Aquatic Resources Study Report

R.L. Harris Hydroelectric Project

FERC No. 2628

HARRIS DAM
RELICENSING

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1.0 INTRODUCTION

Alabama Power Company (Alabama Power) has initiated the Federal Energy Regulatory Commission (FERC) relicensing of the 135-megawatt (MW) R.L. Harris Hydroelectric Project (Harris Project), FERC Project No. 2628. The Harris Project consists of a dam, spillway, powerhouse, and those lands and waters necessary for the operation of the hydroelectric project and enhancement and protection of environmental resources. The Harris Reservoir is the 9,870-acre reservoir created by the R.L. Harris Dam (Harris Dam). The unimpounded reach of the Tallapoosa River between Harris Dam and the headwaters of Lake Martin is approximately 52 miles in length.

Alabama Power began operating the Harris Project in 1983. Initially, the Harris Project operated in peaking mode with no intermittent flows between peaks, known as Pre-Green Plan (PGP). Agencies and non-governmental organizations requested that Alabama Power modify operations to potentially enhance downstream aquatic habitat. In 2005, based on recommendations developed in cooperation with stakeholders, Alabama Power implemented a pulsing scheme for releases from Harris Dam known as the Green Plan (GP) (Kleinschmidt 2018a). The purpose of the GP was to reduce the effects of peaking operations on the aquatic community downstream. Although GP operations are not required by the existing license, Alabama Power has operated Harris Dam according to its guidelines since 2005.

Commonly used acronyms that may appear in this report are included in Appendix A.

1.1 Study Background

Numerous aquatic resource studies have been conducted in the Tallapoosa River below Harris Dam. Some results indicated a positive response by some fish species, while other research indicates that cooler stream temperatures may be affecting the reproduction, growth, and recruitment of other fish species downstream of Harris Dam (Goar 2013; Irwin and Goar 2015) and fish density and species richness have been found to be lower when compared to unregulated reaches (Irwin et al. 2019). The Alabama Department of Conservation and Natural Resources (ADCNR) noted the abundance of some species is below expected levels, which could be due to several factors including sampling methodologies, thermal regime, flow regime, and/or nutrient availability.

During the October 19, 2017 issue identification workshop and other meetings with resource agencies, stakeholders noted that stream temperatures in the Tallapoosa River downstream of Harris Dam are generally cooler than other unregulated streams in the same geographic area, and this portion of the Tallapoosa River experiences temperature fluctuations due to releases from Harris Dam. There is concern that the lower stream temperatures and temperature fluctuations are impacting the aquatic resources (especially fish) downstream of Harris Dam.

In addition to effects on downstream fish populations discussed above, there is concern the Harris Project may have effects on other aquatic fauna within the Project Area, including macroinvertebrates such as mollusks and crayfish. Comments received on the Pre-Application Document (PAD) and Scoping Document 1 recommended that Alabama Power investigate the effects of the Harris Project on these aquatic species. Additionally, commenters suggested Alabama Power perform an assessment of the Harris Project's effects on species mobility and population health.

On November 13, 2018, Alabama Power filed ten proposed study plans for the Harris Project, including a study plan for aquatic resources. FERC issued a Study Plan Determination on April 12, 2019, which included FERC staff recommendations. Alabama Power incorporated FERC's recommendations and filed the Final Study Plans with FERC on May 13, 2019.

The goal of the Aquatic Resources Study is to evaluate the effects of the Harris Project on aquatic resources. Components of this study are a desktop assessment of current and historic information on aquatic resources in the Project Vicinity, a summary of temperature of the Tallapoosa River downstream of Harris Dam, and a study conducted by Auburn University on the fish population downstream of Harris Dam, which consist of a literature review of temperature requirements of a subset of target species, a temperature analysis of regulated and unregulated portions of the Study Area, and bioenergetics modeling to assess the extent to which Harris Dam operations affect target fish growth in the Tallapoosa River.

Alabama Power formed the Harris Action Team (HAT) 3 to specifically address issues pertaining to aquatic and wildlife resources. To present the findings from the FERC-approved study, Auburn University developed an audiovisual presentation on their study progress and preliminary results to date to deliver to HAT 3 at a scheduled meeting for March 19, 2020. The meeting was rescheduled to June 2, 2020 due to COVID-19 and related travel, public gathering restrictions, and statewide office closures. Meetings were held by conference call on November 5, 2020 to update HAT 3 on progress made since the June 2, 2020 meeting and on March 31, 2021 to present results of Auburn University's study to HAT 3.

Alabama Power prepared this report to support the relicensing process and to fulfill the requirements of the FERC-approved Aquatic Resources Study Plan. The report is comprised of three components: 1) results of the updated desktop assessment used to compile background information of various aquatic resources in both the reservoir and river and the possible effects of dam operations and 2) baseline temperature data from the Tallapoosa River below Harris Dam; and 3) Auburn University's final report on the temperature regime of the Tallapoosa River downstream of Harris Dam compared to an unregulated reference site, the fish community downstream of Harris Dam, and the effects of operations on the fitness and growth of fish downstream of Harris Dam. Alabama Power incorporated temperature data into the Draft Downstream Aquatic Habitat Study Report distributed on April 12, 2020; however, after reviewing the comments and the FERC-approved Study Plan, Alabama Power removed all temperature data from the Final Downstream Aquatic Habitat Study Report and inserted that baseline temperature data into this Aquatic Resources Study Report. Effects on temperature as a result of the downstream release alternatives is presented in the Downstream Release Alternatives Phase 2 Study Report.

2.0 DESKTOP ASSESSMENT

2.1 Introduction

The purpose of this desktop assessment was to compile background information regarding the presence of various aquatic resources in both Harris Reservoir and the Tallapoosa River downstream of Harris Dam through Horseshoe Bend and the possible effects of dam operations. Literature used for this assessment includes a study predating Harris Dam as well as studies conducted after the construction of the dam, both in the reservoir and the river downstream, including both Pre-Green Plan (PGP) and GP operations.

2.2 Methods

Relevant current and historic information characterizing aquatic resources at the Harris Project were compiled and summarized. The Study Area[1] for this assessment includes the Harris Reservoir, Tallapoosa River downstream of Harris Dam through Horseshoe Bend, and in selected unregulated reference streams. The focus of this assessment was to identify aquatic species and populations within the Study Area that may have been affected by the Harris Project. Sources of information included reservoir fisheries management reports, scientific literature from aquatic resource studies conducted in the Study Area, ADCNR Natural Heritage Database data, Alabama Power faunal survey data, and state and federal faunal survey data.

2.3 Results

2.3.1 Tallapoosa River Basin

The Tallapoosa River Basin (TRB) encompasses approximately 4,687 square miles, including 1,454 square miles above Harris Dam (Figure 2-1). The Tallapoosa River flows southward 265 miles from its headwaters at the southern end of the Appalachian Mountains in Georgia to its confluence with the Coosa River near Montgomery, Alabama, forming the Alabama River. The Tallapoosa River above Harris Reservoir represents the only unregulated portion of the Tallapoosa River. Four hydropower developments are located on the Tallapoosa River, with Harris Dam being the most upstream. A majority of

[1] The Study Area includes the geographic scope in the FERC-approved Aquatic Resources Study Plan.

the land cover in the TRB is vegetated (~75 percent), with agricultural lands accounting for approximately 14 percent (Multi-Resolution Land Characteristics Consortium 2019).

An estimated 139 species of fish occur or have occurred within the TRB, including 124 native and 14 non-native species from 24 families and 60 genera (Table 2-1) (Freeman et al. 2005). Three of these, Gulf Sturgeon (Acipenser oxyrinchus desotoi), Alabama Sturgeon (Scaphiryhnchus suttkusi), and Alabama Shad (Alosa alabamae) are likely extirpated from the TRB due to dams on the mainstem Alabama River restricting upstream migration (Freeman et al. 2005). The most recent Alabama Sturgeon specimen collected was from the Alabama River in April 2007 (Rider et al. 2011) and another specimen was observed below Robert F. Henry Lock and Dam in April 2009 (Rider et al. 2010); however, recent environmental DNA (eDNA) collections have detected the presence of Alabama Sturgeon upstream of two passage barriers on the Alabama River (Pfleger et al. 2016). Gulf sturgeon have been detected by both eDNA and sonic tag at Claiborne Lock and Dam (Pfleger et al. 2016; Rider et al. 2016). Since impoundment, there have only been two Alabama Shad specimen captured from the Alabama River, one below Claiborne Lock and Dam in 1993 and one below Miller's Ferry Lock and Dam in 1995. Large-scale upstream migrations of Alabama Shad were blocked by the construction of Claiborne, Millers Ferry, and Henry Locks and Dams, but collection records indicate a relict population may still be attempting to spawn in the Alabama River (Mettee et al. 2005). Ongoing studies by ADCNR are utilizing traditional collection methods and eDNA to determine the status of these species in the Mobile Basin. Research may provide a better understanding of the ability of sturgeon and shad to pass through navigational locks. The conservation status of 112 species of TRB native fishes are considered stable, with seven species vulnerable and two species threatened (Table 2-1). Fish species protected from unlawful take are listed in the Alabama Regulations 2019-2020 Protected Nongame Species Regulation 220-2-.92 handbook starting on page 2-198

(http://www.alabamaadministrativecode.state.al.us/docs/con_/220-2.pdf).

Benthic macroinvertebrate communities within the TRB have been assessed by the Alabama Department of Environmental Management (ADEM) and the Alabama Cooperative Fish and Wildlife Research Unit (ACFWRU). The ADEM sampled the benthic macroinvertebrate community in the Tallapoosa River at Wadley, Alabama, in July 2010, using standardized methodology. Sample results indicated a total of 38 taxa, with 11 of those taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly), or Trichoptera (caddisfly) orders (EPT species). Based on metrics that compare sample results to those expected for the region, the ADEM assessed the sample a rating of Fair/Poor (ADEM 2010 as cited in Alabama Power and Kleinschmidt 2018).

Since 2005, the ACFWRU has used surber samplers to sample benthic macroinvertebrate communities at six sampling sites (Figure 2-2). Analysis of samples collected during 2005 and 2014 have identified a total of 151 taxa, 62 of which were from the family Chironomidae. Table 2-2 provides a summary of the benthic macroinvertebrate taxa by class and order. Generally, more individuals and taxa were collected in 2005 samples versus 2014. Differences in species composition between sites and years were variable. At the unregulated sites (Heflin and Hillabee), Plecoptera (stoneflies) made up a larger percentage of insect order composition in comparison with the regulated sites (Malone and Wadley). The unregulated sites appeared to consist of a higher percentage of Ephemeroptera (mayflies) in comparison with the regulated sites (Kleinschmidt 2018a). In addition, higher densities were detected in the regulated reaches, although a later study by Irwin (2019) detected greater macroinvertebrate diversity in unregulated reaches.

An estimated 44 mussel species and one invasive clam (*Corbicula fluminea*) occur or have occurred within the TRB (Table 2-3). The Draft Aquatic Resources Study Report mistakenly presumed one species, the Georgia Pigtoe (*Pleurobema hanleyianum*), to be extirpated from the TRB. ADCNR provided a correction, stating that Johnson (1997), Johnson and Devries. (2002), Williams et al. (2008), and the November 11, 2010 USFWS Georgia Pigtoe federal register listing (75 FR 67512 67550) do not include the Tallapoosa River as a known historical river system for this species. Mussel species protected from unlawful take are listed in the Alabama Regulations 2019-2020 Invertebrate Species Regulation 220-2-.98 handbook (http://www.alabamaadministrativecode.state.al.us/JCARR/JCARR-MAY-18/CON%20220-2-.98.pdf).

An estimated 15 gastropod species occur or have occurred within the TRB (Table 2-4). The exact number of species of the genus *Physella* occurring in the TRB is undetermined. Literature reviewed for this desktop assessment reported four; however, there could possibly be between one and three *Physella* species in the TRB (ADCNR, personal communication). Gastropod species protected from unlawful take are listed in the Alabama Regulations 2019-2020 Invertebrate Species Regulation 220-2-.98 handbook (http://www.alabamaadministrativecode.state.al.us/JCARR/JCARR-MAY-18/CON%20220-2-.98.pdf).

An estimated nine crustacean species in the Upper and Middle TRB have been reported in ADCNR’s Natural Heritage Database (Table 2-5). One species, the Virile Crayfish

(*Orconectes virilis*), has been reported only in the Upper TRB and two species, the Jewel Mudbug (*Lacunicambarus dalyae*) and the Grainy Crayfish (*Procambarus verrucosus*), have been reported only in the Middle TRB. Crustacean species protected from unlawful take are listed in the Alabama Regulations 2019-2020 Invertebrate Species Regulation 220-2-.98 handbook (http://www.alabamaadministrativecode.state.al.us/JCARR/JCARR-MAY-18/CON%20220-2-.98.pdf).

An estimated 129 caddisfly species in the Upper and Middle TRB have been reported in ADCNR's Natural Heritage Database (Table 2-6). Twenty species were reported only in the Upper TRB and 37 species were reported only in the Middle TRB. All occurrences of caddisfly species in the Upper and Middle TRB were reported prior to the construction of Harris Dam. Irwin (2019) performed macroinvertebrate sampling on the mainstem of the Tallapoosa River downstream of Harris Dam. In that study, 24 of the 40 genera listed as occurring in the Middle TRB prior to the construction of Harris Dam were identified from a subset of samples collected in the Tallapoosa River between 2005 and 2014.

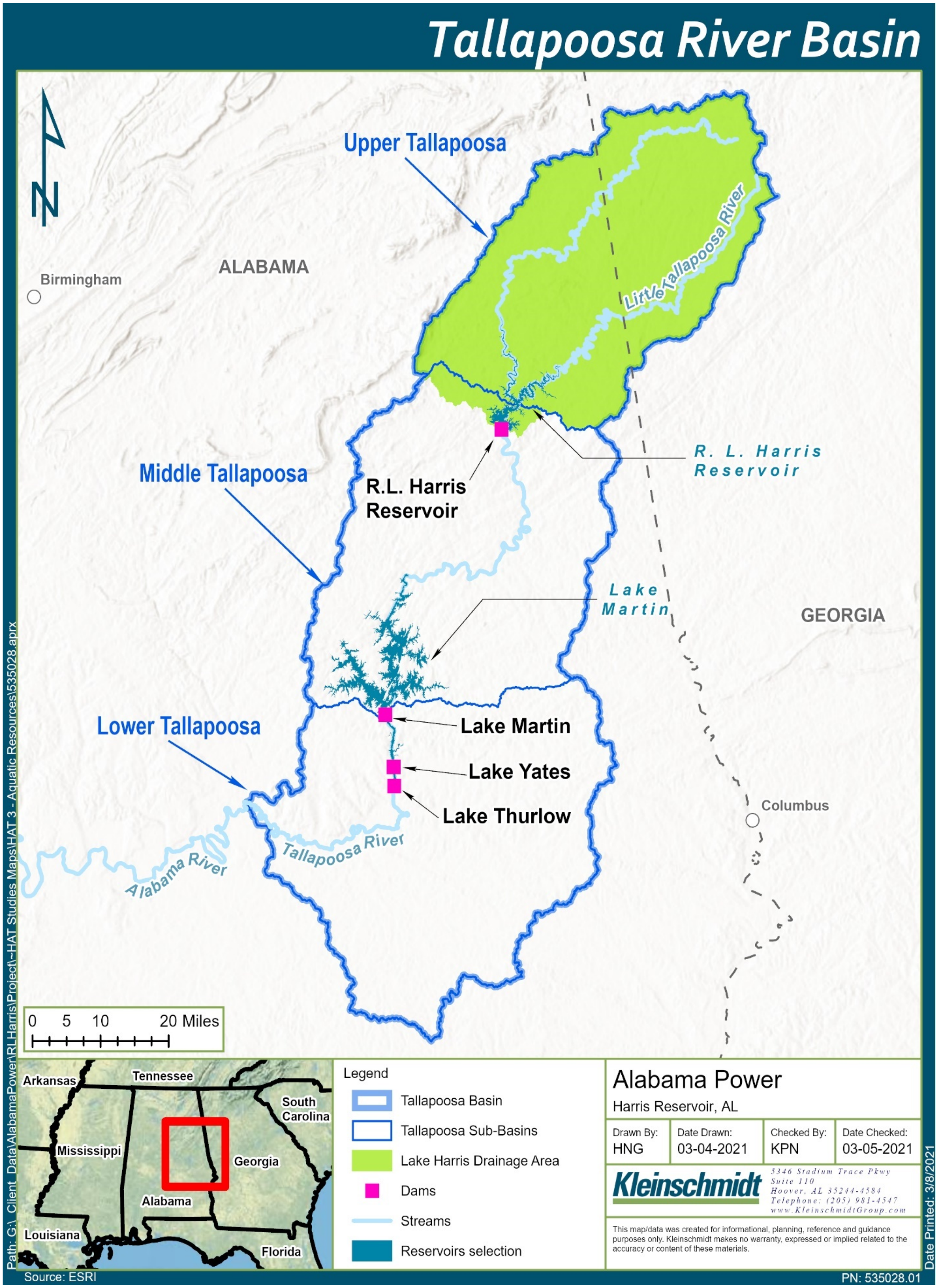

FIGURE 2-1 TALLAPOOSA RIVER BASIN MAP

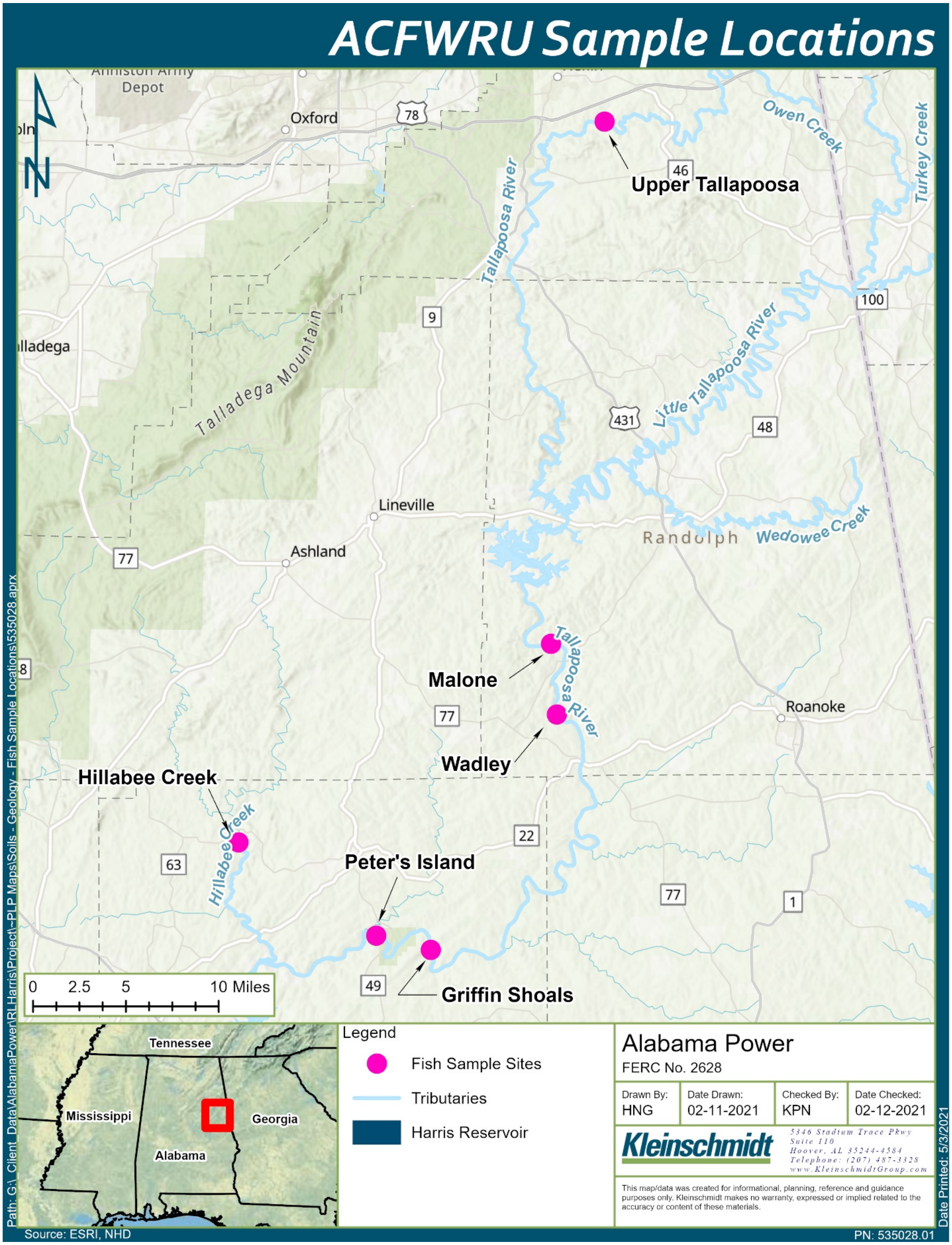

FIGURE 2-2 ACFWRU SAMPLING SITES

TABLE 2-1 FISH SPECIES OF THE TALLAPOOSA RIVER BASIN

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
Petromyzontidae (Lampreys)	*Ichthyomyzon*	*castaneus*	Chestnut Lamprey	N	CS		
	Ichthyomyzon	*gagei*	Southern Brook Lamprey	N	CS		
	Lampetra	*aepyptera*	Least Brook Lamprey	N	CS		
Acipenseridae	*Acipenser*	*oxyrinchus desotoi*	Gulf Sturgeon	PE	T	S1	SP
	Scaphiryhnchus	*suttkusi*	Alabama Sturgeon	PE	E	S1	SP
Polyodontidae (Paddlefishes)	*Polyodon*	*spathula*	Paddlefish	N	V	S3	CNGF, SP
Lepisosteidae (Gar)	*Lepisosteus*	*oculatus*	Spotted Gar	N	CS		
	Lepisosteus	*osseus*	Longnose Gar	N	CS		
Amiidae (Bowfins)	*Amia*	*calva*	Bowfin	N	CS		
Anguillidae (Freshwater Eel)	*Anguilla*	*rostrata*	American Eel	N	CS		
Clupeidae (Herrings and Shads)	*Alosa*	*aestivalis*	Blueback Herring	I			
	Alosa	*alabamae*	Alabama Shad	PE	V	S2	SP
	Alosa	*chrysochloris*	Skipjack Herring	N	CS		
	Dorosoma	*cepedianum*	Gizzard Shad	N	CS		
	Dorosoma	*petenense*	Threadfin Shad	I	CS		
Hiodontidae (Mooneyes)	*Hiodon*	*tergisus*	Mooneye	N	CS	S3S4	
Cyprinidae (Minnows and Carps)	*Campostoma*	*oligolepis*	Largescale Stoneroller	N	CS	S3	
	Campostoma	*pauciradii*	Bluefin Stoneroller	N	CS		
	Carassius	*auratus*	Goldfish	I	CS		
	Ctenopharyngdon	*idella*	Grass Carp	I	CS		
	Cyprinella	*callistia*	Alabama Shiner	N	CS		
	Cyprinella	*gibbsi*	Tallapoosa Shiner	N	CS	S3	
	Cyprinella	*venusta*	Blacktail Shiner	N	CS		

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
	Cyprinus	*carpio*	Common Carp	I	CS		
	Hybognathus	*hayi*	Cypress Minnow	N	CS	S3	
	Hybognathus	*nuchalis*	Mississippi Silvery Minnow	N	CS	S4	
	Hybopsis	*lineapunctata*	Lined Chub	N	V	S3	
	Hybopsis	*winchelli*	Clear Chub	N	CS		
	Luxilus	*chrysocephalus*	Striped Shiner	N	CS		
	Luxilus	*zonistius*	Bandfin Shiner	N	CS	S3	
	Lythrurus	*atrapiculus*	Blacktip Shiner	N	CS		
	Lythrurus	*bellus*	Pretty Shiner	N	CS		
	Macrhybopsis	sp. *cf. aestivalis*	"Fall Line Chub"	N	V		
	Macrhybopsis	sp. *cf. aestivalis*	"Pine Hills Chub"	N	CS		
	Macrhybopsis	*storeriana*	Silver Chub	N	CS		
	Nocomis	*leptocephalus*	Bluehead Chub	N	CS		
	Notemigonus	*crysoleucas*	Golden Shiner	N	CS		
	Notropis	*ammophilus*	Orangefin Shiner	N	CS		
	Notropis	*asperifrons*	Burrhead Shiner	N	CS		
	Notropis	*atherinoides*	Emerald Shiner	N	CS		
	Notropis	*baileyi*	Rough Shiner	N	CS		
	Notropis	*buccatus*	Silverjaw Minnow	N	CS		
	Notropis	*candidus*	Silverside Shiner	N	CS		
	Notropis	*edwardraneyi*	Fluvial Shiner	N	CS		
	Notropis	*stilbius*	Silverstripe Shiner	N	CS		
	Notropis	*texanus*	Weed Shiner	N	CS		
	Notropis	*uranoscopus*	Skygazer Shiner	N	CS	S2	
	Notropis	*volucellus*	Mimic Shiner	N	CS		
	Notropis	*xaenocephalus*	Coosa Shiner	N	CS		
	Opsopoeodus	*emiliae*	Pugnose Minnow	N	CS		
	Phenacobius	*catostomus*	Riffle Minnow	N	CS		

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
	Pimephales	*notatus*	Bluntnose Minnow	N	CS		
	Pimephales	*promelas*	Fathead Minnow	I	CS		
	Pimephales	*vigilax*	Bullhead Minnow	N	CS		
	Semotilus	*atromaculatus*	Creek Chub	N	CS		
	Semotilus	*thoreauianus*	Dixie Chub	N	CS		
Catostomidae (Suckers)	*Carpiodes*	*cyprinus*	Quillback	N	CS		
	Carpiodes	*velifer*	Highfin Carpsucker	N	CS		
	Cycleptus	*meridionalis*	Southeastern Blue Sucker	N	V	S3	CNGF
	Erimyzon	*oblongus*	Eastern Creek Chubsucker	N	CS		
	Erimyzon	*sucetta*	Lake Chubsucker	N	CS		
	Erimyzon	*tenuis*	Sharpfin Chubsucker	N	CS		
	Hypentelium	*etowanum*	Alabama Hog Sucker	N	CS		
	Ictiobus	*bubalus*	Smallmouth Buffalo	N	CS		
	Minytrema	*melanops*	Spotted Sucker	N	CS		
	Moxostoma	*carinatum*	River Redhorse	N	CS		
	Moxostoma	*duquesnei*	Black Redhorse	N	CS		
	Moxostoma	*erythrurum*	Golden Redhorse	N	CS		
	Moxostoma	*poecilurum*	Blacktail Redhorse	N	CS		
Ictaluridae (Catfishes)	*Ameiurus*	*brunneus*	Snail Bullhead	PI	V	S3	CNGF
	Ameiurus	*catus*	White Catfish	I	CS	S3	CNGF
	Ameiurus	*melas*	Black Bullhead	N	CS		
	Ameiurus	*natalis*	Yellow Bullhead	N	CS		
	Ameiurus	*nebulosus*	Brown Bullhead	N	CS		
	Ictalurus	*furcatus*	Blue Catfish	N	CS		
	Ictalurus	*punctatus*	Channel Catfish	N	CS		
	Noturus	*funebris*	Black Madtom	N	CS		
	Noturus	*gyrinus*	Tadpole Madtom	N	CS		

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
	Noturus	*leptacanthus*	Speckled Madtom	N	CS		
	Noturus	*nocturnus*	Freckled Madtom	N	CS	S3	CNGF
	Pylodictis	*olivaris*	Flathead Catfish	N	CS		
Esocidae (Pikes)	*Esox*	*americanus*	Redfin Pickerel	N	CS		
	Esox	*masquinongy*	Muskellunge	I	CS		
	Esox	*niger*	Chain Pickerel	N	CS		
Salmonidae (Trouts and Chars)	*Oncorhynchus*	*mykiss*	Rainbow Trout	I	CS		
Aphredoderidae (Pirate Perch)	*Aphredoderus*	*sayanus*	Pirate Perch	N	CS		
Fundulidae (Topminnows and Killifishes)	*Fundulus*	*bifax*	Stippled Studfish	N	V	S2	
	Fundulus	*olivaceus*	Blackspotted Topminnow	N	CS		
Poeciliidae (Livebearers)	*Gambusia*	*affinis*	Western Mosquitofish	N	CS		
Atherinopsidae (New World Silversides)	*Labidesthes*	*sicculus*	Brook Silverside	N	CS		
Cottidae (Sculpins)	*Cottus*	*carolinae infernatus*	Alabama Banded Sculpin	N	CS		
	Cottus	*tallapoosae*	Tallapoosa Sculpin	N	CS	S3	
Moronidae (Temperate Basses)	*Morone*	*chrysops*	White Bass	I	CS		
	Morone	*saxatilis*	Striped Bass	N	CS		
	Morone	*chrysops x saxatilis*	Hybrid Striped Bass	I	CS		
Elassomatidae (Pygmy Sunfishes)	*Elassoma*	*zonatum*	Banded Pygmy Sunfish	N	CS		
Centrarchidae (Sunfishes)	*Ambloplites*	*ariommus*	Shadow Bass	N	CS		
	Centrarchus	*macropterus*	Flier	N	CS		
	Lepomis	*auritus*	Redbreast Sunfish	PI	CS		

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
	Lepomis	*cyanellus*	Green Sunfish	N	CS		
	Lepomis	*gulosus*	Warmouth	N	CS		
	Lepomis	*humilis*	Orangespotted Sunfish	I	CS		
	Lepomis	*macrochirus*	Bluegill	N	CS		
	Lepomis	*megalotis*	Longear Sunfish	N	CS		
	Lepomis	*microlophus*	Redear Sunfish	N	CS		
	Lepomis	*miniatus*	Redspotted Sunfish	N	CS		
	Micropterus	*dolomieu*	Smallmouth Bass	I	CS		
	Micropterus	*henshalli*	Alabama Bass	N	CS		
	Micropterus	*salmoides*	Largemouth Bass	N	CS		
	Micropterus	*tallapoosae*	Tallapoosa Bass	N	CS		
	Pomoxis	*annularis*	White Crappie	N	CS		
	Pomoxis	*nigromaculatus*	Black Crappie	N	CS		
Percidae (Perches)	*Ammocrypta*	*beanii*	Naked Sand Darter	N	CS		
	Ammocrypta	*meridiana*	Southern Sand Darter	N	CS		
	Crystallaria	*asprella*	Crystal Darter	N	V	S3	SP
	Etheostoma	*artesiae*	Redspot Darter	N	CS		
	Etheostoma	*chlorosoma*	Bluntnose Darter	N	CS		
	Etheostoma	*chuckwachatte*	Lipstick Darter	N	V[2]	S2	SP[3]
	Etheostoma	*davisoni*	Choctawhatchee Darter	N	CS	S3	
	Etheostoma	*histrio*	Harlequin Darter	N	CS	S3	
	Etheostoma	*jordani*	Greenbreast Darter	N	CS		
	Etheostoma	*nigrum*	Johnny Darter	N	CS		

[2] This species was mistakenly reported as "currently stable" in the Draft Aquatic Resources Study Report.

[3] This species is the only State Protected species in the Project Area and the Tallapoosa River downstream of Harris Dam.

Family	Genus	Species	Common Name	Native	Federal Status	State Rank	State Protection Status
	Etheostoma	*parvipinne*	Goldstripe Darter	N	CS		
	Etheostoma	*rupestre*	Rock Darter	N	CS		
	Etheostoma	*stigmaeum*	Speckled Darter	N	CS		
	Etheostoma	*swaini*	Gulf Darter	N	CS		
	Etheostoma	*tallapoosae*	Tallapoosa Darter	N	CS	S3	
	Etheostoma	*zonifer*	Backwater Darter	N	CS	S3	
	Percina	*brevicauda*	Coal Darter	N	T	S2	
	Percina	*kathae*	Mobile Logperch	N	CS		
	Percina	*lenticula*	Freckled Darter	N	T	S2S3	
	Percina	*maculata*	Blackside Darter	N	CS		
	Percina	*nigrofasciata*	Blackbanded Darter	N	CS		
	Percina	*palmaris*	Bronze Darter	N	CS	S3	
	Percina	*shumardi*	River Darter	N	CS	S3	
	Percina	*smithvanizi*	Muscadine Bridled Darter	N	V	S2	
	Percina	*vigil*	Saddleback Darter	N	CS		
	Sander	*vitreus*	Walleye	N	CS		
Sciaenidae (Drums)	*Aplodinotus*	*grunniens*	Freshwater Drum	N	CS		

Source: Freeman et al. (2005); Alabama Natural Heritage Program (2019); Auburn University (2020) (Blueback Herring and Snail Bullhead)

Native = Native (N), Possibly Extirpated (PE), Introduced (I), Possibly Introduced (PI)
Federal Status = Currently Stable (CS), Vulnerable (V), Threatened (T), Endangered (E)
State Rank = Secure (S5), Apparently Secure (S4), Vulnerable (S3), Imperiled (S2), Critically Imperiled (S1), Presumed Extirpated (SX)
State Protection Status = State Protected (SP), Commercial or Non-Game Fish (CNGF)

TABLE 2-2 NUMBER OF INDIVIDUAL BENTHIC MACROINTERTEBRATES COLLECTED BY TAXON IN 2005 AND 2014

	Heflin		Hillabee		Malone		Wadley	
Taxa	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**
Arachnida								
Trombidiformes	10		6		16	5	5	2
Bivalvia								
Veneroida	12	3	11	21	72	5	38	12
Clitellata								
Lumbriculida	1	2			37	37	17	16
Tubificida	17	4	12	8	216	28	19	17
Gastropoda								
Basommatophora	16							
Neotaenioglossa	5	27	6	95	1	3	90	14
Insecta								
Coleoptera	14	97	85	170	49	25	15	25
Diptera	331	23	230	87	648	113	109	96
Ephemeroptera	43	9	125	52	111	150	70	228
Megaloptera	1	2	3	1			2	
Odonata	2	1	5			1		1
Plecoptera	55	34	56	59	5		2	4
Trichoptera	53	22	129	19	103	96	56	29
Malacostraca								
Amphipoda					1			
Isopoda					5			
Nematoda	2		4		10		1	1
Turbellaria								
Tricladida					12			2
Total	**562**	**224**	**672**	**512**	**1286**	**463**	**424**	**447**

Source: Kleinschmidt 2018a

TABLE 2-3 FRESHWATER MUSSEL SPECIES OF THE TALLAPOOSA RIVER BASIN

Common Name	Scientific Name	State Rank	GCN	Federal Status	Sub-Basin	State Protection Status
Threeridge	*Amblema plicata*	S5				
Flat Floater	*Anodonta suborbiculata*	S3			M	PSM
Asian Clam	*Corbicula fluminea*	Exotic			UML	
Tallapoosa Orb	*Cyclonaias archeri*	S1		UR		
Alabama Orb	*Cyclonaias asperata*	S5			UL	
Butterfly	*Ellipsaria lineolata*	S4				
Alabama Spike	*Elliptio arca*	S2	1	UR	UM	PSM
Delicate Spike	*Elliptio arctata*	S2	2	UR	UML	PSM
Elephantear	*Elliptio crassidens*	S5			L	
Gulf Slabshell	*Elliptio fumata*	S3			L	PSM
Gulf Spike	*Elliptio pullata*	S4			L	
Gulf Pigtoe	*Fusconaia cerina*	S4			UL	
Finelined Pocketbook	*Hamiota altilis*	S2	2	T		SP
Southern Pocketbook	*Lampsilis ornata*	S4			L	
Rough Fatmucket	*Lampsilis straminea*	S4				
Yellow Sandshell	*Lampsilis teres*	No Rank			L	
Alabama Heelsplitter	*Lasmigona alabamensis*	S3				PSM
Fragile Papershell	*Leptodea fragilis*	S5			L	
Black Sandshell	*Ligumia recta*	S2	2		L	PSM
Alabama Moccasinshell	*Medionidus acutissimus*	S2		T		SP
Washboard	*Megalonaias nervosa*	S5			L	
Threehorn Wartyback	*Obliquaria reflexa*	S5			L	
Alabama Hickorynut	*Obovaria unicolor*	S2		UR		PSM
Southern Clubshell	*Pleurobema decisum*	S2	2	E		SP
Southern Pigtoe	*Pleurobema georgianum*	S1	1	E		SP
Ovate Clubshell	*Pleurobema perovatum*	S1	1	E		SP

Common Name	Scientific Name	State Rank	GCN	Federal Status	Sub-Basin	State Protection Status
Bleufer	*Potamilus purpuratus*	S5			L	
Alabama Creekmussel	*Pseudodontoideus connasaugaensis*	S3				PSM
Southern Creekmussel	*Pseudodontoideus subvexus*	S3	3		L	PSM
Rayed Kidneyshell	*Ptychobranchus foremanianus*	S1				SP
Eastern Floater	*Pyganodon cataracta*	S5	3		ML	PSM
Giant Floater	*Pyganodon grandis*	S5			ML	
Southern Mapleleaf	*Quadrula apiculata*	S5			L	
Gulf Mapleleaf	*Quadrula nobilis*	S3				PSM
Ridged Mapleleaf	*Quadrula rumphiana*	S3	3		L	
Ebonyshell	*Reginiana ebenus*	S4			L	
Rayed Creekshell	*Strophitus radiatus*	S3	2		L	PSM
Southern Purple Lilliput	*Toxolasma corvunculus*	S1	1	UR	L	PSM
Lilliput	*Toxolasma parvum*	S3			L	PSM
Pistolgrip	*Tritogonia verrucosa*	S4			L	
Fawnsfoot	*Truncilla donaciformis*	S3	3		L	
Pondhorn	*Uniomerus tetralasmus*	S4			L	
Paper Pondshell	*Utterbackia imbecillis*	S5			ML	
Little Spectaclecase	*Villosa lienosa*	S5			ML	
Coosa Creekshell	*Villosa umbrans*	S2		UR		PSM
Southern Rainbow	*Villosa vibex*	S4			ML	

Source: ADCNR (2020); Alabama Natural Heritage Program (2019); Johnson (1997); Johnson and Devries (2002); NatureServe (2020); Williams et al. (2008)

State Rank = Secure (S5), Apparently Secure (S4), Vulnerable (S3), Imperiled (S2), Critically Imperiled (S1), Presumed Extirpated (SX)
Federal Status = Threatened (T), Endangered (E), Under Review (UR)
Sub-Basin = Upper Tallapoosa Basin (U), Middle Tallapoosa Basin (M), Lower Tallapoosa Basin (L)
State Protection Status = State Protected (SP), Partial Status Mussels (PSM)

TABLE 2-4 GASTROPOD SPECIES OF THE TALLAPOOSA RIVER BASIN

Common Name	Scientific Name	State Rank	GCN	State Protection Status
	Amnicola sp.			
Ovate Campeloma	*Campeloma geniculum*			
Cylinder Campeloma	*Campeloma regulare*			
Yellow Elimia	*Elimia flava*			
Marsh Fossaria	*Galba humilis*			
Rock Fossaria	*Galba modicella*			
Golden Fossaria	*Galba obrussa*			
Two-ridge Rams-horn	*Helisoma anceps*			
Bugle Sprite	*Micromenetus dilatatus*			
Carib Physa	*Physella cubensis*		3	
Tadpole Physa	*Physella gyrina albofilata*			
Bayou Physa	*Physella hendersoni*			
Pewter Physa	*Physella heterostropha*			
Mimic Lymnaea	*Pseduosuccinea columella*			
	Somatogyrus sp.			

Source: ADCNR (2020); Alabama Natural Heritage Program (2019); Johnson (1997); Johnson and Devries (2002)

State Rank = Secure (S5), Apparently Secure (S4), Vulnerable (S3), Imperiled (S2), Critically Imperiled (S1), Presumed Extirpated (SX)
State Protection Status = State Protected (SP)

TABLE 2-5 CRUSTACEAN SPECIES REPORTED IN THE UPPER AND MIDDLE TALLAPOOSA RIVER BASINS

Common Name	Scientific Name	Pre-Dam	Pre-Green Plan	Green Plan	State Rank	GCN	State Protection Status
Tallapoosa Crayfish	*Cambarus englishi*	UM	UM	UM	S2	2	
Slackwater Crayfish	*Cambarus halli*	UM	UM	UM	S3	2	
Variable Crayfish	*Cambarus latimanus*	UM	UM	UM			
Ambiguous Crayfish	*Cambarus striatus*	UM		UM			
Jewel Mudbug	*Lacunicambarus dalyae*		M				
Reticulate Crayfish	*Orconectes erichsonianus*		UM				
Virile Crayfish	*Orconectes virilis*			U			
White Tubercled Crayfish	*Procambarus spiculifer*	UM	UM	UM			
Grainy Crayfish	*Procambarus verrucosus*			M		3	

Source: ADCNR (2020); Alabama Natural Heritage Program (2019); Irwin et al. (2011); Johnson (1997)

Sub-Basin = Upper Tallapoosa Basin (U), Middle Tallapoosa Basin (M)
State Rank = Secure (S5), Apparently Secure (S4), Vulnerable (S3), Imperiled (S2), Critically Imperiled (S1), Presumed Extirpated (SX)
State Protection Status = State Protected (SP)

TABLE 2-6 CADDISFLY SPECIES REPORTED IN THE UPPER AND MIDDLE TALLAPOOSA RIVER BASINS

Genus	Species	Sub-Basin
Agapetus	*rossi*	UM
Agarodes	*griseus*	M
Anisocentropus	*pyraloides*	UM
Brachycentrus	*nigrosoma*	M
Ceraclea	*ancylus*	UM
Ceraclea	*cancellata*	UM
Ceraclea	*flava*	UM
Ceraclea	*maculata*	UM
Ceraclea	*nepha*	UM
Ceraclea	*ophioderus*	M
Ceraclea	*protonepha*	UM
Ceraclea	*tarsipunctata*	UM
Ceraclea	*transversa*	UM
Ceratopsyche	*sparna*	UM
Cernotina	*calcea*	M
Cernotina	*spicata*	M
Cheumatopsyche	*burksi*	M
Cheumatopsyche	*campyla*	UM
Cheumatopsyche	*edista*	M
Cheumatopsyche	*ela*	UM
Cheumatopsyche	*geora*	UM
Cheumatopsyche	*harwoodi*	M
Cheumatopsyche	*minuscula*	M
Cheumatopsyche	*pasella*	UM
Cheumatopsyche	*pettiti*	UM
Cheumatopsyche	*pinaca*	UM
Chimarra	*aterrima*	UM
Chimarra	*moselyi*	M
Chimarra	*obscura*	UM
Cyrnellus	*fraternus*	UM
Dolophilodes	*distinctus*	U
Glossosoma	*nigrior*	UM
Goera	*calcarata*	M
Goera	*townesi*	U
Helicopsyche	*borealis*	U
Heteroplectron	*americanum*	U
Hydropsyche	*alvata*	U
Hydropsyche	*betteni*	UM
Hydropsyche	*demora*	M

Genus	Species	Sub-Basin
Hydropsyche	*fattigi*	M
Hydropsyche	*mississippiensis*	UM
Hydropsyche	*phalerata*	U
Hydropsyche	*venularis*	UM
Hydroptila	*alabama*	UM
Hydroptila	*amoena*	U
Hydroptila	*armata*	UM
Hydroptila	*berneri*	U
Hydroptila	*callia*	M
Hydroptila	*delineata*	M
Hydroptila	*gunda*	UM
Hydroptila	*hamata*	UM
Hydroptila	*lonchera*	U
Hydroptila	*novicola*	U
Hydroptila	*oneili*	M
Hydroptila	*paramoena*	UM
Hydroptila	*quinola*	UM
Hydroptila	*remita*	U
Hydroptila	*waubesiana*	UM
Lepidostoma	*latipenne*	UM
Lepidostoma	*togatum*	UM
Lype	*diversa*	UM
Macrostemum	*carolina*	M
Macrostemum	*zebratum*	M
Matrioptila	*jeanae*	UM
Mayatrichia	*ayama*	M
Micrasema	*charonis*	U
Micrasema	*rusticum*	UM
Micrasema	*wataga*	UM
Molanna	*blenda*	U
Molanna	*tryphena*	U
Molanna	*ulmerina*	UM
Mystacides	*sepulchralis*	UM
Nectopsyche	*candida*	UM
Nectopsyche	*exquisita*	UM
Nectopsyche	*pavida*	UM
Neotrichia	*vibrans*	UM
Nyctiophylax	*affinis*	UM
Nyctiophylax	*celta*	M
Nyctiophylax	*denningi*	UM
Nyctiophylax	*serratus*	M

Genus	Species	Sub-Basin
Oecetis	*avara*	M
Oecetis	*cinerascens*	M
Oecetis	*ditissa*	UM
Oecetis	*inconspicua*	UM
Oecetis	*nocturna*	UM
Oecetis	*persimilis*	UM
Oecetis	*sphyra*	UM
Orthotrichia	*aegerfasciella*	UM
Orthotrichia	*cristata*	U
Oxyethira	*forcipata*	UM
Oxyethira	*grisea*	UM
Oxyethira	*janella*	UM
Oxyethira	*lumosa*	M
Oxyethira	*novasota*	UM
Oxyethira	*pallida*	UM
Oxyethira	*rivicola*	M
Oxyethira	*zeronia*	UM
Phylocentropus	*carolinus*	UM
Phylocentropus	*lucidus*	M
Phylocentropus	*placidus*	UM
Plectrocnemia	*cinerea*	UM
Polycentropus	*barri*	M
Polycentropus	*blicklei*	U
Polycentropus	*confusus*	UM
Protoptila	*georgiana*	M
Protoptila	*palina*	UM
Psilotreta	*frontalis*	UM
Psilotreta	*labida*	M
Psychomyia	*flavida*	UM
Ptilostomis	*ocellifera*	M
Ptilostomis	*postica*	U
Pycnopsyche	*indiana*	M
Pycnopsyche	*lepida*	M
Rhyacophila	*carolina*	UM
Rhyacophila	*fuscula*	UM
Rhyacophila	*ledra*	U
Rhyacophila	*nigrita*	UM
Rhyacophila	*torva*	M
Setodes	*incertus*	M
Stactobiella	*delira*	UM
Stactobiella	*martynovi*	UM

Genus	Species	Sub-Basin
Stactobiella	*palmata*	UM
Theliopsyche	*tallapoosa*	M
Triaenodes	*flavescens*	M
Triaenodes	*ignitus*	UM
Triaenodes	*marginatus*	UM
Triaenodes	*nox*	U
Triaenodes	*ochraceus*	U
Triaenodes	*tardus*	M

Source: ADCNR 2020

Sub-Basin = Upper Tallapoosa Basin (U), Middle Tallapoosa Basin (M)

2.3.2 Harris Reservoir

The Harris Reservoir contains many popular sport fish species, such as Largemouth Bass (*Micropterus salmoides*), Alabama Bass (*Micropterus henshalli*), Black Crappie (*Pomoxis nigromaculatus*), Flathead Catfish (*Pylodictis olivaris*), Blue Catfish (*Ictalurus furcatus*), Channel Catfish (*Ictalurus punctatus*), Redear Sunfish (*Lepomis microlophus*), Bluegill (*Lepomis macrochirus*), and White Bass (*Morone chrysops*). The ADCNR Wildlife and Freshwater Fisheries Division rountinely performs standardized sampling for Largemouth Bass, Alabama Bass, and Black Crappie to keep records on these fisheries and to determine the need for, or changes to, the regulations.

On October 1, 1993, a 13-16 inch slot limit[4] for all black bass species was implemented in the reservoir with the goal of improving growth and condition of fish by reducing competition (Andress and Catchings 2005); however, angler attitudes toward the harvest of bass under 13 inches reduced the effect of the imposed limit (Andress and Catchings 2005). In 2006, Largemouth Bass population structure exceeded the state's 75th percentile for many of the larger size classes, and mean lengths for Largemouth Bass ages 1-4 were above statewide averages (Andress and Catchings 2006). Alabama Bass[5] did not respond well (an excessive number of specimens smaller than 13 inches) to the slot limit (Andress and Catchings 2006), so the limit was removed for this species in 2006 (Andress and Catchings 2007). In 2010, the condition of Largemouth Bass had steadily improved (Holley et al. 2010) and by 2012, maintaining the slot limit for Largemouth Bass and removing the slot limit for Alabama Bass in 2006 was found to have a positive effect on black bass populations (Holley et al. 2012). As of 2018, the slot limit on Largemouth Bass and removal of the slot limit on Alabama Bass in 2006 have continued to yield positive results, indicated by a greater relative density of slot-sized or larger bass (Hartline et al. 2018).

In 2015, Black Crappie were targeted for sampling due to a low catch rate reported in 2010 creel surveys (Holley et al. 2010; Hartline et al. 2018). Black Crappie were found in large numbers in the Harris Reservoir and exhibited much better growth and size structure than crappie (*Pomoxis* spp.) in the river around Lee's Bridge, which was attributed to more abundant habitat and forage availability in the reservoir (Hartline et al. 2018).

[4] The slot limit does not allow the harvest of fish between 13 and 16 inches total length.
[5] Previously described in this region as a subspecies of Spotted Bass (*Micropterus punctatus*), but later described as a separate species named Alabama Bass (Baker et al. 2008).

During the spring, Alabama Power coordinates with ADCNR to manage water levels in Harris Reservoir for the benefit of fish species (e.g., Largemouth Bass and crappie) that spawn in littoral (near-shore) areas. Based on input from ADCNR and when conditions permit, Alabama Power voluntarily maintains the lake at a stable or a slightly rising elevation for a period of 14 days to provide improved conditions for spawning and hatching success of these species.

2.3.3 Tallapoosa River and Tributaries

The following is a chronologically ordered synopsis of available information pertaining to aquatic resources in the Tallapoosa River downstream of Harris Dam. Figure 2-3 is provided to help orient the reader to locations within this reach that are commonly referred to throughout this section. Any conclusions presented in the summaries below belong to the original authors of the studies and were not determined by Alabama Power or their representatives. Table 2-8, located at the end of this section, provides some of the major findings of the studies included in this section as interpreted by Alabama Power. It is worth noting that collection methods have changed over time and vary among studies.

Swingle (1954) performed one of the earliest studies on the effects of dams and impoundments on populations of fish in Alabama. Fish were sampled by rotenone in multiple rivers and impoundments from a variety of habitats. Generally, sport fish rarely made up more than five percent of the total population in large rivers. River populations generally consisted of Blue Catfish (*Ictalurus furcatus*), Channel Catfish (*Ictalurus punctatus*), Flathead Catfish (*Pylodictis olivaris*), Freshwater Drum (*Aplodinotus grunniens*), and species of buffalo (*Ictiobus* spp.). In the Tallapoosa River, fish were sampled in deep areas of unimpounded river in 1951 and in coves and deep, open areas of Lake Martin in 1949 and 1951. Gizzard Shad (*Dorosoma cepedianum*), Blue Catfish, and Freshwater Drum were not found in the Tallapoosa River or in Lake Martin. Sport fishes such as Largemouth Bass, Alabama Bass (formerly Spotted Bass in this region at the time of this study), White Bass, and crappie were abundant in Lake Martin, comprising between 24.6 to 27.9 percent of the population. Both Largemouth Bass and Bluegill comprised a larger percentage of the total biomass of fish in Lake Martin than in the river. Common Carp (*Cyprinus carpio*) were already present in the river and became very abundant in Lake Martin shortly after impoundment but gradually declined in the impoundment over the following 24-26 years until they became roughly 4.1 percent of the population.

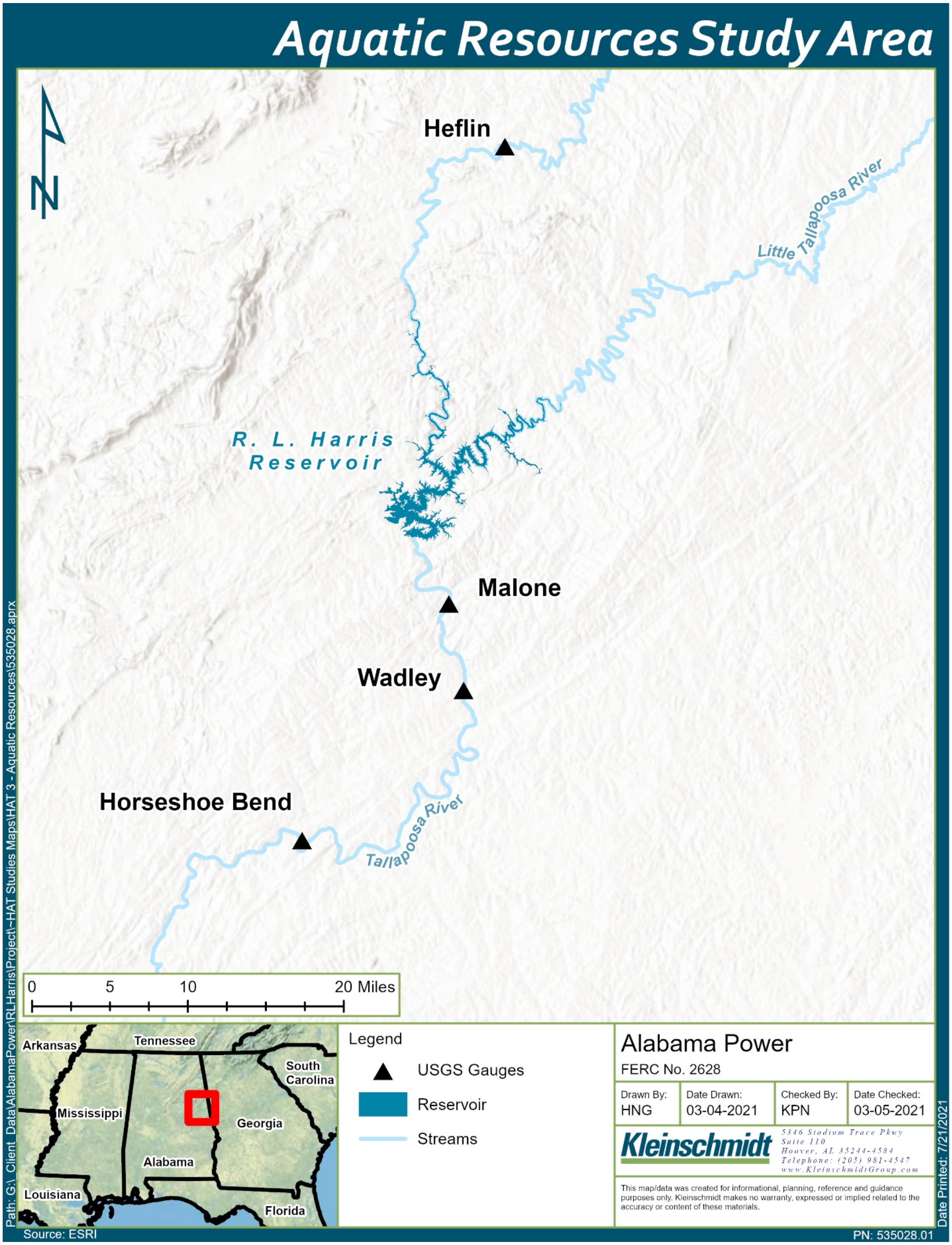

FIGURE 2-3 AQUATIC RESOURCES STUDY AREA

Travnichek and Maceina (1994) measured species richness (the number of species present), diversity (a measure of the number and abundance of each species), and relative abundance (a measure of how common or rare a species is in relation to other species) in two unregulated sites upstream of Harris Reservoir (Little Tallapoosa River and upper Tallapoosa River) and three regulated sites (all downstream of Harris Dam) in both deep and shallow habitats from 1990 to 1992. In deep habitat, species richness was greater in regulated reaches of the Tallapoosa River than in unregulated portions. The catch of catostomids considered fluvial specialists, such as Alabama Hog Sucker (*Hypentelium etowanum*), Black Redhorse (*Moxostoma duqesnei*), Golden Redhorse (*Moxostoma erythrurum*), Highfin Carpsucker (*Carpiodes velifer*), and Quillback (*Carpiodes cyprinus*) was lower in the two regulated areas below Harris Dam and Thurlow Dam than in the unregulated area. There was no significant difference in the number of centrarchid (bass and sunfish) and ictalurid (catfish) species caught between unregulated and regulated reaches. In shallow habitat, fish abundance in unregulated reaches was about twice as high compared with fish abundance in regulated reaches. Species richness was also greater in unregulated reaches and increased progressively with distance from Harris Dam in regulated reaches.

Bowen et al. (1996) sampled fish at the same sites as those sampled in Travnichek and Maceina (1994) in 1994 and 1995. Bowen (1996) used a modified index of biological integrity (IBI), a tool used to assess the health of aquatic ecosystems, based specifically on small-bodied fishes and calculated IBI scores for data gathered in 1994 and 1995 as well as data gathered by Travnichek and Maceina (1994) during 1990-1992. Eight of the 78 species collected were classified as intolerant. Overall, cyprinids (minnows, carps, and shiners) and percids (darters and perch) were highest in relative abundance. The IBI was most affected by changes in the percentage of insectivorous cyprinids (minnows), the percentage of intolerant species, fish abundance, and the number of darter species. The unregulated reach of the Tallapoosa River had higher IBI scores (1990-1992: 60.11; 1994: 72.26; 1995: 83.40) than the regulated reaches (1990-1992: 48.80-52.52; 1994: 68.58-72.74; 1995: 68.19-72.54) of the Tallapoosa River. The IBI scores were higher in 1995 than in 1994 at both unregulated sites and two out of three of the regulated sites, which was attributed to higher discharge in 1994, leading to reduced reproductive success and survival that year.

Irwin and Hornsby (1997) repeated the rotenone survey from Swingle (1954) in 1996 in response to a perceived decline in harvest of Flathead Catfish and Channel Catfish by anglers downstream of Harris Dam. An area at the historical site was blocked and sampled with rotenone. Biomass of fishes was 35.9 kg/ha compared to 51.0 kg/ha in Swingle (1954), and abundance was 438 fish/ha compared to 2,933 fish/ha in Swingle (1954). Samples were dominated by centrarchids (74 percent) instead of cyprinids and ictalurids (47 and 44 percent, respectively) as seen in Swingle (1954). A decline in juvenile catfish was attributed to a possible impact on recruitment. Catostomids represented a larger portion of the sample than in Swingle (1954), but juvenile catostomids declined greatly, suggesting that catostomid recruitment may be limited in regulated systems. Irwin and Hornsby (1997) concluded that the repeated study supports the hypothesis that generalist species are more suited to regulated systems and suggested that modifications to releases from Harris Dam could provide more suitable habitats for more specialized fishes.

Johnson (1997) developed a list of mussel, snail, and crayfish species in the Tallapoosa River drainage by surveying 35 sites from June through August 1995. In the headwater reaches of the Tallapoosa River (~43-50 miles upstream of Harris Dam between the Cleburne County Road 84 and Cleburne County Road 46 bridge crossings), the mussel species Delicate Spike (*Elliptio arctata*), Gulf Pigtoe (*Fusconaia cerina*), and Finelined Pocketbook (*Hamiota altilis*)[6] were found along with the snail species Yellow Elimia (*Elimia flava*). In tributaries of the upper Tallapoosa River (Snake Creek, Lebanon Church Creek, Silas Creek, Verdin Creek, and two tributaries presumed by the author to be Lochelooge Creek and Carr Creek[7]), the mussel species Alabama Spike (*Elliptio arca*)[8], the snail species Yellow Elimia, Carib Physa (*Physella cubensis*), a subspecies of Tadpole Physa (*Physella gyrina albofilata*), and the crayfish species Tallapoosa Crayfish (*Cambarus englishi*), Slackwater Crayfish (Cambarus *halli*), Variable Crayfish (*Cambarus latimanus*), and White Tubercled Crayfish (*Procambarus spiculifer*) were present. In Harris Reservoir, the mussel species Paper Pondshell (*Utterbackia imbecillis*) was found around an ADCNR public boat ramp (west of Wedowee, Alabama) but no snail or crayfish species were collected. The mussel species Southern Rainbow (*Villosa vibex*[9]), the snail species Yellow Elimia, the Tadpole Physa subspecies *albofilata*, a subspecies of Pewter Physa (*Physella heterostropha*

[6] Finelined Pocketbook belonged to the genus *Lampsilis* at the time of the publication but is now *Hamiota*.

[7] It has been confirmed that the location presumed to be Carr Creek by Johnson 1997 is indeed Carr Creek. The location presumed to be Lochelooge Creek appears to be either a small, possibly unnamed creek or Dynne Creek.

[8] This species was mistakenly reported as Delicate Spike (*Elliptio arctata*) in the Draft Aquatic Resources Report. Johnson (1997) only reported Delicate Spike in the headwater portion of the Tallapoosa river between the Cleburne County Road 84 and Cleburne County Road 46 bridge crossings.

[9] The species name for Southern Rainbow was *iris* at the time of the publication but is now *vibex* (ADCNR, personal communication).

pomila), and the crayfish species White Tubercled Crayfish were found in a tributary downstream of Harris Dam and upstream of Malone. In the mainstem between Malone and Wadley, Yellow Elimia were present. Tributaries near Wadley contained Yellow Elimia and *Physella* spp. and Tallapoosa Crayfish, Slackwater Crayfish, Variable Crayfish, and White Tubercled Crayfish. Tributaries between Wadley and Bibby's Ferry contained Yellow Elimia, Rock Fossaria (*Galba modicella*), Tadpole Physa (*Physella gyrina*), Mimic Lymnaea (*Pseudosuccinea columella*), and White Tubercled Crayfish and Slackwater Crayfish. In tributaries between Germany's Ferry and Horseshoe Bend National Military Park (HSB), no mussels were found; however, the snail species Yellow Elimia, Carib Physa, the Tadpole Physa subspecies *albofilata*, Slackwater Crayfish, Variable Crayfish, Tallapoosa Crayfish, and White Tubercled Crayfish were present. Around HSB, Southern Rainbow, Cylinder Campeloma (*Campeloma regulare*)[10] and Yellow Elimia, and Tallapoosa Crayfish, Variable Crayfish, and White Tubercled Crayfish were found. In Jaybird Creek, Yellow Elimia and the Tadpole Physa subspecies *albilata* were present along with the Slackwater Crayfish. The invasive clam species *Corbicula fluminea* was present at nearly every site.

Bowen et al. (1998) examined the availability and persistence of key habitats and fish assemblages at the same regulated and unregulated sites as Travnichek and Maceina (1994) and Bowen et al. (1996) in 1994 and 1995. Hydropeaking dam operations decreased both the average duration of shallow water habitats and year-to-year variation in persistence of these habitats when compared to unregulated sites. The relative abundance of percids was lower with median availability of deep-fast habitat during the spring and summer, likely due to limited suitable habitat for spawning. Catostomids showed the lowest densities in some of the larger, regulated reaches. In the summer, persistence of shallow and slow-water habitats yielded greater abundances of percids, catostomids, and cyprinids. Bowen et al. (1998) concluded that increased availability of shallow water habitats during the spring and summer can likely lead to an increase in reproductive success by a large variety of stream fishes.

Irwin and Belcher (1999) gathered angler use data by installing a creel station at the boat ramp at HSB from June 1997 to December 1998. They also collected 38 harvestable size (>400 mm) Flathead Catfish from the Elkahatchee Creek arm of Lake Martin and stocked them at the HSB site in June 1997. There was no creel clerk present at the creel station, so it was unknown if survey respondents were representative of all anglers in the area. Creel

[10] This species was referred to as Pointed Campeloma (*Campeloma decisum*) at the time of the publication but is now known to be Cylinder Campeloma (*Campeloma regulare*) (ADCNR, personal communication).

survey results yielded a catch of 38 percent ictalurids and 62 percent centrarchids. Referencing five angler diaries predating the impoundment, the catch-per-unit-effort (CPUE) in the 1970's on the Tallapoosa River in the area of interest was 1.9 fish/hour, compared to 0.8 fish/hour from the creel survey in 1997 and 1998. Similarly, in the early 1970's, Alabama Bass (formerly Spotted Bass in this region at the time of this study) were caught at a rate of 0.7 fish/hour compared to 0.1 fish/hour in the 1997-1998 creel survey. Although anglers reported catches of Flathead Catfish, no tagged and released individuals were reported. This was attributed to either fish migrating out of the area, a low amount of fishing effort, or a lack of angler response to the survey.

Freeman et al. (2001) assessed the relationship between young-of-year (YOY) (i.e., fish born within the past fiscal year) fish abundance and hydrologic and habitat variability in an unregulated reach approximately 32.9 miles upstream of Harris Reservoir and a regulated reach approximately 12.4 miles downstream of Harris Dam during the summers of 1994-1997. YOY abundances in the unregulated reach were most commonly correlated with the availability of shallow, slow-moving habitat in summer and the persistence of shallow, slow-moving and shallow, fast-moving habitat in the spring. YOY abundances in the regulated reach were most commonly correlated with the persistence of shallow habitats than with habitat availability or the intensity of flow extremes. In the regulated reach, habitat persistence levels comparable to those in the unregulated reach only happened during summer when power generation occurred less frequently due to factors such as lower rainfall. Therefore, species that spawn in the summer were a large part of the assemblage at the regulated reach. Five of the six species that spawn during spring and occur at both study reaches were less abundant at the regulated reach.

In 1999 and 2000, Irwin et al. (2001) compared nesting habits across river reaches, measured the effects of flow on nest survival, and estimated the amount of time necessary for development to post-larval life stages for centrarchids. Redbreast Sunfish (*Lepomis auritus*) nests were observed in a regulated area of the Tallapoosa River near Wadley and an unregulated area near Heflin. At the Wadley site, nest success was more likely affected by discharge than thermal regime. The greatest rate of nest failure occurred in Wadley in 1999 due to 2-unit generation events causing physical damage to nests that were not protected by substantial cover. In 2000, nest success rate was greater in Wadley than in Heflin, which could be attributed to periods of non-generation and flows that were less variable and lower in magnitude than in the previous year. The cumulative number of degree days required for larval fish development was higher at Wadley than at Heflin. However, this difference may not be biologically significant. Irwin et al. (2001) concluded that both flow and temperature regime affect Redbreast Sunfish nest success and flow regulation can disrupt the relationship between these variables.

Sakaris (2006) assessed how hydrology affected growth and hatching success of age-0 Channel Catfish in both regulated (Malone to Wadley and Peters Island) and unregulated (both upstream and downstream of Harris Dam) reaches in 2005. Growth was unexpectedly lower in unregulated sites than in the regulated reaches despite fluctuating water temperatures, citing fluctuations up to 10 °Celsius (℃) downstream of Harris Dam reported in Irwin and Freeman (2002). In unregulated reaches, age-0 Channel Catfish mainly hatched in early June to late August. In regulated reaches, hatching occurred during this time frame but also occurred during September, suggesting a prolonged spawning period downstream of the Harris Dam. This was attributed to a possible alternative life history strategy that may occur in more unpredictable environments (Einum and Fleming 2004 as cited in Sakaris 2006). Another study reported Channel Catfish in regulated sites were typically older than those in unregulated sites (Nash 1999 as cited in Sakaris 2006). Based on model results, Sakaris (2006) recommended several periods of low and stable flow conditions in the summer months, a moderate number of high pulses with slow and steady fall rates[11], and the maintenance of a higher minimum flow to enhance growth and spawning success of age-0 Channel Catfish.

Martin (2008) observed behavior and measured nesting success of male Redbreast Sunfish in unregulated reaches downstream of Harris Dam (Saugahatchee Creek) and a regulated reach (near Wadley) in 2006 and 2007 using video recordings of nests. Due to drought in 2007, approximately half the number of nests and a quarter of attempted nests were examined compared to 2006; however, nest success was no different between years. Because temperature and discharge were correlated, Martin could not determine whether temperature had an impact on nest survival. During base flow conditions (defined by Martin 2008 as low flow conditions), the most common behaviors observed were *defend* (male displaying aggressiveness; presumed to be protecting nest) and *leave* (male leaving the nest). When discharge from one-unit generation events reached Wadley, these behaviors initially decreased while the *clean* behavior (tending to the nest and removing debris) increased. The *leave* behavior became more common over the duration of one-unit generation flows and *defend* began to occur less frequently while *clean* increased. Spawning behaviors such as *court* and *milt* were never seen during one-unit generation

[11] This is the rate at which the volume of dam releases decreases, defined by Sakaris (2006) as the "mean or median of all negative differences between consecutive daily values" of discharge volume ($-m^3/s/d$). Sakaris (2006) tested fall rates of -2.8 $m^3/s/d$ and -14.2 ($-m^3/s/d$).

events. Martin (2008) suggested a spawning window of 10-11 days based on findings in this study and findings in Andress (2001).

Martin (2008) also collected male Redbreast Sunfish in 2007 to compare bioenergetic models between the regulated river and an unregulated site downstream of Harris Dam (Saugahatchee Creek) and to perform diet analysis. The diets of male Redbreast Sunfish were comprised of invertebrates. There was no difference between whole body caloric content of pre-spawn males between sites. However, post-spawn males exhibited greater caloric content in the regulated reach than in the unregulated tributary. Martin (2008) attributed this to lower temperature, and resulting lower energetic cost, related to generation in the regulated reach.

Irwin et al. (2011) sampled fish during spring and fall of 2005-2009 in two unregulated reaches upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively) and in three regulated reaches (Malone, Wadley, and Horseshoe Bend). The main purpose of the study was to investigate the effects of GP operations on the recovery of shoal species of greatest conservation need: Tallapoosa Darter (*Etheostoma tallapoosae*), Muscadine Darter (*Percina smithvanzini*), Lipstick Darter (*Etheostoma chuckwachatte*), Tallapoosa Shiner (*Cyprinella gibbsi*), Tallapoosa Sculpin (*Cottus tallapoosae*), and Stippled Studfish (*Fundulus bifax*). Methods from Bowen et al. (1996) were used to calculate IBI scores for spring and summer samples. IBI scores varied greatly among sites, within and among river reaches, between seasons, and among years. Overall, IBI scores were lower in regulated sites than in unregulated sites but scores were not always consistent. Occupancy and colonization estimates suggested that Tallapoosa Darter and Muscadine Darter were unaffected by Harris Dam operations, and high occupancy estimates and an extinction estimate of 0 in the regulated river indicated that Lipstick Darter may be positively affected by GP flow regulation. Irwin et al. (2011) hypothesized that flow management was maintaining the type of shallow habitat preferred by these three species. Furthermore, they are benthic species, meaning they occupy habitat near the riverbed and can likely find refuge from increased flows. Occupancy estimates suggested that Tallapoosa Shiner and Tallapoosa Sculpin were in decline and that Stippled Studfish were absent in the regulated river. The Tallapoosa Shiner usually dwells higher in the water column, so occasional high flows from generation are more likely to carry this species downstream. The Tallapoosa Sculpin and Stippled Studfish had generally low detection probabilities in both regulated and unregulated reaches, so reasons for their possible decline or absence in the regulated reaches are not explicit. Sucker species such as the Black Redhorse and Blacktail Redhorse (*Moxostoma poecilurum*) were also deemed possible species of concern whose populations may have declined in the regulated river due to a reduced availability of shoal habitat serving as spawning grounds for adults and refuge for juveniles (Boschung and Mayden 2004 as cited in Irwin et al. 2011).

Irwin et al. (2011) also measured reproductive condition and hatch date and found that regulated reaches generally had higher percentages of mature females than unregulated reaches. Specifically, Alabama Shiners showed high percentages of mature females in 2006 due to the frequency of pulses but low percentages in 2007 due to drought. Recruitment of Tallapoosa Shiners and Bullhead Minnows (*Pimephales vigilax*) may have been impacted by river regulation, but Tallapoosa Darters seemed to be reproducing and faring well downstream of the dam.

Irwin et al. (2011) also sampled crayfish to measure differences in CPUE, size distribution using the metric of carapace length, and species composition and found three species: White Tubercled Crayfish, Tallapoosa Crayfish, and Slackwater Crayfish. Juvenile crayfish were not identified by species but were included in analyses as a fourth category. Species CPUE did not differ between unregulated and regulated sites overall, but there was a slight difference when unidentified juveniles were excluded from analysis. When data for White Tubercled Crayfish were pooled, carapace length was greater in the regulated river than the unregulated; however, there were significant differences in carapace lengths between seasons and among years, and when regulated and unregulated reaches were compared by season and by year, significant differences in carapace length between unregulated and regulated sites were only found in the summer of 2007 for all three species. Percent composition of White Tubercled Crayfish and Tallapoosa Crayfish were greater in regulated sites. Estimates of detection and occupancy were also calculated. Generally, there was no indication of an effect of flow regulation on occupancy estimates for crayfish species with the exception of Tallapoosa Crayfish in 2006 and 2007 and juveniles in 2006. Occupancy estimates were greatest nearest to the dam. Detection was a function of habitat variables and was affected positively by vegetation and velocity and negatively by depth. Overall, fish and crayfish assemblages varied between regulated and unregulated reaches, within unregulated reaches, between seasons, and among years, suggesting there is a level of natural variability that exists within the Tallapoosa River.

Earley (2012) sampled Alabama Bass and Tallapoosa Bass[12] from 2009-2011 in two regulated sites between Horseshoe Bend and Germany's Ferry (lower site) and between

[12] Previously described in this region as Redeye Bass (Micropterus coosae), but later described as a separate species (*Micropterus tallapoosae*; Baker et al. 2013) and commonly referred to as Tallapoosa Bass.

Wadley and Price Island (middle site) and in an unregulated site on the upper Tallapoosa River upstream of Harris Dam (upper site). Earley (2012) found that Harris Dam operations had a small effect on growth of Alabama and Tallapoosa Bass. Greater growth in both species appeared to be related to years of minimal flow variability, although hydrology appeared to have a smaller effect on the growth of older fish. Alabama Bass growth was negatively affected by high and steady flows in the unregulated site, and both Alabama and Tallapoosa Bass growth were affected by variability of flow in the middle site, where flow variations were greatest. Alabama Bass in the middle site showed higher growth rates, possibly resulting from decreased intraspecies competition due to low density, increased foraging opportunities during pulses due to the drift of prey downstream (Cushman 1985 as cited in Earley 2012), or some effect of temperature. Additionally, movement of Alabama and Tallapoosa Bass was influenced by season, but flow periods (the study observed four categories of flow periods: base/low, rising, peak, and falling) and Harris Dam operations had little effect on movement and habitat use. Earley (2012) noted this may be due to the presence of velocity refugia such as boulders and large woody debris.

Earley (2012) also investigated the stress response of Alabama Bass and Tallapoosa Bass using cortisol as an indicator. Fish were sampled from a regulated site approximately 20 kilometers downstream of the dam and at two unregulated reference sites (Hillabee Creek and Saugahatchee Creek) in October and November 2011. Baseline cortisol levels, an indicator of physiological stress, were higher in fish at the regulated site compared to the unregulated sites; however, fish from the unregulated sites exhibited higher cortisol response when subjected to an additional confinement stressor than fish in the regulated site. Earley (2012) suggested lower cortisol response in the regulated site could indicate that fish below Harris Dam are acclimated to chronic stress or are trying to regain homeostasis (physiological equilibrium). Earley (2012) cited Hontela et al. (1992) and Norris et al. (1999) in support of this last theory, stating that the biological mechanism controlling the release of cortisol may not function at normal capacity in chronically stressed animals. Despite higher baseline cortisol levels in fish from the regulated site, there was no substantial effect on growth in fish at the regulated site and no difference in condition between the unregulated and regulated sites. Therefore, elevated baseline cortisol levels may not have decreased overall fitness of these species.

Goar (2013) sampled age-0 Redbreast Sunfish in 2005 and 2007-2009 to examine growth and hatchery success in regulated (Malone and Wadley) and unregulated sites upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively). Daily growth rate and incremental growth rate of age-0 Redbreast Sunfish varied among years and was greater at regulated sites than at unregulated sites, although overall model fit was poor. This was attributed to lower competition for resources among fish due to lower population density or higher prey density due to increased discharge. Modeling results did not indicate that hydrologic and temperature variables had an effect on incremental growth rates in age-0 Redbreast Sunfish; however, those variables did have an impact on hatching success. Hatch frequency was higher and occurred earlier in unregulated sites than in regulated sites. Most Redbreast Sunfish hatched when discharge was less than 7,770 cfs. When flows were greater than 7,770 cfs, adult Redbreast Sunfish often abandoned nests, causing the nests to fail (Martin 2008 as cited in Goar 2013). Redbreast Sunfish hatch rates were higher during drought years.

Goar (2013) also conducted laboratory experiments to examine the effects of fluctuating flows and water temperatures on early growth and survival of Channel Catfish fry and Alabama Bass fry and juveniles. Results suggested that simulated high flows and temperature fluctuations (decrease of ~10 ℃) had a negative effect on daily growth and survival of both species, but the negative effects of these treatments had a lesser effect on relatively older fish. Daily growth and survival were lowest in treatments with decreases in temperature, suggesting that growth and survival may be more impacted by fluctuations in temperature than by fluctuations in flow.

Sammons et al. (2013) examined potential impacts of dam operations on age and growth of Alabama Bass, Channel Catfish, Redbreast Sunfish, and Tallapoosa Bass (formerly Redeye Bass in this region at the time of this study) from 2009-2011. Fish were sampled in an unregulated reach of the Tallapoosa River upstream of the dam (upper reach), in a regulated reach between Price Island and Wadley (middle reach), and in a regulated reach between Germany's Ferry and Horseshoe Bend (lower reach). Recruitment of Alabama Bass and Channel Catfish was negatively affected by high flow variability in the unregulated reach but unaffected in regulated reaches. Recruitment of Tallapoosa Bass was unaffected by hydrologic variability in any portion of the river, but the short lifespan of this species may have reduced the ability of residual analysis to identify relationships between hydrology and recruitment. Recruitment of Channel Catfish was negatively affected by high flow in the unregulated reach. The hydrologic regime had a minor effect on the growth of all four species, which was likely biologically insignificant in Alabama and Tallapoosa Bass. However, for the bass species, growth of age-1 fish seemed to improve in years with low variability of flow.

Sammons et al. (2013) also investigated behavior and habitat use of Alabama and Tallapoosa Bass in response to hydrologic regimes in 2010 and 2011. The movement of both species was more affected by season than by dam operations, with more movement occurring during the spring. Both species moved during higher flow releases and likely sought refuge from higher water velocities. Alabama Bass typically showed more hourly movement than Tallapoosa Bass over most flow periods and seasons, indicating that Tallapoosa Bass may be a more sedentary species or that Alabama Bass adapt better to alternative flows. Increased flows caused Alabama Bass to move deeper in the winter and move toward the banks during other seasons. In the winter, Alabama Bass selected large rock substrates when flows increased while Tallapoosa Bass utilized smaller rock. In the spring, both species selected smaller rock or fine sediment during high flows. Overall, Tallapoosa Bass exhibited less lateral movement toward the banks in response to Harris Dam operations than Alabama Bass.

A third objective of Sammons et al. (2013) was to investigate impacts of flow on hatch date and growth of age-0 Alabama Bass, Redbreast Sunfish, and Tallapoosa Bass in 2010 and 2011. All three species generally started hatching earlier in the lower reach, which was less regulated due to attenuation of the effects of Harris Dam operations, compared to the middle and upper reaches below Harris Dam. Fish that hatch later in the season often grow faster due to warmer temperatures, less variable hydrology, and a greater abundance of food. However, fish that hatch earlier have the advantage of an extended growing season, which may allow them to reach sizes similar to later-hatched fish near the end of the first growing season (Diana 1995 as cited in Sammons et al. 2013). Continuous hatching distributions were seen in Alabama Bass, Redbreast Sunfish, and Tallapoosa Bass in 2011, a year in which flows were lower and more stable in both regulated and unregulated reaches. In 2010, the growth rate of Alabama Bass was greater in the unregulated reach than in the regulated reaches, but in 2011, the growth of both bass species was greatest in the middle reach where the flow effects of Harris Dam operations were greater. This may be the result of drought conditions that year, which prevented Harris Dam from conducting daily hydropeaking discharges and reduced the effects of Harris Dam operations. Researchers concluded that the dam can cause substantial fluctuation in flow that attenuates downstream, but there were no large differences in spawning or age-0 growth among areas sampled, both unregulated and regulated. All species showed an unexpected ability to hatch successfully even during sudden movements of water through the river, but both years sampled were characterized by below-average rainfall. Sampling effort was not recorded, but catch rates of age-0 fish of all three species were noticeably higher in the lower and upper reaches than in the middle reach, which indicated that recruitment at the population level was likely being affected in the middle reach.

Gerken (2015) sampled fish to measure catch rates, species size and composition, and the effects of environmental impacts on catch rates of sport fish from 2013-2015. Fish were sampled at an unregulated reach between Heflin and the uppermost unimpounded section of the Tallapoosa River (upper reach), a regulated reach from Malone to Wadley (middle reach), and another regulated reach between Germany's Ferry and Horseshoe Bend (lower reach). A total of 10 species were caught during sampling: Alabama Bass, Redbreast Sunfish, Tallapoosa Bass, Bluegill, White Crappie (*Pomoxis annularis*), Striped Bass (*Morone saxatilis*), Largemouth Bass, Shadow Bass (*Ambloplites ariommus*), White Bass, and Channel Catfish. Gerken (2015) determined that lower water temperatures resulting from dam releases may affect fishing success for Redbreast Sunfish. In the lower reach, where the effects of dam operations are not likely as great as the effects at the middle reach, Redbreast Sunfish were caught most frequently, followed by Alabama Bass and then Tallapoosa Bass. Specific variables correlated with harvest-per-unit-effort were calculated for the three most common species captured in the study: Alabama Bass, Tallapoosa Bass, and Redbreast Sunfish. HPUE of Alabama Bass and Redbreast Sunfish was positively correlated with water temperature and negatively correlated with discharge, and HPUE of Tallapoosa Bass was negatively correlated to both water temperature and discharge.

Irwin and Goar (2015) measured the influence of hydrology on growth and hatching success of age-0 black bass species and Channel Catfish in both regulated (Malone, Wadley, and Horseshoe Bend) and unregulated reaches upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively) from 2010-2014. Growth was generally greatest among age-0 fish in regulated reaches. In regulated reaches, most hatching occurred during times of low, stable flow. Initial hatches also occurred later (with the exception of 2013) and generally over a shorter period of time than in the unregulated reaches. Hatches sometimes seemed to occur during unfavorable temperature conditions but may be attributed to recruitment from warmer tributaries. In regulated reaches, suitable conditions for Channel Catfish spawning do not occur until later in the year compared to unregulated reaches, likely due to cooler temperatures. Irwin and Goar (2015) reported faster growth rates in age-0 fish downstream of the dam, citing similar findings in Sakaris (2006), Earley (2012), and Goar (2013), and attributed these findings to less intraspecific competition for resources resulting from lower densities of fish downstream of the dam. An alternative theory proposed by Irwin and Goar (2015) is that fish collected in these areas are survivors of these conditions and are therefore more genetically suited for faster growth rates. Models predicted overall that daily incremental growth was positively correlated with low flow parameters and negatively correlated with flow fluctuations. The study suggests that hatching success could increase if 10-15-day spawning periods of stable flows < 5,000 cfs are provided in the spring and summer months.

Kennedy (2015) used a modeling framework to estimate occupancy, colonization, and extinction rates of fish collected from 2005-2010 in regulated (between Harris Dam and Malone, between Malone and Wadley, and near Horseshoe Bend) and unregulated reaches upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively). Fifty species of fish were collected from the 22 sites sampled in the Piedmont region of the Tallapoosa River Basin. Of these species, 13 had high detection (detected in a minimum of 40 replicates across all years sampled) in one or more of the 22 sampled sites. Most species observed showed changes in occupancy as distance from the Harris Dam increased, indicating attenuation of the effects of Harris Dam operations further downstream. Blacktail Shiner, Speckled Darter (*Etheostoma stigmaeum*), Tallapoosa Darter, and Bronze Darter did not show an obvious occupancy pattern with distance from the dam. Consistent flows in regulated reaches lead to an increase in availability of deep, fast habitat which likely resulted in an increase in occupancy of the Alabama Shiner. Largescale Stoneroller and Alabama Hog Sucker both had occupancy probabilities estimated to decline in regulated reaches but stay consistent in unregulated reaches throughout the study. Low abundance of Largescale Stoneroller and Alabama Hog Sucker in regulated reaches has been attributed to a low persistence of spawning habitat during the spring (Freeman et al. 2001 as cited in Kennedy 2015). Redbreast Sunfish and Muscadine Darter also had estimated decreases in occupancy during the duration of sampling. Juvenile Muscadine Darter prefer shallow, slow water habitats and Redbreast Sunfish require shallow and stable habitat for spawning. These species' decline in occupancy was attributed to changes in the availability and persistence of suitable physical and thermal habitat. Redbreast Sunfish, Muscadine Darter, and Bullhead Minnow all showed increased occupancy in unregulated reaches, possibly due to drought conditions that created favorable habitat. Occupancy of Tallapoosa Shiner was estimated to increase in regulated reaches due to increased baseflow; and decrease in unregulated reaches, possibly due to shallow, slow habitat during the study. By the end of sampling in 2010, occupancy probabilities of Tallapoosa Shiner did not differ among sites. Kennedy

(2015) stated that tributaries can cause increases in baseflows and attenuation of hydrological effects of dams, could provide refuge from unfavorable mainstem conditions, and could serve as a source to supplement populations of fish in the mainstem, citing Bruns et al. (1984), Bain and Boltz (1989), and Kingsolving and Bain (1993). Kennedy (2015) therefore concluded that the 2007 drought may have caused fish to migrate out of tributaries and increase occupancy in the mainstem.

Lloyd et al. (2017) stocked marked juvenile Redbreast Sunfish and Channel Catfish in regulated areas below Harris Dam in 2015 and 2016 to determine if stocking these species could affect year-class strength. Redbreast Sunfish were marked by immersion in oxytetracycline to mark calcified structures of the fish. Stocked Channel Catfish were genetically distinguishable from native Channel Catfish and therefore did not need to be marked. Redbreast Sunfish did not uptake the marker (determined by withholding some marked fish from stocking) and no marked Channel Catfish were recaptured. The lack of recovered Channel Catfish may have been due to high mortality, predation, or emigration to tributaries or the downstream reservoir (Lake Martin) to escape thermal or hydrologic changes or to pursue better foraging opportunities. Length data gathered from the study showed low numbers of 150-250 mm Channel Catfish, a size class in which the stocked juveniles would likely belong. This was attributed to the likelihood of environmental bottlenecks for recruitment of this species.

Lloyd et al. (2017) also estimated growth, mortality, and recruitment in Channel Catfish and observed age-specific survivorship and fecundity rates in 2015 and 2016. The Channel Catfish population consisted of fish from ages 0 to 17. Capture rates were generally low but were highest at Horseshoe Bend. Temperature data was collected in both unregulated and regulated reaches and used to calculate cumulative degree days (°D) for Channel Catfish spawning for 2005-2016. In the regulated portion, median conditions for spawning (100°D) occurred in 7 out of 12 years and occurred as early as July 8. In the unregulated site, thermal spawning conditions occurred every year and were reached earlier than in regulated reaches every year. Population models determined that survival to age-1 was estimated to be < 0.03 percent and survival of fish at the first four age classes had the most substantial effect on population growth. Nash (1999), as cited in Lloyd et al. (2017), stated that low capture rates of younger fish and a lack of optimal thermal conditions for spawning could indicate recruitment overfishing.[13]

[13] Recruitment overfishing occurs when the population of mature, spawning adults is harvested at a rate that prevents the overall population from replenishing itself.

Irwin (2019) assessed the occupancy of shoal dwelling fish species above and below Harris Dam from 2005-2016. Specifically, Irwin (2019) measured persistence (defined as the likelihood of a fish species present one year being present the following year) and colonization (defined as the likelihood of an absent fish species being present the following year), noting that wet years were underrepresented and dry/drought years were common during the study period. Fish were sampled from both regulated sites (reaches near Malone, Wadley, and Horseshoe Bend) and unregulated sites upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively). A total of 46 species were recorded over the duration of the study. Overall, fishes exhibited lower persistence and colonization rates at regulated sites than at unregulated sites, and there were considerable differences found among sites and years. Models of the effects of river regulation indicated lower probabilities of persistence and colonization of fishes at regulated sites compared to unregulated sites, which was attributed to flow instability and reduced temperatures. However, location downstream from the dam had an estimated positive effect on persistence of 23.7 percent of sampled species and an estimated positive effect on colonization of Shadow Bass and Lipstick Darter. Irwin (2019) stated that adults of the majority of species could likely persist below Harris Dam, but the GP may not be conducive to colonization rates capable of increasing populations. IBI scores calculated from data gathered in Irwin (2019) are available in Alabama Power and Kleinschmidt (2018).

Irwin (2019) also assessed the macroinvertebrate community from 2005-2017 in both regulated (Malone, Wadley, Horseshoe Bend) and unregulated sites upstream and downstream of Harris Dam (Heflin and Hillabee Creek, respectively). The macroinvertebrate communities downstream of Harris Dam had overall lower diversity but greater density characterized by increased numbers of taxa that are tolerant to flow disturbance and the absence of some flow-sensitive species. More specifically, the average density of caddisflies (Trichoptera) was over three times greater in regulated sites than in unregulated sites. Mayflies (Ephemeroptera), true flies (Diptera), and caddisflies dominated regulated sites. Mayflies, true flies, and beetles (Coleoptera) dominated unregulated sites. Specifically, mayflies in regulated sites were mostly comprised of small minnow mayflies (baetids). True flies were mostly comprised of non-biting midges (chironomids) in regulated sites and both non-biting midges and black flies (simuliids) in unregulated sites. Greater diversity was found within the five most dominant orders (true flies, caddisflies, mayflies, beetles, and aquatic oligochaete worms (Tubificida)) in unregulated sites than in regulated sites. The absence of burrowing taxa requiring finer burrowing sediments and the abundance of generalist feeders in regulated sites suggest hydropeaking releases may reduce habitat and foraging resources for some species.

TABLE 2-7 SUMMARY OF FINDINGS FROM STUDIES IN THE TALLAPOOSA RIVER BELOW HARRIS DAM

Source	Years Sampled	Findings
Swingle 1954	1949, 1951	Pre-Harris Reservoir surveys showed productivity in the Tallapoosa River was much lower than in other Alabama rivers
Travnichek and Maceina 1994	1990-1992	Sport fish catch rates in deep water habitats same in regulated vs. unregulated
		Catostomid (sucker) species densities higher in unregulated
		Overall, densities higher in unregulated than regulated
Bowen et al. 1996	1990-1992[14], 1994, 1995	Mean IBI scores typically higher in unregulated than in regulated
Irwin and Hornsby 1997	1996	Sample composition dominated by centrarchids, compared to cyprinids and ictalurids in 1951
		Recruitment of ictalurids and catostomids possibly impacted by regulation
Johnson 1997	1995	Yellow Elimia and an invasive species of Asian clam were present at nearly every mainstem and tributary survey site within the Project Area
Bowen et al. 1998	1994, 1995	Lower average duration persistence of shallow water habitats may explain reduced densities of suckers
Irwin and Belcher 1999	1997, 1998	Creel data showed mostly catches of centrarchids (bass and sunfish) followed by ictalurids (catfish)
		Overall, catch-per-unit-effort lower than in 1970s
		Catch-per-unit-effort of Alabama Bass higher than in 1970s
Freeman et al. 2001	1994-1997	Young-of-year abundance in regulated reach most commonly correlated with persistence of shallow habitat than with availability or intensity of flow extremes
		In regulated reach, habitat persistence levels similar to those in unregulated reaches only occurred in summer
		Summer-spawning species were large portion of assemblage at regulated reach and most spring-spawning species were less abundant at regulated sites
Irwin et al. 2001	1999, 2000	Nest success of Redbreast Sunfish greater when flows are less variable, lower in magnitude, and when there are longer periods of non-generation
		Extremely high flows can cause nest failure
Sakaris 2006	2005	Age-0 catfish grew faster in regulated reaches
		Prolonged hatching period in regulated reaches

[14] Data collected by Travnichek and Maceina (1994) during 1990-1992 was used in this study in addition to data collected in 1994 and 1995.

Source	Years Sampled	Findings
Martin 2008	2006, 2007	Redbreast Sunfish abandon nests during peak flows
		Redbreast Sunfish consumption was always positively correlated with temperature in regulated river, where thermal maxima was 28℃, but decreased in unregulated reach at the thermal maximum of 33℃
		Greater whole body caloric content of post-spawn males in regulated reaches may be attributed to lower temperatures reducing metabolic cost
Irwin et al. 2011	2005-2009	IBI scores lower at regulated sites, but varied widely
		Tallapoosa Darter and Muscadine Darter possibly unaffected by Harris Dam operations
		Lipstick Darter may be positively affected by GP
		Tallapoosa Shiner, Tallapoosa Sculpin, Black Redhorse, and Blacktail Redhorse possibly in decline downstream of Harris Dam
		Stippled Studfish possibly absent downstream of Harris Dam
Earley 2012	2009-2011	Altered hydrologic regime had a minor effect on growth and movement of Alabama and Tallapoosa Bass, but did have an effect on habitat use
		Fish at regulated sites more stressed
Goar 2013	2005, 2007-2009	Fish growth rates higher at regulated sites
		Hatch frequency of Redbreast Sunfish was higher and occurred earlier in unregulated sites
		Flow and temperature fluctuations (decrease of ~10 ℃) in lab studies negatively impacted growth and survival of age-0 Channel Catfish and Alabama Bass
		Growth and survival may be more impacted by fluctuations in temperature than fluctuations in flow
Sammons et al. 2013	2009-2011	No strong evidence that growth, mortality, or recruitment of Alabama Bass, Tallapoosa Bass, Channel Catfish, and Redbreast Sunfish were heavily impacted by flow
		During high flows, Alabama Bass were found close to shore in spring and summer and in rock habitat in winter, while Tallapoosa Bass moved close to shore in spring but showed no change in habitat use during other seasons
Gerken 2015	2013-2015	Water temperature positively correlated with harvest-per-unit-effort
		Discharge negatively correlated with harvest-per-unit-effort of Alabama Bass, Tallapoosa Bass, and Redbreast Sunfish
Irwin and Goar 2015	2010-2014	Growth of age-0 fish generally higher at regulated sites

Source	Years Sampled	Findings
		Daily incremental growth positively correlated with low flow parameters and negatively correlated with flow fluctuations
Kennedy 2015	2005-2010	Species occupancy probabilities increased with distance from Harris Dam
		Some species' occupancy probabilities were greater in the unregulated reaches and some were greater in the regulated
Lloyd et al. 2017	2015, 2016	Possible environmental bottlenecks for recruitment of Channel Catfish
		Thermal spawning conditions for Channel Catfish met more frequently in unregulated site and occurred earlier
Irwin 2019	2005-2017	Overall lower persistence and colonization rates of fish species in regulated sites than in unregulated sites
		Macroinvertebrates showed greater density in regulated sites and greater richness in unregulated sites
		Macroinvertebrates that are generalist feeders are more abundant in regulated sites

2.4 Summary

The following is a summary of the available information pertaining to aquatic resources in the Tallapoosa River downstream of Harris Dam as interpreted by Alabama Power.

An estimated 139 species of fish have been known to occur within the TRB: 15 are non-native and three are possibly extirpated (Gulf Sturgeon, Alabama Surgeon, and Alabama Shad). An estimated 45 mussel species have been known to occur within the TRB: one is considered extirpated, nine are considered imperiled or critically imperiled, two are considered threatened, and three are considered endangered.

In the spring, Alabama Power coordinates with ADCNR to maintain Harris Reservoir at a stable or slightly rising elevation for a two-week period to increase spawning success of sport fish species, including Largemouth Bass, Alabama Bass, and Black Crappie in Harris Reservoir. A 13-16 inch slot limit was implemented in 1993 for all black bass species (Andress and Catchings 2005) but was later removed from Alabama Bass in 2006 (Andress and Catchings 2006). Since then, black bass population metrics and conditions have improved (Holley et al. 2012). Black Crappie have exhibited greater growth rates and size structures in the reservoir than in the river (Hartline et al. 2018).

After construction of Harris Dam, the Tallapoosa River downstream was initially regulated by peaking operations only, with no intermittent flows between peaks. Rotenone surveys conducted before and after construction of the dam suggested a decrease in abundance and biomass of fishes as well as a shift from a cyprinid and ictalurid dominated community to a centrarchid dominated community (Swingle 1954; Irwin and Hornsby 1997). In studies comparing the regulated portion of the river to unregulated reaches, the unregulated reaches typically showed higher IBI scores, and higher discharges were found to negatively affect IBI scores (Bowen et al. 1996). River regulation, which limited the amount and persistence of shallow habitat, appeared to affect fish that preferred those habitats more so than those that prefer deeper habitat (Travnichek and Maceina 1994; Bowen et al. 1998). Increased availability of these shallow water habitats during spring and summer would likely increase reproductive success in a large variety of species (Bowen et al. 1998). However, the abundance of some species did not appear to differ in regulated reaches (Travnichek and Maceina 1994). Hydropeaking could also reduce nest success by causing physical damage to nests (Irwin et al. 2001) or by causing nest abandonment (Martin 2008). Nest success appears to be more affected by discharge than thermal regime (Irwin et al. 2001) and is more likely greater when flows are less variable, lower in magnitude, and when periods of non-generation are longer (Irwin et al. 2001).

The GP was introduced in 2005 to reduce operational effects on downstream aquatic habitats. Spawning success of some species may benefit from periods of low and stable flow conditions in the summer and a moderate number of high pulses with steady fall rates (Sakaris 2006). The maintenance of higher minimum flow has been recommended to enhance growth and spawning success in Channel Catfish (Sakaris 2006). Spawning windows with suitable conditions of 10-15 days have also been recommended (Andress 2001; Martin 2008; Irwin and Goar 2015); however, thermal differences have been reported between unregulated and regulated reaches due to discharges being below ambient temperature. Channel Catfish appear to have a delayed spawning period below Harris Dam, possibly due to lower temperatures (Sakaris 2006), and some species tend to hatch earlier in less regulated reaches (Sammons et al. 2013; Lloyd et al. 2017). Conversely, growth rates of some species have been found to be higher in regulated reaches, possibly due to lower fish densities and a resulting lack of intraspecific competition for resources (Sakaris 2006; Earley 2012; Goar 2013). Some studies have found no significant differences in spawning or age-0 growth between unregulated and regulated reaches (Sammons et al. 2013).

3.0 TEMPERATURE IN THE TALLAPOOSA RIVER

3.1 Introduction

Alabama Power gathered water temperature data from May 2019 through April 2020 from 20 water temperature and level loggers installed in the Tallapoosa River from the tailrace of Harris Dam to Irwin Shoals (Figure 3-1) in April 2019. Loggers were set to record measurements at 15-minute intervals. Data was downloaded from loggers in the field twice between May 2019 and April 2020 to prevent the loggers from reaching their data storage capacity. On one occasion, malfunctioning equipment caused faulty data transfers and portions of data were lost from four loggers (logger #s 12, 14, 18, 20) (Figure 3-1). Therefore, four of the 20 loggers, including the logger at Irwin Shoals, did not provide continuous, 15-minute data through April 2020 and were omitted from analysis.

