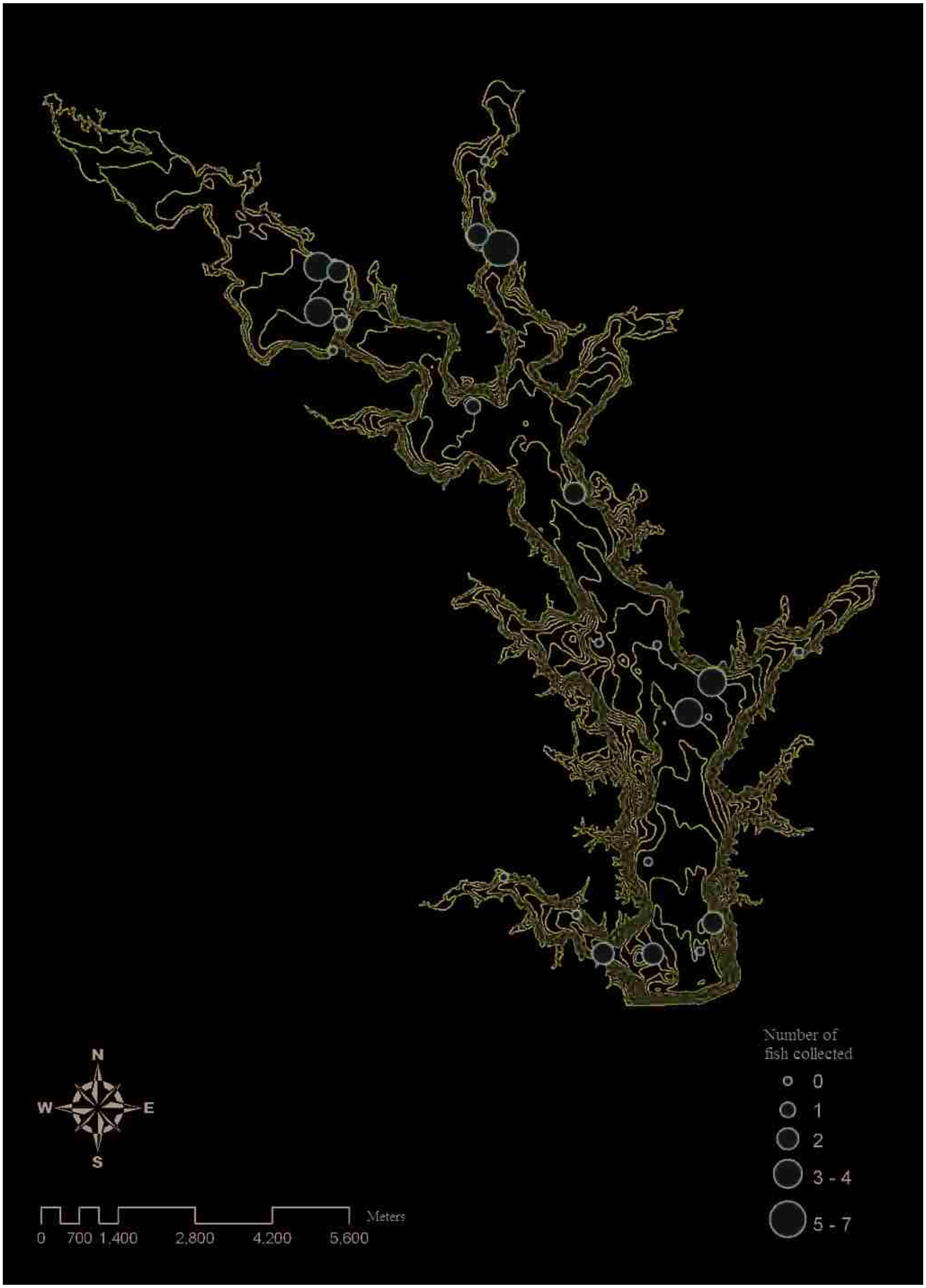


Figure B20.–Map of sampling locations and number of fish captured at each location for Limestone reservoir.