When considering the results, it is important to note that the data includes the effects of inflows from numerous tributaries within the Study Area. These inflows, especially during localized or widespread storm events, could have considerable effects on temperature at individual monitoring sites, depending on the magnitude and duration of the storm/high flow event. It is also worth noting that river flows during August and September of 2019, typically the warmest months of the year, were well below normal which could have resulted in greater daily and hourly temperature fluctuations when compared to a typical year.

Air temperatures between May 2019 and April 2020, as measured at Alexander City, AL (Station USC00010160; NOAA 2020), ranged from a maximum of 38.3 ℃ (101 ℉; September 18, 2019) to a minimum of -7.8 ℃ (18 ℉; November 13, 2019). Average air temperatures from May 2019 to April 2020 were generally slightly warmer than 30-year normals, with the exception of November 2019 being slightly cooler (Figure 3-2).

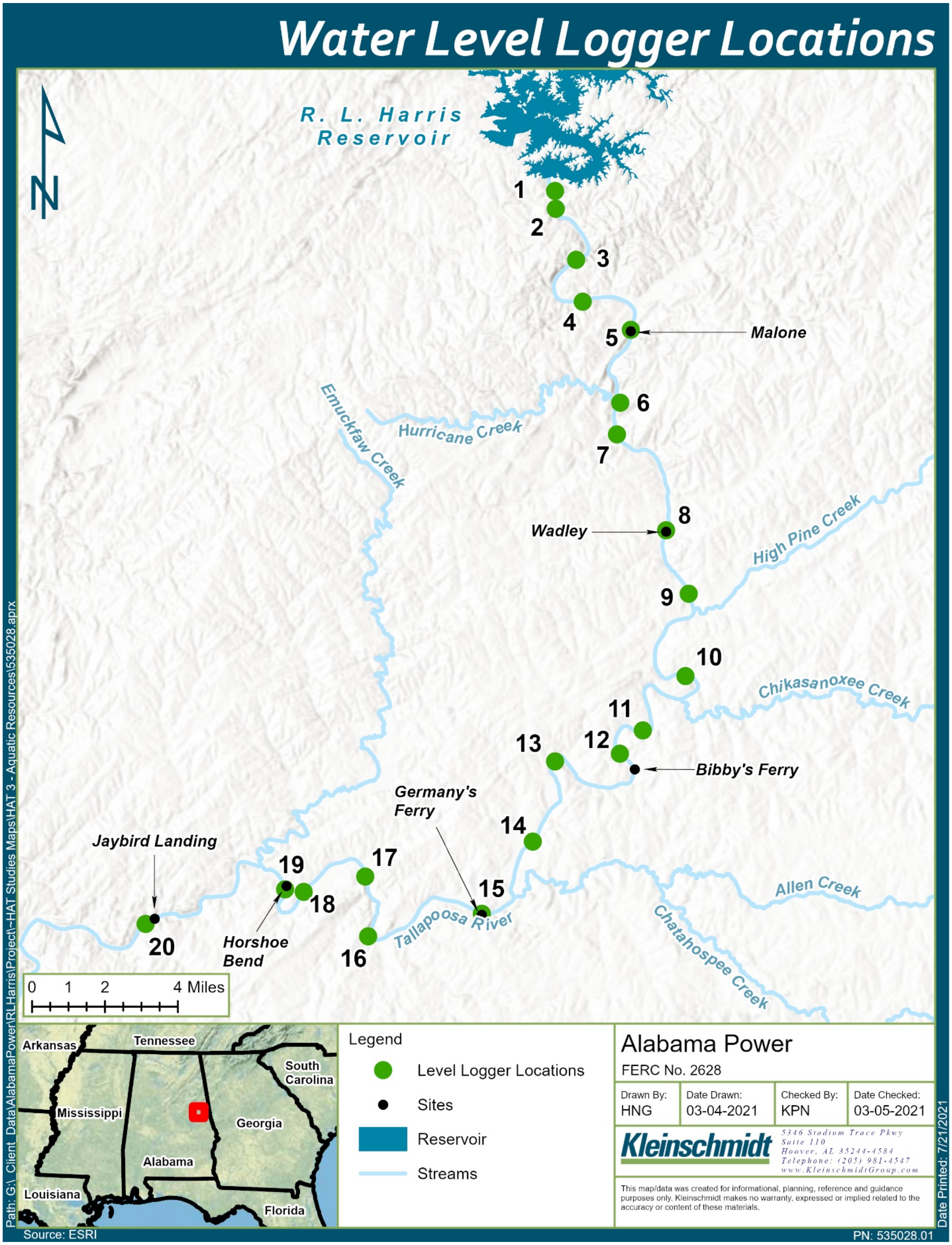

FIGURE 3-1 WATER LEVEL LOGGER LOCATIONS

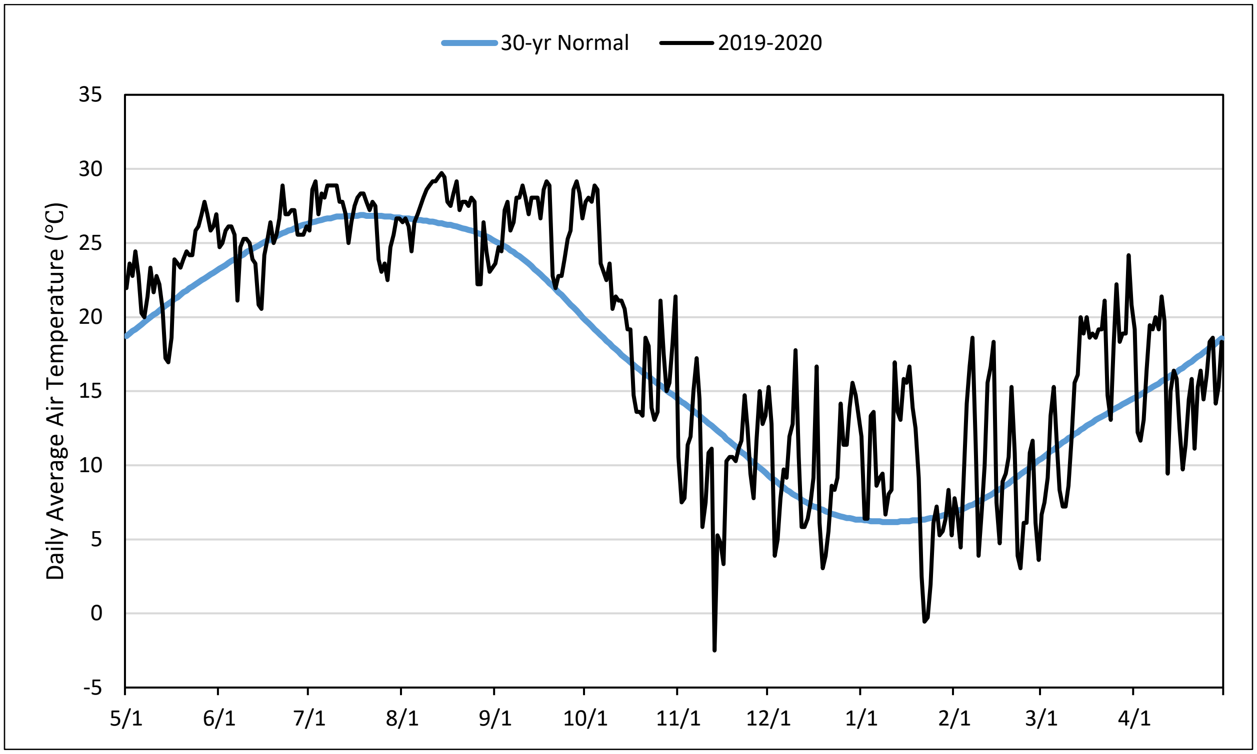

FIGURE 3-2 30-YEAR NORMAL AND 2019-2020 AIR TEMPERATURES

3.1.1 Water Temperature – Tallapoosa River Below Harris Dam

Water level logger data were aggregated by month and location to depict the annual trend for the May 1, 2019 through April 30, 2020 monitoring period. Water temperatures were generally highest in July through September and lowest in December through February. Water temperatures generally increased with increasing distance from Harris Dam (Figure 3-3). Water temperature data were analyzed to determine how water temperatures fluctuate at daily and hourly intervals. The difference between the maximum and minimum water temperature was calculated for each day and each hour between May 1, 2019 and April 30, 2020. Average daily water temperature fluctuations ranged from 4.1 to 1.0 °C and decreased with increasing distance from Harris Dam (Figure 3-4; Table 3-1). Average hourly water temperature fluctuations ranged from 0.38 to 0.05 °C and decreased with increasing distance from Harris Dam (Figure 3-5; Table 3-2). Maximum daily and hourly temperature fluctuations were usually the result of prolonged periods of non-generation creating relatively shallow, still conditions that were more heavily influenced by solar radiation or surrounding air temperature, followed by a release from Harris Dam. Histograms summarizing the frequency and magnitude of hourly water temperature fluctuations for each logger location are presented in Appendix C.

3.1.2 Water Temperature – Unregulated Tallapoosa and Little Tallapoosa Rivers

Water temperature was collected from the USGS gages at Heflin and Newell from May 2019 to April 2020 and compared with temperatures at regulated locations. Average daily water temperature was typically higher at Heflin and Newell than at the tailrace and Malone during the months of May through August (Figure 3-6). During the months of October through January, water temperatures at Heflin and Newell were typically lower, but occasionally met or exceeded temperatures in the regulated Tallapoosa River (Figure 3-6). Average seasonal temperatures were warmer at Heflin and Newell than at the Tailrace and Malone during spring and summer and cooler at Heflin and Newell than all regulated sites during fall and winter (Table 3-3).

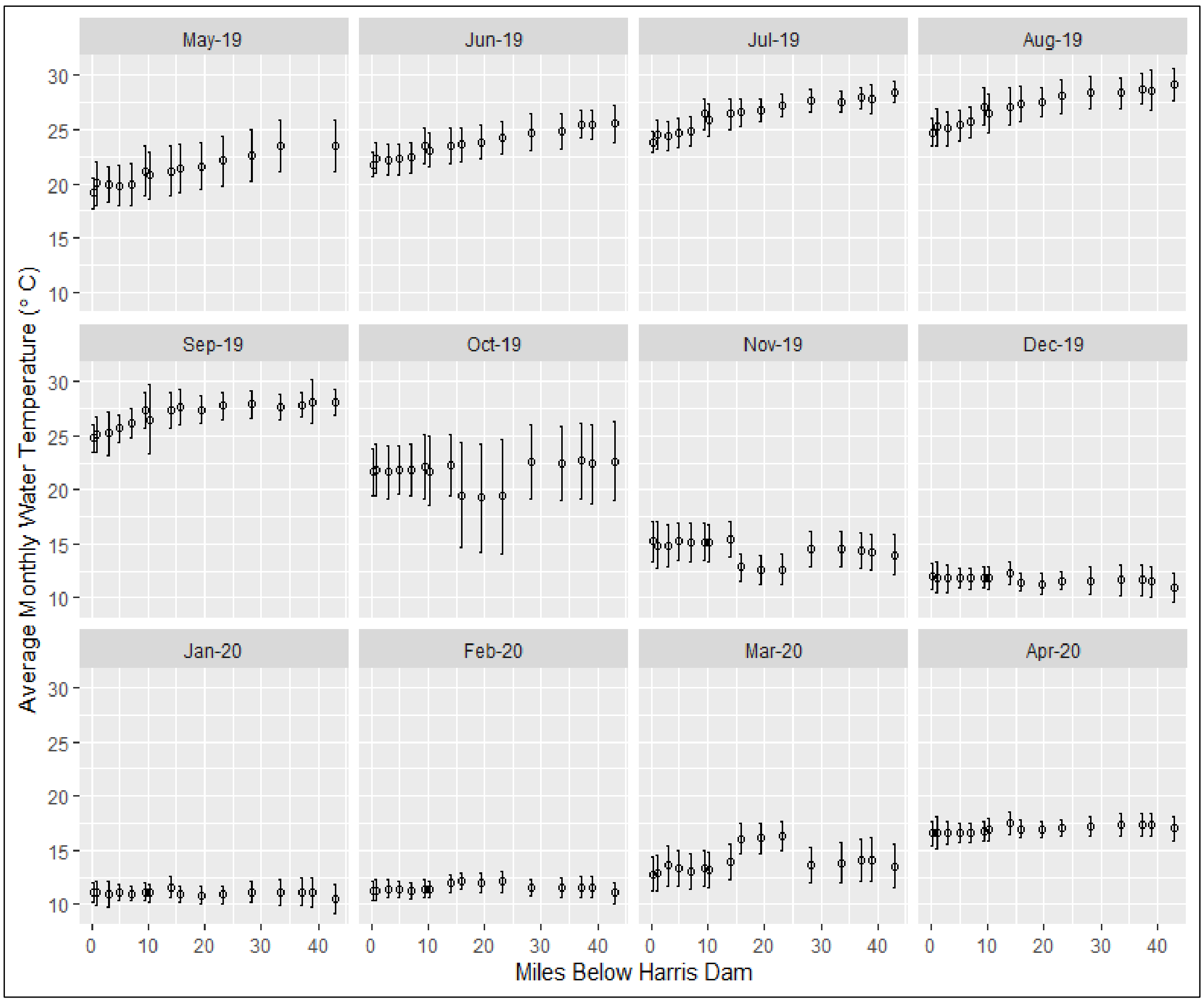

FIGURE 3-3 MONTHLY AVERAGE WATER TEMPERATURE FROM MAY 2019 – APRIL 2020

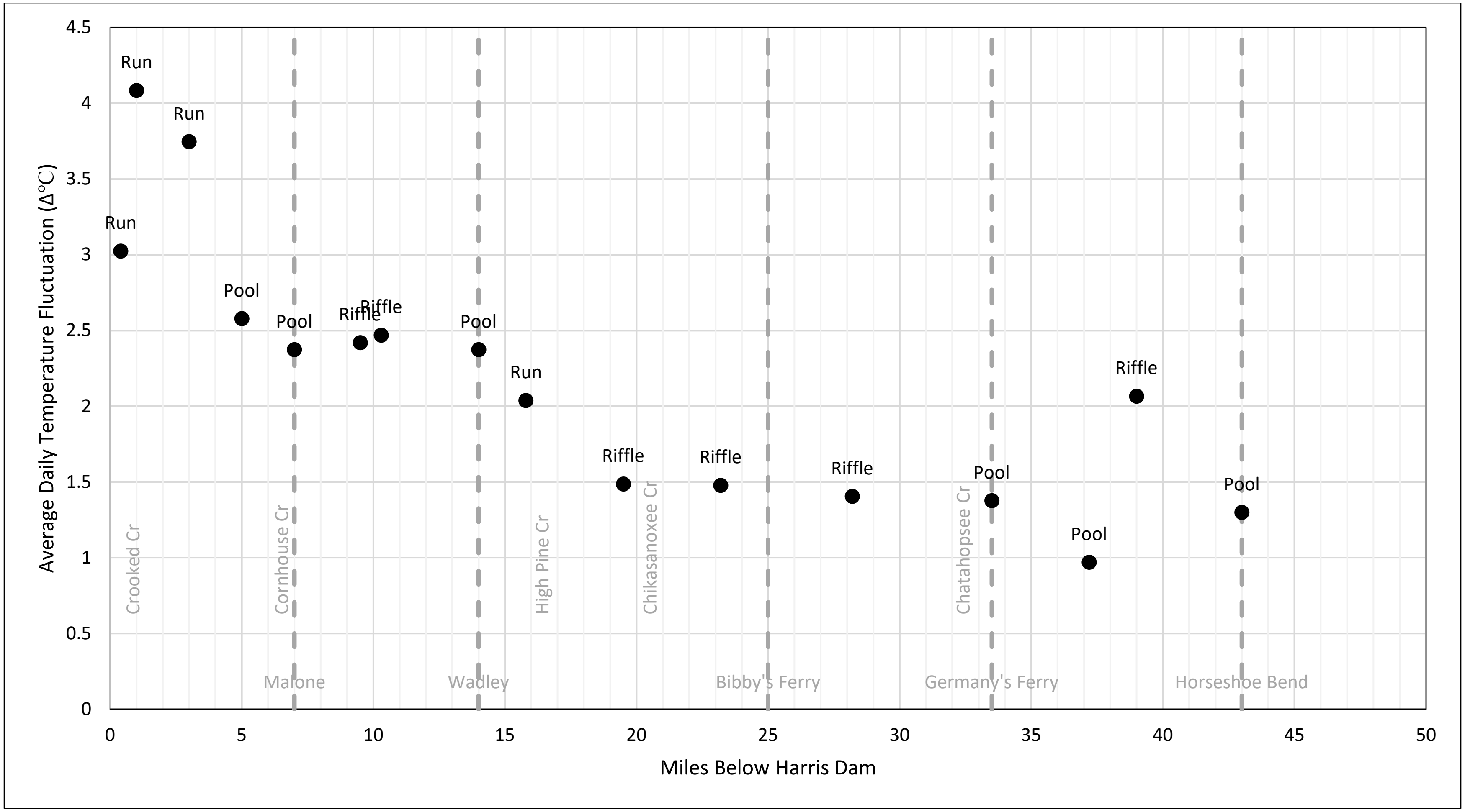

FIGURE 3-4 AVERAGE DAILY WATER TEMPERATURE FLUCTUATION FROM MAY 2019 TO APRIL 2020

TABLE 3-1 SUMMARY OF DAILY WATER TEMPERATURE FLUCTUATIONS

Reach	Miles Below Harris Dam	Logger Number	Mesohabitat Type	Mean[1] (°C)	Minimum (°C)	Maximum (°C)	Median (°C)	25th Percentile (°C)	75th Percentile (°C)
Malone	0.4	1	Run	3.0 (1.6)	0.1	7.3	3.3	1.8	4.2
	1.0	2	Run	4.1 (2.2)	0.1	8.8	4.4	2.4	5.6
	3.0	3	Run	3.7 (2.2)	0.1	8.7	3.8	1.8	5.4
	5.0	4	Pool	2.6 (1.4)	0.0	6.3	2.5	1.4	3.8
	7.0	5	Pool	2.4 (1.2)	0.2	5.1	2.3	1.6	3.8
Wadley	9.5	6	Riffle	2.4 (1.2)	0.1	5.1	2.5	1.4	3.4
	10.3	7	Riffle	2.5 (1.5)	0.1	6.5	2.3	1.2	3.6
	14.0	8	Pool	2.4 (1.2)	0.2	5.1	2.3	1.4	3.4
Bibby's Ferry	15.8	9	Run	2.0 (1.1)	0.2	5.0	2.0	1.1	3.0
	19.5	10	Riffle	1.5 (0.7)	0.2	4.5	1.4	1.1	1.8
	23.2	11	Riffle	1.5 (0.7)	0.2	5.1	1.4	1.0	1.9
Germany's Ferry	28.2	13	Riffle	1.4 (0.7)	0.1	3.6	1.4	0.9	1.9
	33.5	15	Pool	1.4 (0.6)	0.2	3.9	1.3	1.0	1.7
Horseshoe Bend	37.2	16	Pool	1.0 (0.5)	0.2	3.9	0.9	0.7	1.2
	39.0	17	Riffle	2.1 (1.4)	0.3	6.5	1.7	1.0	2.8
	43.0	19	Pool	1.3 (0.6)	0.2	3.2	1.2	0.9	1.6

[1]Standard Deviation in Parentheses

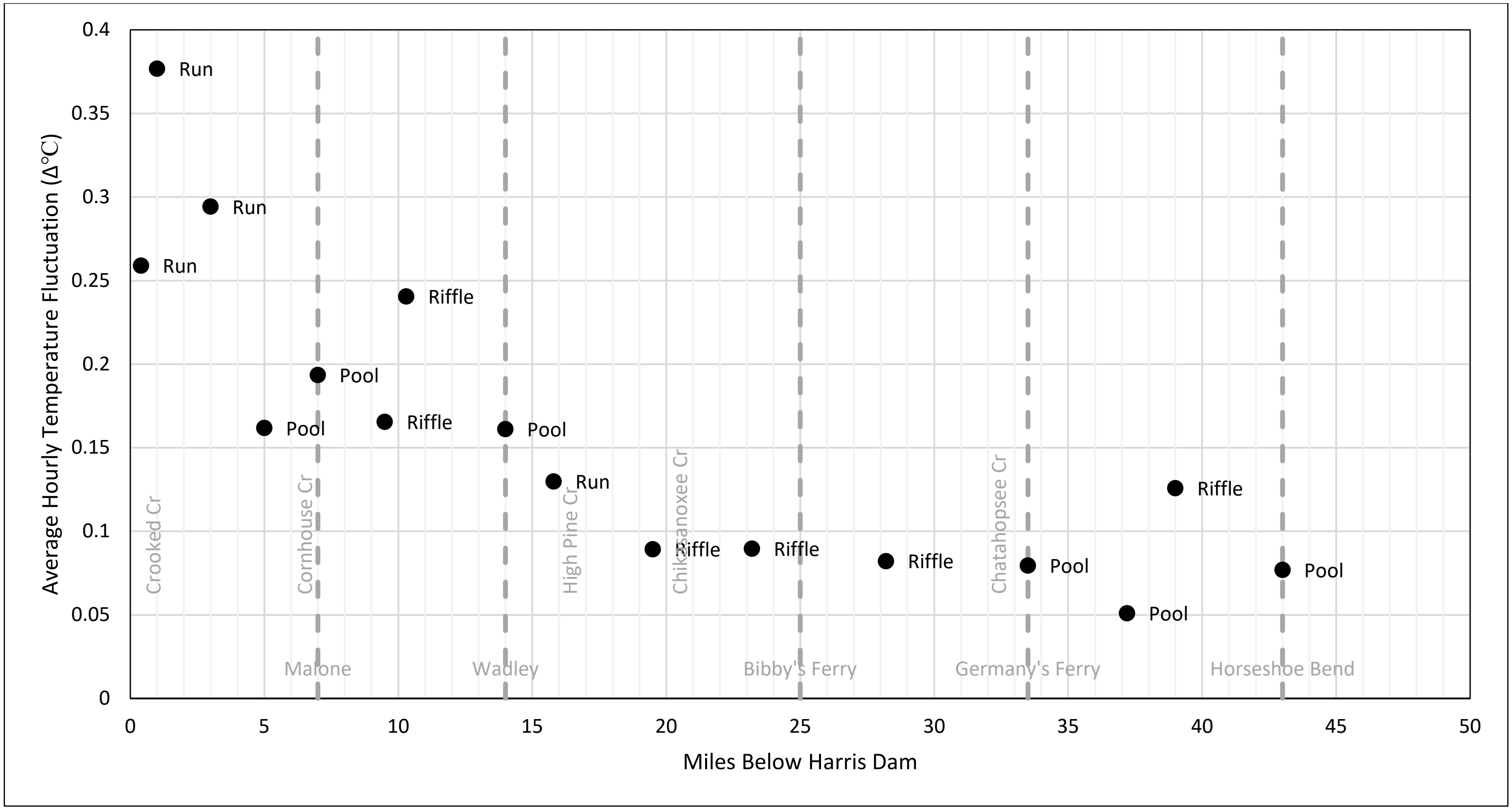

FIGURE 3-5 AVERAGE HOURLY TEMPERATURE FLUCTUATION FROM MAY 2019 TO APRIL 2020

TABLE 3-2 SUMMARY OF HOURLY WATER TEMPERATURE FLUCTUATIONS

Reach	Miles Below Harris Dam	Logger #	Mesohabitat Type	Mean[1] (°C)	Min. (°C)	Max. (°C)	Median (°C)	25th Percentile (°C)	75th Percentile (°C)
Malone	0.4	1	Run	0.26 (0.48)	0.00	5.68	0.10	0.00	0.29
	1.0	2	Run	0.38 (0.73)	0.00	6.90	0.10	0.00	0.38
	3.0	3	Run	0.29 (0.51)	0.00	5.70	0.10	0.10	0.29
	5.0	4	Pool	0.16 (0.23)	0.00	3.40	0.10	0.00	0.19
	7.0	5	Pool	0.19 (0.33)	0.00	4.20	0.10	0.00	0.20
Wadley	9.5	6	Riffle	0.17 (0.19)	0.00	2.57	0.10	0.00	0.20
	10.3	7	Riffle	0.24 (0.32)	0.00	3.78	0.10	0.10	0.29
	14.0	8	Pool	0.16 (0.19)	0.00	3.10	0.10	0.00	0.20
Bibby's Ferry	15.8	9	Run	0.13 (0.15)	0.00	1.29	0.10	0.00	0.19
	19.5	10	Riffle	0.09 (0.11)	0.00	4.12	0.10	0.00	0.10
	23.2	11	Riffle	0.09 (0.09)	0.00	1.18	0.10	0.00	0.10
Germany's Ferry	28.2	13	Riffle	0.08 (0.09)	0.00	1.15	0.10	0.00	0.10
	33.5	15	Pool	0.08 (0.08)	0.00	0.79	0.10	0.00	0.10
Horseshoe Bend	37.2	16	Pool	0.05 (0.06)	0.00	1.14	0.00	0.00	0.10
	39.0	17	Riffle	0.13 (0.15)	0.00	2.03	0.10	0.00	0.20
	43.0	19	Pool	0.08 (0.08)	0.00	0.80	0.10	0.00	0.10

[1] Standard Deviation in Parentheses

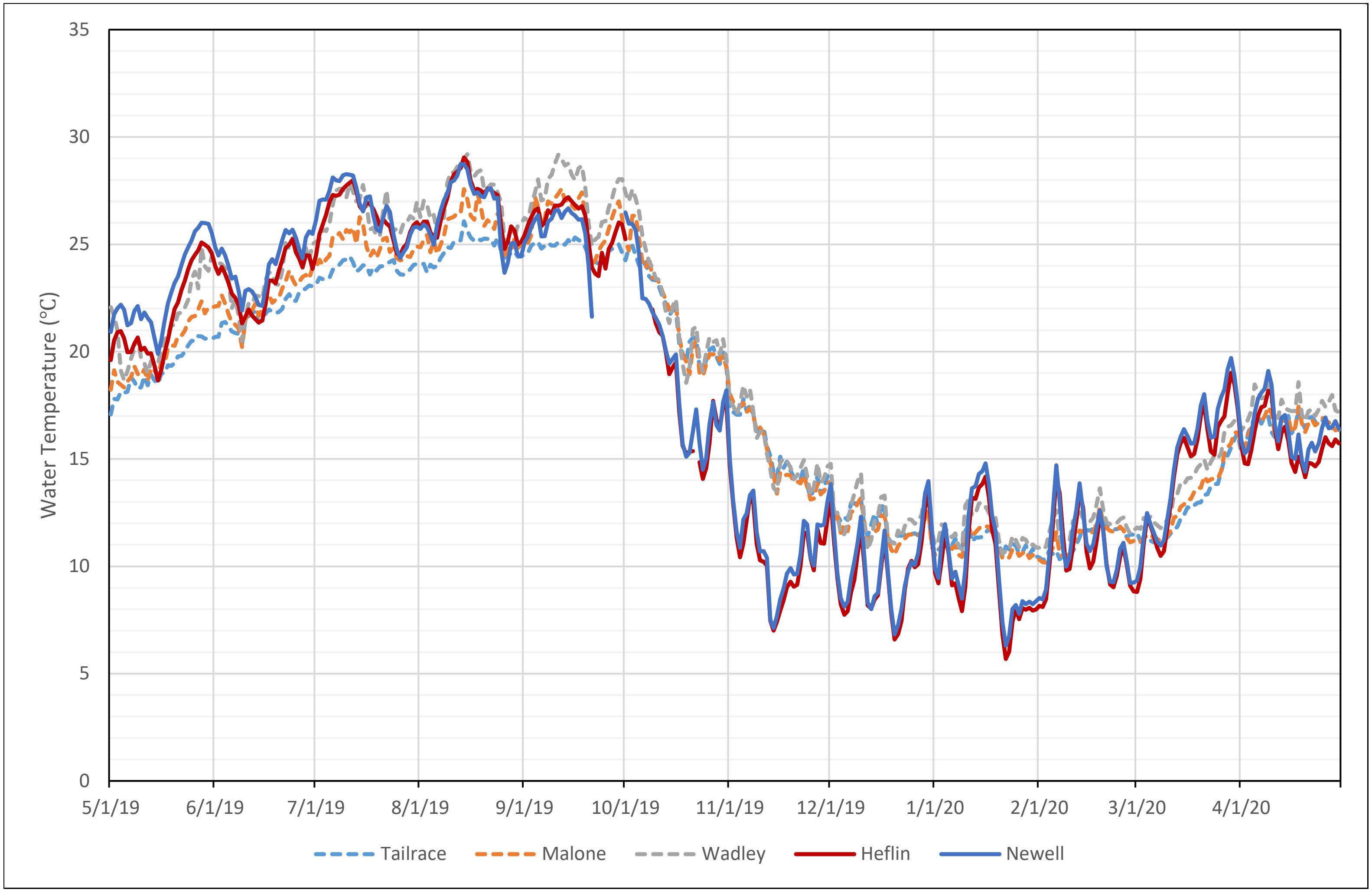

FIGURE 3-6 DAILY AVERAGE WATER TEMPERATURE IN THE TALLAPOOSA AND LITTLE TALLAPOOSA RIVERS

TABLE 3-3 SUMMARY OF MONTHLY AND SEASONAL WATER TEMPERATURE IN THE TALLAPOOSA AND LITTLE TALLAPOOSA RIVERS

Month/Season	Tailrace	Malone	Wadley	Heflin	Newell
Mar	12.8	13.1	13.9	14.5	15.0
Apr	16.6	16.6	17.4	15.7	16.4
May	19.2	20.0	21.2	21.6	22.9
Spring	**16.2**	**16.6**	**17.5**	**17.3**	**18.1**
Jun	21.8	22.4	23.5	23.2	24.1
Jul	23.9	24.9	26.4	26.3	26.6
Aug	24.8	25.7	27.2	26.8	26.5
Summer	**23.5**	**24.4**	**25.7**	**25.5**	**25.8**
Sep	24.8	26.2	27.4	25.9	25.7
Oct	21.7	21.8	22.3	17.9	19.5
Nov	15.3	15.1	15.4	10.5	10.9
Fall	**20.6**	**21.1**	**21.7**	**18.1**	**18.0**
Dec	12.1	11.8	12.3	9.7	10.0
Jan	11.1	11.0	11.6	9.7	10.2
Feb	11.2	11.3	11.9	10.6	10.9
Winter	**11.5**	**11.4**	**12.0**	**10.0**	**10.4**

4.0 DISCUSSION AND CONCLUSIONS

Water temperature data collected between May 2019 and April 2020 provided insight into the frequency and magnitude of water temperature fluctuations at varying distances from the dam. Results indicate that daily water temperature fluctuations were greatest near Harris Dam and decreased according to a relatively linear trend in the downstream direction through Horseshoe Bend.

As previously stated, river flows during August and September of 2019 were well below normal. Under such conditions, temperature loggers in shallow areas may be more susceptible to the influence of solar radiation. Figure 3-6 illustrates this concept using September 2019 data from the logger located in a riffle approximately 19.5 miles downstream of Harris Dam (logger #10). As can be seen in the figure, during a period of stable, low flow, water temperature increased by approximately 13 °C. Under such conditions, loggers may be subject to direct solar radiation, yielding water temperature readings that may not necessarily be representative of actual water temperatures across the entire river channel.

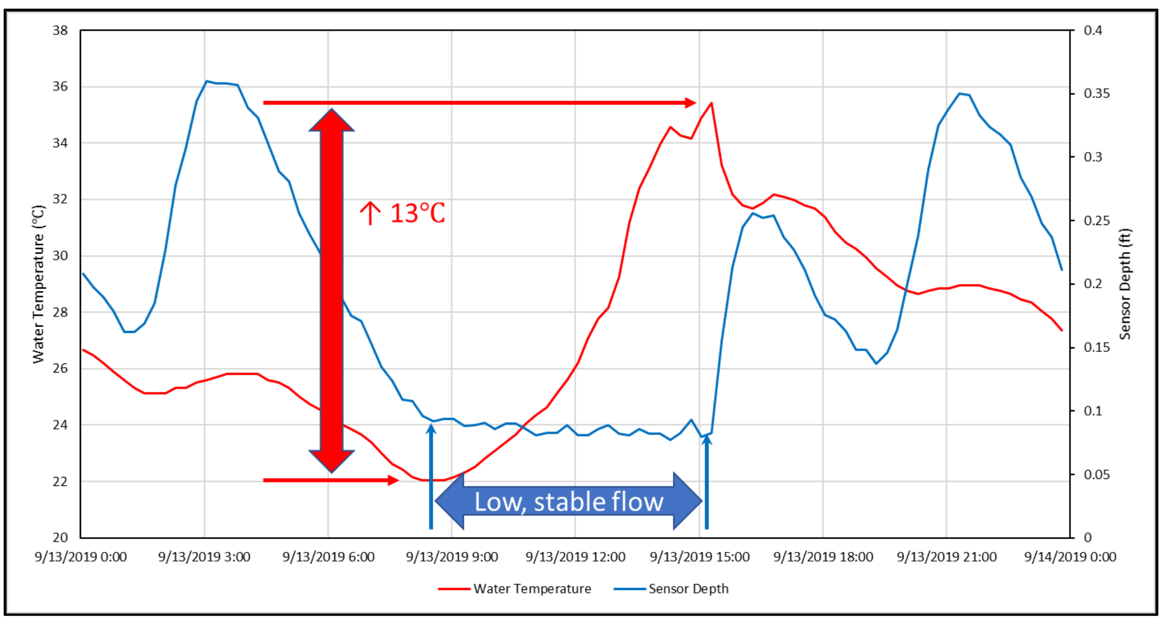

FIGURE 4-1 EXAMPLE OF EFFECTS OF LOW FLOWS ON MEASUREMENTS OF WATER TEMPERATURE FLUCTUATION

5.0 DOWNSTREAM FISH POPULATION STUDY

5.1 Introduction

Alabama Power and Auburn University evaluated factors affecting fish populations in the Tallapoosa River below Harris Dam. Auburn conducted a total of 12 bimonthly sampling events from 2019 to 2021. Although this study includes an assessment of the entire fish population, a subset of target species were studied more intensively. The target species include Redbreast Sunfish, Tallapoosa Bass, Alabama Bass, and Channel Catfish. Data gathered from target species includes age, growth, and diet data. A literature review of existing information of preferred temperature ranges for the target species, including data on specific life stages (e.g., spawning) was conducted and historical water temperature data was evaluated to compare conditions pre- and post-Green Plan and to assess temperature in regulated and unregulated portions of the Study Area. Finally, Auburn University simulated specific growth rate for one of the target species using a bioenergetics model to assess the extent to which Harris Dam operations affect fish growth in the Tallapoosa River. The model incorporated a variety of inputs collected by Auburn University including: existing literature/studies, age, growth, and diet data, laboratory respirometry testing, and historical water temperature data. Auburn University's report is included in Appendix D.

5.2 Summary

5.2.1 Literature Based Temperature Requirements for Fish

Auburn University reviewed existing literature for information on temperature requirements and limitations of the four target species; specifically, thermal minima, optimal range, preferred temperatures (which can be dependent on acclimation temperatures), spawning/hatching, and thermal maxima. There is little existing temperature data on the recently described Alabama Bass and Tallapoosa Bass species. Spotted Bass data were gathered as a surrogate to Alabama Bass data since the two species are closely related. Redeye Bass and Shoal Bass data were gathered as surrogates to Tallapoosa Bass as recommended by ADCNR, but only spawning and hatching data were available for these species.

Auburn University's literature review of temperature requirement data yielded over 70 publications, but the utility of these data is limited. Thermal minima ranges were very broad. Optimal ranges were based on a variety of metrics (e.g., digestion or growth), and some sources did not specify what metrics were being considered to define optimal ranges. Furthermore, preferred temperature could vary based on the temperature at which fish are accustomed or acclimated. The current known temperature requirement information of target species is summarized in Appendix D.

5.2.2 Comparison of Temperature Data in Regulated and Unregulated Portions of the Study Area

Auburn University obtained historic temperature data (2000-2018) from Alabama Power at the Harris Dam tailrace, Malone, and Wadley to assess PGP and GP temperature ranges, fluctuations, and averages. Historic temperature data (2018-2020) was also downloaded from the USGS gage in Heflin to assess temperature in an unregulated reach of river; however, unregulated and regulated river temperatures were not compared statistically due to limited data from the Heflin gage and a variety of other variables that could contribute to temperature differences between the regulated and unregulated river. Monthly averages, yearly variation, daily ranges, hourly variation, and average air and water temperatures are summarized in Appendix D.

5.2.3 Description of Current Fish Population

Auburn University assessed the fish population at three locations in the Tallapoosa River downstream of Harris Dam (the Harris Dam tailrace, Wadley, and Horseshoe Bend) and at one reference site upstream of Harris Reservoir on the Tallapoosa River (near Lee's Bridge)[15]. The 30+2 method of sampling was proposed for shallow habitat in the Final Aquatic Resources Study Plan, but Auburn University discovered that it was not feasible at any of the study sites. Boat and barge electrofishing equipment were able to incorporate shallow habitat into overall samples. All collected fish were identified, weighed, and measured. Target fish were transported to Auburn University for respirometry tests and to have otoliths, gonads, and stomach contents removed to gather growth, reproductive, and diet data for bioenergetics modeling.

Shannon's Diversity Index (H) and CPUE was calculated overall, by season, and by site. Shannon's Diversity Index was compared to the results of Travnichek and Maceina (1994).

[15] Shallow water sampling methodology varied from the 30+2 method (O'Neil et al. 2006) proposed in the FERC-approved Aquatic Resources Study Plan. Auburn University determined that sampling using these methods was not feasible at the study sites and found that boat and barge electrofishing equipment were effective at reaching shallow habitat.

Body condition of target species was assessed by calculating relative weight, using published weight parameters of Spotted Bass for Alabama Bass and Tallapoosa Bass. Relative condition was calculated for Redbreast Sunfish instead of relative weight due to the lack of standard weight equations for that species. Diets of target species were assessed across seasons and sites.

Telemetry was also used to examine fish movement in the Tallapoosa River downstream of Harris Dam. Thirteen Alabama Bass and three Tallapoosa Bass were implanted with acoustic radio transmitter tags (CART, Lotek MM-MC-8-SO) between Harris tailrace and Malone. Fish movement was monitored during weekly intervals of manual tracking and using ten stationary acoustic receivers. Fish closest to the dam moved less than those further downstream. Results and conclusions of fish community sampling, body condition across sites, and fish movement are summarized in Appendix D.

5.2.4 Bioenergetics Modeling

Auburn University conducted respirometry tests of the target species in response to hydropeaking. Specifically, intermittent flow static respirometry was conducted to quantify standard metabolic rates of fish at multiple temperatures (10, 21, and 24 ℃). Swimming respirometry trials were used to quantify performance capability and the active metabolic rates of target species. Swimming respiration tests also assessed the effects of rapid flow changes, rapid temperature changes, and a combination of both rapid flow and rapid temperature changes on active metabolic rate. Results provided inputs for bioenergetics models to assess the effects of releases from Harris Dam on specific growth rate. Auburn University incorporated the necessary physiological parameters into bioenergetics models to conduct simulations needed to test potential influence of water temperature and flow on specific growth rates of target fishes below Harris Dam. Auburn University conducted growth simulations of Redbreast Sunfish using respiration rate parameters largely gathered from Bluegill, a closely-related species. Growth simulations could not be conducted for other target species due to one or more factors, such as low sample sizes for laboratory experiments, a lack of published models developed for riverine populations, or because parameters for other target species did not fit models developed for surrogate species. Results and conclusions of respirometry tests and bioenergetics modeling are summarized in Appendix D.

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APPENDIX A

ACRONYMS AND ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS

A

A&I	Agricultural and Industrial
ACFWRU	Alabama Cooperative Fish and Wildlife Research Unit
ACF	Apalachicola-Chattahoochee-Flint (River Basin)
ACT	Alabama-Coosa-Tallapoosa (River Basin)
ADCNR	Alabama Department of Conservation and Natural Resources
ADECA	Alabama Department of Economic and Community Affairs
ADEM	Alabama Department of Environmental Management
ADROP	Alabama-ACT Drought Response Operations Plan
AHC	Alabama Historical Commission
Alabama Power	Alabama Power Company
AMP	Adaptive Management Plan
ALNHP	Alabama Natural Heritage Program
APE	Area of Potential Effects
ARA	Alabama Rivers Alliance
ASSF	Alabama State Site File
ATV	All-Terrain Vehicle
AWIC	Alabama Water Improvement Commission
AWW	Alabama Water Watch

B

BA	Biological Assessment
B.A.S.S.	Bass Anglers Sportsmen Society
BCC	Birds of Conservation Concern
BLM	U.S. Bureau of Land Management
BOD	Biological Oxygen Demand

C

°C	Degrees Celsius or Centrigrade
CEII	Critical Energy Infrastructure Information
CFR	Code of Federal Regulation
cfs	Cubic Feet per Second
cfu	Colony Forming Unit
CLEAR	Community Livability for the East Alabama Region
CPUE	Catch-per-unit-effort
CWA	Clean Water Act

D

DEM	Digital Elevation Model
DIL	Drought Intensity Level
DO	Dissolved Oxygen
dsf	day-second-feet

E

EAP	Emergency Action Plan
ECOS	Environmental Conservation Online System
EFDC	Environmental Fluid Dynamics Code
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act

F

°F	Degrees Fahrenheit
ft	Feet
F&W	Fish and Wildlife
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FNU	Formazin Nephelometric Unit
FOIA	Freedom of Information Act
FPA	Federal Power Act

G

GCN	Greatest Conservation Need
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning Systems
GSA	Geological Survey of Alabama

H

Harris Project	R.L. Harris Hydroelectric Project
HAT	Harris Action Team
HEC	Hydrologic Engineering Center
HEC-DSSVue	HEC-Data Storage System and Viewer
HEC-FFA	HEC-Flood Frequency Analysis
HEC-RAS	HEC-River Analysis System
HEC-ResSim	HEC-Reservoir System Simulation Model
HEC-SSP	HEC-Statistical Software Package

HDSS	High Definition Stream Survey
hp	Horsepower
HPMP	Historic Properties Management Plan
HPUE	Harvest-per-unit-effort
HSB	Horseshoe Bend National Military Park

I

IBI	Index of Biological Integrity
IDP	Inadvertent Discovery Plan
IIC	Intercompany Interchange Contract
IVM	Integrated Vegetation Management
ILP	Integrated Licensing Process
IPaC	Information Planning and Conservation
ISR	Initial Study Report

J

JTU	Jackson Turbidity Units

K

kV	Kilovolt
kva	Kilovolt-amp
kHz	Kilohertz

L

LIDAR	Light Detection and Ranging
LWF	Limited Warm-water Fishery
LWPOA	Lake Wedowee Property Owners' Association

M

m	Meter
m^3	Cubic Meter
M&I	Municipal and Industrial
mg/L	Milligrams per liter
ml	Milliliter
mgd	Million Gallons per Day
µg/L	Microgram per liter
µs/cm	Microsiemens per centimeter
mi^2	Square Miles
MOU	Memorandum of Understanding

MPN	Most Probable Number
MRLC	Multi-Resolution Land Characteristics
msl	Mean Sea Level
MW	Megawatt
MWh	Megawatt Hour

N

n	Number of Samples
NEPA	National Environmental Policy Act
NGO	Non-governmental Organization
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NTU	Nephelometric Turbidity Unit
NWI	National Wetlands Inventory

O

OAR	Office of Archaeological Resources
OAW	Outstanding Alabama Water
ORV	Off-road Vehicle
OWR	Office of Water Resources

P

PA	Programmatic Agreement
PAD	Pre-Application Document
PDF	Portable Document Format
pH	Potential of Hydrogen
PID	Preliminary Information Document
PLP	Preliminary Licensing Proposal
Project	R.L. Harris Hydroelectric Project
PUB	Palustrine Unconsolidated Bottom
PURPA	Public Utility Regulatory Policies Act
PWC	Personal Watercraft
PWS	Public Water Supply

Q

QA/QC	Quality Assurance/Quality Control

R

RM	River Mile
RTE	Rare, Threatened and Endangered
RV	Recreational Vehicle

S

S	Swimming
SCORP	State Comprehensive Outdoor Recreation Plan
SCP	Shoreline Compliance Program
SD1	Scoping Document 1
SH	Shellfish Harvesting
SHPO	State Historic Preservation Office
Skyline WMA	James D. Martin-Skyline Wildlife Management Area
SMP	Shoreline Management Plan
SU	Standard Units

T

T&E	Threatened and Endangered
TCP	Traditional Cultural Properties
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TRB	Tallapoosa River Basin
TSI	Trophic State Index
TSS	Total Suspended Soils
TVA	Tennessee Valley Authority

U

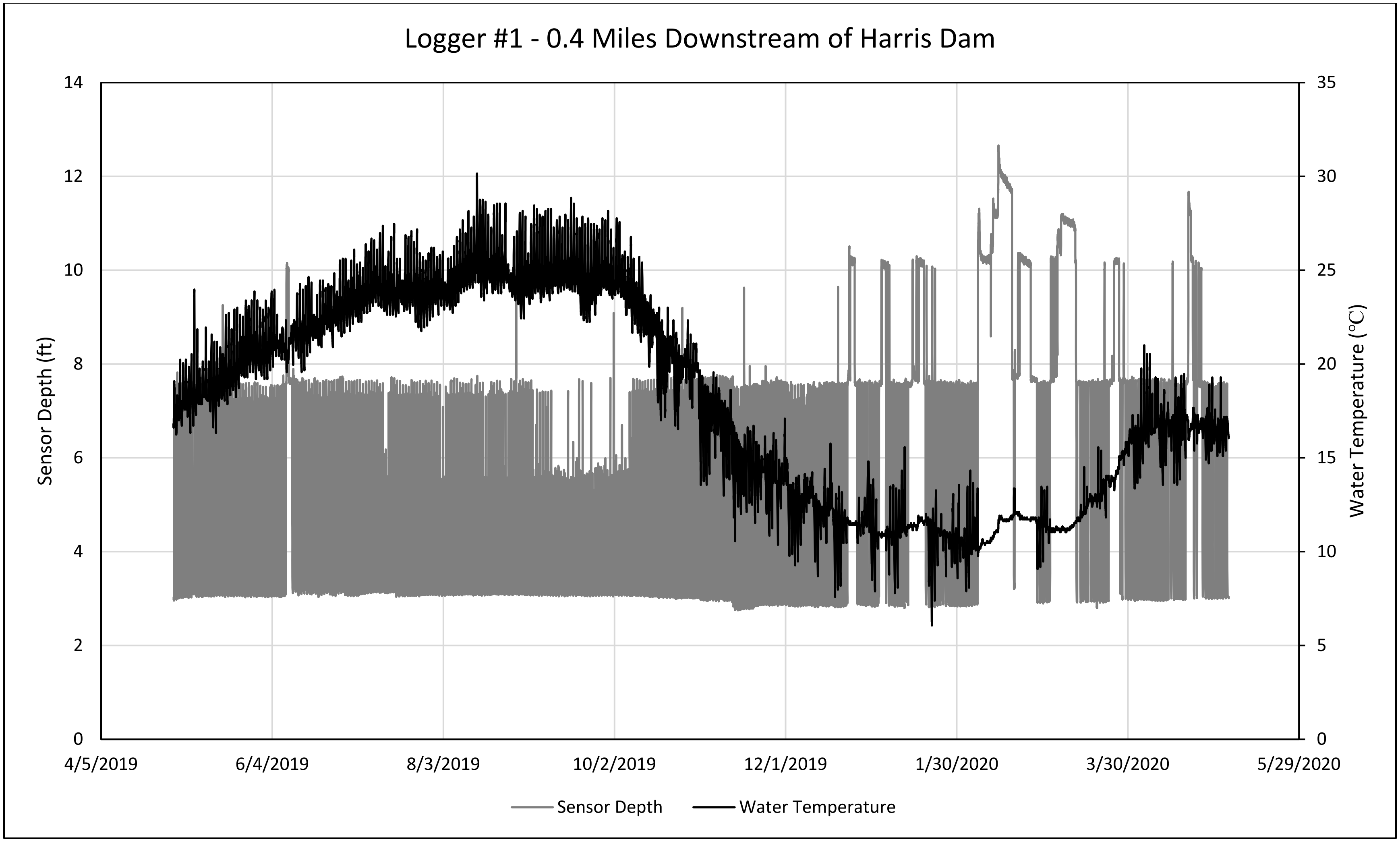
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

W

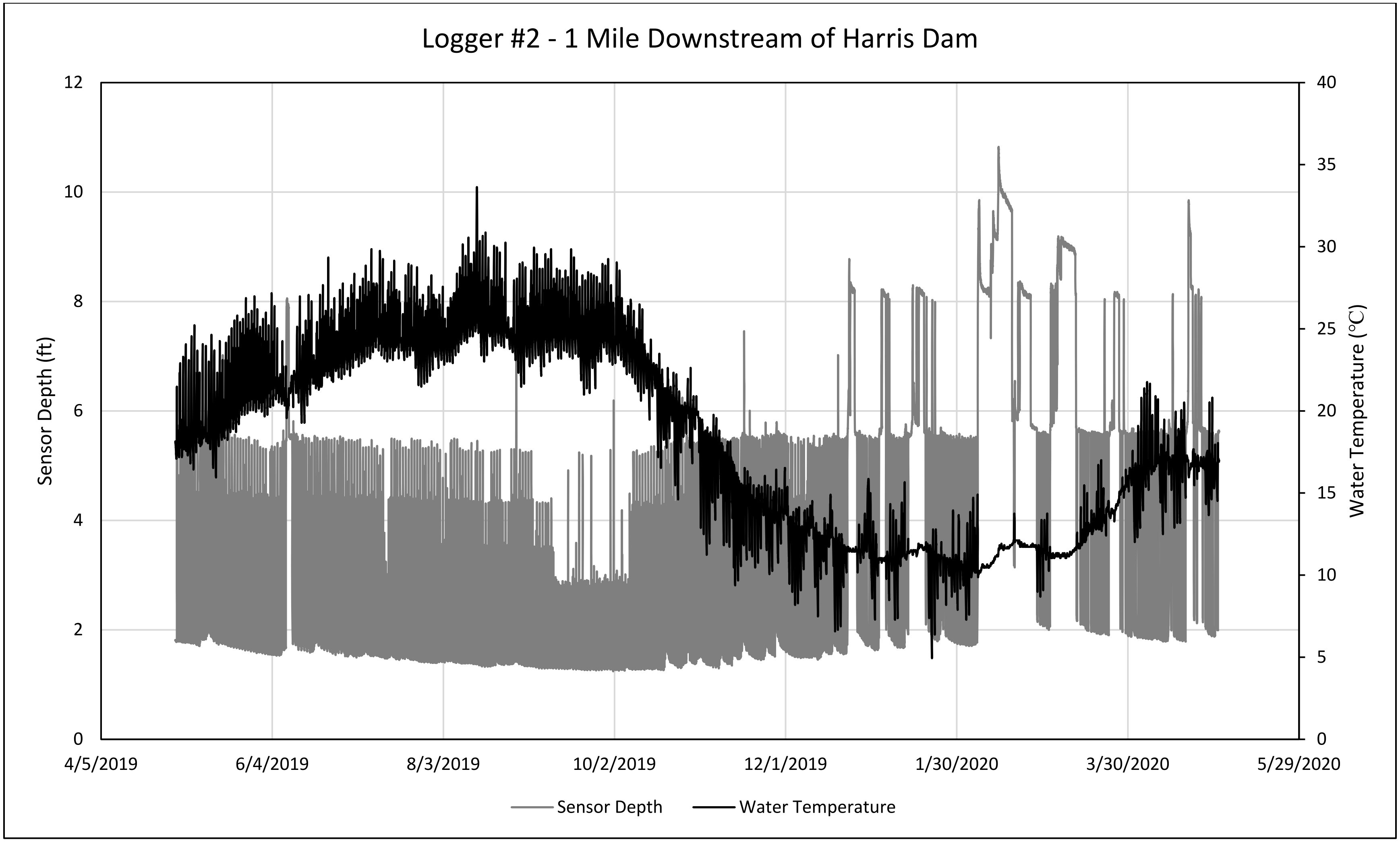
WCM	Water Control Manual
WMA	Wildlife Management Area
WMP	Wildlife Management Plan
WQC	Water Quality Certification

APPENDIX B

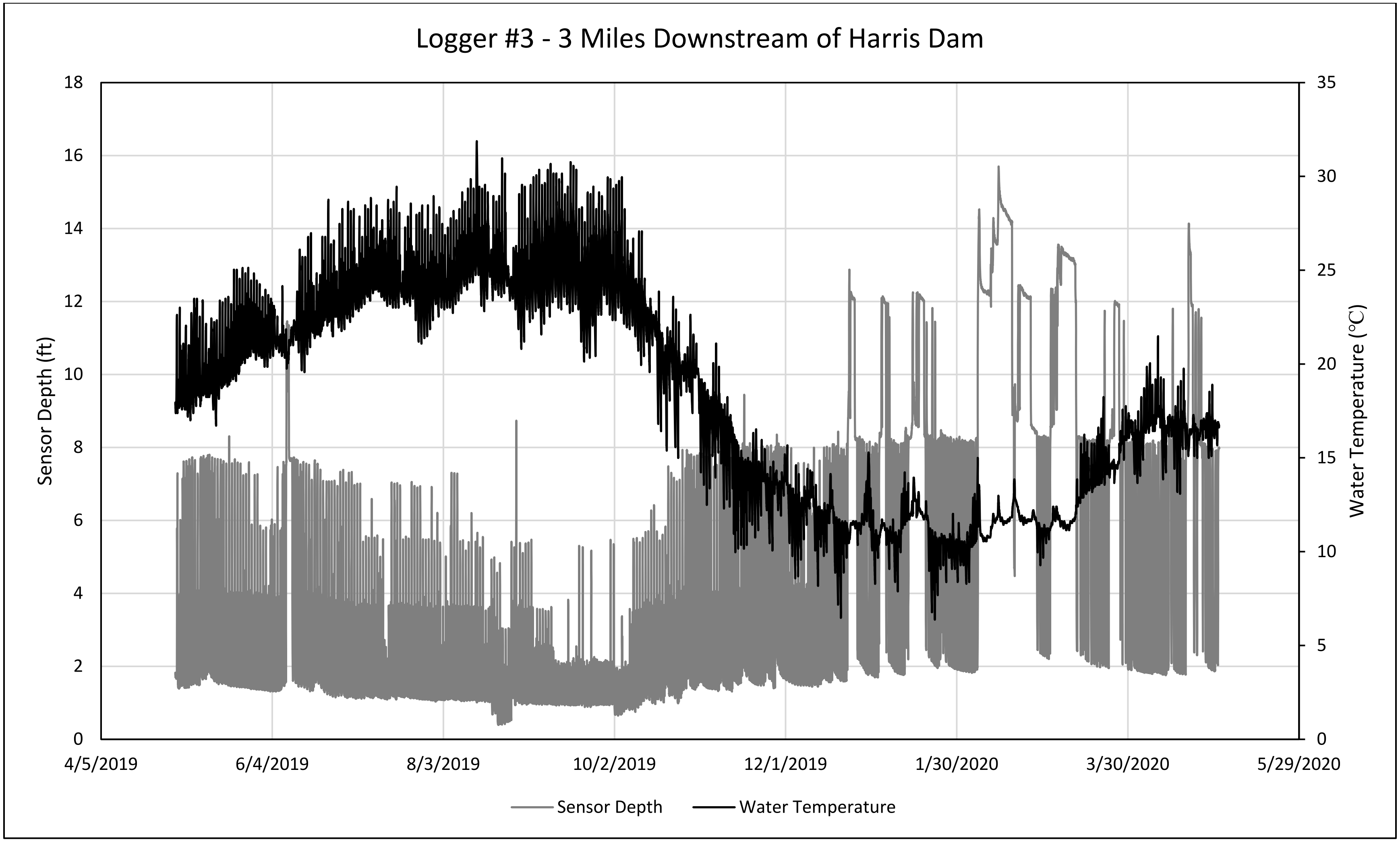
LINE PLOTS OF 15-MINUTE WATER LEVEL AND TEMPERATURE DATA

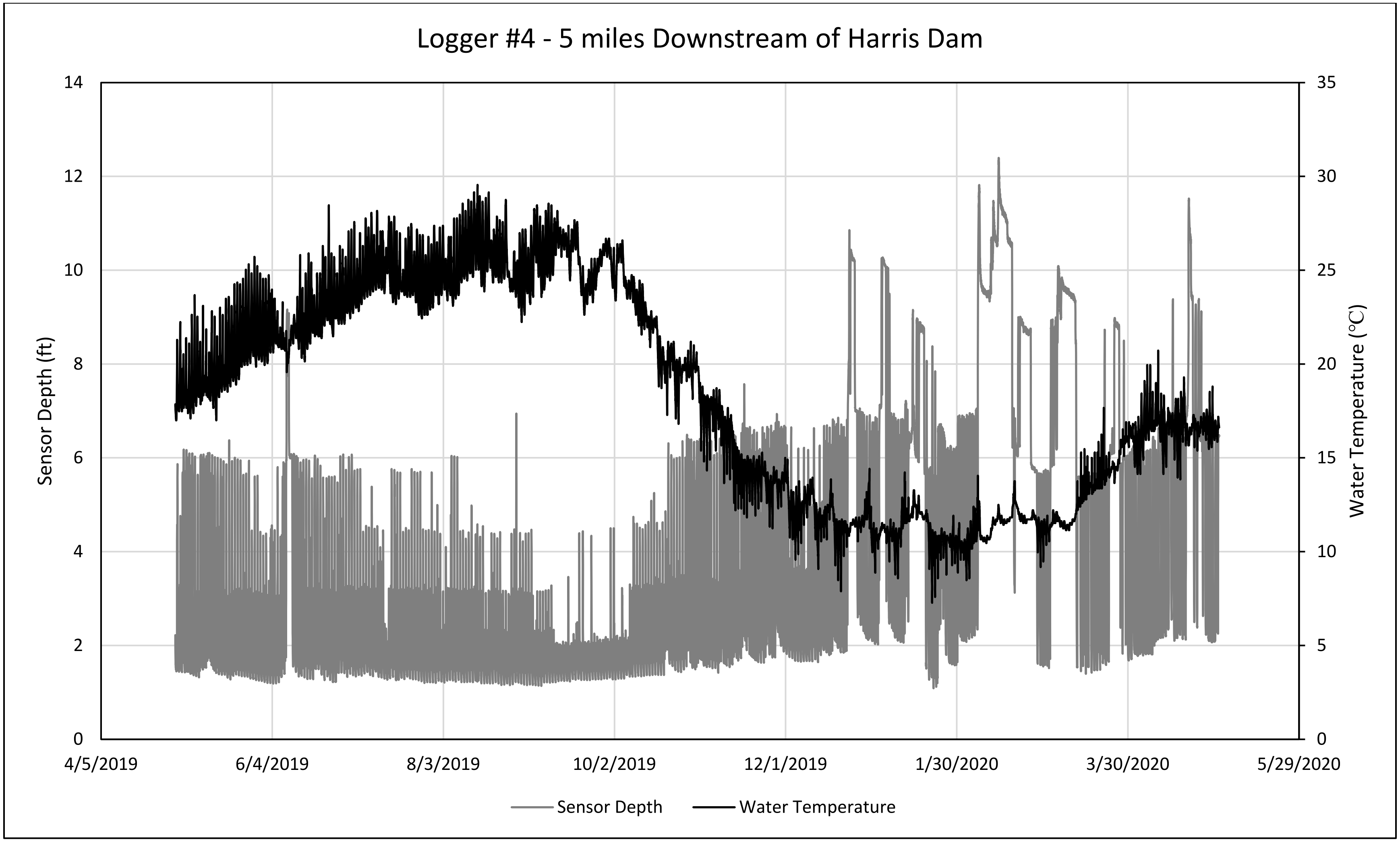


Logger #1 - 0.4 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

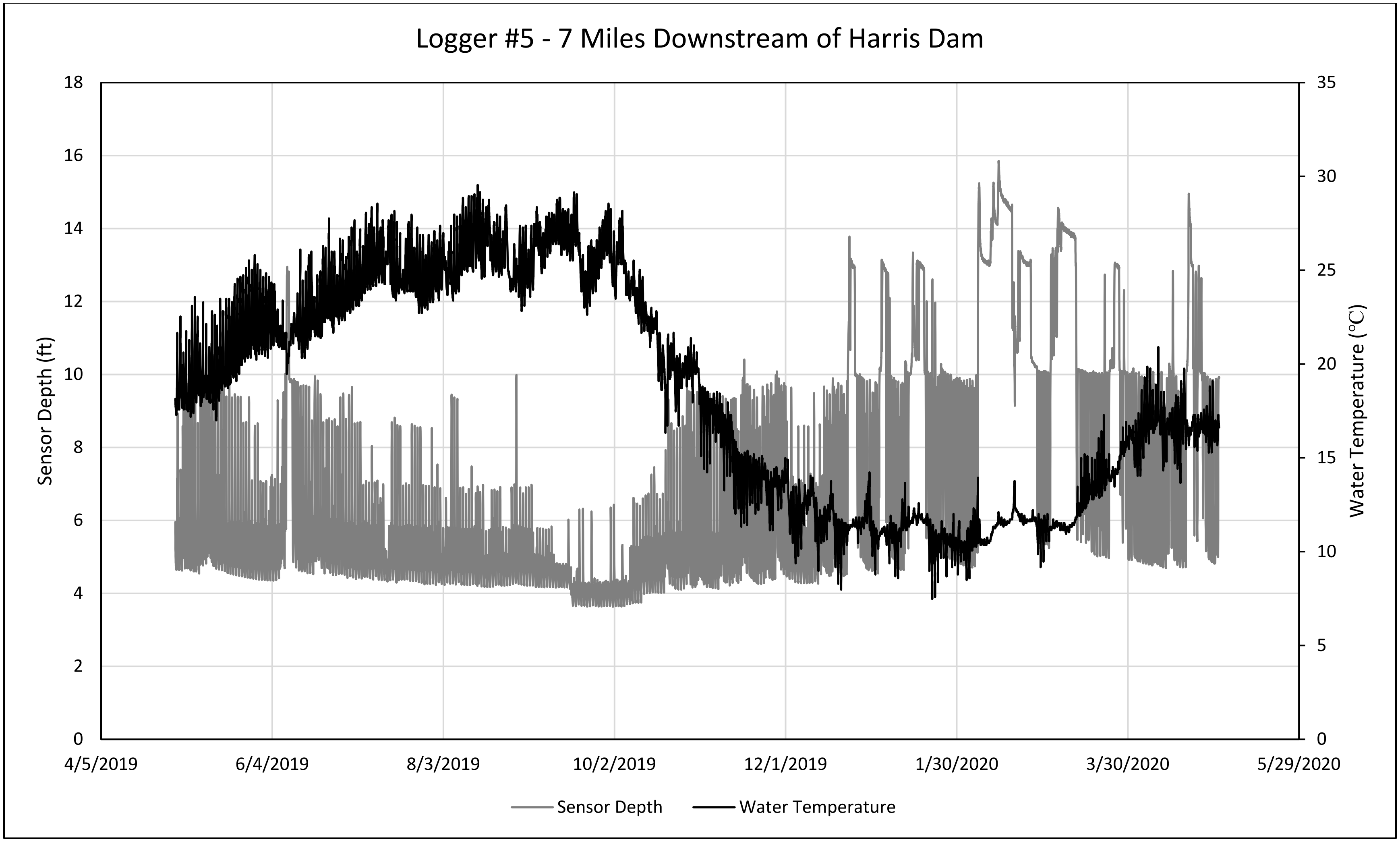


Logger #2 - 1 Mile Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

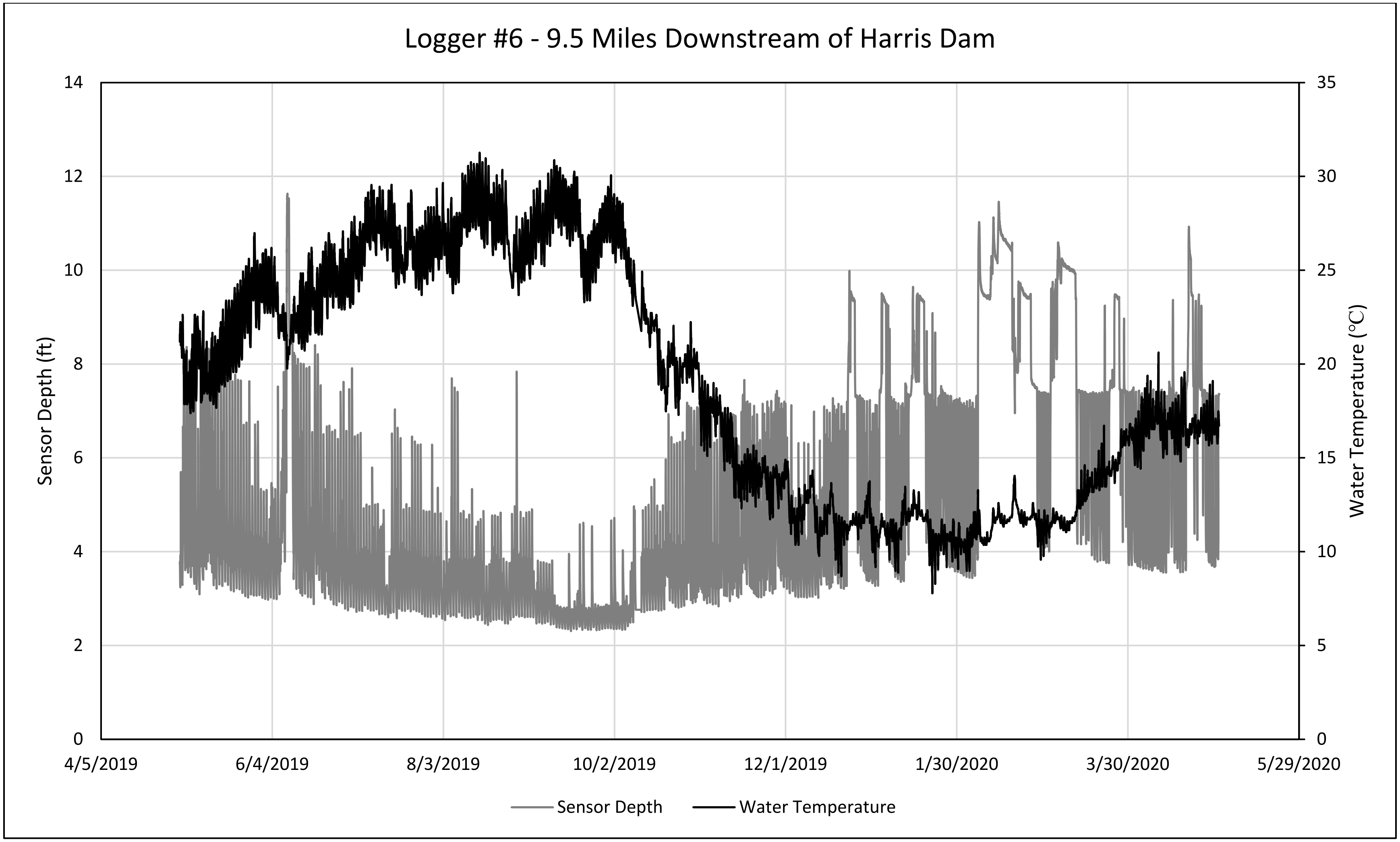

Logger #3 - 3 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



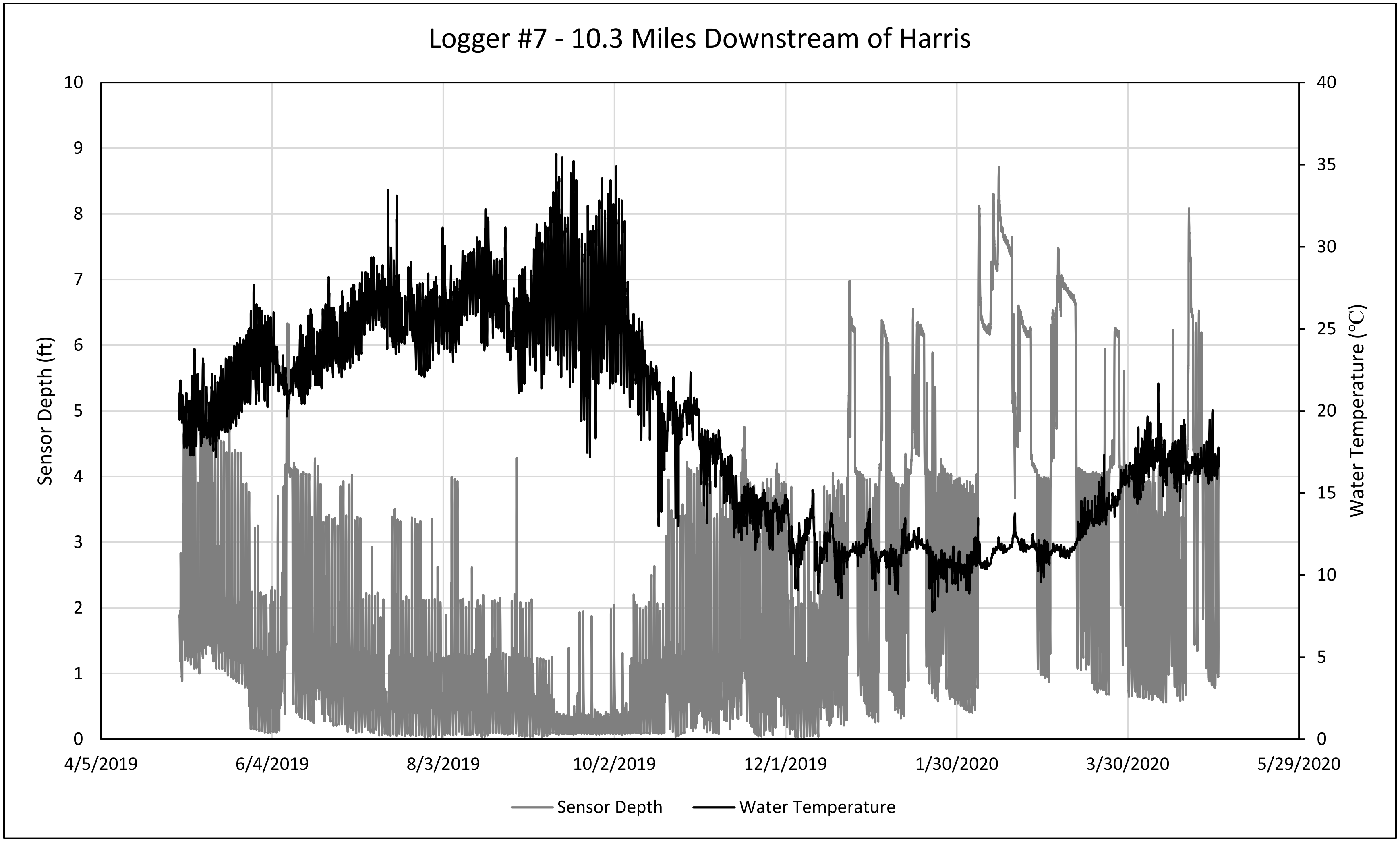
Logger #4 - 5 miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



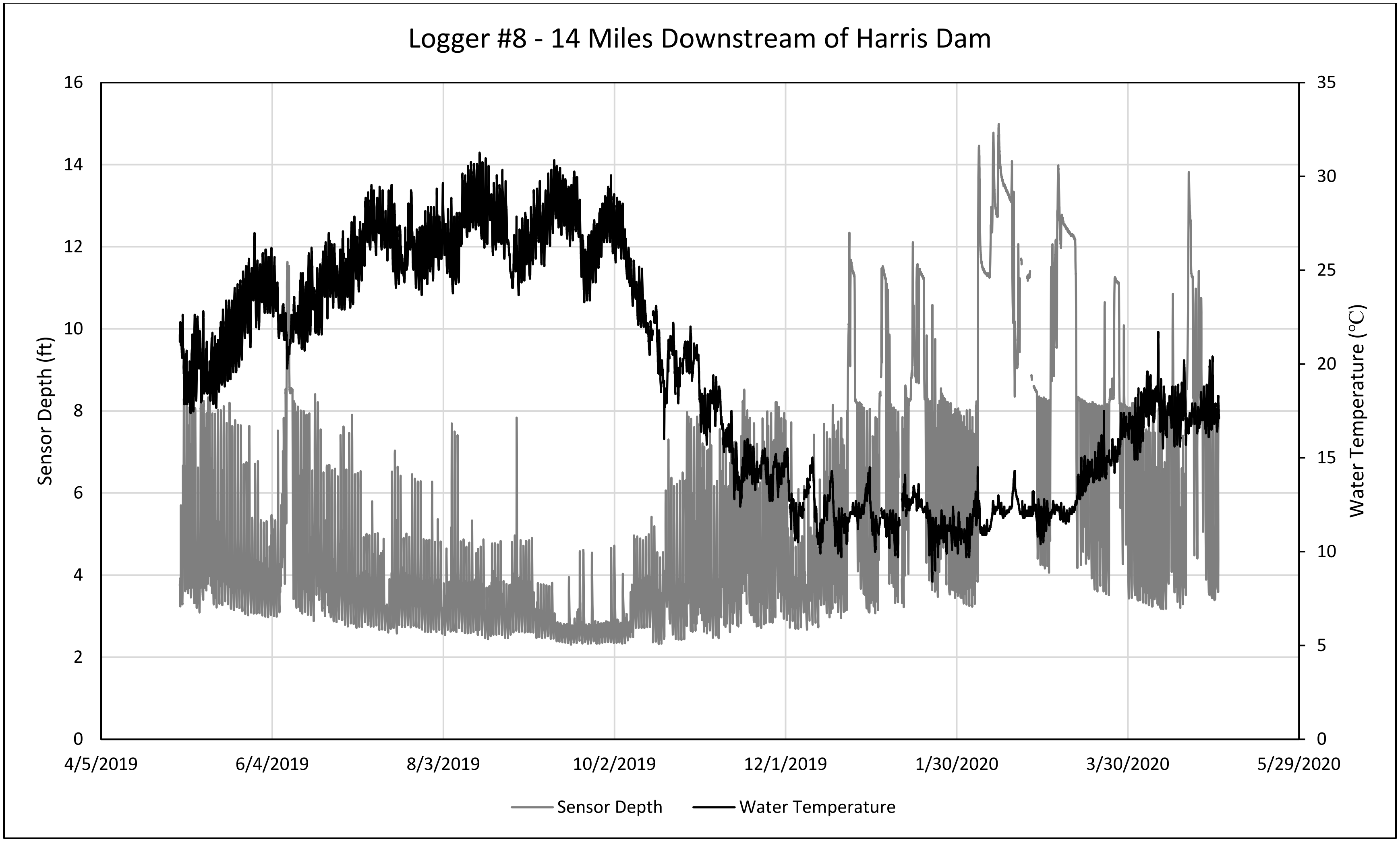
Logger #5 - 7 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
18
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



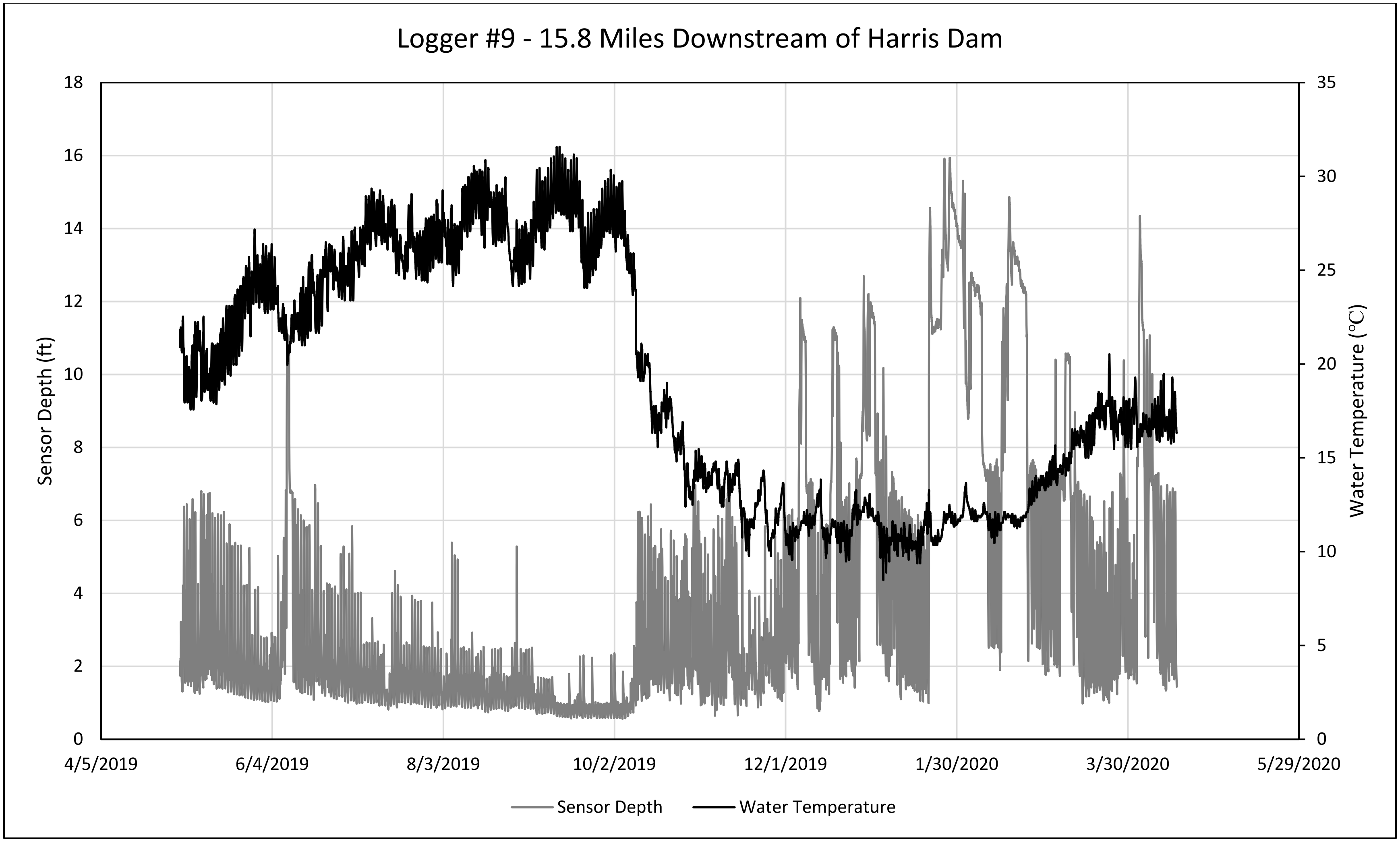
Logger #6 - 9.5 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



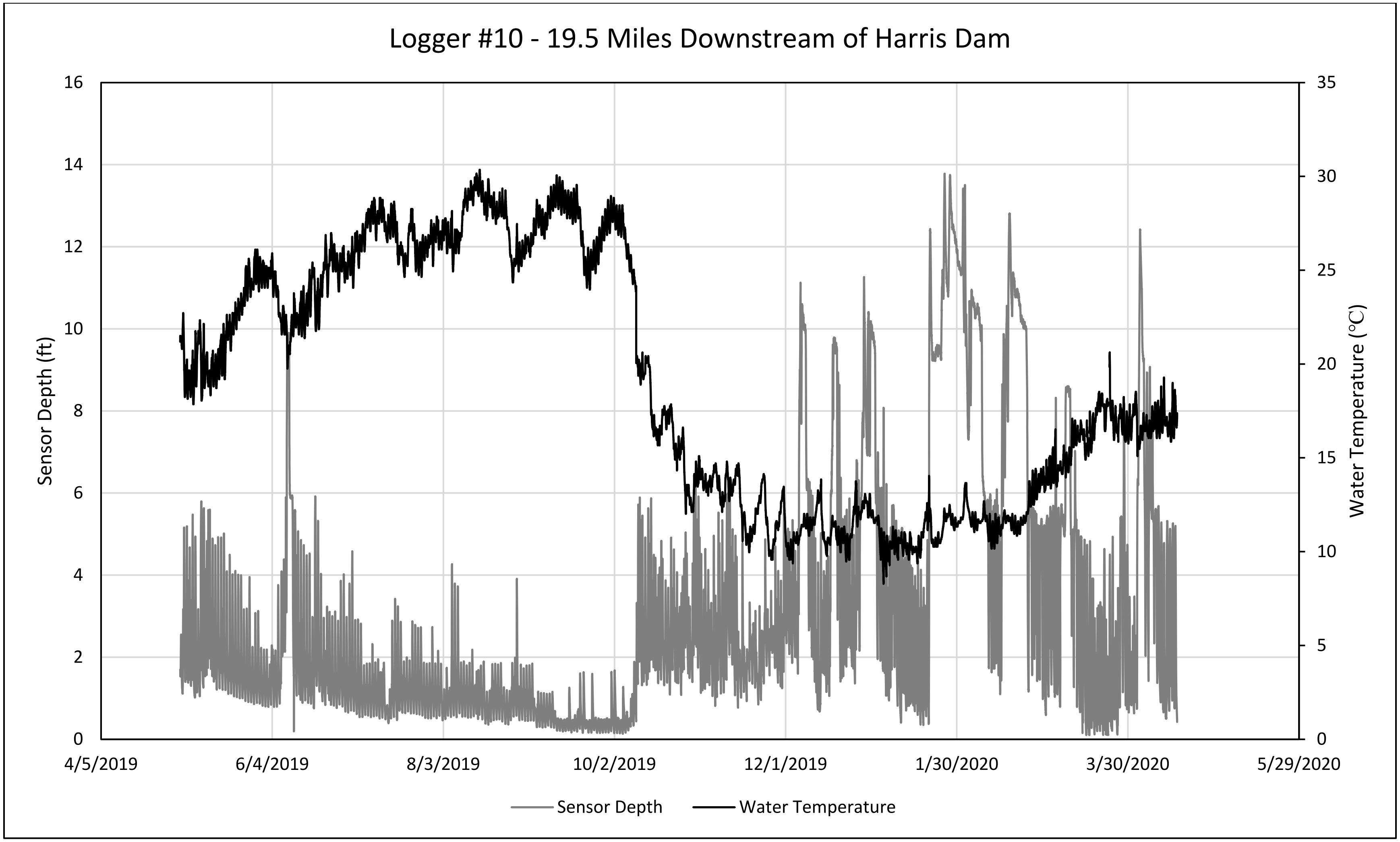
Logger #7 - 10.3 Miles Downstream of Harris
Sensor Depth (ft)
Water Temperature (°C)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
35
40
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



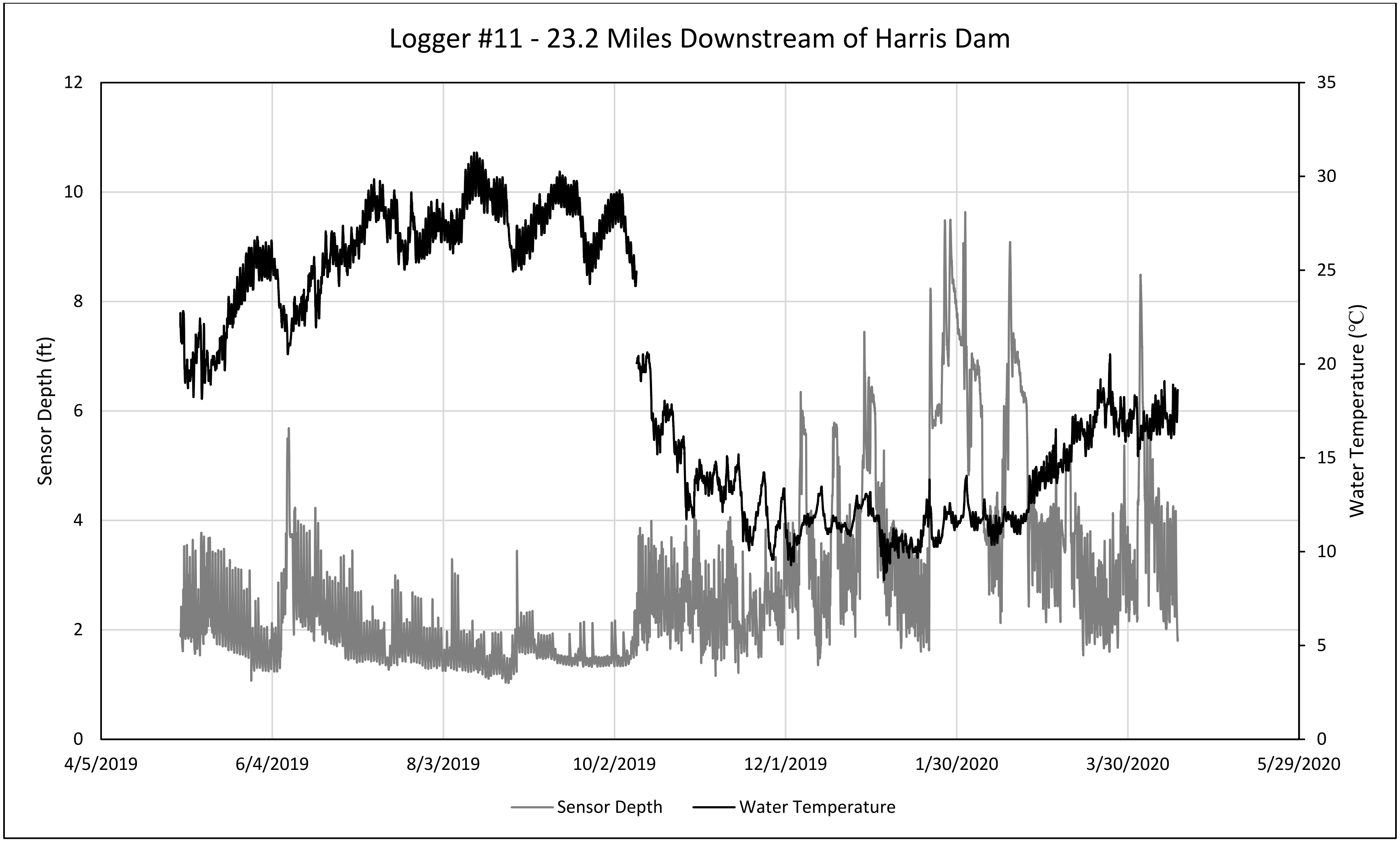
Logger #8 - 14 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



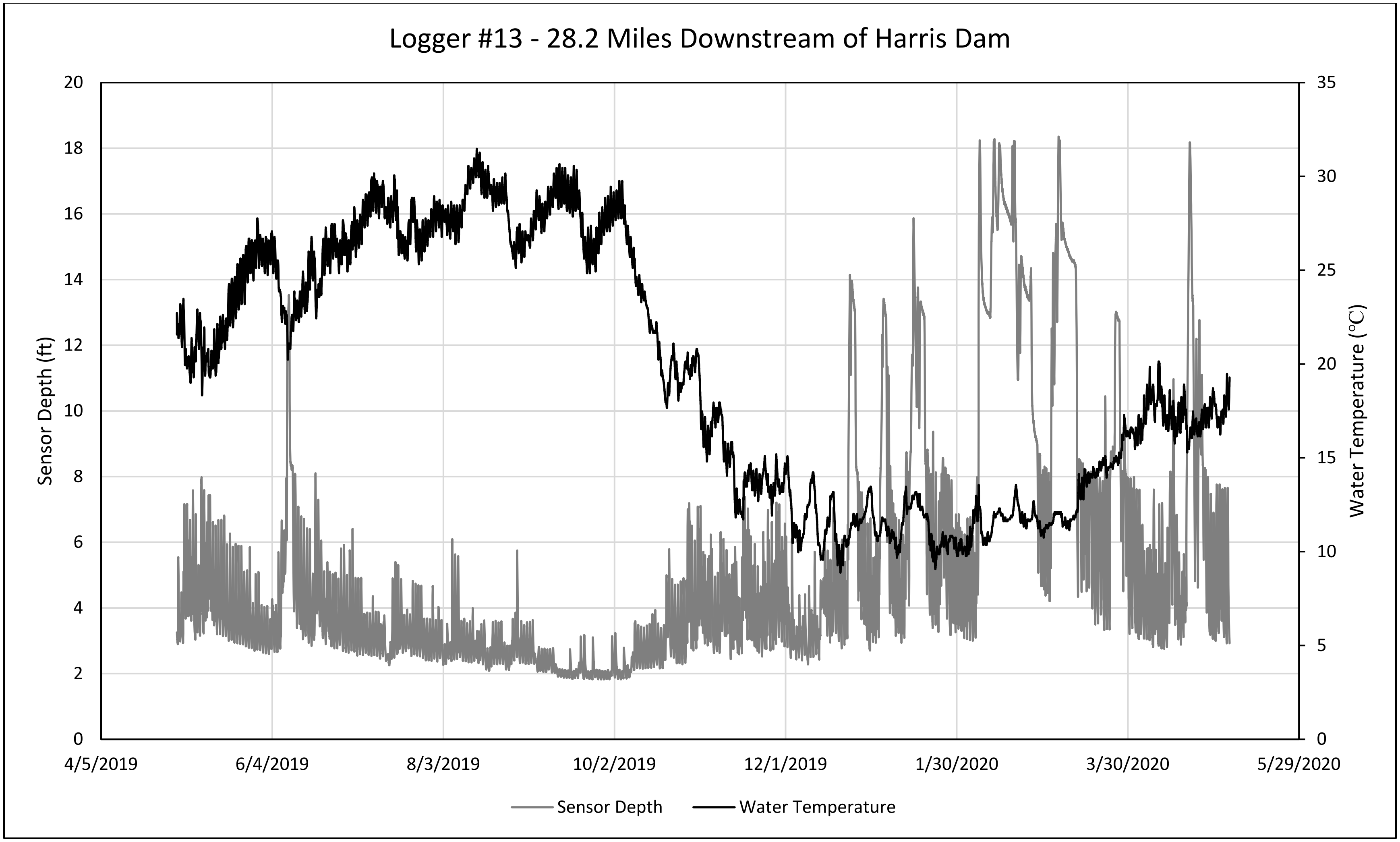
Logger #9 - 15.8 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
18
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

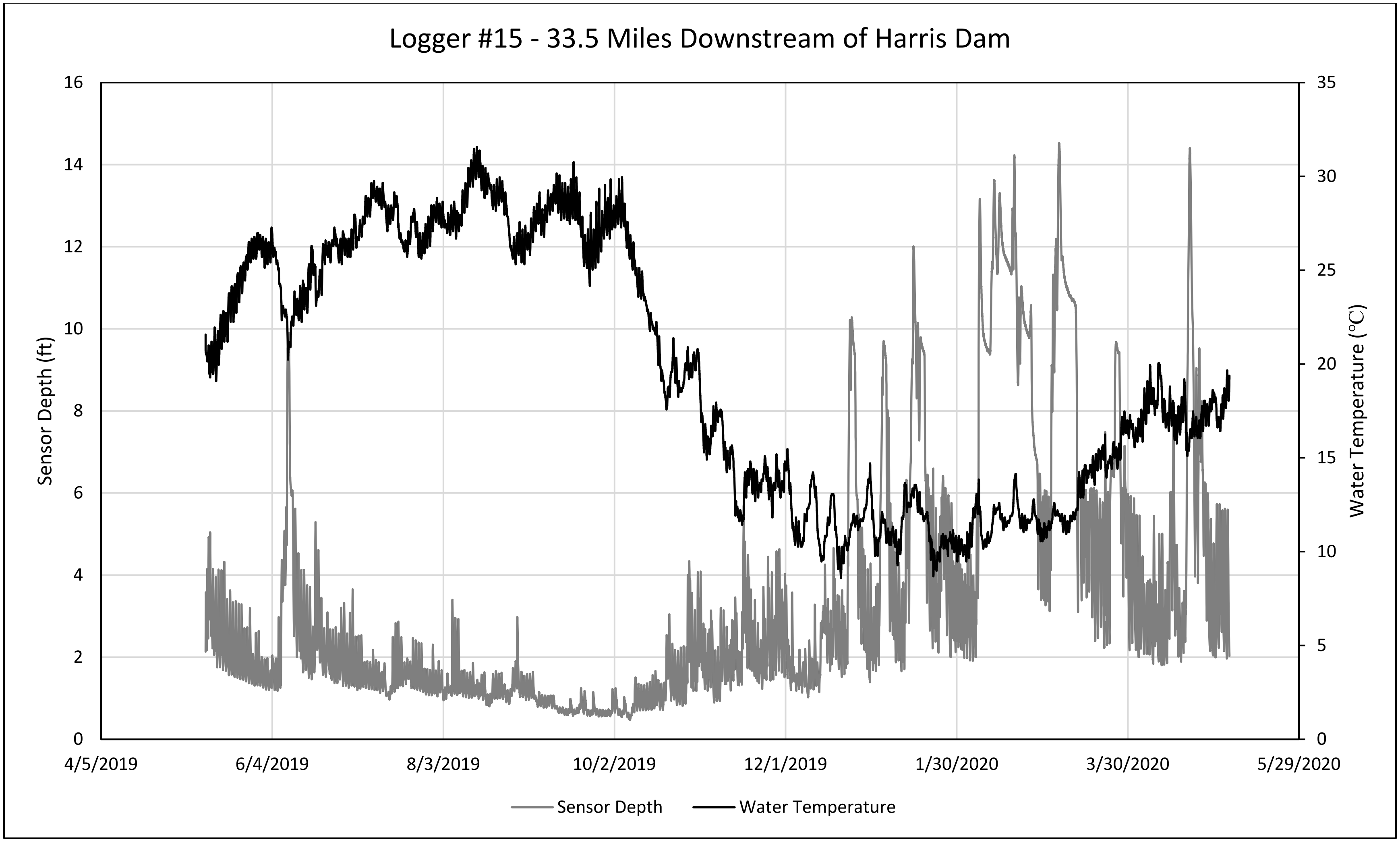


Logger #10 - 19.5 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

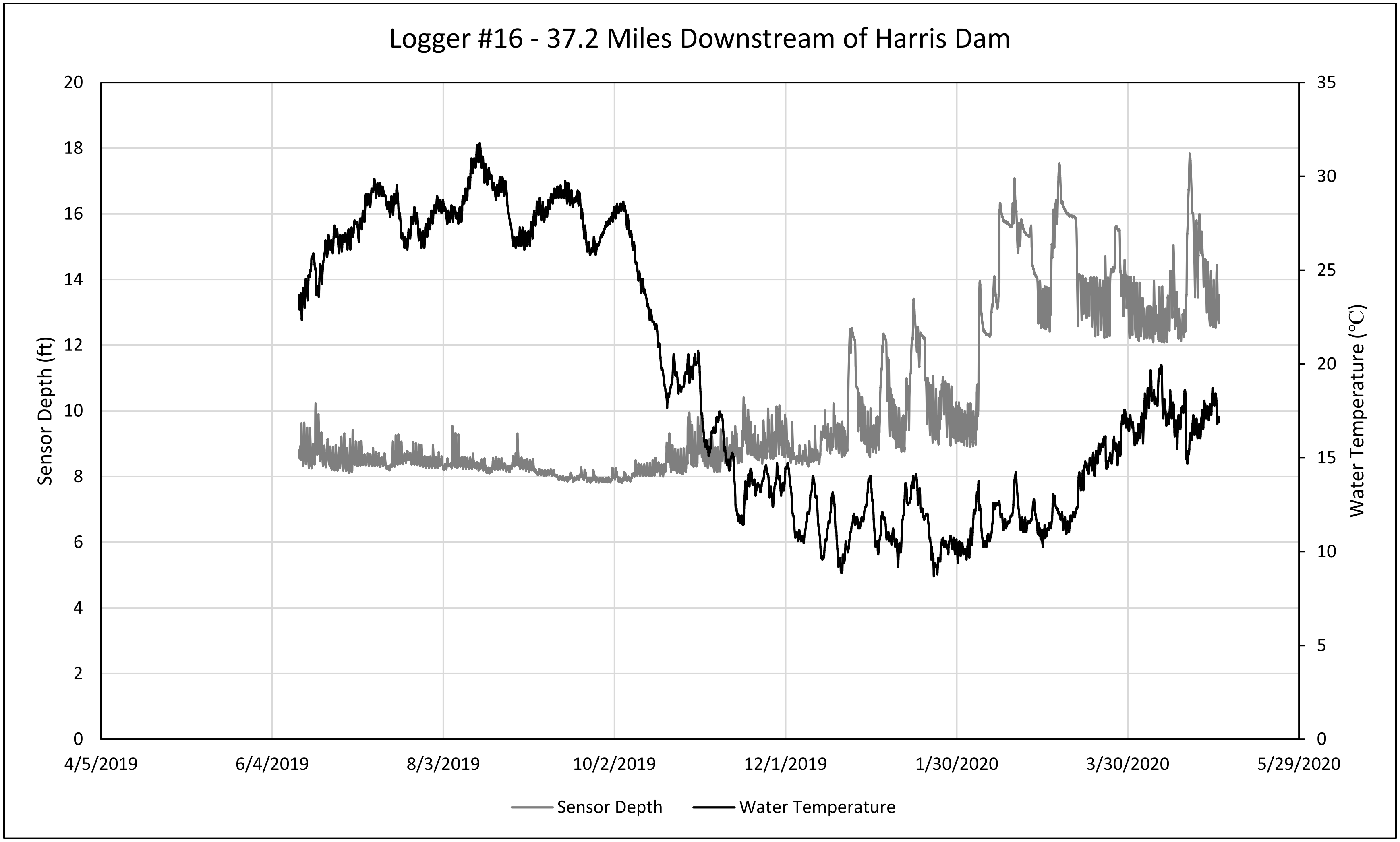


Logger #11 - 23.2 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

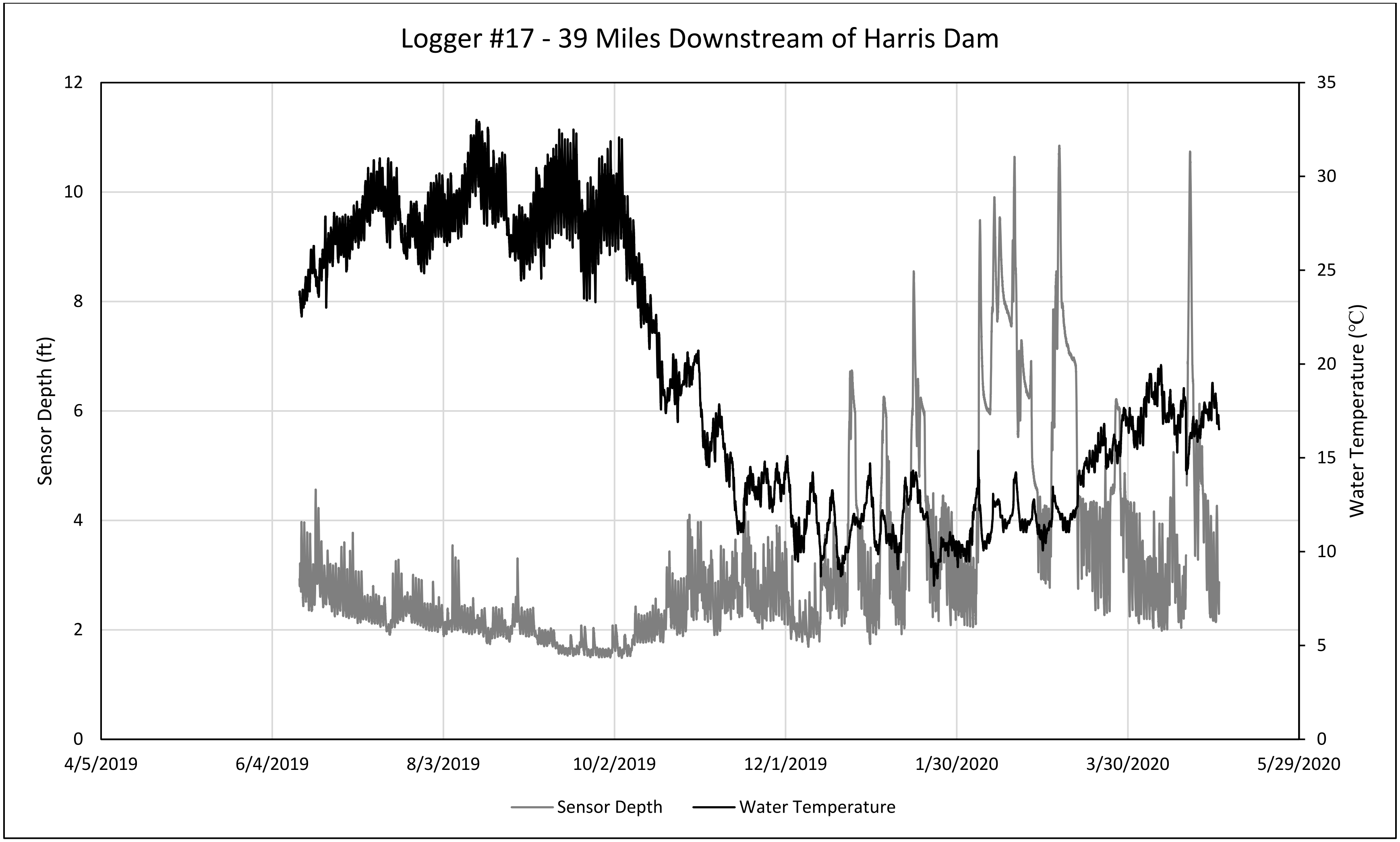

Logger #13 - 28.2 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



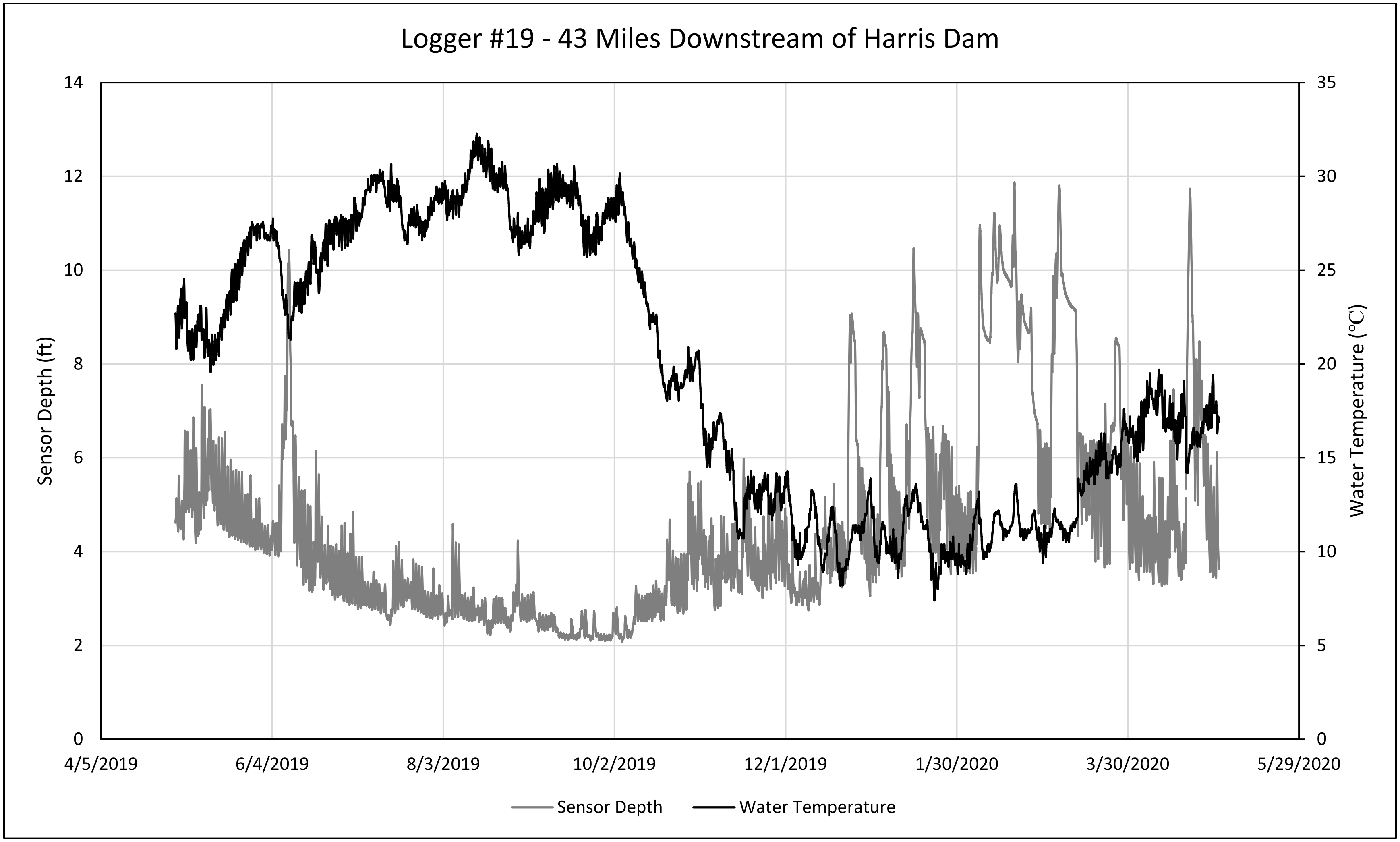
Logger #15 - 33.5 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



Logger #16 - 37.2 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
20
18
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature



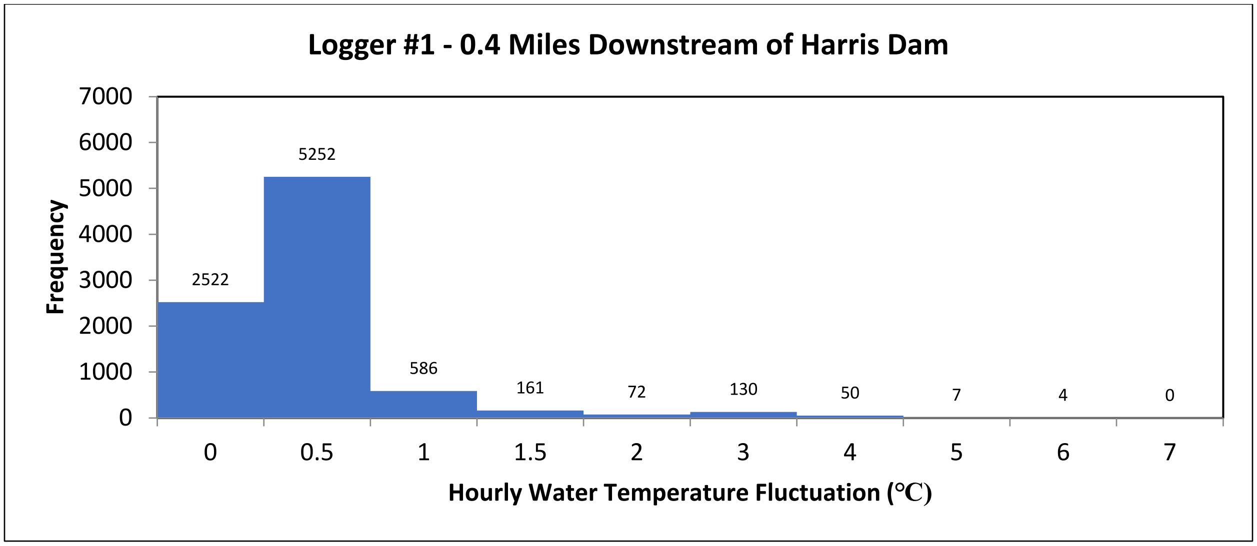
Logger #17 - 39 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

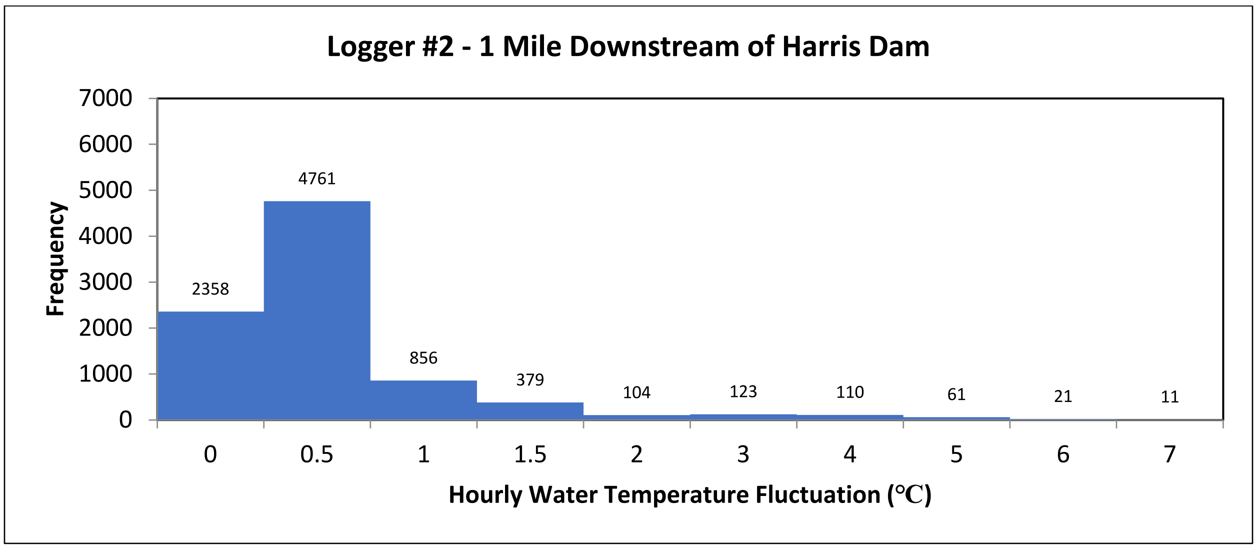


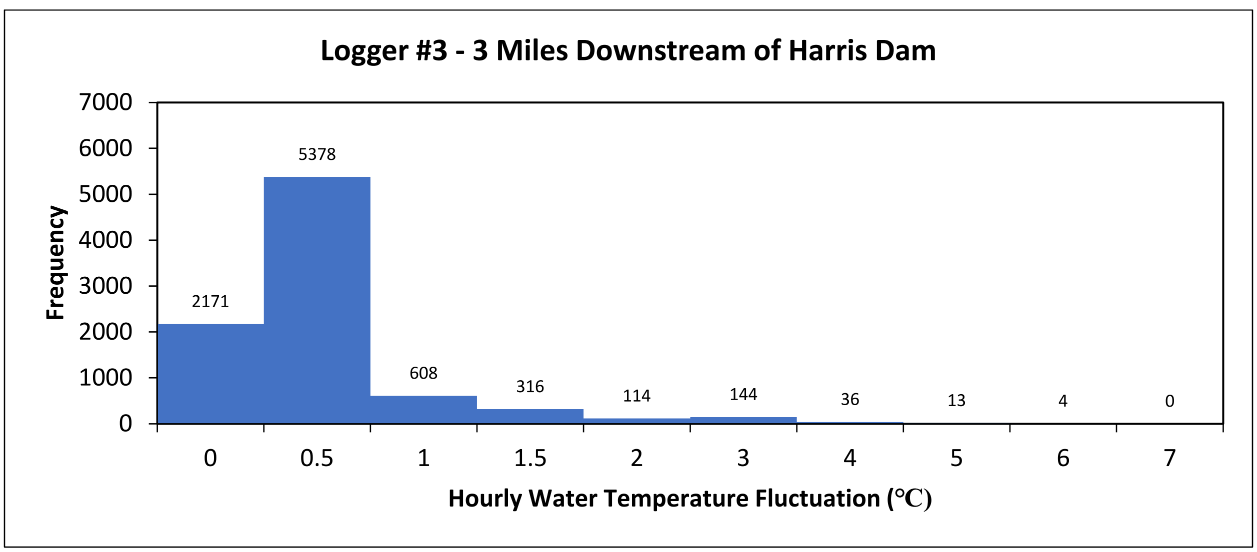
Logger #19 - 43 Miles Downstream of Harris Dam
Sensor Depth (ft)
Water Temperature (°C)
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
4/5/2019
6/4/2019
8/3/2019
10/2/2019
12/1/2019
1/30/2020
3/30/2020
5/29/2020
Sensor Depth
Water Temperature

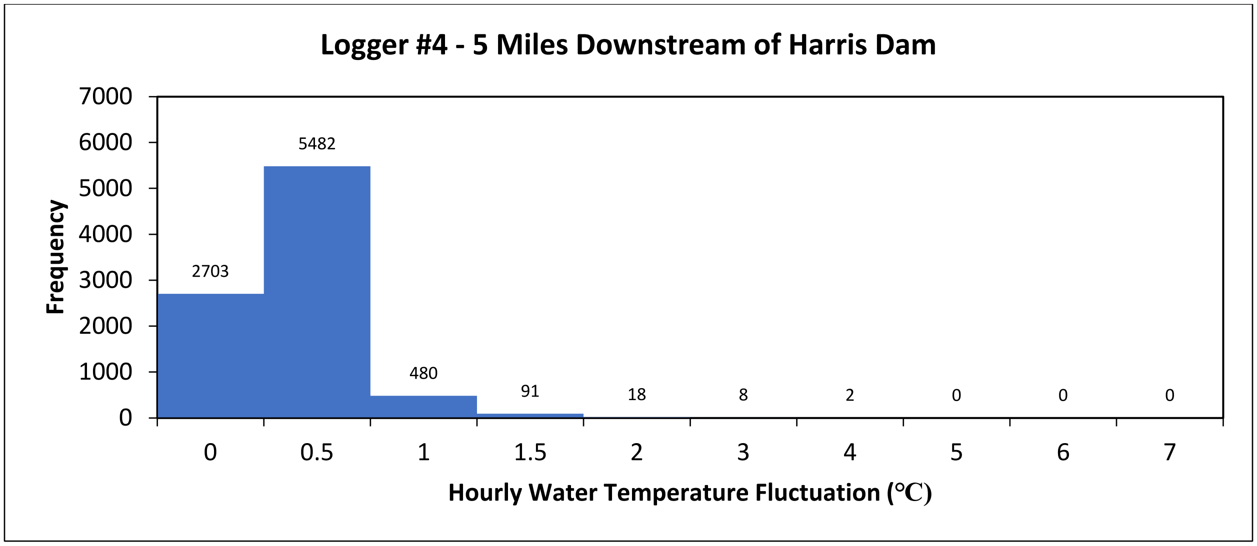
APPENDIX C

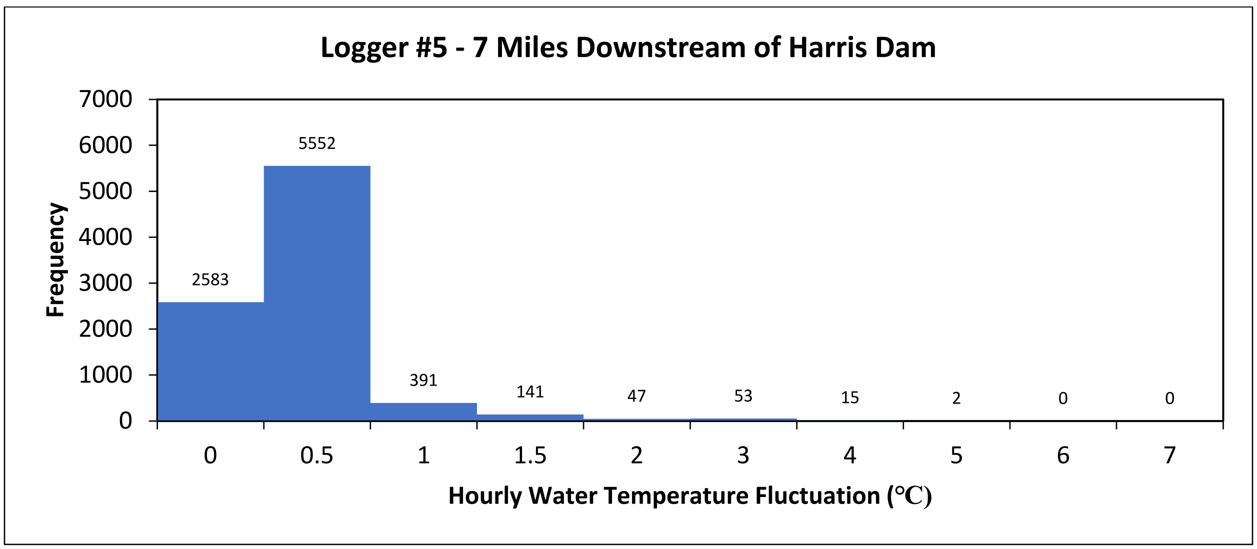
HISTOGRAMS OF HOURLY WATER TEMPERATURE FLUCTUATIONS

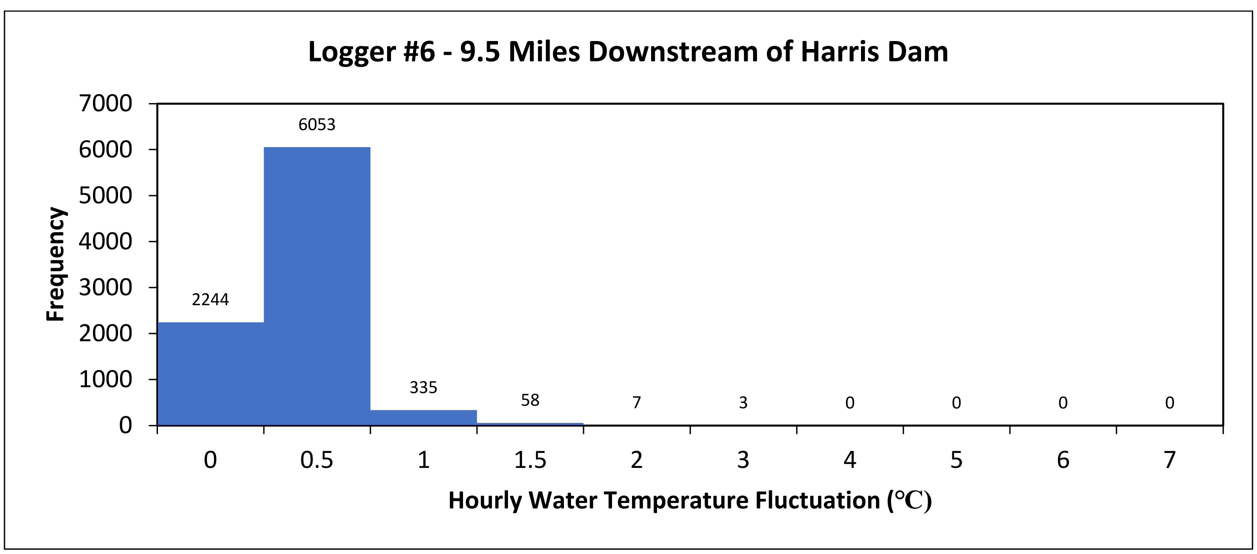

Logger #1 - 0.4 Miles Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2522
5252
586
161
72
130
50
7
4
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)

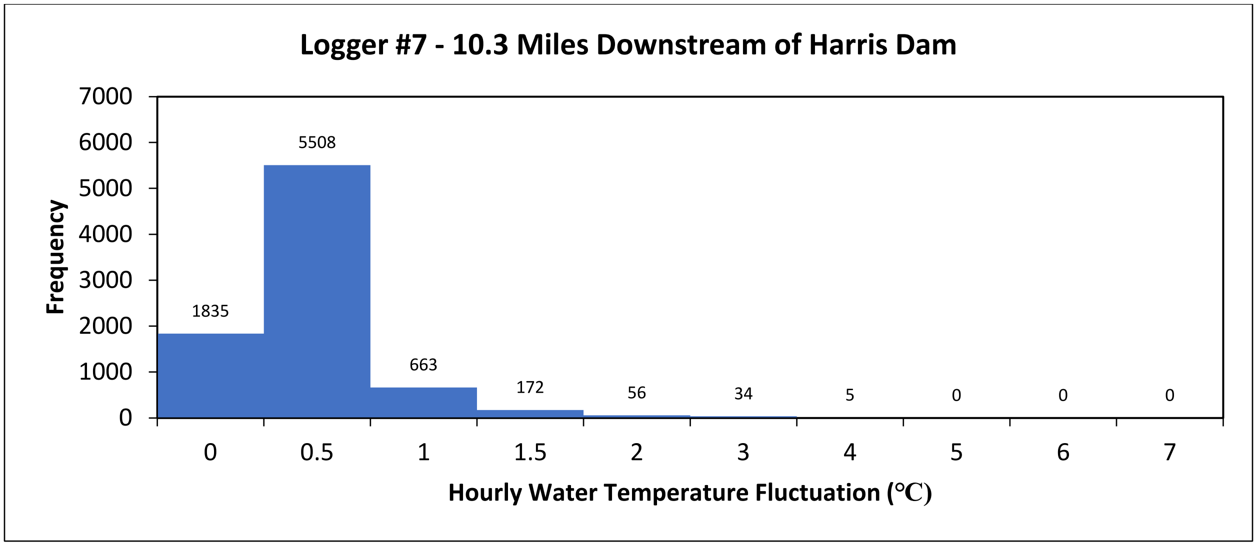

Logger #2 - 1 Mile Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2358
4761
856
379
104
123
110
61
21
11
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)

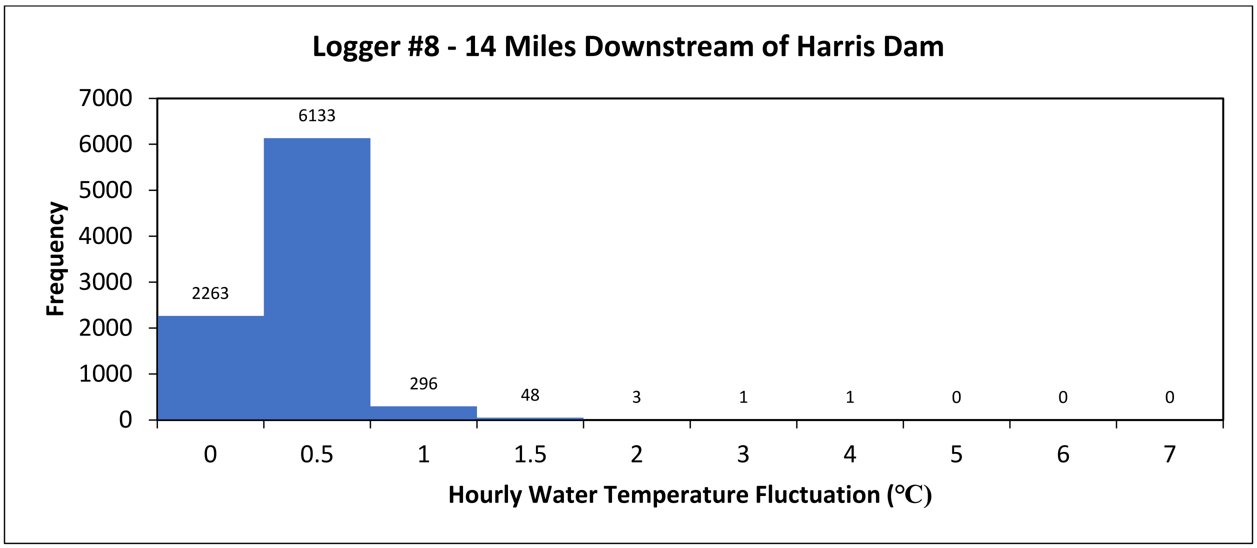

Logger #3 - 3 Miles Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2171
5378
608
316
114
144
36
13
4
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #4 - 5 Miles Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2703
5482
480
91
18
8
2
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #5 - 7 Miles Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2583
5552
391
141
47
53
15
2
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #6 - 9.5 Miles Downstream of Harris Dam
Frequency
7000
6000
5000
4000
3000
2000
1000
0
2244
6053
335
58
7
3
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #7 - 10.3 Miles Downstream of Harris Dam
Frequency
0
1000
2000
3000
4000
5000
6000
7000
1835
5508
663
172
56
34
5
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #8 - 14 Miles Downstream of Harris Dam
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3000
4000
5000
6000
7000
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6133
296
48
3
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0
0
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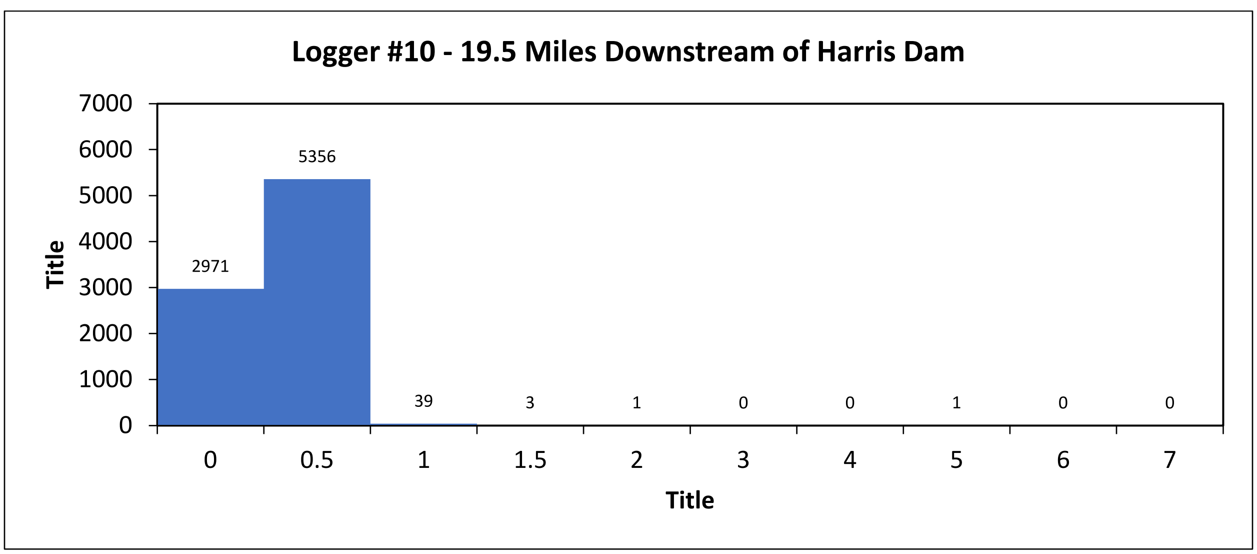
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #10 - 19.5 Miles Downstream of Harris Dam
Title
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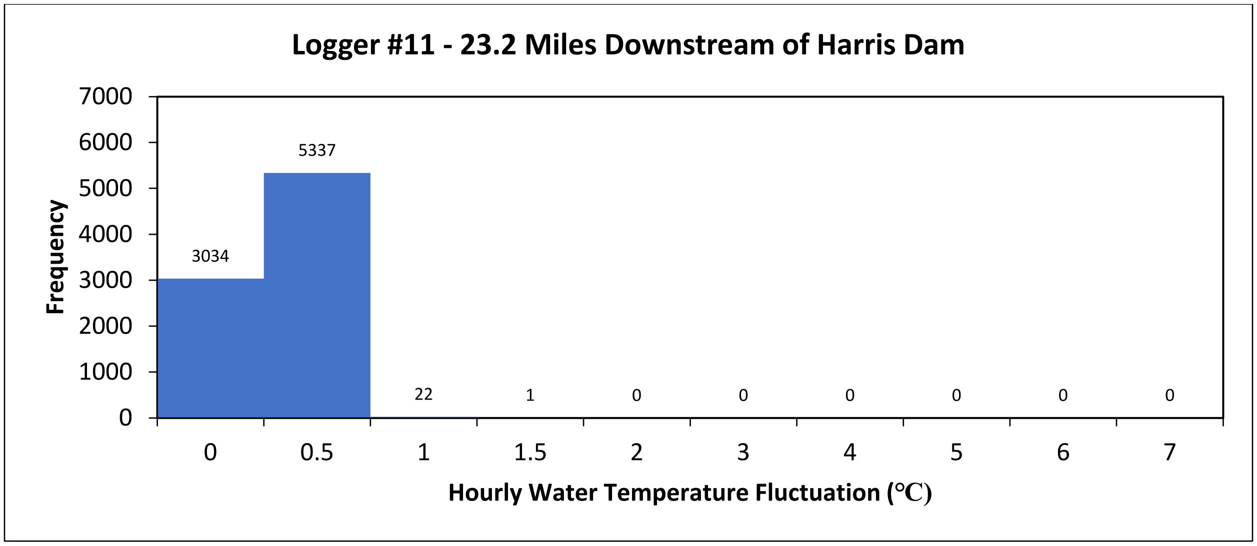
1000
2000
3000
4000
5000
6000
7000
2971
5356
39
3
1
0
0
1
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Title


Logger #11 - 23.2 Miles Downstream of Harris Dam
Frequency
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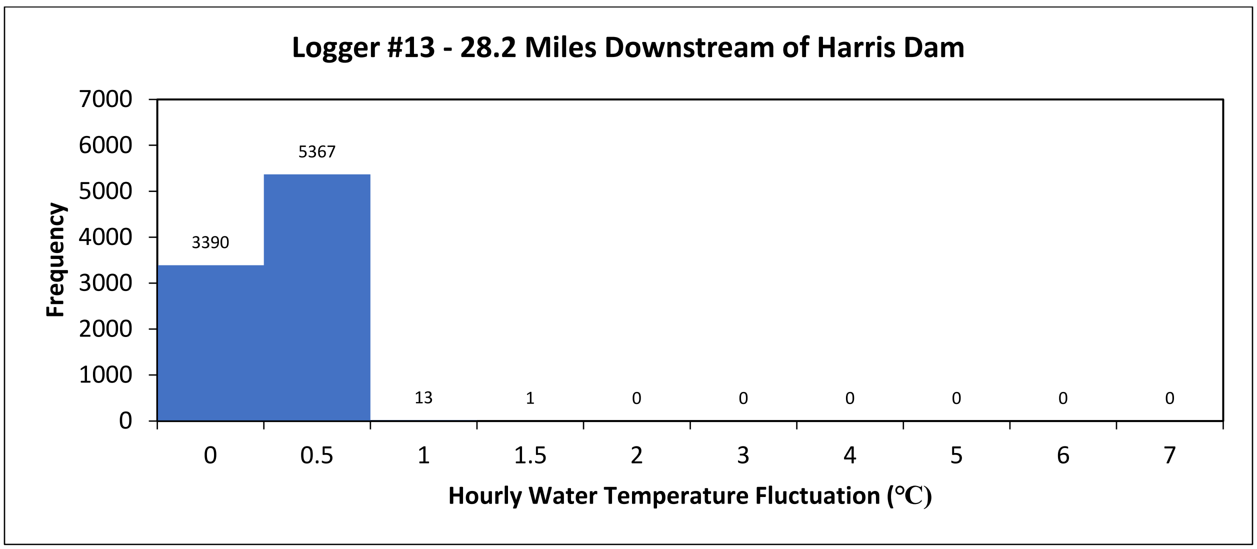
6000
5000
4000
3000
2000
1000
0
3034
5337
22
1
0
0
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #13 - 28.2 Miles Downstream of Harris Dam
Frequency
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5000
4000
3000
2000
1000
0
3390
5367
13
1
0
0
0
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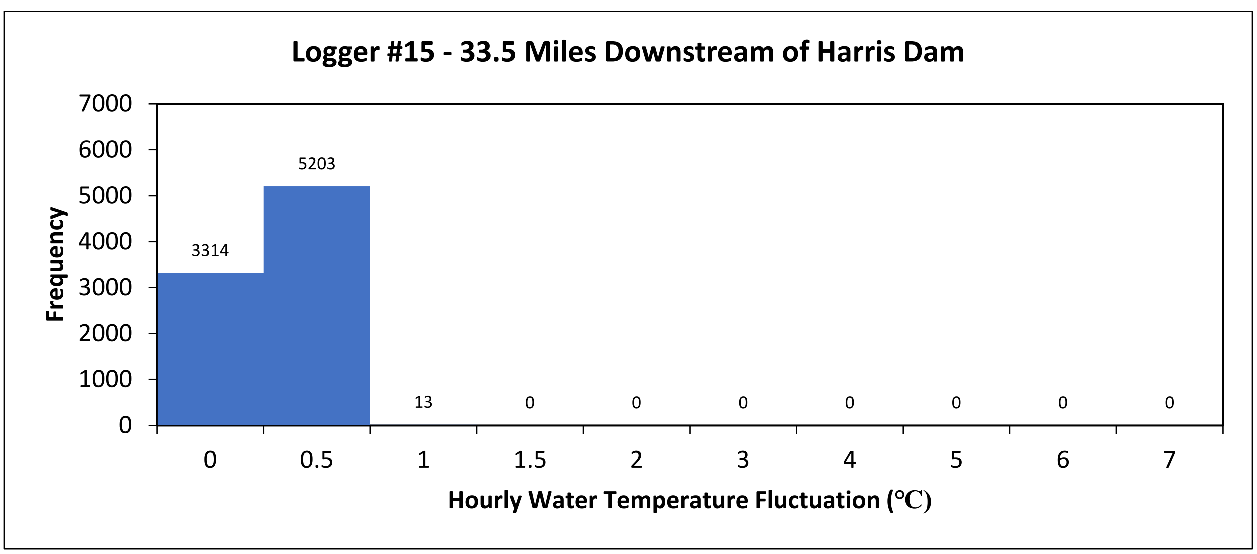
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #15 - 33.5 Miles Downstream of Harris Dam
Frequency
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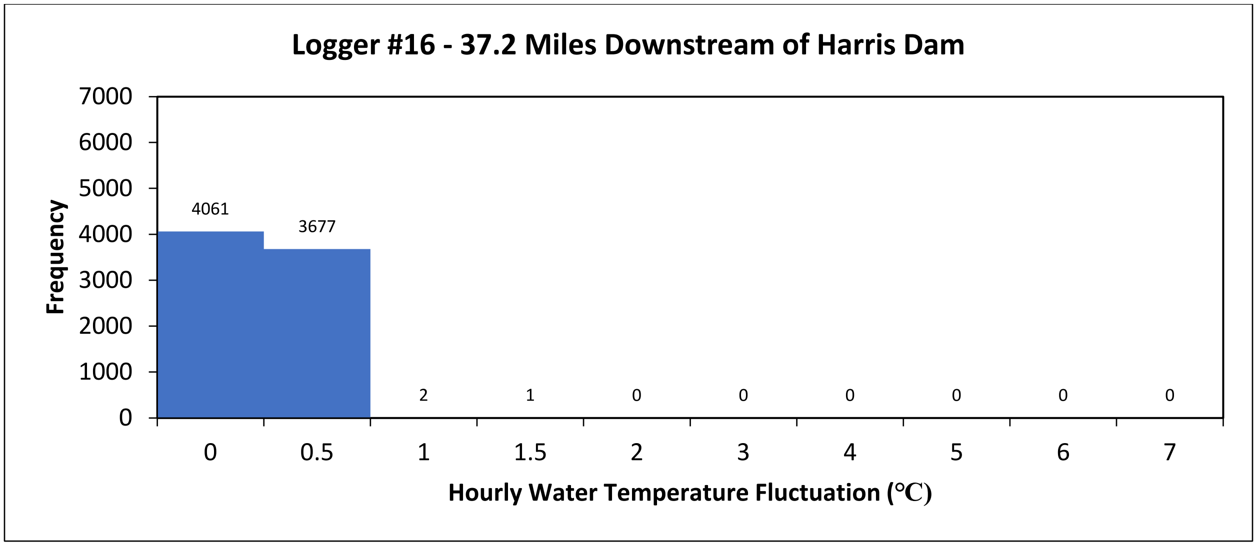
6000
5000
4000
3000
2000
1000
0
3314
5203
13
0
0
0
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (℃)


Logger #16 - 37.2 Miles Downstream of Harris Dam
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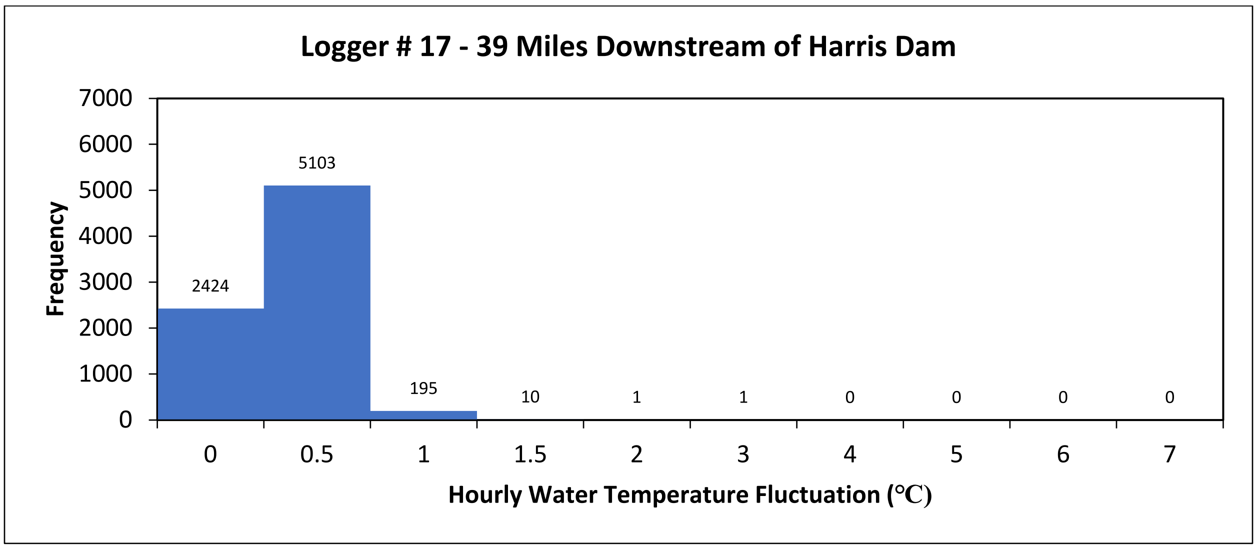
6000
5000
4000
3000
2000
1000
0
Frequency
4061
3677
2
1
0
0
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (°C)


Logger # 17 - 39 Miles Downstream of Harris Dam
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6000
5000
4000
3000
2000
1000
0
Frequency
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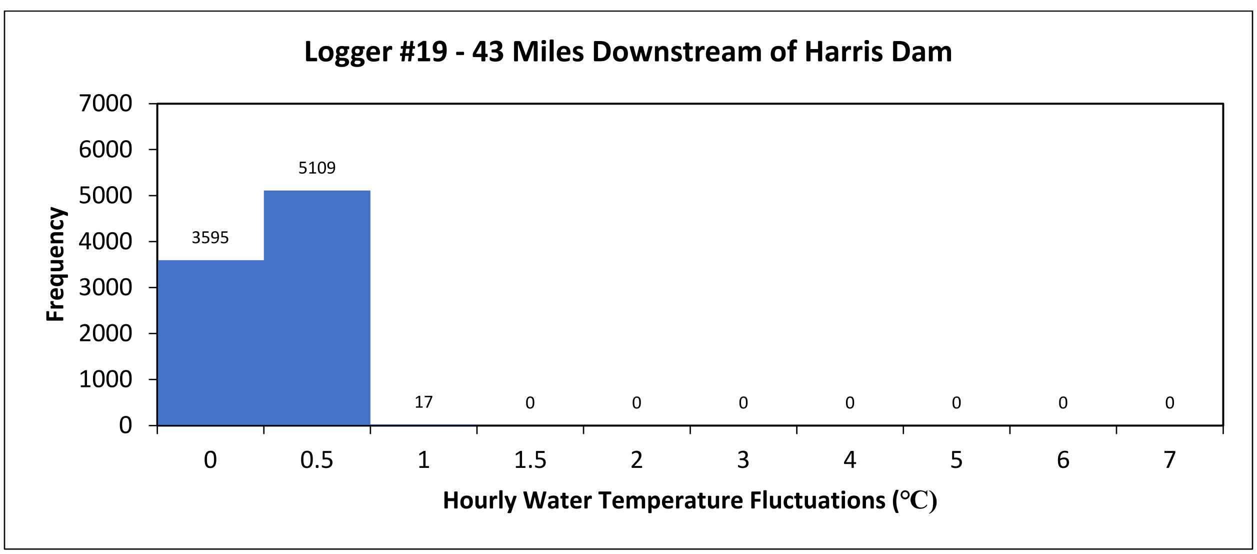
5103
195
10
1
1
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuation (°C)


Logger #19 - 43 Miles Downstream of Harris Dam
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6000
5000
4000
3000
2000
1000
0
Frequency
3595
5109
17
0
0
0
0
0
0
0
0
0.5
1
1.5
2
3
4
5
6
7
Hourly Water Temperature Fluctuations (°C)

APPENDIX D

USING BIOENERGETICS TO ADDRESS THE EFFECTS OF TEMPERATURE AND FLOW ON FISHES IN THE HARRIS DAM TAILRACE

USING BIOENERGETICS TO ADDRESS THE EFFECTS OF TEMPERATURE AND FLOW ON FISHES IN THE HARRIS DAM TAILRACE

FINAL REPORT

Prepared for:

Alabama Power Company
Birmingham, Alabama

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INTRODUCTION

Peaking hydroelectric dams are an important component of the energy production portfolio of many electric power generation companies (U.S. DOI Bureau of Reclamation 2005; Kaunda et al. 2012; FERC 2017). In these peaking systems, the upstream reservoir provides stored water for generation of hydropower during periods of high demand for electricity. Although some possible benefits of these peaking flows to the downstream riverine environments have been suggested (e.g., vegetation control, sediment scouring, cues for spawning or migration; Young et al. 2011), most quantified effects have been negative (reviewed in Young et al. 2011). Unfortunately, the fluctuation of high and low flows causes dramatic changes in the habitat downstream for aquatic species (Cushman 1985; Perry and Perry 1986; Ligon et al. 1995; Young et al. 2011). Not only does flow increase as water is released during generation but variation can occur in water temperature (depending on both the amount of base flow and the temperature of water released from the reservoir relative to that in the tailrace) and dissolved oxygen (e.g., Ashby et al. 1999). Rapid shifts in either flow or temperature as well as a combination of the two can create stressful conditions for aquatic life, including fishes, in the tailrace (e.g., Floodmark et al. 2004; Carolli et al. 2012; Taylor et al. 2012). Some short-term effects of increasing flow for fishes include increased energetic expenditure due to rapid swimming against the current, forcing the fish to take refuge in low flow perhaps suboptimal areas, or causing them to be swept downstream. High flow events can also scour the streambed, potentially removing habitat, reducing available food, or destroying nests if occurring during nesting or spawning. Water temperature shifts can cause behavioral changes in fishes, reduced swimming performance (reduced scope for activity), reduced feeding rate, and/or reduced respiration rates. Clearly there are complex and interconnected effects that such peaking flows can have on the tailrace community below a dam (Young et al. 2011).

Harris Dam on the Tallapoosa River is an example of a peaking generation hydroelectric facility. Operation of the Harris Project began in 1983, functioning at that time as a peaking facility with no intermittent flows between generation periods. During generation events at Harris Dam, water is released from the deeper, colder layers of water, the hypolimnion, from the upstream reservoir causing a simultaneous rapid decrease in tailrace water temperature (during the warmer months) and increase in water velocity; effects are most pronounced in the immediate tailrace area and, at least for temperature, can decrease with distance downstream of the tailrace (e.g., Ashby et al. 1995, 1999). Discussions among stakeholders led to a modification of the Harris Dam operations in 2005 which included a pulsing scheme for releases from Harris Dam that came to be known as the "Green Plan" (Kleinschmidt Associates 2018; also see Parasiewicz et al. 1998, L'Abee-Lund and Otero 2018). Although the Green Plan does provide for flows between peaking flows, the water is still pulled from the hypolimnion, continuing to yield pulses of higher flow with cold water temperatures during peaking high flow events.

More than a decade has passed since implementation of the Green Plan for the operation of Harris Dam, but questions remain as to the effects of current operations on temperatures, flow, and ultimately on fishes in the immediate tailrace and downstream. Some stakeholders are concerned that water temperatures are cooler downstream of Harris Dam than in unregulated areas and that those lower temperatures, temperature fluctuations, and flow variation are affecting fishes (see Goar 2013).

Bioenergetics modelling is a powerful approach to understand the effects of this complex combination of environmental conditions and biological factors. More specifically, bioenergetics models have been used to integrate and investigate the impacts of changing diet, temperature, activity rates, and the influence of stressors on the growth of fishes (Hartman and Hayward 2007). Parameters of these models are largely drawn from experiments where the fish are acclimated to relatively constant temperature and activity conditions. The conditions downstream of peaking generation facilities are highly variable, requiring the evolution of these models to be applicable.

Here we propose to use a multifaceted approach combining use of published data, field sampling, and laboratory investigations, all integrated within a bioenergetics modeling framework to quantify and describe the potential impacts of variation in both flow and temperature on the performance of fish species that are both recreationally and ecologically important below Harris Dam.

Project Objectives: The overall objective for this project is to evaluate the effects of altered flow and temperature due to discharge from Harris Dam on resident fishes in the tailrace using a bioenergetics modeling approach. Specific objectives are to:

1. Summarize the data that are available in the literature concerning temperature requirements for target species, including spawning and hatching temperatures, lethal limits, and thermal optima.
2. Summarize the data that are available in reports and from relevant agencies for water temperatures across a gradient downstream from the Harris Dam tailrace and compare those data with similar data from reference sites upstream of Harris Reservoir.

3. Quantify the fish community across a gradient downstream from the Harris Dam tailrace and in a reference site upstream of Harris Reservoir.
4. Quantify effects of temperature and flow variation on target fish species energy budgets using bioenergetics modeling.

SITE DESCRIPTIONS (see Figure 0.1)

Lee's Bridge. The Lee's Bridge site was our upstream, least-impacted ("control") site and is located 6.4 RKM upstream of the Lee's Bridge boat ramp. There is little habitat heterogeneity at this site which is dominated by sluggish, turbid water. The upstream boundary of our sampling area was a small shoal that is impassible under normal flow conditions. We had two temperature loggers (Onset Computer Corporation; Massachusetts, USA) deployed at this site- one located immediately downstream of the bounding shoal and one in a deeper, slower pool. We sampled this site once every other month using standardized boat electrofishing (Midwest Lake Management, Inc.; Missouri, USA). Low flows during November 2019 prevented us from reaching our usual site; for this one trip, we substituted a reach ~0.8 RKM downstream.

Tailrace. The tailrace site was in the immediate tailrace of R.L. Harris Dam. This site is composed primarily of shoal habitat interspersed with deep, rocky pools. On the western side of the river there is a large, man-made "rip-rap" bank that extends ~0.3 km downstream of the dam. We had one temperature logger (Onset Computer Corporation; Massachusetts, USA) deployed at this site at the base of the rip-rap bank. We sampled this site once every other month using standardized push-barge electrofishing (Midwest Lake Management, Inc., Missouri, USA). Given that barge electrofishing requires the sampling team to be in the water while sampling, the voltage/amperage used was slightly lower than boat electrofishing.

Wadley. The Wadley site was located just southeast of Wadley, Alabama, and was accessed via bank-launch under the AL-77 bridge. Sampling at this site was limited by a small, impassible shoal upstream and a larger shoal complex downstream. The area between shoals is mostly deep, flowing water with abundant hard woody debris along the banks. We had two temperature loggers (Onset Computer Corporation; Massachusetts, USA) deployed at this site- one in the deeper central stretch and one in a shallow part of the downstream shoal. We sampled this site once every other month using standardized boat electrofishing (Midwest Lake Management, Inc.; Missouri, USA).

Horseshoe Bend. The Horseshoe Bend site was at a popular recreational location on the Tallapoosa River with a paved boat ramp and parking area. Riffles and runs dominate the habitat within the immediate vicinity of the access point; however, upstream and downstream of the access point are deep pools and channels. We had two active temperature loggers (Onset Computer Corporation; Massachusetts, USA) deployed at this site- one upstream of the access point and one downstream. The upstream logger was in an eddy off a large run while the downstream logger was in a deep pool were both anchored to trees on the bank and to a brick in the water. We sampled this site once every other month using standardized boat electrofishing (Midwest Lake Management, Inc.; Missouri, USA).

TARGET SPECIES

Based on extensive discussions with all stakeholders in the relicensing process for Harris Dam, a group of target species was agreed on that would be the focus of this project. These species included Channel Catfish *Ictalurus punctatus*, Redbreast Sunfish *Lepomis auritus*, Alabama Bass *Micropterus henshalli*, and Tallapoosa Bass *Micropterus tallapoosae*. These are the species that form the focus of our research efforts for this project.

METHODS AND FINDINGS

In this section, we present the methods used to address each of our objectives, and results associated with each objective. We follow with a general discussion where we integrate all of these findings.

Objective 1: Summarize the data that are available in the literature concerning temperature requirements for target species including spawning and hatching temperatures, lethal limits, and thermal optima.

For this objective, we conducted a thorough review of the literature, including both the published, peer-reviewed literature and the non-peer reviewed grey literature. We used both Web of Science and Google Scholar to locate papers in the primary literature with information related to temperature requirements for our four target species, as well as searched thesis and dissertation databases, state management agency information, and national and global fish information databases. Once again, our four target species were Channel Catfish, Redbreast Sunfish, Alabama Bass, and Tallapoosa Bass. In addition, Alabama Bass was recently defined as a separate species from the Spotted Bass *Micropterus punctulatus* (Baker et al. 2008); therefore, we also included temperature requirement information for Spotted Bass. Similarly, no published temperature requirement information exists for Tallapoosa Bass given that it was just recently defined as a species (Baker et al. 2013); as such, we also researched temperature requirements of Redeye Bass *Micropterus coosae* and Shoal Bass *Micropterus cataractae* as related species that might provide insight. Below we present our findings.

Channel Catfish. Data found for Channel Catfish showed thermal minima that ranged from 0-9.8 C, although the higher values were derived from studies that included either acclimation to different temperatures or diel fluctuations in temperature (Table 1.1). While distributional temperature range was 10-32 C, optimal ranges varied from 24-30 C, and preferred temperatures ranged from 18-31 C, depending on acclimation (25.2-30.5 C without acclimation). Spawning temperatures ranged from 20-30 C, and thermal maxima ranged from 30.9-42.1 C, depending on acclimation (31.32-40.3 C without acclimation).

Redbreast Sunfish. The only thermal minima information we found for Redbreast Sunfish was one source that noted that individuals schooled at 5-10 C (while not schooling at warmer temperatures) and that fish experienced decreased growth at temperatures <15 C (Table 1.2). The distributional temperature range was 4-22 C, but optimal temperature range in another publication was 25-30 C. Preferred temperatures ranged from 18-32 C, depending on acclimation (they were 27-29 without acclimation). Spawning/hatching occurred across temperatures from 16.8-27.8 C in several studies and thermal maxima ranged from 33-41 C.

Alabama Bass/Spotted Bass. The only temperature requirement information we found for Alabama Bass was for spawning, which ranged from 13-20.6 C (Table 1.3). We did find one study with thermal minimum data for Spotted Bass, which was at <10 C. Preferred temperatures for Spotted Bass ranged from 22.5-32.5 C, spawning temperatures ranged from 13-23.3 C, and thermal maxima ranged from 30.76-36 C.

Tallapoosa Bass/Redeye Bass/Shoal Bass. As expected, due to its recent definition as a species, we found no temperature requirement information for Tallapoosa Bass (Table 1.4). We did find spawning/hatching information for both Redeye Bass and Shoal Bass, which ranged from 16.6-

22.8 C for Redeye Bass and from 15-24 C for Shoal Bass. No other temperature requirement information was found.

Overview. Clearly, there is significant variation in the information produced across these studies. Some of the variation is likely due to acclimation, which was explicitly demonstrated in several studies (Allen and Strawn 1968; Cheetham et al. 1976; Mathur et al. 1981; Currie et al. 1998; Bennett et al. 1998). In addition, one study demonstrated that diel temperature fluctuations can also lead to changes in measured temperature requirements, i.e. critical thermal minima in their case (Currie et al. 2004). The variation in approaches and methods used to identify temperature requirements is also likely a large cause of variation. Additional work using standardized methods will be needed before more conclusive findings can be produced.

As expected, no data were available for Tallapoosa Bass, and little information was available for Alabama Bass. More work is obviously needed with these species to characterize their temperature requirements. We did find information on related species of black basses; Redeye Bass and Shoal Bass in the case of Tallapoosa Bass, and Spotted Bass in the case of Alabama Bass. Whether information from those related species is comparable to the target species will only be revealed through time as more work is done with these newly-defined species and more information becomes available.

Several papers noted the potential importance of degree days (or degree-hours) versus simple temperature (e.g., Andress 2002; Phelps 2007). Given the complications of potential population differences across latitudes and effects of acclimation (including on a diel or daily temperature cycle), combined with variable findings across results in our review, perhaps a degree-day approach might be worth examining.

Objective 2: Summarize the data that are available in reports and from relevant agencies for water temperatures across a gradient downstream from the Harris Dam tailrace and compare those data with similar data from reference sites upstream of Harris Reservoir.

Historic temperature data from 2000 - 2018 were provided to Auburn by the Alabama Power Company. Temperature loggers (Hobo Temps Onset Computer Corporation) recorded temperature once per hour at 3 locations (Harris Dam tailrace, Malone, Wadley) along the Tallapoosa River; however, due to periods of high flow or device malfunction, some data were missing every year. These missing data tended to occur during winter, and thus winter temperatures could not be analyzed for any year. Data were also downloaded from the USGS gage at Heflin, AL for 2018-2020. Temperature data were analyzed using the statistical package R (R Studios 2015). No statistical analyses were conducted using the Heflin data given the short data record (there were only 3 years of data) and the numerous biotic and abiotic differences between the Heflin site and sites downstream from Harris Dam (e.g., higher turbidity, smaller channel, large agricultural inputs, fewer tributaries, plus other variables not measured here).

In total there were 111,366 temperature measurements across the 19 years, with 2000-2004 in the pre-Green Plan period and 2005-2018 during the post-Green Plan. Hourly data points were used to generate hourly and daily averages, minimum, and maximum temperatures through the year. This eliminated some variation but allowed for a consistent comparison of temperatures across years. Once this was done for each site, average monthly temperatures pre- and post-Green Plan were analyzed using analysis of variance. The only significant differences were within years due to seasonality while there were no significant differences in monthly temperatures pre- versus post-Green Plan (Figure 2.1).

Most years showed temperatures rising over the summer and being lower in fall and spring. Some years did have periods of relatively higher variation during both pre- and post-Green Plan periods, although these fluctuations did not differ significantly from other years (Figure 2.2). The range in daily temperatures was lowest at the unregulated Heflin site. Temperatures at Heflin were much lower in January 2018 versus 2019 or 2020, but otherwise the unregulated section exhibited the same temperature pattern across seasons (Figure 2.2). Extreme fluctuations in temperature were rare (extreme fluctuations were defined here as a 10 C shift within a day; Malone: 0.60% days pre-Green Plan, 0% days post-Green Plan; Wadley: 0% days pre-Green Plan, 0.52% days post-Green Plan; Heflin 0% 2018-2020; tailrace: 0.28% days pre-Green Plan, 0.43% days post-Green Plan [driven by 2015 data]) (Figure 2.3). When we considered hourly temperature fluctuations, we found them to range from 0-15.3 C with less than a 2 C hourly change being by far the most common (Figure 2.4). In fact, the percentage of hourly observations post-Green Plan that were greater than 2 C across all regulated sites (excluding Heflin) was 0.67% (Table 2.1 Figure 2.5), and no visible differences could be observed in the distributions of hourly temperature fluctuation frequencies between pre- versus post-green plan. The unregulated site at Heflin experienced 22 hourly temperature changes that were >10 C changes over the three years of available data, however these all occurred in January 2018 when the lowest average temperatures were recorded. It is possible low water levels in 2018 caused the logger to become exposed to air, leading to these low recorded temperatures. This possibility is supported by the low daily average temperature fluctuations as water immediately warmed back to average within an hour. Temperature tended to increase as water moved downstream across most months, with slightly greater differences, though not statistically significant, among locations post-Green Plan versus pre-Green Plan (Figure 2.6). Water temperature in the tailrace tended to be warmer than air temperature in the fall and spring, and cooler than air temperature in the summer, while water temperature at the Malone and Wadley sites was generally higher than air temperature in all months (Figure 2.7).

Temperature (C) data from April 2019 – May 2020 were recorded every 15 minutes by HOBO temperature loggers (Onset Computer Corporation) deployed within the Tallapoosa River between Harris Dam and Martin Reservoir. Average hourly temperatures were calculated for each season (spring: March, April, May; summer: June, July, August; fall: September, October, November; winter: December, January, February) at 20 locations (Data provided by Kleinschmidt Consultants). Temperatures were mapped onto the river using ArcMap 10.7.1 and interpolated between logger sites using the spline function which interpolates a raster surface from two-dimensional data using a minimum curvature approach passing through the known points. The resulting raster was confined to the boundaries of the river. Power generation information for 2018 was provided by Alabama Power and used to determine when generation occurred most frequently.

Temperatures ranged greatly across seasons (spring: 15.0 - 24.5 C; summer: 22.4 – 29.5 C; fall: 16.6 - 30.1 C; winter: 10.4 – 12.3 C) though general trends occurred within each season. Spring generation times (Figure 2.8) showed a bimodal distribution with the most common times of generation being 06:00 and 18:00 which are among the planned generation times in the Green Plan (Downstream Release Alternatives Study Plan). However, generation occurred frequently within 2 - 3 hours of those peak generation times suggesting a prolonged or subsequent generation. Figure 2.9 is a large multi-panel figure that shows the hourly temperature patterns across 24-hours during each of the four seasons along the Tallapoosa River. The section of river south of Wadley, Alabama (L08 – L11) appeared to be consistently warmer (+ 2 to 3 C) than the majority of the river during spring. There was some evidence of periodic warming in the tailrace as seen in figures Spring 12:00 to Spring 13:00 though the change was quite small. Summer generation was more limited than in other seasons, with most generations occurring at 06:00, 12:00, and 16:00 – 19:00. The water in the tailrace during summer was consistently cooler than the downstream river which gradually warmed with increasing distance from the dam (Figure 2.9). The tailrace temperature increased over the course of a typical summer day (Summer 12:00 - Summer 14:00), likely due to the shallow water exposed to solar heating between pulses. However, the water between L04 and L05 remained cooler despite the time of day. Fall had the largest variation in temperatures as expected due to increased rainfall and generation as the reservoir begins to lower to winter pool level. There tended to be 3 peaks in generation time (06:00, 12:00, and 17:00 - 19:00) (Figure 2.8) during fall, with temperatures in the tailrace being lowest in the morning and warming as the day progressed up until nightfall (Figure 2.9). Other sections of the river held relatively steady temperatures throughout the day. Winter experienced the least amount of variation in hourly average temperatures, not varying more than 2 C (Figures 2.9 and 2.10). Unlike other seasons, morning tailrace temperatures in the winter were not the coolest temperatures recorded and indeed the temperature remained elevated compared to other sections of the river (though within 2 C). The warmest section of river tended to be the section between Malone and Wadley, which includes some of the more developed areas adjacent to the river. While generation during winter also seemed to be bimodal, some generations occurred periodically at all times between 05:00 and 21:00 (Figure 2.8).

Water temperature tended to increase with increasing distance from Harris Dam during spring, summer, and fall. During winter, the warmest water was recorded near the dam in the tailrace and between loggers 7 and 8 (stretch between Malone and Wadley). Though summer temperatures did not vary as greatly as spring and fall temperatures, the gradation was more pronounced with cooler water always in the tailrace of Harris Dam.

Because the most common generation times were near 06:00, 12:00, and 18:00, average temperature for January, April, June, August, October, and December were interpolated from the data recorded by loggers at these times and plotted to show the relative change in temperature throughout the day for these six months (Figure 2.11). By comparing maps (e.g., August 12:00 and August 18:00), the location of generation pulses can be seen as the water cools in different sections of the river.

Objective 3: Quantify the fish community across a gradient downstream from the Harris Dam tailrace and in a reference site upstream of Harris Reservoir.

Field Collection Methods. Fish were collected by boat electrofishing (Midwest Lake Management, Inc. Missouri, USA) once every other month, with sampling at each site consisting of six, 600-second transects; a total of 12 bimonthly sampling events took place over the duration of this study. Output voltage was standardized between 700-900 volts with 100-120 pulses per second, and GPS coordinates were recorded at the start and end of each transect. A floating barge electrofisher was used at the tailrace site given that it is inaccessible by a regular boat; sampling consisted of one individual with the anode and dip-netters wading alongside, with another individual pushing the barge itself. Barge electrofishing followed the same procedures, although a lower voltage (500-700 volts) was used for safety. For roughly half the sample events, all collected fish were bagged and immediately placed in an ice water slurry with fish from each transect stored separately; for the remainder of the sampling events, target species individuals were kept separate by transect in an ice water slurry while non-target individuals were identified, measured (nearest mm TL), weighed (nearest g), and returned to the area from which they were collected. For each sampling date dissolved oxygen and temperature were measured at the surface with a Yellow Springs Instruments model 55 meter.

Telemetry Methods. During July 2020 we surgically implanted 16 combined acoustic and radio transmitter tags (CART tags, Lotek MM-MC-8-SO) in 13 Alabama Bass and 3 Tallapoosa Bass (tag weight was always <2% of individual's body weight; Winter et al. 1996). Collection took place between the Harris tailrace and the Randolph County Road 15 bridge in Malone, Alabama. Fish were sedated with MS-222 (approximate concentration = 300 ppm) prior to surgery and aerated water was pumped across the fish's gills during tag implantation. Implantation followed the procedures outlined in Cooke et al. (2012). Fish were held in a tank after surgery to ensure recovery before being released at their capture sites. After release, manual radio tracking efforts occurred at weekly intervals starting three weeks post-tagging from a canoe paddled from the tailrace to the CR 15 bridge. Manual tracking was conducted using a Lotek VHF Receiver with an attached GPS antenna. Fish position was determined by paddling downstream until a radio signal was detected and then wading or paddling until signal strength was highest when the antenna was pointed at the water (Sammons and Earley 2015).

In addition, eight stationary acoustic receivers were deployed to provide four gates between the R.L. Harris tailrace and CR 15 in Malone, with each gate consisting of an upstream receiver and a downstream receiver (receivers were located 20.54, 20.14, 16.90, 17.74, 14.69 14.31, and 10.52 RKM upstream of the Wadley site). Receivers were attached to concrete anchors cabled to the bank with steel cable and deployed in water exceeding 1.5 m in depth during non-generation flows. The upstream-downstream configuration was an attempt to identify any directional movement should a fish pass both receivers within a gate. An additional two receivers (for a total of 10 receivers) formed a gate at the Wadley site to detect any further extreme downstream movement.

Laboratory Methods. In the lab, all fish were identified to species and up to 10 individuals of each non-target species were weighed and measured; if more than 10 individuals of a given species were present in a transect, the remaining individuals were counted and the group was bulk weighed. The same methods were used when the non-target species were processed and returned to their capture location in the field. All individuals of the target species were weighed, measured, and sexed. Additionally, stomach contents, gonad weight, and sagittal otoliths (lapillar otoliths for Ictalurids) were extracted from all collected individuals of each target species. Stomach contents were viewed under a dissecting microscope and all prey items were identified to the lowest taxon possible, measured to the nearest 0.1 mm along their longest axis using an ocular micrometer, and counted; a note was made if the item was not whole (e.g., a head, an otolith, etc.). In instances where large numbers of a diet item were present, a haphazard subsample of 10 individuals of that diet item was measured, the remaining items were counted, and the total number recorded.

Otoliths were aged by two independent readers, with disagreements resolved by a third independent reader and discussion. Inter-annular distances were measured for age-and-growth calculations using an image-analysis system. All otoliths estimated to be five years old or older were sectioned to 0.6 mm using an Isomet diamond wheel low-speed saw before ageing. Any otoliths that readers could not agree on an age for were sectioned and read again.

Data Analysis: Age and Growth. Length of all target species was estimated to the last observed annulus using the direct proportion method (Quist et al. 2012). Estimated lengths were then used to fit a von Bertalanffy growth curve to the data using negative log-likelihood. As a measure of body condition, relative weight (Wr) or relative condition (K_n) was calculated for all fish of each target species (Neuman et al. 2012). Standard weight parameter estimates published for Spotted Bass were used to calculate relative weight of Alabama Bass and Tallapoosa Bass and a length-weight regression of all observed individuals was created to estimate average weights by total length for Redbreast Sunfish as standard weight equations for these species are not widely available. Relative condition for Redbreast Sunfish was calculated as the ratio of predicted weight from the length-weight regression to observed weight.

An analysis of variance was conducted on Wr by site for Channel Catfish, Alabama Bass, and Tallapoosa Bass, and on K_n for Redbreast Sunfish with a Tukey's HSD post-hoc test to make pairwise comparisons between sites when the overall model was significant. Age-frequency graphs were constructed for each target species by site to help visualize the data and identify age related bias in sampling.

Data Analysis: Diet. The weight of each diet item was estimated using published length-weight regressions (i.e., Benke et al. 1999) as in Purcell et al. (2011) or calculated length-weight regression as follows:

$$W = aTL^b$$

where W is the diet item weight, TL is the length of the diet item, *a* is the intercept, and *b* is the slope. Percent-by-weight of each diet item was then calculated for all target species by season and site by calculating percent by weight within an individual fish and then calculating an average across individuals within each site x season combination.

Data Analysis: Fish Community Composition. Shannon's diversity index (H) and total species richness were calculated for each site to allow comparison across sites as well as with previous studies (Shannon and Weaver 1949; Travnichek and Maceina 1993; Freeman et al. 2005). Additionally, tables of abundance by site and catch per effort (CPE) by site and month were generated.

Data Analysis: Telemetry. The river-km positional location of each tag was recorded from the beginning of August 2020 until the end of September 2020. False detections and instances where receivers detected other receivers were identified and eliminated from the dataset. Graphs of each detected fish's location over time were constructed to visually assess movement. Additionally, a table of the total number of detections for each tagged fish and the last detection of each fish was generated.

Results:

Fish Community Composition

Shannon's Diversity Index (H) for all sites combined was 3.06. When considering individual sites, Wadley had the highest species diversity (2.88), while Horseshoe Bend had the lowest (2.46), although all values were very close (range among sites was 0.39; Table 3.2). Species richness ranged from 33-39 among sites, and the number of families ranged from 7-9 (Table 3.2).

Seasonal shifts in community composition were evident in our collections. At the family level, both clupeid and cyprinid catch rates were highest in the winter while catastomid catch rates varied little across season (Table 3.3). Ictalurid catch rates were highest in summer and fall, while centrarchid catch rates were highest during spring, summer and fall (Table 3.3).

Catch rate for families of fishes differed among sites as well, with the tailrace being most distinct from the other three sites. Centrarchid catch rates were the highest of any family across sites, followed by cyprinids at all but the tailrace where percids had the second highest catch rate (cyprinid catch rate at the tailrace was third highest; Table 3.4). Catostomids were also an important element of the catch at the Lee's Bridge and Wadley sites (Table 3.4).

The Lee's Bridge site was inaccessible during winter due to reservoir drawdown, but during other seasons, catch rates were highest in the fall followed by summer (Table 3.5). In the tailrace, catch rates were highest in winter and fall, with values being lower in spring and summer (Table 3.6). Catch rates at Wadley were highest in the summer, followed by fall and spring, and were lowest during the winter (Table 3.7). Horseshoe Bend catch rates were highest in the spring, followed by winter, fall, and summer (Table 3.8). The five most frequently collected species at each site were (Table 3.4):

Lee's Bridge – Blacktail Redhorse, Bluegill, Alabama Bass, Blacktail Shiner, and Gizzard Shad;

tailrace – Bluegill, Bronze Darter, Alabama Shiner, Shadow Bass, and Lipstick Darter;

Wadley – Alabama Bass, Blacktail Redhorse, Redbreast Sunfish, Blacktail Shiner, and Bronze Darter;

Horseshoe Bend – Alabama Bass, Redbreast Sunfish, Silverstripe Shiner, Blacktail Shiner, and Blacktail Redhorse.

Age-and-Growth

Channel Catfish. A total of 200 Channel Catfish were collected – 68 from Lee's Bridge, 59 from the tailrace, 21 from Wadley, and 52 from Horseshoe Bend. Of these, 177 exceeded the minimum length limit (70 mm) for relative weight calculation (Gabelhouse 1984a). An ANOVA of Wr revealed that body condition in the tailrace was 19.4% ($p<0.001$) greater than at Lee's Bridge (Table 3.9, Figure 3.1). Two additional pairwise comparisons were marginally significant – Wr was 9.52% higher ($p=0.09$) in the tailrace compared to Horseshoe Bend and 9.88% higher ($p=0.06$) at Horseshoe Bend than at Lee's Bridge (Table 3.9; Figure 3.1). We did not find a strong relationship between relative weight and fish length, indicating that further analysis of this relationship was not necessary (Figure 3.5).

Channel Catfish ages ranged from 0 to 12 years old with age-2 the most frequently collected (Figures 3.7, 3.8). More Channel Catfish in the age 0-2 classes were collected in the tailrace than any other site while catfish collected from Lee's Bridge and Horseshoe Bend tended to be older (Figure 3.7). Otoliths from 168 Channel Catfish were used to calculate von Bertalanffy growth parameters (Figure 3.15). The asymptotic length for all sites combined was 413.8 mm with the highest site-specific value at Wadley and the lowest at Horseshoe Bend (Table 3.10). Site-specific parameters calculated for the tailrace were outside of the expected range, likely because older fish were absent from the sample, causing growth to appear linear with no asymptote (Table 3.10; Figures 3.16). Channel Catfish reached a higher asymptotic maximum length below the reservoir, though parameter estimates were likely biased due to low numbers of age 0 and 1 catfish collected from Lee's Bridge (Figures 3.7, 3.17).

Redbreast Sunfish. A total of 337 Redbreast Sunfish were collected – 24 from Lee's Bridge, 53 from the tailrace, 97 from Wadley, and 163 from Horseshoe Bend. Of these, 304 exceeded the minimum length limit (80 mm) for relative condition calculation (Gabelhouse 1984a). An ANOVA of relative condition revealed no significant differences among sites though the mean relative condition of Redbreast collected from the tailrace was highest (Table 3.9; Figure 3.2).

Redbreast Sunfish ages ranged from 0 to 7 years old, with age-3 fish most frequently collected (Figures 3.9, 3.10). There were no obvious trends by site in the ages of collected Redbreast Sunfish (Figure 3.9). Otoliths from 277 fish were used to calculate von Bertalanffy growth parameters (Table 3.10; Figure 3.18). The asymptotic length for Redbreast Sunfish from all sites was 263.27 mm, with Wadley having the highest site-specific value and the tailrace the lowest (Table 3.10). Small sample size from Lee's Bridge prevented reliable parameter calculations for that site (Table 3.10). The maximum age captured at Lee's Bridge was 4 years old, limiting our ability to produce site-specific estimates of growth curves or make comparisons of those parameters estimates with those from sites below the reservoir (Figure 3.20).

Alabama Bass. A total of 418 Alabama Bass were collected, including 61 from Lee's Bridge, 72 from the tailrace, 147 from Wadley, and 138 from Horseshoe Bend. Of these, 367 were above the minimum length limit (100 mm) for Wr calculation (Gabelhouse 1984a). Average Wr differed significantly by site with fish in the tailrace being 6.5% ($p<0.01$), 7.5% ($p<0.01$) , and 4.3% ($p<0.01$) higher than those at Horseshoe Bend, Lee's Bridge, and Wadley respectively (Table 3.9, Figure 3.3).

Alabama Bass age ranged from 0 to 11 years old, with age-1 the most frequently collected (Figures 3.11, 3.12). At the tailrace and Horseshoe Bend, age classes 0 and 1 dominated collected Alabama Bass while ages were more broadly distributed at Wadley and Lee's Bridge (Figure 3.11). A total of 382 Alabama Bass otoliths were used to calculate von Bertalanffy growth parameters (Table 3.10; Figure 3.22). The asymptotic length for Alabama Bass was 549.09 mm across all sites, with Horseshoe Bend having the highest site-specific value and Wadley the lowest (Table 3.10). Lee's Bridge had the second highest site-specific asymptotic length and a higher growth coefficient than the combined downstream sites (Table 3.10). There were not enough Alabama Bass collected from the tailrace in older age classes to generate reliable site-specific growth parameters; however, all observations of age-3 fish from the tailrace fell below the expected length using parameters estimated across all sites (Figures

3.21, 3.24). Alabama Bass grew faster above the reservoir but reached a lower asymptotic length (Table 3.10; Figure 3.23).

Tallapoosa Bass. A total of 60 Tallapoosa Bass were collected – 2 from Lee's Bridge, 3 from the tailrace, 20 from Wadley, and 35 from Horseshoe Bend. Of these, 58 exceeded the minimum length limit (100 mm) for Wr calculation (Gabelhouse 1984a). An ANOVA of Wr revealed no significant differences among sites, and mean Wr for all sites was above 90% (Figure 3.4).

Tallapoosa Bass age ranged from 0 to 8 years old with most fish in the age-2 and age-4 classes (Figures 3.13, 3.14). Sample size prevented comparison of age-frequency by site; however, overall Tallapoosa Bass ages were distributed among several ages (Figure 3.14). All 60 otoliths collected from Tallapoosa Bass were used to calculate von Bertalanffy growth parameters (Table 3.10). The asymptotic length for Tallapoosa Bass was 363.91 mm for all sites combined. Low sample size prevented development of site-specific parameters (Table 3.10, Figures 3.25). Examination of length at age by site showed no noticeable trends in Tallapoosa Bass growth (Figure 3.26).

Diets:

Channel Catfish. Channel Catfish diets had the highest number of different prey types of all target fish species with insects contributing the highest proportion of all categories by weight. During spring, the weight of insect larvae in Channel Catfish diets increased, similar to trends observed in Alabama Bass and Redbreast Sunfish (Figure 3.27).

Channel Catfish in the tailrace consumed more crustaceans by weight than at any other site, consisting primarily of isopods and amphipods (Figure 3.28). At other sites, insects and insect larvae were the largest contributors to Channel Catfish diets (Figure 3.28).

Redbreast Sunfish. As expected, insects contributed the majority of Redbreast Sunfish diets across all seasons. During spring, there was a distinct increase in consumption of insect larvae, a trend shared across all target species (Figure 3.29).

In the tailrace, the contribution of crustaceans to Redbreast Sunfish diets was substantially greater than at any other site (Figure 3.30; also seen Channel Catfish diets; Figure 3.28). Outside of the tailrace, insect and insect larvae contributed to the vast majority of Redbreast Sunfish diets by weight (Figure 3.30).

Alabama Bass. Across all seasons, the majority of Alabama Bass diets by weight consisted primarily of crayfish and insects, but there was variation in diets across seasons (Figure 3.31). During summer (June – August) and fall (September – November) crayfish were the primary diet item. During spring (March – May), insects and insect larvae contributed most to Alabama Bass diets. Finally, fishes and insects dominated winter (December – February) Alabama Bass diets (Figure 3.31).

Comparing across sites, fishes made up a larger percentage of diets at the Lee's Bridge site while bass in the tailrace consumed far more insects (Figure 3.32). At Wadley, crayfish were the dominant diet item and at Horseshoe Bend insects were the largest group. Zooplankton and Crustaceans contributed more to Alabama Bass diets in the tailrace than any other site (Figure 3.32).

Tallapoosa Bass. The primary diet item across all seasons in Tallapoosa Bass diets was crayfish (Figure 3.33). During spring, higher levels of insect and insect larvae were observed, while during winter, crayfish dominated Tallapoosa Bass diets (Figure 3.33).

Diets from only a few Tallapoosa Bass were collected from Lee's Bridge and the tailrace, and crayfish was the only prey type consumed (Figure 3.34). Diets were similar between Horseshoe Bend and Wadley with fish from Horseshoe Bend having a more even distribution of prey types.

Telemetry:

Of the 16 total tags deployed, 12 were detected by the stationary acoustic receiver array and 10 were detected during at least one manual tracking trip (Table 3.11; Figure 3.35). Smaller CART tags implanted in fish <600 g had a battery life of ~30 days and were not active beyond the second manual tracking effort. Nine of the remaining 10 active tags were detected in at least one subsequent manual tracking event (Figure 3.35). The river position of fish closest to the dam changed less than that of fish further downstream (Figure 3.35). Of the 12 tags detected by the stationary acoustic receiver array, 8 were detected only at a single location (i.e., their locations did not change to any other receivers) the majority of the time and maximum movement detected was 6.23 RKM (Figure 3.36). The remaining four tags were detected at more than one receiver in the array (Figure 3.36). A test tag towed through the receiver array was detected at all receivers, supporting that the array of receivers was functioning properly.

Objective 4: Quantify effects of temperature and flow variation on target fish species energy budgets using bioenergetics modeling.

Part A- Metabolic measures and swimming performance

Target species were collected from all four study sites on the Tallapoosa River using boat and barge electrofishing as described for objective 3. Fish were placed into an aerated hauling tank and transported to Auburn University's E.W. Shell Fisheries Station and placed in quarantine for 1 week at the same temperature as in the river on the day of collection. Dechlorinated city water was used in all quarantine tanks, holding tanks, and swim challenge flumes. After the 1-week quarantine, fish were moved into holding tanks and fed worms or Fathead Minnows once every 2 days at 2% of their body weight. Water quality was monitored daily and any necessary water chemistry changes were performed. Temperature was altered by 1 degree every two days until the desired trial temperature was reached (10, 21 or 24 C). Once the trial temperature was reached, fish were acclimated for two additional weeks at the trial temperature. Individual fish were only used once in swim trials to avoid any training effect (Parsons and Foster 2007) or bias due to excessive stress. Feeding was halted 48 hours prior to trials to ensure fish were in a post absorptive state. Lights in the room were set to an automatic 12:12 hour day: night schedule.

To measure standard metabolic rate (SMR) Fish were sedated with neutrally buffered MS-222 so they could be weighed prior to placement inside one of two respirometer chambers (either 600 or 2700 ml, chosen to be appropriate for the size of the test fish). Each respirometer chamber had an open loop (flushing loop) and a closed loop (recirculating) to allow for water to both move across the fish and allow for intermittent measurement of oxygen consumption using Autoresp software (Loligo Systems, Tjele, Denmark). A fiber-optic oxygen probe was included in each recirculating loop and measured oxygen once every second. Fish were acclimated overnight (minimum of 12 hours) with intermittent flow respirometry (300 seconds closed recirculating loop, 1200 seconds flushing loop) and oxygen levels were never allowed to drop below 80% oxygen saturation during these intermittent cycles. After fish were acclimated overnight and then allowed to respire through at least 10 intermittent cycles after the lights had turned on, chambers were switched to remain solely on the recirculating loop and fish were allowed to respire until oxygen declined to below 5 ppm. Fish were then euthanized according to the approved Auburn University IACUC protocol (Auburn University IACUC protocol #2018-3387).

Piecewise regression was used with respiration rates through time to determine when acclimation occurred. Respiration rates calculated after acclimation and the calculated rate from closed respiration were all used to obtain an average MO_2 (mg O_2*$kg^{-}1$*hr^{-1}). We compared individuals within a species across sites and across fish sizes.

Critical swimming speed trials were conducted in a 90-L Loligo (Loligo Systems, Tjele, Denmark) swimming respirometer (Figures 4.1a-b). AutoResp 2.3.0 software (Loligo Systems, Tjele, Denmark) was used to control water velocity and record oxygen concentration through a Witrox4 fiber-optic probe and DAQ – q controller. This system allowed precise incremental velocity increases at predetermined time intervals, recorded oxygen concentration once every second, and calculated an average oxygen concentration once every 30 sec. AutoResp software was also used to calculate active metabolic rate (AMR) at each speed increment (VO_2, mg O_2*kg^{-1}*hr^{-1}). Generated metabolic rates were confirmed by manually calculating VO_2 for a randomly selected subsample of data using the following equation:

$$VO_2 = (O_{2i} - O_{2f}) * (V/t) * (1/W)$$

where O_{2i} is the initial concentration of dissolved oxygen (mg/L), O_{2f} is the final dissolved oxygen concentration, V is the chamber volume (L), t is the time period (h), and W is the wet weight of the fish (kg).

Individual fish were randomly selected from the holding tanks and quickly transferred to a bucket of water mixed with 40 mg*L^{-1} of neutrally buffered MS-222. After sedation was confirmed (via loss of equilibrium and little to no reaction to external stimuli), fish were measured for total length (mm), body depth (mm), body width (mm), and weight (g). Fish were placed into the 90-L swimming respirometer and monitored for signs of recovery from sedation. All fish quickly recovered equilibrium (facing forward with normal posture) within 2 min and began to swim within the chamber at a water speed of 0.5 bl*s^{-1} (body lengths per s). Once fish started moving, the lid of the working section of the respirometer was secured, and the flush pump activated. Temperature in the respirometer was maintained by circulating water through the water bath in which the respirometer was submerged. Water was continually flushed through the respirometer system and water velocity was set at 0.5 bl*s^{-1} overnight to allow fish to acclimate to the swimming respirometer and minimize disturbance to the fish. Swimming trials began the following morning after lights were on for at least one hour. The chamber was sealed to prevent water exchange between the water reservoirs and the swimming respirometer while maintaining a constant temperature. Fish swam for a predetermined time (Alabama Bass = 30 mins, Channel Catfish = 30 mins, Redbreast Sunfish = 45 mins) at each speed, after which the water velocity was increased by 0.5 bl*s^{-1} for the next time segment. The lengths of segment times were chosen based on how quickly fish had reduced the oxygen concentration in the system during preliminary trial runs. Speed continued to increase after each complete time interval until the fish impinged twice at the same speed or remained impinged for longer than 20 seconds. At no point did oxygen decrease to < 5 ppm, maintaining normoxic conditions. After the fish was removed, the chamber was resealed, and background respiration was recorded for 90 minutes to allow for correction of fish respiration rates. Upon completion of the trial, fish were euthanized in 300 ppm neutrally buffered MS-222 until operculation ceased for 10 minutes. Fish were then processed, with otoliths removed for aging and gonads weighed for calculation of gonadosomatic index (GSI).

Additional trials were conducted to evaluate fish respiration responses to combinations of rapidly cooling water and rapidly changing water velocity. These trials were split into three categories: (1) water temperature change (warm to cool), (2) combined water temperature change (warm to cool) and water velocity increase, and (3) combined water change but with no temperature change and water velocity increase. Fish were sedated and measured as previously stated and acclimated in the swimming respirometer overnight at 0.5 $bl*s^{-1}$. All trials were split into two segments: 2 hours pre-water change and 2 hours post-water change. Water velocity for the pre-water change segment was set at one-half of that species' average U_{crit}. The trial began after acclimation when the flush pump was turned off and the system was sealed. After 2 hours the system was opened and water exchanged between a large water reservoir (24°C for warm water, 19°C for cool water) and the swimming respirometer. Water was continually exchanged until temperature and oxygen stabilized (~5 - 7 minutes). For treatment 3, water was exchanged for the same time duration, but there was no temperature change. When the water exchange was complete, the system was resealed, and the water bath was maintained with the appropriate temperature. The trial was continued for 2 additional hours with the speed either maintained at one-half U_{crit} (treatment 1) or increased to the species' average U_{crit} (treatments 2 and 3).

Oxygen consumption was measured as previously described and respiration rate was calculated separately for each segment.

<u>Statistical Methods</u>. Critical swimming speed was compared across sites within a species using a one-way ANOVA. Linear regression was used to determine if any other variables (fish length, weight, age, sex) affected U_{crit}. Respiration rate measured before versus after water temperature and/or water velocity changes were analyzed using a mixed linear model with individual fish as a random variable and temperature and water velocity as fixed variables. Standard metabolic rates were compared within species across sites using linear models. Active metabolic rates calculated from U_{crit} trials were compared across sites within a species using linear regression. All analyses were conducted in R with an alpha value of 0.05.

Results

<u>Critical Swimming Speed.</u>

A total of 11 Redbreast Sunfish (18.5 - 21.0 cm total length), 10 Channel Catfish (28.6-42.2 cm total length), 15 Alabama Bass (21.3 – 40.1 cm total length), and 8 Tallapoosa Bass (25.7 – 28.0 cm total length) were used in critical swimming speed (U_{crit}) trials. Critical swimming speed (cm*s^{-1}) for Alabama Bass did not differ significantly across sites ($F_{2,12} = 0.76$, $p = 0.49$) (Table 4.1) (Figure 4.2). However, the relative U_{crit} (bl*s^{-1}) of Alabama Bass from Wadley did differ significantly ($F_{2,12} = 6.087$, $p = 0.01$) from Alabama Bass collected from Horseshoe Bend (Figure 4.3). Fish from Horseshoe Bend swam 1.30 (± 1.2, ± SE) body lengths*s^{-1} faster than Alabama Bass collected from Wadley. Alabama Bass collected from Horseshoe Bend were 81.09 mm (± 54, ± SE) shorter than fish from Wadley ($F_{2,12} = 4.517$ p =

0.011) (Table 4.1). Both absolute and relative U_{crit} of Redbreast Sunfish from Horseshoe Bend versus Wadley did not differ ($F_{1,11} = 0.15$, $p = 0.71$) (Table 4.1) (Figures 4.2, 4.3). No Redbreast Sunfish of sufficient size were collected from Lee's Bridge. Both absolute and relative U_{crit} did not differ between Channel Catfish from Horseshoe Bend versus Lee's Bridge ($F_{1,8} = 0.31$, $p = 0.60$) (Table 4.1) (Figures 4.2, 4.3). Sufficiently sized Channel Catfish were not captured from Wadley. Fish length had no effect on U_{crit} ($F_{1,39} = 1.65$, $p = 0.21$) across sites or species for the sizes of fish that were tested.

Because there were no significant differences in absolute U_{crit} within species across all sites, individuals from each site within a species were grouped for analysis. Overall, absolute critical swimming speed ranged from 22.28 – 117.86 $cm*s^{-1}$ with an average U_{crit} of 74.10 $cm*s^{-1}$. Channel Catfish had the individual with the highest U_{crit} while Redbreast Sunfish had the individual with the lowest U_{crit} along with a lower average U_{crit} (average U_{crit} ± SE: Alabama Bass=79.99 ± 5.59; Channel Catfish=73.03 ± 7.41; Tallapoosa Bass=64.06 ± 15.63; Redbreast Sunfish=57.33 ± 6.21 $cm*s^{-1}$) although differences were not significant ($F_{3,37} = 2.08$, $p = 0.12$) (Figure 4.4).

Relative U_{crit} ranged across species from 1.05 – 5.41 $bl*s^{-1}$ with Redbreast Sunfish having the individual with the highest relative U_{crit} value and the highest average relative U_{crit} (average relative U_{crit} ± SE: Alabama Bass=2.39 ± 0.25; Channel Catfish=2.09 ± 0.25; Tallapoosa Bass=2.38 ± 0.66; and Redbreast Sunfish=2.89 ± 0.32 $bl*s^{-1}$) However, again this was not statistically significant (Figure 4.4) ($F_{3,38} = 2.248$, $p = 0.09842$).

Absolute U_{crit} was not significantly affected by fish length, though relative U_{crit} was ($F_{1,40} = 12.6$, $p = 0.001$) for Alabama Bass. For every 1 mm increase in length, Alabama Bass relative U_{crit} decreased by 0.01 body $lengths*s^{-1}$. There was no significant relationship between total length and relative U_{crit} for Redbreast Sunfish, Channel Catfish, or Tallapoosa Bass (Figure 4.5).

Standard Metabolic Rate (SMR).

Linear models were used to test for differences in SMR within species across sites at two temperatures (10 and 20°C). Rates were log transformed to satisfy model assumptions of normally distributed residuals. There were no significant differences in SMR across sites for Redbreast Sunfish at 21°C (ANOVA, $F_{4, 46}$ = 1.528, p = 0.2201); Lees Bridge: n = 4; tailrace: n = 4; Wadley: n = 18; Horseshoe Bend: n = 26) (Figure 4.6). The best model for Redbreast Sunfish included only temperature and fish weight (g), although capture location, sex, and GSI were tested. For every 1 gram of added weight, respiration rate decreased by 0.33 % (± 0.002 SE; p = 0.036) (Figure 4.7). Temperature had a large and significant effect on Redbreast Sunfish SMR (p < 0.001; Figure 4.8), with respiration rate being 151% (± 0.14 SE; p < 0.001) higher at 21°C than at 10°C. Alabama Bass SMR did not vary across sites (Upper Tallapoosa: n = 9; Tail Race: n = 6; Wadley: n = 11; Horseshoe Bend: n = 6) ($F_{3,17}$ = 1.36, p < 0.29) (Figure 4.6). As with Redbreast Sunfish, temperature and weight formed the best model, with respiration rate decreasing by 0.13% for every 1 g of weight gained. There was a 115% increase in metabolic rate between 10 and 21°C. To date, there have not been enough Channel Catfish of sufficient size to test fish at two temperatures so all (n = 7) were tested at 21°C. However, there was no effect of weight, sex, or collection site on respiration rate, although this could be due to low sample size (Figure 4.7). Although SMR was quantified for 19 Tallapoosa Bass, only fish from Horseshoe Bend were tested at both 10 and 21°C. Therefore, only fish from Horseshoe Bend were used for modeling analysis (n = 12). Only temperature was a significant variable for predicting Tallapoosa Bass SMR, although again this could be due to low sample size (Figures 4.7, 4.8).

<u>Active Metabolic Rate (AMR).</u>

Average maximum AMR (MMR) did not significantly vary across species ($F_{3,142}$ = 1.172, p = 0.32) (Figure 4.9) or within species across sites ($F_{3,31}$ = 0.868, p = 0.47) (Figure 4.10). Therefore, fish within species were combined across sites for analysis.

A linear mixed effects analysis was used to determine the relationship between VO_2 and swimming speed during the U_{crit} trials for each species. Fixed effects for each model were relative swimming speed ($bl*s^{-1}$) and/or wet weight (g), while the random effect was individual fish (given that each individual was measured at multiple speeds) for both Alabama Bass and Redbreast Sunfish. Individual variation was not significant for the Channel Catfish model, likely due to small sample size. Multiple models were considered (both fixed and mixed effect models) for each species; the models reported here were identified based on maximum likelihood comparison (Alabama Bass: χ^2 = 8.40, p = 0.0037; Tallapoosa Bass: χ^2 = 3.1665, p < 0.0001; Redbreast Sunfish: χ^2 = 9.04, p = 0.0026; Channel Catfish: χ^2 = 9.0453, p = 0.0026). For every 1% change in relative speed and 1% change in wet weight of Alabama Bass, there was a 0.24% (± 0.08 SE) increase and a 0.43% (± 0.26 SE) decrease in respiration rate, respectively. Approximately 36% of the remaining variation after accounting for the fixed variables was explained by the random variation in individuals. Only relative speed was a significant fixed effect in the Redbreast Sunfish model, likely due to the limited range weights tested (110 - 160 g). The model for Redbreast Sunfish showed for every 1% change in relative speed, there was a 0.32% (± 0.07 SE) increase in respiration rate and individuals explained 89% of the remaining variation. For every 1% change in relative speed, Channel Catfish respiration increased 0.54%. Likewise, the simple linear regression with only relative speed was the best model for Tallapoosa Bass which also was affected by low sample size. For every 1% increase in relative speed, Tallapoosa Bass respiration increased 0.28%.

Both U_{crit} and VO_2 used in the above models were corrected for cheating behavior (holding position in high flow by bracing the tail against the back screen of the swimming respirometer and arching the body with no evidence of active swimming, such as fin movement) by eliminating speeds at which the fish did not actively swim at least 90% of the time. Often MMR was achieved immediately prior to fish reaching U_{crit} (Figure 4.9) suggesting fish switched to anaerobic respiration. Average AMR at each speed was used along with SMR to calculate a scope for activity for each species (Figure 4.12). Active metabolic rate was best represented by a second order polynomial with the peak representing MMR exhibited by fish.

<u>Water Exchange.</u>

Fish within species were combined across sites comparison of water exchange trials given that no differences were found within species across sites in the previous analyses. Paired t-tests were used to determine any differences before and after each trial type. There were no significant differences in active metabolic rate before versus after the water exchange/velocity change among Alabama Bass across all trials (cold water exchange with constant velocity (CW) $p = 0.09$, cold water with velocity change (CW+WV) $p=0.16$, and velocity change with constant water temperature (WV) $p=0.22$) (Figure 4.12). While not significant, there was a downward trend in both the CW and CW+WV trials (from 161.19 ± 24.02 to 149.39 ± 24.29 (average ± SE), n = 8; from 130.45 ± 25.69 to 103.67 ± 14.51, n = 5 respectively). The opposite trend occurred when water temperature remained constant and water velocity increased (from 149.57 ± 15.89 to 195.07 ± 30.67; n=7). Redbreast Sunfish had significantly lower respiration rates after cold water was introduced (from 196.91 ± 26.91 to 116.27 ± 22.27, average ± SE, t_5=2.988, p=0.03). There were no significant differences within the CW+WV or WV (p=0.35, 0.54; n=3 and 2, respectively) trials though both exhibited the same trend as was seen in Alabama Bass (Figure 4.13). Channel Catfish demonstrated the same trend as the other species for CW and CW+WV trials, but only mean respiration rate within the CW trial was significant (from 120.33 ± 15.16 to 69.36 ± 7.35; n=4; p=0.02). Respiration decreased from 118.19 (± 17.54) to 141.17 ± 20.89 (n=4; p=0.14) in CW+WV. To date, only a single Channel Catfish has been tested in WV and thus analysis was not possible (Figure 4.13).

An analysis of covariance was used to determine the effect of water velocity increases and temperature decreases on the AMR of fishes after controlling for the starting metabolic rate (pre-water exchange) of each individual. After adjusting for the variation pre-water exchange, there was a statistically significant difference in AMR between fish exposed to different conditions ($F_{2, 36}$=8.721, p=0.0008). A pairwise comparison using a Bonferroni multiple testing correction and estimated marginal means was used to determine which groups differed significantly. Fish exposed to CW had a significantly lower mean AMR (117 ± 12.6, mean ± SE) compared to fish exposed to WV (205 ± 17.0, mean ± SE (p=0.0002). Likewise, mean AMR of fish exposed to CW+WV (141 ± 15.7, mean ± SE) had a significantly lower AMR versus fish exposed to WV (p=0.009). Fish exposed to CW and those exposed to CW+WV did not show any significant differences (p=0.23) (Figure 4.14).

Part B- Bioenergetics modeling

Bioenergetics modeling can be a powerful approach to integrate the effects of temperature, diet, and activity on the growth rate of fishes (Hartman and Hayward 2007). Bioenergetics models have been developed for many species of fish and some invertebrates. These models are based on a relatively simple mass-balance concept. That is, that growth rate is equal to food consumed minus losses due to respiration and waste production (Figure 4.15). Such models require estimates of parameters for functions relating metabolism and food consumption to body-size of the organism and water temperature. Activity rate is often modelled as either a multiplier of routine metabolism or as a function of swimming speed. For the target species in this project, only one has an already-developed, parameterized, and validated model; that is for the Channel Catfish, but unfortunately (for our application), that model was developed for lentic populations (Blanc and Margraf 2002). Models do not exist for our other target species. As such, for each target species we attempted to modify existing models from related species (within the same genus) using data we generated from the respirometry and swimming performance portions of our overall project (as described earlier).

The modeling process.

A generalized fish bioenergetics model, Fish Bioenergetics 4.0 (Deslauriers et al. 2017), was used to simulate respiration, food consumption, and growth of target species. The model as published has the necessary parameters for weight- and temperature-dependent functions for several species of fish and a few invertebrates. To simulate growth and estimate food consumption of a fish through a season, the modeler must provide input data including water temperature, initial and final weight of the fish, diet (proportion by weight of each major diet type), energy density of all prey types, energy density of the fish itself, and, if reproduction is included, the proportion of weight or energy lost due to reproduction. Data collected as part of this project included fish diets and length-at-age (described in Objective 3), as well as water temperature (described in Objective 2). Energy densities were obtained from published accounts (Hanson et al 1997; Martin 2008). The model uses the input data and the physiological model to iteratively determine an average proportion of maximum consumption (termed the "P-value", or "p of Cmax") needed for the fish to grow from the initial to final weight.

In this project, we conducted 3 types of simulations. First, to test the ability of the model for each species to reproduce the respiration rates that we had measured in the lab, 1-day simulations were run for each fish that had been tested in the laboratory using the test temperature (10 or 21 C) and fish weight. The model generated specific respiration rates that could then be compared to lab results. In the second type of simulation, we modeled growth over the course of one month using both the temperatures that we recorded in the field and the diets we quantified from our field-collected fish. Hourly water temperatures from the tailrace and Horseshoe Bend from mid-July to mid-August were used in the simulations for the growth of 3 ages of fish. These runs were conducted to compare the general effects of water temperature differences at these sites and to estimate average P-values, or the proportion of maximum consumption needed to simulate the observed growth. These P-values were then used in our third type of simulation to estimate the effect of generation (= flow) pulses on specific rates of respiration and growth. To characterize the conditions potentially experienced by fish during a generation pulse, the temperature was lowered by 5 C during 3 1-hr periods within a single day simulation. At the same time as the temperature was lowered in the model, activity rate (ACT) was increased to 1.307, 2.009, and 2.03 for age-1, age-3, and age-5 individuals, respectively, using rates determined as described earlier in this report. The water velocities used to determine these ACT rates were provided by Jason Moak (personal communication Kleinschmidt Group) from modeled velocities at Horseshoe Bend during generation. Predicted velocities in the tailrace were greater than our measured U_{crit} values for the target species, so no simulations were conducted for those conditions.

Simulation Results.

Channel Catfish. Unfortunately, we were unable to test sufficient Channel Catfish in the lab to adequately parameterize the respiration models (weight- and temperature-dependence of oxygen consumption). Therefore, we tested the model developed by Blanc and Margraf (2002) to determine if it would simulate the respiration rates we observed in catfish we tested. Respiration rates (MO_2) for 7 Channel Catfish ranging from 74-314g were estimated at 21 C. Single-day simulations at 21 C were run for each fish and specific respiration rate estimated (input model parameters are listed in Table 4.2). For these fish, the model tended to underestimate respiration rates and with greater proportional error at larger size (Figure 4.16). This size dependence and large underestimation of respiration rendered the model not useful to simulate the effect of temperature and activity on the performance of channel catfish in the Tallapoosa River.