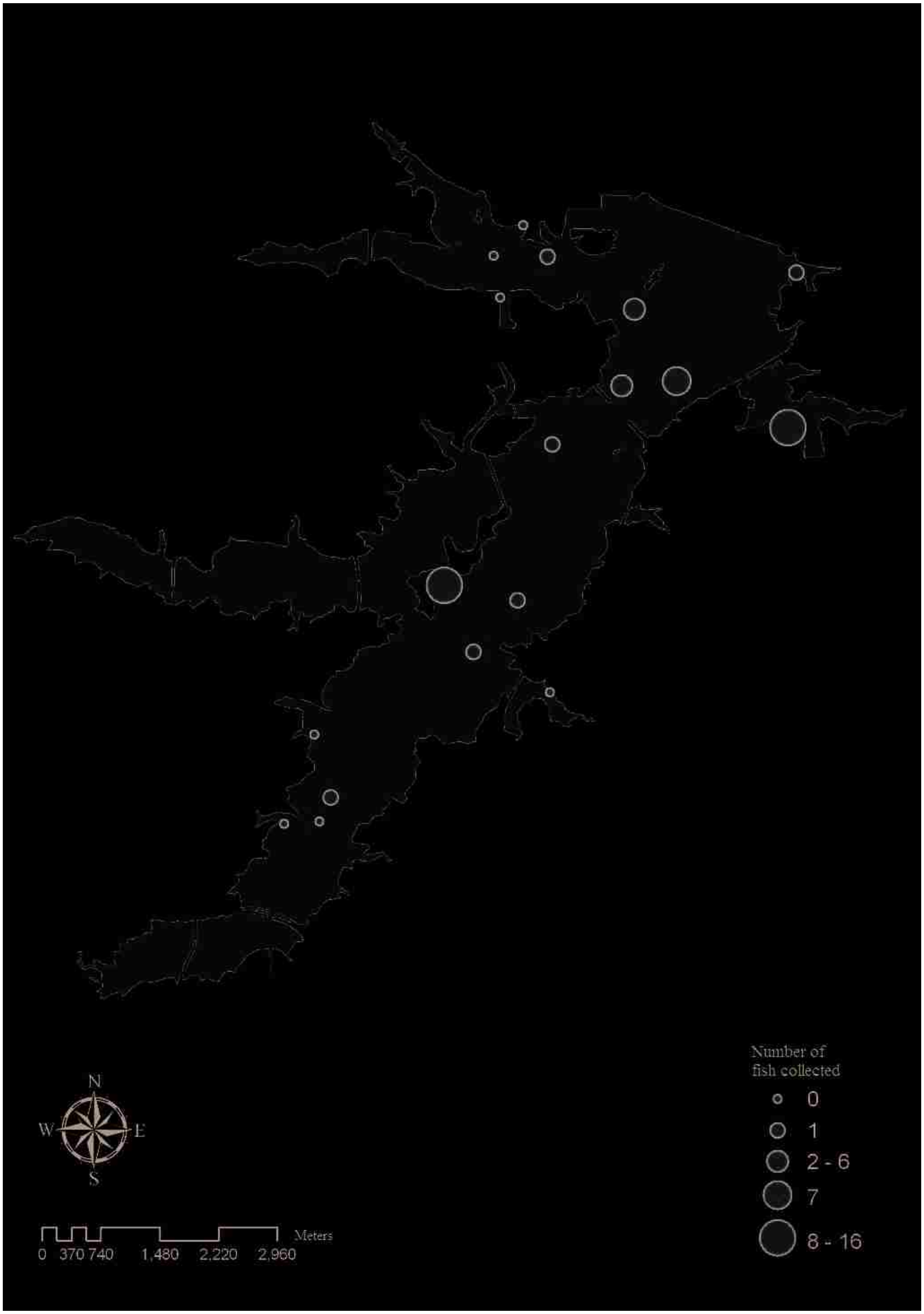
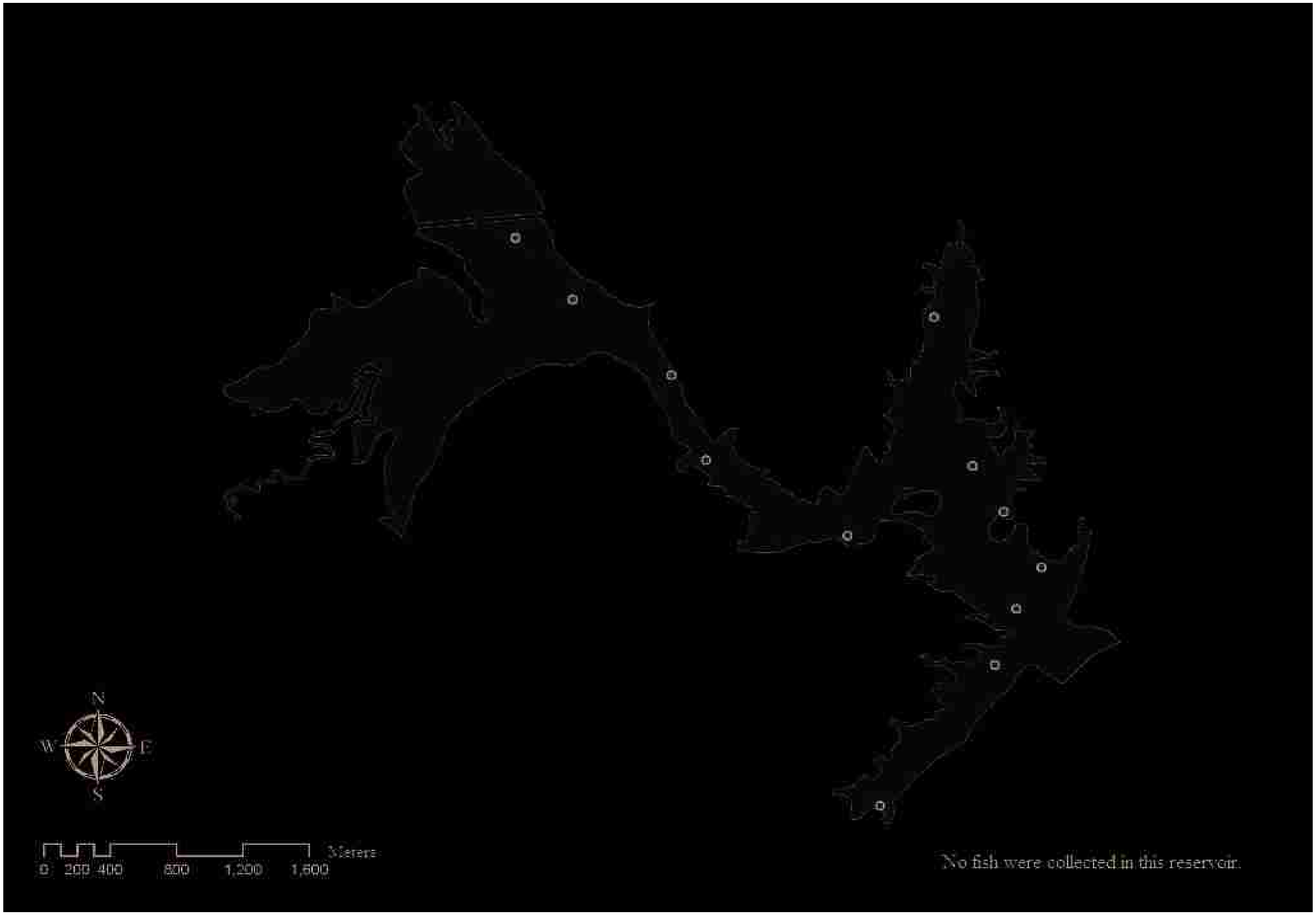