Redbreast Sunfish. Respiration rate parameters for the purposes of modeling Redbreast Sunfish growth were largely taken from those published for Bluegill with the exception of the R_Q parameter (the slope of the change in respiration rate with change in temperature) which was estimated via static respirometry in this study (see description of this work earlier in Objective 4). The other weight-dependent and temperature-dependent parameters could not be adequately estimated due to insufficient range in the weight of fish and temperatures used in our respiration trials. Predicted specific respiration rates were somewhat greater than our observed rates as quantified in the lab (Figure 4.17). No effect of temperature or fish weight was evident in the resulting residuals. Increased respiration rate is consistent with increased activity as might be expected in the riverine environment.

Input parameters for initial conditions of model runs are listed in Table 4.3. Initial and final weights of the fish were estimated using von Bertalanffy length-at-age curves and the length-to-weight relationship as estimated in Objective 3 of this project (and described earlier in this report).

Growth simulations (Table 4.4) for Redbreast Sunfish using late summer temperatures (15 July - 15 August) from both the tailrace and Horseshoe Bend generated specific growth rate patterns demonstrating strong effects of water temperature on respiration rate (Figures 4.18, 4.19). Daily fluctuations in temperature were evident in the resulting specific growth rate at both sites. A seasonal trend was particularly evident with Horseshoe Bend water temperatures, generating negative specific growth rate as water temperatures exceed 30 C (Figure 4.19).

Focusing in on a 24-hour period, simulated effects of generation showed different patterns depending on fish age. For all ages simulated, individual Redbreast Sunfish lost weight over the 24 hr time period in scenarios both with and without generation pulses. During the generation pulses, the 5 C temperature decrease combined with increased activity rate yielded slight positive increases (i.e., decreased weight loss) in specific growth rate for age-1 Redbreast Sunfish (Figure 4.20). In the generation scenarios, Age-1 fish lost about 0.41% of body weight versus 0.43% weight loss in non-generation simulations. The average specific growth rate during the pulse was -0.0000378 g/g/hr versus -0.00018 g/g/hr during non-pulse periods. For both age-3 and age-5 fish the temperature effects from generation yielded negative effects on specific growth rate (Figures 4.21, 4.22). Age-3 Redbreast Sunfish lost about 0.39% of body weight in generation simulations versus 0.33% weight loss in non-generation model runs. The average specific growth rate during the pulse was -0.000387 g/g/hr and -0.00015 g/g/hr during non-pulse periods. Similar to age-3 fish, age-5 Redbreast Sunfish lost about 0.38% of body weight in generation simulations versus 0.33% weight loss in non-generation model runs. The average specific growth rate during the pulse was -0.00037 g/g/hr and -0.00015 g/g/hr during non-pulse periods.

<u>Alabama Bass</u>. There are no published bioenergetics models for Alabama Bass. Therefore, we attempted to modify the parameters of a Smallmouth Bass *Micropterus dolomieu* model using the slope of the respiration response (RQ) measured for Alabama Bass in this study (Table 4.5). Smallmouth Bass is a coolwater species native to streams in central North America, including streams in the Tennessee Valley that are similar to the Tallapoosa River. Modelled respiration rates generated by the modified model failed to agree with those measured in the lab for Alabama Bass (Figure 4.23).

GENERAL DISCUSSION

This project has involved work conducted at a diverse array of scales and methods of data collection, including a thorough review of the published literature, detailed analyses of historical and recent temperature data (including more than 100,000 data points over 19 years), extensive field sampling of the fish community for 2 years across four field sites, quantifying resting and swimming metabolic rates of the four target species, quantifying effects of temperature and flow on fish swimming performance and metabolic rate, and mathematical modeling of fish energetics using our collected data (in addition to information from the literature). Here we summarize our findings and attempt to draw some overall conclusions from the work.

Literature Review of Temperature Requirements.

Our literature review yielded more than 70 publications that in some way addressed temperature requirements, limits, thresholds, etc. of our target species, plus information for a few species related to Alabama Bass and Tallapoosa Bass that were recently described as separate from Spotted Bass and Redeye Bass, respectively. Based on the literature review, it is clear that any information on temperature thresholds or requirements drawn from the literature will be unresolved, and that limits or thresholds found in the literature will not be consistent or well defined. For example, information on the thermal minima for our target species were poorly defined, ranging widely from <0 C to 9.8 C for Channel Catfish, being simply <15 C for Redbreast Sunfish, and <10 C for Spotted Bass (no published values were available for Alabama Bass, Tallapoosa Bass, or Shoal Bass). Identifying optimal ranges was sometimes based on digestion or growth (e.g., Bulow 1967; Shrable et al. 1969), as well as by distributions in the field (Froese and Casal 2017). Given that different outputs for optimizing are considered by different authors, and that it is not always clear what authors are considering to be optimized when defining optimal temperatures, this metric is also not particularly useful. And while preferred temperatures potentially could be more solidly based on field observations of where fish are located, many of the reported values were from laboratory studies that documented variation in the temperature that fish preferred based on the temperature at which they had been acclimated (e.g., Mathur et al. 1981), including additional differences based on whether the acclimation temperatures were rising or falling (Cherry et al. 1975, 1977). Interestingly, even though the authors were looking at thermal minima, Curie et al. (2004) found that diel fluctuations in temperature (as would be seen downstream of Harris Dam) also affected estimated thermal minima, begging the question of whether diel temperature fluctuations could lead to alterations in other aspects of temperature requirements in fishes.

Perhaps the best temperature threshold and requirement data that we found to be available was for spawning, although the ranges were again quite wide. Channel Catfish spawning was said to occur between 20-30 C, Redbreast Sunfish between 16-27.8 C, Alabama Bass between 13-20.6 C, Spotted Bass between 13-23.3 C, Redeye Bass between 16.6-22.8 C, and Shoal Bass between 15-24 C (the only temperature requirement information that was located for Redeye Bass and Shoal Bass was for spawning). Most of these data came from observations in the field, so it is not clear whether acclimation, or perhaps even latitude, might affect the temperatures required for spawning.

Finally, a reasonable number of studies identified thermal maxima information, perhaps because it is an easier endpoint to observe or quantify than the thermal minima. But again, some studies demonstrated that acclimation substantively affected the thermal maximum.

After our review of the literature, it is clear that caution must be exercised when identifying temperature requirement information for a species and then applying it to a field situation. While there are some clearly-defined and standard approaches to quantifying upper lethal limits (e.g., Brungs and Jones 1977; Cherry et al. 1977; Ern et al. 2016), there remains some disagreement about the appropriate endpoints (e.g., Bonin et al. 1981) and even the role of oxygen availability (Neubauer and Anderson 2019). In addition, many times field observations may be used to identify thermal limits, despite the fact that fish may simply avoid temperatures in which they are capable of survival, but simply do not prefer to remain there (Beitinger et al. 2000). As such, field observations can be inherently biased when determining thermal requirements or limits. And acclimation (to temperatures that were increasing, decreasing, fluctuating) has been shown to play a large role in defining temperature requirements for fishes, which must be considered in any attempt to apply literature values to a field situation. And finally, it took a lot of effort to locate and obtain the data that we report here, and these were for our target species (or closely related species), which are game species and/or relatively widely distributed. Clearly, species with more restricted distributions or limited recreational value will have much less information available, so additional study of temperature requirements of some of those species may be warranted.

Summary of Analysis of Existing Temperature Data.

The abundant historical data for temperatures of the Tallapoosa River downstream of Harris Dam provided an excellent tool to both quantify and visualize trends in temperature across a spatial landscape, as well as across multiple temporal scales, including annual, seasonal, daily, and hourly. Seasonal variation was as expected, being warmest in summer, coldest in winter, and intermediate in spring and fall. Variation in daily temperature was least in the tailrace and greatest at Wadley. We found that extreme fluctuations of 10 C were rare, and when we focused in to look at variation in 1-hour observations, we found that 99.71% of all observations were within 2 C of the next hourly measure. There were no significant differences in temperature recorded before and after the Green Plan was instituted and the fluctuations in temperature over 10 C were not more common before the Green Plan. Temperature tended to increase as water moved downstream during spring, summer, and fall, while in winter water was warmest near the dam. It is possible the reservoir is releasing slightly warmer water during the winter than tributaries downstream of the dam, thus leading to warmer temperatures in the tailrace. The reservoir is less susceptible to large temperature fluctuations given its depth, but any buffering is minimal as the variation in winter was small compared to other seasons. The increase in temperature downstream from the dam in all other seasons is likely a combination of warm tributary inputs and solar heating as the water slows through shoals and pools.

Fish Community Sampling.

Fish community composition. Releases of water from dams can strongly affect habitat conditions for fish and other aquatic organisms downstream (Freeman et al. 2001; Young et al. 2011). These impacts that affect fish at the individual scale can be expressed at both the population and community scales. Our sampling spanned a longitudinal gradient from a site above Harris Dam to sites progressively downstream, allowing us to examine whether there are patterns in fish communities that are consistent with the effects of the dam. Over the course of several decades, a number of studies (see below) have quantified community structure and response of particular fish populations across this same reach, allowing us to make some comparisons that span various temporal scales.

Our sampling found sunfishes and minnows to be the most common families of fish sampled in this part of the Tallapoosa River. While shifts in diversity from upstream to downstream were not dramatic, catostomids and centrarchids were dominant in catches above Harris Dam, similar to the findings of Travnichek and Maceina (1994) who conducted a pre-Green Plan survey of the Tallapoosa River from its headwaters to the coastal plains. Overall values of H (i.e., species diversity) in their study were slightly higher in 1994 compared to our study (2019-2021) (3.53 compared to 3.07 respectively), though this change may be influenced by differences in sampling technique versus actual fish diversity differences. Overall trends in fish diversity upstream to downstream were similar between our findings and those of Travnichek and Maceina (1994), who found little evidence of river regulation effect on fish diversity. Catch rates of centrarchids remained high below the reservoir supporting the contention that generalist *Lepomis* species (as one important family member) are less affected by river regulation (Travnichek and Maceina 1995).

Freeman et al. (2005) noted that the percentage of native darter and minnow species persisting in the regulated stretch of the Tallapoosa River was higher than that in similar stretches of the Coosa River and our data agree given that we found 16 total minnow species (14 native) and 7 darter species. Higher catch rates of clupeids above the reservoir were likely due to the high connectivity between the reservoir and the Lee’s Bridge site. In addition, the abundance of clupeids upstream was likely linked to higher average percent by weight of fishes in the diets of Channel Catfish and Alabama Bass above the reservoir.

In a report to the Alabama Department of Conservation and Natural Resources, Irwin and Hornsby (1997) compared rotenone surveys conducted at Horseshoe Bend in 1951 and 1996 to assess the effects of river regulation on downstream fish assemblages. Differences in species composition in the rotenone studies suggested that the fish community at Horseshoe Bend had shifted from cyprinids and ictalurids to a community dominated by centrarchids (Irwin and Hornsby 1997). Our findings show that the relative contribution of centrarchids increased compared to the 1951 rotenone sample but decreased compared to the 1996 sample. The proportion of cyprinids and catostomids in our sample were higher than in the 1996 rotenone sample and the combined contribution of the two families was similar to the 1951 sample (Irwin and Hornsby 1997). Unfortunately, many of these trends may result from variation in sampling method (electrofishing versus rotenone), sampling frequency (bimonthly versus a single sample), and sampling season.

<u>Age and growth</u>. For Channel Catfish and Alabama Bass, body condition was higher in the tailrace than at sites further downstream. While there are many factors that could contribute to this effect, cooler water temperatures in this area could certainly impact growth and potentially body condition (see objective 4 this study relative to Redbreast Sunfish). Higher Channel Catfish and Alabama Bass body condition in the tailrace could also be influenced by differences in diet at this site. While not statistically significant, Redbreast Sunfish body condition was similarly higher on average in the tailrace versus the downstream sites. There was no clear relationship between fish length and body condition for any species, indicating that even though fish collected from the tailrace were generally smaller/younger than at other sites, fish size was likely not responsible for higher body condition. Goar et al. (2013) demonstrated that early life stage

Redbreast Sunfish growth was highest at sites in the regulated stretch of the Tallapoosa River and hypothesized that this was likely due to lower densities at regulated sites. This is a plausible explanation for the centrarchid target species, but CPE for Channel Catfish in the tailrace was higher than at the further downstream sites. Based on this evidence, it appears that abundance and diet variation could be, in part, affecting the observed patterns of body condition in the tailrace. Analysis of the availability of items that fish consumed in the tailrace could be used in conjunction with their diets to determine if fish in the tailrace preferentially select crustaceans or if they are feeding in a non-selective manner. Jolley and Irwin (2011) suggested that tailwater habitats on the Coosa River provided better quality environments for growth and abundance of three catfish species – including Channel Catfish – supporting our observation of differences in Channel Catfish body condition among sites. Observed ranges of length and age were similar to the published distribution from the Coosa River making this a reasonable comparison (Jolley and Irwin 2011).

Previously published von Bertalanffy growth curve parameters are similar to our findings, indicating that a quality sample was collected (Colombo et al. 2008; Sammons and Maceina 2009; Sammons et al. 2013; Rider and Maceina 2015). Our calculation of site-specific parameters was limited by small sample sizes from certain sites and low abundances of fish in certain age-classes.

<u>Telemetry</u>. Overall movement of fish was very low, with most fish occupying a small stretch of river for the majority of the time they were detected in the array. Redeye Bass home range size was previously estimated by Knight et al. (2011) in tributaries of the Tallapoosa River, and they concluded that home range decreased with increased fish size. This supports our results given

that all or our tagged Tallapoosa Bass were at or near the maximum average size limit estimated with our von Bertalanffy model. It is important to note that the fish tagged in Knight et al. (2011) were far smaller (81-200 g) than the Tallapoosa Bass tagged in this study (380-400 g) and care must be taken when extrapolating outside of observed ranges. A more recent study by Earley and Sammons (2015) with Alabama Bass found similar results, stating that Alabama Bass remained within the 8 km river reach where they were tagged. The maximum movement detected by the acoustic array was for tag numbers 28688 and 28692, which both made maximum movements of only approximately 6.2 RKM. Based on the evidence in the literature combined with our telemetry data, it is clear that high flow from peaking hydropower operation is not displacing Tallapoosa or Alabama Bass downstream. Manual tracking data further support this claim as most fish were detected within a few hundred meters of where they were detected during the previous trip. By examining the manual tracking detections that occurred closest to the tailrace versus those further downstream, it appears that movement may increase with distance from the dam (although additional data would be required for such a conclusion). This could indicate that fish closer to the tailrace are confined to smaller pockets of suitable habitat. Further work comparing available habitat to finer scale positional location/movement is needed to elucidate such a pattern.

Respirometry and Bioenergetics Modeling.

Critical Swimming Speed. Swimming performance is one of the most critical behaviors determining survival in aquatic organisms (Plaut 2001; Wolter and Arlinghaus 2004). The ability to move efficiently and cost effectively throughout the environment determines their success at prey capture, predator avoidance, reproduction, migration, and allows them to move from areas with unfavorable conditions which all in turn affect individual fitness. Evolution acts upon this fitness and often selects for species with the best swimming performance for a specific habitat. However, to evaluate and compare swimming performance within and across species, a common metric must be used. Critical swimming speed has become the most used metric amongst ecologists. This measure lies within the prolonged swimming spectrum and is a calculated variable that is often used in the design of culverts and other passageways (Peake 2004). In addition to making comparisons across species, comparison of performance among populations within a species can reveal underlying differences between swimming abilities that can be genetic and/or environmental in origin.

The first section of Objective 4 focused on measuring U_{crit} of all the targeted species from the four study sites. The estimates were far ranging with the highest estimates being 5 times greater than the lowest estimates, and Alabama Bass performing better on average than either Channel Catfish or Redbreast Sunfish. The range in U_{crit} measured for Alabama Bass and Tallapoosa Bass is similar to that of other black basses that have been studied (Hocutt 1973; Bunt et al. 1999; Peak 2008). While Alabama Bass collected from Horseshoe Bend swam significantly faster (in $bl*s^{-1}$, or relative critical swimming speed) than Alabama Bass from other sites, the same absolute speeds were reached. It has been well established that absolute swimming speed increases with fish size (Wardle 1975; Beamish 1978; Videler 1993; Hammer 1995; Domenici 2001; Wolter and Arlinghaus 2003). It is possible the lack of a significant relationship between size and speed in this study was an effect of swimming respirometer size (Tudorache et al. 2007) given that longer flumes may allow for some additional swimming behaviors such as bursting and gliding, although we feel that our flume size combined with the fish sizes we used allowed for relatively normal behaviors. More likely it was a result of our limited size range (27% of tested fish were 27.9-29.7 cm, 66% of tested fish were 31.1-39.0 cm tl) and sample size. Channel Catfish have been found to transition from sustained to prolonged swimming at 50 $cm*s^{-1}$, with burst swimming behavior occurring at speeds over 110 $cm*s^{-1}$ which is similar to our findings (3 Channel Catfish swam between 100-127 $cm*s^{-1}$ for less than two minutes). Critical swimming speed is often greater than prolonged speeds (speed maintained for 20 s – 200 min without fatigue) because the time frames being tested are relatively short allowing the fish to work longer before fatigue. Jones at el. (2008) measured maximum swimming speed (U_{max}) of Bluegill at multiple temperatures and found that U_{max} peaked before speed began to decline as aerobic performance was exceeded. At 22 C, similarly sized fish to those presented here obtained U_{max} of ~40 $cm*s^{1}$ and continued to swim at speeds up to 50 $cm*s^{-1}$ before trials were halted. These results are below our measured U_{crit} for Redbreast Sunfish, though the fish that Jones et al. (2008) used were from a cold-water lentic system. It is possible sunfishes in the Tallapoosa have higher basal metabolic rates and are capable of performing at higher levels. Fish collected from a lotic system such as the Tallapoosa River would also be expected to be better performers due to their constant exposure to flow. The river may lead to acclimation, where resident fish have improved swimming performance versus similar species and populations in lentic environments (Foster and Parsons 2007). More work is needed to compare Redbreast Sunfish with other *Lepomis* spp. within the Tallapoosa River to determine if the closely related species are equal performers when exposed to the same conditions. Furthermore, more samples expanding the complete size range of target species in the Tallapoosa River are needed to establish a U_{crit} vs fish size relationship in order to predict U_{crit} for these species in the system.

While all U_{crit} trials were performed at 21 C, it is well established that swimming performance decreases with water temperature for temperate species (Fry and Hart 1948; Brett 1967; Hocutt 1973; Parsons and Smiley 2003; Tudorache et al. 2007; Jones et al. 2008), suggesting that fish may not be capable of performing at these high speeds in cooler water temperatures. Furthermore, U_{crit} declines with prolonged time spent swimming (Tudorache et al. 2007). The fish in this study were tested at 30 min (bass and catfish) and 45 min (sunfish) time intervals. If fish are exposed to longer time intervals at the same velocity, it is likely their swimming performance will decrease.

Based on the results of the HAT 3 HEC-RAS simulated flow model (Jason Moak, Kleinschmidt Group personal communication), the tailrace of Harris Dam may experience flows up to 98 $cm*s^{-1}$ under single turbine generation. This velocity is nearly double the U_{crit} measured for adult Redbreast Sunfish and ranges between 20-30 $cm*s^{-1}$ faster than the U_{crit} values recorded for the other species. However, there were 5 individuals (2 Alabama Bass, 3 Channel Catfish) which did reach U_{crit} speeds over 100 $cm*s^{-1}$ (100-127 $cm*s^{-1}$) but were unable to maintain position and exhibited cheating behavior. Due to the high degree of cheating behavior, their U_{crit} values were corrected to between 70 - 81 $cm*s^{-}$. This suggests that fish are unable to maintain position in the open water column during single turbine generation without using burst swimming behaviors (maximal speed maintained for < 20 s) and must seek shelter when water velocity increases. Large fish were not often captured during community sampling in the tailrace. While this may be partially explained by the difference in sampling gear, it is also possible that larger fish find it harder to obtain shelter during generations and thus do not spend much time in the habitat. Smaller fish are able to seek shelter behind the bedrock projections, take advantage of the boundary layer along the river bottom, within the rip rap, and among the roots of vegetation until pulses are completed and the tailrace returns to a slow water system. While flow was predicted to be high in the tailrace, further downstream at Horseshoe Bend, the flow under single turbine generation (after accounting for tributary inputs) is predicted to be 48 $cm*s^{-1}$ which is well within the capabilities of fish tested in this study. Earley and Sammons (2015) manually tracked Alabama Bass and redeye bass near Wadley, Alabama and found that during pulses these fish tended to move laterally into tributaries or along the bank of the river and then returned to the main channel once the pulse subsided, suggesting fish choose to seek shelter during these events. Measurements of the precise velocity that triggers movement to shelter and the types of shelter available would greatly inform strategies to manage and maintain these habitats.

Standard Metabolic Rate. Variation in standard metabolic rate can have significant implications for maximum growth, maximum performance, susceptibility to stress, and social interactions (cited in Chabot 2016) which means that it is extremely important ecologically. The rate is used to determine aerobic scope (Fry 1971; Whitledge et al. 2002; Rubio-Garcia et al. 2020), inform bioenergetics models, and compare populations exposed to different stimuli to determine sub-lethal effects (Du et al. 2019; Ackerly and Esbaugh 2020). In order to measure SMR, fish activity must be reduced to zero and energetically demanding processes hindered. For this reason, fish often forgo feeding for at least 48 hours to ensure a post-absorptive state and thus eliminating digestion as an energetic cost. Fish that are reproductively active and in the process of creating or maintaining gametes are often eliminated or any energy diverted to reproduction must be incorporated. In this study, there was no effect of gamete production on SMR as indicated by the insignificance of the GSI. However, not all processes can be halted. There are basic physiological processes which must continue in order to maintain homeostasis such as circulation, ventilation, and muscle tonnage (in order to keep the fish upright) (Chabot et al. 2016).

In this study SMR was measured in all target species at two temperatures (when sample size was sufficient) for use in the bioenergetics models, aerobic scope models, and to compare species from different sites above and below Harris Dam. There were no differences in SMR of fish collected above and below Harris Dam, suggesting there has not been a measurable shift in physiology between populations despite their physical separation. The SMR of Redbreast Sunfish was similar to that of Alabama Bass and Tallapoosa Bass at 21 C. These fish are often found in similar habitats and unlike Channel Catfish, they spend the majority of their time above the benthos. Generally, catfishes are more sedentary (Hunter et al 2010). It has been suggested that ambush predators (i.e. black basses) may maintain a minimum muscle tone so as to be ready to strike or attack should prey be located (Chabot 2016) which would increase the maintenance cost of those muscles and thus increase SMR.

Our estimates of Redbreast Sunfish SMR are similar to those found in other studies of *Lepomis* spp.. Du et al. (2019) measured SMR in Bluegill and compared naïve fish to fish exposed to wastewater effluent. The naïve fish SMR was 87.04-91.2 $mgO_2*kg^{-1}*h^{-1}$ for fish of similar length to those measured here. Rubio-Garcia et al. (2020) measured SMR in Pumpkinseed *Lepomis gibbosus*. Indeed, while not found in the Tallapoosa River, Pumpkinseed are even more closely related taxonomically to Redbreast Sunfish than in Bluegill. In that study, SMR was back calculated from a regression of AMR at speed to when activity was 0. Their model predicted for a 23g fish, SMR equals 105.8 mg $O_2*kg^{-1}*h^{-1}$. Given our average SMR at 21C (95.79 mg $O_2*kg^{-1}*h^{-1}$), this suggests that these closely related species maintain some physiological similarities and supports our use of Bluegill parameters in our Redbreast bioenergetics model.

As with Redbreast Sunfish, there are no previously published SMR values for Alabama Bass or Tallapoosa Bass. However, other Micropterus spp. have been studied in great detail. One is the Smallmouth Bass for whom standard metabolic rates have been estimated at 305 mg O_2*kg^{-1}*h^{-1} for a 71g fish and 146.66 mg O_2*kg^{-1}*h^{-1} for a 202 g fish (Whitledge et al. 2002, 2003). However, Largemouth Bass *Micropterus salmoides* acclimated at 21 C (2.3 – 3.7 g) only had a respiration rate of 49.7 mgO_2*kg^{-1}*h^{-1} (Diaz et al 2007). White and Wahl (2020) determined 5.28 g Largemouth Bass acclimated to power cooling ponds had SMR of 184.2 mgO_2*kg^{-1}*h^{-1} and 196.4 mgO_2*kg^{-1}*h^{-1} at 24 C and 30 C, respectively, though they did note that SMR seemed to be lower in fish acclimated to the warmer waters. Beyers et al (1999) reported the bass SMR most similar to the ones reported in this study. They estimated the physiological cost of a toxin by using bioenergetics modeling. Their reported SMR was 135 mgO_2*kg^{-1}*h^{-1} across a size range of 30.6 – 103.8. Our mean value was 93.31 mgO_2*kg^{-1}*h^{-1}. These previous studies are highly inconsistent in their estimates of black bass SMR. To resolve this lack of agreement and create models that adequately estimate the SMR of black basses in the Tallapoosa River, further measurements of respiration for these populations increasing both the range of size of fish and water temperature are needed.

Channel Catfish bioenergetics models have largely been based on the respiration parameters reported by Andrews and Matsuda (1975). Unfortunately, due to limited sample size it is difficult to compare our SMR results with theirs and thus to determine if they are similar to what has been previously reported. The vast majority of work on Channel Catfish has been focused on lentic populations due to their popularity in aquaculture. More samples from lotic systems are needed across a broad weight range to generate the needed SMR estimates required for a more complete model, although the sizes of Channel Catfish available in the Tallapoosa River limits can be larger than what will fit within our current intermittent flow respirometer. It may be possible to estimate SMR from AMR when water speed is equal to zero, however this approach would need to be validated by testing fish of the same size in the intermittent flow respirometer and the swimming respirometer (Norin and Clark 2016).

None of our target species demonstrated the predicted and well-established trend of decreasing SMR with increasing fish weight (Winberg 1960; Brett and Groves 1979; Peters 1983; Clarke and Johnston 1999; Bokma 2004; Glazier 2005; White et al. 2006). While similar species have been reported to follow this trend, we likely require inclusion of a wider range of fish sizes before we can show such an effect. Our results are heavily weighted by small individuals with few large, adult fish. This was in part due to limitations in test chamber size and availability of fish from the river. As we work to expand our capabilities to incorporate larger fish within all target species, we can better evaluate the full influence of weight on SMR. This is important for our bioenergetics modeling efforts as well, given that the model calculates weight-dependent parameters.

Temperature did have the expected effect on SMR, dramatically reducing it by more than half in Redbreast Sunfish, Alabama Bass, and Tallapoosa Bass. The largest change was for Redbreast Sunfish, which may be a function of their surface area to volume ratio. The sunfishes are laterally compressed and have a larger surface area across which water can wick energy (heat) away from the body, which may keep them colder than the black basses. These lower respiration rates are what we expect fish experience on average during winter temperatures (see objective 2). However, there are days when temperature does drop below 10 C and because these fish are ectotherms, we can expect MO_2 (and not just SMR) to decrease even further. Once MO_2 decreases to basal metabolic rate (the absolute minimum rate necessary to sustain life), fish may enter a torpor state where they do not move, feed, or respond to stimuli (Moran et al. 2018; Ultsch 1989). While 3 of our target species were tested at 10 C and 4 target species were tested at 21 C, more fish should be tested at higher temperatures to determine the optimal and lethal temperatures for these fish which has yet to be completed (two of the species have only recently been defined and thus are lacking in life history information, and even much of the information for Channel Catfish has come from lentic versus lotic habitats; see also results from Objective 1).

Active Metabolic Rate. The results of this study show all four target species to have similar MMR and AMR increases with increased swimming speed. This is an expected trend that has been observed before (Tudorache et al 2008; Rubio-Gracia 2020). However, most fish in this study showed a decrease in AMR as swimming speed rose from its lowest value (0.5 $bl*s^{-1}$) to 1 $bl*s^{-1}$ before exceeding 1 $bl*s^{-1}$. It is likely fish were being forced to actively ventilate at 0.5 $bl*s^{-1}$ whereas at higher speeds they were able to passively, or ram, ventilate which is much a much more efficient mode of respiration (Roberts 1975). The model predicting AMR from relative swimming speed suggests that centrarchids are increasing AMR at the same rate with swimming speed, while Channel Catfish have a much more rapid increase in AMR with swimming speed. Channel Catfish also had the lowest SMR of our target species, and their life history suggests they are more sedentary than Centrarchids, often using their pectoral fins to anchor themselves along the bottom of the river where they can scavenge for food. While there are no other studies on U_{crit} and AMR for Redbreast Sunfish, a study has been done on Bluegill. Currier et al 2020 found oxygen consumption increased with swimming speed between 1.5 and

3.0 bl*s^{-1}. However, while the SMR rates for Bluegill and Redbreast Sunfish were similar in the before mentioned studies, the AMR of the two species do not match. On average at 2.0 bl*s^{-1}, Currier et al (2020) measured an AMR of ~290 mgO_2*kg^{-1}*h^{-1} at 2.0 bl*s^{-1} while in this study Redbreast Sunfish had an average AMR of ~197 mgO_2*kg^{-1}*h^{-1} at 2.0 bl*s^{-1}. The Bluegill in Currier et al (2020) paper were obtained from a fish farm and thus were raised in a lentic habitat. It is possible the Redbreast Sunfish collected from a lotic habitat were trained to swim against high flows and thus had better conditioned muscles and required less oxygen to meet metabolic demand. Such a phenomenon has been documented in laboratory settings (Davison 1997).

It is often assumed that U_{crit} represents the time when maximal oxygen uptake occurs (Tudorache et al. 2008) and thus would be when AMR is predicted to peak. Interestingly, this was the case in our study. Most fish reached their MMR within ± 1 SD of average U_{crit} for their species. Fish that continued swimming beyond their MMR engaged in excessive cheating behavior and left the cheating position to perform a burst and glide maneuver. Burst and glide movements use white muscle which only contracts for < 20 s before relaxing. This type of swimming behavior cannot be maintained or repeated indefinitely and ultimately results in the complete fatigue of the fish. While this behavior is commonly seen in swimming respirometers, it is not likely to happen in the wild, though some cases do exist. Such fatigue in the wild has been seen in spawning run salmon when the fish use too much of their energy store before reaching the spawning ground and do not have enough energy to traverse waterfalls and other high flow, high turbulence environments (Crossin et al. 2008). However, in most cases fish will seek shelter behind some object which obstructs flow before they are fatigued. More work is needed to identify at what speeds fish choose to find refuge and how they identify refuge. By seeking refuge, fish can then recover from any incurred oxygen debt.

The energetic cost of swimming consumes a large portion of the fish energy budget, with some estimates being as high as 40% of total energy being used for movement (Ohlberger et al. 2005). The ability to quickly mobilize energy and oxygen to increase swimming speed depends upon fish having excess energy available. This excess is represented by the Scope for Activity (SA) which is calculated based on SMR and MMR at any given temperature and speed. In some cases, individual fish had an AMR below average SMR for the species, likely resulting from a size bias. Fish used for swimming respirometry were larger than those used for static respirometry which should be kept in mind, although previous studies have described the phenomenon of constant metabolic rates equivalent to SMR at low speeds (Forstner and Wieser 1990; Ohlberger et al 2007). Redbreast Sunfish had the highest SA (104 mg O_2*$kg^{-1}h^{-1}$) followed by Channel Catfish SCA (92.74 mg O_2*$kg^{-1}h^{-1}$). Surprisingly, Alabama Bass had the most limited SA (70 mg O_2*$kg^{-1}h^{-}$1), suggesting that they are the least likely fish of the target species to be able to compensate for environmental changes. It is believed SA scales with temperature in adult fish with the MMR increasing at a greater pace than SMR (Tirsgarrd et al. 2015.). Warmer temperatures increase both SMR and MMR until a thermal optimum is achieved, beyond which both decrease steeply until the fish fatigues or dies.

<u>Water Exchange</u>. The final experiment conducted was the water exchange which was developed in order to model the effects of cool-water release and rapidly increasing water velocity on fish swimming performance and AMR. The most dramatic change in before and after AMR occurred when only cool water was introduced by water velocity remained constant at 0.5*U_{crit}. Active metabolic rate decreased as predicted due to the temperature dependence of metabolic rate. However, there was no large change in AMR when both cool water and a higher water velocity

were introduced suggesting the effort of swimming generated enough work to maintain an elevated AMR despite the lowered temperature. Indeed, when only water velocity was increased, AMR increased as temperature did not alter and thus only increased activity was influencing AMR as in the U_{crit} trials. This together suggest that when fish are only exposed to changes in temperature or only changes in water velocity, they behave as expected. However, when both a cool water change (which should lower AMR) and an increased water velocity (which should raise AMR), the two cancel out, at least within the range of temperature and speed used in this study. The increased effort, or work, exerted by the fish to maintain position in the swimming respirometer generated enough oxygen demand to compensate for the decreased temperature. However, it is likely the fish were working harder at that water velocity than they would under warmer conditions which may inadvertently lower their SA.

Bioenergetics modeling. Clearly model predictions of Channel Catfish respiration rate based on the model developed by Blanc and Margraf (2002) did not match our observations. Given that our work was conducted using fish from a lotic system, while Blanc and Margraf (2002) generated their model parameters using fish taken from aquaculture ponds (Andrews and Matsuda 1975), the source of the fish is the likely reason for the disagreement. New parameters for respiration rate for riverine populations of Channel Catfish will need to be derived independently to be able to fully and more accurately model their growth and respiration rates.

Modeling growth and respiration rates of Redbreast Sunfish under temperature conditions experienced both in the Harris Dam tailrace and further downstream at Horseshoe Bend, suggests that water temperatures at the Horseshoe Bend exceeds the optimal growth temperature for Redbreast Sunfish. This result is consistent with previous simulations by Martin (2008) using the unmodified Bluegill bioenergetics model in which he demonstrated greater periods of predicted negative growth for Redbreast Sunfish in Saugahatchee Creek versus in the Tallapoosa River at Wadley. In his simulations, Saugahatchee Creek temperatures were consistently greater than 30 C during summer, while temperatures in the Tallapoosa River were less often this warm. The cool water releases in the tailrace creates better average temperature conditions for growth of Redbreast Sunfish during the late summer versus in sections that are further downstream. The higher P-value estimates for fish further downstream similarly reflect these increased respiration costs. The average P-values of Redbreast Sunfish estimated for fish in both the tailrace and at Horseshoe Bend were relatively low (less than 0.45, on a scale from 0-1), suggesting a significant potential for increased growth. Increased available forage or greater time available for foraging (i.e. higher proportion of their potential maximum consumption rate) could lead to increased growth. To fully explore this potential using a bioenergetics modeling approach, specific consumption parameters for Redbreast Sunfish (versus borrowing parameters from another related species) would need to be developed using laboratory-based, controlled feeding studies.

The effect of simulated hydropower generation on Redbreast Sunfish specific growth was limited to downstream conditions. Upstream (i.e., in the tailrace) water speed during generation exceeds the prolonged swimming capability of Redbreast Sunfish (as quantified earlier in this report), suggesting that these fish must seek refuge from the flow during these events if they are to remain in the area. Altering the activity parameter and water temperature for 3, 1-hour generation periods resulted in slight increases in growth for age-1 fish, which was consistent with an effect of reducing water temperature. For older fish, the increased respiration cost of swimming faster exceeded the reduction of respiration due to decreased water temperature, resulting in a net greater weight loss than that experienced by age-1fish. It is clear from our simulations across the range of temperatures at the tailrace and at Horseshoe Bend in summer that the impact of increased activity on respiration and therefore growth potential caused by increased flow rates will be greatest during the warmest periods. While the percent weight changes indicated from our simulations appear very small, it is important to note that these effects were over a single day and changes in growth have a multiplicative impact over longer periods. All of these simulations are based on the assumption that the fish do not seek refuge from the flow. Characterizing behavioral responses (e.g., seeking flow refuge, changing foraging behavior patterns, etc.) to increased flow especially during the warmest water conditions would allow better application of the bioenergetics modeling approach to conditions that fish actually experience during increased periods of increased flow, whether that comes from generation or rainfall events.

Our inability to fully characterize the bioenergetics models for these species, does limit the conclusions we can draw. Clearly, further data collection extending both the sizes of fish and temperatures tested would allow better characterization of the physiological parameters needed for bioenergetics modeling.

Summary and Recommendations.

- If detailed information on fish temperature thresholds is needed for future management of this system, testing of fish from this system in controlled laboratory setting may be required.
- Analysis of the historical temperature data supports that variation has been similar during pre- versus post-Green Plan periods.

- Relative weight and body condition were not compromised in the tailrace relative to downstream sites for the target species.
- To our knowledge these data represent the first comprehensive sampling effort of the tailrace fish community. With these data species diversity and richness varied little among sites, although the most common species varied by site and season.
- Results of our laboratory swimming performance trials suggest that high flow rates including that from hydroelectric peaking generation can exceed the prolonged swimming capability of our target species. Riverine species are well-adapted for survival in systems with variable flow rates seeking refuge when necessary to avoid being swept downstream or excessive energy loss due to exertion. This result highlights the importance of further extending our approach to a broader array of species. In addition fine scale tracking in field conditions or experimentally testing the behavioral responses to increased flow for species of differing body size and vagility combined with simulation studies can be used to identify and maintain or even enhance refuge habitats.
- Bioenergetic simulations and patterns of respirometry suggest that temperature and the interaction of temperature and flow can significantly influence the growth conditions for fishes in the Tallapoosa River. Cooler water on average in the tailrace appears to improve growth conditions for Redbreast Sunfish. It is uncertain, however, how these cooler temperatures might influence sustained swimming performance.
- Given the lack of information for species beyond our target species, particularly non-game species, similar work with those species may be warranted including population metrics and physiological/performance parameters.

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TABLES

Table 1.1. Temperature information for Channel Catfish obtained from the published literature and unpublished grey literature publications.

thermal minima	optimal range	preferred temperatures	spawning/hatching	thermal maxima	Reference(s)
<0 C					http://www.fao.org/fishery/affris/species-profiles/channel-catfish/channel-catfish-home/en/
2.7-9.8 (depends on acclimation)					Currie et al. 1998
6.1-6.6 C (w/diel temp fluctuations)					Currie et al. 2004
	10-32 C (distribution)				https://www.fishbase.se/summary/290
	24-30 C				http://www.fao.org/fishery/affris/species-profiles/channel-catfish/channel-catfish-home/en/
	26.6-29.4 C				Bulow 1967; Shrable et al. 1969; Chen 1976
	26-29 C				McMahon and Terrell 1982
		18.9-30.5 C (depends on acclimation)			Cherry et al. 1975
		25.2-30.5 C			Coutant 1977; Reutter and Herdendorf 1976;

		18-31 C (depends on acclimation)			Mathur et al. 1981
			20 C		Marzolf 1957; Pflieger 1975
			21 C		McMahon and Terrell 1982
			23-30 C		Welborn 1988
			21-29 C		Small and Bates 2001
			24-30 C		Lang et al. 2003
				38 C	http://www.fao.org/fishery/affris/species-profiles/channel-catfish/channel-catfish-home/en/
				36.6-37.8 C (depends on acclimation)	Allen and Strawn 1968
				38 C	Reutter and Herdendorf 1976
				34.5-41 C (depends on acclimation)	Cheetham et al. 1976
				33.5 C	McMahon and Terrell 1982
				38 C	Watenpaugh et al. 1985
				35 C	Eaton and Scheller 1996
				31.32-33.31 C	Lutterschmidt and Hutchison 1997
				30.9-42.1 C (depends on acclimation)	Bennett et al. 1998
				36.4-40.3 C (depends on acclimation)	Currie et al. 1998
				38.5-39.6	Currie et al. 2004

				38.6-40.3	Stewart and Allen 2014

Table 1.2. Temperature information for Redbreast Sunfish obtained from the published literature and unpublished grey literature publications.

thermal minima	optimal range	preferred temperatures	spawning/ hatching	thermal maxima	Reference(s)
schooled @ 5-10 C			16-21 C		Boschung and Mayden 2004
<15 C (decreased growth)	25-30 C			33-35 C	Aho et al. 1986
	4-22 C (distribution)				Froese and Casal 2017
		18-32 (dependent on acclimation)			Mathur et al. 1981
		27-29 C			Aho et al. 1986; Beauchere et al. 2014;
			20-27.8 C		Breeder and Nigrelli 1935
			21.1-23.9 C		Shannon 1966
			21.6-25.5 C		Davis 1971
			22.2-24.4 C		Sandow et al. 1974
			16.8-25.6 C		Bass and Hitt 1974
			23 C		Levine et al. 1986
			20-27.5 C		Lukas and Orth 1993
			20 C		Gatreau and Curry 2012
				35-41 C	Clugston 1973
				39 C	Woolcott 1974
				33-35 C	Siler 1975

Table 1.3. Temperature information for Alabama Bass/Spotted Bass obtained from the published literature and unpublished grey literature publications.

<u>Alabama Bass</u>:

thermal minima	optimal range	preferred temperatures	spawning/ hatching	thermal maxima	Reference(s)
			20.6 C (eggs first observed)		Smitherman and Ramsey 1972
			20.6 C (first spawn)		Smitherman and Ramsey 1972
			13-16 C		Greene 1995; Rider and Maceina 2015

<u>Spotted Bass</u>:

thermal minima	optimal range	preferred temperatures	spawning/ hatching	thermal maxima	Reference(s)
<10 C					McMahon et al. 1984
		22.5-27 C			Gammon 1973
		16.9-32.1 C (depends on acclimation to falling temps)			Cherry et al. 1975
		24 C			Coutant 1975
		24.4-32.5 C			Coutant 1977;

		24.8-31.4 C (depends on acclimation to rising temps)			Cherry et al. 1977
			14-23 C		Ryan et al. 1970; Smitherman and Ramsey 1972; Gilbert 1973; Olmstead 1974; Sammons et al. 1999; Churchill and Bettoli 2015
			16.5-20.6 C		Sammons et al. 1999
			23.3 C (eggs first observed)		Smitherman and Ramsey 1972
			13.9-23.3 C		Vogele 1975
			13-23 C		Boschung and Mayden 2004
				36 C	Cherry et al. 1977
				34 C	McMahon et al. 1984
				30.9 C	Eaton and Scheller 1996
				30.76-34.22 C	Lutterschmidt and Hutchison 1997

Table 1.4. Temperature information for Tallapoosa Bass/Redeye Bass/Shoal Bass obtained from the published literature and unpublished grey literature publications.

Tallapoosa Bass - **NO PUBLISHED DATA AVAILABLE**

Redeye Bass:

thermal minima	optimal range	preferred temperatures	spawning/ hatching	thermal maxima	Reference(s)
			16.6-20.5 C		Parsons 1954
			21.1-22.8 C		Smitherman and Ramsey 1972
			18-20 C		Hurst et al. 1975
			17-21 C		Moyle 2002; Boschung and Mayden 2004
			16.7-20 C		https://www.dnr.sc.gov/fish/species/redeyebass.html
			21 C		Boschung and Mayden 2004

Shoal Bass:

thermal minima	optimal range	preferred temperatures	spawning/ hatching	thermal maxima	Reference(s)
			15-22 C (hatching)		Sammons et al. 2015
			17-24 C		Boschung and Mayden 2004

Table 2.1. The proportion of temperature fluctuations that was less than the indicated temperature limit, ranging from 2 C to >12 C (in 2 degree C increments) for the tailrace, Malone, and Wadley sites. Missing values are the result of insufficient data.

		2 °C		4 °C		6 °C		8 °C		10 °C		12+ °C	
	Site	**Pre GP**	**Post GP**	**Pre GP**	**Post GP**	**Pre GP**	**Post GP**	**Pre GP**	**Post GP**	**Pre GP**	**Post GP**	**Pre GP**	**Post GP**
Spring	Heflin		0.97		0.005		0.0006						
	Tailrace		0.98		0.01		0.0003						
	Malone	0.97	0.99	0.018	0.01	0.0059	0.0012	0.0018				0.00059	
	Wadley	0.99	0.99	0.0089	0.0043	0.00089	0.0003						
Summer	Heflin		0.99		0.0057		0.0006						
	Tailrace		0.99		0.0077		0.0001						
	Malone	0.98	0.99	0.019	0.0072	0.0021	0.0014		0.00011				
	Wadley	0.99	0.99	0.0089	0.0061		0.001	0.00033	0.00052		0.0001		
Fall	Heflin		0.97		0.0058		0.0035		0.0018		0.004		
	Tailrace		0.99		0.0039		0.0001						
	Malone	0.99	0.99	0.0096	0.0011								
	Wadley	0.99	0.99	0.0011	0.0019		0.00031		0.00015				
Winter	Heflin		0.97		0.01		0.004		0.002		0.0024		0.001
	Tailrace												
	Malone	0.97		0.027									
	Wadley												

Table 3.1. Scientific names, common names, and species abbreviations used in this report.

Scientific Name	Common Name	Abbreviation
Amia calva	Bowfin	BOWF
Alosa aestivalis	Blueback Herring	BBHR
Alosa chrysochloris	Skipjack Herring	SKJH
Dorosoma cepedianum	Gizzard Shad	GIZS
Dorosoma petenense	Threadfin Shad	THSH
Campostoma oligolepis	Largescale Stoneroller	LSSR
Cyprinella callistia	Alabama Shiner	ALSH
Cyprinella gibbsi	Tallapoosa Shiner	TPSH
Cyprinella venusta	Blacktail Shiner	BTSH
Cyprinus carpio	Common Carp	CCAR
Ctenopharyngodon idella	Grass Carp	GCAR
Luxilus chrysocephalus	Striped Shiner	STSH
Luxilus zonistius	Bandfin Shiner	BAFS
Lythrurus bellus	Pretty Shiner	PRSH
Notemigonus crysoleucas	Golden Shiner	GLDA
Notropis baileyi	Rough Shiner	RSHN
Notropis stilbius	Silverstripe Shinner	SPSH
Notropis texanus	Weed Shiner	WESH
Notropis xaenocephalus	Coosa Shiner	COOS
Pimephales vigilax	Bullhead Minnow	BUMN
Semotilus thoreauianus	Dixie Chub	DXCB
Hypentelium nigricans	Alabama Hogsucker	AHOG
Minytrema melanops	Spotted Sucker	SPSR
Moxostoma carinatum	River Redhorse	RVRH
Moxostoma duquesnei	Black Redhorse	BREH
Moxostoma poecilurum	Blacktail Redhorse	BTRH
Ameiurus brunneus	Snail Bullhead	SNBL
Ameiurus melas	Black Bullhead	BLBH
Ameiurus natalis	Yellow Bullhead	YBUL
Ameiurus nebulosus	Brown Bullhead	BRBH
Ictalurus furcatus	Blue Catfish	BCAT
Ictalurus punctatus	Channel Catfish	CCAT
Noturus funebris	Black Madtom	BLMT
Noturus leptacanthus	Speckled Madtom	SPMT
Pylodictis olivaris	Flathead Catfish	FCAT
Fundulus olicaceus	Blackspotted Topminnow	BLTM
Morone chrysops	White Bass	WHBA
Morone saxatilis	Striped Bass	STBA

Ambloplites ariommus	Shadow Bass	SHBA
Lepomis auritus	Redbreast Sunfish	RBSF
Lepomis cyanellus	Green Sunfish	GSUN
Lepomis gulosus	Warmouth	WARM
Lepomis macrochirus	Bluegill	BLGL
Lepomis microlophus	Redear Sunfish	REAR
Lepomis spp.	Bluegill X Green Sunfish	BGGN
Lepomis spp.	Hybrid Redbreast	RBSX
Micropterus henshalli	Alabama Bass	ALAB
Micropterus tallapoosae	Tallapoosa Bass	TPBA
Pomoxis annularis	White Crappie	WHCP
Pomoxis nigromaculatus	Black Crappie	BLCP
Etheostoma chuckwachatte	Lipstick Darter	LIPD
Etheostoma stigmaeum	Speckled Darter	SPDR
Etheostoma tallapoosae	Tallapoosa Darter	TPDA
Perca flavescens	Yellow Perch	YPER
Percina kathae	Mobile Logperch	MLOG
Percina palmaris	Bronze Darter	BRDT
Percina smithvanizi	Muscadine Darter	MBDT

Table 3.2. Total number of fish species, families, and biodiversity indices for four sites on the Tallapoosa River, Alabama. Sites are: LB = Lee's Bridge, TR = tailrace, WD = Wadley, HB = Horseshoe Bend.

Site	Total Species	Total Families	Shannon's H
LB	39	9	2.80
TR	38	7	2.59
WD	35	7	2.88
HB	33	7	2.49
All	55	9	3.06

Table 3.3. Frequency and catch-per-effort (fish/hr) by season and overall for fish collected from the Tallapoosa River, Alabama. Species are as defined in Table 3.1.

	Winter	Spring	Summer	Fall	All	Winter CPE	Spring CPE	Summer CPE	Fall CPE	CPE
BOWF	0	4	1	2	7	0	0.26	0.13	0.13	0.15
BBHR	0	2	0	0	2	0	0.13	0	0	0.04
GIZS	0	15	11	33	59	0	0.98	1.38	2.06	1.3
SKJH	0	1	0	0	1	0	0.07	0	0	0.02
THSH	49	13	1	2	65	8.17	0.85	0.13	0.13	1.43
ALSH	82	50	20	86	238	13.67	3.26	2.5	5.38	5.25
BAFS	0	0	0	2	2	0	0	0	0.13	0.04
BTSH	105	131	62	115	413	17.5	8.53	7.75	7.19	9.11
BUMN	0	19	1	32	52	0	1.24	0.13	2	1.15
CCAR	2	15	19	29	65	0.33	0.98	2.38	1.81	1.43
COOS	1	20	33	24	78	0.17	1.3	4.13	1.5	1.72
DXCB	11	0	0	0	11	1.83	0	0	0	0.24
GCAR	0	0	1	0	1	0	0	0.13	0	0.02
GLDA	0	1	0	0	1	0	0.07	0	0	0.02
LSSR	30	21	8	59	118	5	1.37	1	3.69	2.6
PRSH	0	0	3	0	3	0	0	0.38	0	0.07
RSHN	0	1	0	0	1	0	0.07	0	0	0.02
SPSH	67	208	0	32	307	11.17	13.55	0	2	6.77
STSH	7	3	0	1	11	1.17	0.2	0	0.06	0.24
TPSH	1	2	2	8	13	0.17	0.13	0.25	0.5	0.29
WESH	0	4	1	5	10	0	0.26	0.13	0.31	0.22
AHOG	31	24	26	64	145	5.17	1.56	3.25	4	3.2
BREH	9	20	10	21	60	1.5	1.3	1.25	1.31	1.32
BTRH	53	124	81	232	490	8.83	8.08	10.13	14.5	10.8
RVRH	0	0	0	3	3	0	0	0	0.19	0.07
SPSR	6	0	3	33	42	1	0	0.38	2.06	0.93

BCAT	1	14	9	12	36	0.17	0.91	1.13	0.75	0.79
BLBH	0	1	0	0	1	0	0.07	0	0	0.02
BLMT	0	0	0	3	3	0	0	0	0.19	0.07
BRBH	1	1	1	0	3	0.17	0.07	0.13	0	0.07
CCAT	10	39	37	88	174	1.67	2.54	4.63	5.5	3.84
FCAT	0	3	17	11	31	0	0.2	2.13	0.69	0.68
SNBL	0	0	3	5	8	0	0	0.38	0.31	0.18
SPMT	0	0	1	2	3	0	0	0.13	0.13	0.07
YBUL	7	15	5	34	61	1.17	0.98	0.63	2.13	1.35
BLTM	7	9	3	3	22	1.17	0.59	0.38	0.19	0.49
STBA	0	6	0	1	7	0	0.39	0	0.06	0.15
WHBA	0	4	0	0	4	0	0.26	0	0	0.09
ALAB	52	138	138	237	565	8.67	8.99	17.25	14.81	12.46
BGGN	1	4	0	0	5	0.17	0.26	0	0	0.11
BLCP	0	31	4	7	42	0	2.02	0.5	0.44	0.93
BLGL	69	339	109	330	847	11.5	22.08	13.63	20.63	18.68
GSUN	8	28	10	6	52	1.33	1.82	1.25	0.38	1.15
RBSF	26	107	109	179	421	4.33	6.97	13.63	11.19	9.28
RBSX	0	2	5	0	7	0	0.13	0.63	0	0.15
REAR	2	16	11	30	59	0.33	1.04	1.38	1.88	1.3
SHBA	16	62	9	59	146	2.67	4.04	1.13	3.69	3.22
TPBA	15	18	16	21	70	2.5	1.17	2	1.31	1.54
WARM	1	2	0	2	5	0.17	0.13	0	0.13	0.11
WHCP	0	3	1	7	11	0	0.2	0.13	0.44	0.24
BRDT	18	124	62	122	326	3	8.08	7.75	7.63	7.19
LIPD	2	28	43	33	106	0.33	1.82	5.38	2.06	2.34
MBDT	20	8	18	66	112	3.33	0.52	2.25	4.13	2.47
MLOG	4	41	18	19	82	0.67	2.67	2.25	1.19	1.81
SPDR	0	4	6	15	25	0	0.26	0.75	0.94	0.55

TPDA	0	4	0	2	6	0	0.26	0	0.13	0.13
YPER	0	0	0	1	1	0	0	0	0.06	0.02

Table 3.4. Frequency and catch-per-effort (fish/h) by site and overall for fish collected from the Tallapoosa River, Alabama. Sites are: LB = Lee's Bridge, TR = tailrace, WD = Wadley, HB = Horseshoe Bend. Species are as defined in Table 3.1.

	LB	TR	WD	HB	All	LB CPE	TR CPE	WD CPE	HB CPE	CPE
BOWF	7	0	0	0	7	0.78	0	0	0	0.15
BBHR	0	0	0	2	2	0	0	0	0.17	0.04
GIZS	52	0	1	6	59	5.78	0	0.1	0.5	1.3
SKJH	0	0	0	1	1	0	0	0	0.08	0.02
THSH	6	0	26	33	65	0.67	0	2.48	2.75	1.43
ALSH	0	136	86	16	238	0	9.82	8.19	1.33	5.25
BAFS	0	2	0	0	2	0	0.14	0	0	0.04
BTSH	62	51	123	177	413	6.89	3.68	11.71	14.75	9.11
BUMN	52	0	0	0	52	5.78	0	0	0	1.15
CCAR	36	5	16	8	65	4	0.36	1.52	0.67	1.43
COOS	28	13	33	4	78	3.11	0.94	3.14	0.33	1.72
DXCB	0	11	0	0	11	0	0.79	0	0	0.24
GCAR	1	0	0	0	1	0.11	0	0	0	0.02
GLDA	0	0	0	1	1	0	0	0	0.08	0.02
LSSR	1	70	47	0	118	0.11	5.05	4.48	0	2.6
PRSH	3	0	0	0	3	0.33	0	0	0	0.07
RSHN	0	1	0	0	1	0	0.07	0	0	0.02
SPSH	10	0	108	189	307	1.11	0	10.29	15.75	6.77
STSH	0	8	3	0	11	0	0.58	0.29	0	0.24
TPSH	3	1	9	0	13	0.33	0.07	0.86	0	0.29
WESH	6	4	0	0	10	0.67	0.29	0	0	0.22
AHOG	4	19	110	12	145	0.44	1.37	10.48	1	3.2
BREH	4	0	22	34	60	0.44	0	2.1	2.83	1.32
BTRH	171	8	183	128	490	19	0.58	17.43	10.67	10.8
RVRH	3	0	0	0	3	0.33	0	0	0	0.07
SPSR	7	2	28	5	42	0.78	0.14	2.67	0.42	0.93

BCAT	29	0	0	7	36	3.22	0	0	0.58	0.79
BLBH	0	0	0	1	1	0	0	0	0.08	0.02
BLMT	0	3	0	0	3	0	0.22	0	0	0.07
BRBH	0	2	1	0	3	0	0.14	0.1	0	0.07
CCAT	51	59	19	45	174	5.67	4.26	1.81	3.75	3.84
FCAT	23	1	0	7	31	2.56	0.07	0	0.58	0.68
SNBL	0	8	0	0	8	0	0.58	0	0	0.18
SPMT	0	0	3	0	3	0	0	0.29	0	0.07
YBUL	1	57	1	2	61	0.11	4.12	0.1	0.17	1.35
BLTM	1	7	5	9	22	0.11	0.51	0.48	0.75	0.49
STBA	6	1	0	0	7	0.67	0.07	0	0	0.15
WHBA	4	0	0	0	4	0.44	0	0	0	0.09
ALAB	66	82	212	205	565	7.33	5.92	20.19	17.08	12.46
BGGN	0	3	1	1	5	0	0.22	0.1	0.08	0.11
BLCP	23	6	6	7	42	2.56	0.43	0.57	0.58	0.93
BLGL	149	490	121	87	847	16.56	35.38	11.52	7.25	18.68
GSUN	0	43	6	3	52	0	3.1	0.57	0.25	1.15
RBSF	25	56	138	202	421	2.78	4.04	13.14	16.83	9.28
RBSX	0	0	6	1	7	0	0	0.57	0.08	0.15
REAR	42	3	4	10	59	4.67	0.22	0.38	0.83	1.3
SHBA	2	92	20	32	146	0.22	6.64	1.9	2.67	3.22
TPBA	2	3	21	44	70	0.22	0.22	2	3.67	1.54
WARM	1	1	1	2	5	0.11	0.07	0.1	0.17	0.11
WHCP	5	1	5	0	11	0.56	0.07	0.48	0	0.24
BRDT	1	185	122	18	326	0.11	13.36	11.62	1.5	7.19
LIPD	0	86	18	2	106	0	6.21	1.71	0.17	2.34
MBDT	4	69	38	1	112	0.44	4.98	3.62	0.08	2.47
MLOG	13	51	15	3	82	1.44	3.68	1.43	0.25	1.81
SPDR	1	1	23	0	25	0.11	0.07	2.19	0	0.55

TPDA	0	2	4	0	6	0	0.14	0.38	0	0.13
YPER	1	0	0	0	1	0.11	0	0	0	0.02

Figure 3.5. Frequency and catch-per-effort (fish/h) by season and overall for fish collected from the Lee's Bridge site on the Tallapoosa River, Alabama. Species are as defined in Table 3.1.

	Spring	Summer	Fall	All	Spring CPE	Summer CPE	Fall CPE	CPE
BOWF	4	1	2	7	1.33	0.5	0.5	0.78
GIZS	15	10	27	52	5	5	6.75	5.78
THSH	4	1	1	6	1.33	0.5	0.25	0.67
BTSH	14	17	31	62	4.67	8.5	7.75	6.89
BUMN	19	1	32	52	6.33	0.5	8	5.78
CCAR	4	14	18	36	1.33	7	4.5	4
COOS	17	0	11	28	5.67	0	2.75	3.11
GCAR	0	1	0	1	0	0.5	0	0.11
LSSR	0	0	1	1	0	0	0.25	0.11
PRSH	0	3	0	3	0	1.5	0	0.33
SPSH	8	0	2	10	2.67	0	0.5	1.11
WESH	0	1	5	6	0	0.5	1.25	0.67
AHOG	2	1	1	4	0.67	0.5	0.25	0.44
BREH	2	2	0	4	0.67	1	0	0.44
BTRH	23	27	121	171	7.67	13.5	30.25	19
RVRH	0	0	3	3	0	0	0.75	0.33
SPSR	0	1	6	7	0	0.5	1.5	0.78
BCAT	14	7	8	29	4.67	3.5	2	3.22
CCAT	15	11	25	51	5	5.5	6.25	5.67
FCAT	1	13	9	23	0.33	6.5	2.25	2.56
YBUL	1	0	0	1	0.33	0	0	0.11
BLTM	1	0	0	1	0.33	0	0	0.11
STBA	6	0	0	6	2	0	0	0.67
WHBA	4	0	0	4	1.33	0	0	0.44
ALAB	12	22	32	66	4	11	8	7.33
BLCP	17	2	4	23	5.67	1	1	2.56

BLGL	29	22	98	149	9.67	11	24.5	16.56
RBSF	3	12	10	25	1	6	2.5	2.78
REAR	9	8	25	42	3	4	6.25	4.67
SHBA	0	0	2	2	0	0	0.5	0.22
TPBA	0	1	1	2	0	0.5	0.25	0.22
WARM	1	0	0	1	0.33	0	0	0.11
WHCP	0	0	5	5	0	0	1.25	0.56
BRDT	0	1	0	1	0	0.5	0	0.11
MBDT	0	0	4	4	0	0	1	0.44
MLOG	1	1	11	13	0.33	0.5	2.75	1.44
SPDR	0	0	1	1	0	0	0.25	0.11
TPSH	2	1	0	3	0.67	0.5	0	0.33
YPER	0	0	1	1	0	0	0.25	0.11

Figure 3.6. Frequency and catch-per-effort (fish/h) by season and overall for fish collected from the tailrace of R.L. Harris Dam on the Tallapoosa River, Alabama. Species are as defined in Table 3.1.

	Winter	Spring	Summer	Fall	All	Winter CPE	Spring CPE	Summer CPE	Fall CPE	CPE
ALSH	62	23	1	50	136	31	3.93	0.5	12.5	9.82
BAFS	0	0	0	2	2	0	0	0	0.5	0.14
BTSH	29	21	0	1	51	14.5	3.59	0	0.25	3.68
CCAR	0	5	0	0	5	0	0.85	0	0	0.36
COOS	0	1	2	10	13	0	0.17	1	2.5	0.94
DXCB	11	0	0	0	11	5.5	0	0	0	0.79
LSSR	30	21	5	14	70	15	3.59	2.5	3.5	5.05
RSHN	0	1	0	0	1	0	0.17	0	0	0.07
STSH	5	3	0	0	8	2.5	0.51	0	0	0.58
TPSH	0	0	0	1	1	0	0	0	0.25	0.07
WESH	0	4	0	0	4	0	0.68	0	0	0.29
AHOG	13	3	0	3	19	6.5	0.51	0	0.75	1.37
BTRH	1	6	1	0	8	0.5	1.03	0.5	0	0.58
SPSR	0	0	0	2	2	0	0	0	0.5	0.14
BLMT	0	0	0	3	3	0	0	0	0.75	0.22
BRBH	1	1	0	0	2	0.5	0.17	0	0	0.14
CCAT	8	17	10	24	59	4	2.91	5	6	4.26
FCAT	0	0	1	0	1	0	0	0.5	0	0.07
SNBL	0	0	3	5	8	0	0	1.5	1.25	0.58
YBUL	7	12	5	33	57	3.5	2.05	2.5	8.25	4.12
BLTM	4	1	0	2	7	2	0.17	0	0.5	0.51
STBA	0	0	0	1	1	0	0	0	0.25	0.07
ALAB	17	21	15	29	82	8.5	3.59	7.5	7.25	5.92
BGGN	0	3	0	0	3	0	0.51	0	0	0.22
BLCP	0	4	0	2	6	0	0.68	0	0.5	0.43
BLGL	54	251	28	157	490	27	42.91	14	39.25	35.38
GSUN	8	27	4	4	43	4	4.62	2	1	3.1

RBSF	5	4	7	40	56	2.5	0.68	3.5	10	4.04
REAR	1	0	0	2	3	0.5	0	0	0.5	0.22
SHBA	12	47	4	29	92	6	8.03	2	7.25	6.64
TPBA	0	2	0	1	3	0	0.34	0	0.25	0.22
WARM	1	0	0	0	1	0.5	0	0	0	0.07
WHCP	0	0	1	0	1	0	0	0.5	0	0.07
BRDT	17	87	27	54	185	8.5	14.87	13.5	13.5	13.36
LIPD	2	26	38	20	86	1	4.44	19	5	6.21
MBDT	20	5	17	27	69	10	0.85	8.5	6.75	4.98
MLOG	4	36	10	1	51	2	6.15	5	0.25	3.68
SPDR	0	1	0	0	1	0	0.17	0	0	0.07
TPDA	0	0	0	2	2	0	0	0	0.5	0.14

Figure 3.7. Frequency and catch-per-effort (fish/h) by season and overall for fish collected from the Wadley site on the Tallapoosa River, Alabama. Species are as defined in Table 3.1.

	Winter	Spring	Summer	Fall	All	Winter CPE	Spring CPE	Summer CPE	Fall CPE	CPE
GIZS	0	0	1	0	1	0	0	0.5	0	0.1
THSH	17	9	0	0	26	8.5	3.6	0	0	2.48
ALSH	16	17	19	34	86	8	6.8	9.5	8.5	8.19
BTSH	12	42	34	35	123	6	16.8	17	8.75	11.71
CCAR	1	3	5	7	16	0.5	1.2	2.5	1.75	1.52
COOS	0	2	30	1	33	0	0.8	15	0.25	3.14
LSSR	0	0	3	44	47	0	0	1.5	11	4.48
SPSH	38	61	0	9	108	19	24.4	0	2.25	10.29
STSH	2	0	0	1	3	1	0	0	0.25	0.29
TPSH	1	0	1	7	9	0.5	0	0.5	1.75	0.86
AHOG	17	15	24	54	110	8.5	6	12	13.5	10.48
BREH	5	4	1	12	22	2.5	1.6	0.5	3	2.1
BTRH	33	52	36	62	183	16.5	20.8	18	15.5	17.43
SPSR	4	0	1	23	28	2	0	0.5	5.75	2.67
BRBH	0	0	1	0	1	0	0	0.5	0	0.1
CCAT	1	0	4	14	19	0.5	0	2	3.5	1.81
SPMT	0	0	1	2	3	0	0	0.5	0.5	0.29
YBUL	0	0	0	1	1	0	0	0	0.25	0.1
BLTM	1	1	3	0	5	0.5	0.4	1.5	0	0.48
ALAB	13	31	66	102	212	6.5	12.4	33	25.5	20.19
BGGN	1	0	0	0	1	0.5	0	0	0	0.1
BLCP	0	3	2	1	6	0	1.2	1	0.25	0.57
BLGL	10	28	44	39	121	5	11.2	22	9.75	11.52
GSUN	0	1	4	1	6	0	0.4	2	0.25	0.57
RBSF	8	22	50	58	138	4	8.8	25	14.5	13.14
RBSX	0	1	5	0	6	0	0.4	2.5	0	0.57

REAR	0	0	3	1	4	0	0	1.5	0.25	0.38
SHBA	0	6	4	10	20	0	2.4	2	2.5	1.9
TPBA	3	2	9	7	21	1.5	0.8	4.5	1.75	2
WARM	0	0	0	1	1	0	0	0	0.25	0.1
WHCP	0	3	0	2	5	0	1.2	0	0.5	0.48
BRDT	1	20	33	68	122	0.5	8	16.5	17	11.62
LIPD	0	0	5	13	18	0	0	2.5	3.25	1.71
MBDT	0	2	1	35	38	0	0.8	0.5	8.75	3.62
MLOG	0	4	5	6	15	0	1.6	2.5	1.5	1.43
SPDR	0	3	6	14	23	0	1.2	3	3.5	2.19
TPDA	0	4	0	0	4	0	1.6	0	0	0.38

Table 3.8. Frequency and catch-per-effort (fish/h) by season and overall for fish collected from the Horseshoe Bend site on the Tallapoosa River, Alabama. Species are as defined in Table 3.1.

	Winter	Spring	Summer	Fall	All	Winter CPE	Spring CPE	Summer CPE	Fall CPE	CPE
BBHR	0	2	0	0	2	0	0.5	0	0	0.17
GIZS	0	0	0	6	6	0	0	0	1.5	0.5
SKJH	0	1	0	0	1	0	0.25	0	0	0.08
THSH	32	0	0	1	33	16	0	0	0.25	2.75
ALSH	4	10	0	2	16	2	2.5	0	0.5	1.33
BTSH	64	54	11	48	177	32	13.5	5.5	12	14.75
CCAR	1	3	0	4	8	0.5	0.75	0	1	0.67
COOS	1	0	1	2	4	0.5	0	0.5	0.5	0.33
GLDA	0	1	0	0	1	0	0.25	0	0	0.08
SPSH	29	139	0	21	189	14.5	34.75	0	5.25	15.75
AHOG	1	4	1	6	12	0.5	1	0.5	1.5	1
BREH	4	14	7	9	34	2	3.5	3.5	2.25	2.83
BTRH	19	43	17	49	128	9.5	10.75	8.5	12.25	10.67
SPSR	2	0	1	2	5	1	0	0.5	0.5	0.42
BLBH	0	1	0	0	1	0	0.25	0	0	0.08
BCAT	1	0	2	4	7	0.5	0	1	1	0.58
CCAT	1	7	12	25	45	0.5	1.75	6	6.25	3.75
FCAT	0	2	3	2	7	0	0.5	1.5	0.5	0.58
YBUL	0	2	0	0	2	0	0.5	0	0	0.17
BLTM	2	6	0	1	9	1	1.5	0	0.25	0.75
ALAB	22	74	35	74	205	11	18.5	17.5	18.5	17.08
BGGN	0	1	0	0	1	0	0.25	0	0	0.08
BLCP	0	7	0	0	7	0	1.75	0	0	0.58
BLGL	5	31	15	36	87	2.5	7.75	7.5	9	7.25
GSUN	0	0	2	1	3	0	0	1	0.25	0.25
RBSF	13	78	40	71	202	6.5	19.5	20	17.75	16.83
RBSX	0	1	0	0	1	0	0.25	0	0	0.08

REAR	1	7	0	2	10	0.5	1.75	0	0.5	0.83
SHBA	4	9	1	18	32	2	2.25	0.5	4.5	2.67
TPBA	12	14	6	12	44	6	3.5	3	3	3.67
WARM	0	1	0	1	2	0	0.25	0	0.25	0.17
BRDT	0	17	1	0	18	0	4.25	0.5	0	1.5
LIPD	0	2	0	0	2	0	0.5	0	0	0.17
MBDT	0	1	0	0	1	0	0.25	0	0	0.08
MLOG	0	0	2	1	3	0	0	1	0.25	0.25

Table 3.9. Results of ANOVAs with a Tukey's post-hoc test for pairwise comparisons between sites testing W_r (relative condition for Redbreast Sunfish) for the four target species collected from four sites on the Tallapoosa River. Species are: ALAB=Alabama Bass, RBSF=Redbreast Sunfish, CCAT=Channel Catfish, TPBA=Tallapoosa Bass, and sites are LB=Lees Bridge, TR=tailrace, WD=Wadley, and HB=Horseshoe Bend. Rows that are in bold text indicate comparisons that were significant.

Species	Pair	Estimate	p	PR(>F)	Degrees of Freedom
CCAT	LB-HB	-9.88	0.06	0.00	172
CCAT	TR-HB	9.52	0.09		
CCAT	WD-HB	-4.82	0.83		
CCAT	**TR-LB**	**19.40**	**<0.001**		
CCAT	WD-LB	5.07	0.81		
CCAT	WD-TR	-14.34	0.06		
RBSF	LB-HB	-1.65	0.84	0.32	330
RBSF	TR-HB	2.15	0.44		
RBSF	WD-HB	0.11	0.99		
RBSF	TR-LB	3.80	0.32		
RBSF	WD-LB	1.76	0.83		
RBSF	WD-TR	-2.04	0.55		
ALAB	LB-HB	-0.94	0.89	0.00	363
ALAB	**TR-HB**	**6.54**	**<0.01**		
ALAB	WD-HB	2.21	0.11		
ALAB	**TR-LB**	**7.48**	**<0.01**		
ALAB	WD-LB	3.14	0.06		
ALAB	**WD-TR**	**-4.33**	**<0.01**		
TPBA	LB-HB	-4.59	1.00	0.66	54
TPBA	TR-HB	8.05	0.97		
TPBA	WD-HB	10.15	0.64		
TPBA	TR-LB	12.65	0.97		
TPBA	WD-LB	14.74	0.91		
TPBA	WD-TR	2.09	1.00		

Table 3.10. von Bertalanffy growth parameters for four target species collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last measured annulus using the direct proportion method. Species are: ALAB=Alabama Bass, RBSF=Redbreast Sunfish, CCAT=Channel Catfish, TPBA=Tallapoosa Bass.

		Site					
Parameter	**Species**	**Lee's Bridge**	**Tailrace**	**Wadley**	**Horseshoe Bend**	**All Downstream**	**All**
L_∞	**CCAT**	425.97	350443.80	588.67	356.09	523.27	413.79
K	**CCAT**	0.13	0.00	0.13	0.53	0.15	0.24
t_0	**CCAT**	-4.34	-2.49	-0.56	-0.46	-0.80	-0.62
n	**CCAT**	56.00	50.00	16.00	46.00	112.00	168.00
L_∞	**RBSF**	70356.06	229.81	291.26	238.62	253.48	263.27
K	**RBSF**	0.00	0.32	0.17	0.31	0.24	0.23
t_0	**RBSF**	-1.44	-0.80	-1.03	-0.14	-0.68	-0.70
n	**RBSF**	19.00	51.00	88.00	119.00	258.00	277.00
L_∞	**ALAB**	491.51	13140.00	479.91	521.07	566.64	549.09
K	**ALAB**	0.28	0.00	0.28	0.21	0.18	0.19
t_0	**ALAB**	-0.19	-2.53	-0.13	-0.10	-0.49	-0.45
n	**ALAB**	55.00	53.00	141.00	133.00	327.00	382.00
L_∞	**TPBA**						363.91
K	**TPBA**						0.25
t_0	**TPBA**						-0.56
n	**TPBA**						58.00

Table 3.11. Metadata for fish tagged with combined acoustic and radio tags in the Tallapoosa River, Alabama. Species are as defined in Table 3.1. Weight NAs due to scale malfunction.

Radio ID	Acoustic ID	Detections	Species	TL	WT	External Tag	Release Timestamp
20	28688	42	ALAB	344	490	1917	6/30/2020 12:30
21	28690	0	ALAB	358	550	1918	6/30/2020 12:30
22	28692	59991	ALAB	365	572	1919	6/30/2020 10:43
23	28604	0	TPBA	312	410	N	7/3/2020 8:32
24	28696	0	TPBA	310	380	N	7/3/2020 11:30
25	28698	1642	TPBA	295	380	1914	7/9/2020 10:10
160	29388	96854	ALAB	472	1100	1922	6/30/2020 10:43
161	29390	665	ALAB	418	860	1921	6/30/2020 10:43
162	29392	43367	ALAB	418	806	1920	6/30/2020 10:43
163	29394	0	ALAB	442	900	1916	6/30/2020 12:30
165	29398	419	ALAB	474	1140	1915	6/30/2020 12:30
193	29454	869	ALAB	451	NA	1913	7/9/2020 10:10
196	29460	67	ALAB	432	NA	1911	7/9/2020 10:10
199	29466	115325	ALAB	432	870	N	7/3/2020 14:11
202	29472	476	ALAB	432	870	N	7/3/2020 11:30
204	29476	61233	ALAB	489	NA	1912	7/9/2020 10:10

Table 4.1. Critical swimming speed and length (TL) of each species and site.

Site	Channel Catfish		Redbreast Sunfish		Alabama Bass		Tallapoosa Bass	
	U_{crit} ($cm*s^{-1}$) ± SE	Length (cm) ± SE	U_{crit} ($cm*s^{-1}$) ± SE	Length (cm) ± SE	U_{crit} ($cm*s^{-1}$) ± SE	Length (cm) ± SE	U_{crit} ($cm*s^{-1}$) ± SE	Length (cm) ± SE
Lees Bridge	72.72 ± 12.66	33.7 ± 2.06			78.61 ± 15.56	32.67 ± 2.3		
Wadley			53.34 ± 7.83	19.9 ± 0.37	75.83 ± 6.36	34.89 ± 1.3	56.28 ± 30.48	26.6 ± 0.89
Horseshoe Bend	73.54 ± 3.39	38.83 ± 1.4	59.13 ± 11.24	19.7 ± 0.27	94.01 ± 15.64	26.7 ± 2.9	67.01 ± 28.18	27.1 ± 0.95

Table 4.2. Physiological parameters used in the Fish Bioenergetics 4 model to estimate respiration rates of Channel Catfish. Parameters were taken from Blanc and Margraf (2002); all citations to the original sources can be found therein.

Parameters	Definition	Value
	Consumption	
CA	Weight dependent intercept for maximum consumption	0.33
CB	Weight dependent slope for maximum consumption	-0.33
CQ	Temperature dependent slope for maximum consumption	2.3
CTO	Optimum temperature for consumption	31 C
CTM	Maximum temperature for consumption	37 C
	Respiration	
RA	Weight dependent intercept for respiration	0.00833
RB	Weight dependent slope for respiration	-0.20
RQ	Temperature dependent slope for respiration	2.0
RTO	Optimum temperature for respiration	35 C
RTM	Maximum temperature for respiration	36.6 C
ACT	Activity parameter	1
SDA	Specific Dynamic Action	0.15
	Egestion / Excretion	
FA	Egestion constant	0.3
FU	Excretion constant	0.05

Table 4.3. Physiological parameters used in the Fish Bioenergetics 4 model to simulate patterns of growth and respiration rates of Redbreast Sunfish. With the exception of RQ, which was derived from respiration measurement from this project, all parameters were taken from the published values for Bluegill in the Fish Bioenergetics 4 model and sources for these parameters can be found therein (Deslauriers et al. 2017).

Parameters	**Definition**	**Value**
	Consumption	
CA	Weight dependent intercept for maximum consumption	0.007583*
CB	Weight dependent slope for maximum consumption	-0.274
CQ	Temperature dependent slope for maximum consumption	2.3
CTO	Optimum temperature for consumption	27
CTM	Maximum temperature for consumption	36
	Respiration	
RA	Weight dependent intercept for respiration	0.000642*
RB	Weight dependent slope for respiration	-0.2
RQ	Temperature dependent slope for respiration	2.394
RTO	Optimum temperature for respiration	30
RTM	Maximum temperature for respiration	37
ACT	Activity parameter	1
SDA	Specific Dynamic Action	0.172
	Egestion / Excretion	
FA	Egestion constant	0.158
FU	Excretion constant	-0.222

*Modified from the original daily rates to simulate hourly rates

Table 4.4. Initial settings and P-value (i.e., proportion of maximum consumption) produced for model runs for a 1-month period (July 15 – August 15) for Redbreast Sunfish at the tailrace and Horseshoe Bend.					
	Initial Weight (g)	Final Weight (g)	P-value for tailrace	P-value for Horseshoe Bend	
Age 1	14.27	15.16	0.357	0.395	
Age 3	65.98	68.61	0.397	0.436	
Age 5	130.16	132.64	0.395	0.44	
hours simulated	768				

Table 4.5. Physiological parameters used in the Fish Bioenergetics 4 model to simulate patterns of respiration rate of Alabama Bass. With the exception of RQ, which was derived from respiration measurements from this project, parameters were taken from the Smallmouth Bass model published values in Fish Bioenergetics 4 and sources for these parameters can be found therein (Deslauriers et al. 2017).		
Parameters	**Definition**	**Value**
	Consumption	
CA	Weight dependent intercept for maximum consumption	0.339
CB	Weight dependent slope for maximum consumption	-0.31
CQ	Temperature dependent slope for maximum consumption	1.95
CTO	Optimum temperature for consumption	22
CTM	Maximum temperature for consumption	37
	Respiration	
RA	Weight dependent intercept for respiration	0.244
RB	Weight dependent slope for respiration	-0.756
RQ	Temperature dependent slope for respiration	2.23
RTO	Optimum temperature for respiration	36
RTM	Maximum temperature for respiration	40
ACT	Activity parameter	2.0295
SDA	Specific Dynamic Action	0.172
	Egestion / Excretion	
FA	Egestion constant	0.158
FU	Excretion constant	-0.222

FIGURES

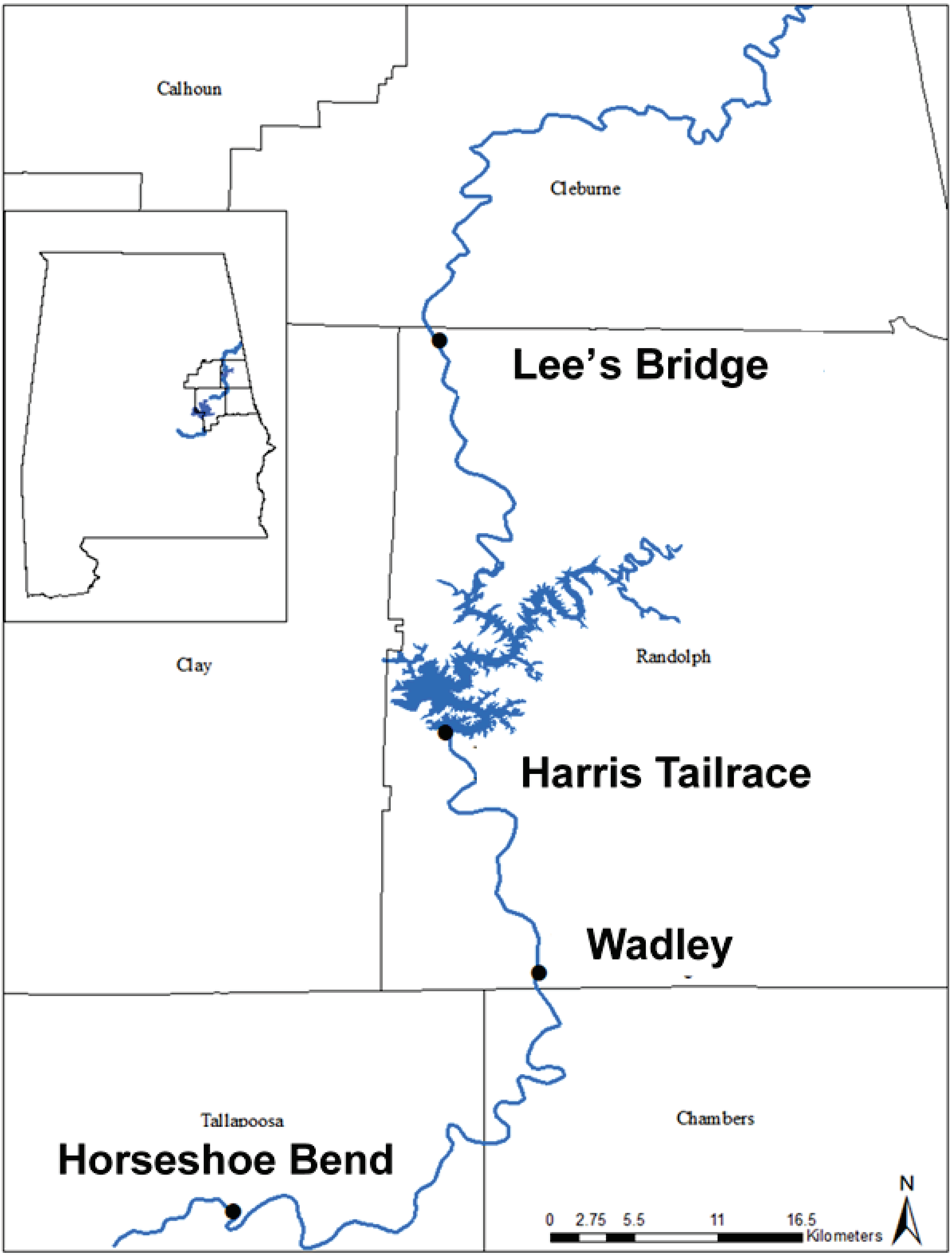


Figure 0.1. Map of study area.

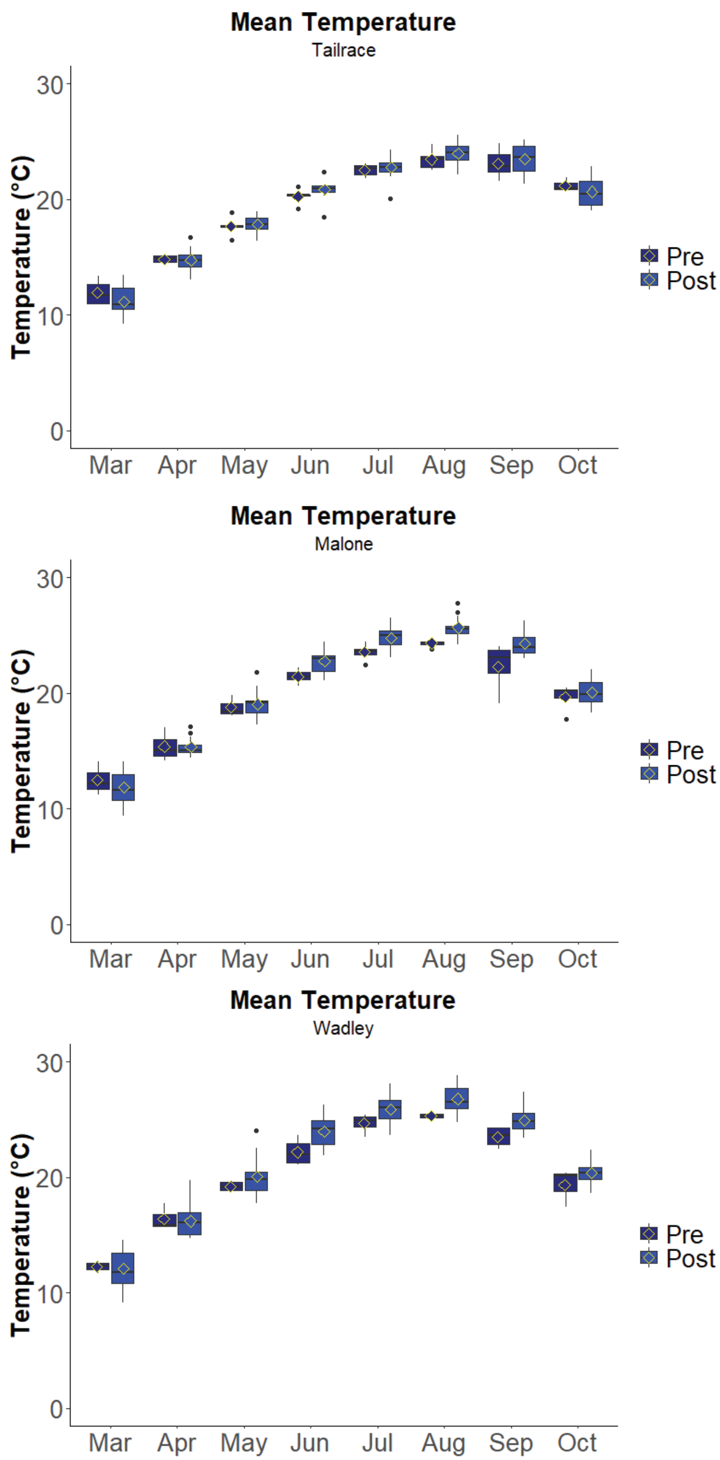
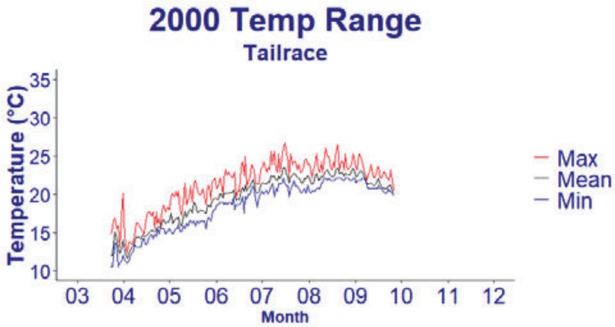


Figure 2.1. Boxplots showing the mean average temperatures (diamonds) per month pre- and post-Green Plan for all three locations. First and third quartiles are represented by boxes and whiskers show 1.5*interquartile range with outliers being plotted points. Mean average temperatures were not significantly different between pre- and post-Green Plan years. Though not significant, the largest variation was recorded at Wadley, which is the furthest site downstream.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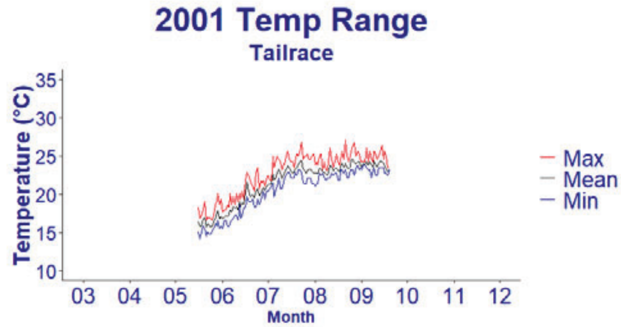
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2001 Temp Range
Tailrace
Temperature (°C)
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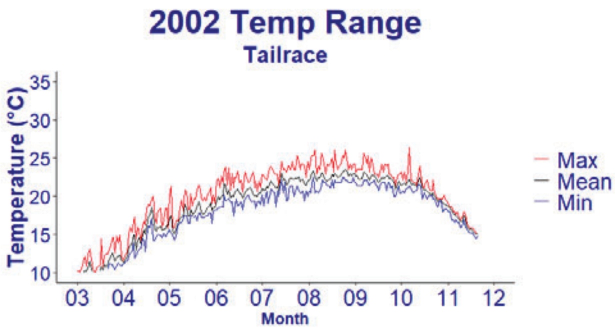
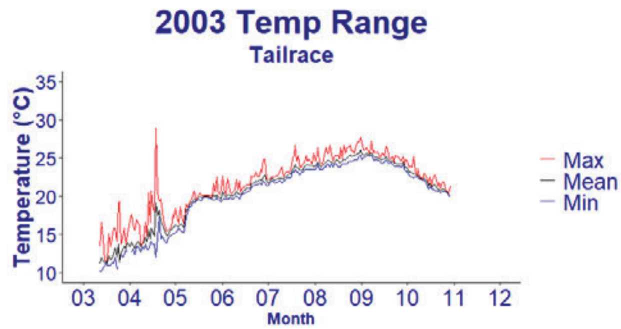
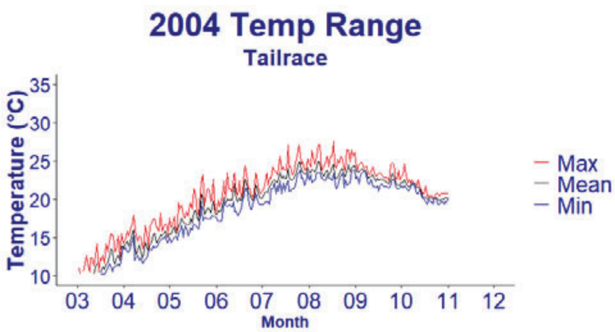
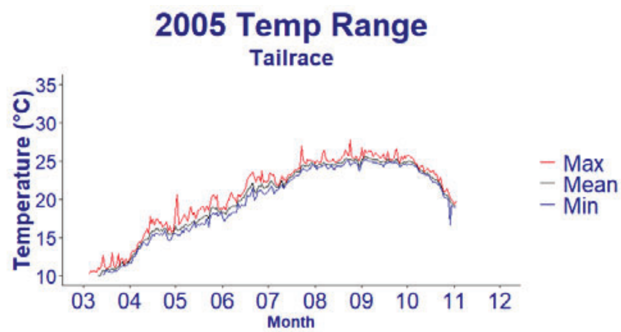
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2002 Temp Range
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2003 Temp Range
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2004 Temp Range
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min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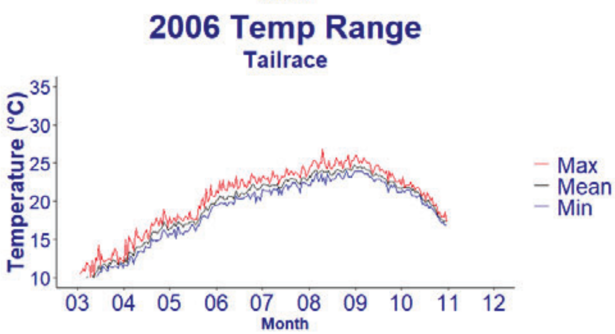
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min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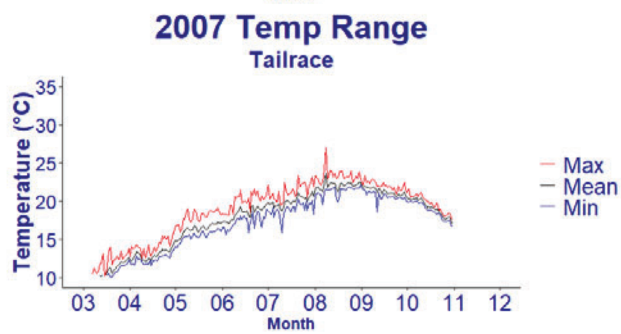
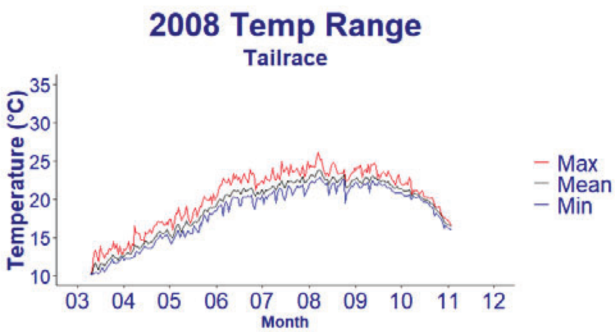
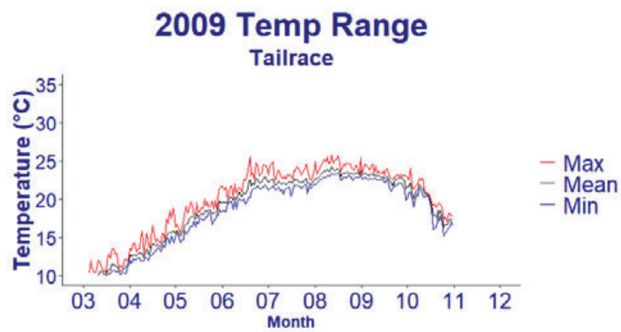
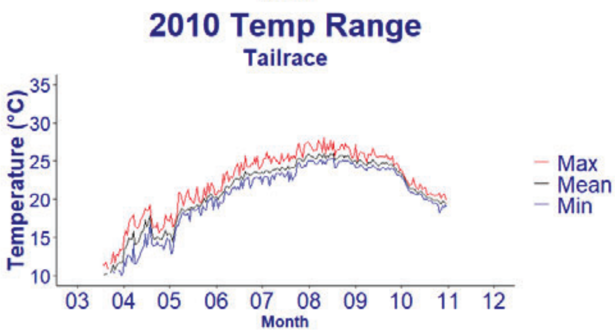
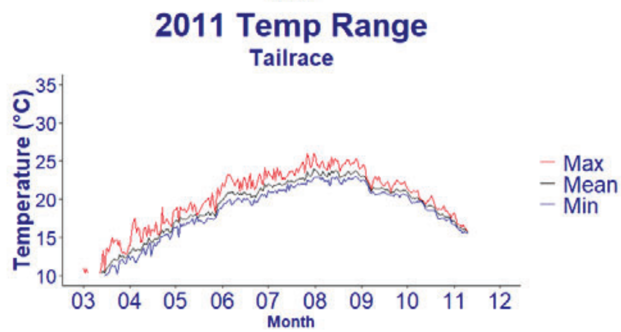
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

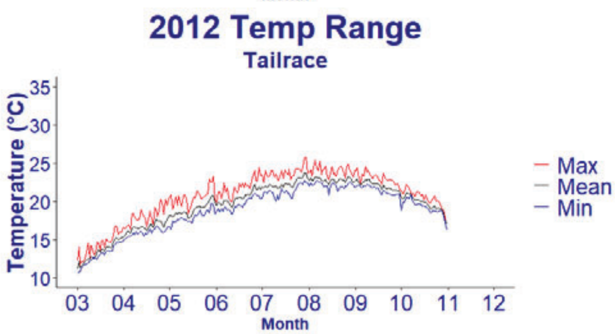

2007 Temp Range
Tailrace
Temperature (°C)
10 15 20 25 30 35
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

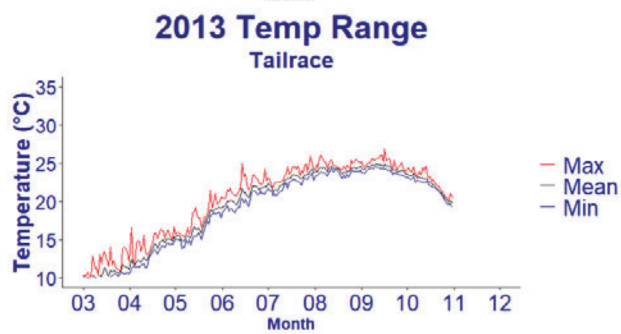

2008 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min

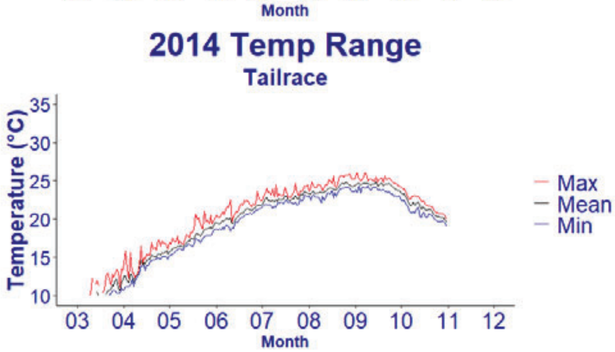

2009 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min

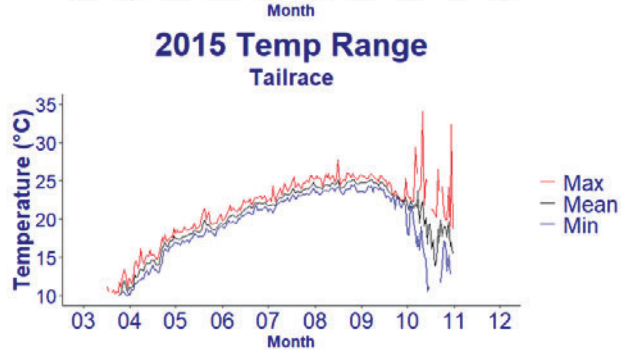

2010 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min


2011 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min


2012 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min


2013 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min


2014 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min


2015 Temp Range
Tailrace
Temperature (°C)
Month
Max
Mean
Min

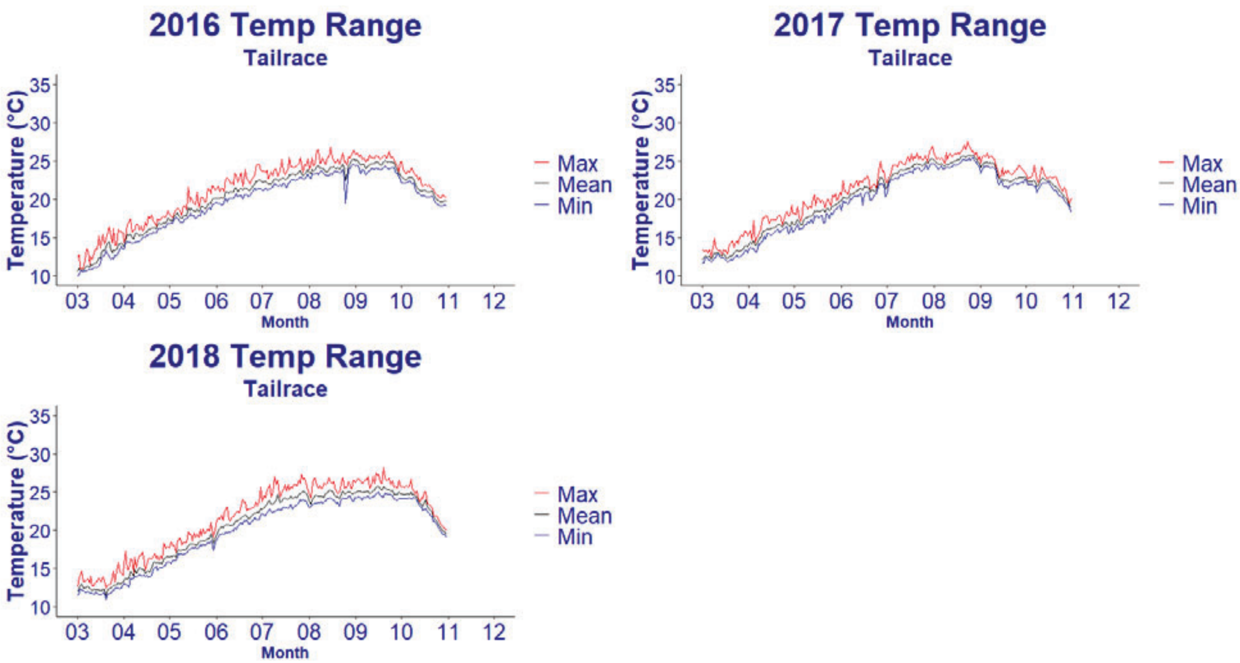
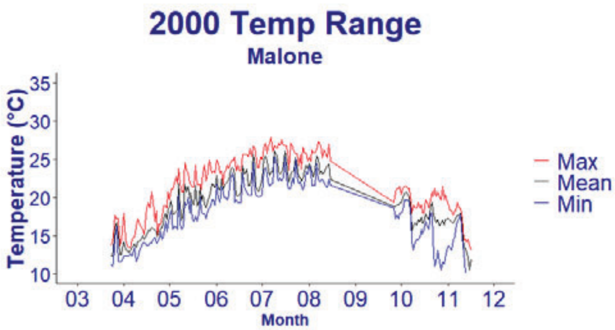


Figure 2.2A Yearly temperature variation (maximum, mean, and minimum) at the Harris Dam tailrace site.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Malone
Temperature (°C)
35
30
25
20
15
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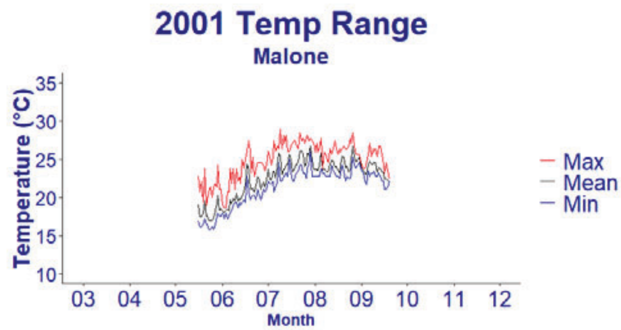
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min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Temperature (°C)
35
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03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
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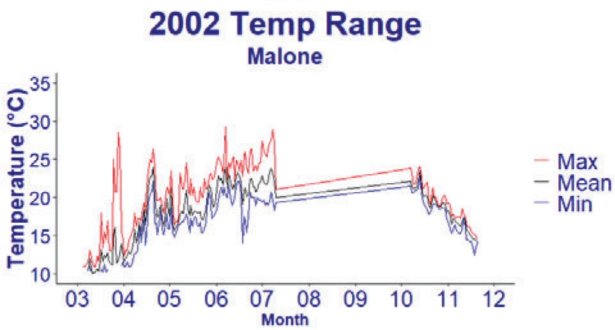
2002 Temp Range
Malone
Temperature (°C)
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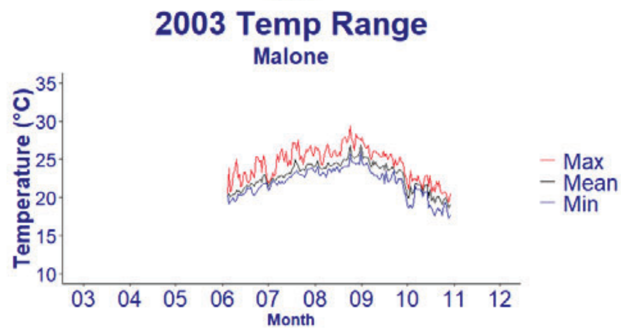
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2003 Temp Range
Malone
Temperature (°C)
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30
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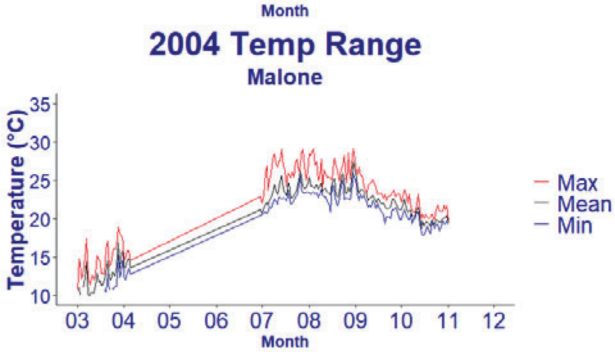
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2004 Temp Range
Malone
Temperature (°C)
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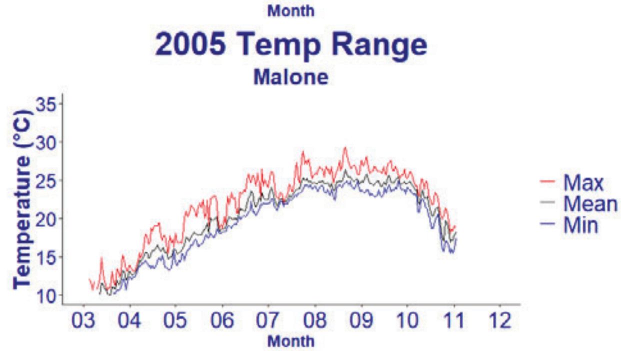
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2005 Temp Range
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Temperature (°C)
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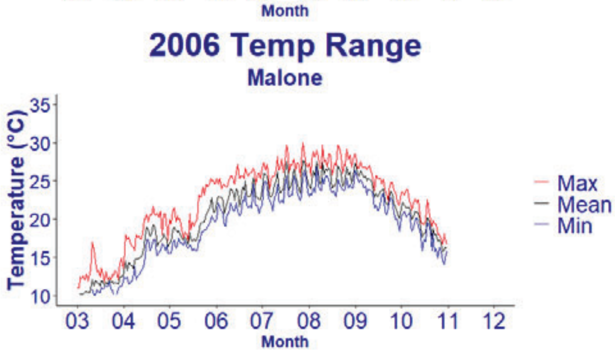
Month
Max
Mean
Min


2006 Temp Range
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Temperature (°C)
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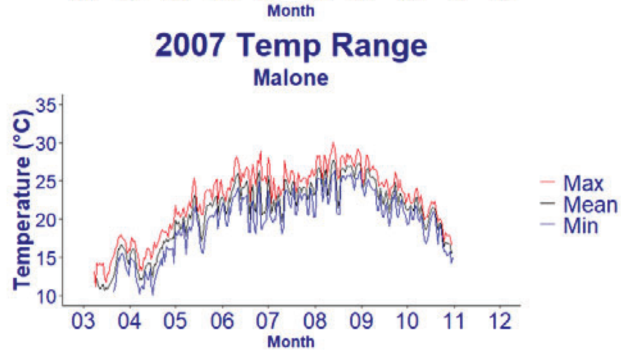
Month
Max
Mean
Min


2007 Temp Range
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Temperature (°C)
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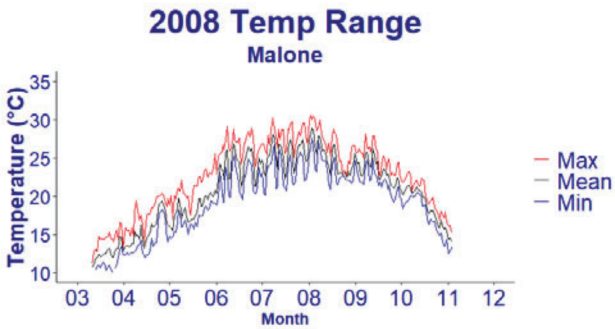
Month
Max
Mean
Min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Malone
Temperature (°C)
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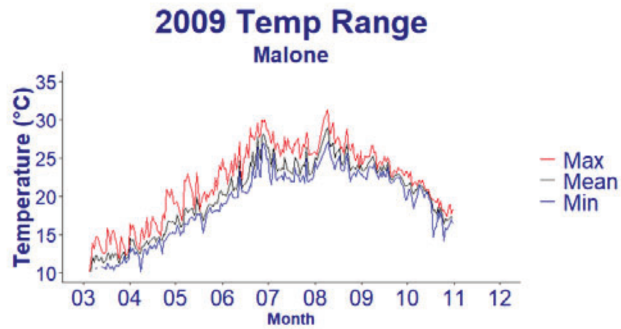
Month
Max
Mean
Min


2009 Temp Range
Malone
Temperature (°C)
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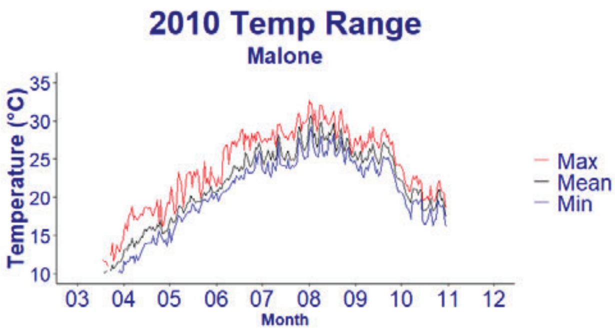
2010 Temp Range
Malone
Temperature (°C)
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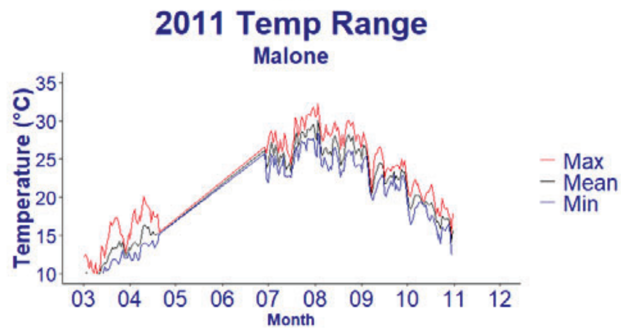
2011 Temp Range
Malone
Temperature (°C)
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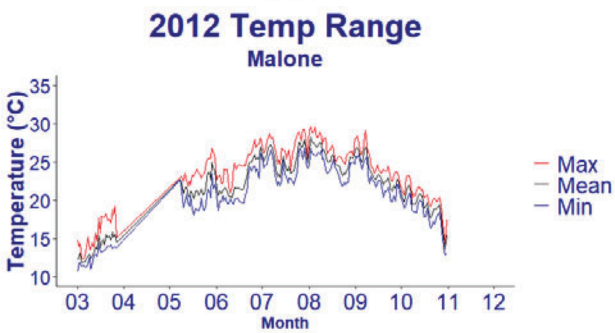
Max
Mean
Min


2012 Temp Range
Malone
Temperature (°C)
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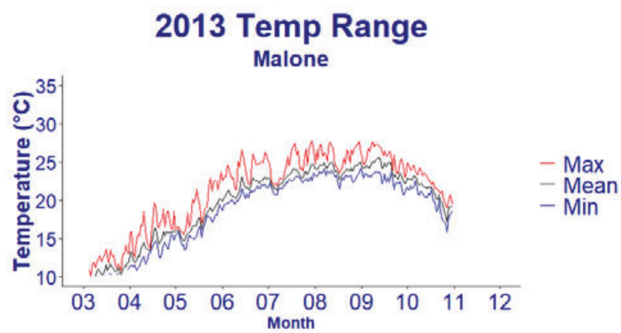
Max
Mean
Min


2013 Temp Range
Malone
Temperature (°C)
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Month
Max
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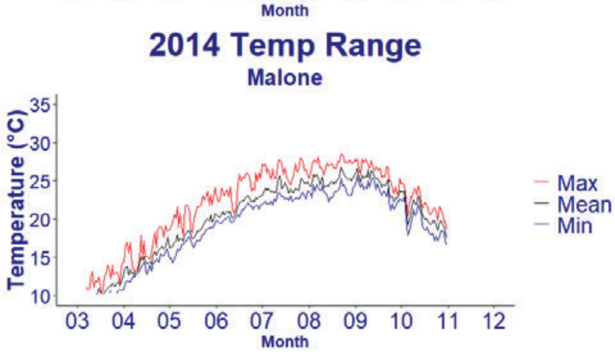
2014 Temp Range
Malone
Temperature (°C)
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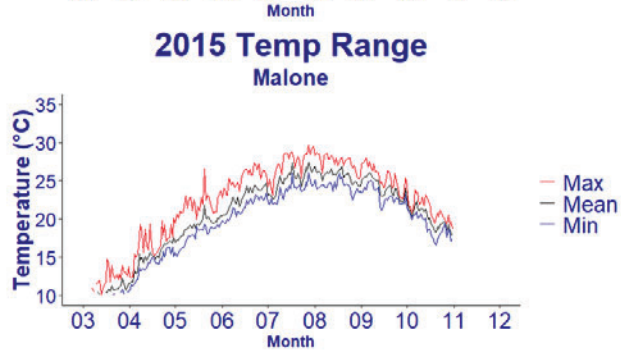
Month
Max
Mean
Min


2015 Temp Range
Malone
Temperature (°C)
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11
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Month
Max
Mean
Min

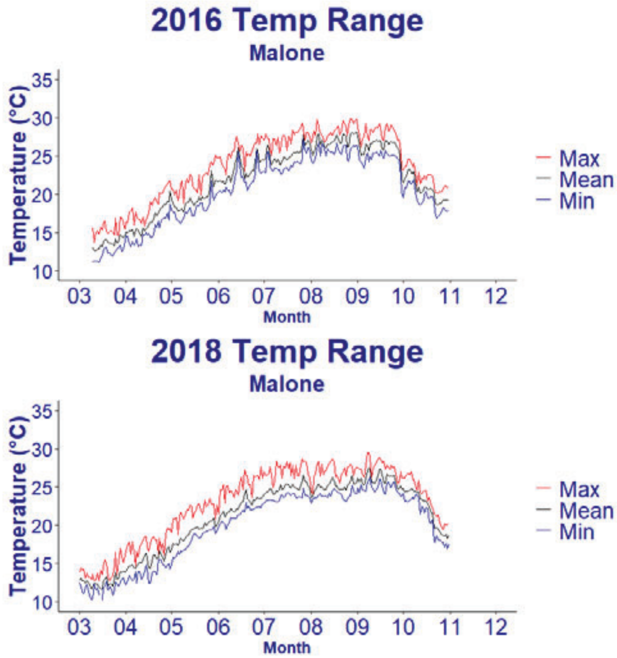
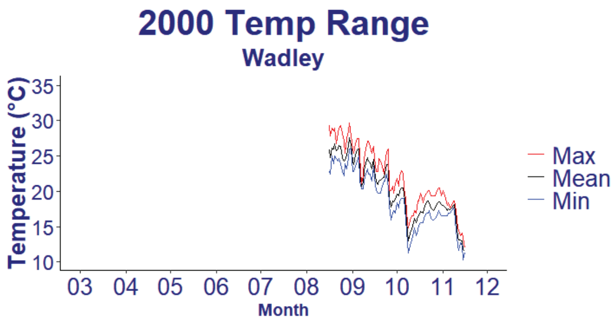
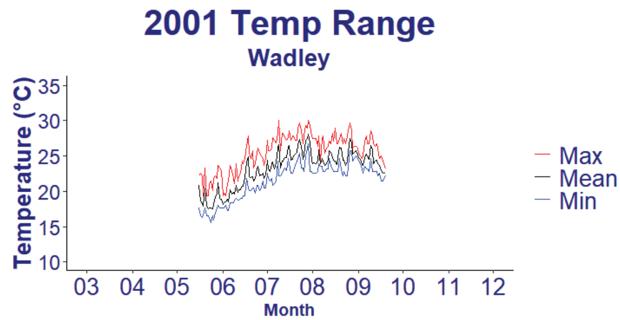
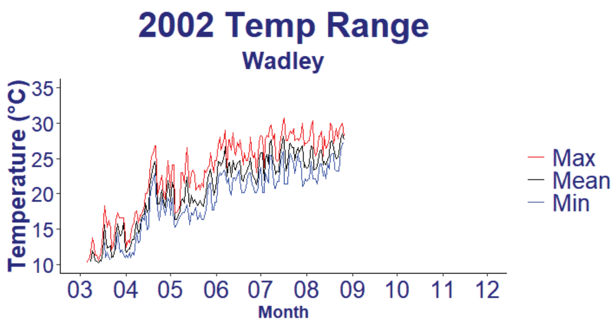
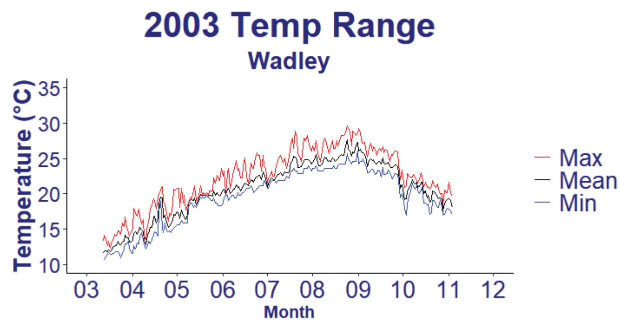


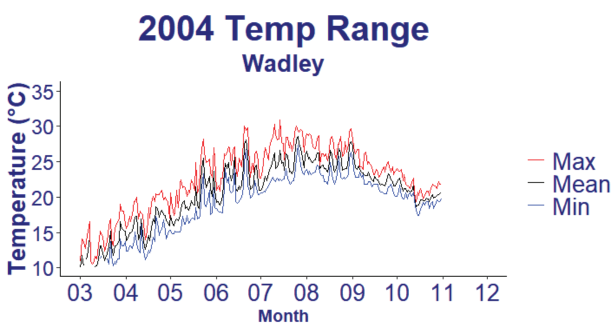
Figure 2.2B. Yearly temperature variation (maximum, mean, and minimum) at the Malone site.

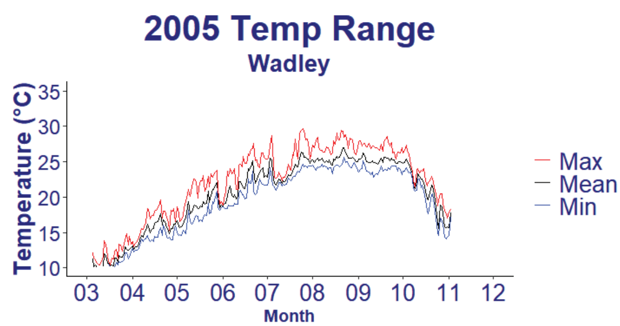

2000 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

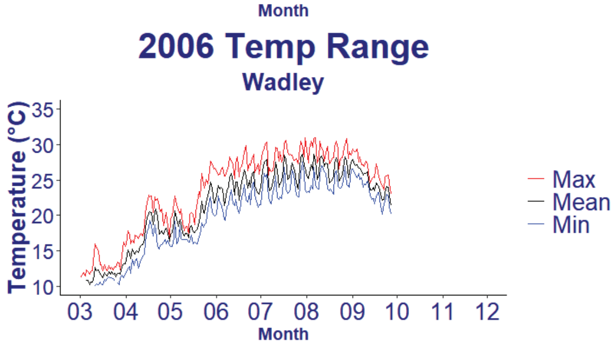

2001 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

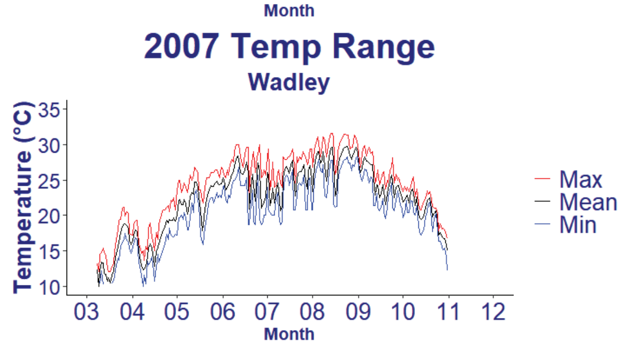

2002 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

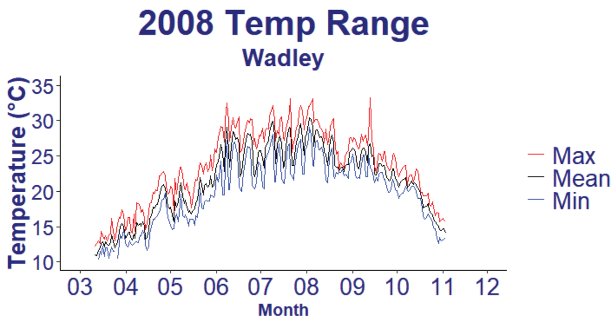

2003 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

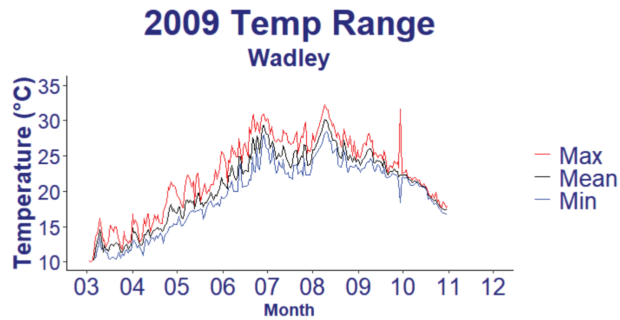

2004 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

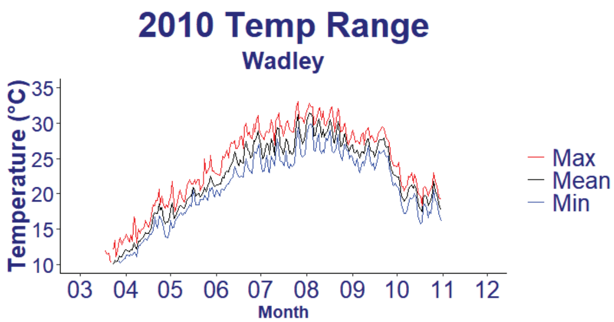

2005 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

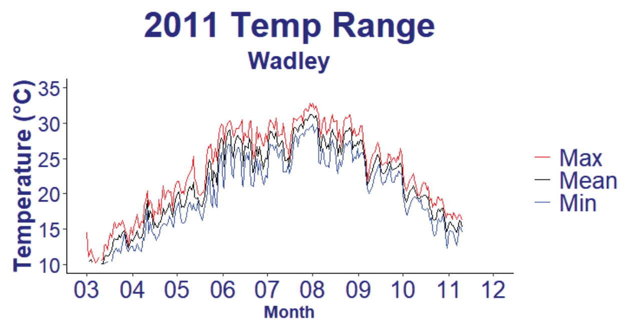

2006 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

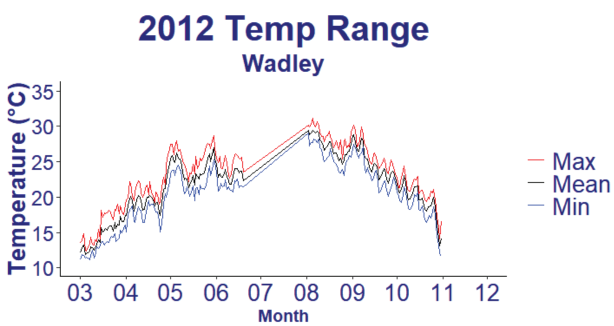

2007 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

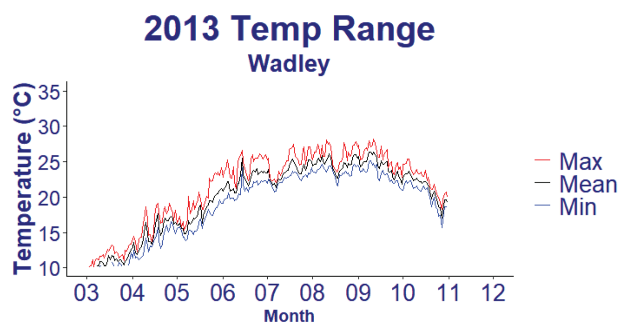

2008 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

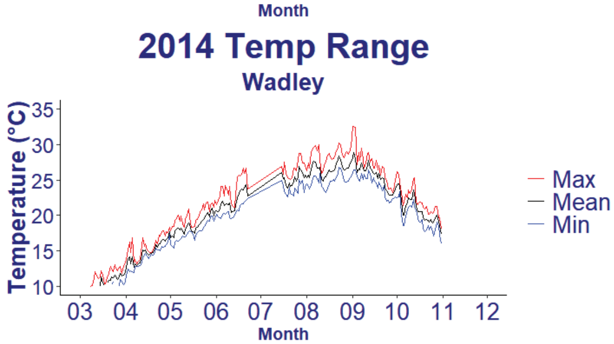

2009 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

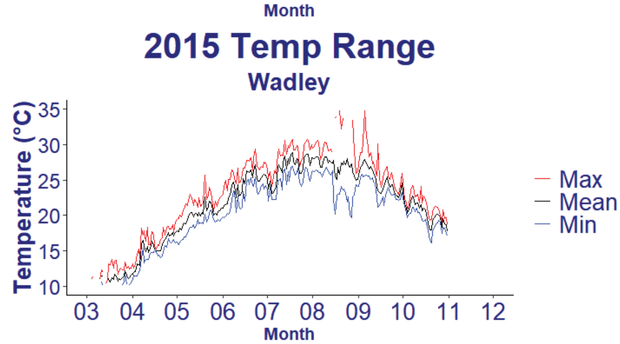

2010 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2011 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2012 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2013 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2014 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min


2015 Temp Range
Wadley
Temperature (°C)
35
30
25
20
15
10
03 04 05 06 07 08 09 10 11 12
Month
Max
Mean
Min

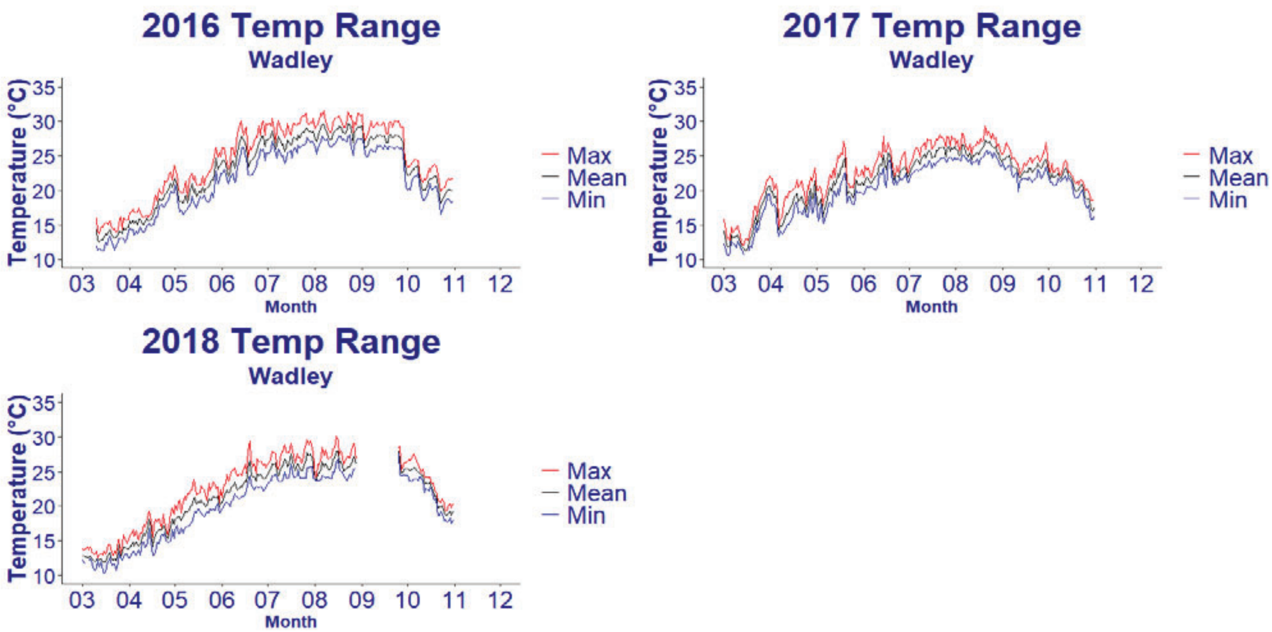


Figure 2.2C. Yearly temperature variation (maximum, mean, and minimum) at the Wadley site.

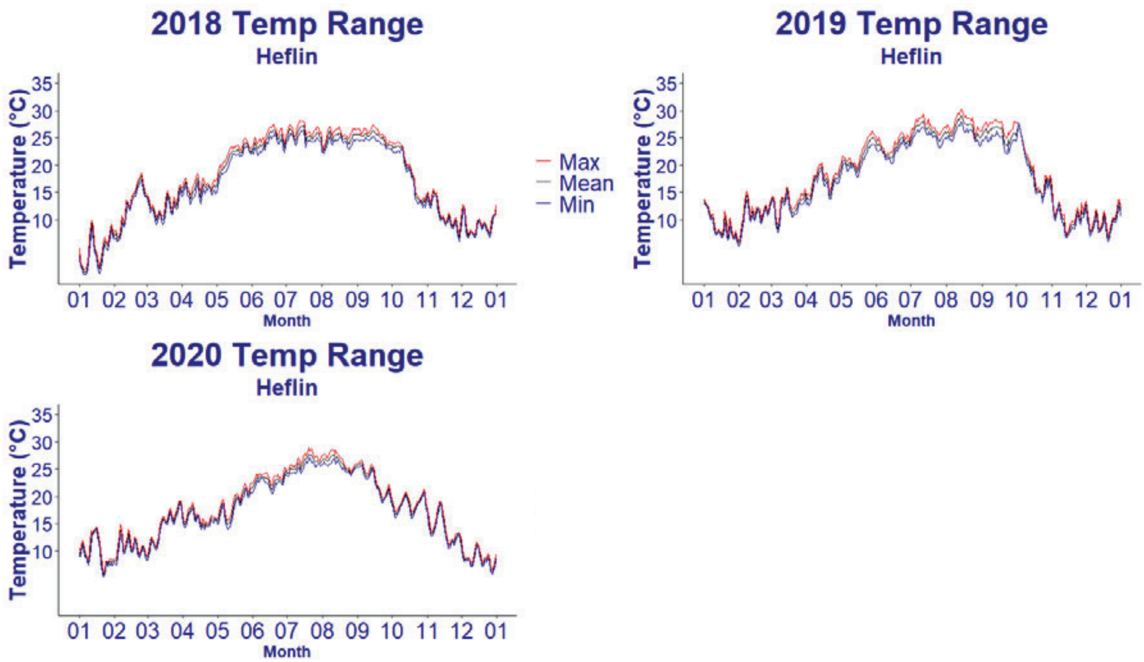
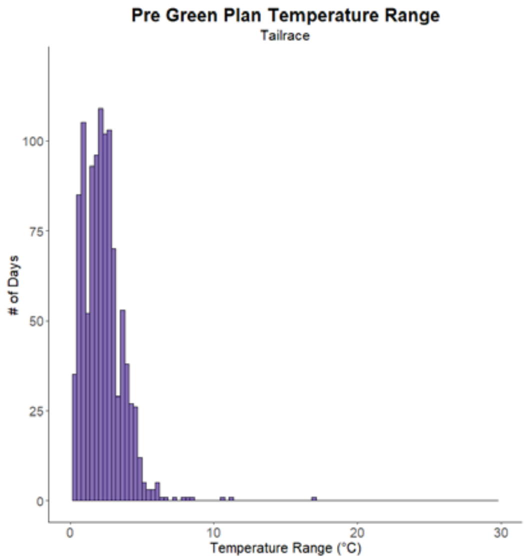
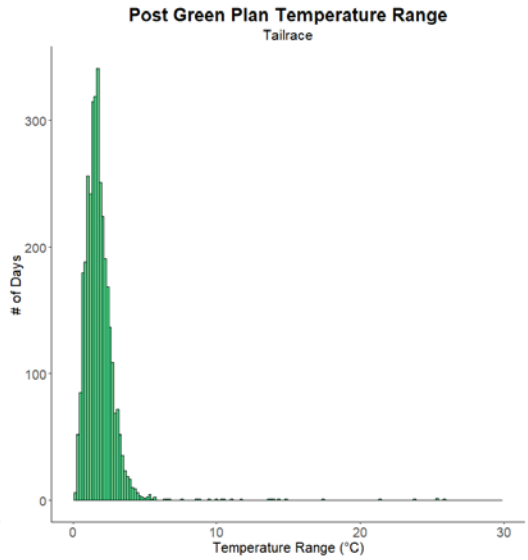
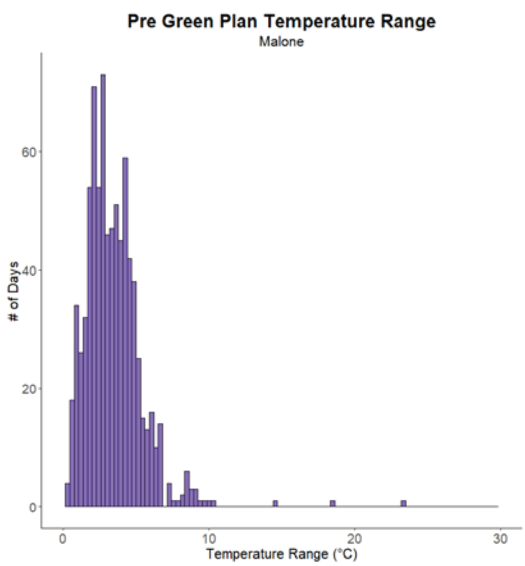
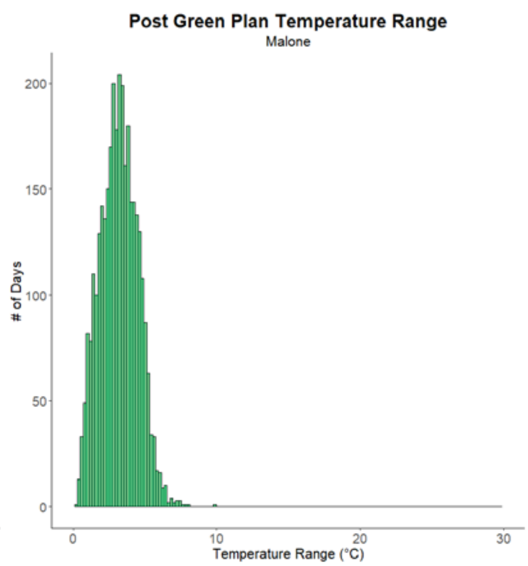


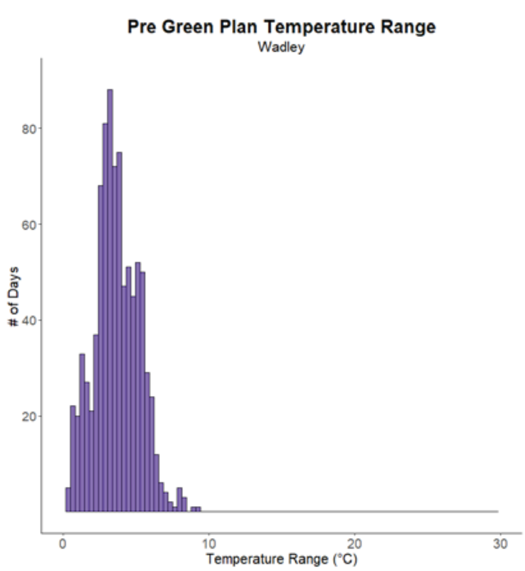
Figure 2.2D. Yearly temperature variation (maximum, mean, and minimum) at Heflin (upriver from Lee's Bridge), Alabama.

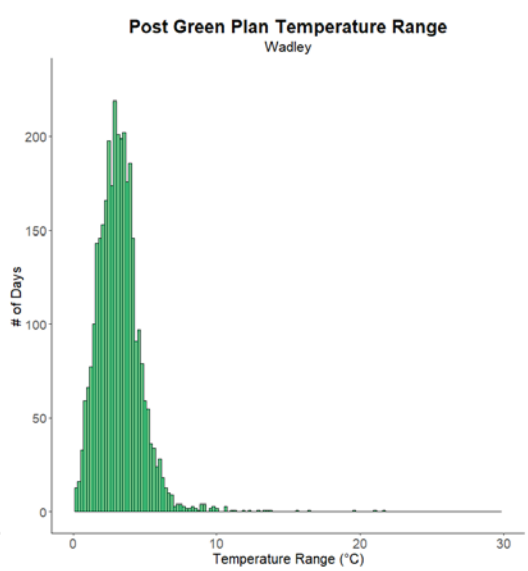

Pre Green Plan Temperature Range
Tailrace
# of Days
0
25
50
75
100
Temperature Range (°C)
0
10
20
30


Post Green Plan Temperature Range
Tailrace
# of Days
0
100
200
300
Temperature Range (°C)
0
10
20
30


Pre Green Plan Temperature Range
Malone
# of Days
0
20
40
60
Temperature Range (°C)
0
10
20
30


Post Green Plan Temperature Range
Malone
# of Days
0
50
100
150
200
Temperature Range (°C)
0
10
20
30


Pre Green Plan Temperature Range
Wadley
# of Days
20
40
60
80
Temperature Range (°C)
0
10
20
30


Post Green Plan Temperature Range
Wadley
# of Days
0
50
100
150
200
Temperature Range (°C)
0
10
20
30

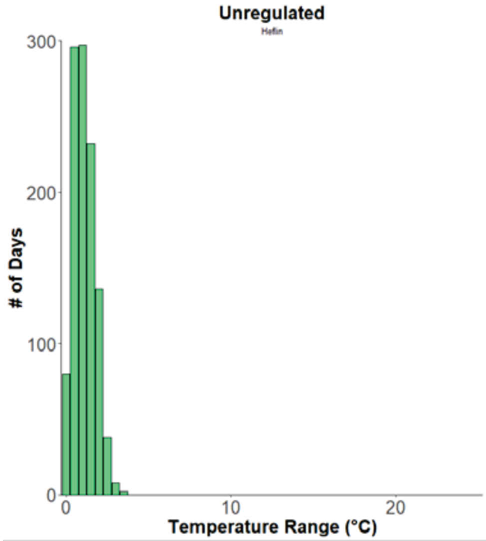
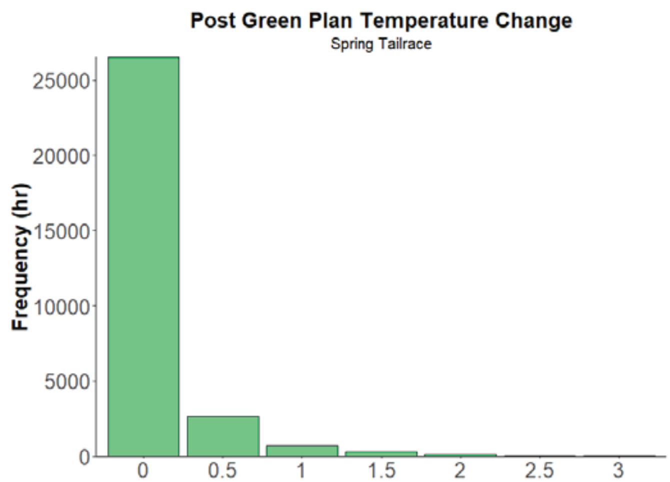
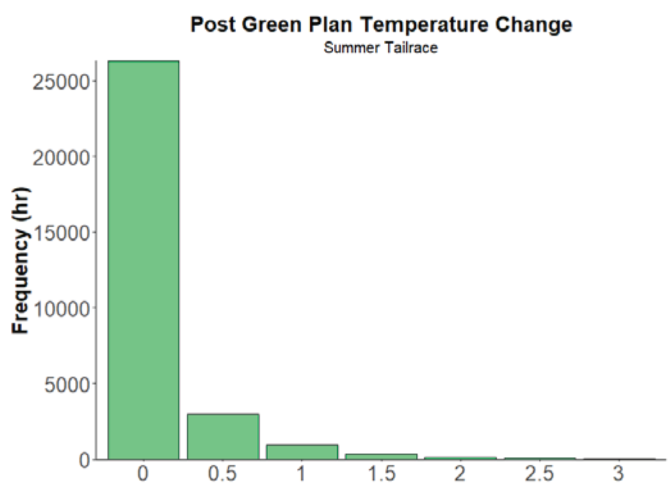
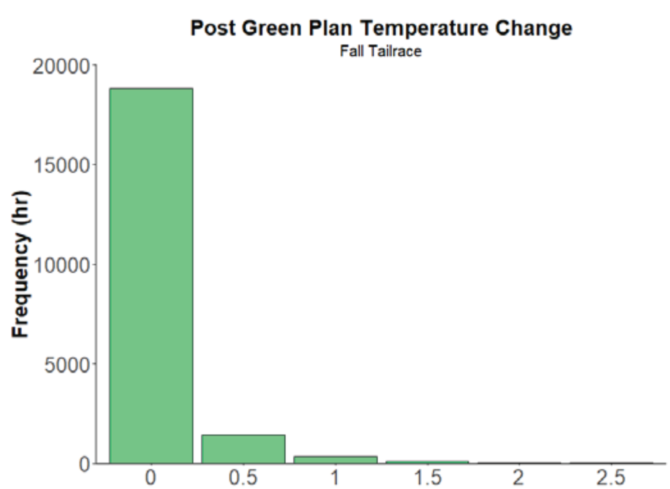
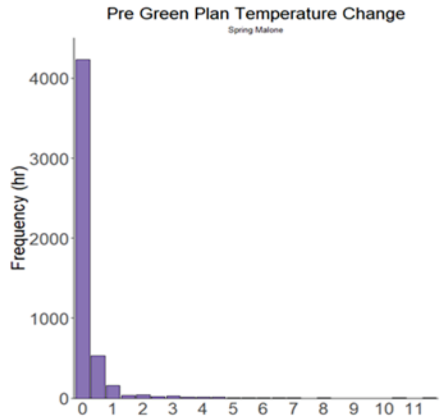


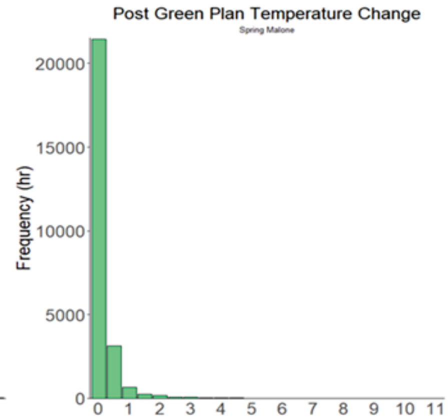
Figure 2.3. Frequency distributions of daily temperature ranges for the Harris tailrace, Malone, Wadley (Pre Green Plan 2000-2004, Post Green Plan 2005-2018), and Heflin (2018-2020).

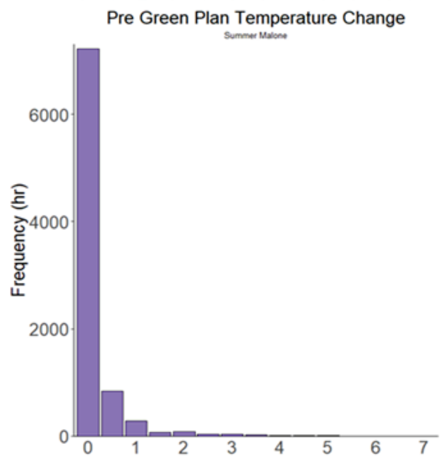

Post Green Plan Temperature Change
Spring Tailrace
Frequency (hr)
25000
20000
15000
10000
5000
0
0
0.5
1
1.5
2
2.5
3

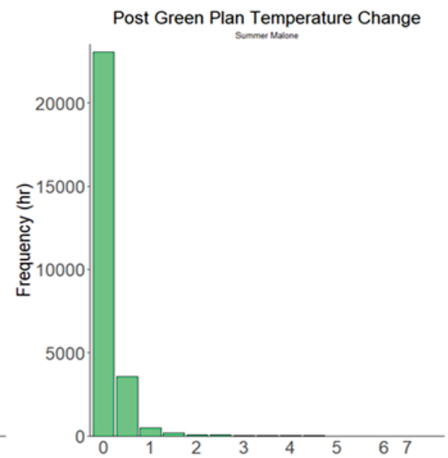

Post Green Plan Temperature Change
Summer Tailrace
Frequency (hr)
25000
20000
15000
10000
5000
0
0
0.5
1
1.5
2
2.5
3

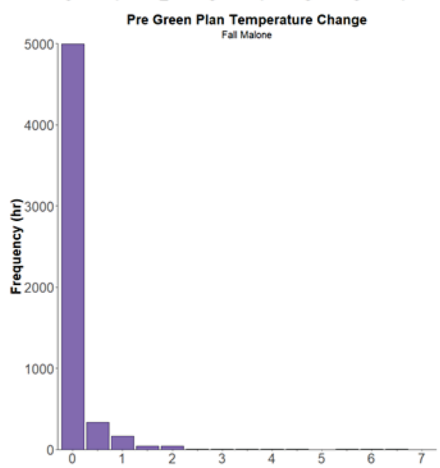

Post Green Plan Temperature Change
Fall Tailrace
Frequency (hr)
20000
15000
10000
5000
0
0
0.5
1
1.5
2
2.5

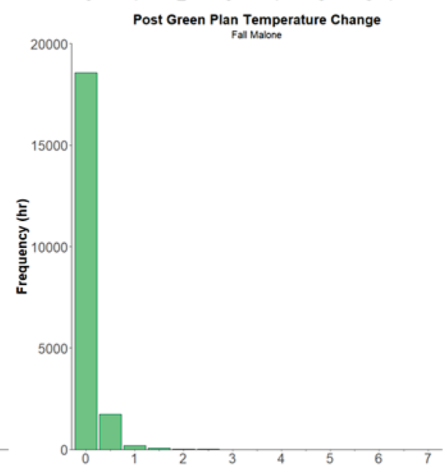

Pre Green Plan Temperature Change
Spring Malone
Frequency (hr)
0
1000
2000
3000
4000
0 1 2 3 4 5 6 7 8 9 10 11

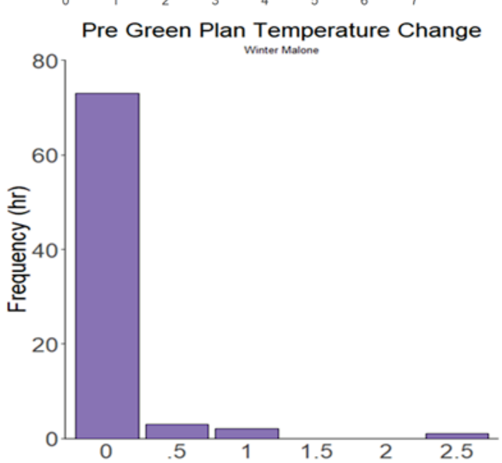

Post Green Plan Temperature Change
Spring Malone
Frequency (hr)
0
5000
10000
15000
20000
0 1 2 3 4 5 6 7 8 9 10 11


Pre Green Plan Temperature Change
Summer Malone
Frequency (hr)
0
2000
4000
6000
0 1 2 3 4 5 6 7


Post Green Plan Temperature Change
Summer Malone
Frequency (hr)
0
5000
10000
15000
20000
0 1 2 3 4 5 6 7


Pre Green Plan Temperature Change
Fall Malone
Frequency (hr)
0
1000
2000
3000
4000
5000
0 1 2 3 4 5 6 7


Post Green Plan Temperature Change
Fall Malone
Frequency (hr)
0
5000
10000
15000
20000
0 1 2 3 4 5 6 7


Pre Green Plan Temperature Change
Winter Malone
Frequency (hr)
0
20
40
60
80
0 .5 1 1.5 2 2.5

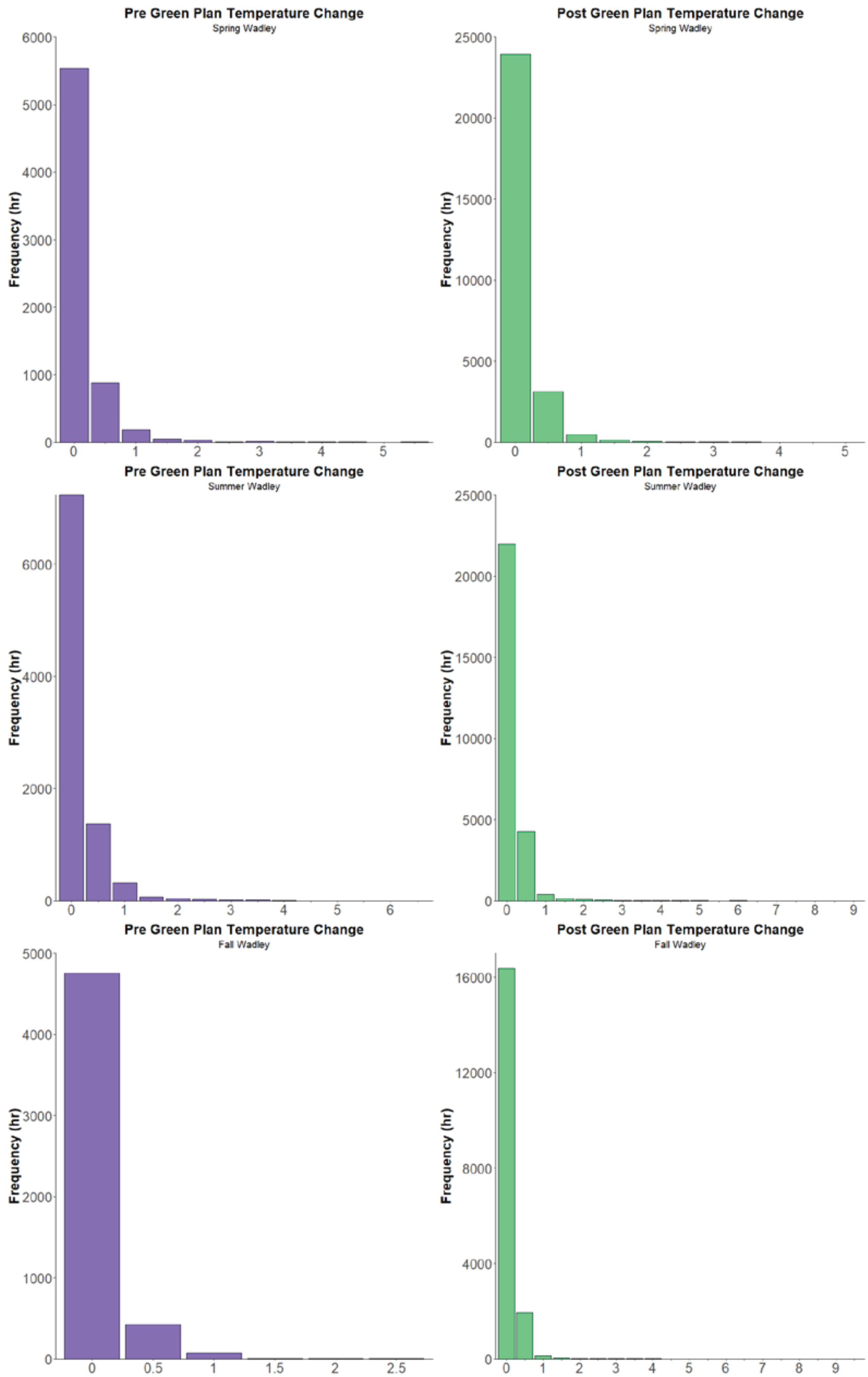


Figure 2.4. Frequency distributions of hourly temperature variation for three sites below Harris Dam (tailrace, Malone, and Wadley).

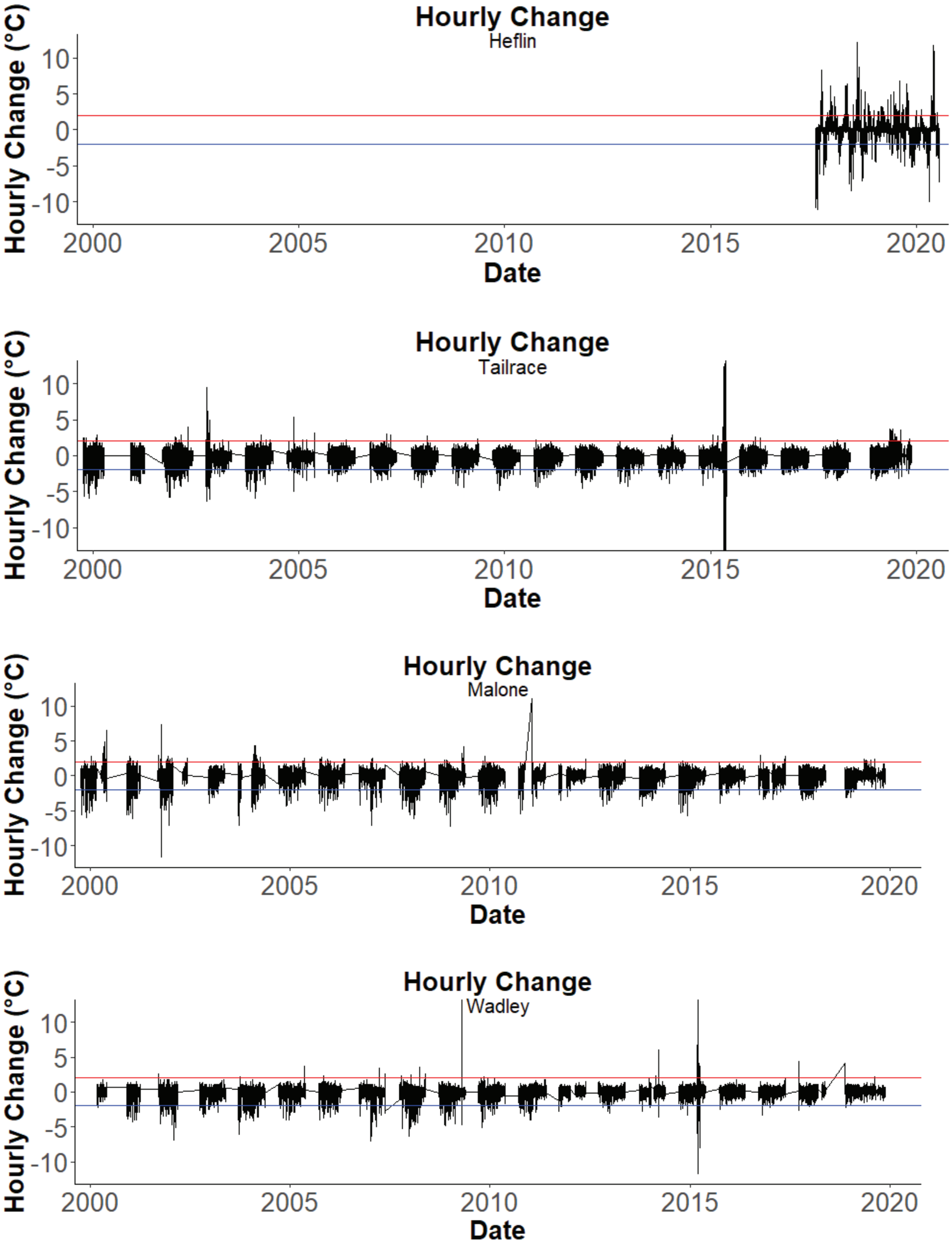


Figure 2.5. Hourly temperature variation at Heflin (unregulated), Harris tailrace, Malone, and Wadley (all regulated) showing when water cooled (negative values) and water warmed (positive values). Horizontal lines show +2 C (red) and -2 C (blue).

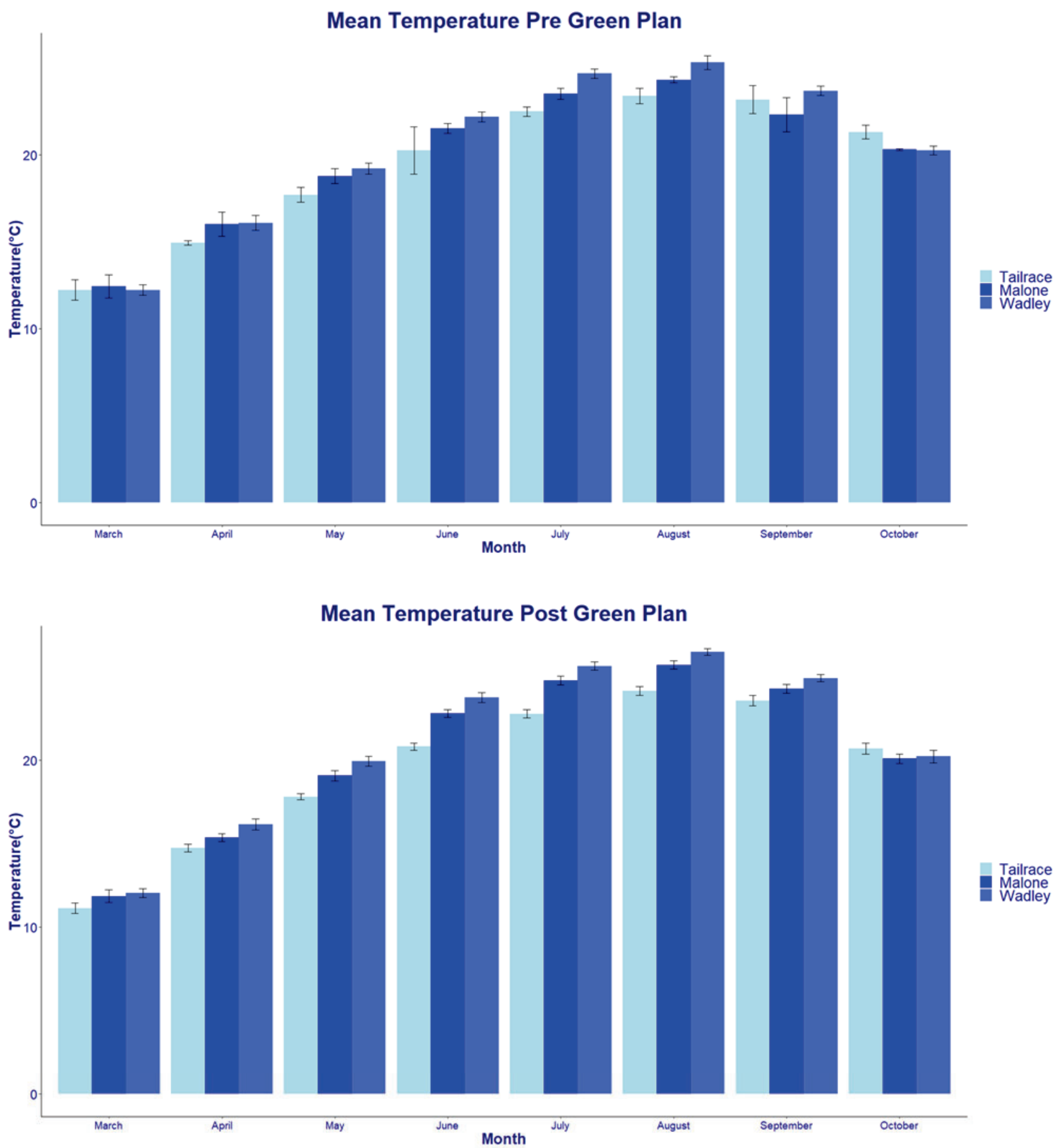


Figure 2.6. Mean temperature trends pre- and post-Green Plan across three locations.

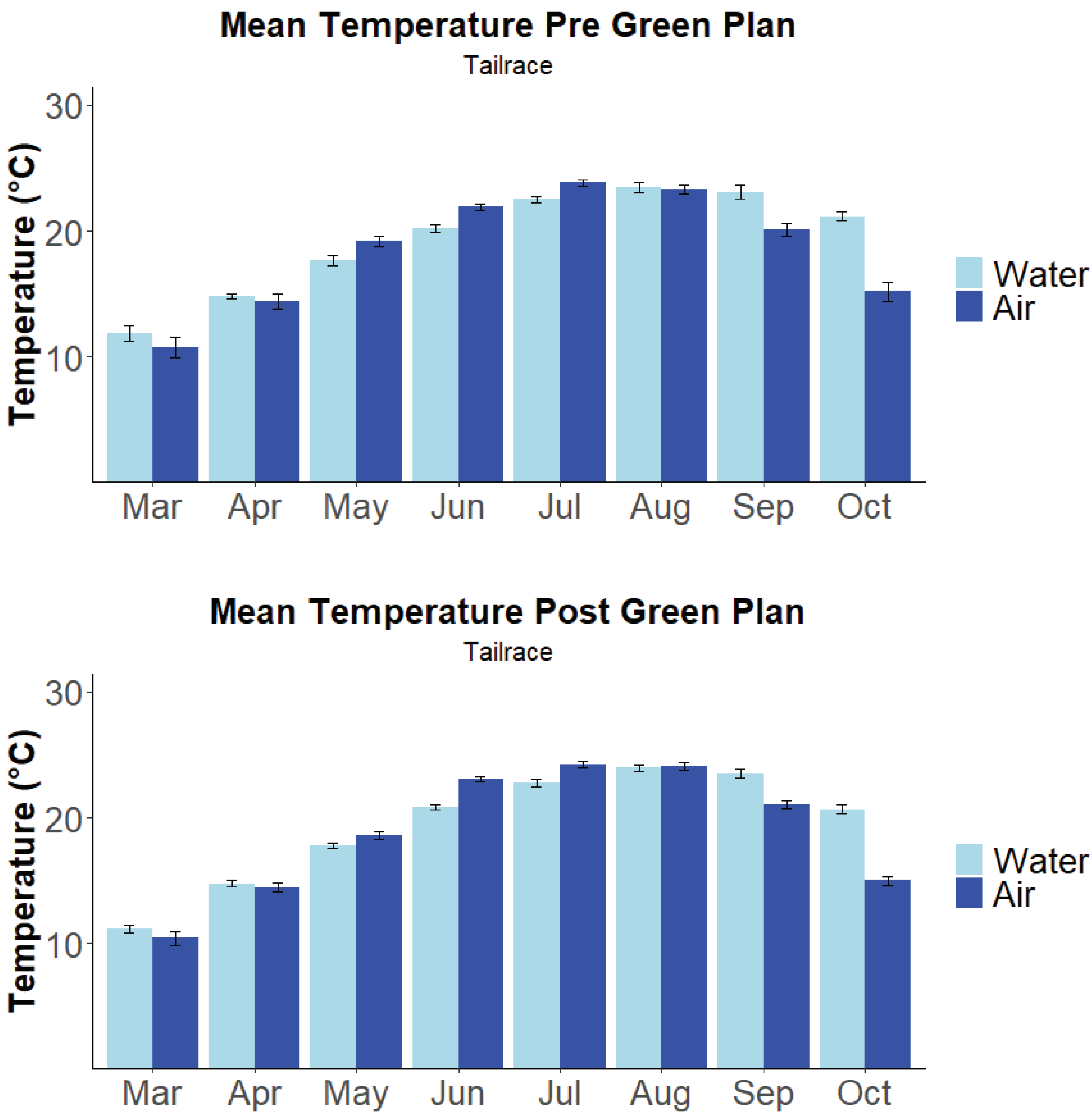
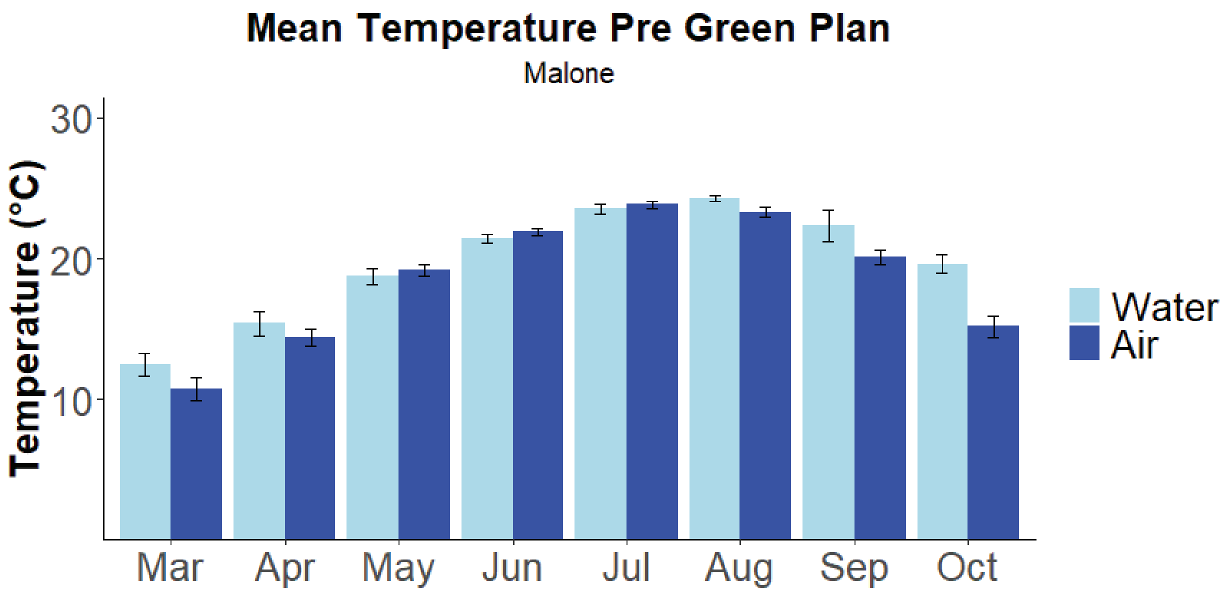


Figure 2.7A. Average air and water temperatures pre- and post-Green Plan at the Harris Dam tailrace site.



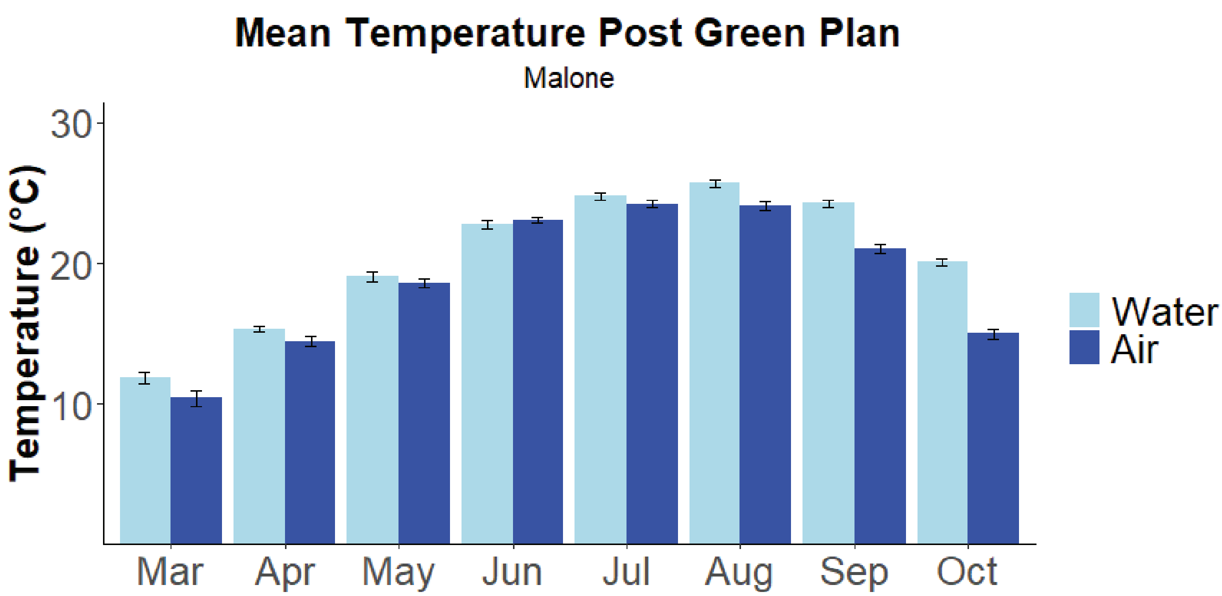


Figure 2.7B. Average air and water temperatures pre- and post-Green Plan at the Malone site.

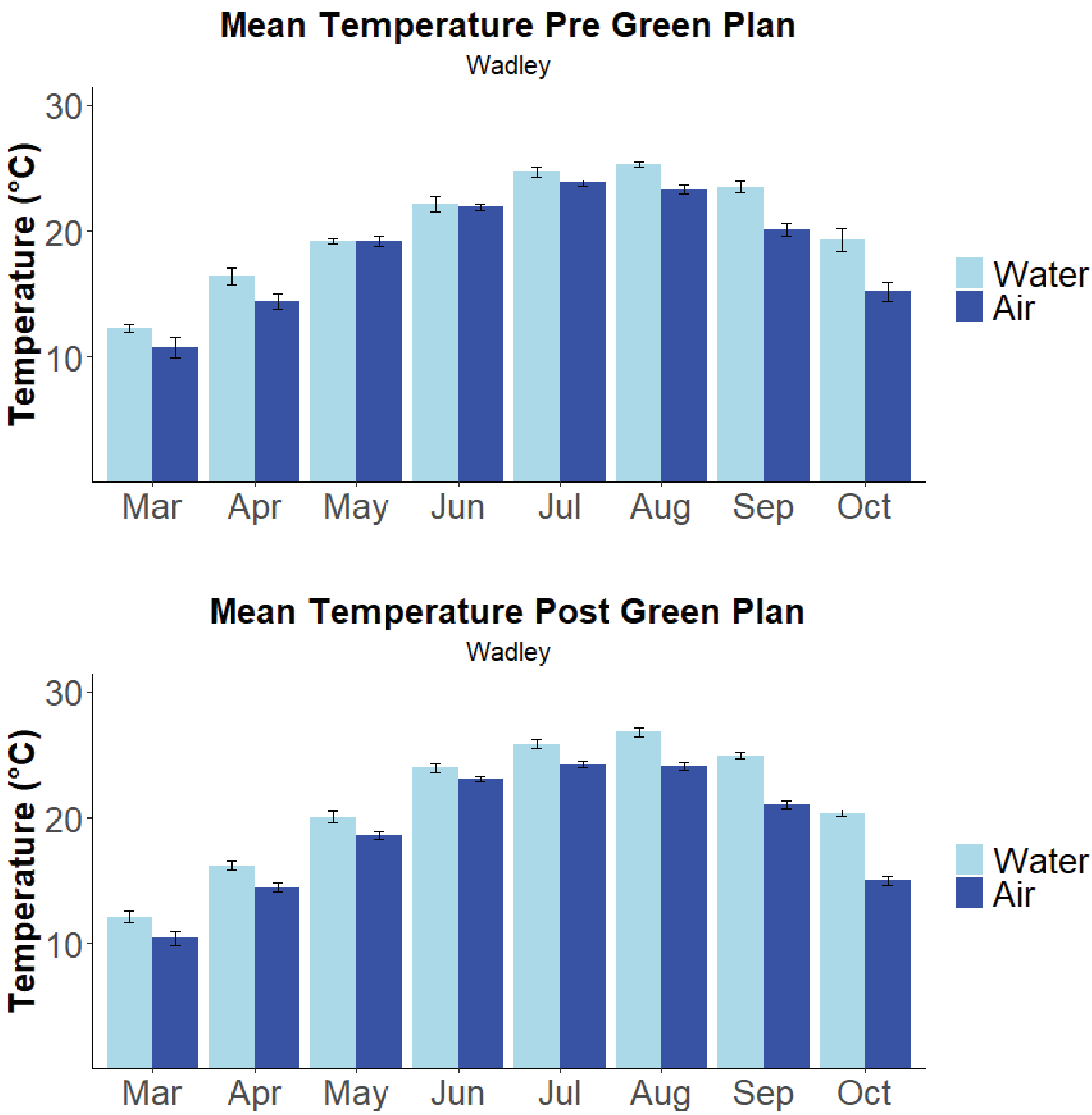
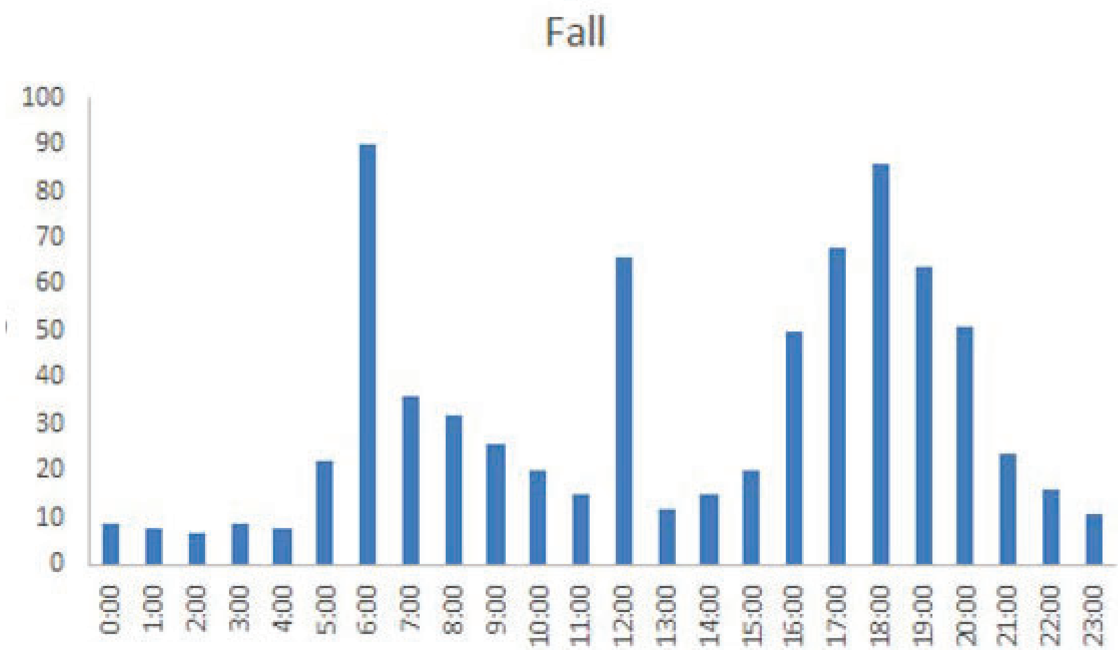
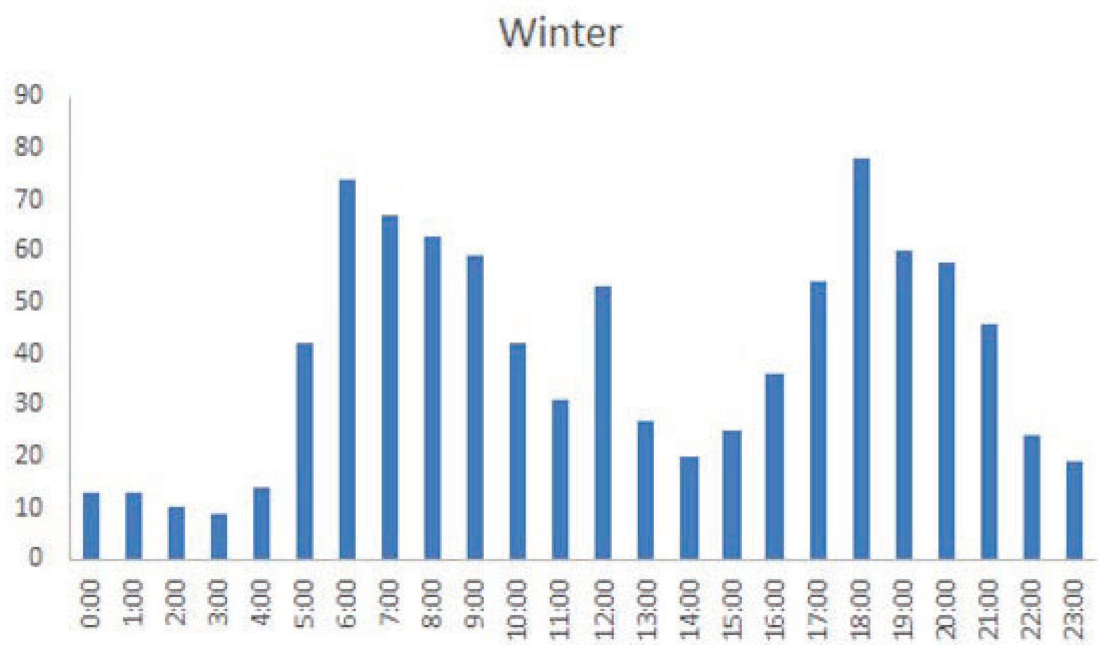


Figure 2.7C. Average air and water temperatures pre- and post-Green Plan at the Wadley site.


Fall
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Winter
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

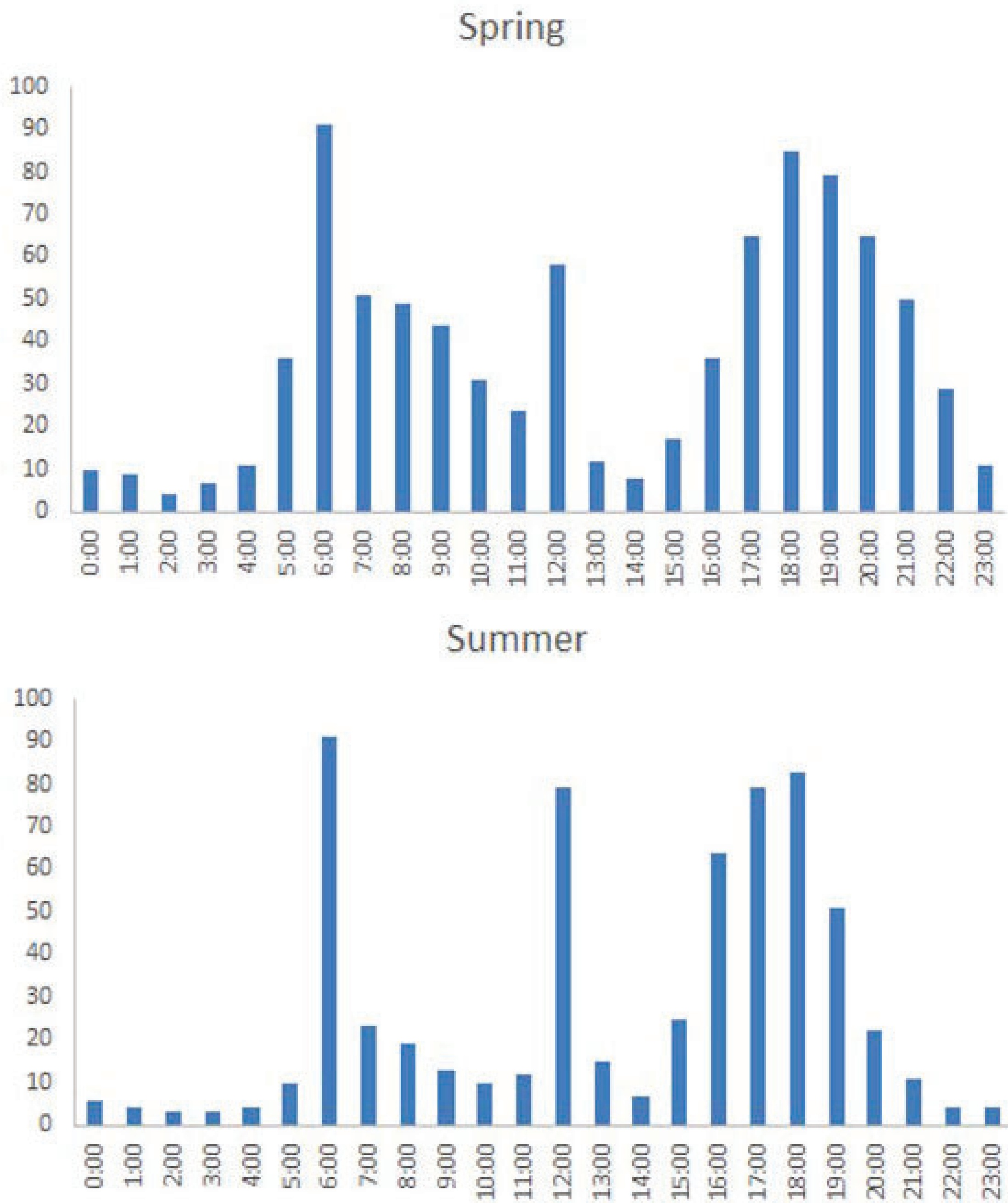
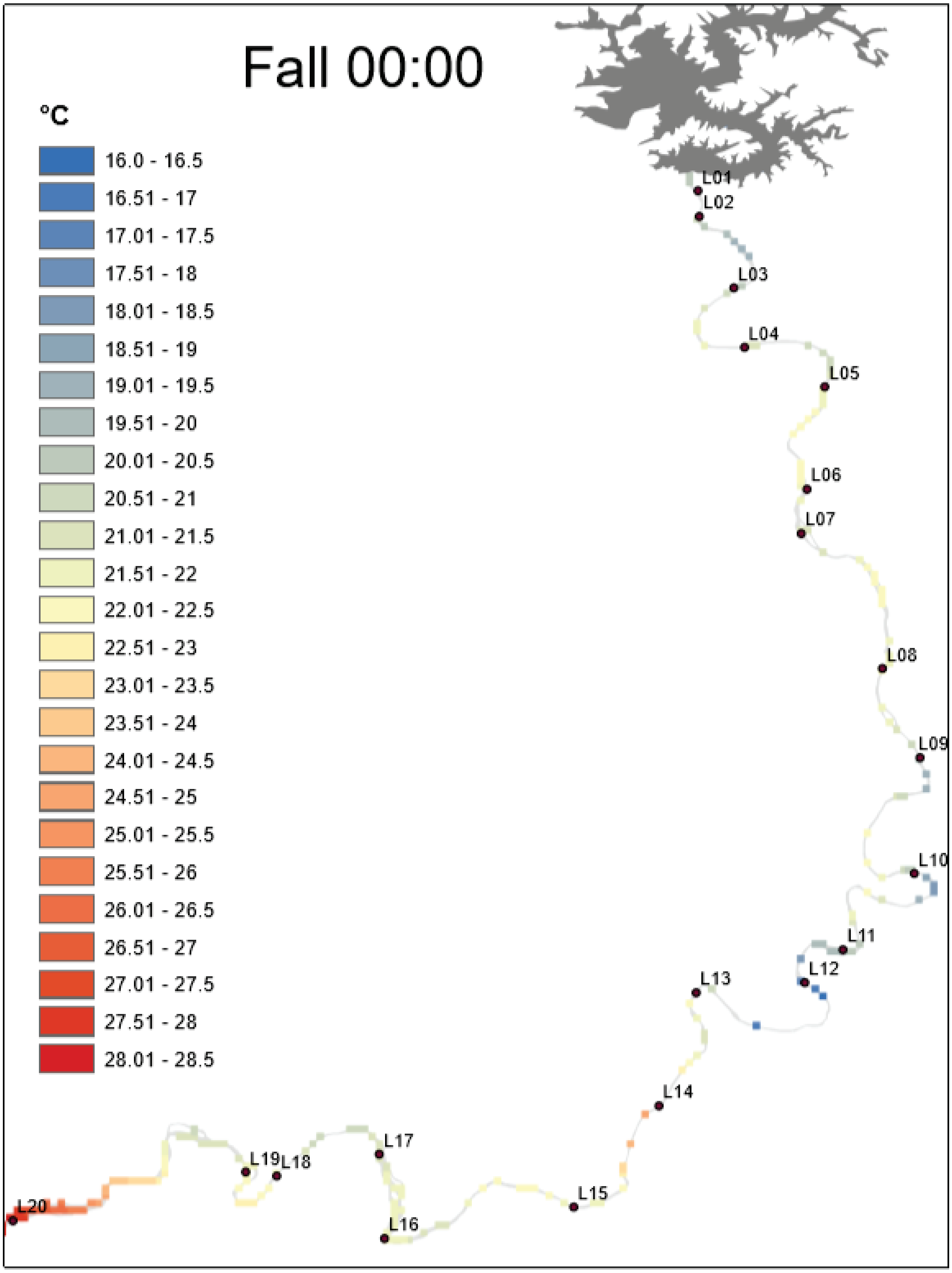
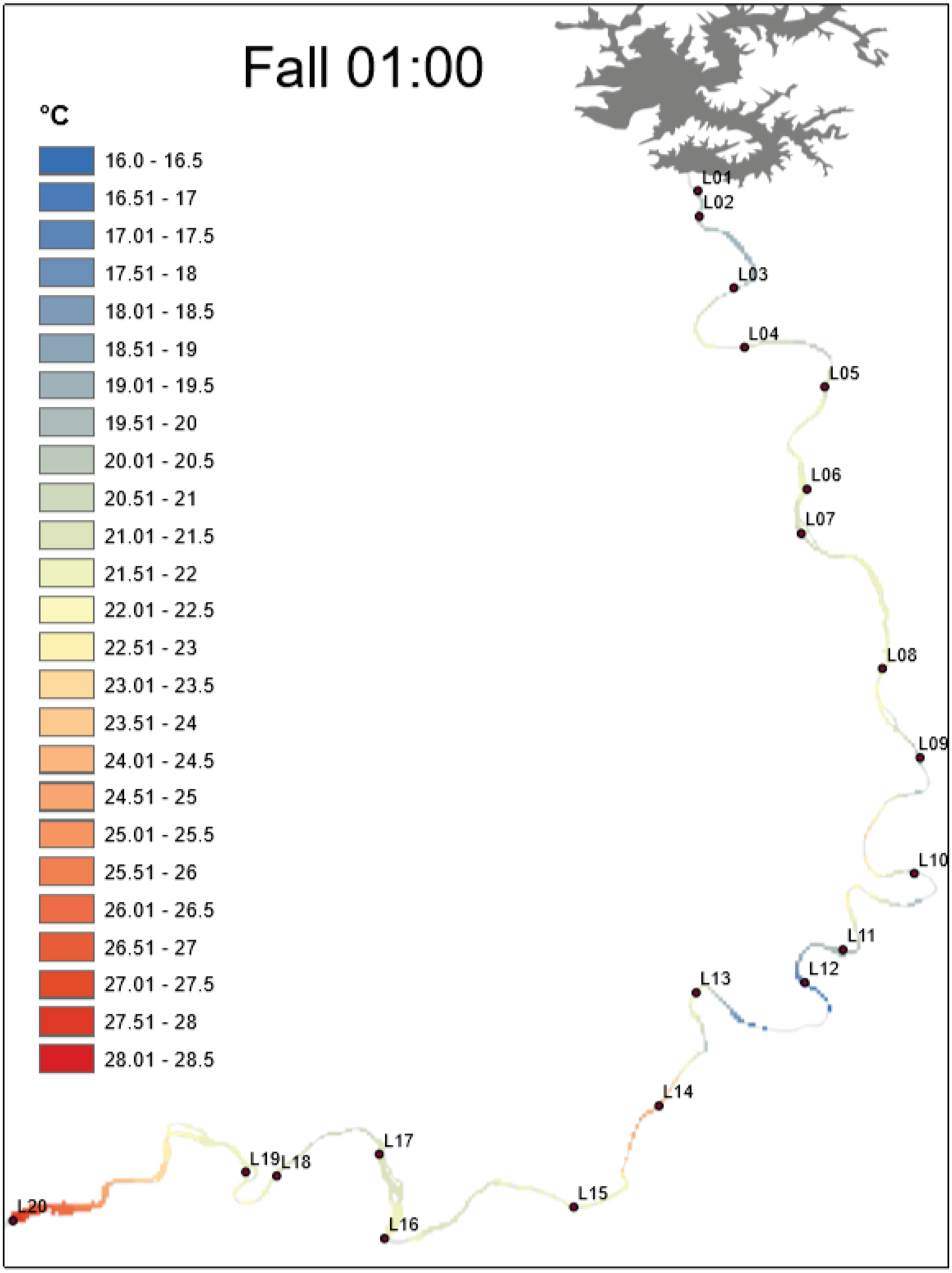
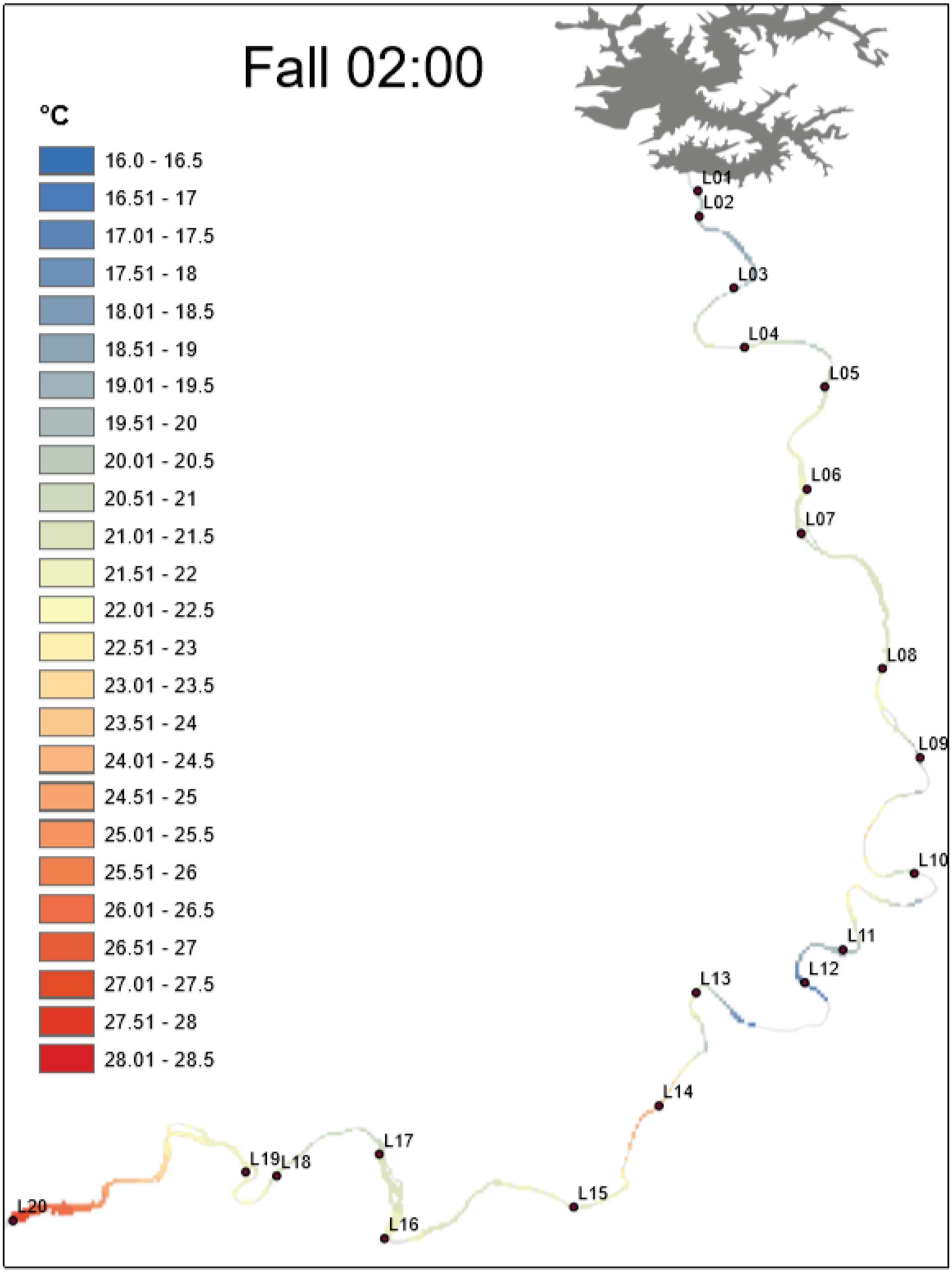


Figure 2.8. Frequency of generation times for each season.