Figure B21.–Map of sampling locations and number of fish captured at each location for Martin Creek reservoir.



No fish were collected in this reservoir.

Figure B22.–Map of sampling locations and number of fish captured at each location for Mexia reservoir.

Figure B23.–Map of sampling locations and number of fish captured at each location for New Ballinger reservoir.

Figure B24.–Map of sampling locations and number of fish captured at each location for O.C. Fisher reservoir.

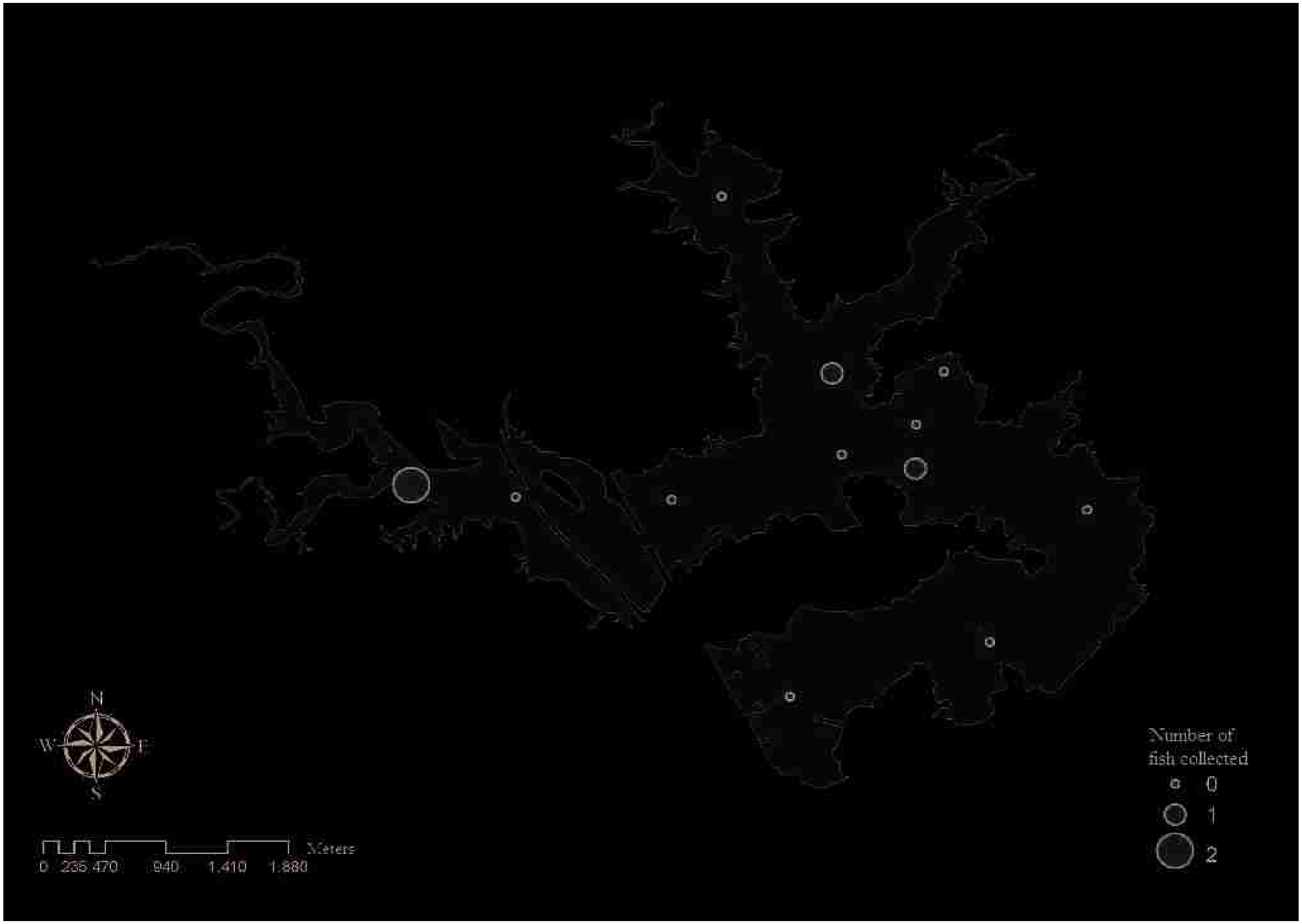


Figure B25.–Map of sampling locations and number of fish captured at each location for Oak Creek reservoir.