Fall 00:00
°C
16.0 - 16.5
16.51 - 17
17.01 - 17.5
17.51 - 18
18.01 - 18.5
18.51 - 19
19.01 - 19.5
19.51 - 20
20.01 - 20.5
20.51 - 21
21.01 - 21.5
21.51 - 22
22.01 - 22.5
22.51 - 23
23.01 - 23.5
23.51 - 24
24.01 - 24.5
24.51 - 25
25.01 - 25.5
25.51 - 26
26.01 - 26.5
26.51 - 27
27.01 - 27.5
27.51 - 28
28.01 - 28.5
L01
L02
L03
L04
L05
L06
L07
L08
L09
L10
L11
L12
L13
L14
L15
L16
L17
L18
L19
L20


Fall 01:00
°C
16.0 - 16.5
16.51 - 17
17.01 - 17.5
17.51 - 18
18.01 - 18.5
18.51 - 19
19.01 - 19.5
19.51 - 20
20.01 - 20.5
20.51 - 21
21.01 - 21.5
21.51 - 22
22.01 - 22.5
22.51 - 23
23.01 - 23.5
23.51 - 24
24.01 - 24.5
24.51 - 25
25.01 - 25.5
25.51 - 26
26.01 - 26.5
26.51 - 27
27.01 - 27.5
27.51 - 28
28.01 - 28.5
L01
L02
L03
L04
L05
L06
L07
L08
L09
L10
L11
L12
L13
L14
L15
L16
L17
L18
L19
L20


Fall 02:00
°C
16.0 - 16.5
16.51 - 17
17.01 - 17.5
17.51 - 18
18.01 - 18.5
18.51 - 19
19.01 - 19.5
19.51 - 20
20.01 - 20.5
20.51 - 21
21.01 - 21.5
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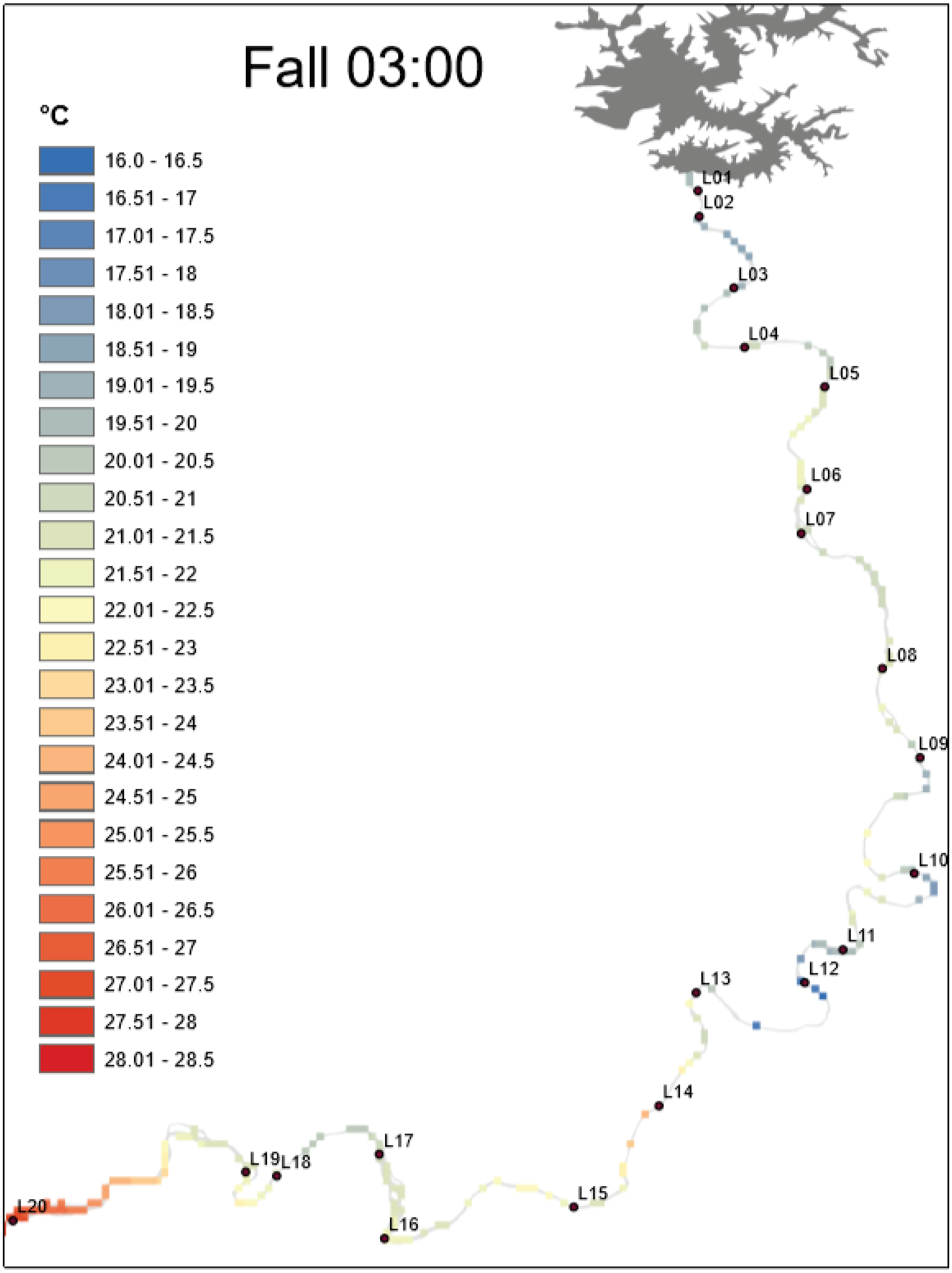
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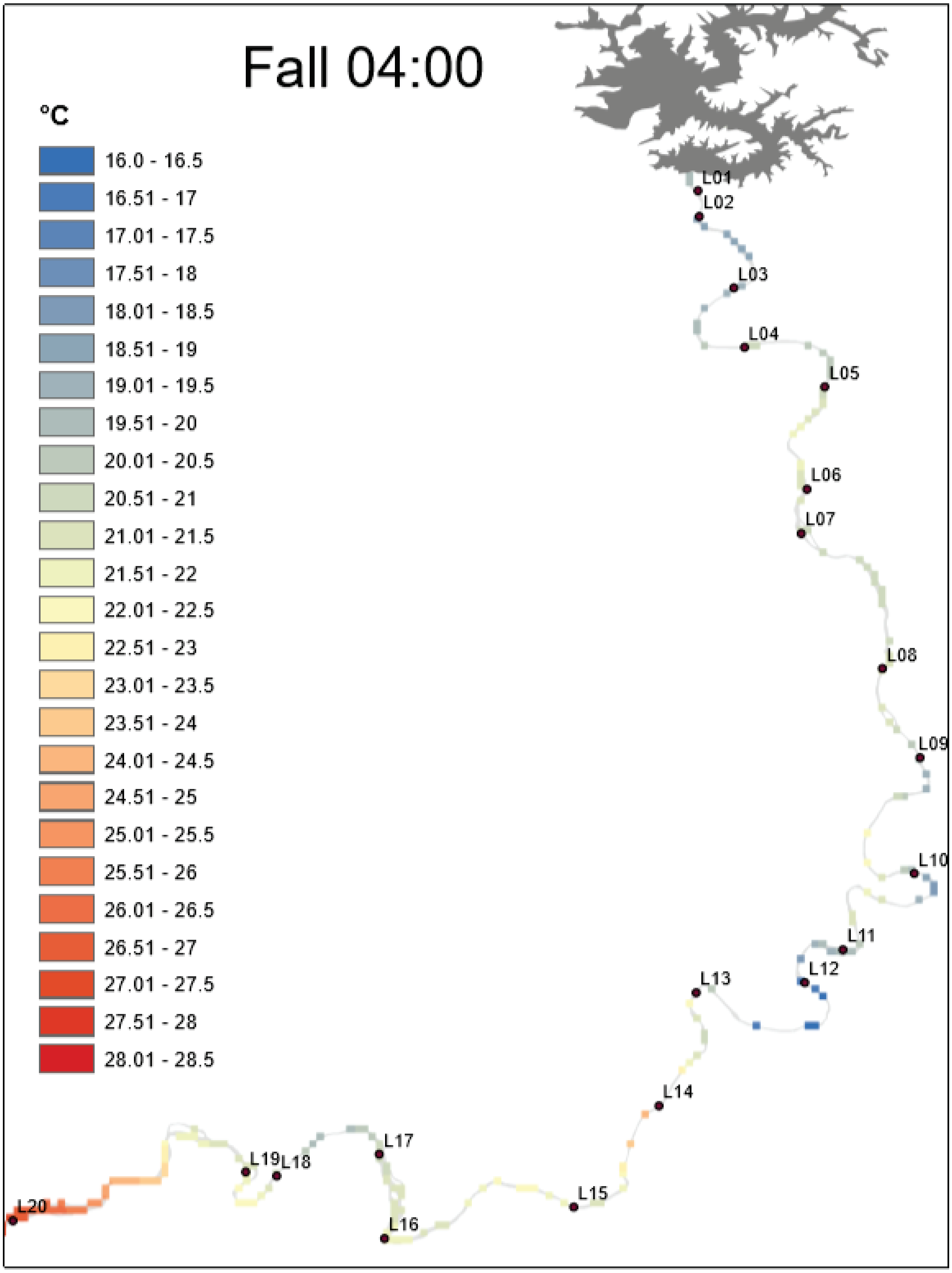
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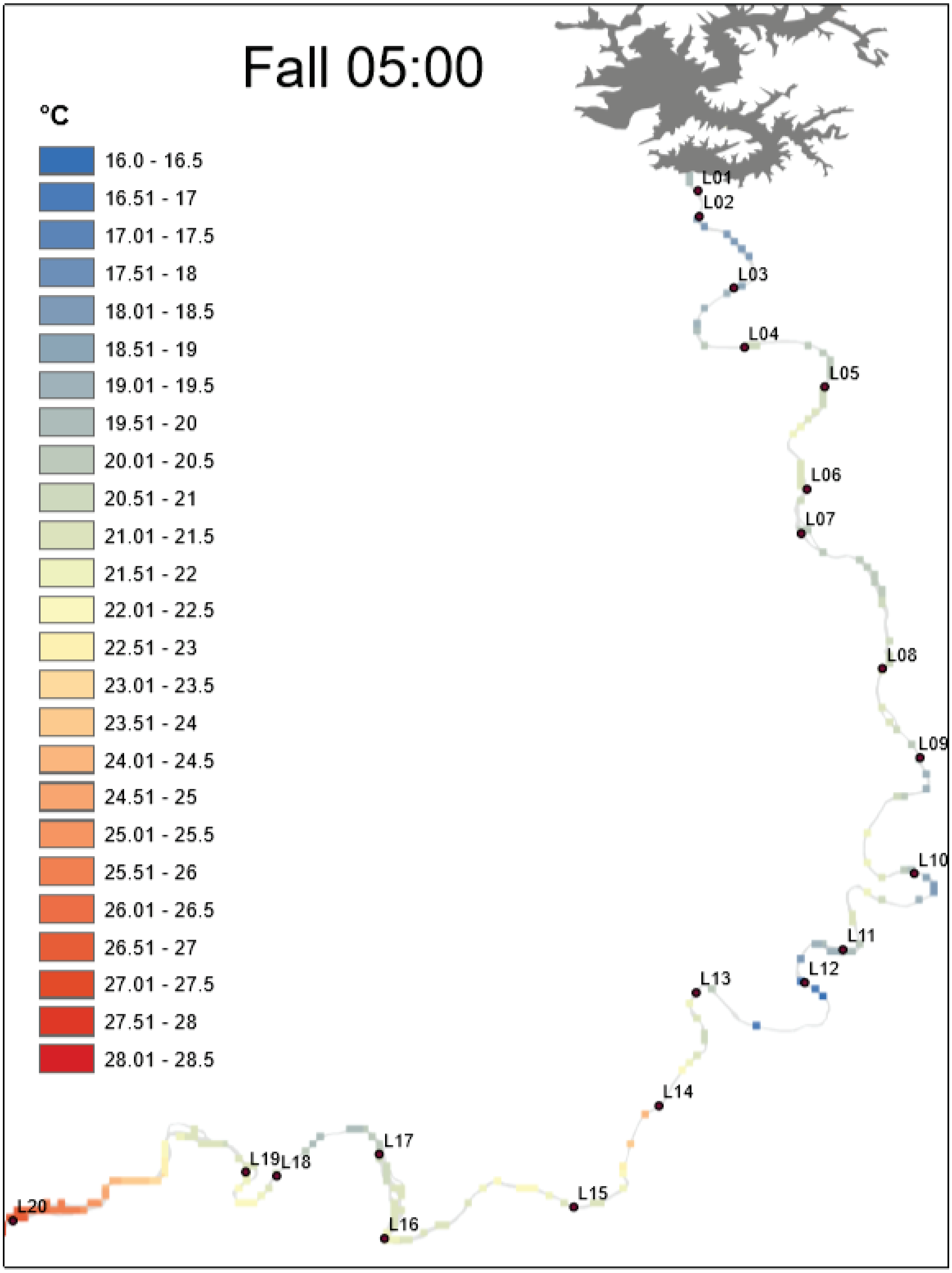
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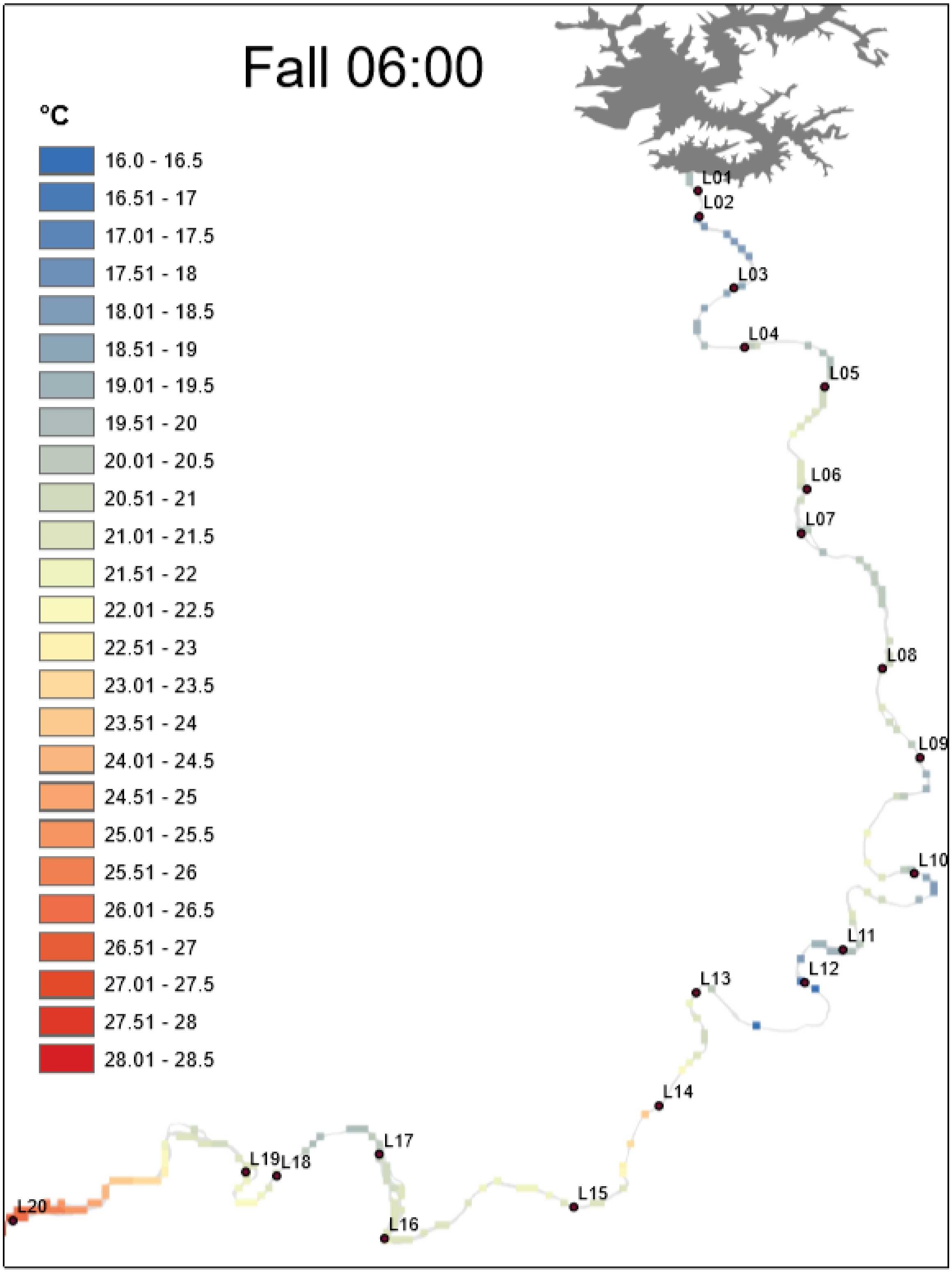

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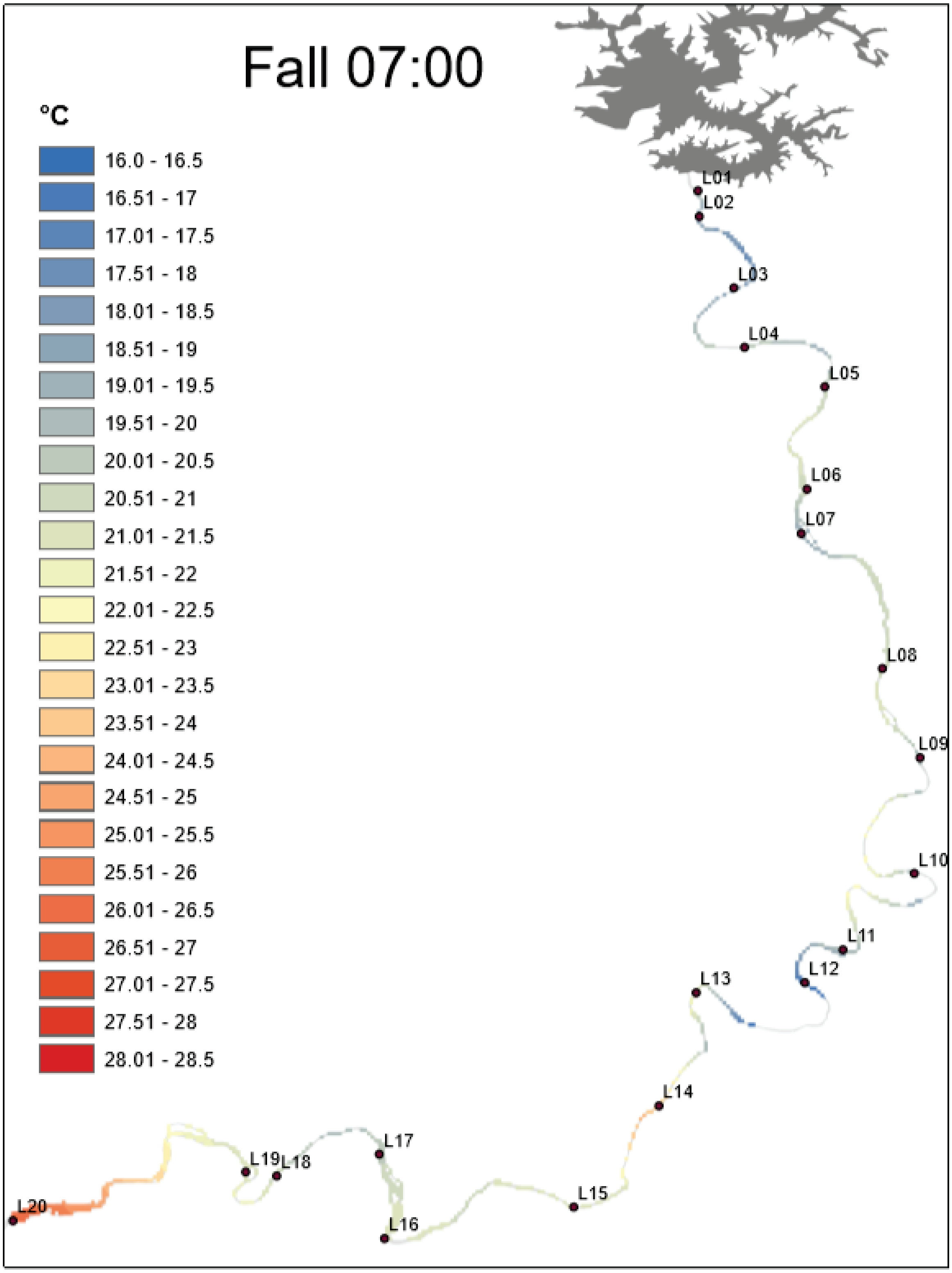
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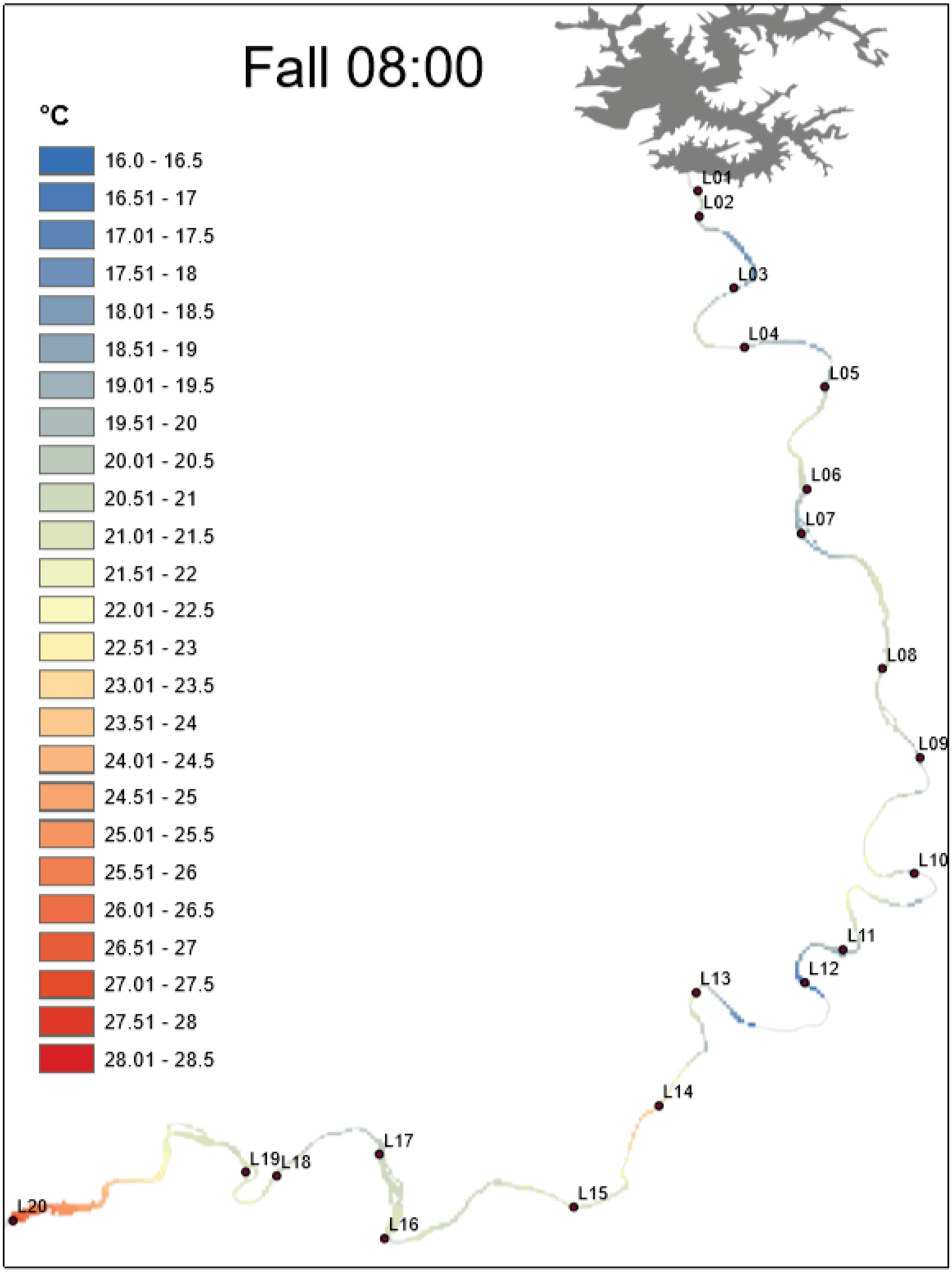
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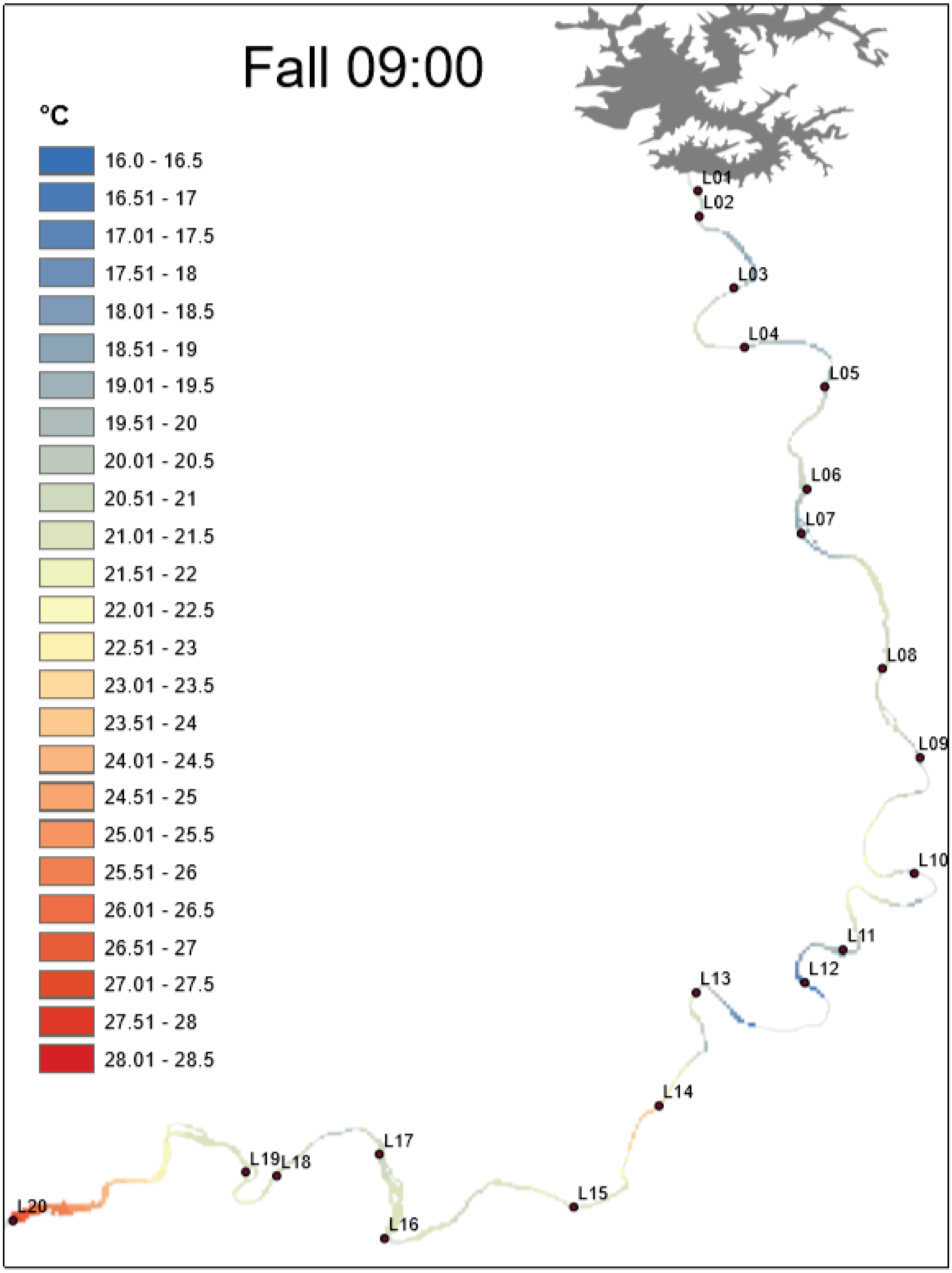
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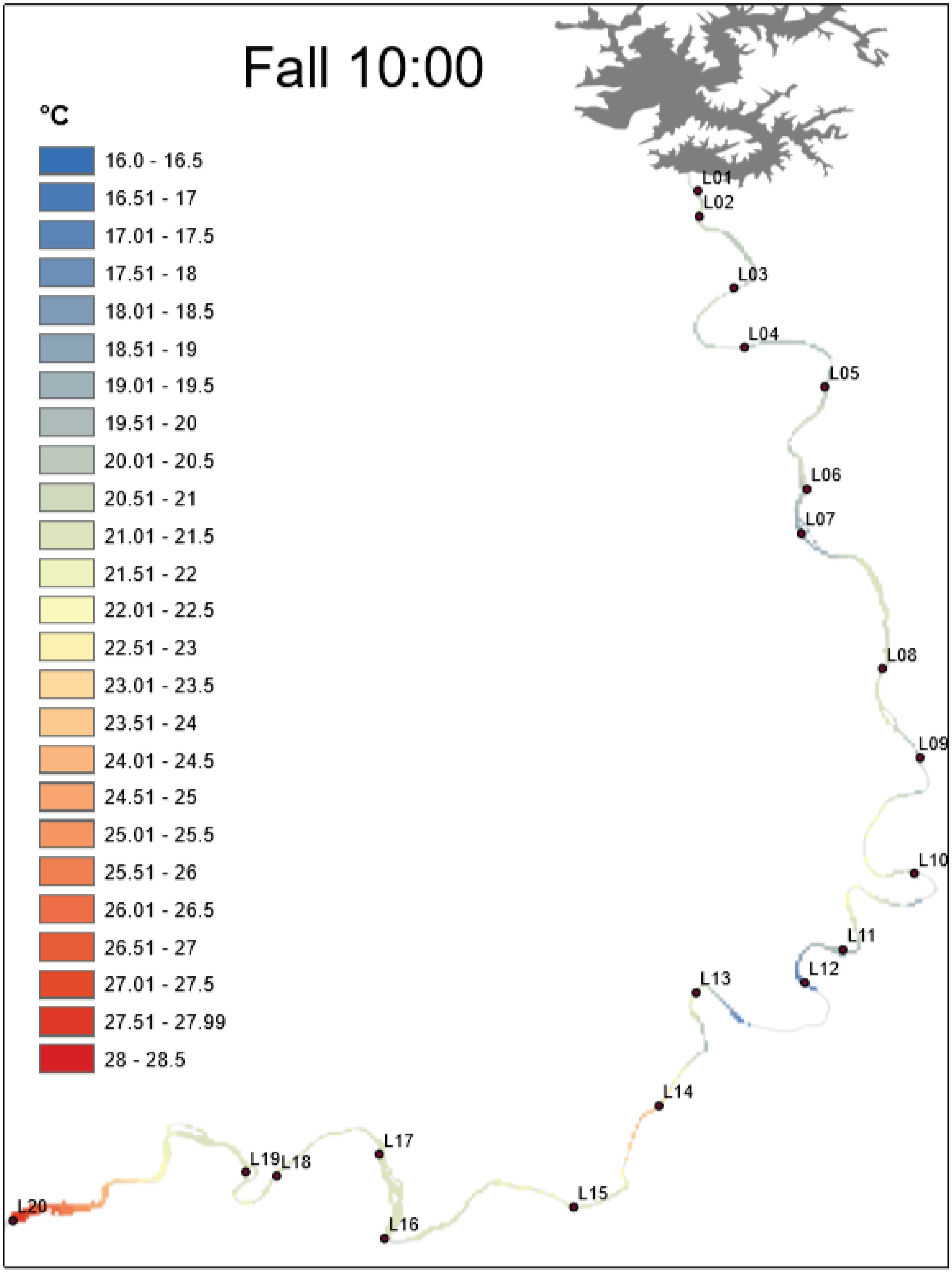
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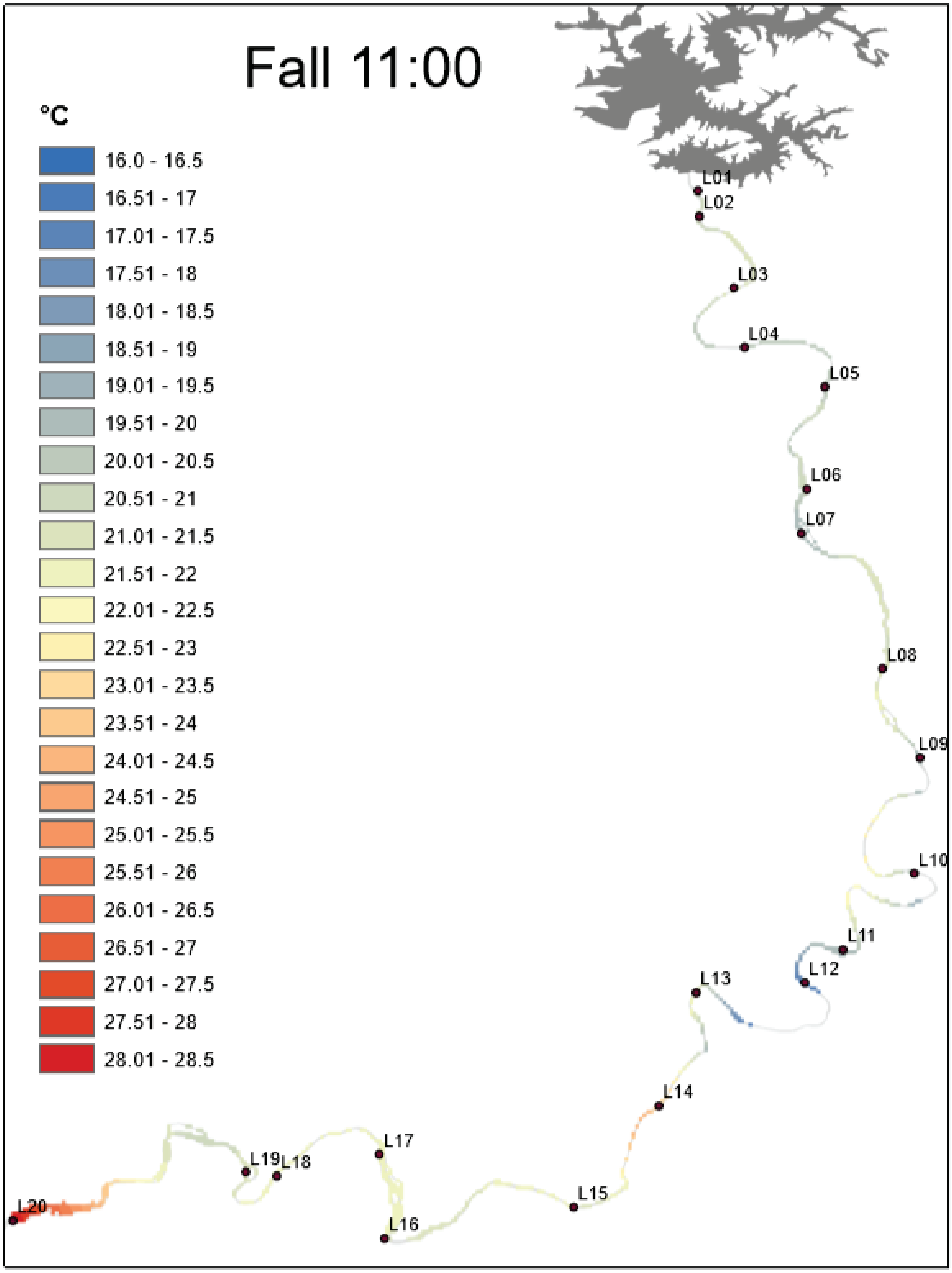
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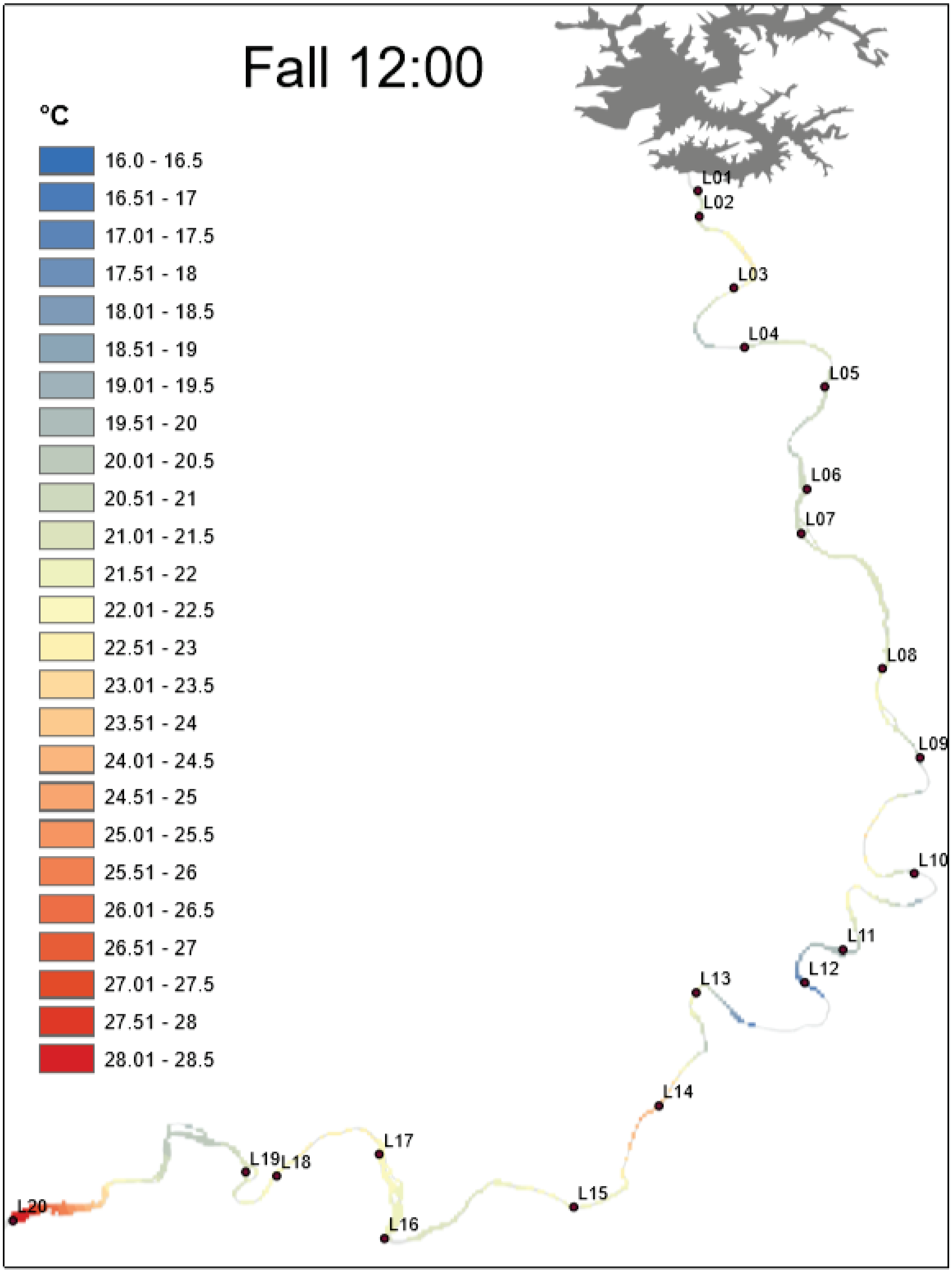
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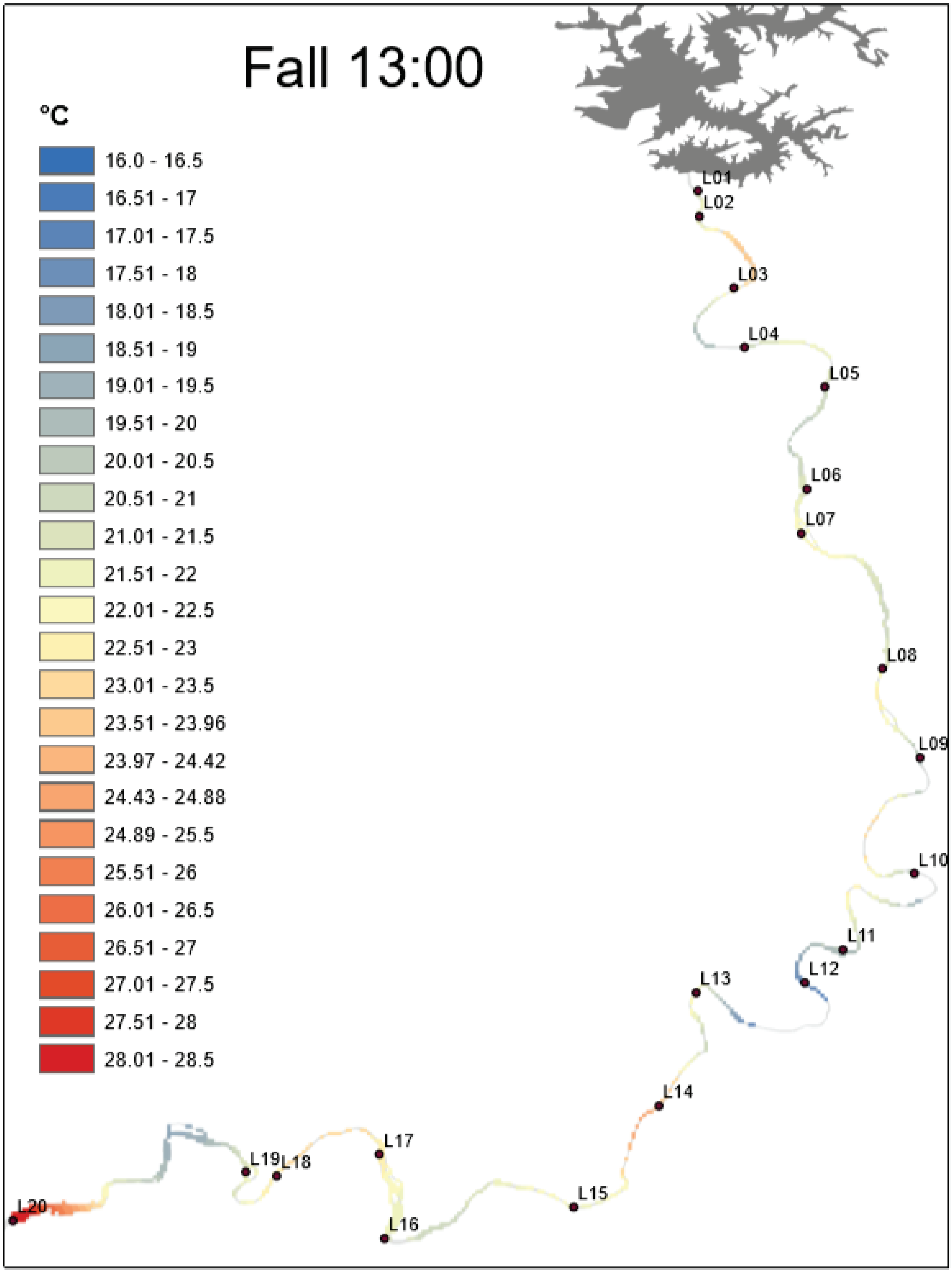
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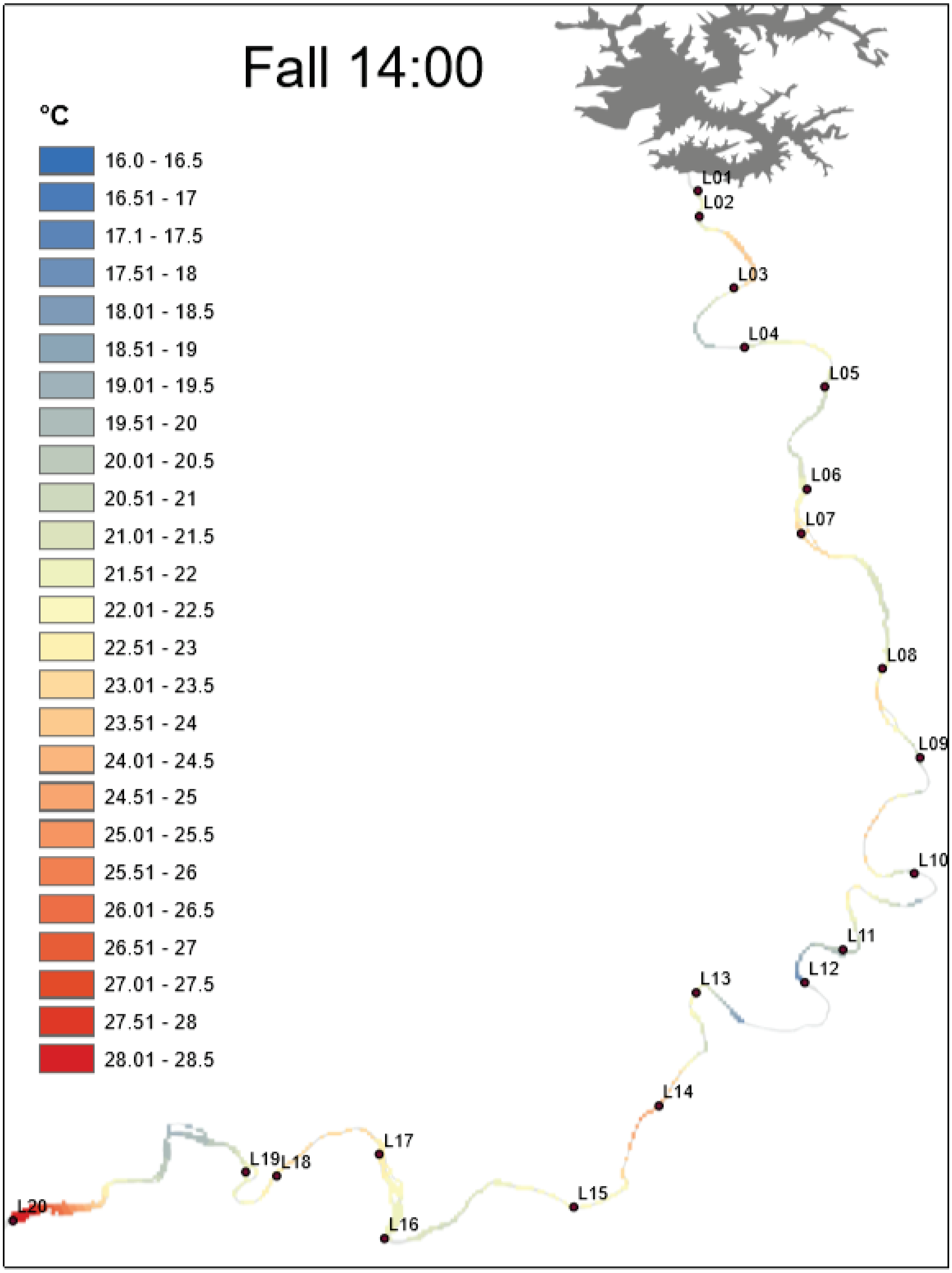
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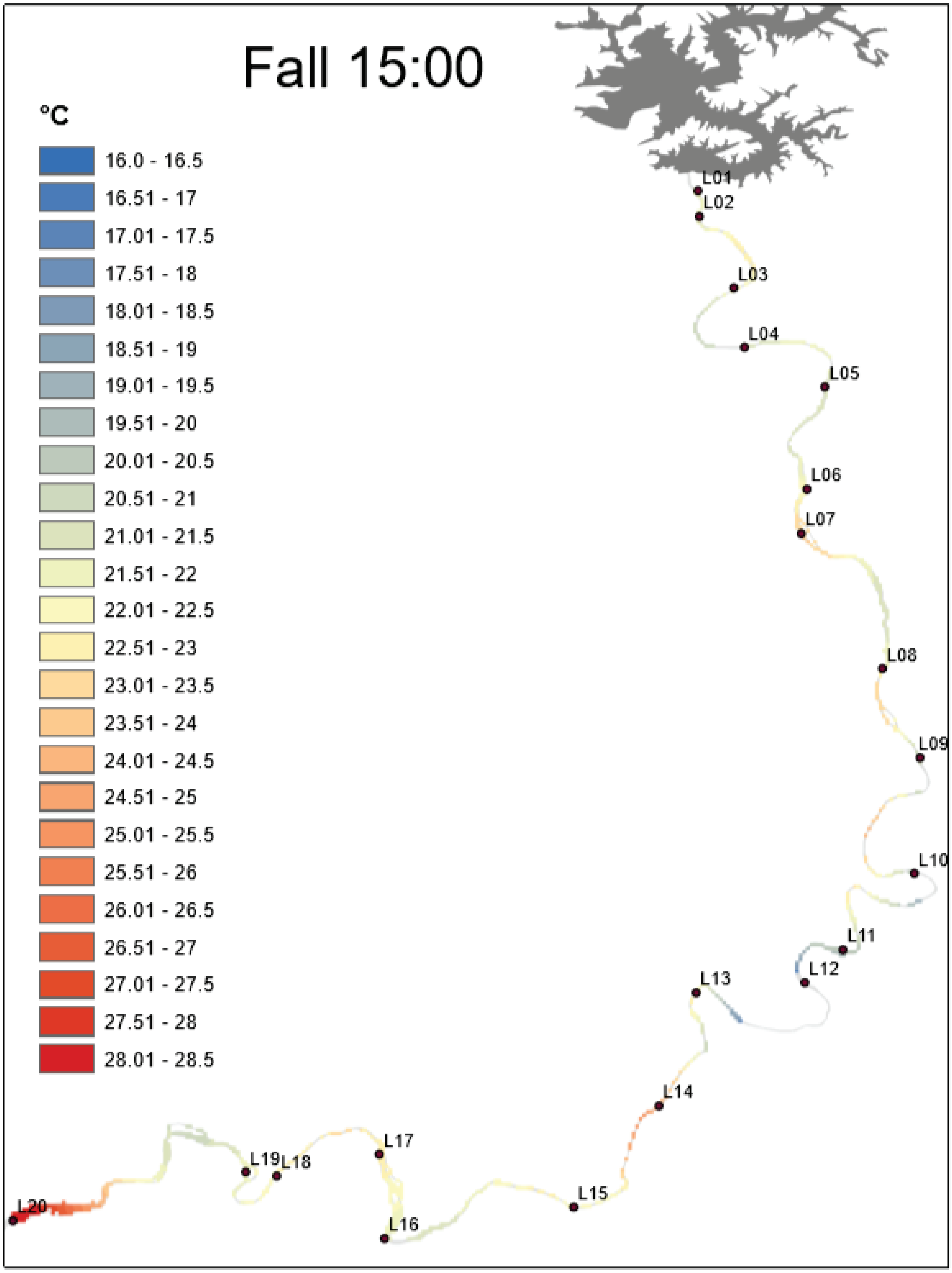
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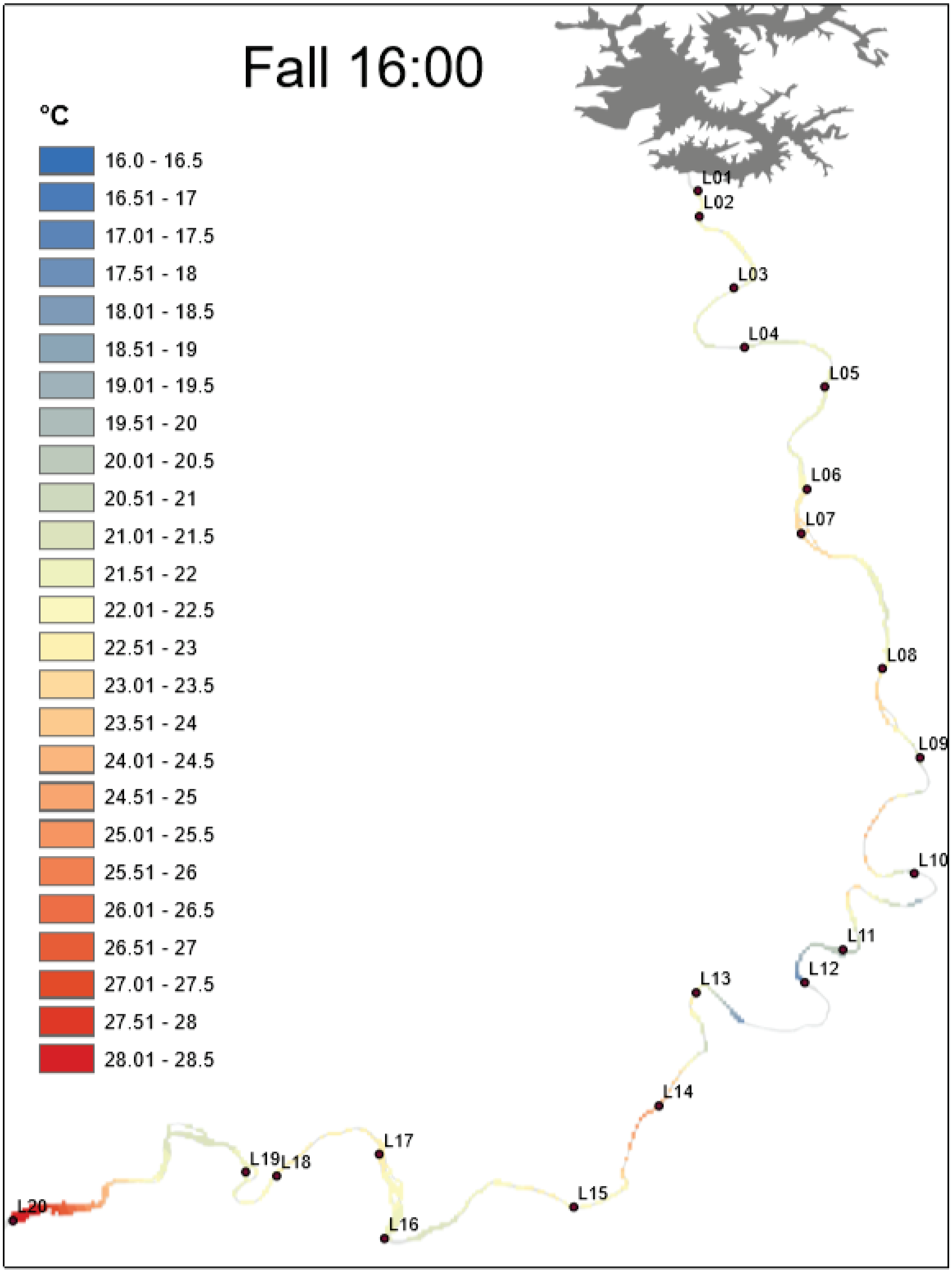

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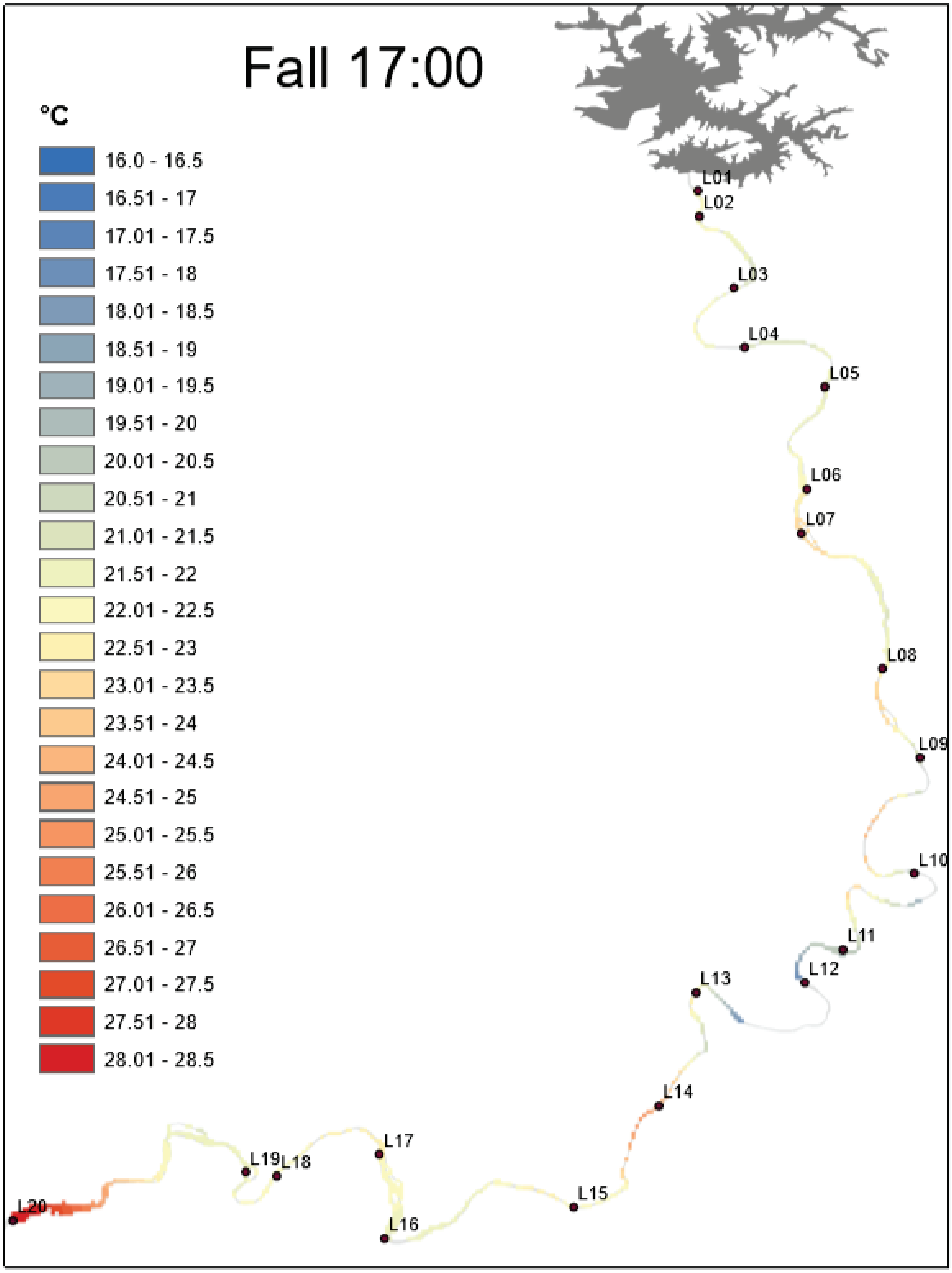

Fall 17:00
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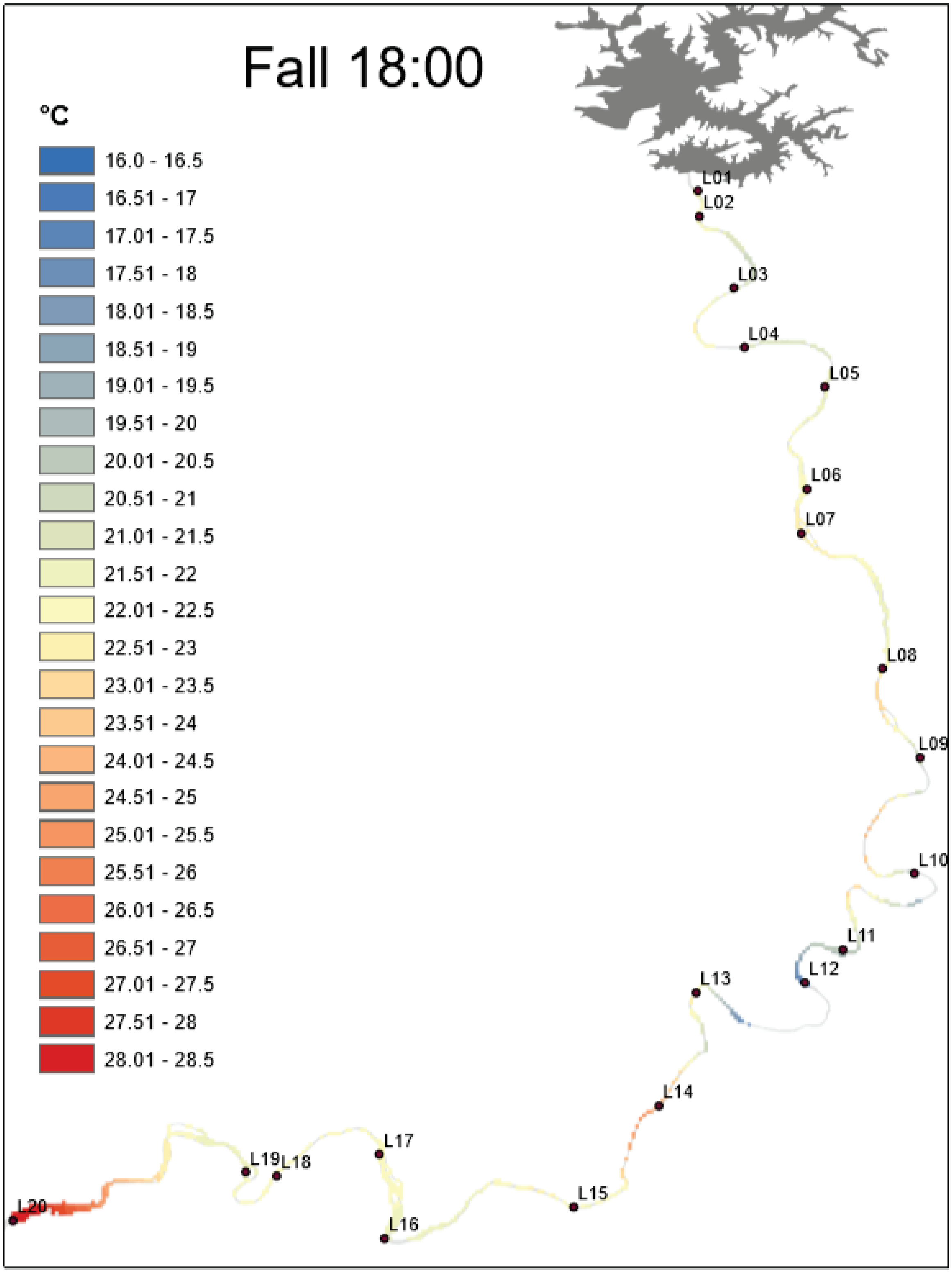
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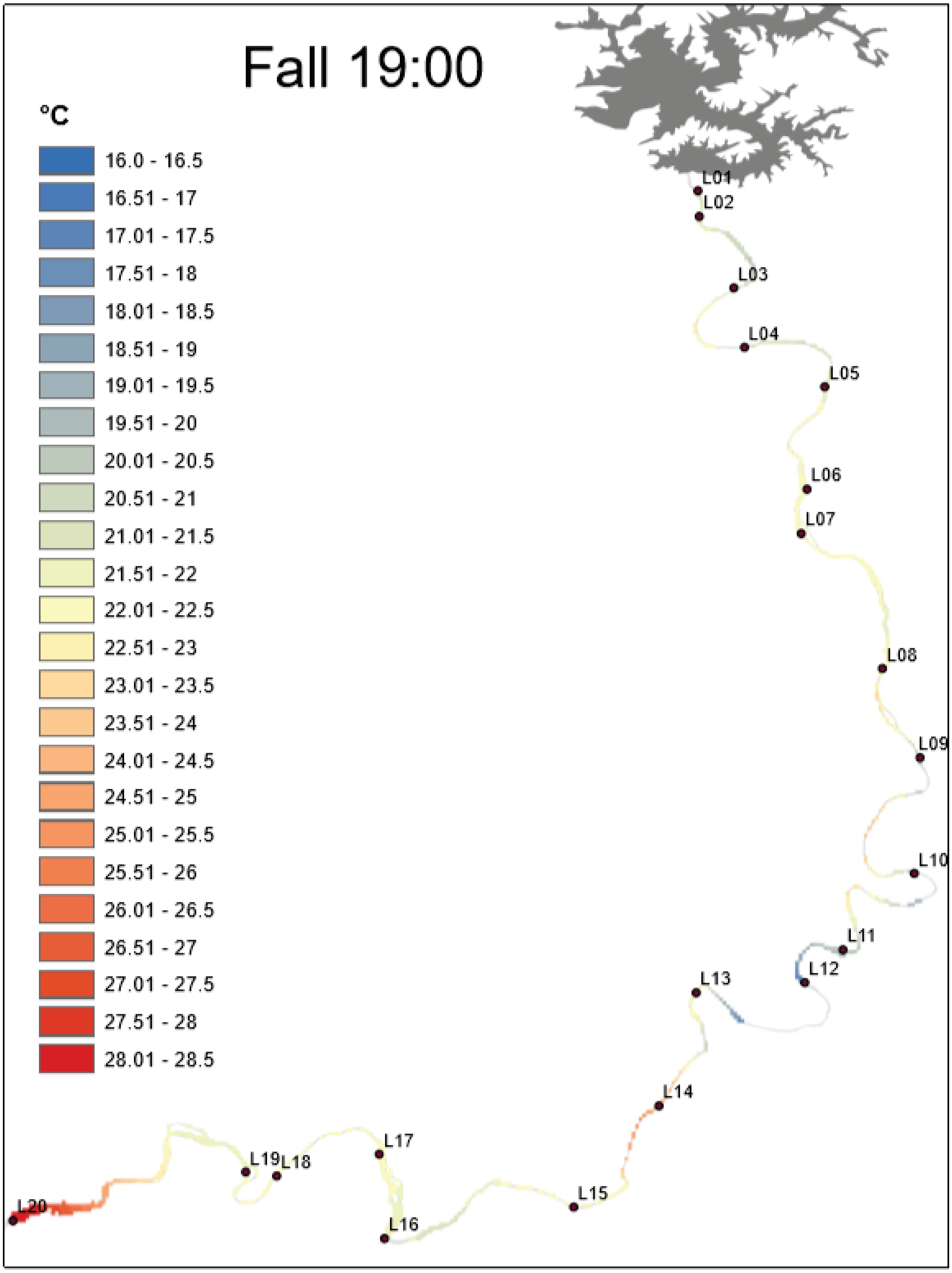
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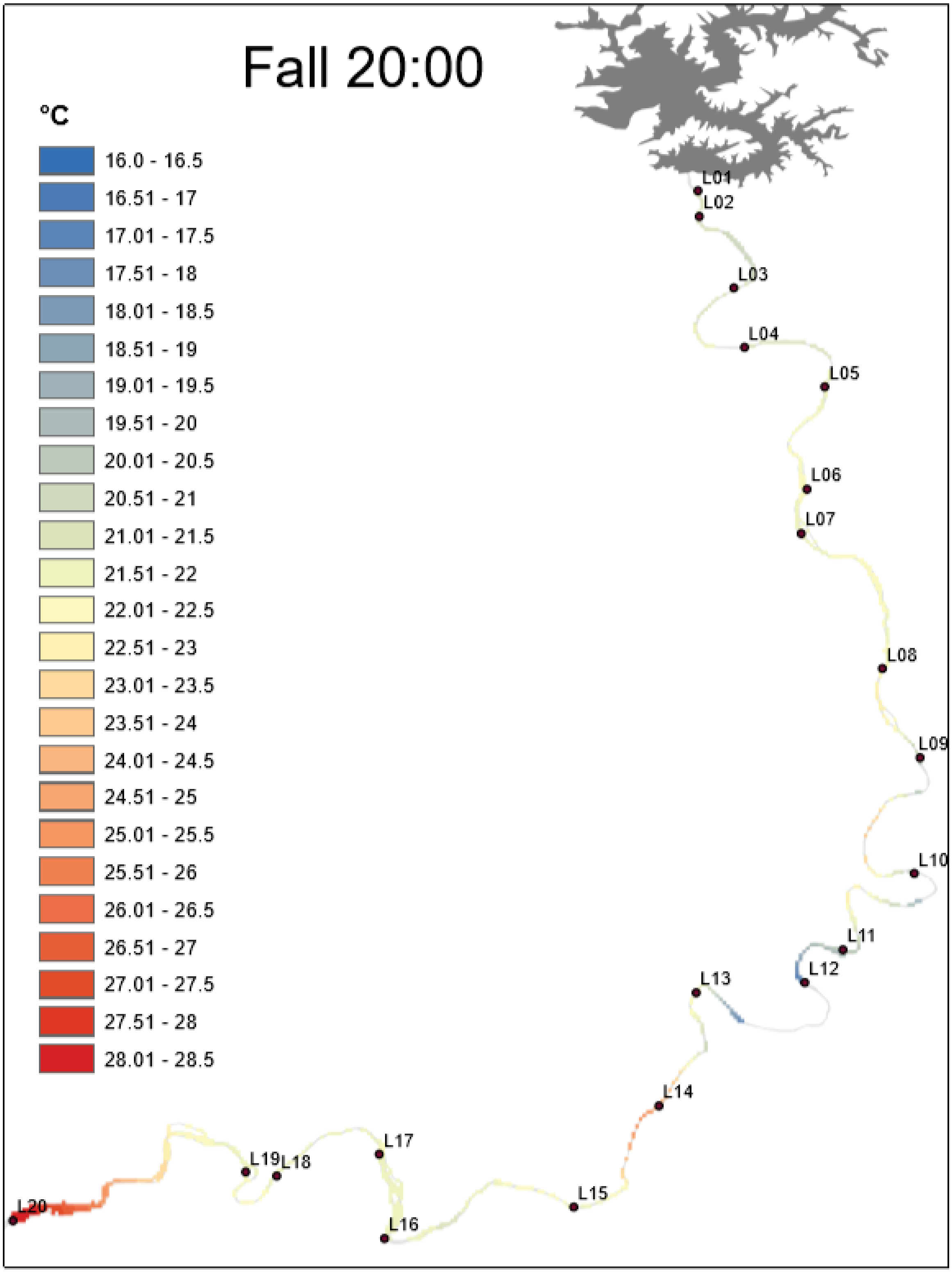

Fall 20:00
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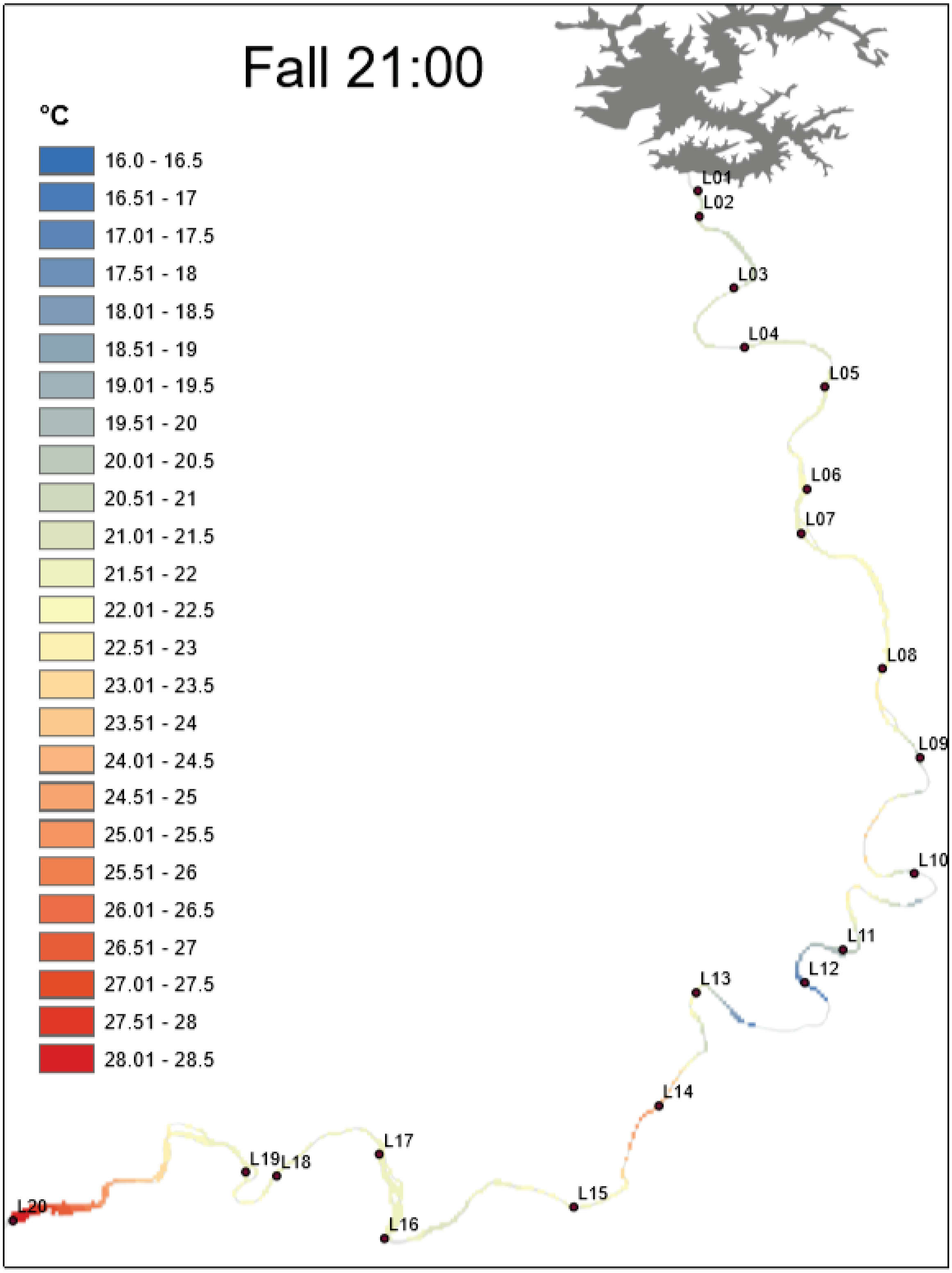

Fall 21:00
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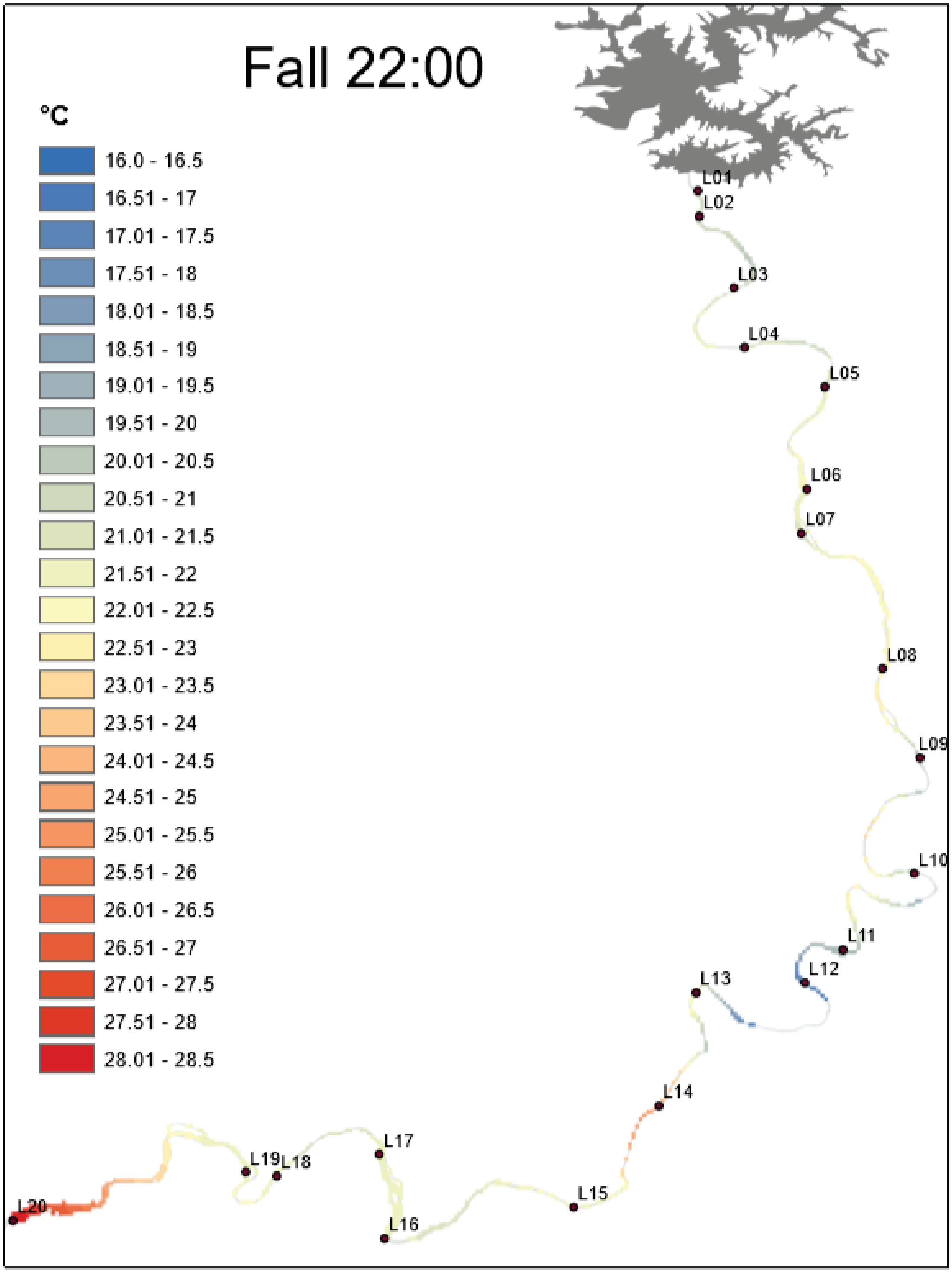

Fall 22:00
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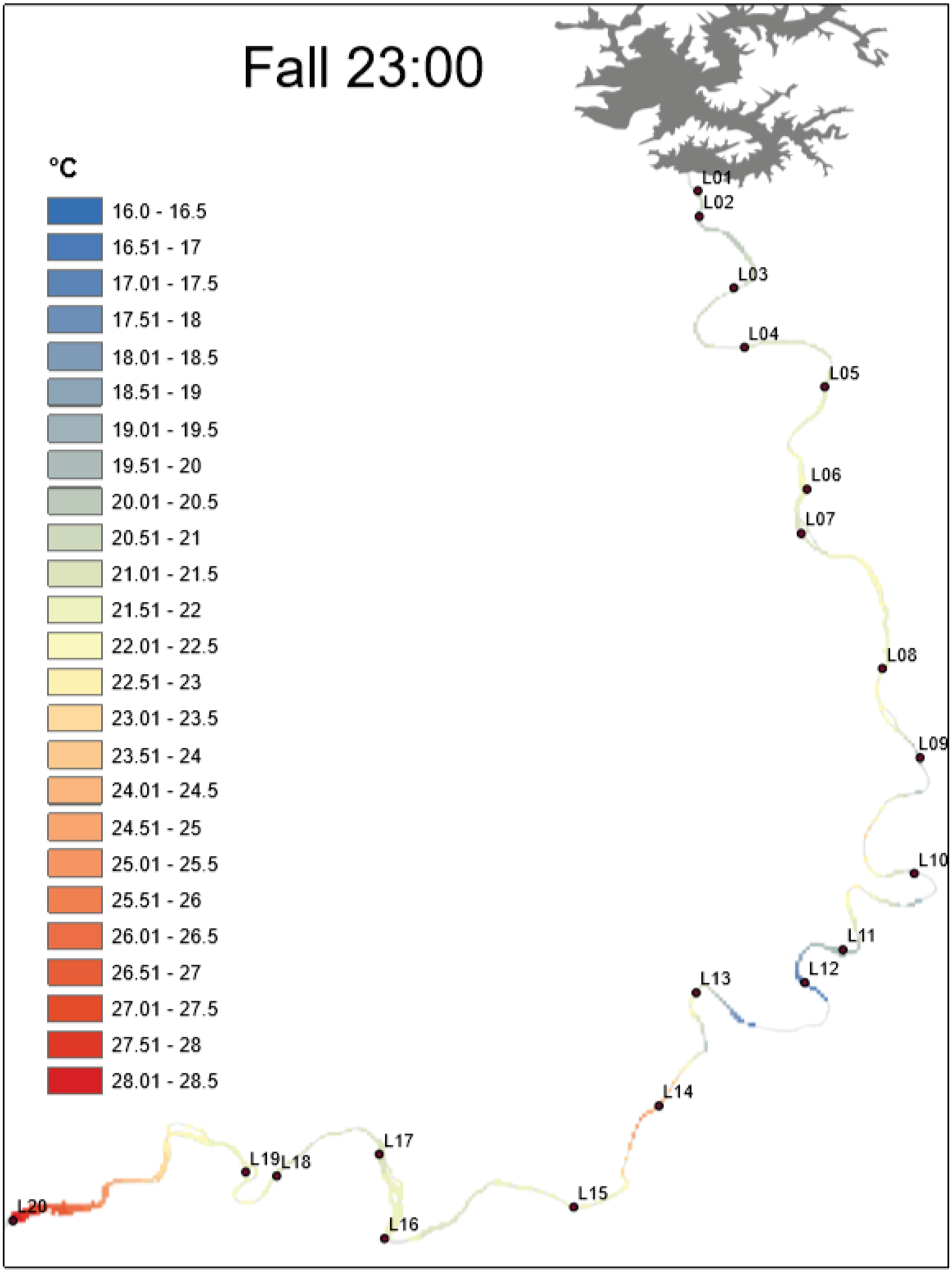
Fall 23:00
°C
16.0 - 16.5
16.51 - 17
17.01 - 17.5
17.51 - 18
18.01 - 18.5
18.51 - 19
19.01 - 19.5
19.51 - 20
20.01 - 20.5
20.51 - 21
21.01 - 21.5
21.51 - 22
22.01 - 22.5
22.51 - 23
23.01 - 23.5
23.51 - 24
24.01 - 24.5
24.51 - 25
25.01 - 25.5
25.51 - 26
26.01 - 26.5
26.51 - 27
27.01 - 27.5
27.51 - 28
28.01 - 28.5
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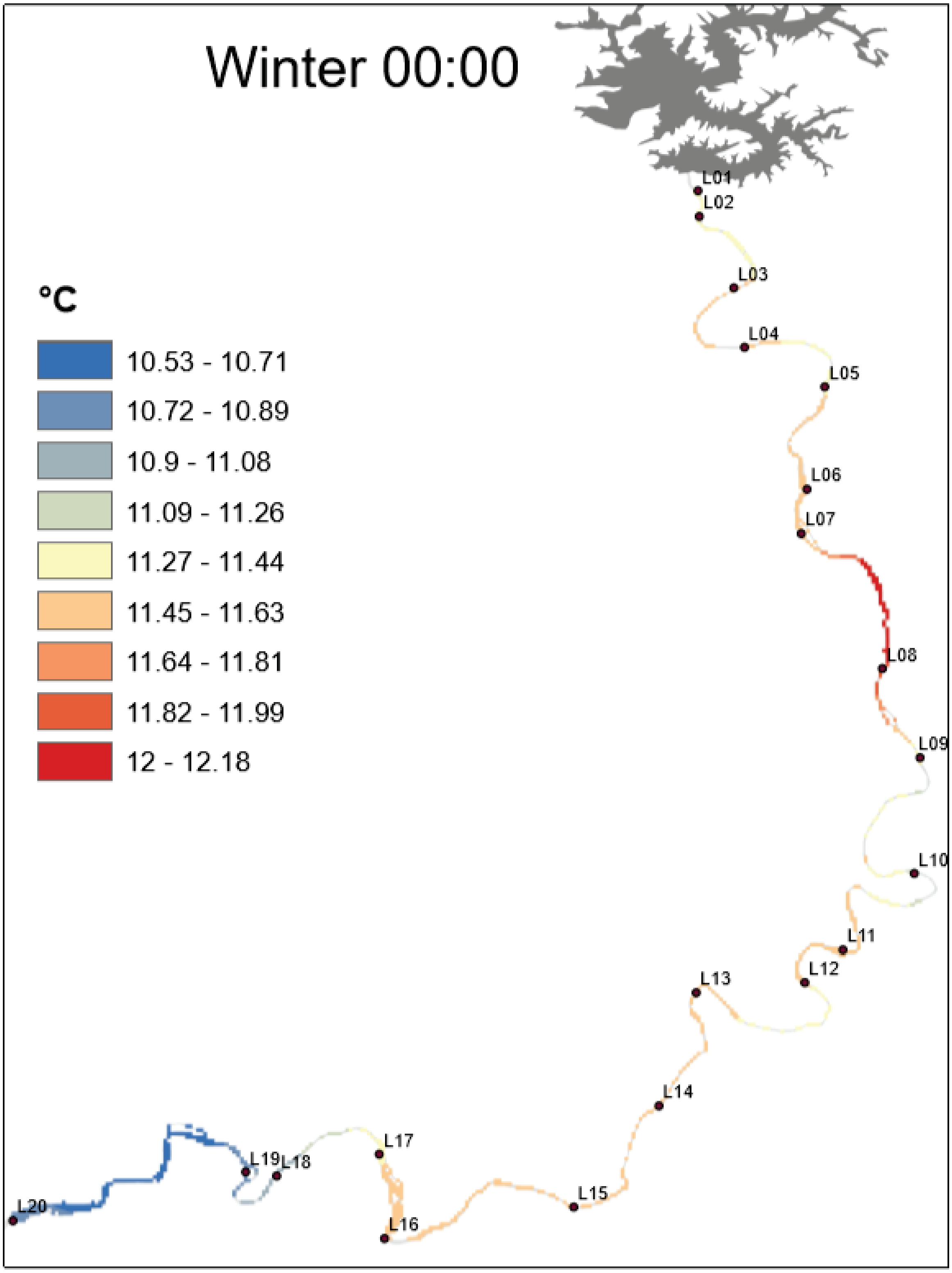
Winter 00:00
°C
10.53 - 10.71
10.72 - 10.89
10.9 - 11.08
11.09 - 11.26
11.27 - 11.44
11.45 - 11.63
11.64 - 11.81
11.82 - 11.99
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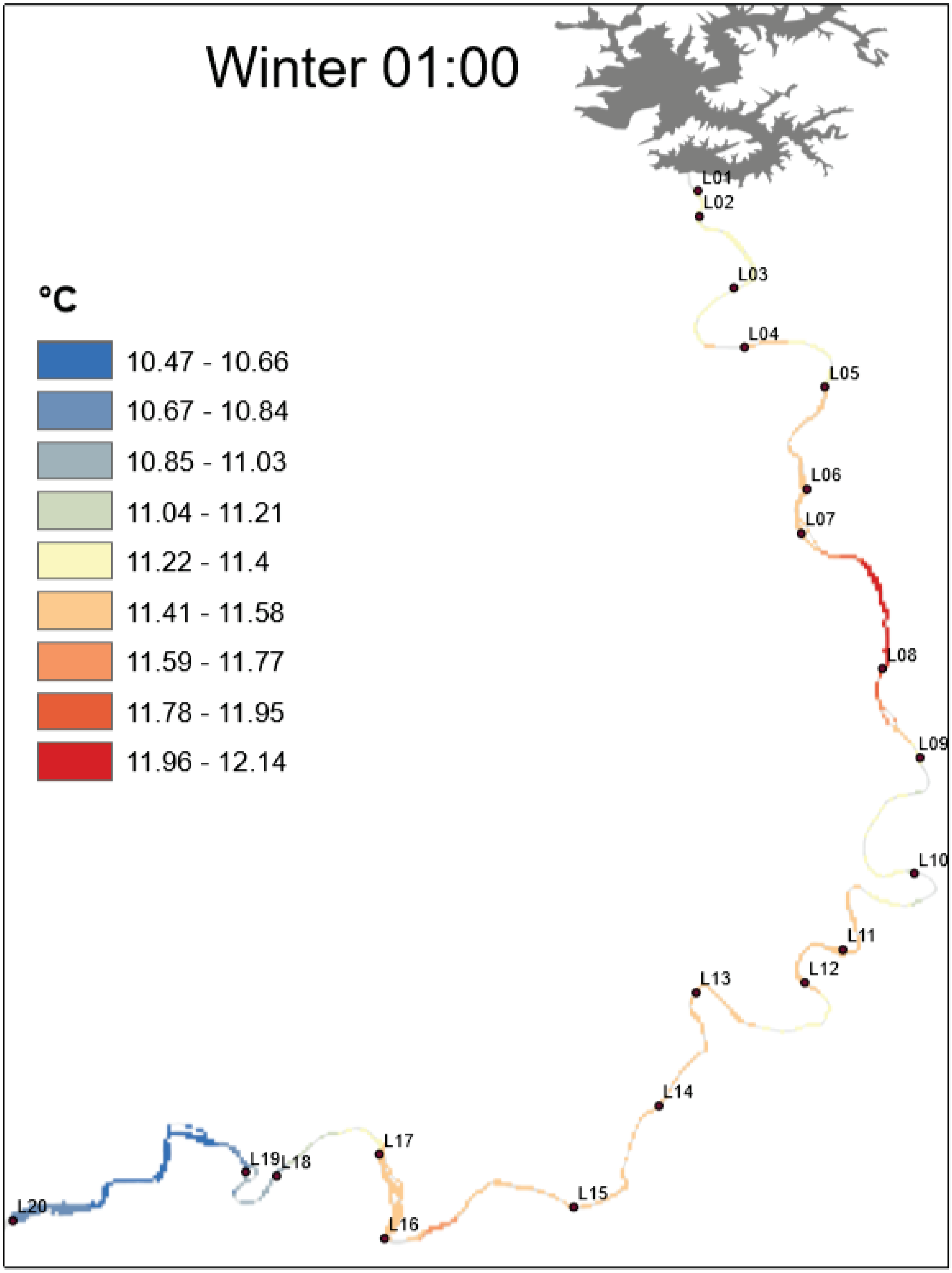
Winter 01:00
°C
10.47 - 10.66
10.67 - 10.84
10.85 - 11.03
11.04 - 11.21
11.22 - 11.4
11.41 - 11.58
11.59 - 11.77
11.78 - 11.95
11.96 - 12.14
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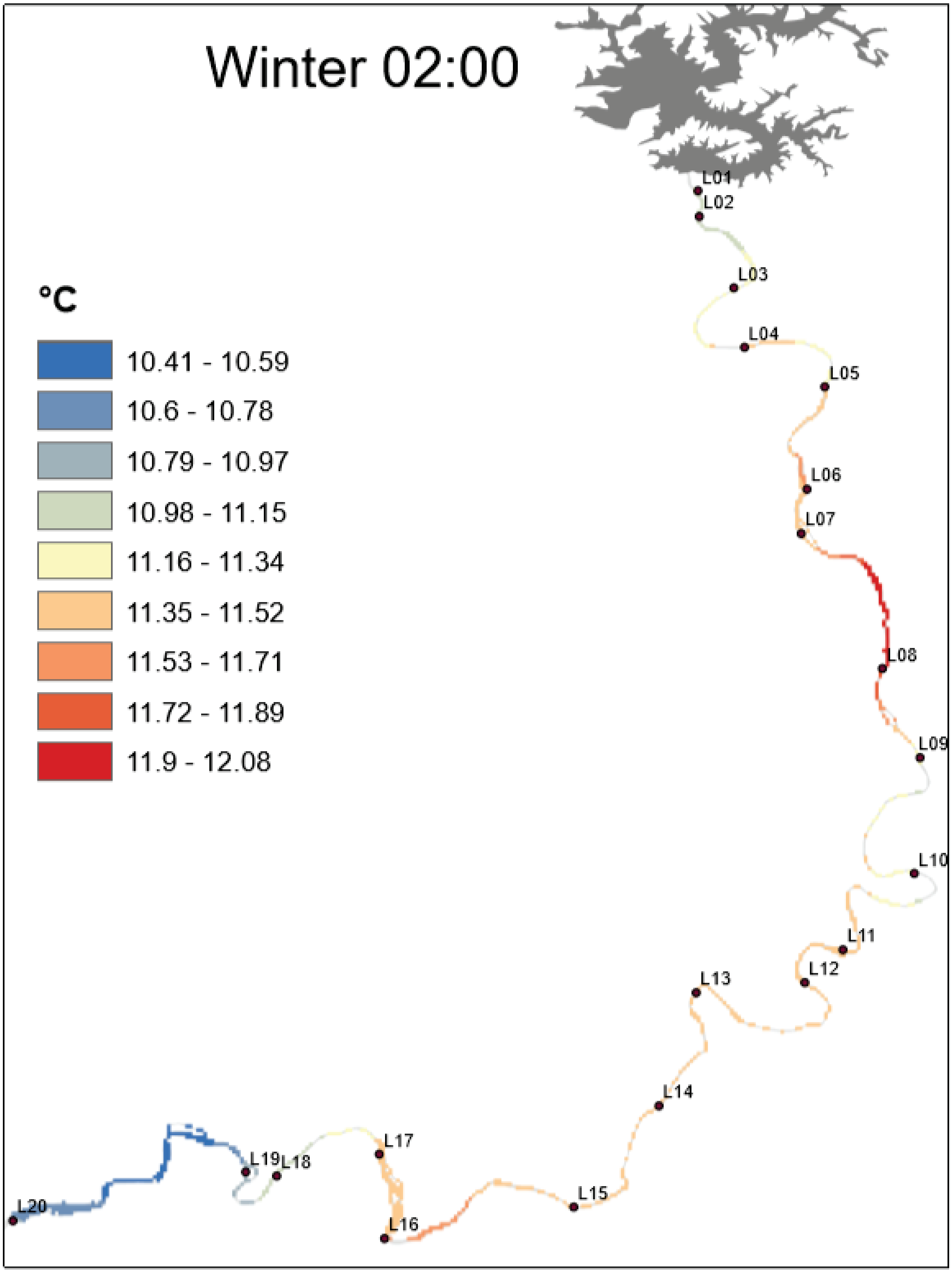
Winter 02:00
°C
10.41 - 10.59
10.6 - 10.78
10.79 - 10.97
10.98 - 11.15
11.16 - 11.34
11.35 - 11.52
11.53 - 11.71
11.72 - 11.89
11.9 - 12.08
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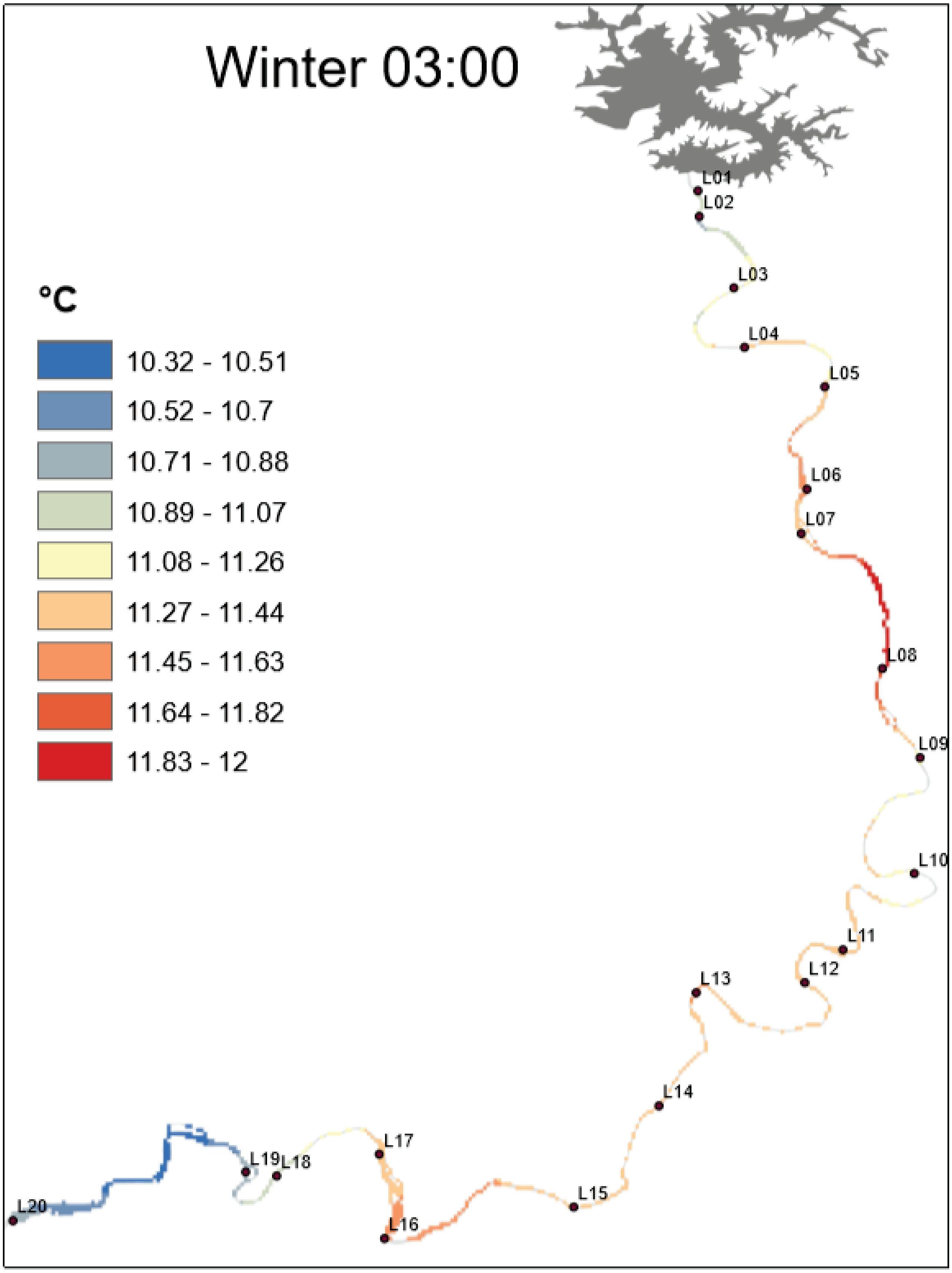