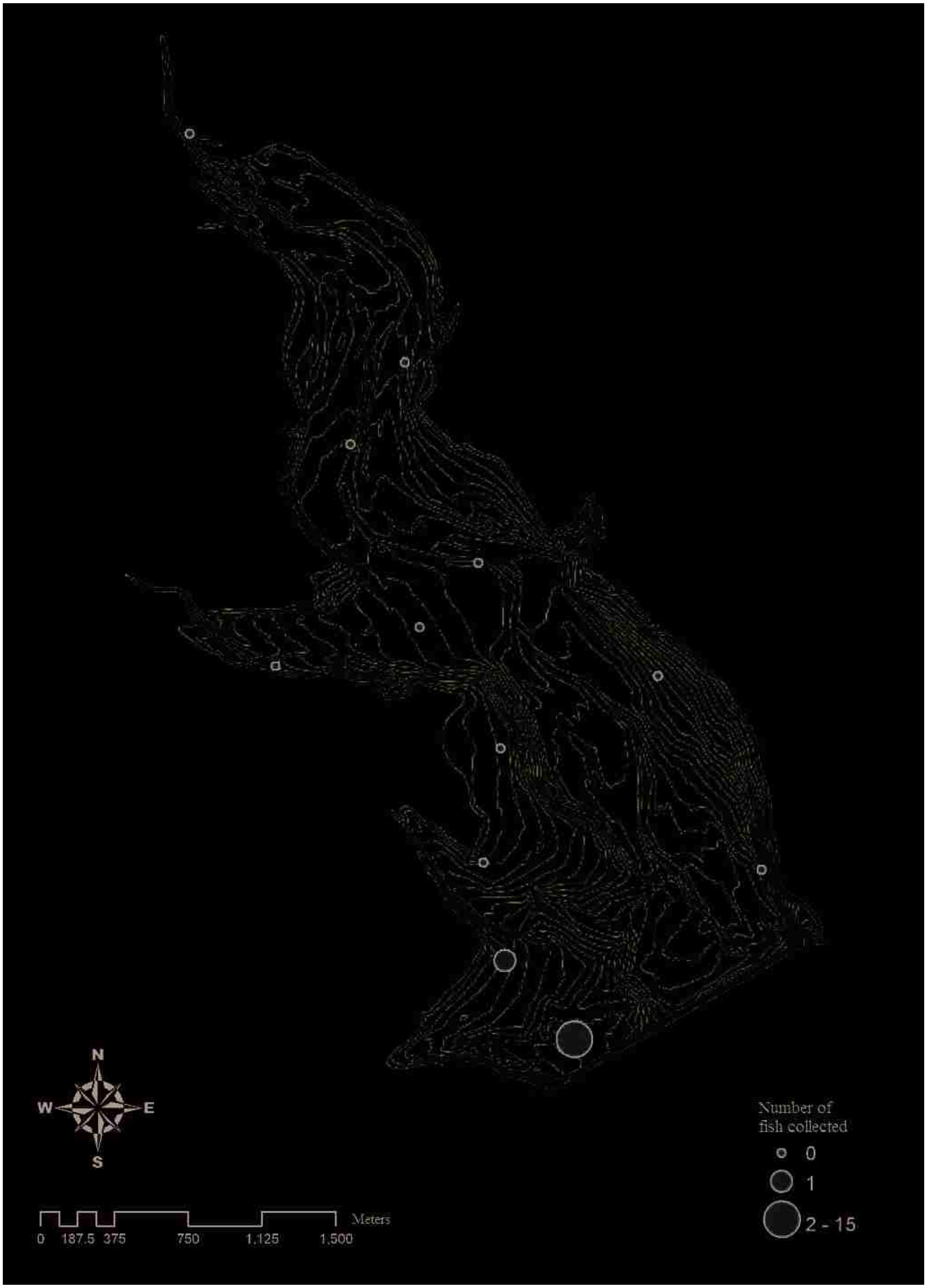


Figure B26.–Map of sampling locations and number of fish captured at each location for Pat Cleburne reservoir.