Winter 03:00
°C
10.32 - 10.51
10.52 - 10.7
10.71 - 10.88
10.89 - 11.07
11.08 - 11.26
11.27 - 11.44
11.45 - 11.63
11.64 - 11.82
11.83 - 12
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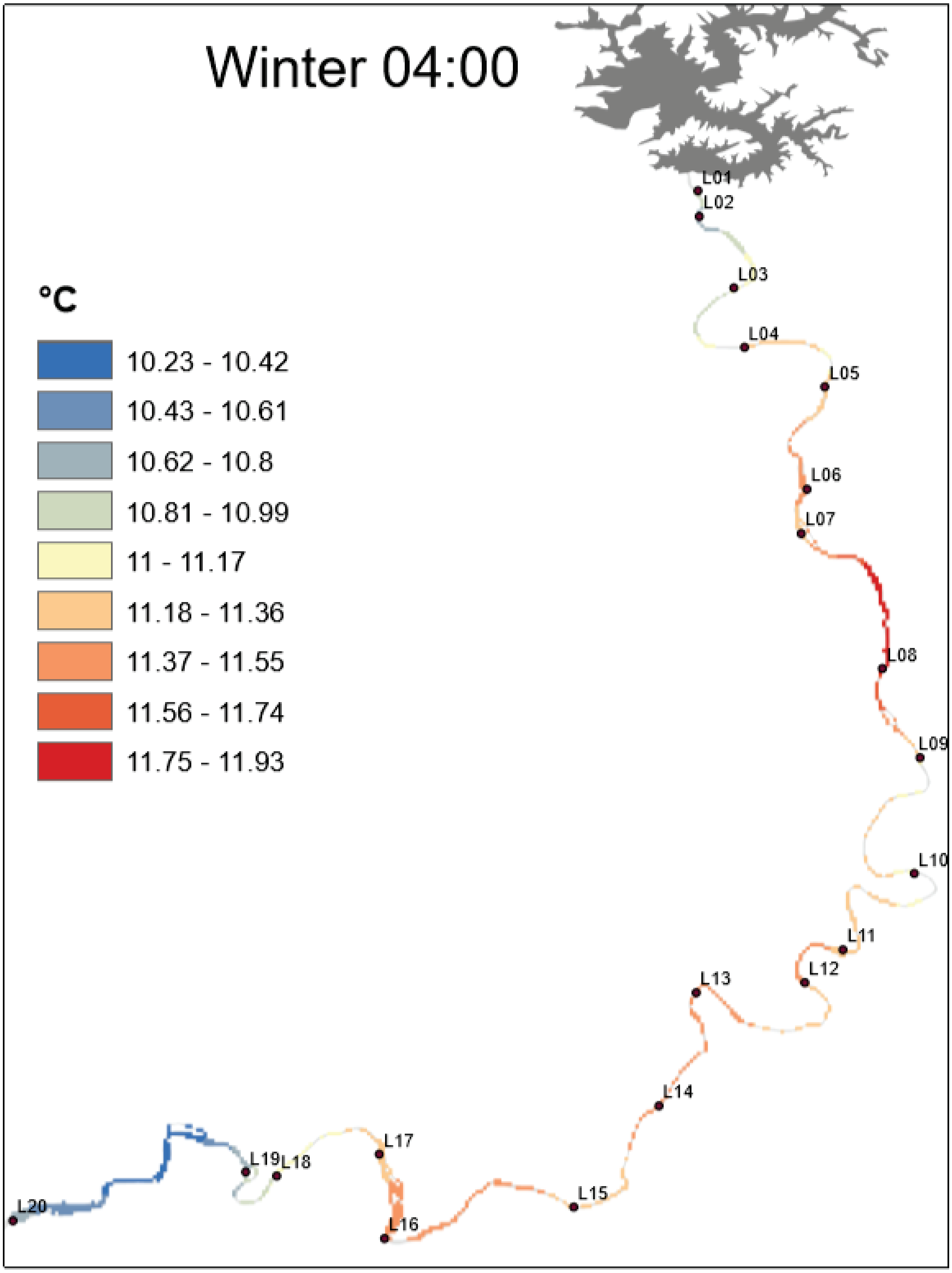
Winter 04:00
°C
10.23 - 10.42
10.43 - 10.61
10.62 - 10.8
10.81 - 10.99
11 - 11.17
11.18 - 11.36
11.37 - 11.55
11.56 - 11.74
11.75 - 11.93
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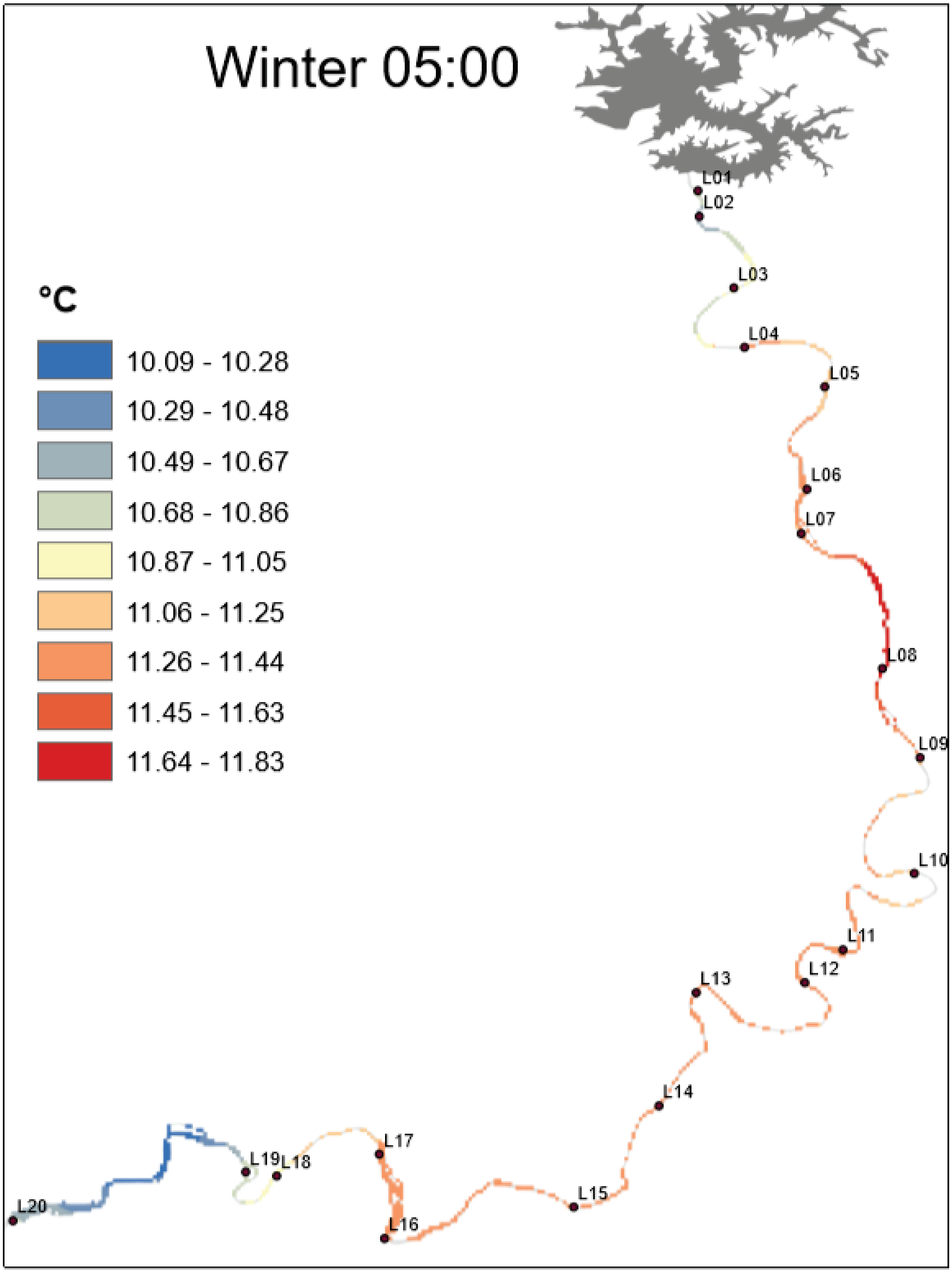
Winter 05:00
°C
10.09 - 10.28
10.29 - 10.48
10.49 - 10.67
10.68 - 10.86
10.87 - 11.05
11.06 - 11.25
11.26 - 11.44
11.45 - 11.63
11.64 - 11.83
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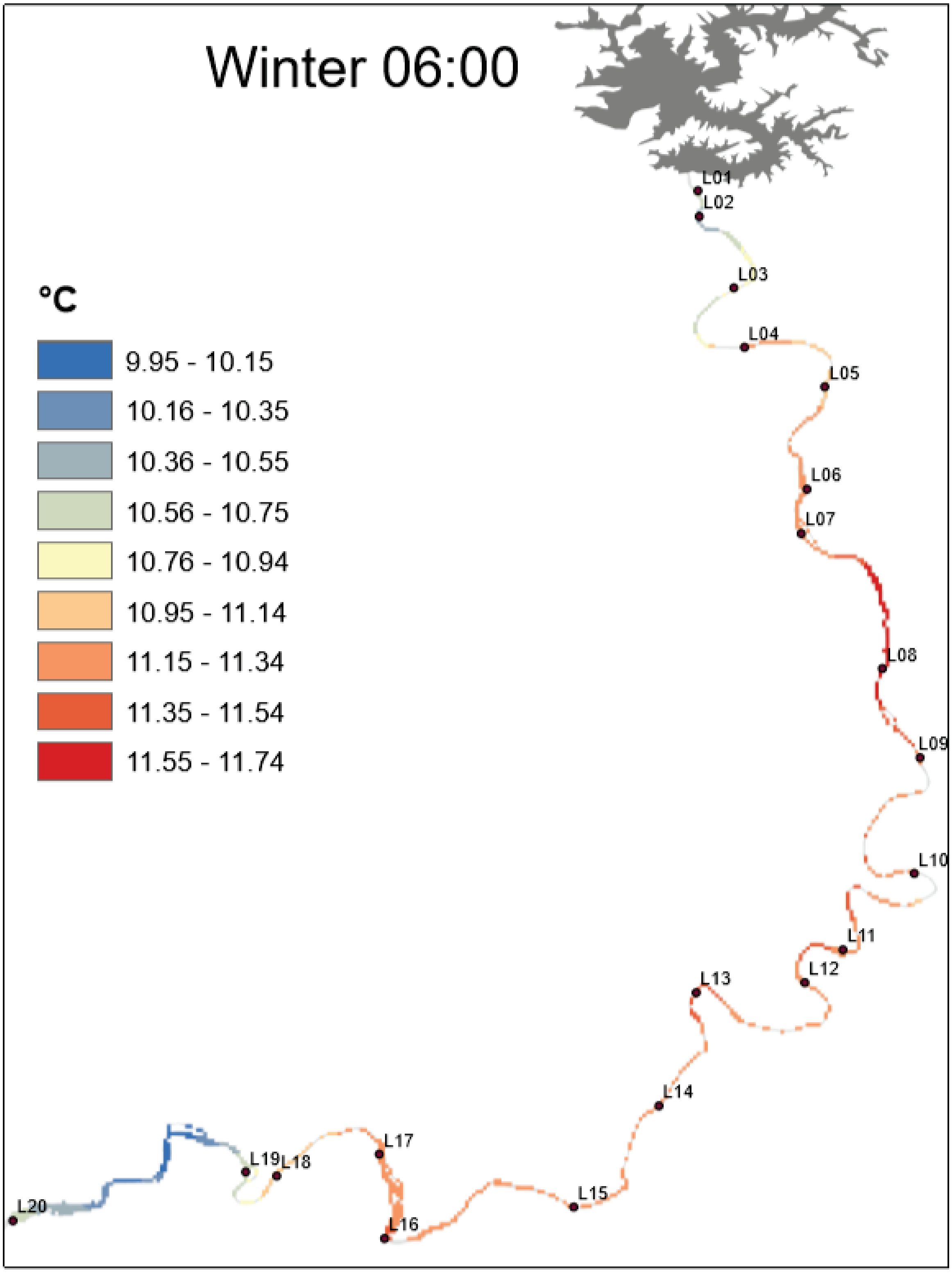
Winter 06:00
°C
9.95 - 10.15
10.16 - 10.35
10.36 - 10.55
10.56 - 10.75
10.76 - 10.94
10.95 - 11.14
11.15 - 11.34
11.35 - 11.54
11.55 - 11.74
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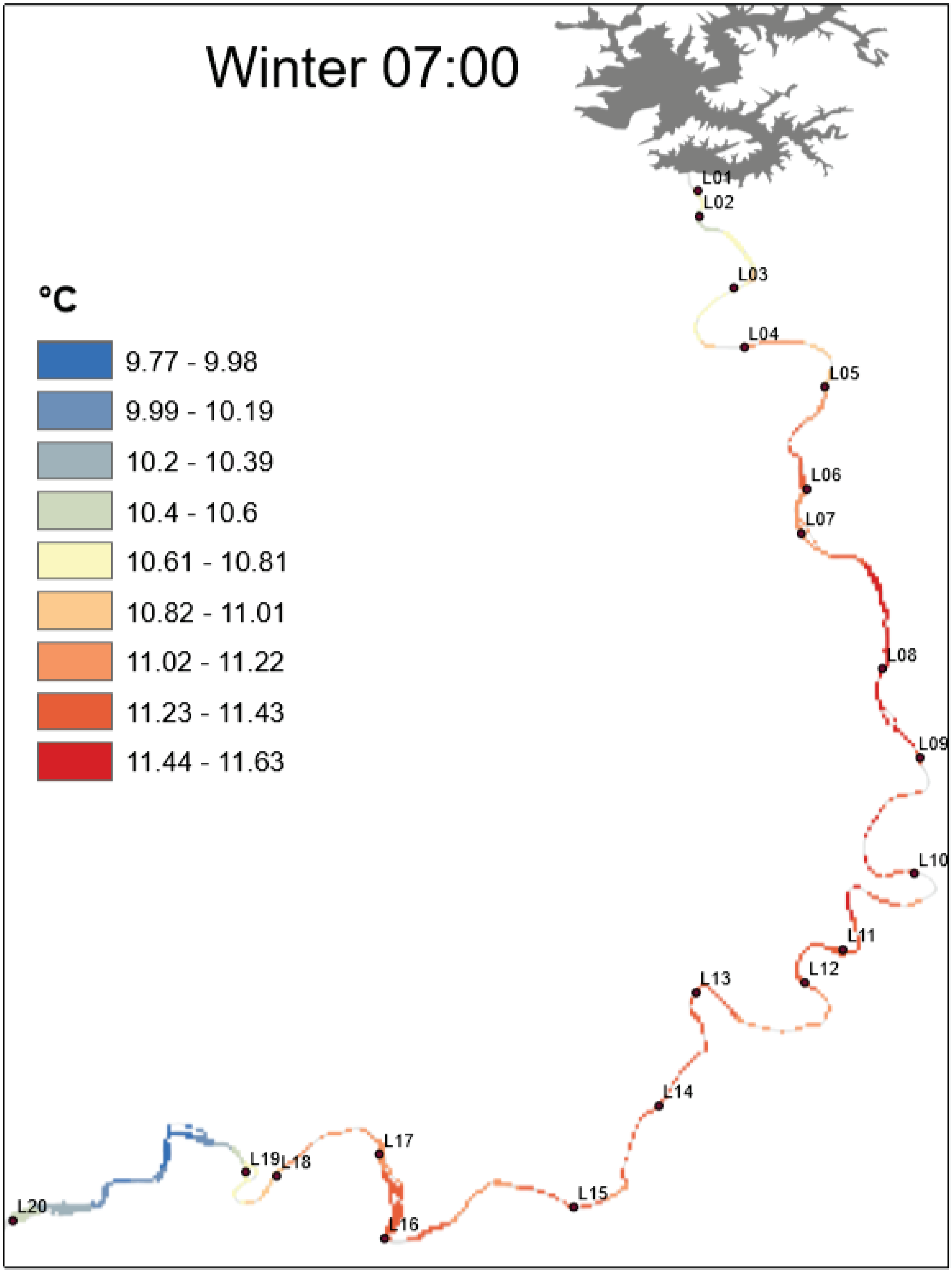
Winter 07:00
°C
9.77 - 9.98
9.99 - 10.19
10.2 - 10.39
10.4 - 10.6
10.61 - 10.81
10.82 - 11.01
11.02 - 11.22
11.23 - 11.43
11.44 - 11.63
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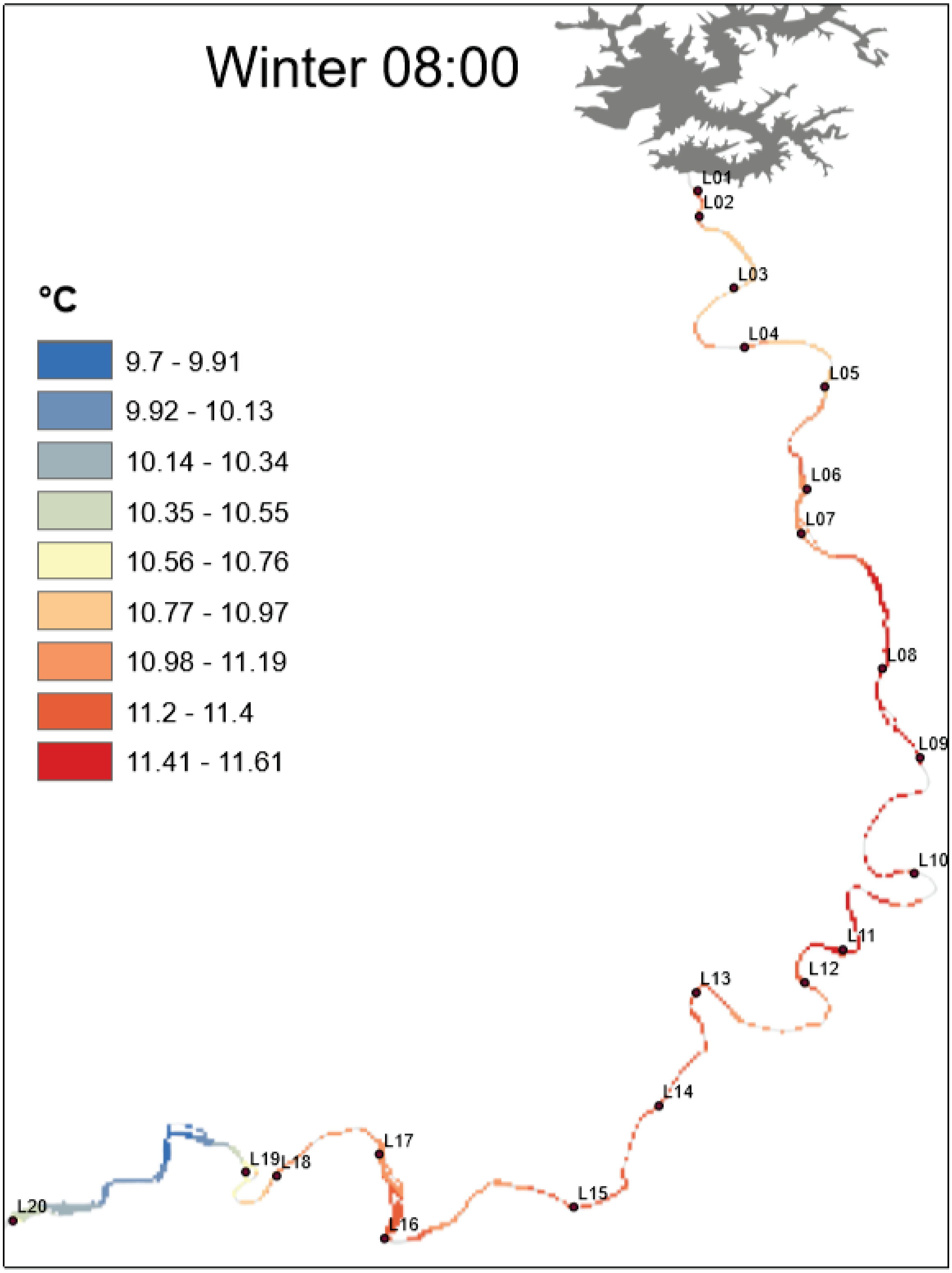
Winter 08:00
°C
9.7 - 9.91
9.92 - 10.13
10.14 - 10.34
10.35 - 10.55
10.56 - 10.76
10.77 - 10.97
10.98 - 11.19
11.2 - 11.4
11.41 - 11.61
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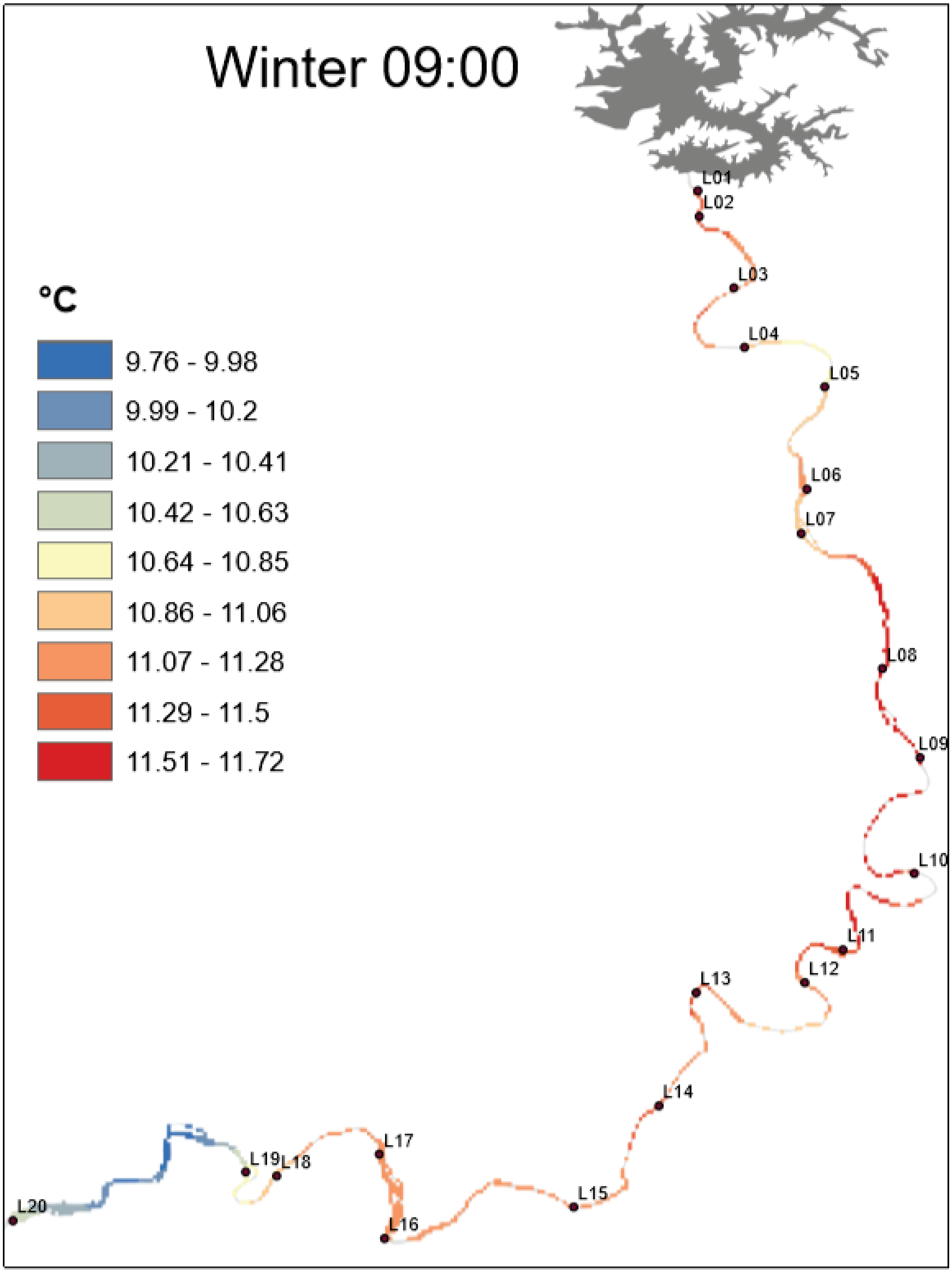
Winter 09:00
°C
9.76 - 9.98
9.99 - 10.2
10.21 - 10.41
10.42 - 10.63
10.64 - 10.85
10.86 - 11.06
11.07 - 11.28
11.29 - 11.5
11.51 - 11.72
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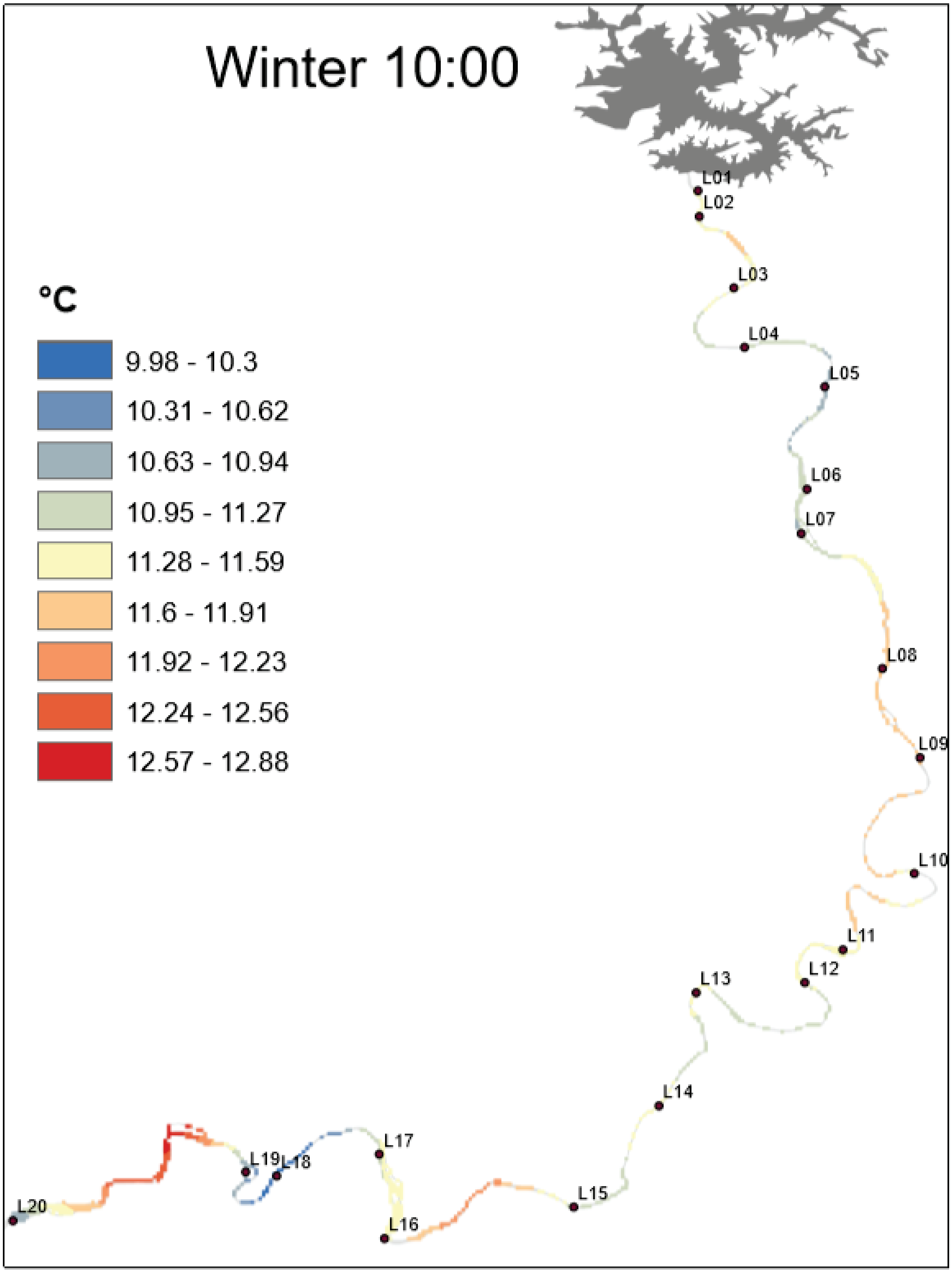

Winter 10:00
°C
9.98 - 10.3
10.31 - 10.62
10.63 - 10.94
10.95 - 11.27
11.28 - 11.59
11.6 - 11.91
11.92 - 12.23
12.24 - 12.56
12.57 - 12.88
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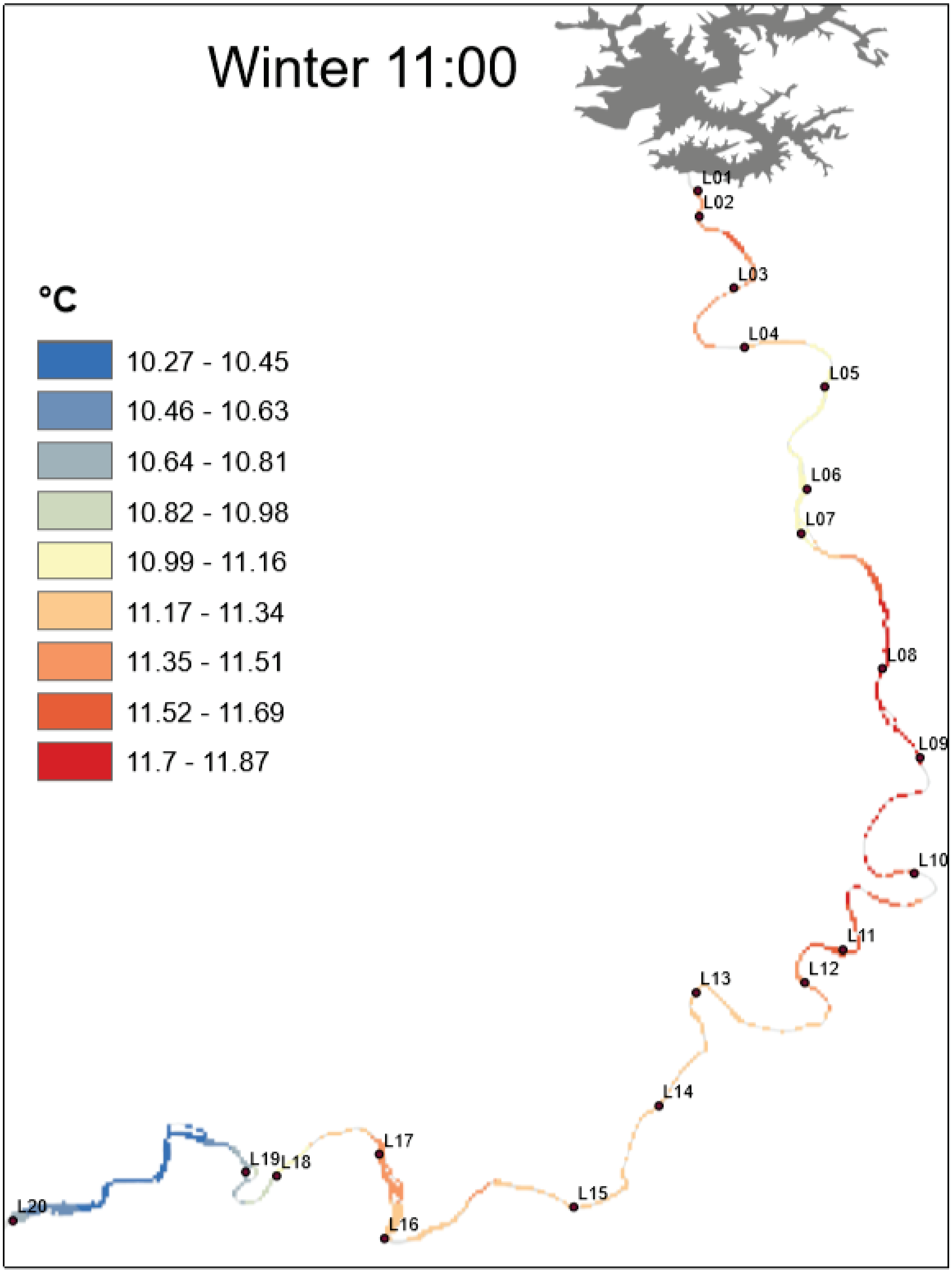
Winter 11:00
°C
10.27 - 10.45
10.46 - 10.63
10.64 - 10.81
10.82 - 10.98
10.99 - 11.16
11.17 - 11.34
11.35 - 11.51
11.52 - 11.69
11.7 - 11.87
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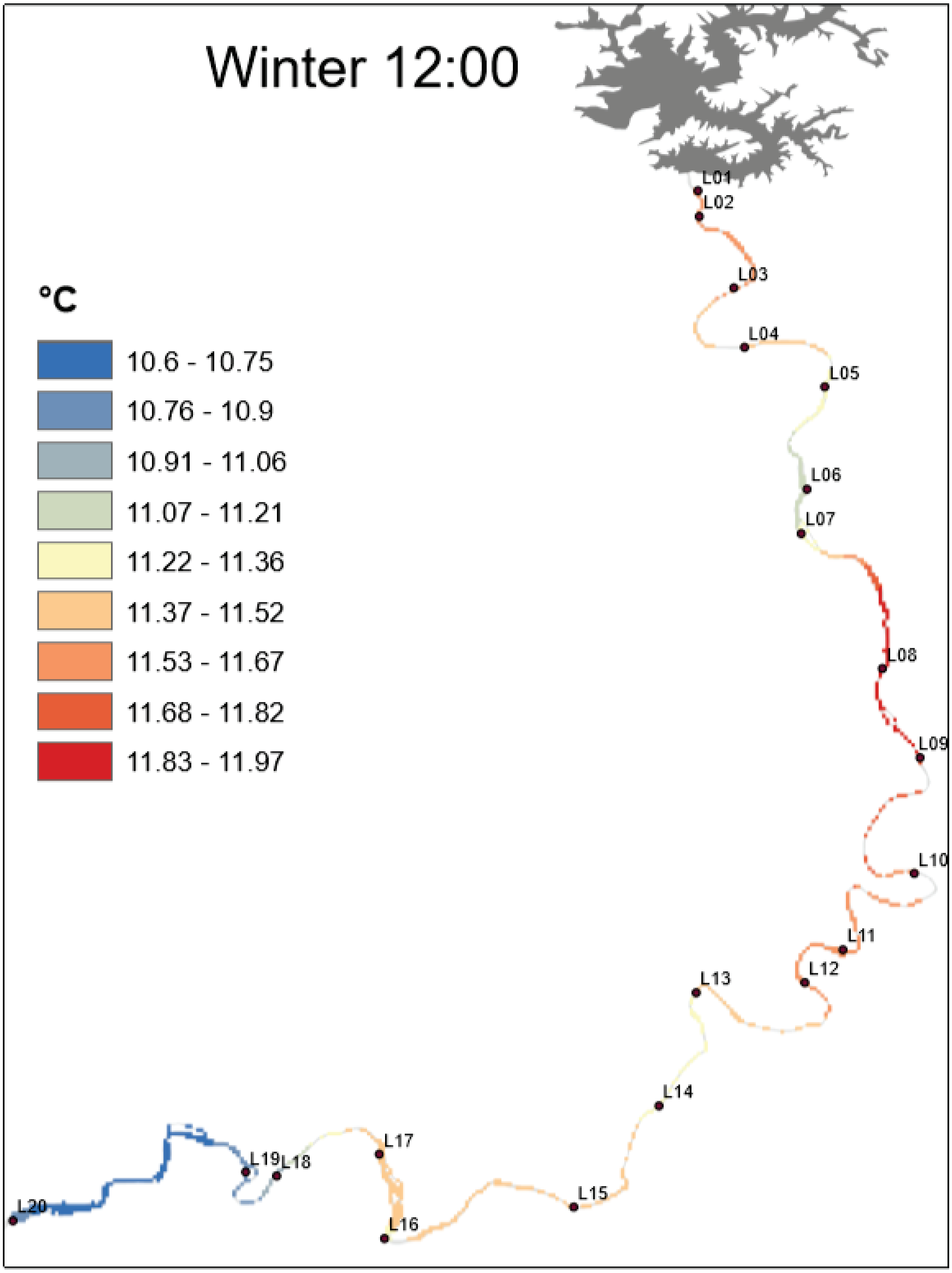
Winter 12:00
°C
10.6 - 10.75
10.76 - 10.9
10.91 - 11.06
11.07 - 11.21
11.22 - 11.36
11.37 - 11.52
11.53 - 11.67
11.68 - 11.82
11.83 - 11.97
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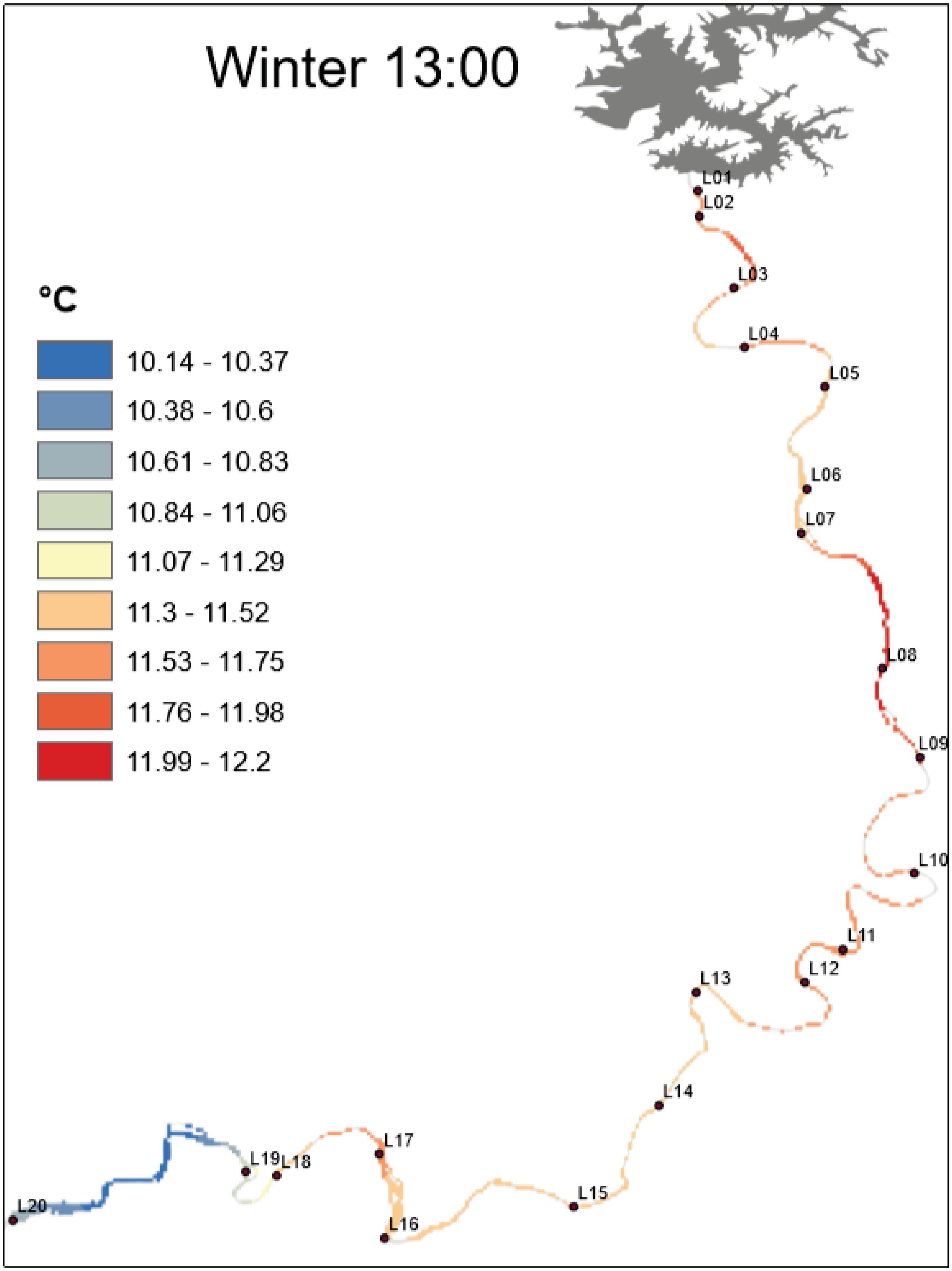
Winter 13:00
°C
10.14 - 10.37
10.38 - 10.6
10.61 - 10.83
10.84 - 11.06
11.07 - 11.29
11.3 - 11.52
11.53 - 11.75
11.76 - 11.98
11.99 - 12.2
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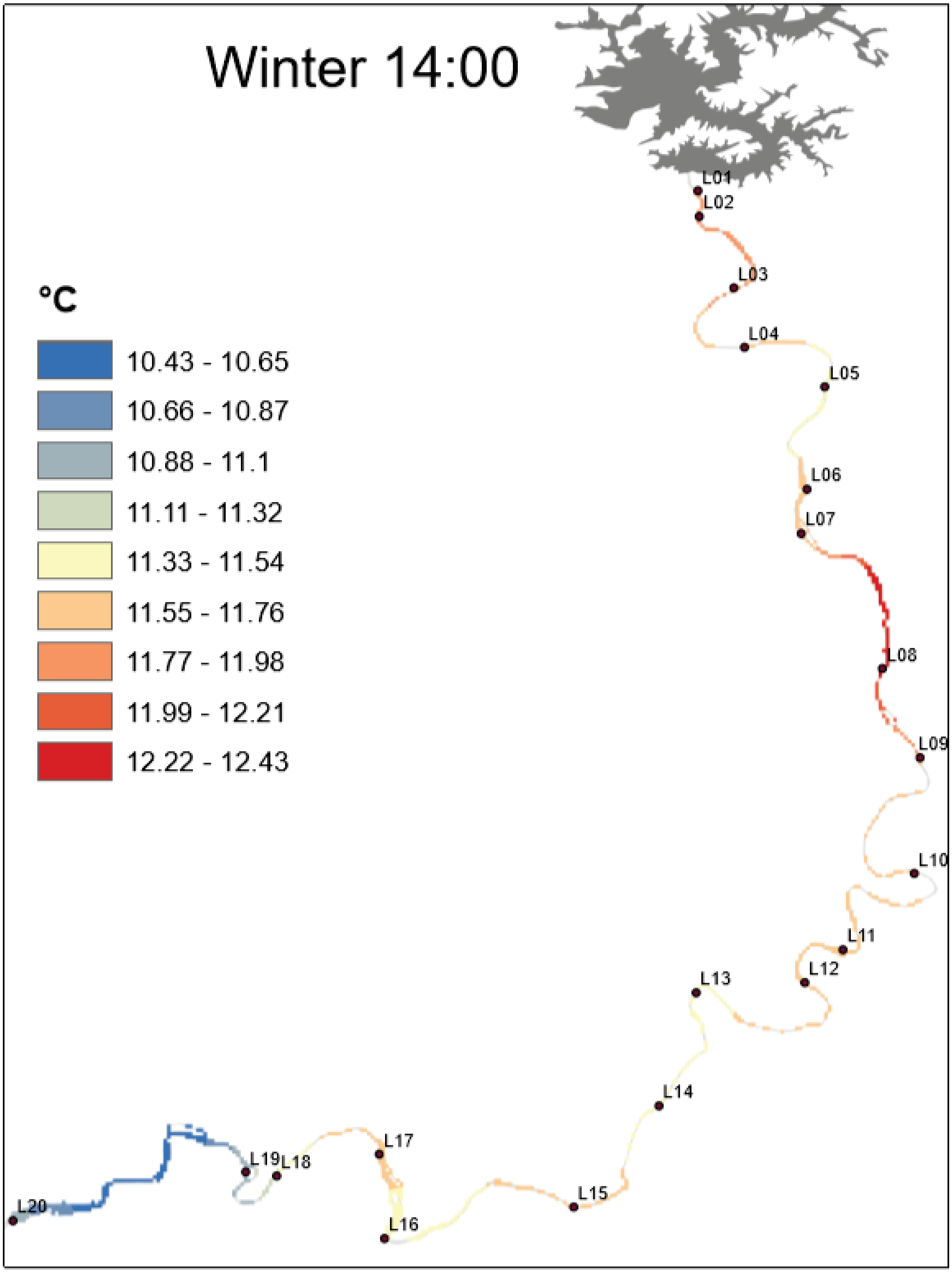
Winter 14:00
°C
10.43 - 10.65
10.66 - 10.87
10.88 - 11.1
11.11 - 11.32
11.33 - 11.54
11.55 - 11.76
11.77 - 11.98
11.99 - 12.21
12.22 - 12.43
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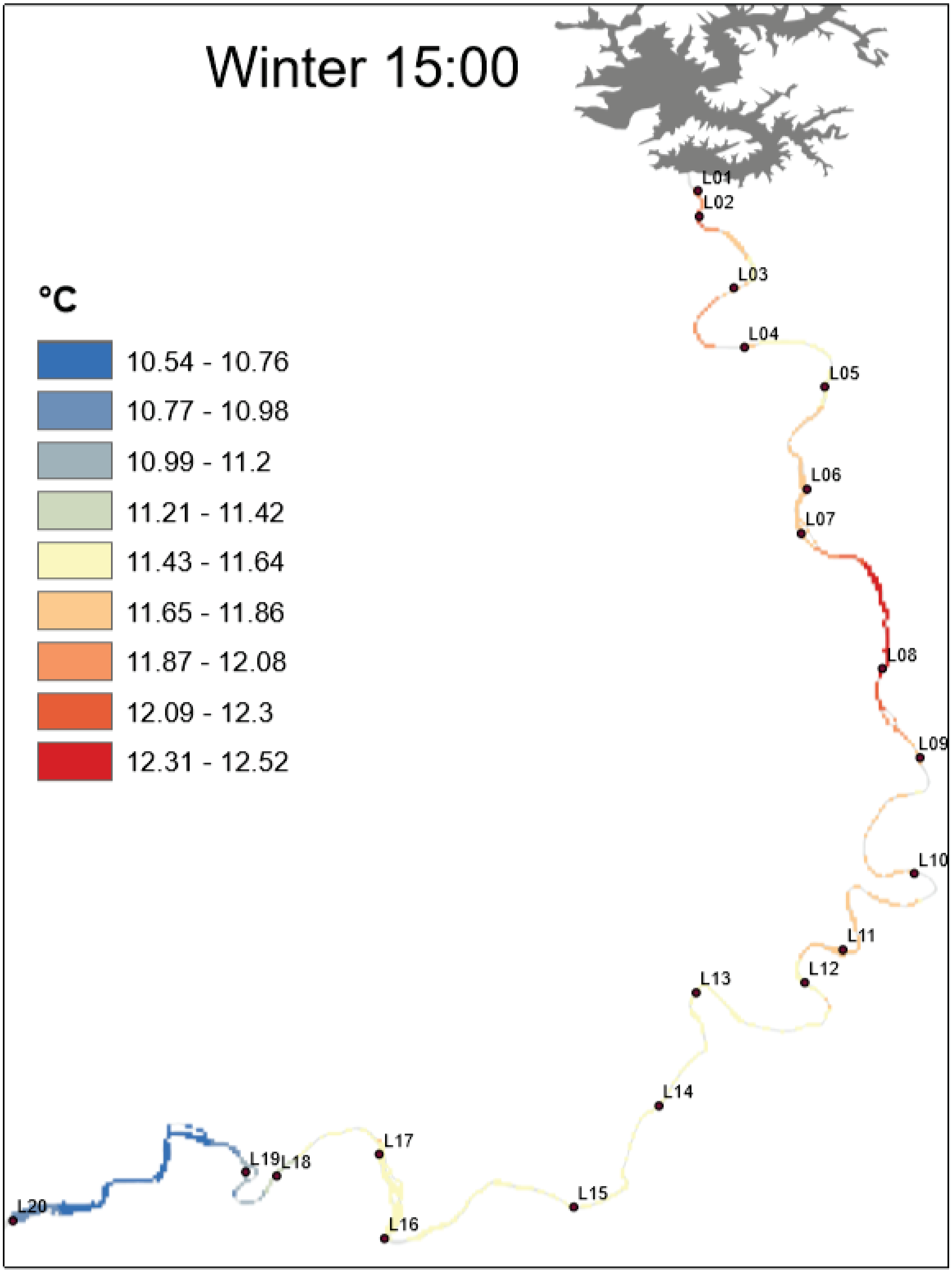

Winter 15:00
°C
10.54 - 10.76
10.77 - 10.98
10.99 - 11.2
11.21 - 11.42
11.43 - 11.64
11.65 - 11.86
11.87 - 12.08
12.09 - 12.3
12.31 - 12.52
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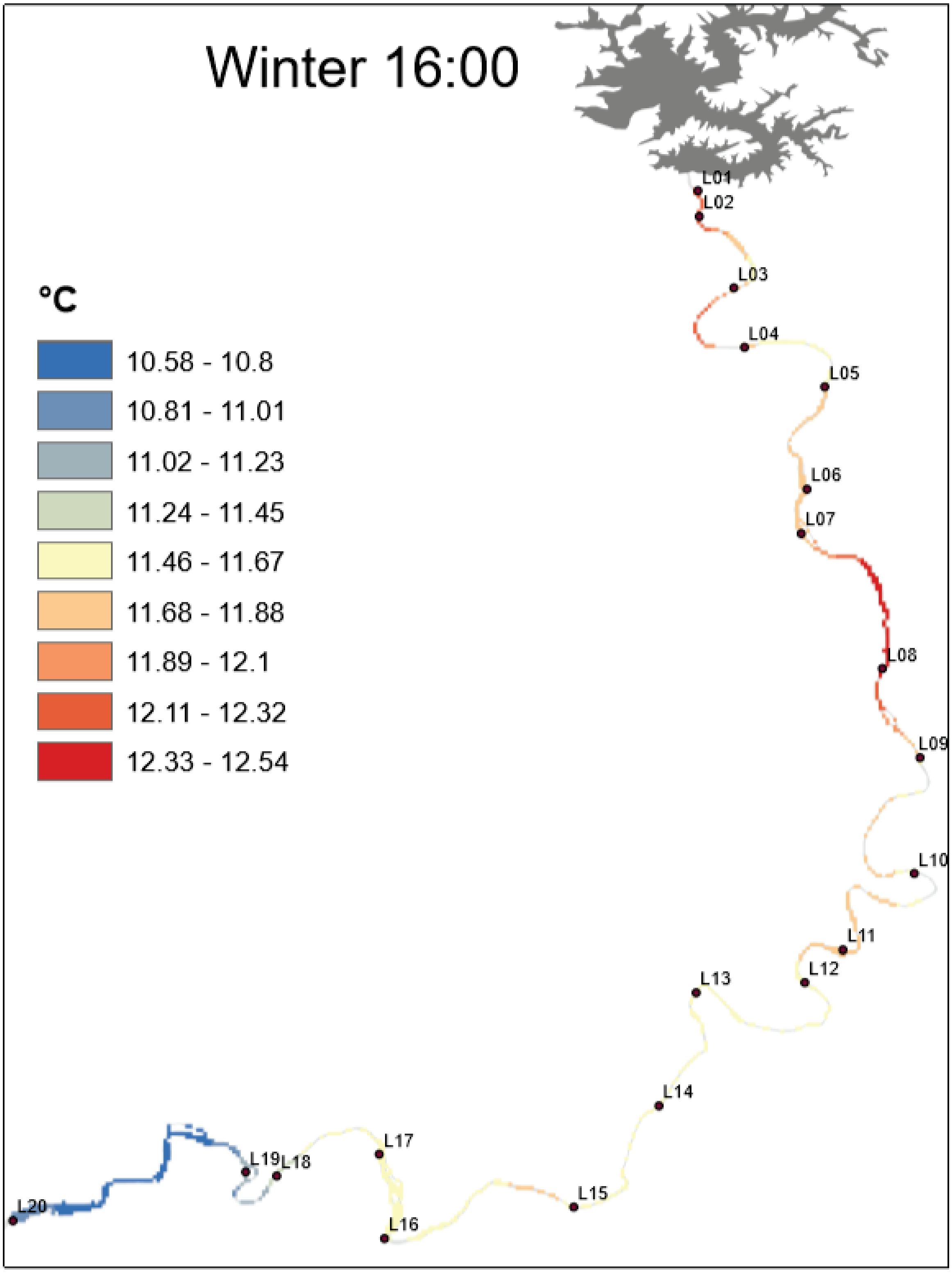

Winter 16:00
°C
10.58 - 10.8
10.81 - 11.01
11.02 - 11.23
11.24 - 11.45
11.46 - 11.67
11.68 - 11.88
11.89 - 12.1
12.11 - 12.32
12.33 - 12.54
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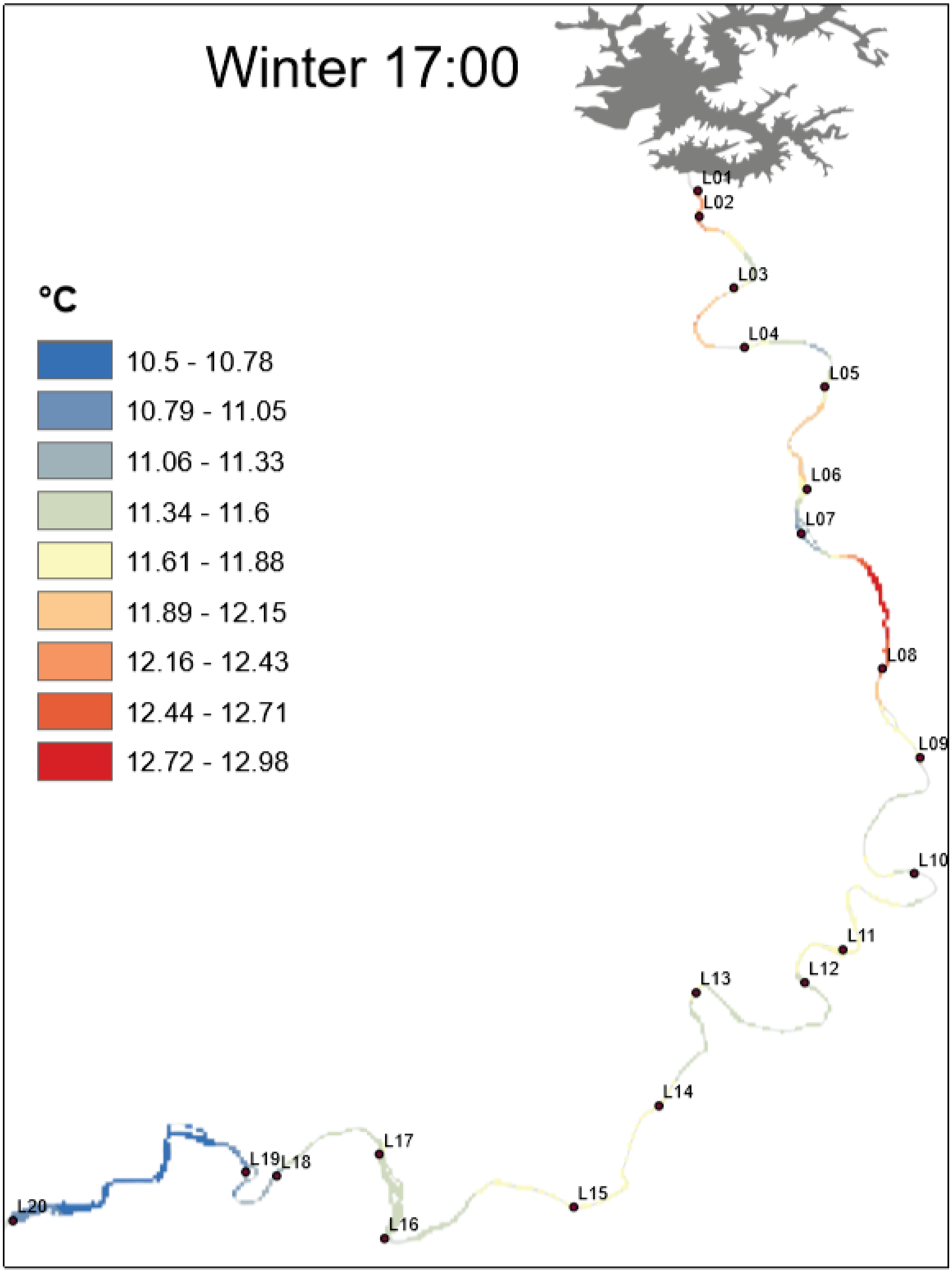
Winter 17:00
°C
10.5 - 10.78
10.79 - 11.05
11.06 - 11.33
11.34 - 11.6
11.61 - 11.88
11.89 - 12.15
12.16 - 12.43
12.44 - 12.71
12.72 - 12.98
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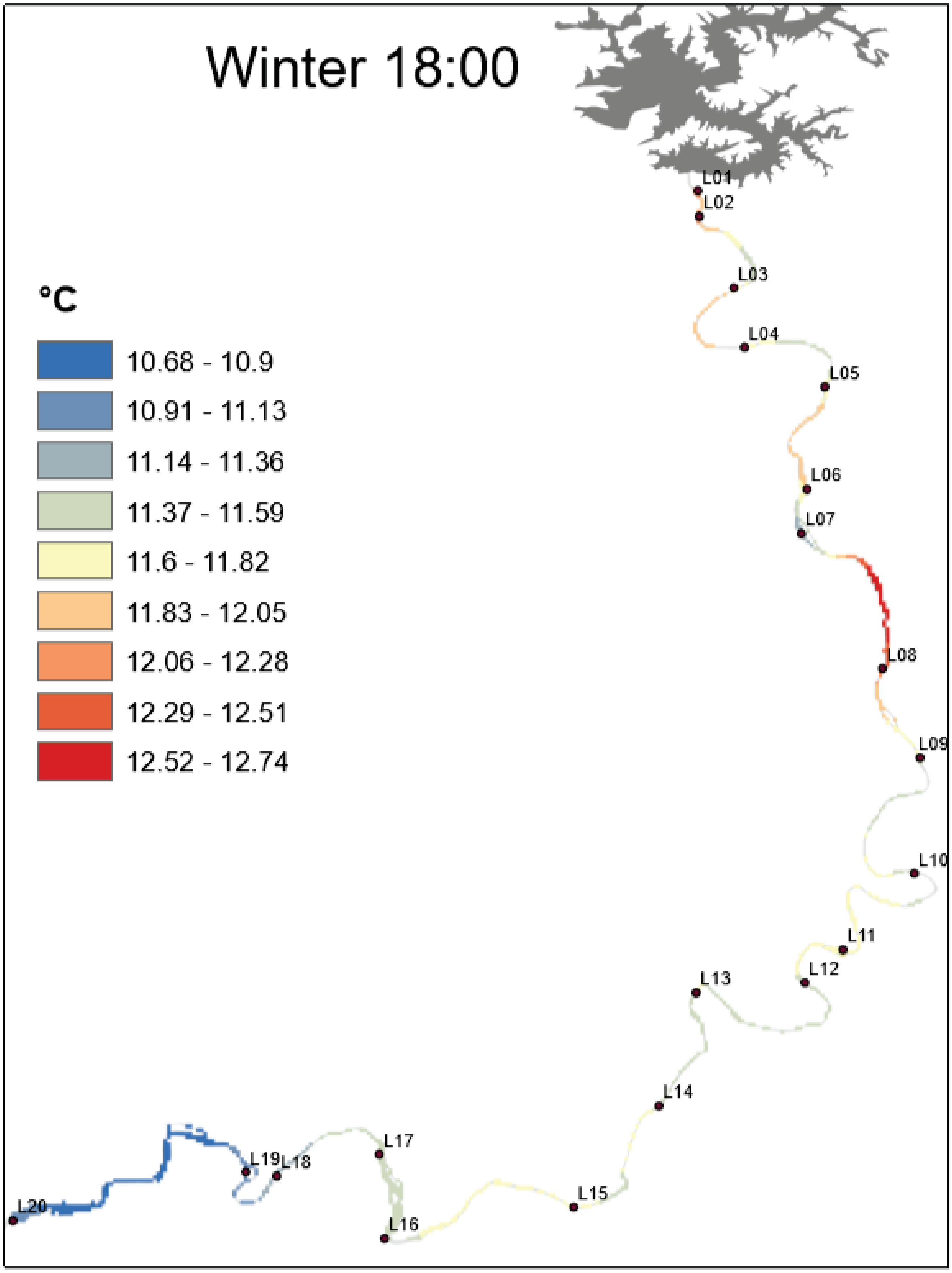
Winter 18:00
°C
10.68 - 10.9
10.91 - 11.13
11.14 - 11.36
11.37 - 11.59
11.6 - 11.82
11.83 - 12.05
12.06 - 12.28
12.29 - 12.51
12.52 - 12.74
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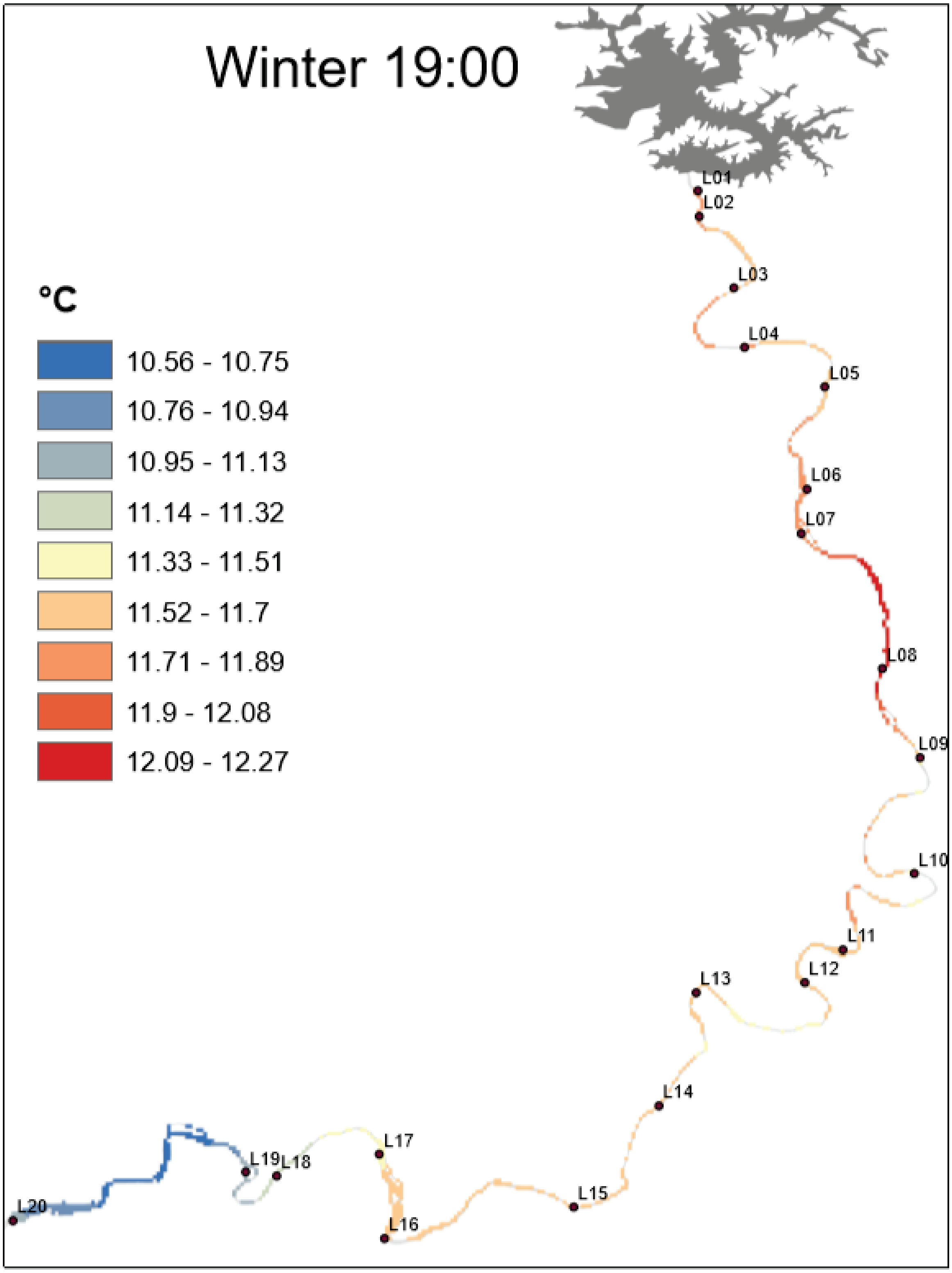
Winter 19:00
°C
10.56 - 10.75
10.76 - 10.94
10.95 - 11.13
11.14 - 11.32
11.33 - 11.51
11.52 - 11.7
11.71 - 11.89
11.9 - 12.08
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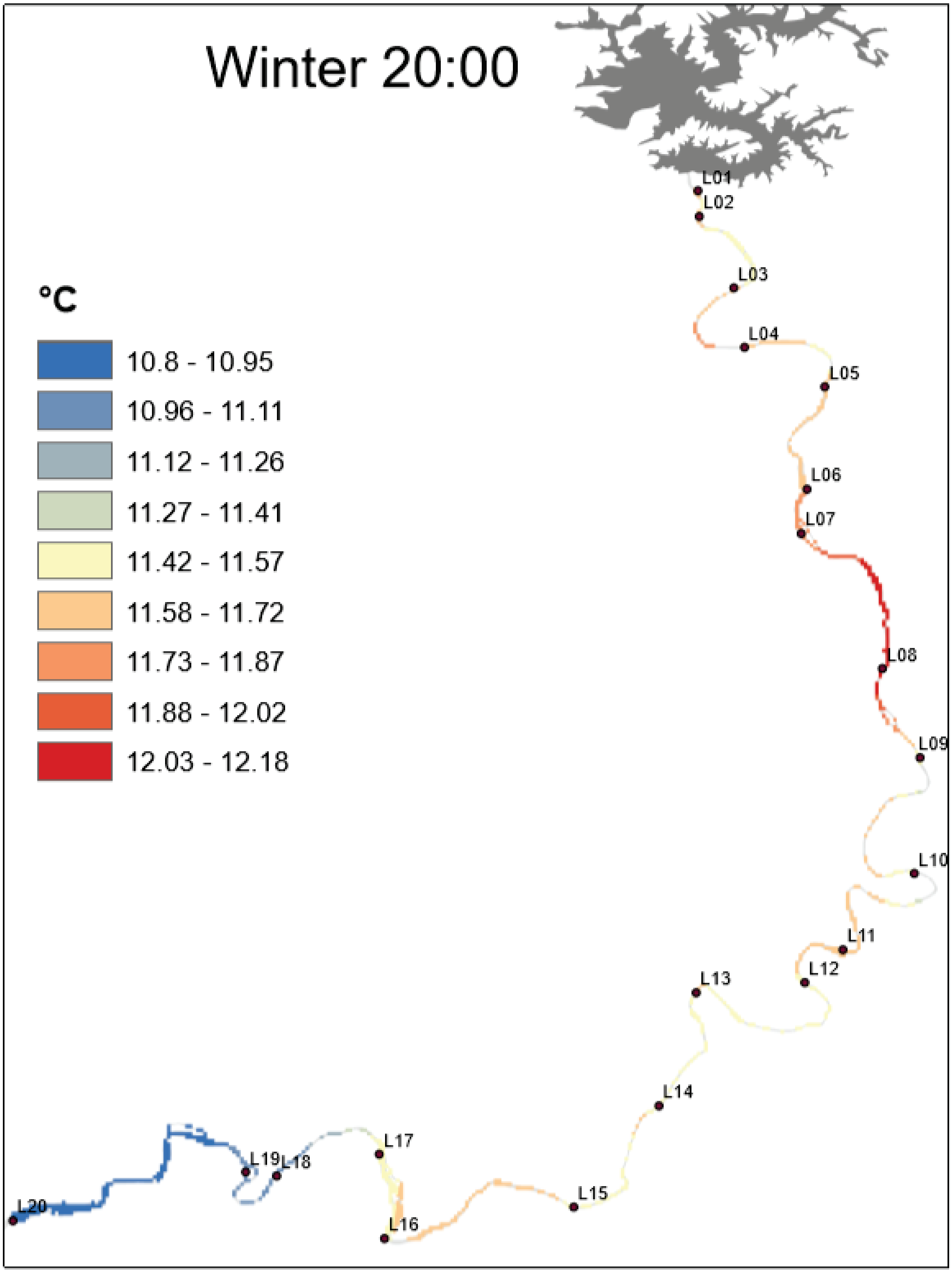
Winter 20:00
°C
10.8 - 10.95
10.96 - 11.11
11.12 - 11.26
11.27 - 11.41
11.42 - 11.57
11.58 - 11.72
11.73 - 11.87
11.88 - 12.02
12.03 - 12.18
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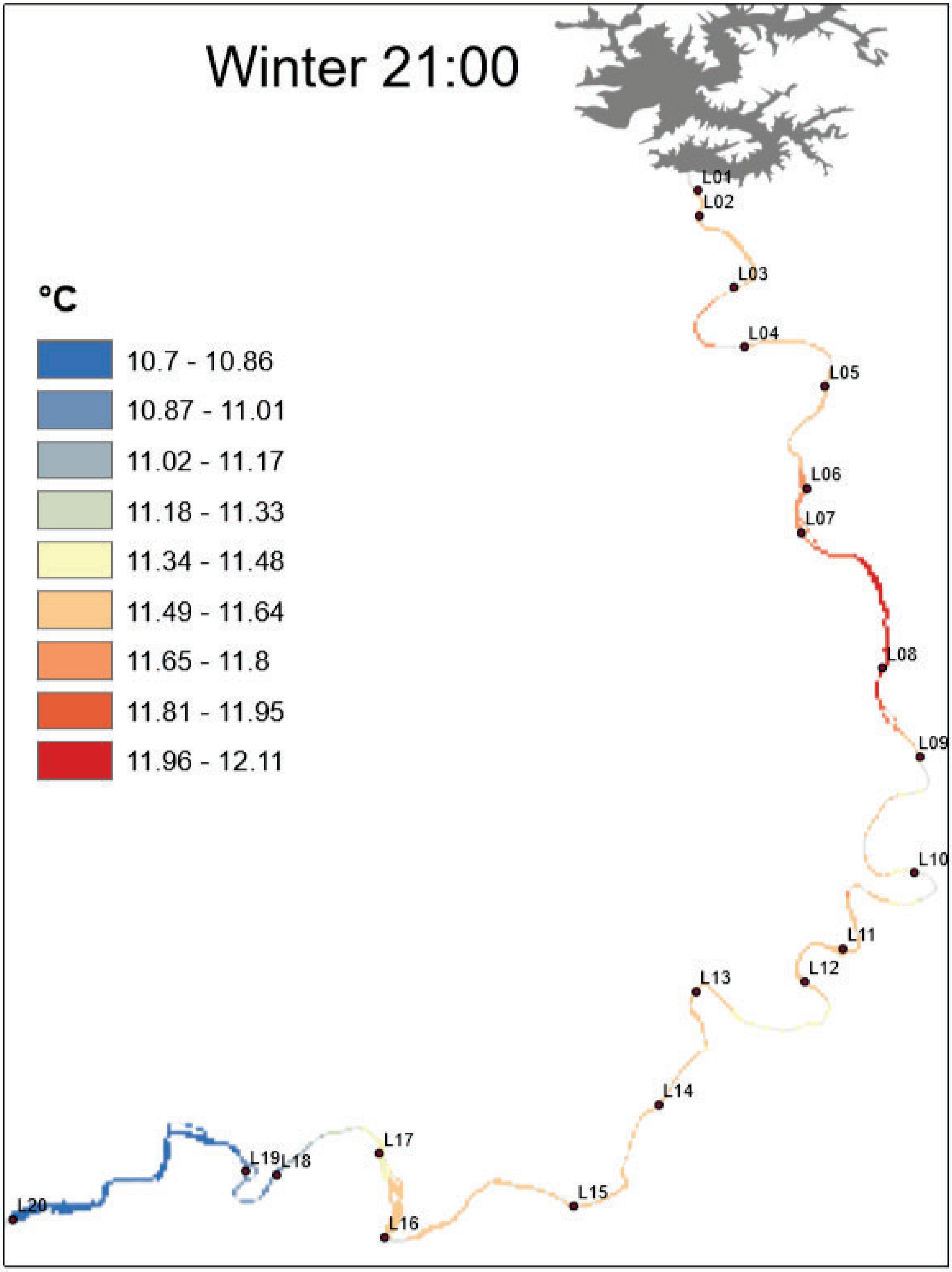
Winter 21:00
°C
10.7 - 10.86
10.87 - 11.01
11.02 - 11.17
11.18 - 11.33
11.34 - 11.48
11.49 - 11.64
11.65 - 11.8
11.81 - 11.95
11.96 - 12.11
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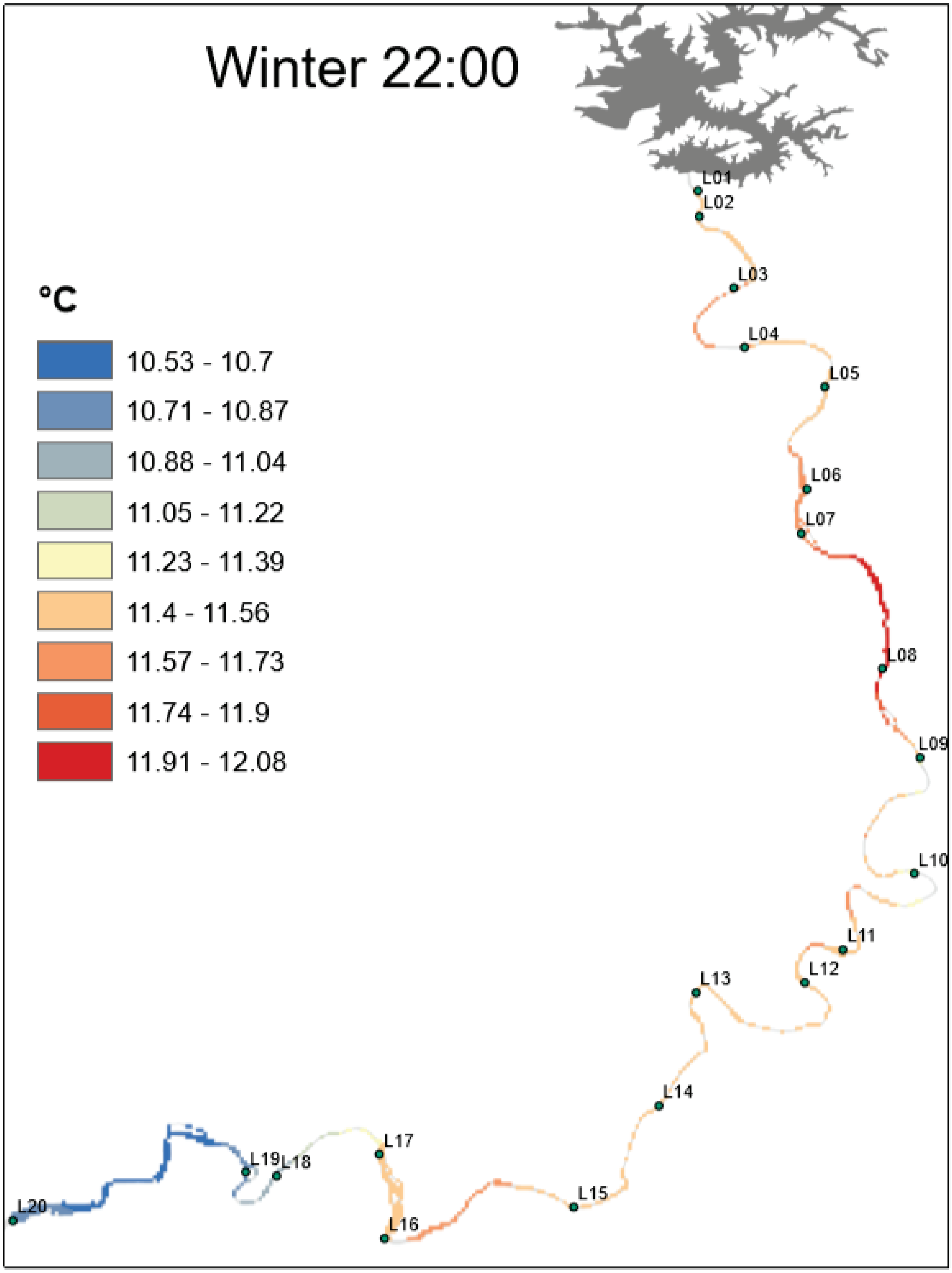

Winter 22:00
°C
10.53 - 10.7
10.71 - 10.87
10.88 - 11.04
11.05 - 11.22
11.23 - 11.39
11.4 - 11.56
11.57 - 11.73
11.74 - 11.9
11.91 - 12.08
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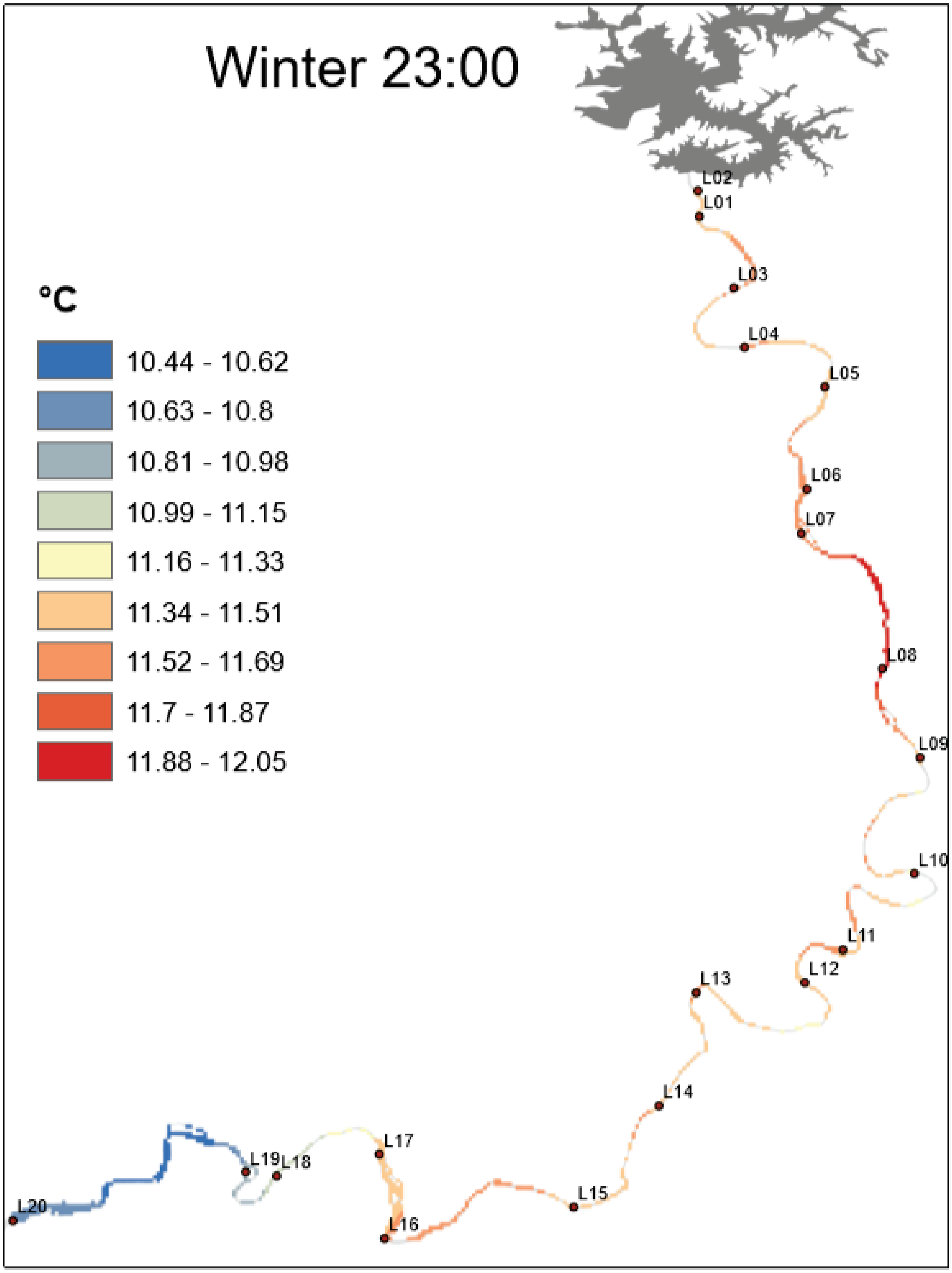

Winter 23:00
°C
10.44 - 10.62
10.63 - 10.8
10.81 - 10.98
10.99 - 11.15
11.16 - 11.33
11.34 - 11.51
11.52 - 11.69
11.7 - 11.87
11.88 - 12.05
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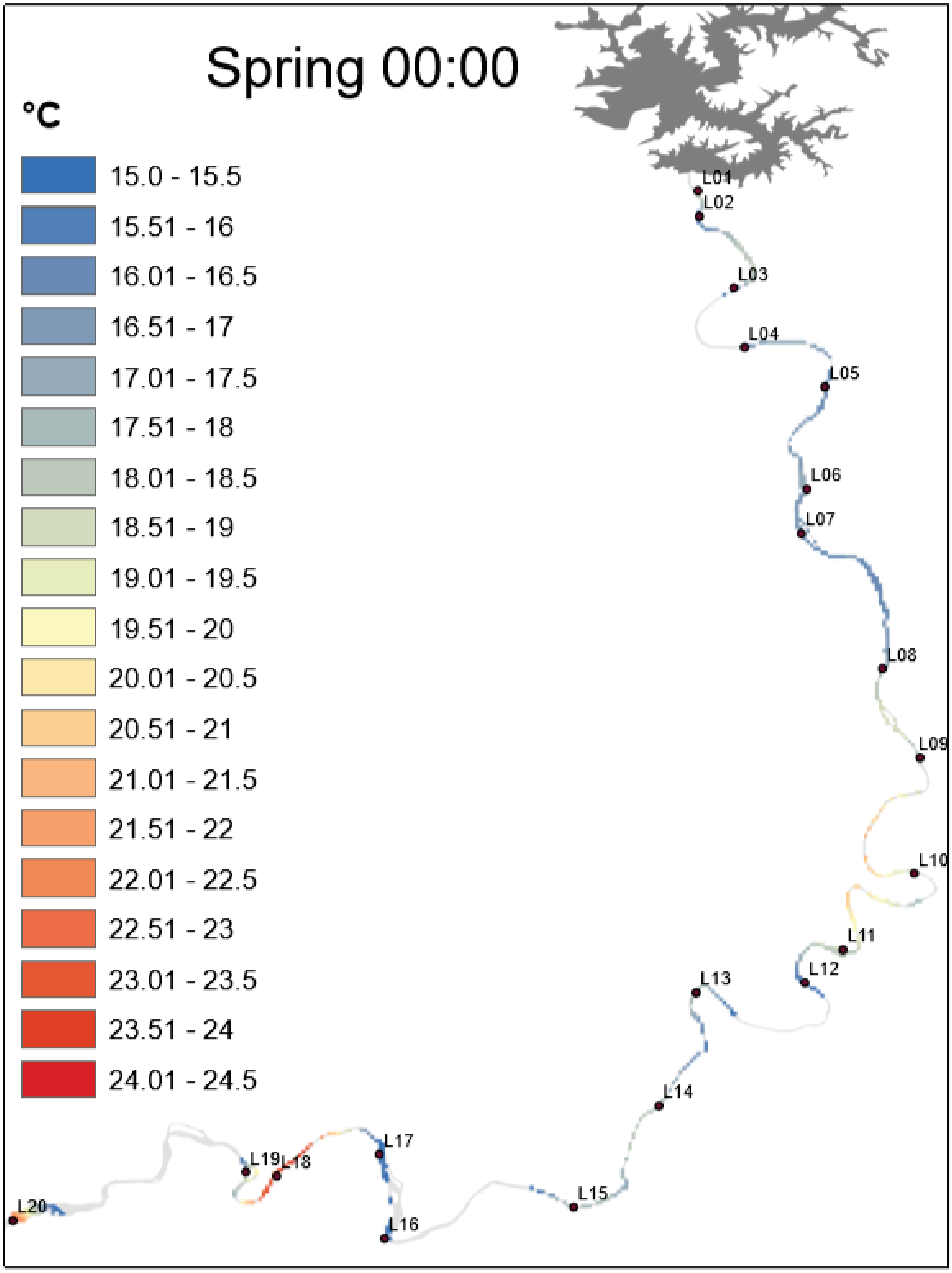
Spring 00:00
°C
15.0 - 15.5
15.51 - 16
16.01 - 16.5
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17.01 - 17.5
17.51 - 18
18.01 - 18.5
18.51 - 19
19.01 - 19.5
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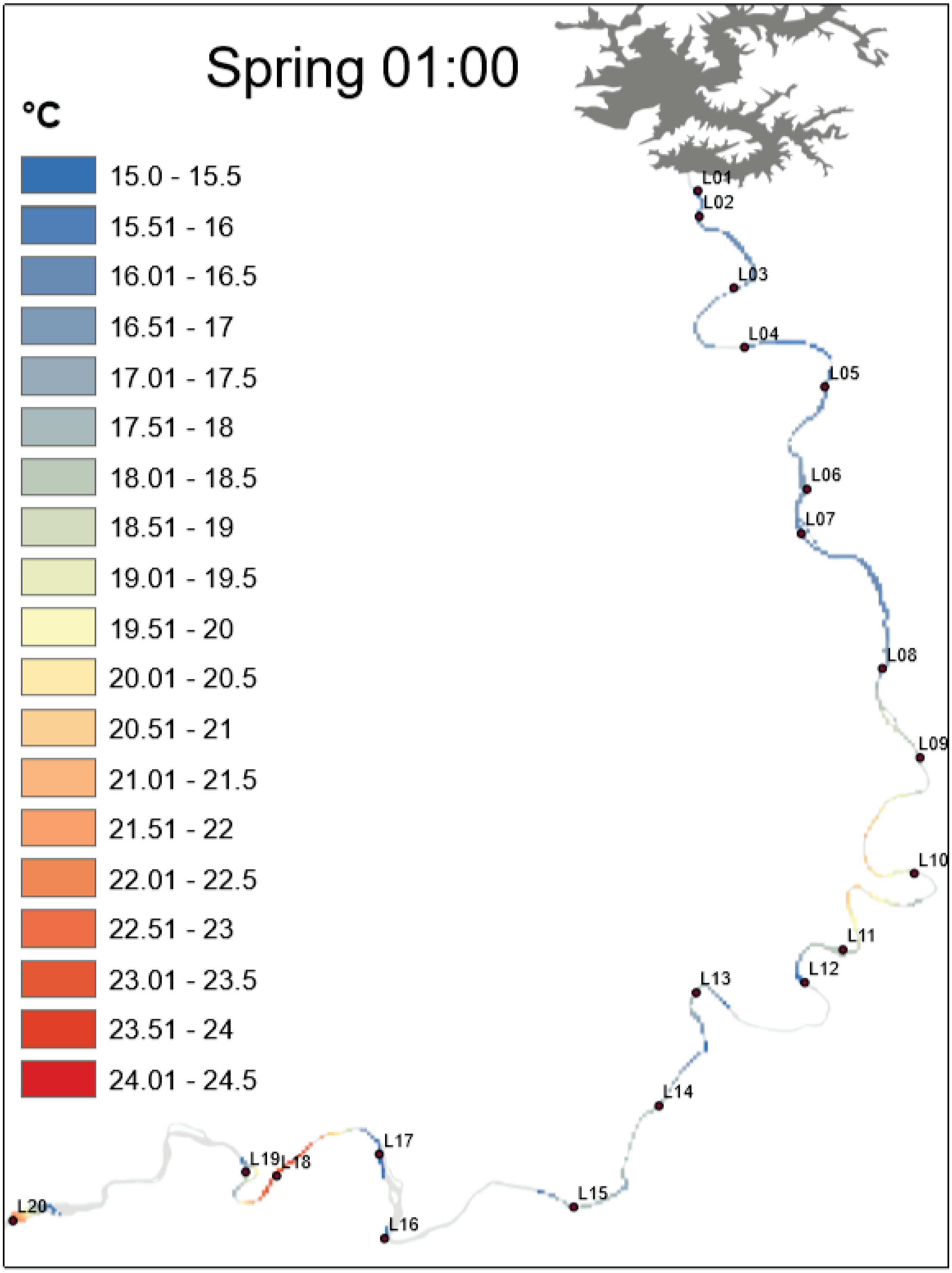
Spring 01:00
°C
15.0 - 15.5
15.51 - 16
16.01 - 16.5
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17.01 - 17.5
17.51 - 18
18.01 - 18.5
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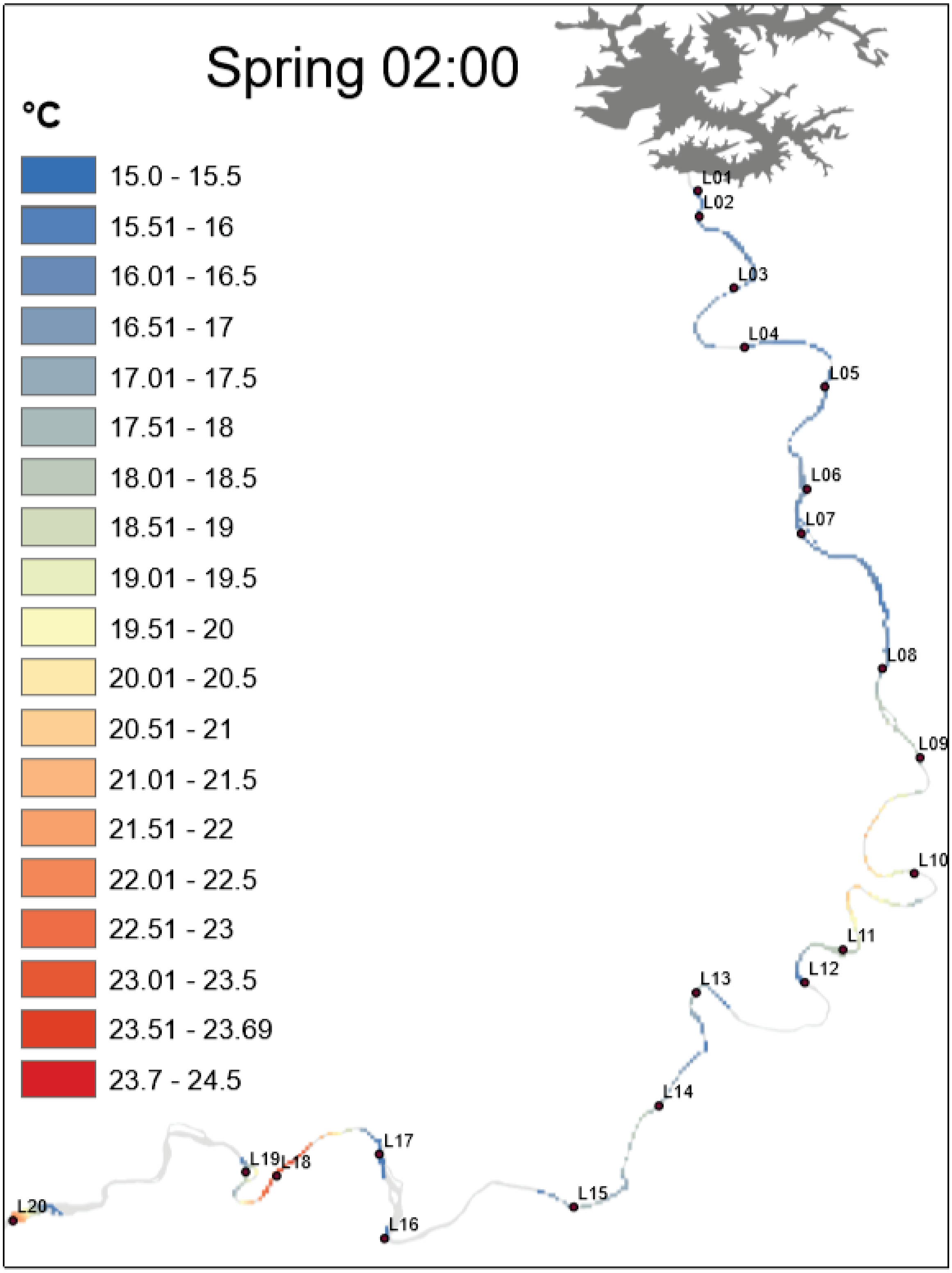

Spring 02:00
°C
15.0 - 15.5
15.51 - 16
16.01 - 16.5
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17.01 - 17.5
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18.01 - 18.5
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23.01 - 23.5
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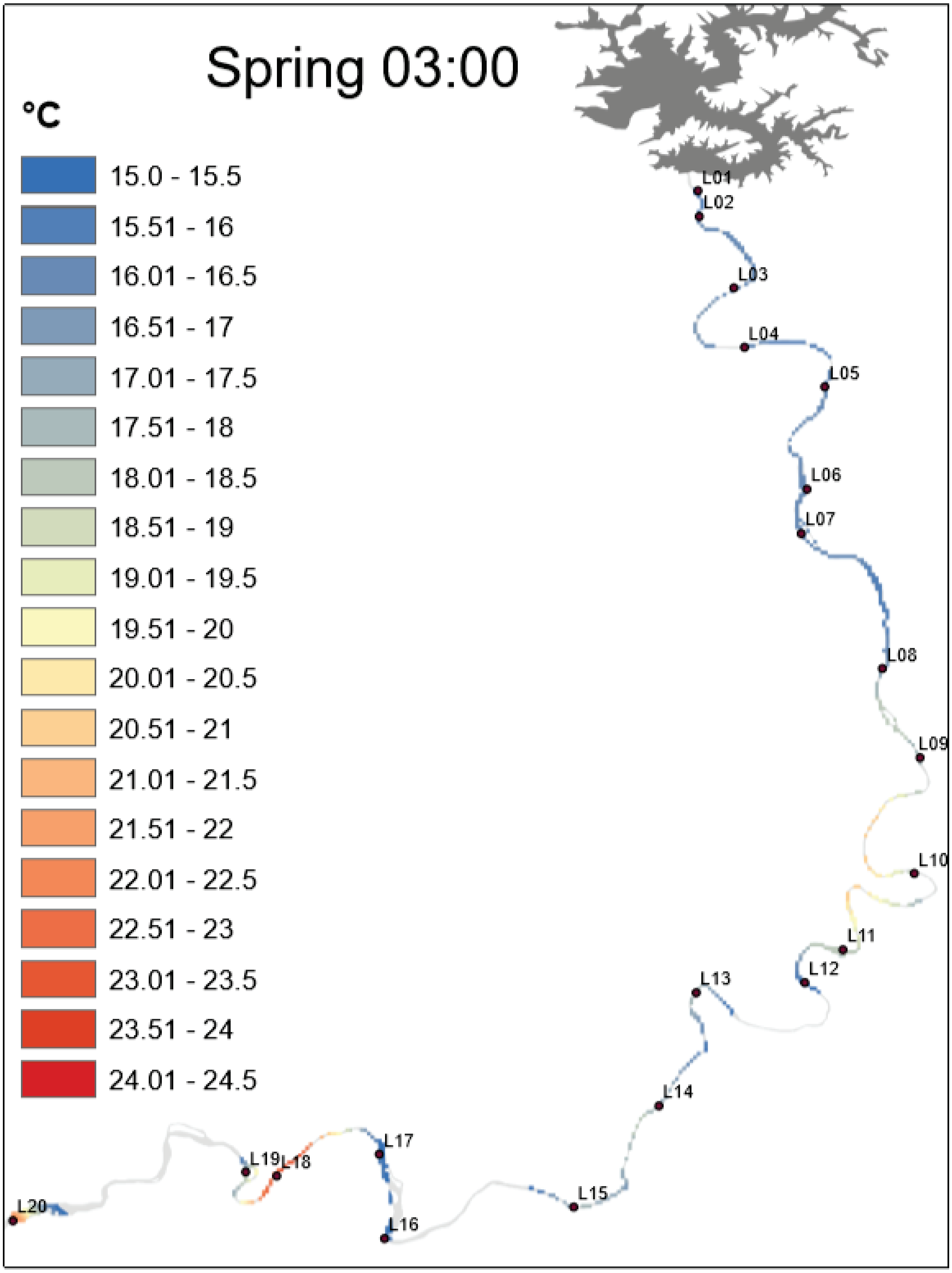