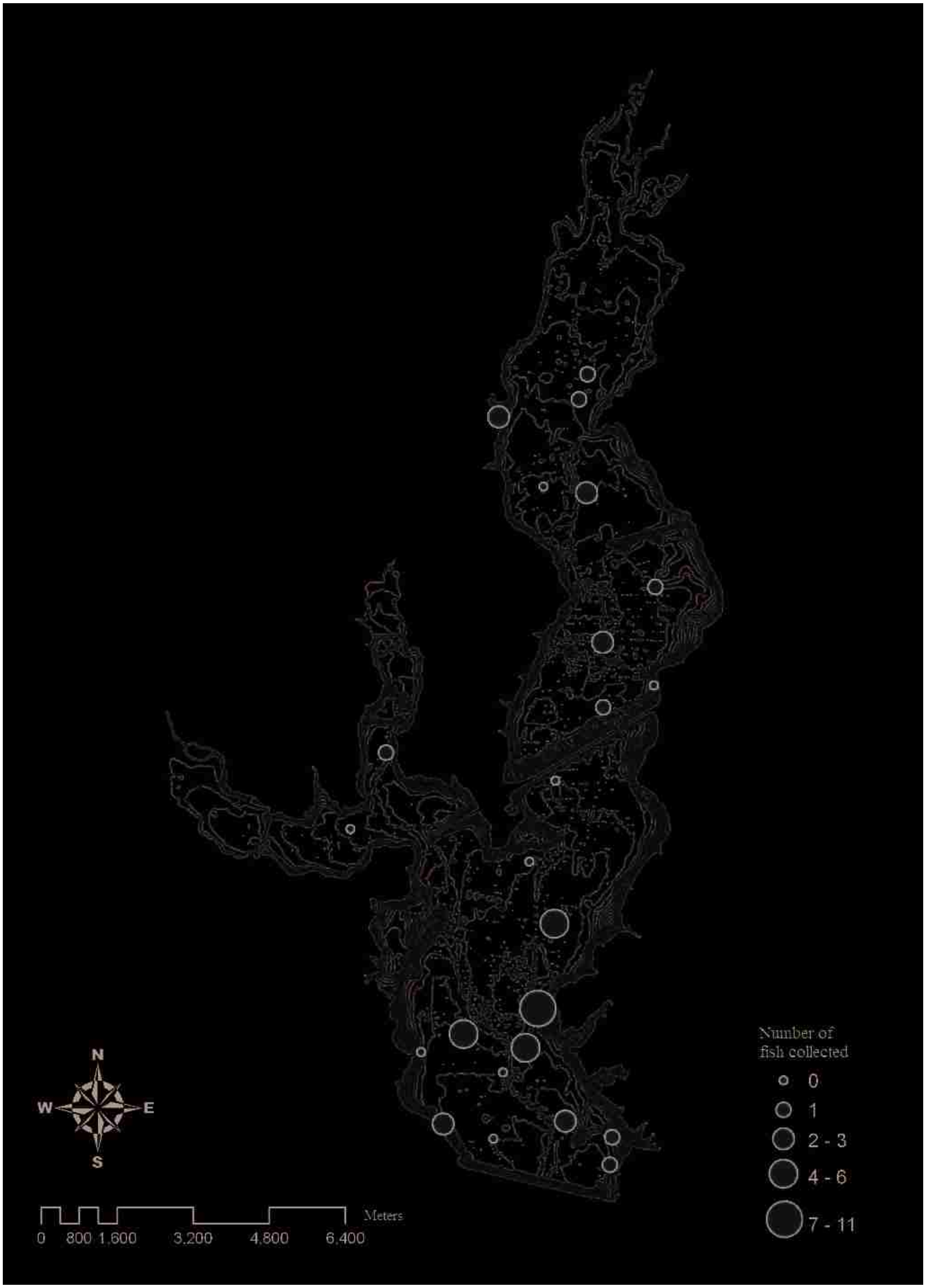


Figure B27.–Map of sampling locations and number of fish captured at each location for Ray Hubbard reservoir.

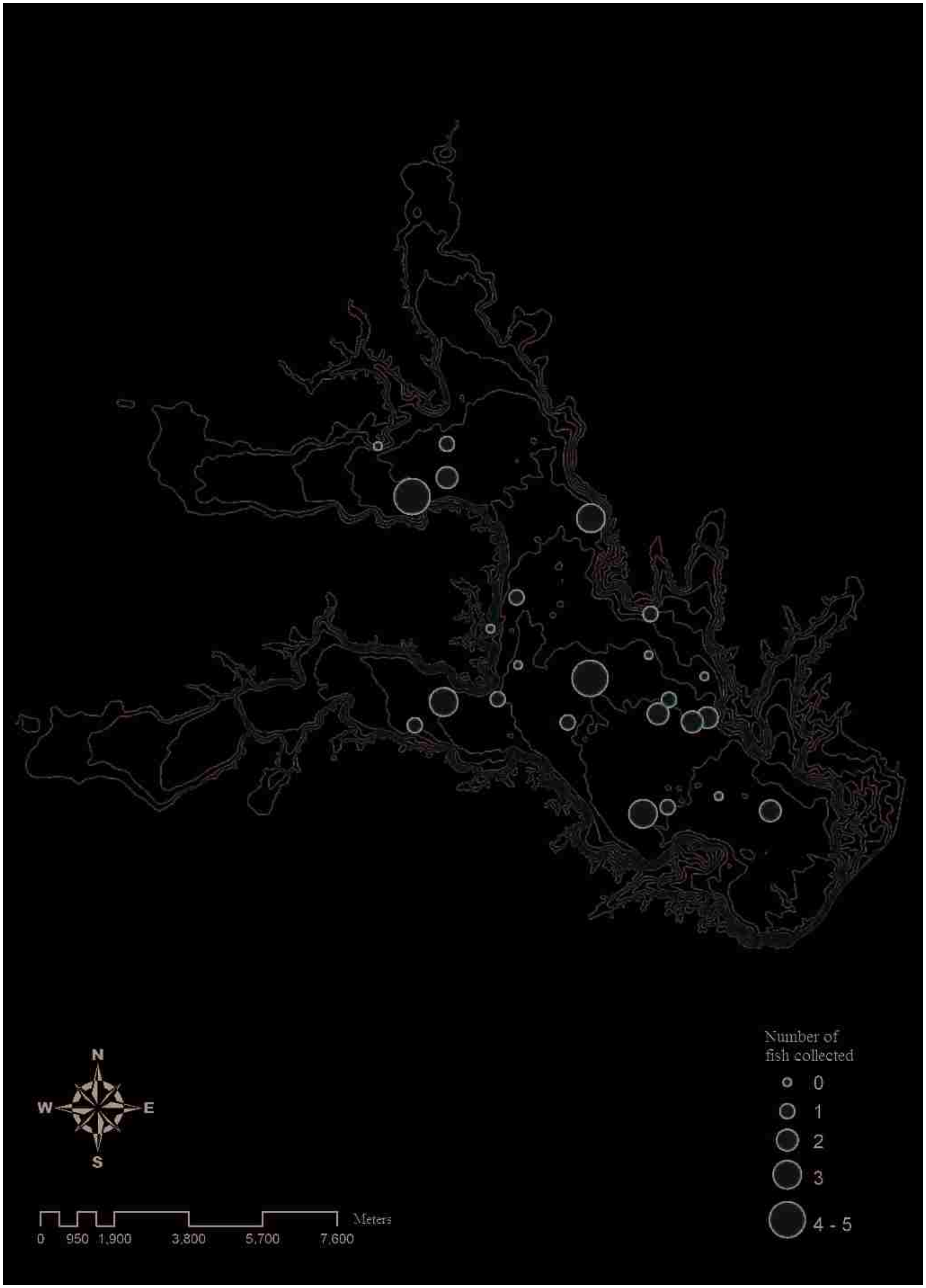
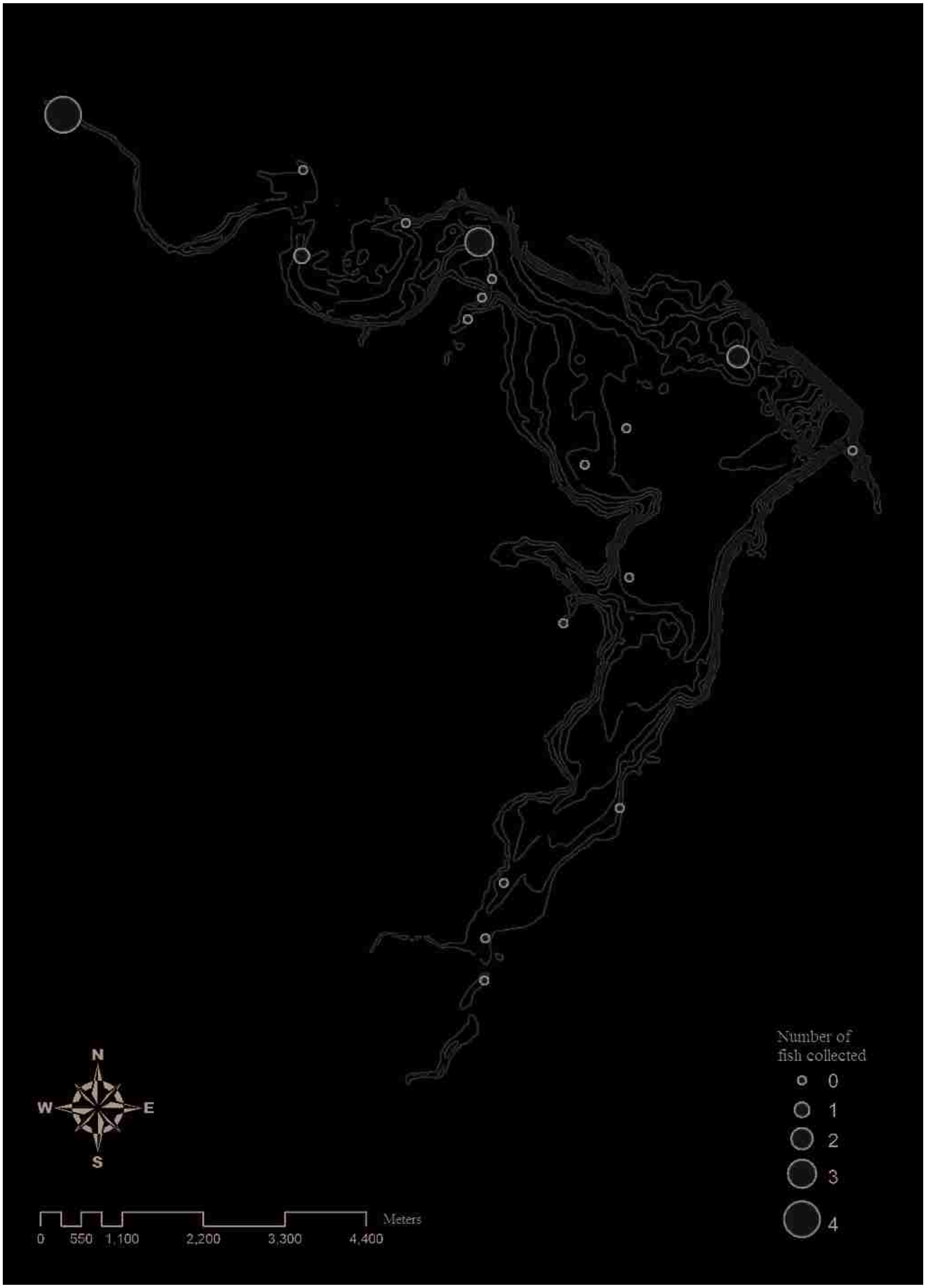


Figure B28.–Map of sampling locations and number of fish captured at each location for Tawakoni reservoir.

Figure B29.–Map of sampling locations and number of fish captured at each location for Waco reservoir.



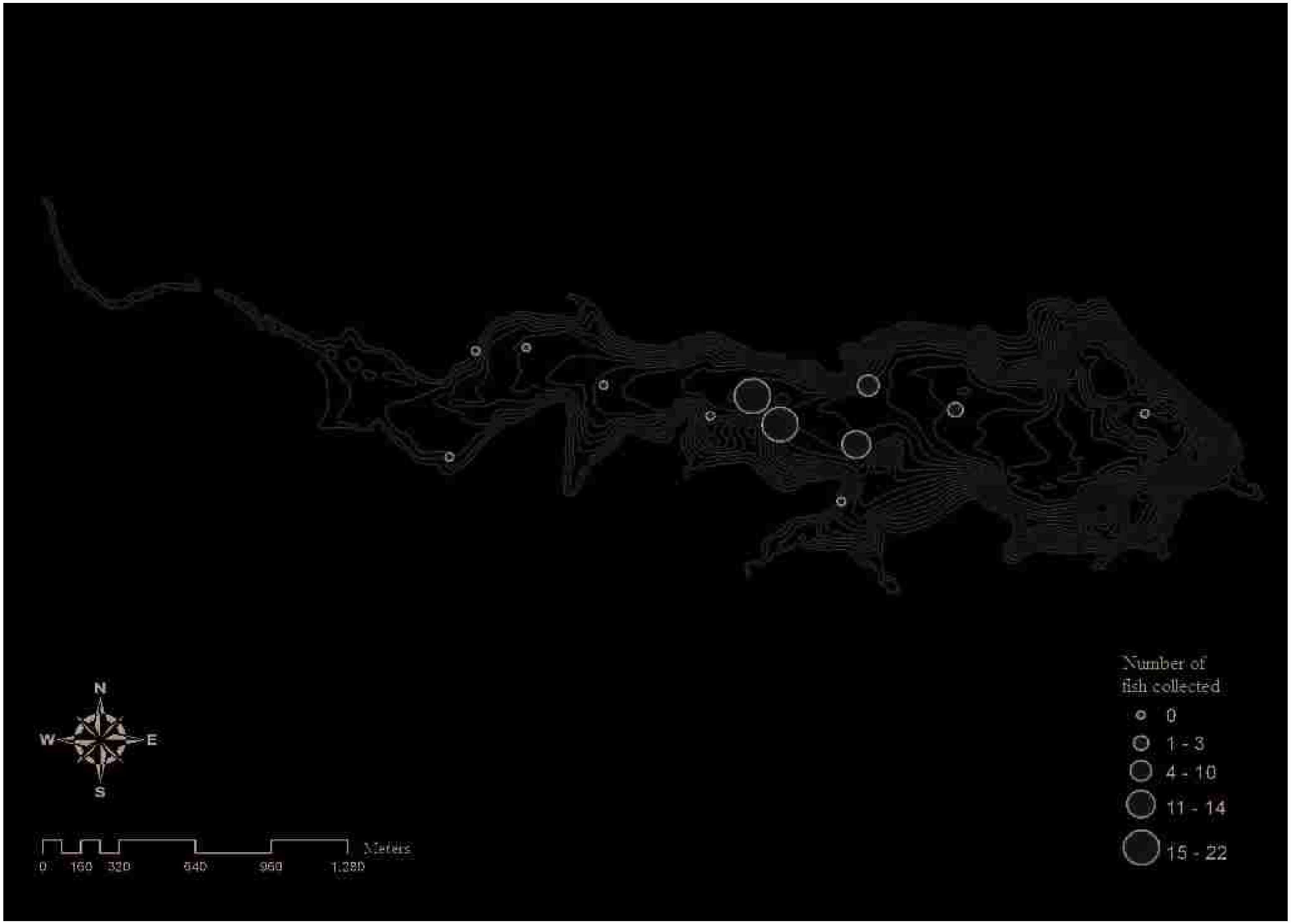


Figure B30.–Map of sampling locations and number of fish captured at each location for Waxahachie reservoir.

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