Spring 03:00
°C
15.0 - 15.5
15.51 - 16
16.01 - 16.5
16.51 - 17
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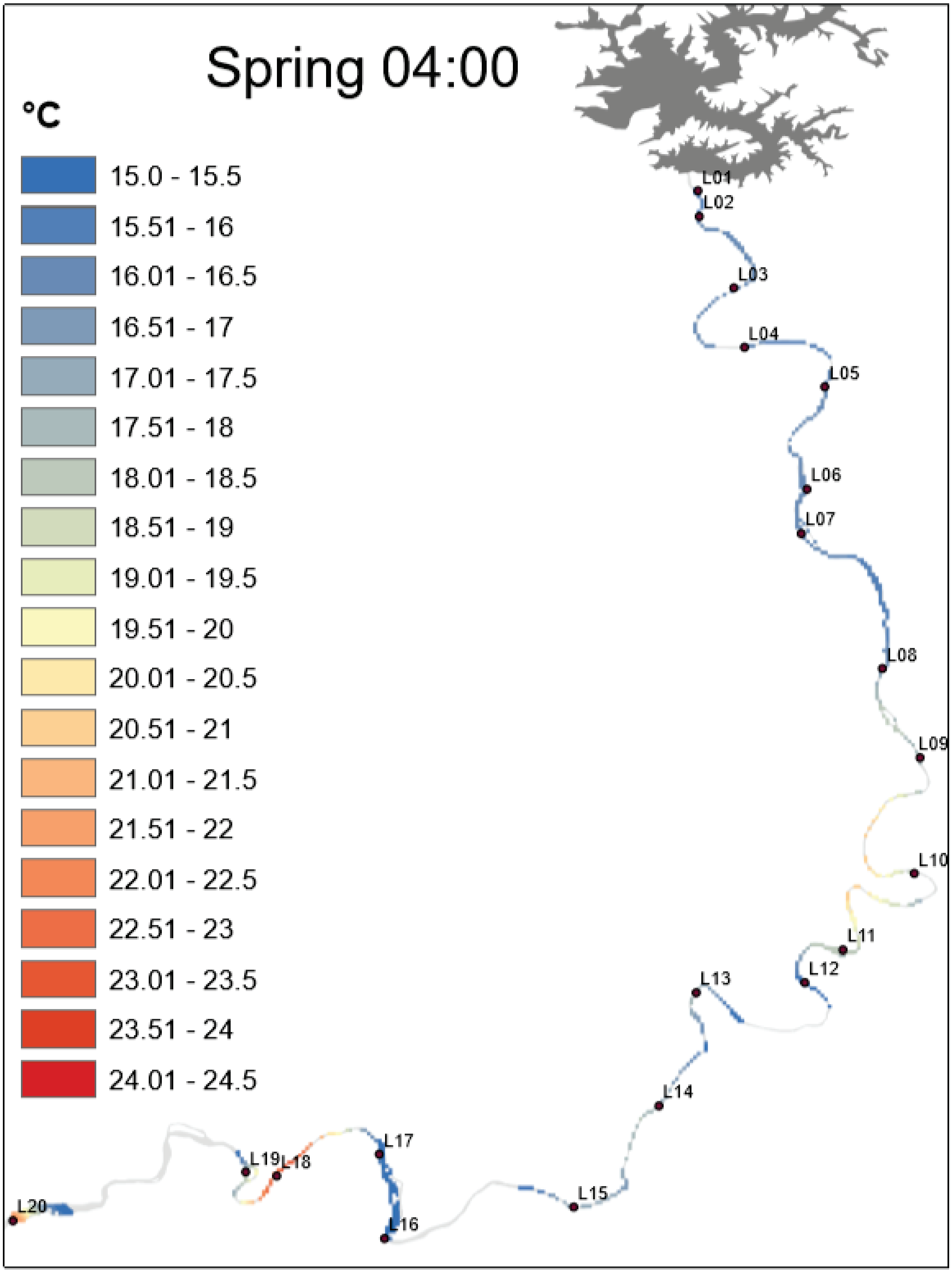
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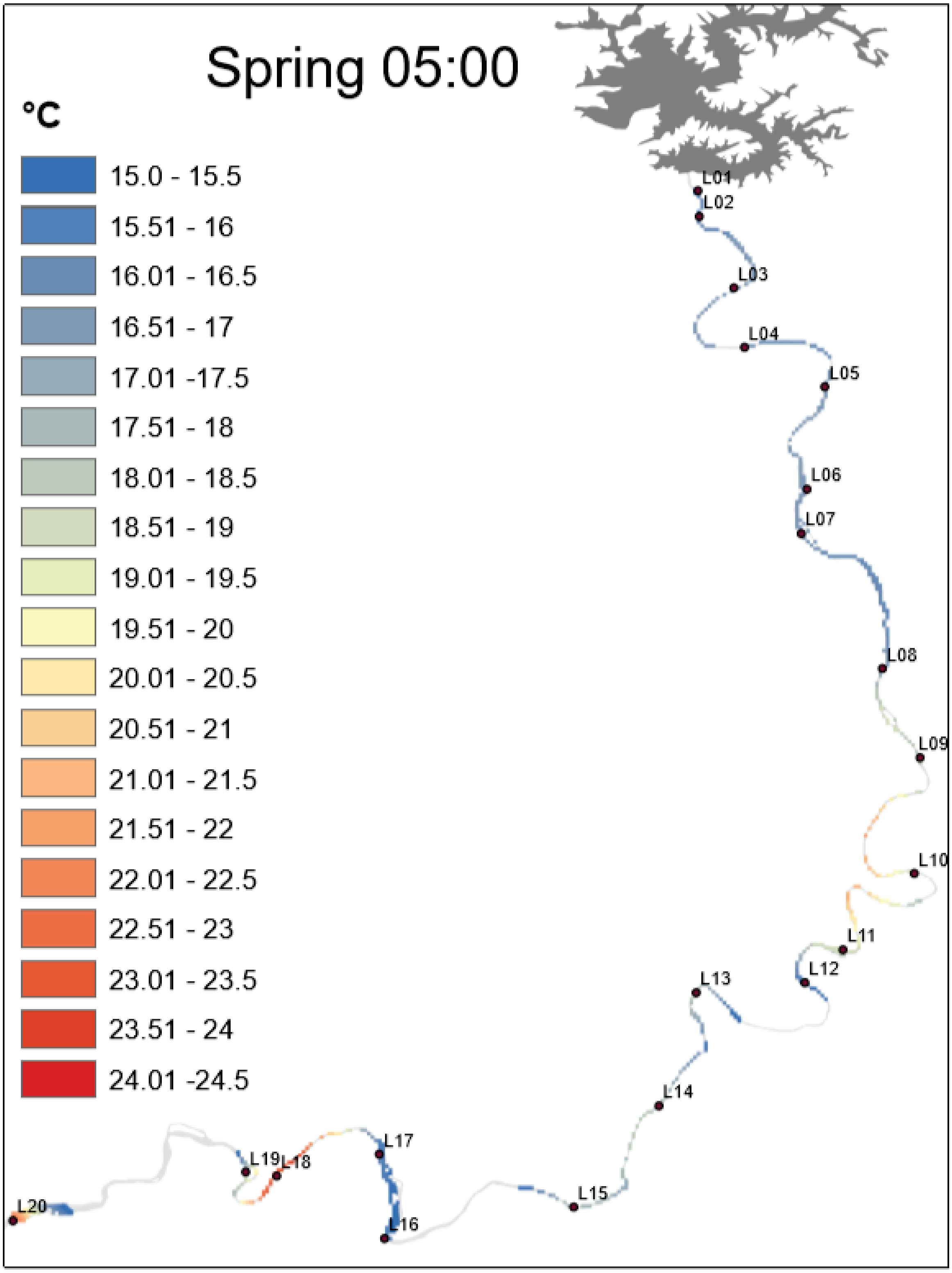
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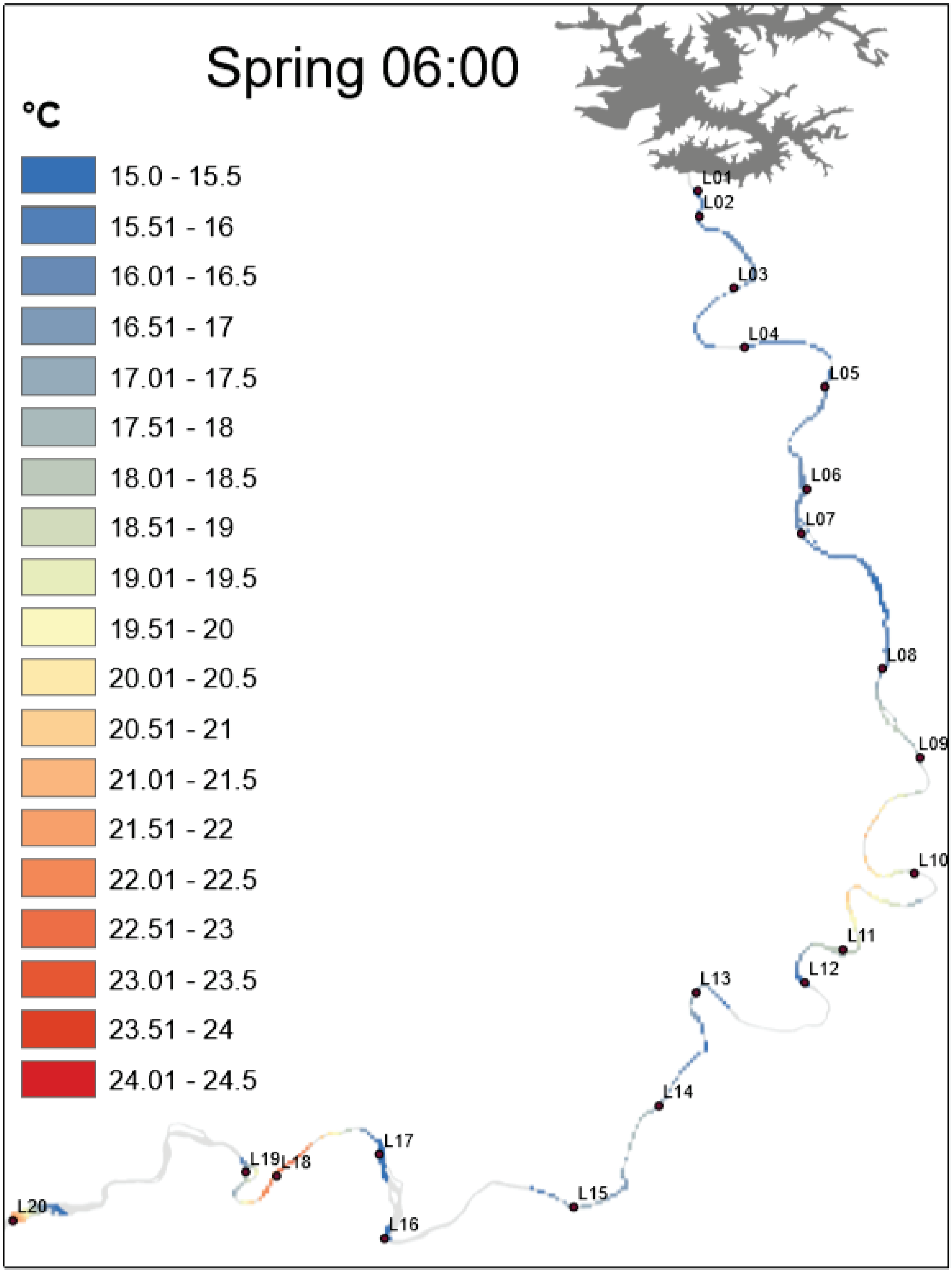
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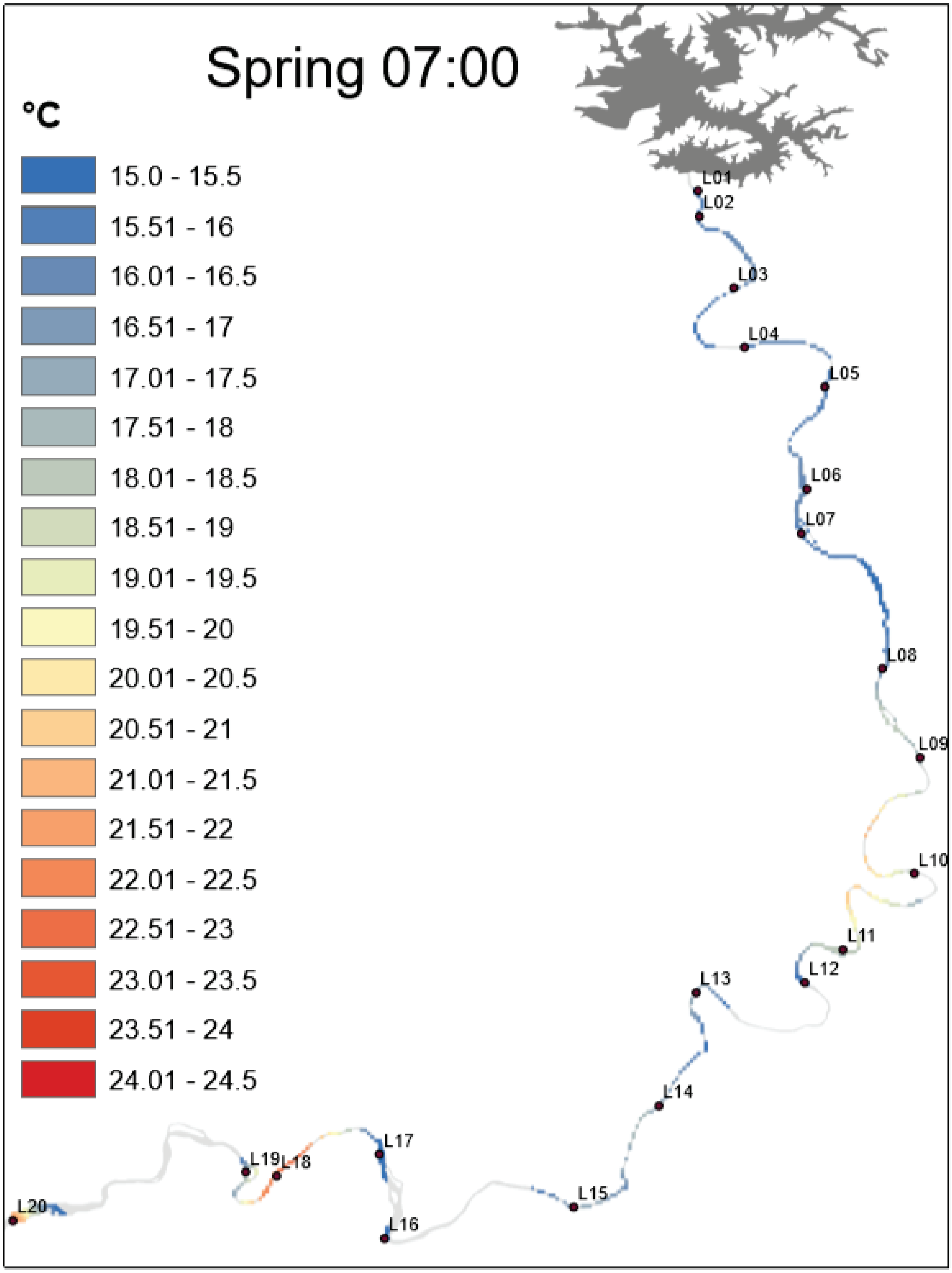
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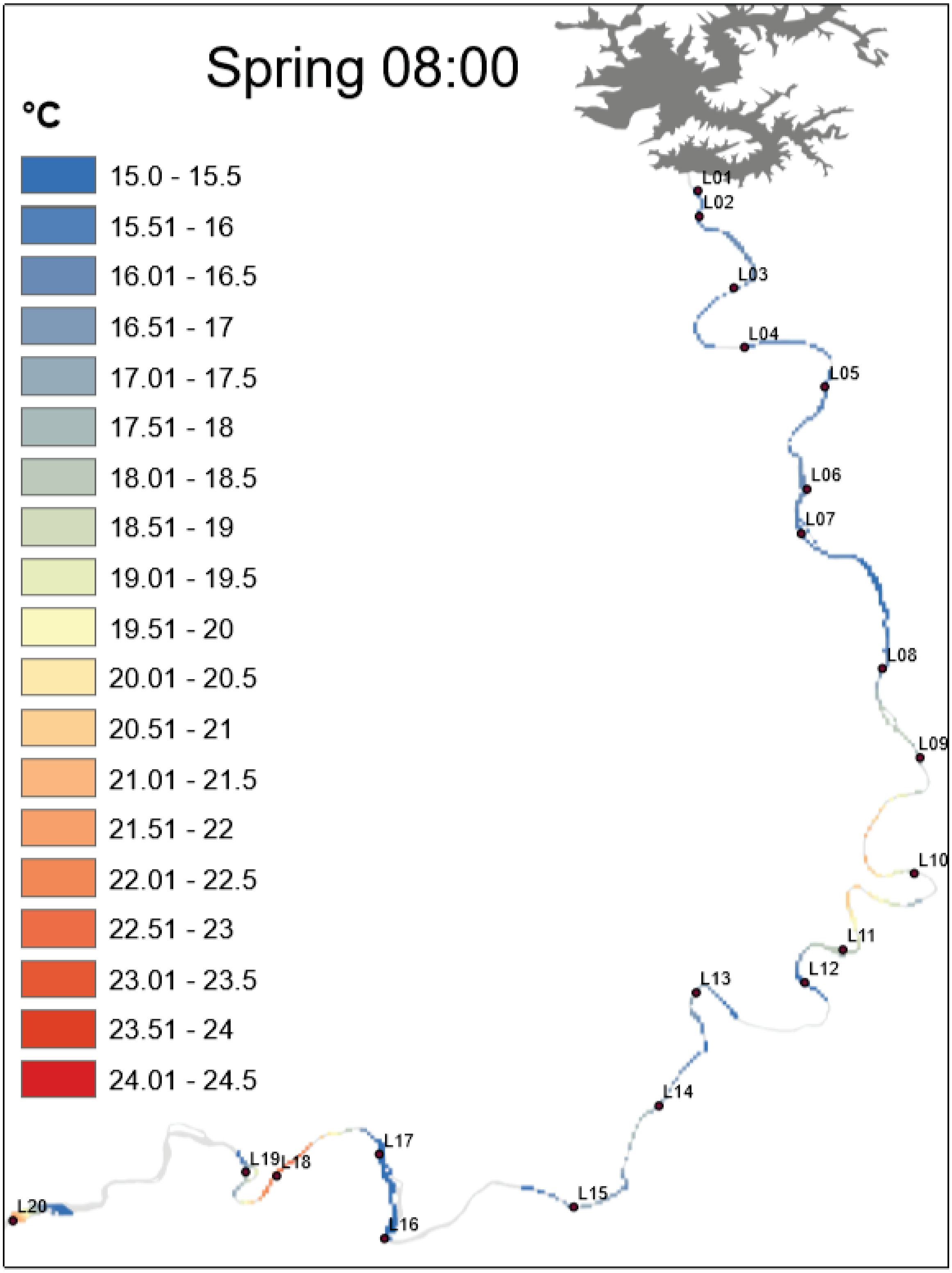
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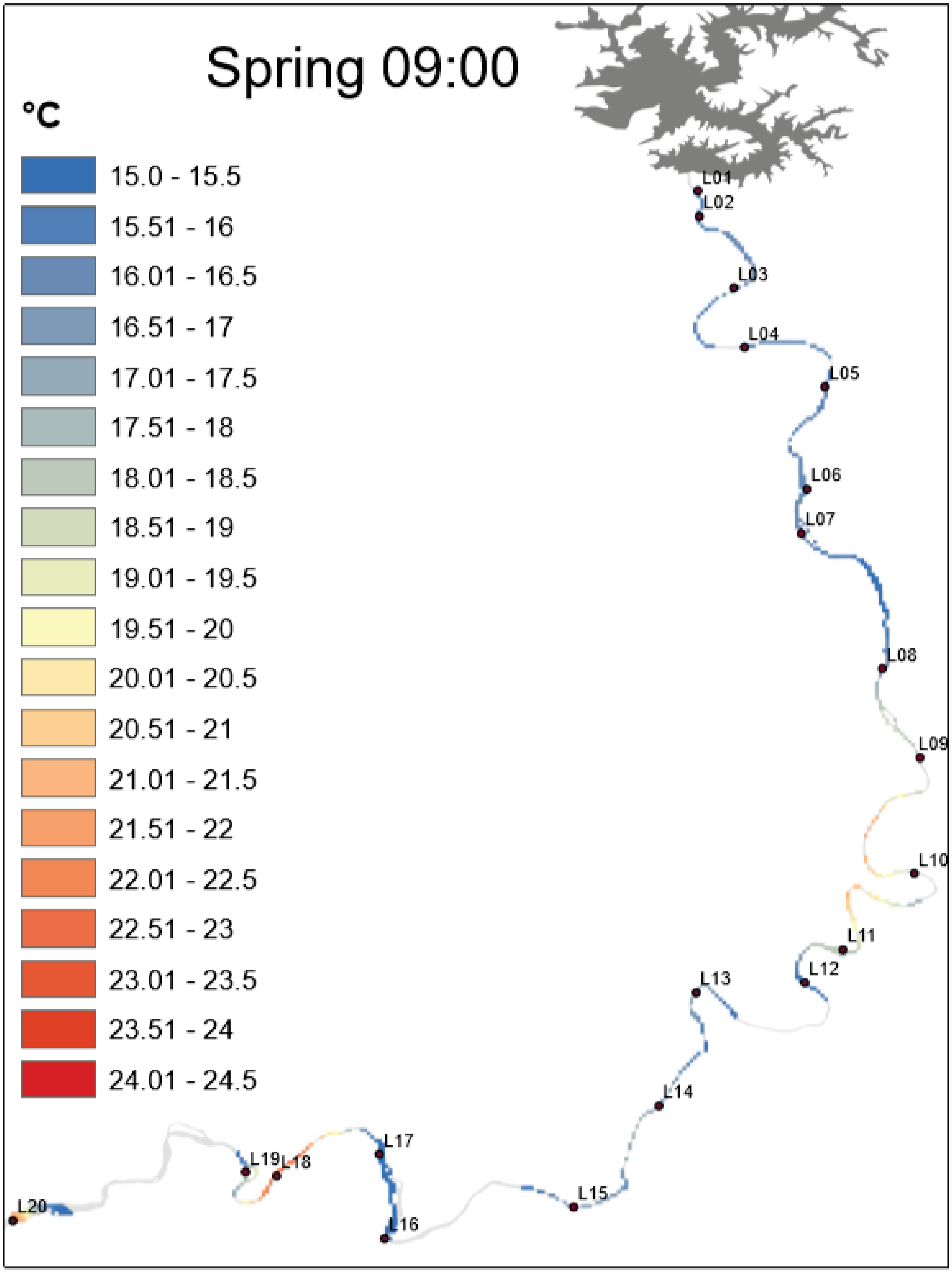

Spring 09:00
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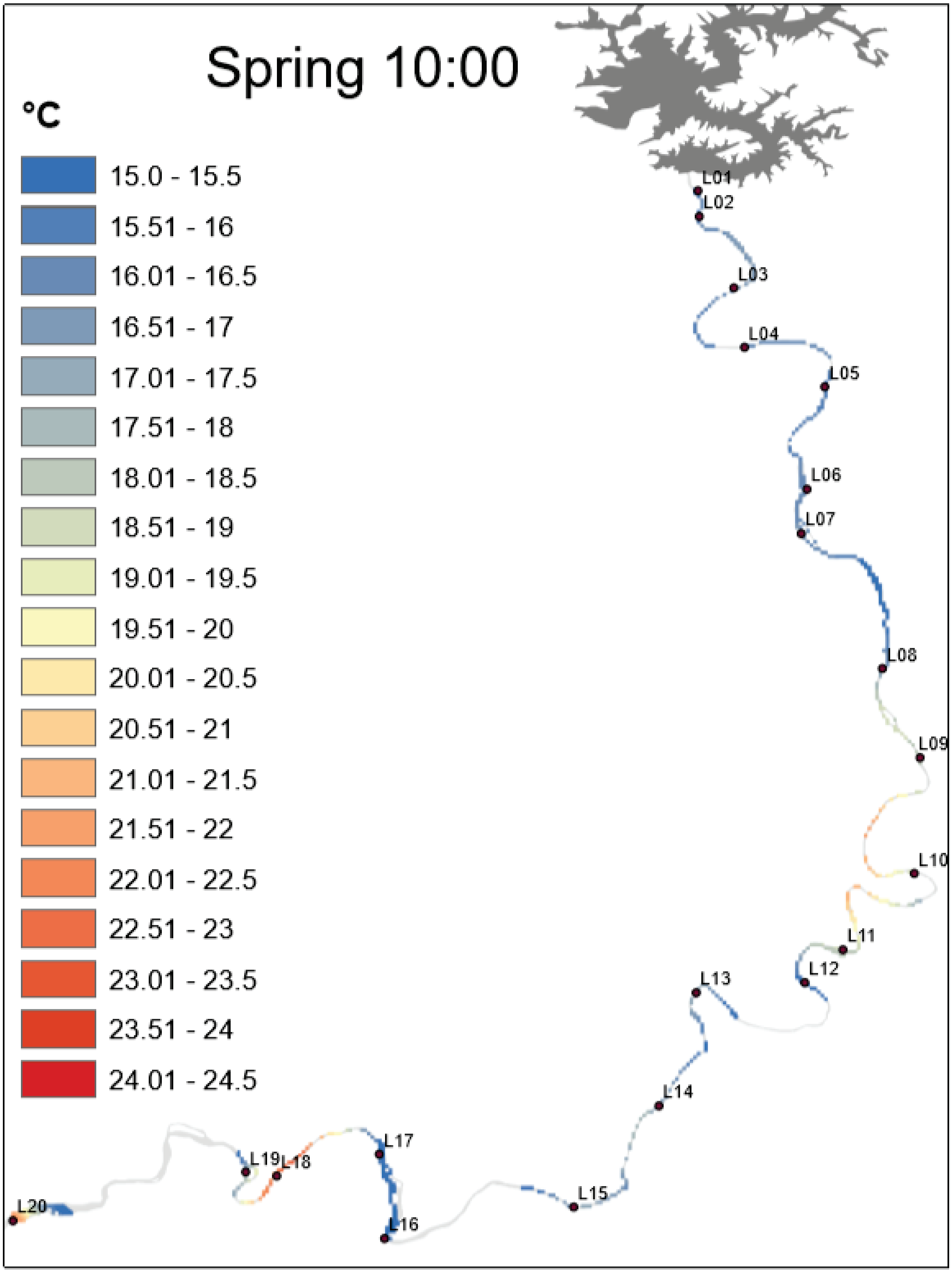
Spring 10:00
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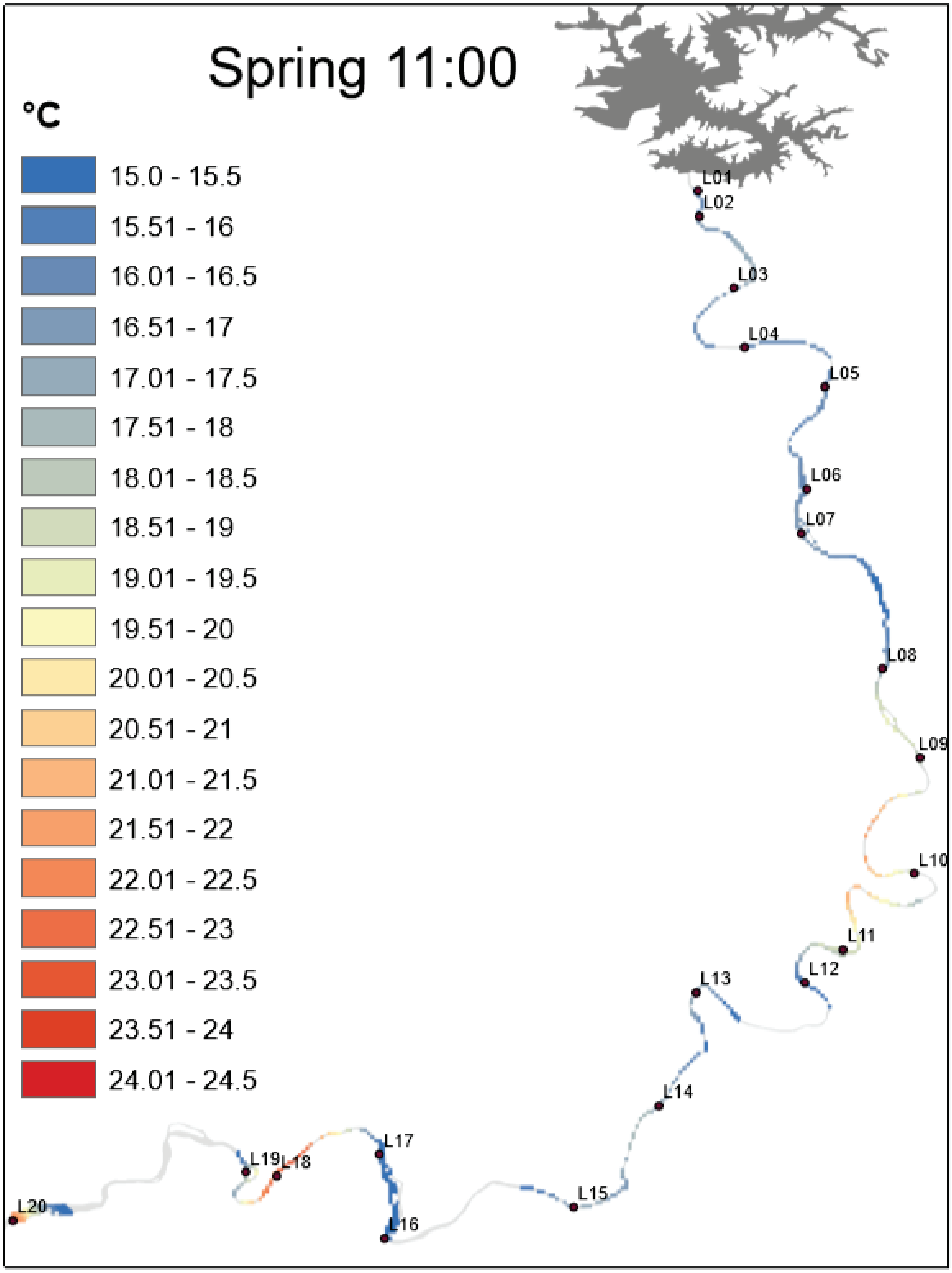
Spring 11:00
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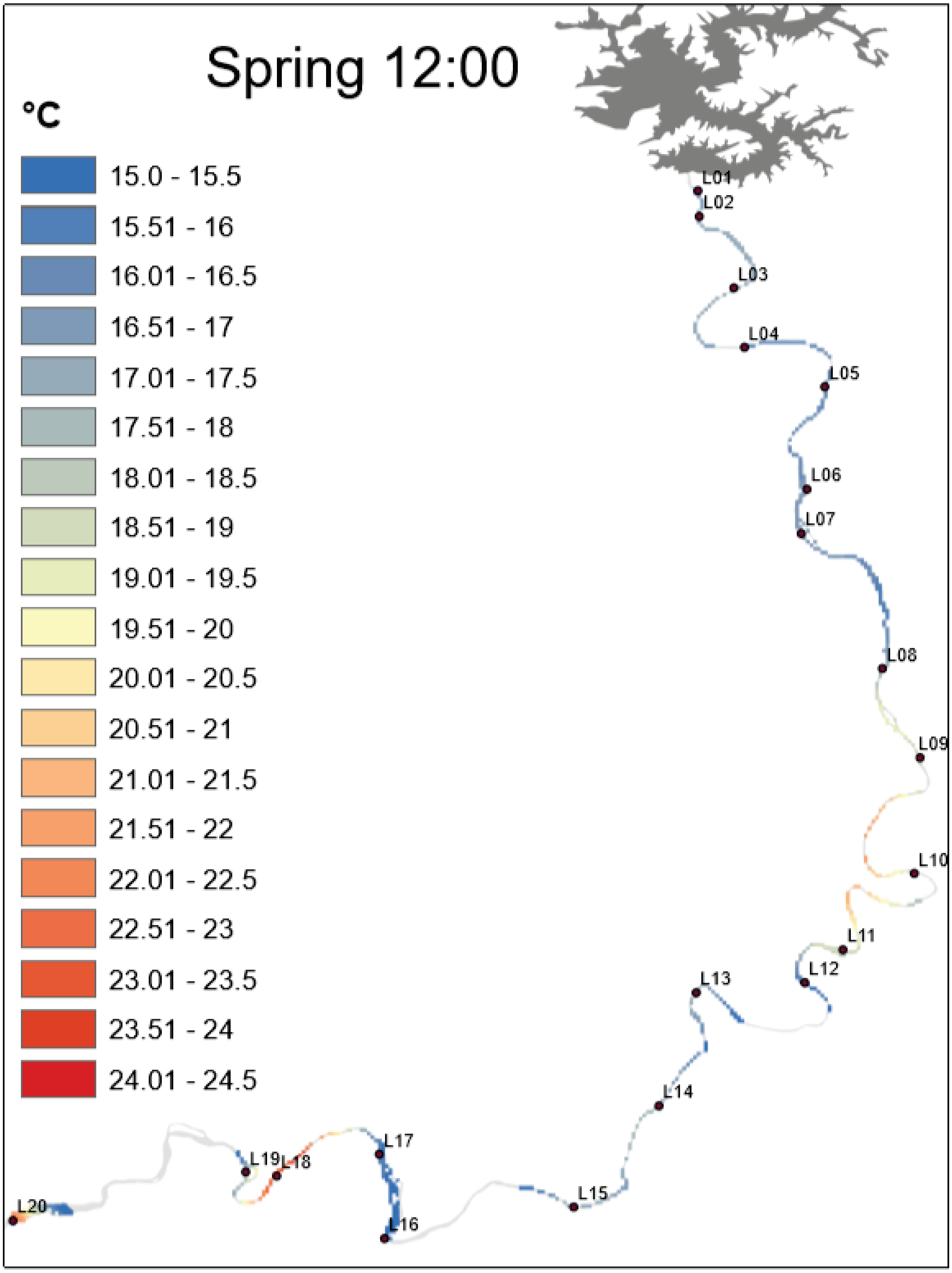
Spring 12:00
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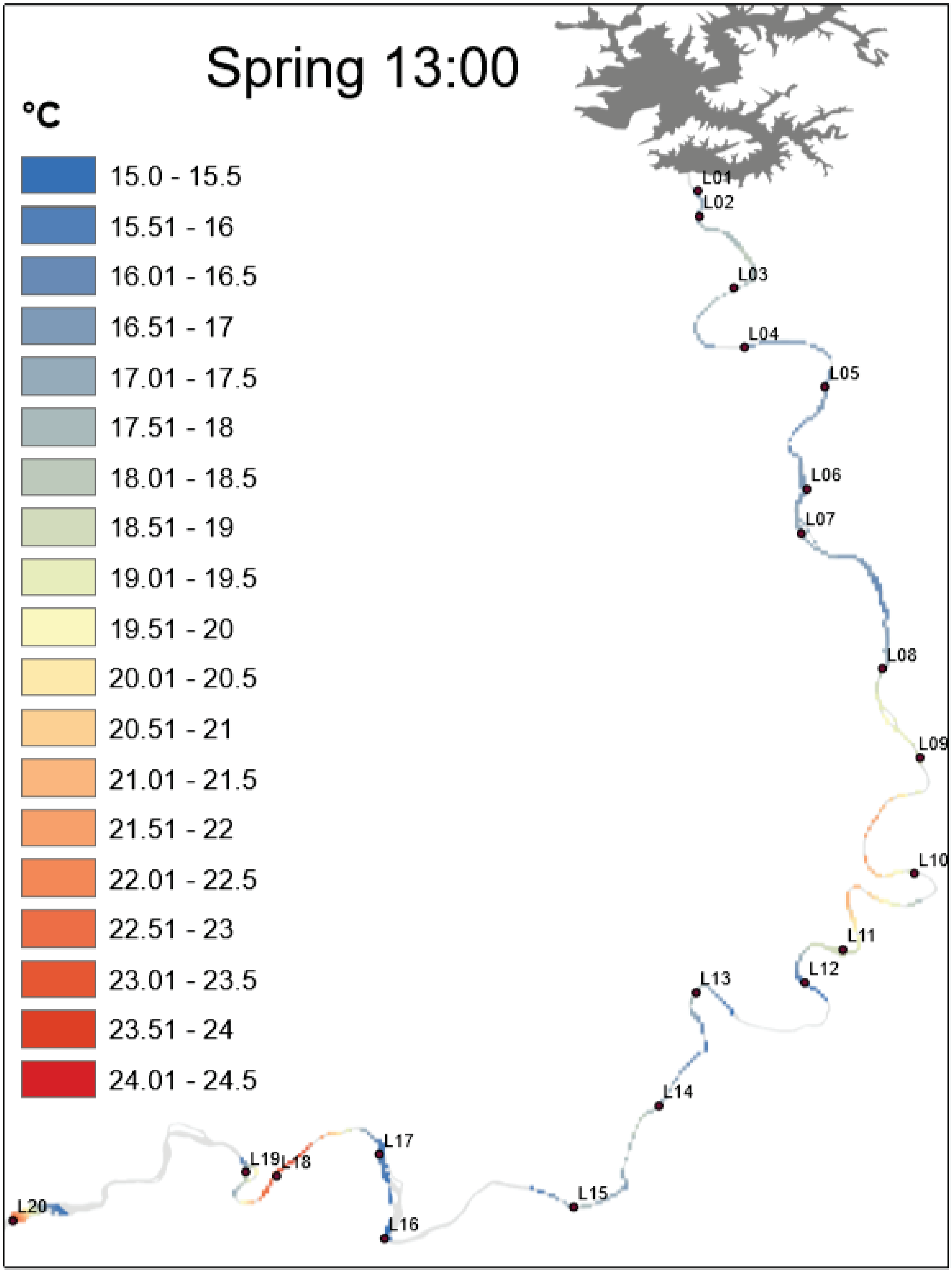

Spring 13:00
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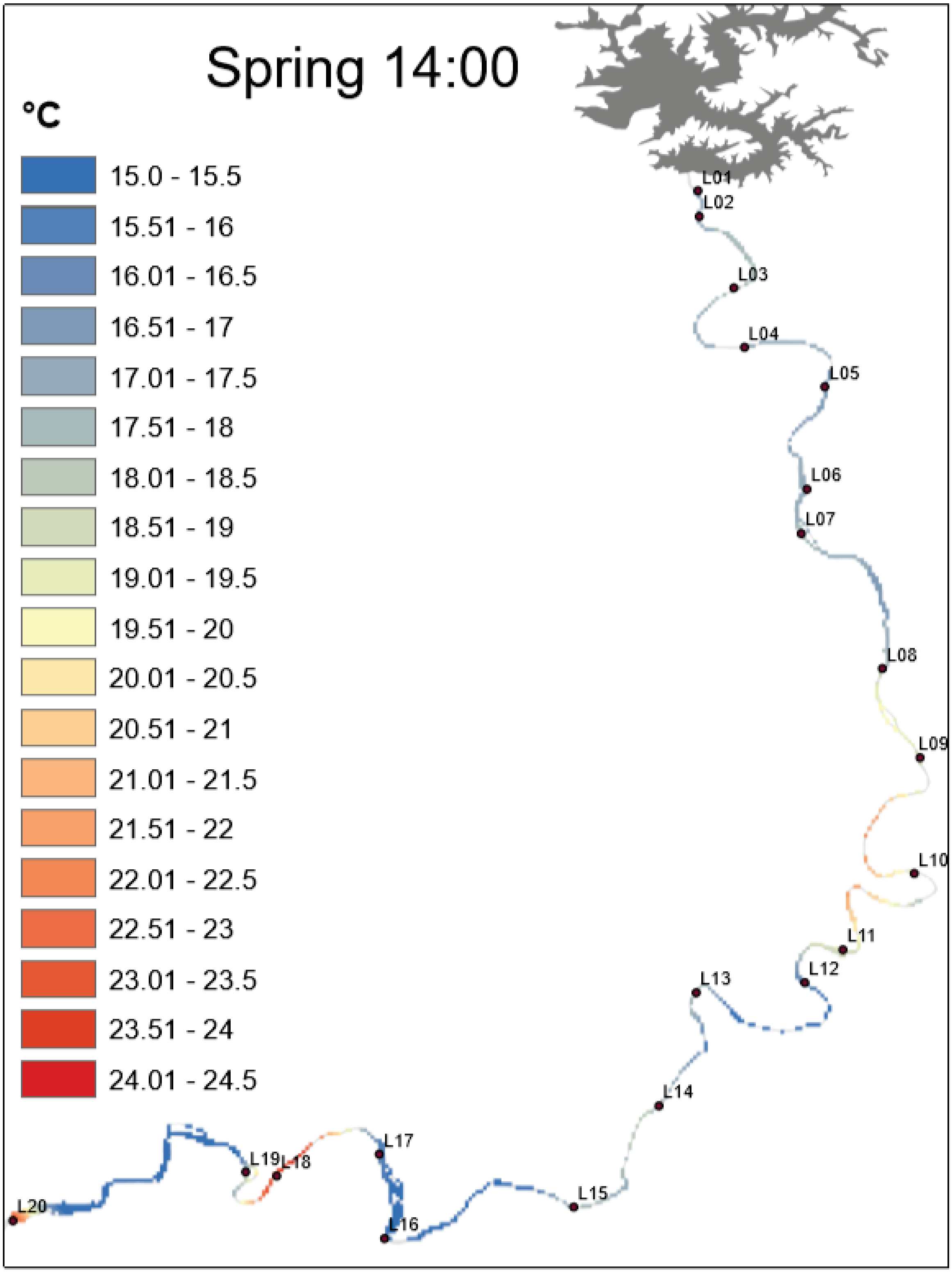
Spring 14:00
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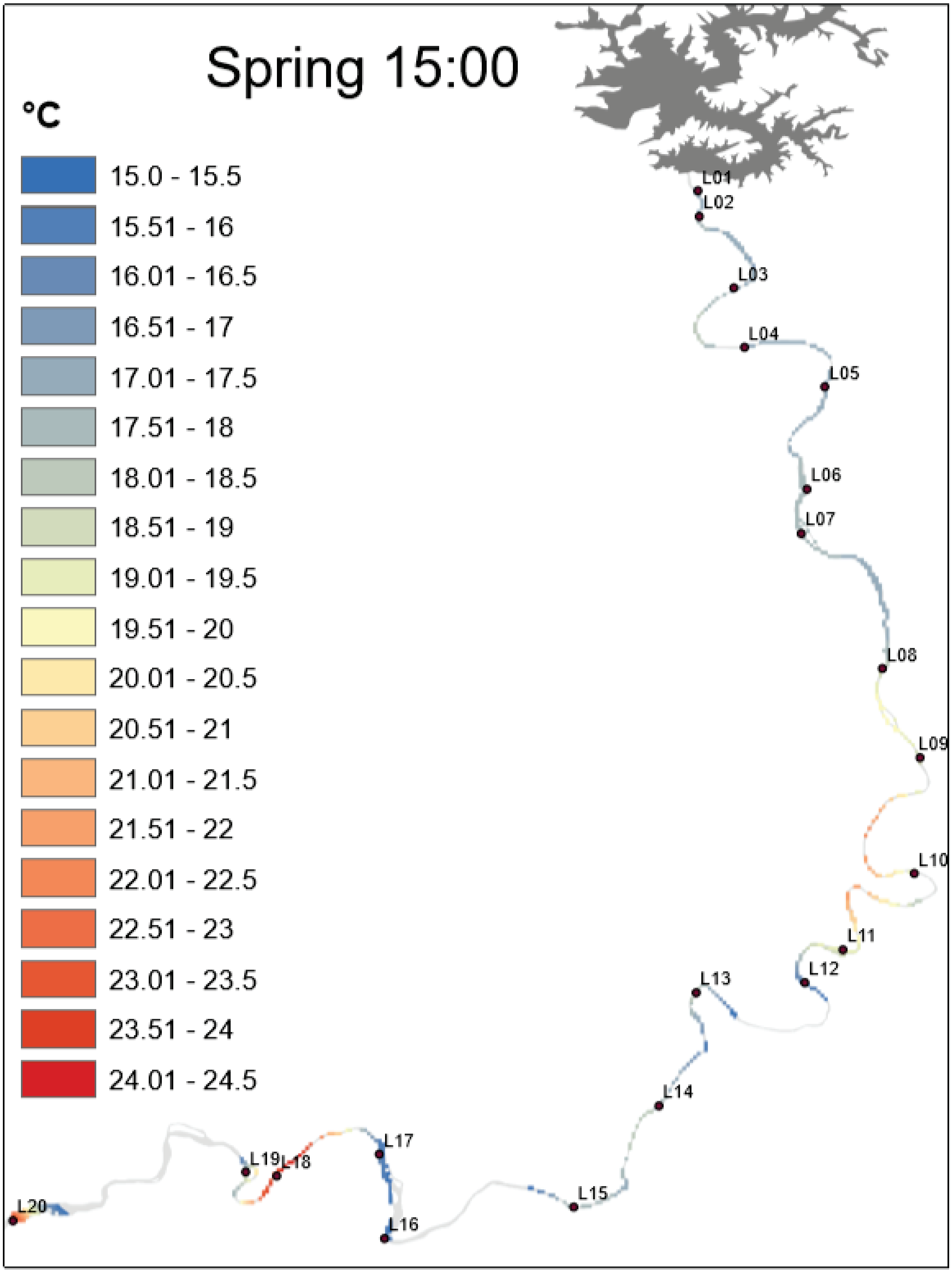

Spring 15:00
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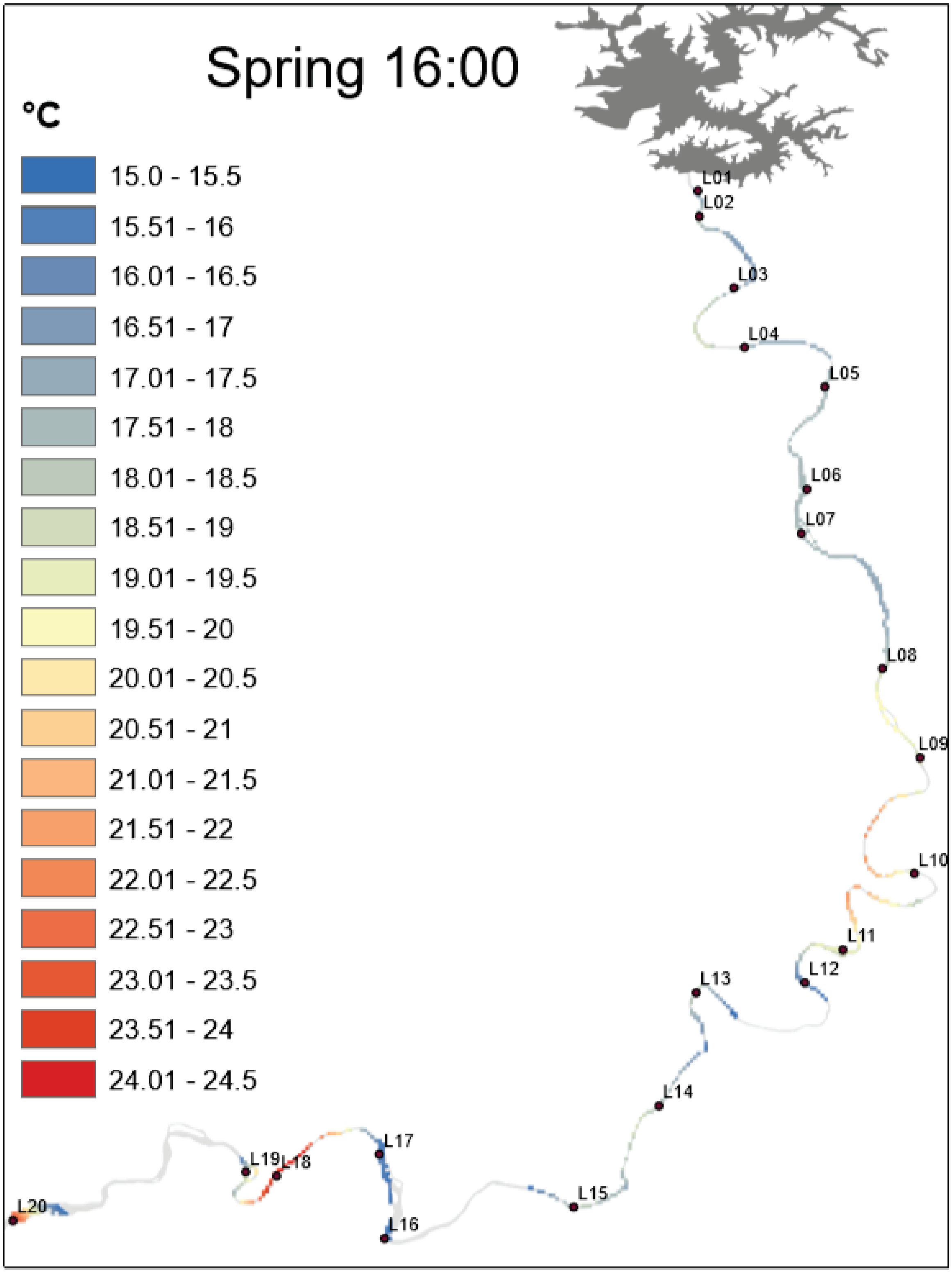
Spring 16:00
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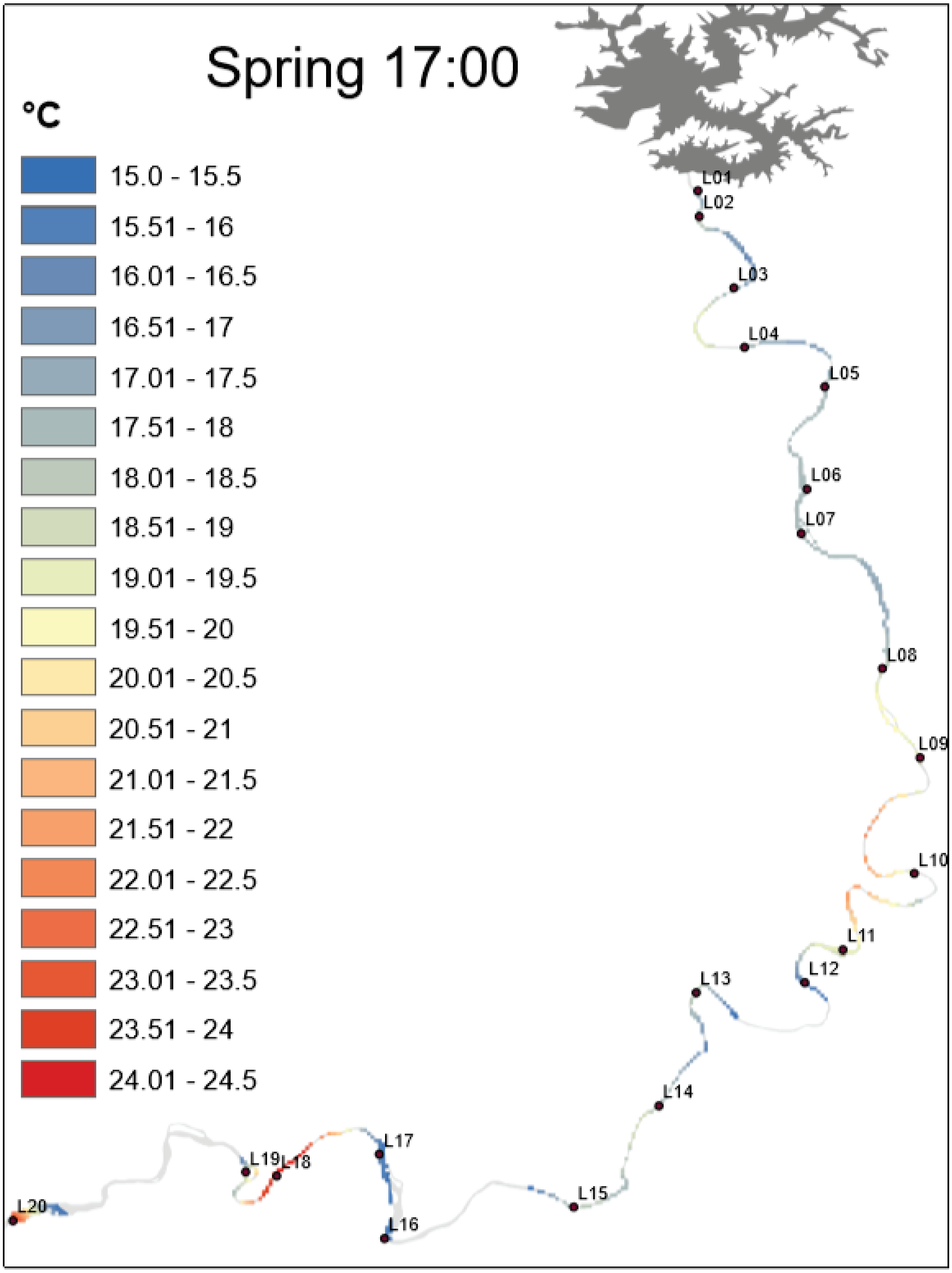
Spring 17:00
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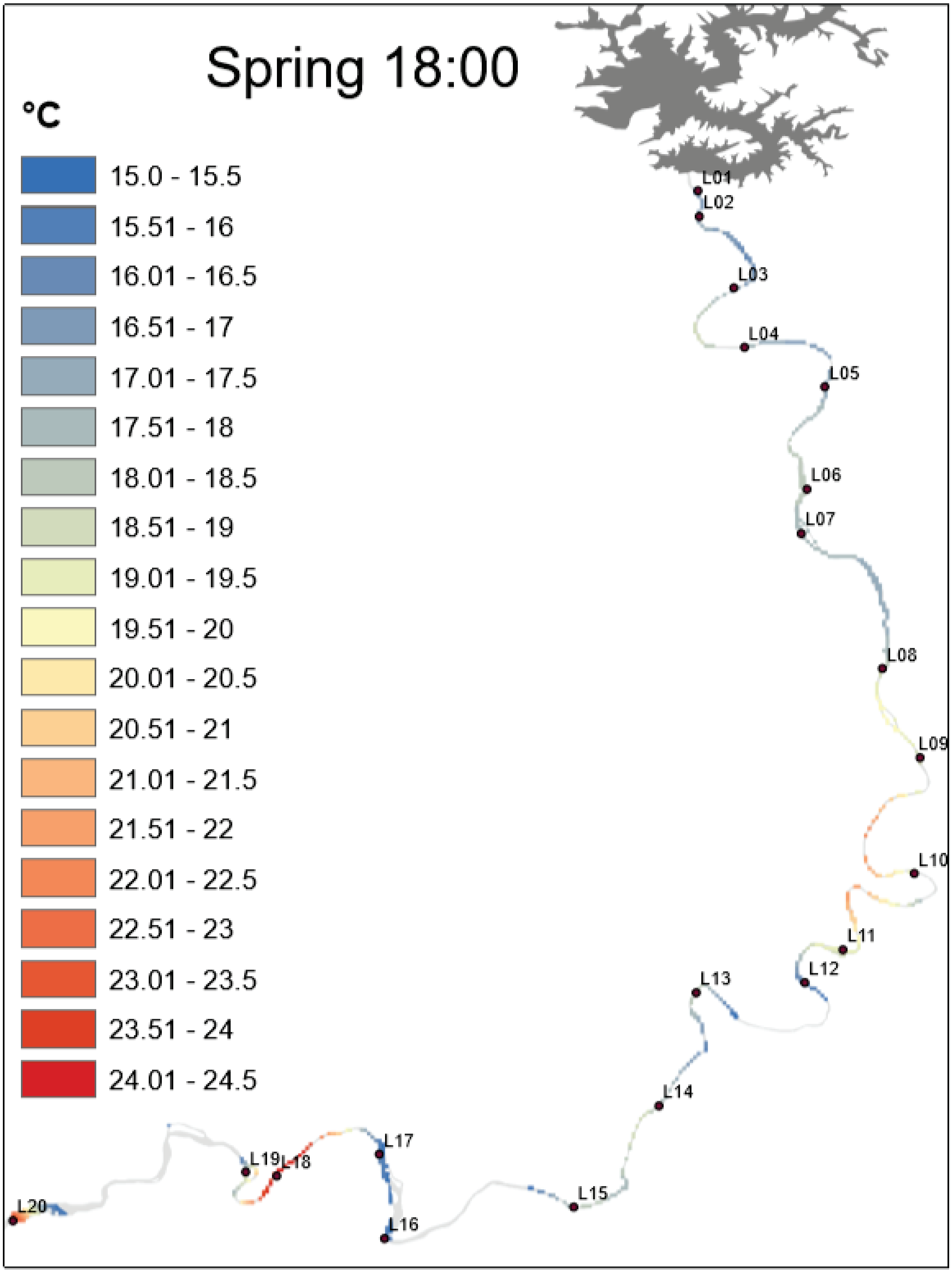

Spring 18:00
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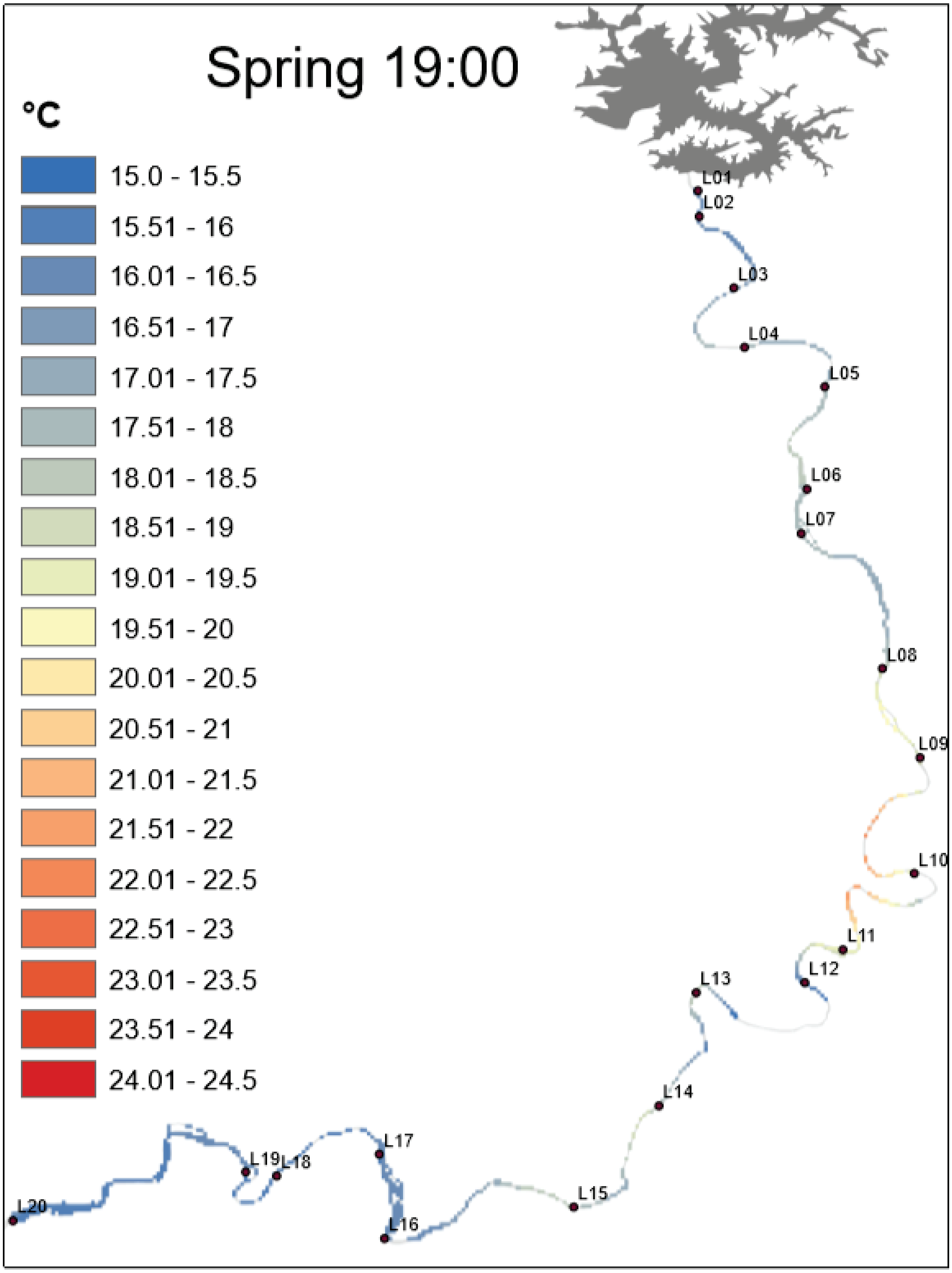

Spring 19:00
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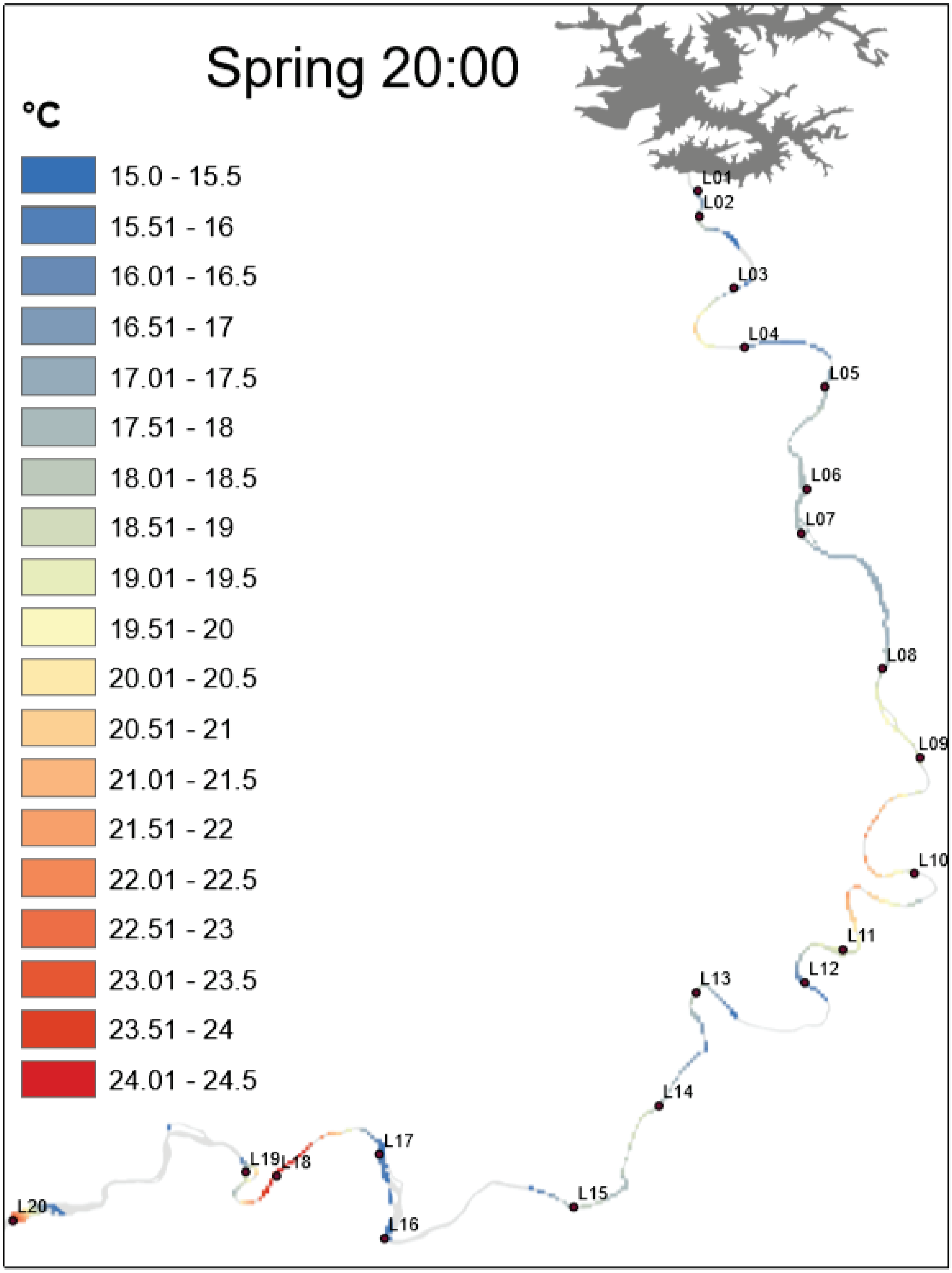
Spring 20:00
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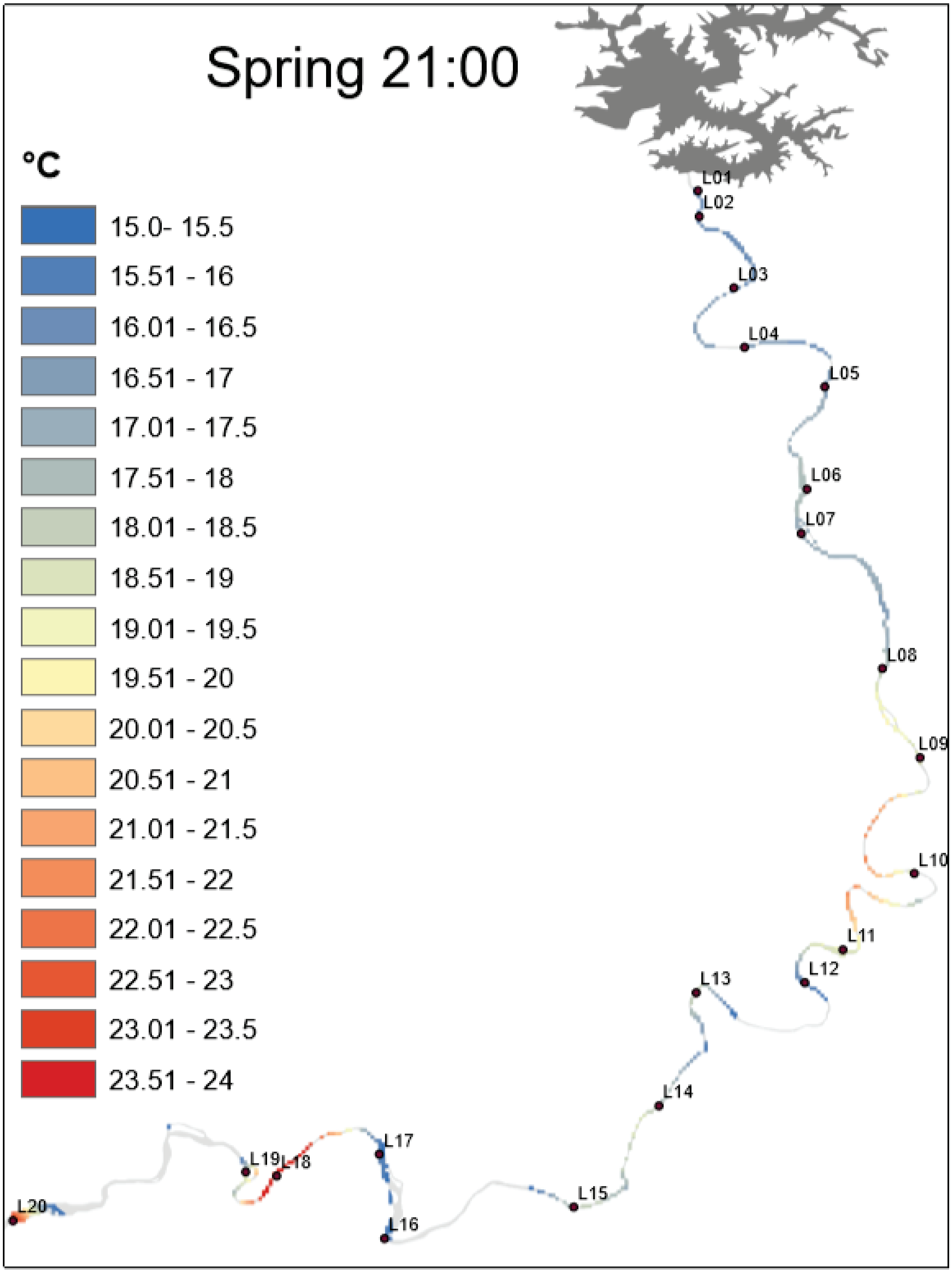

Spring 21:00
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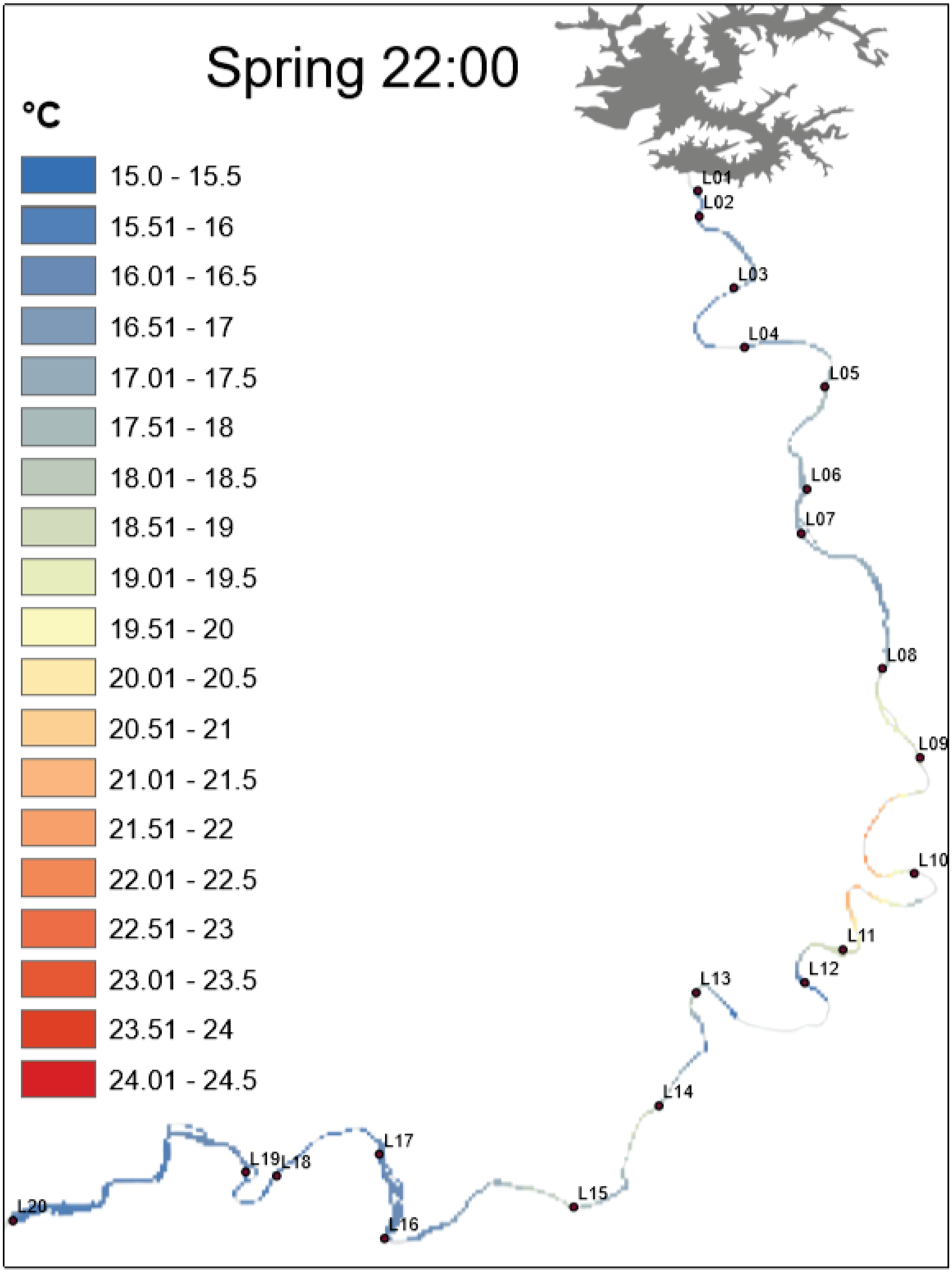

Spring 22:00
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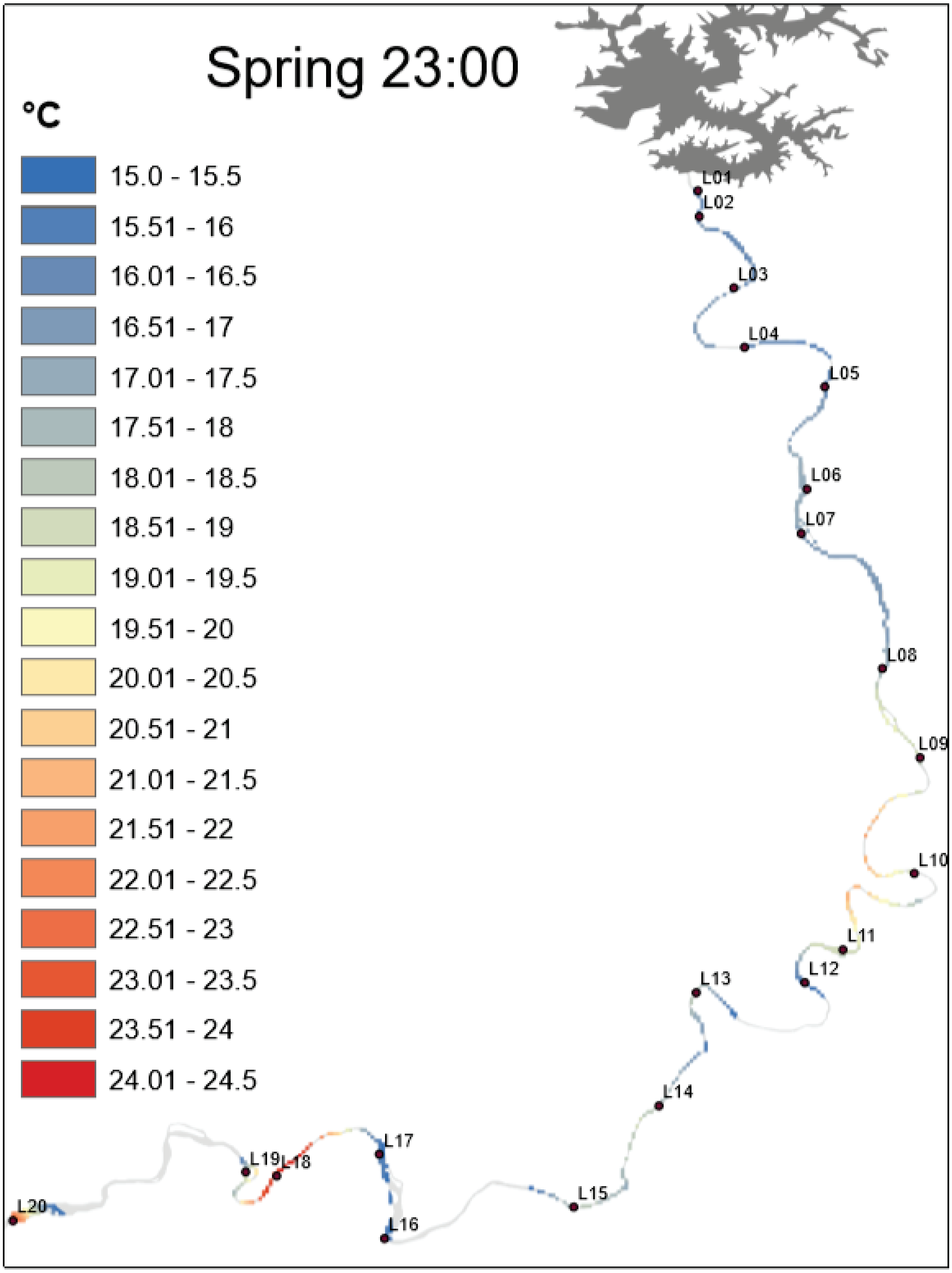
Spring 23:00
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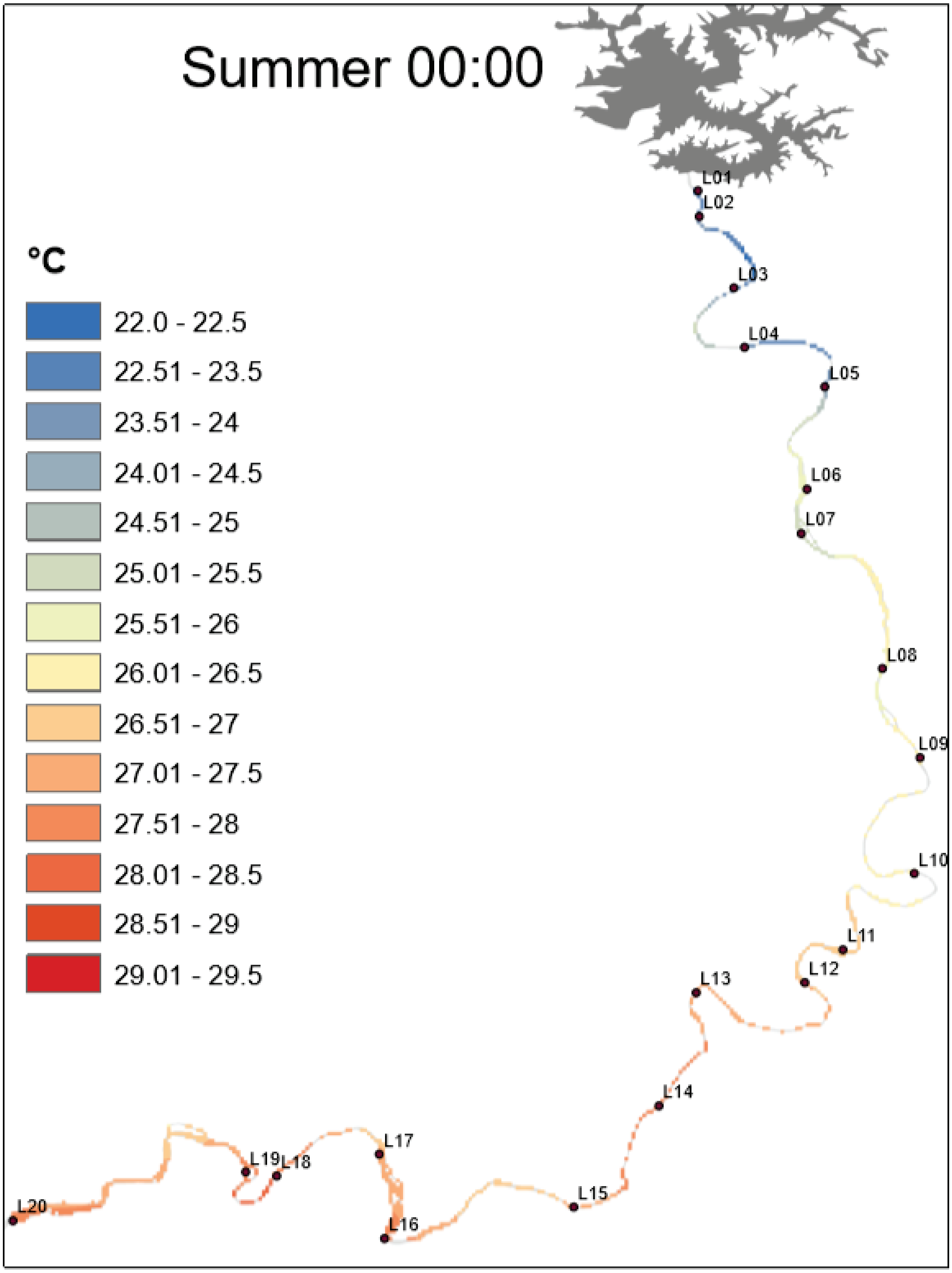
Summer 00:00
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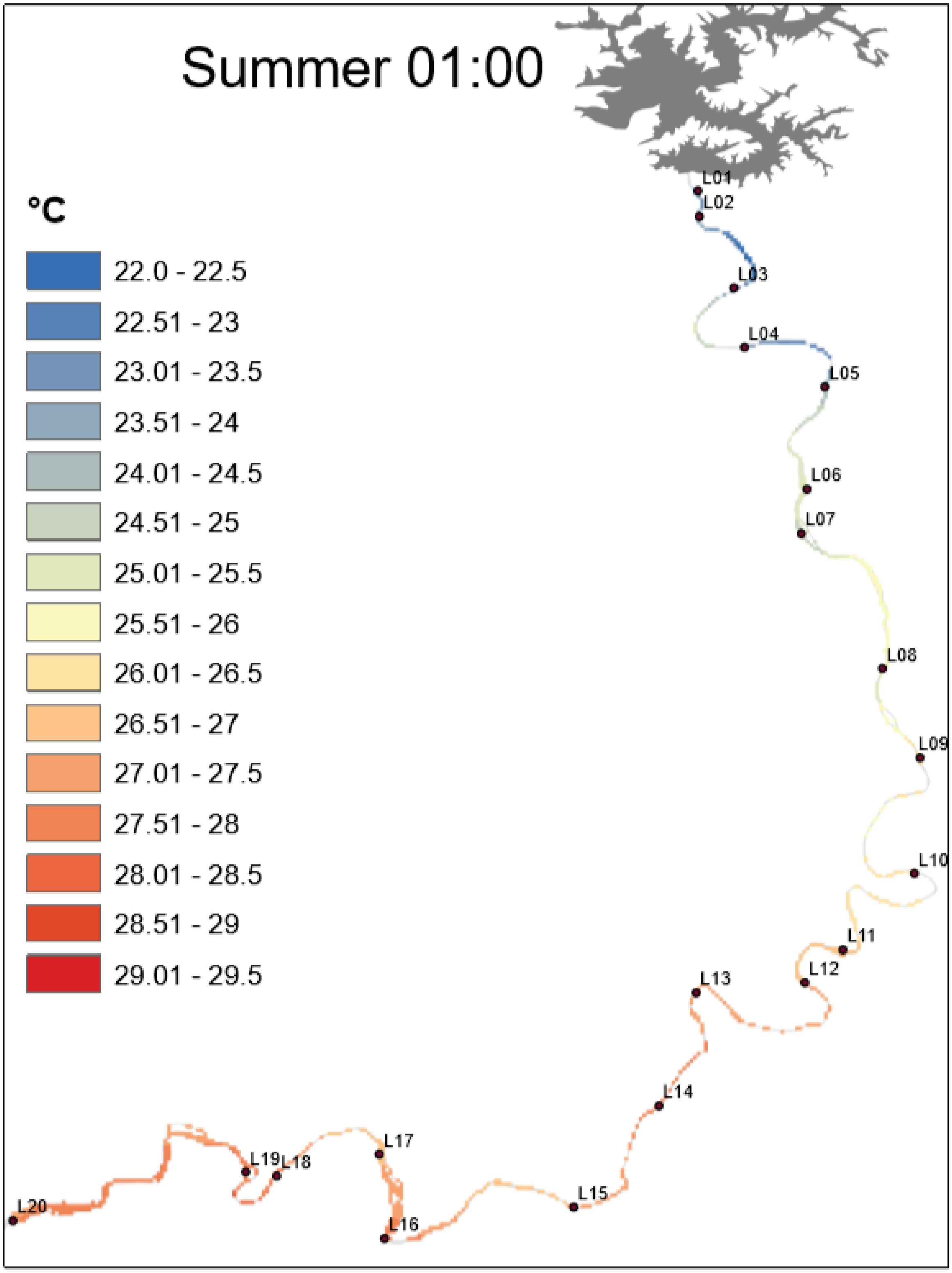
Summer 01:00
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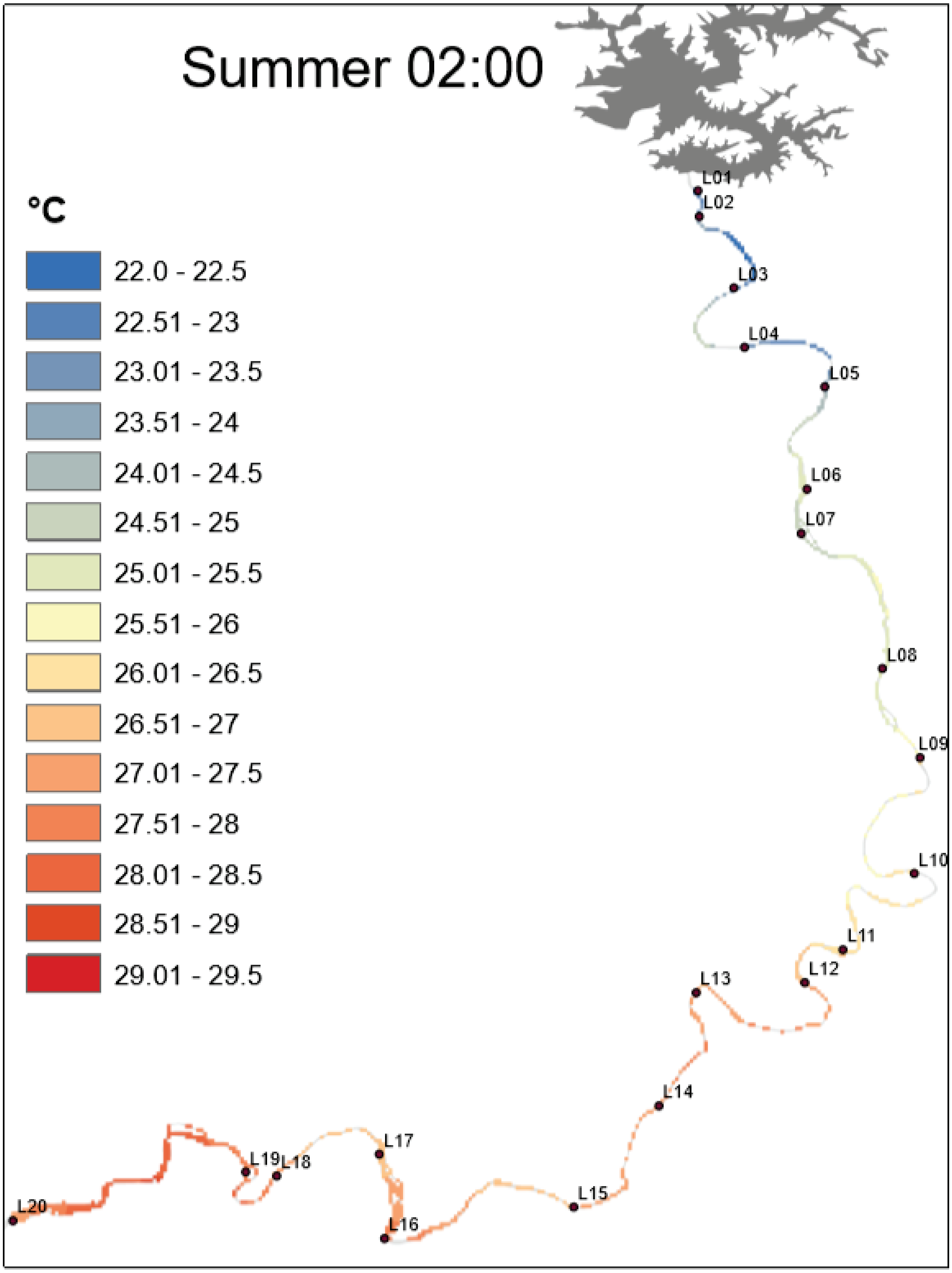

Summer 02:00
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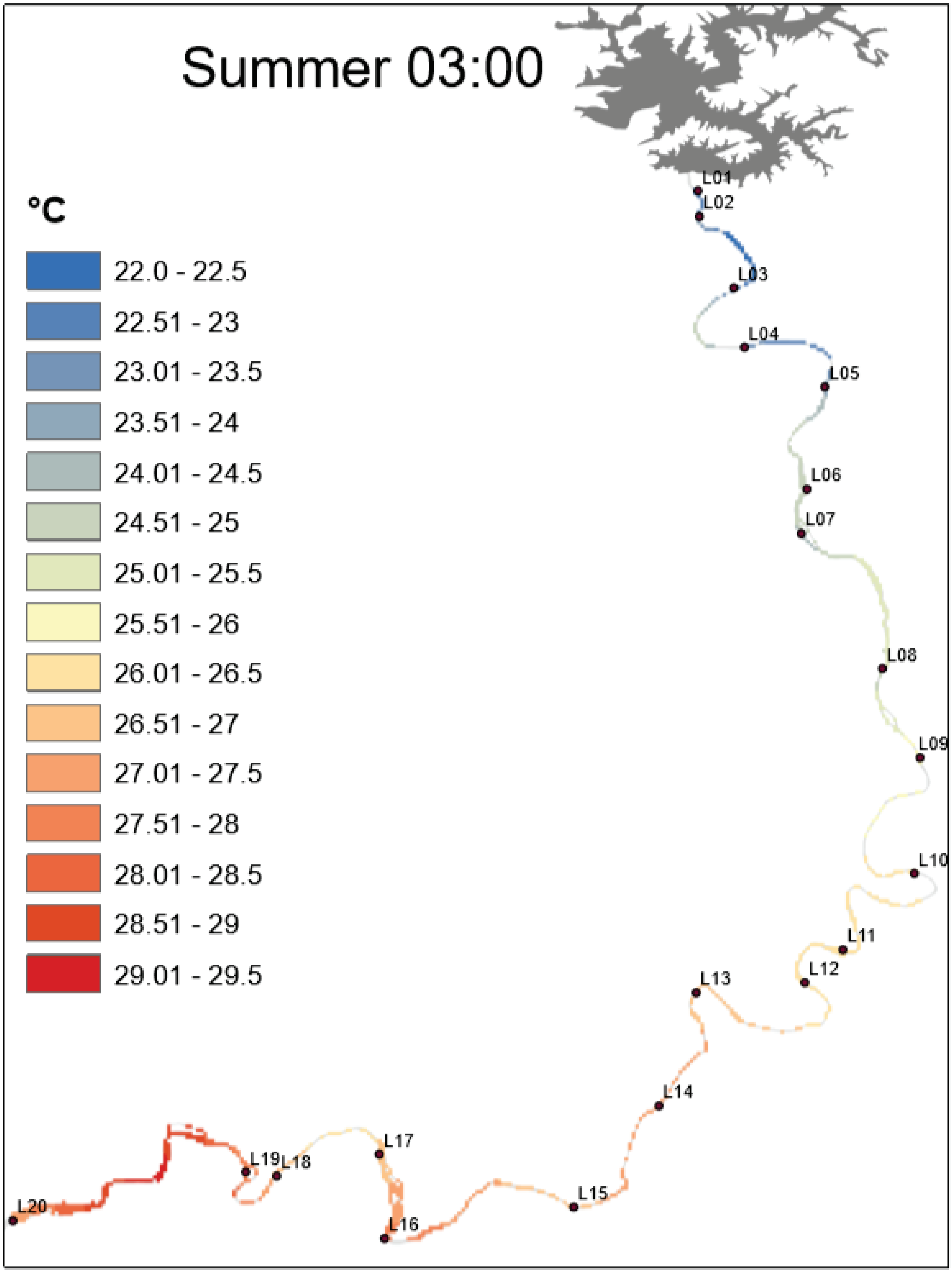
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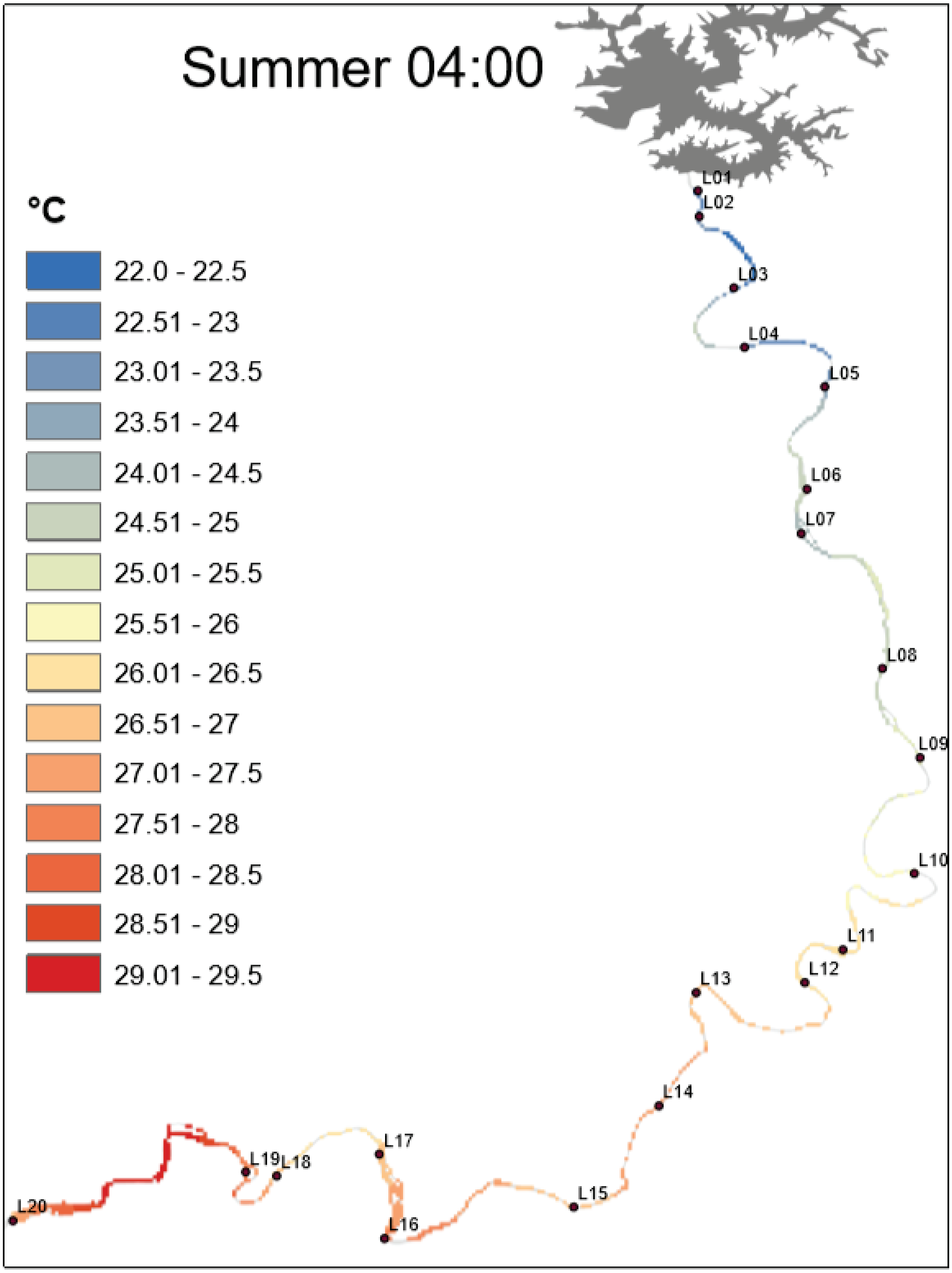
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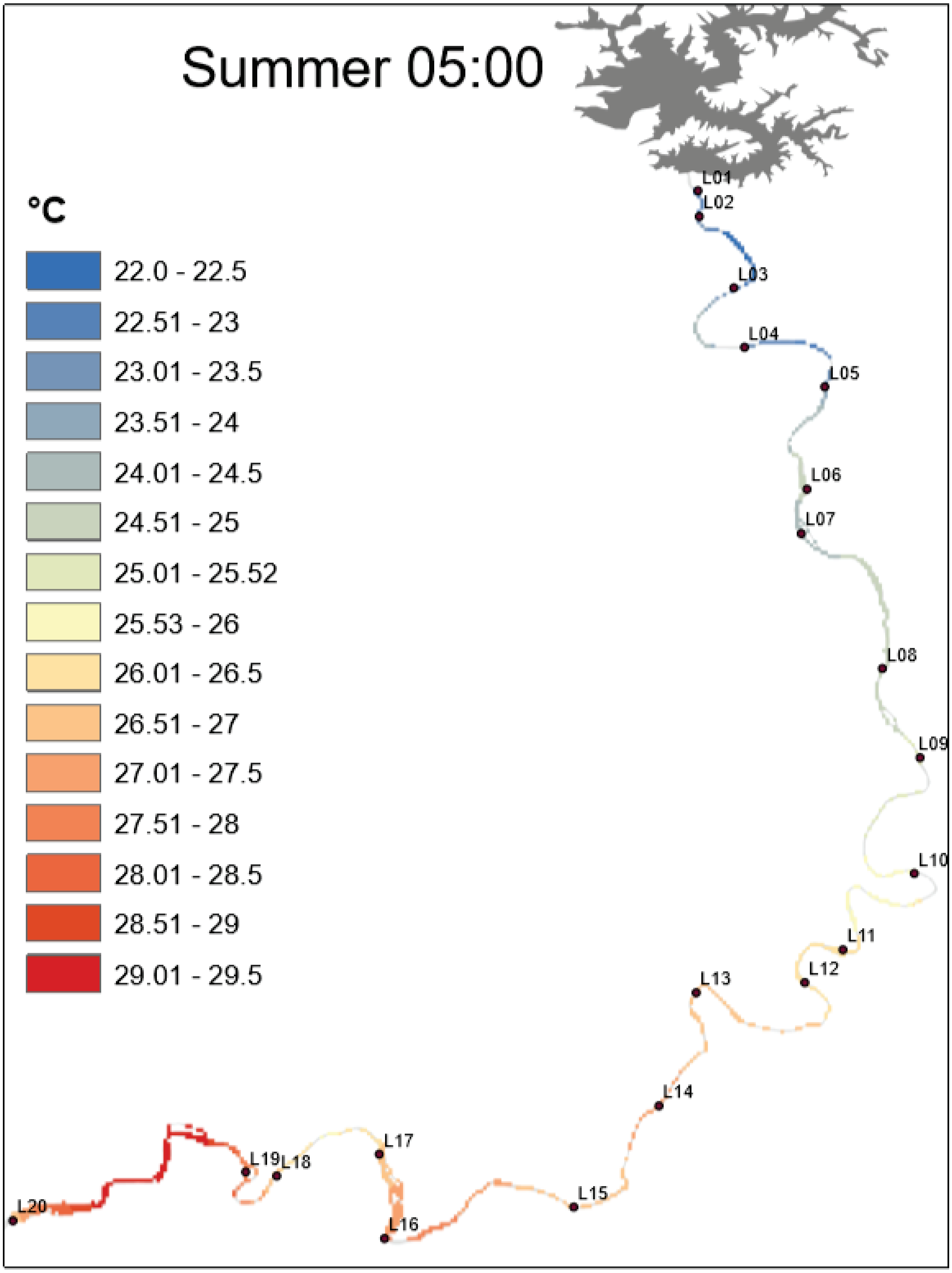
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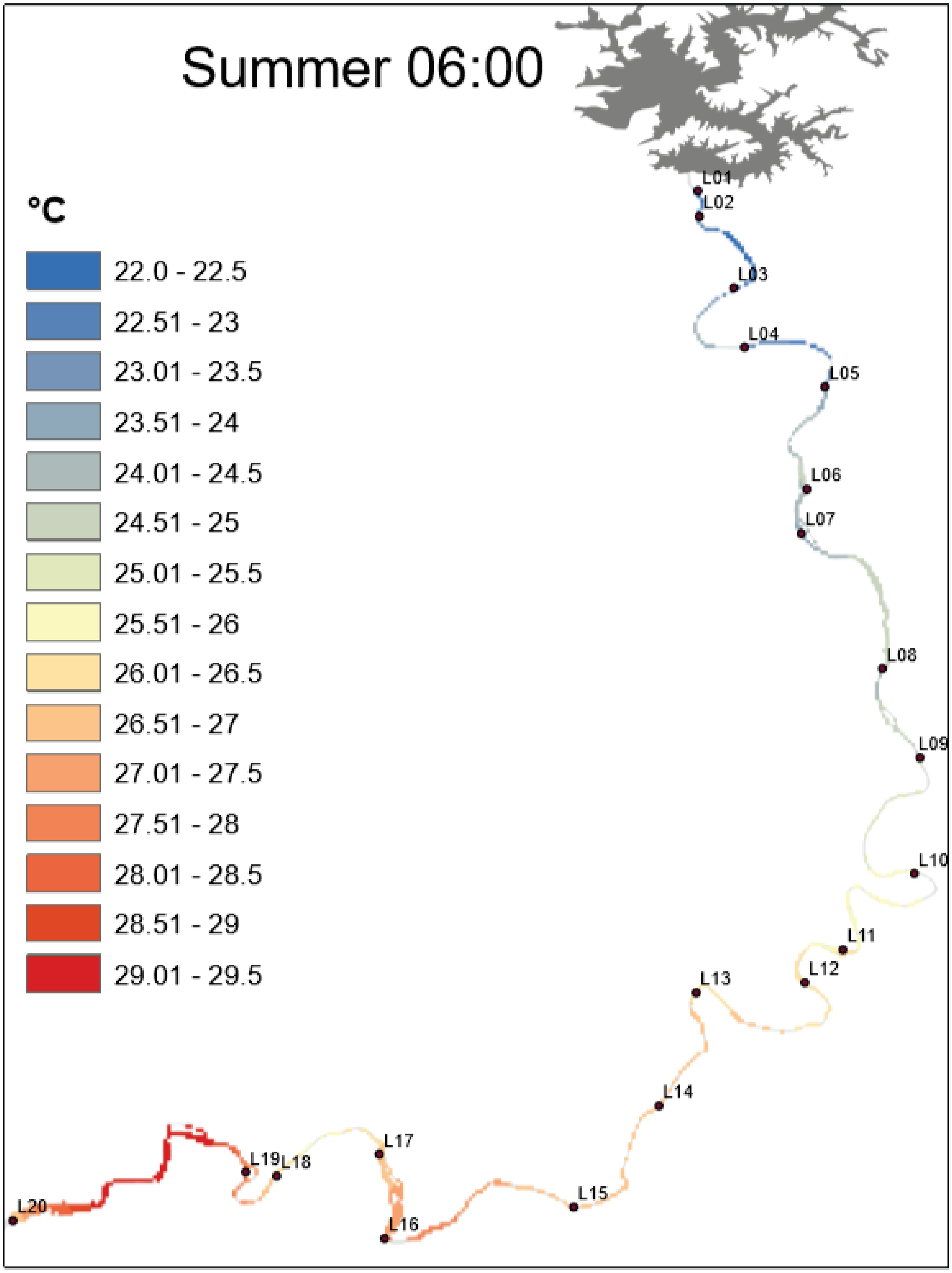
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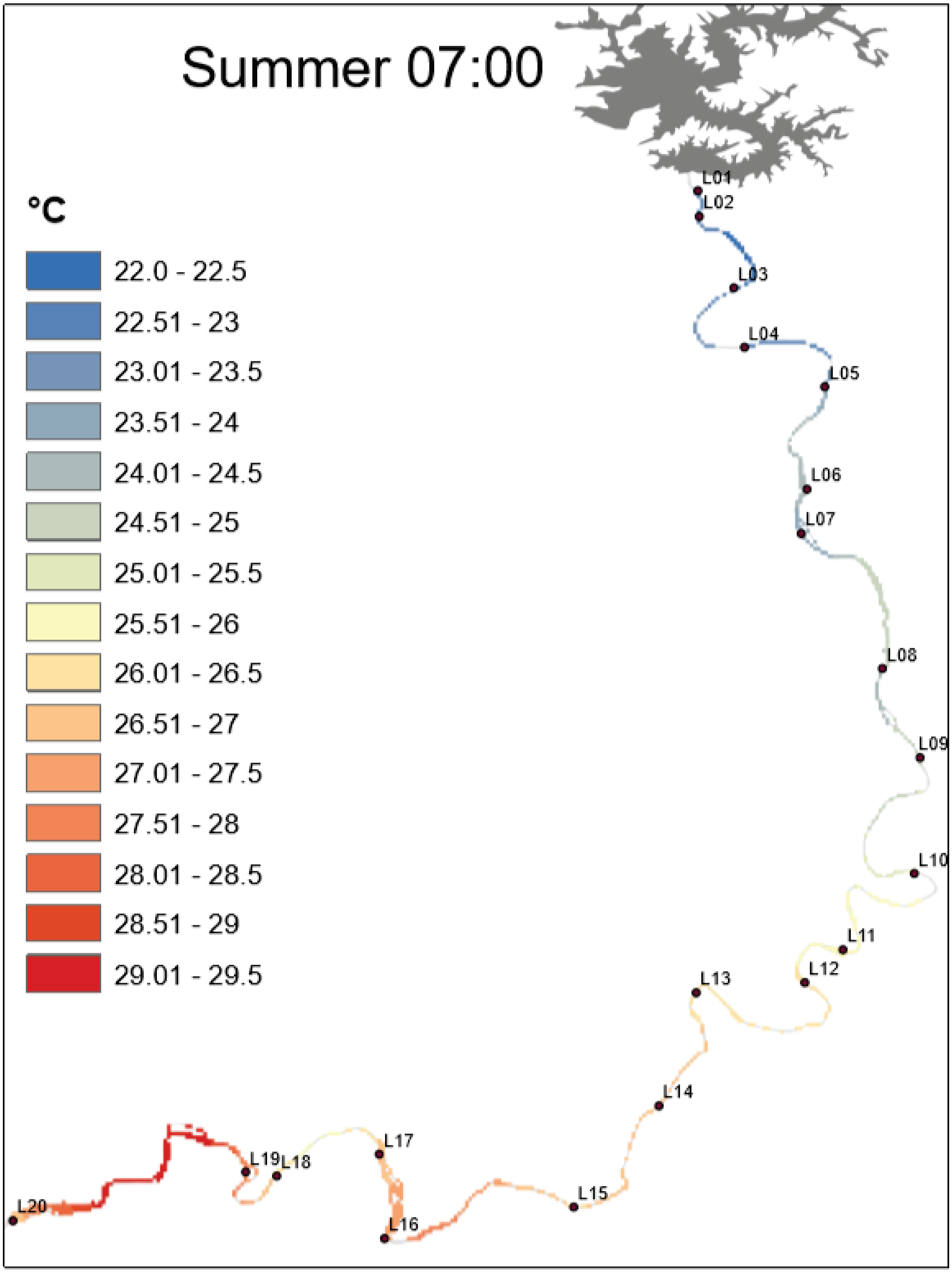
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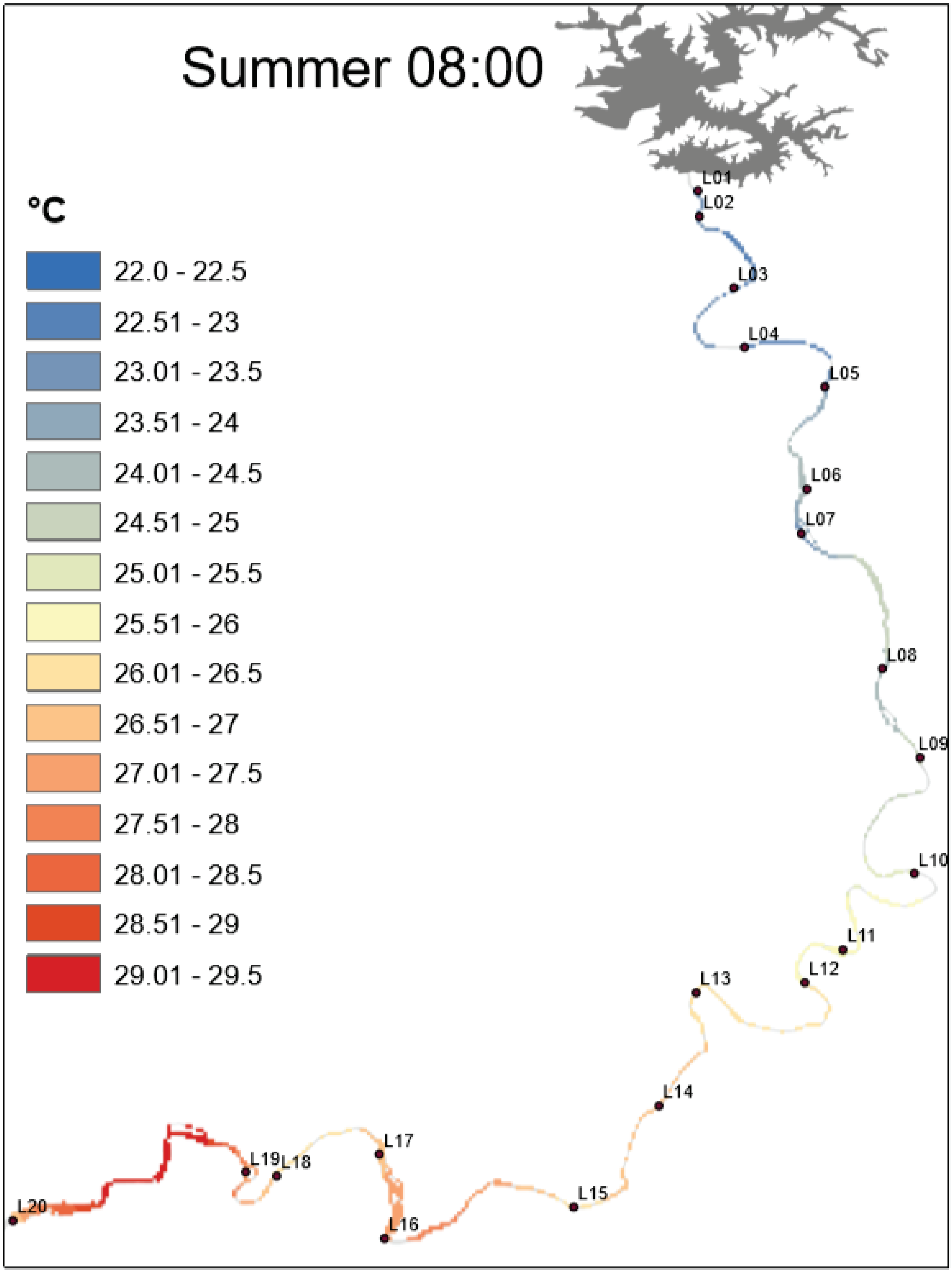
Summer 08:00
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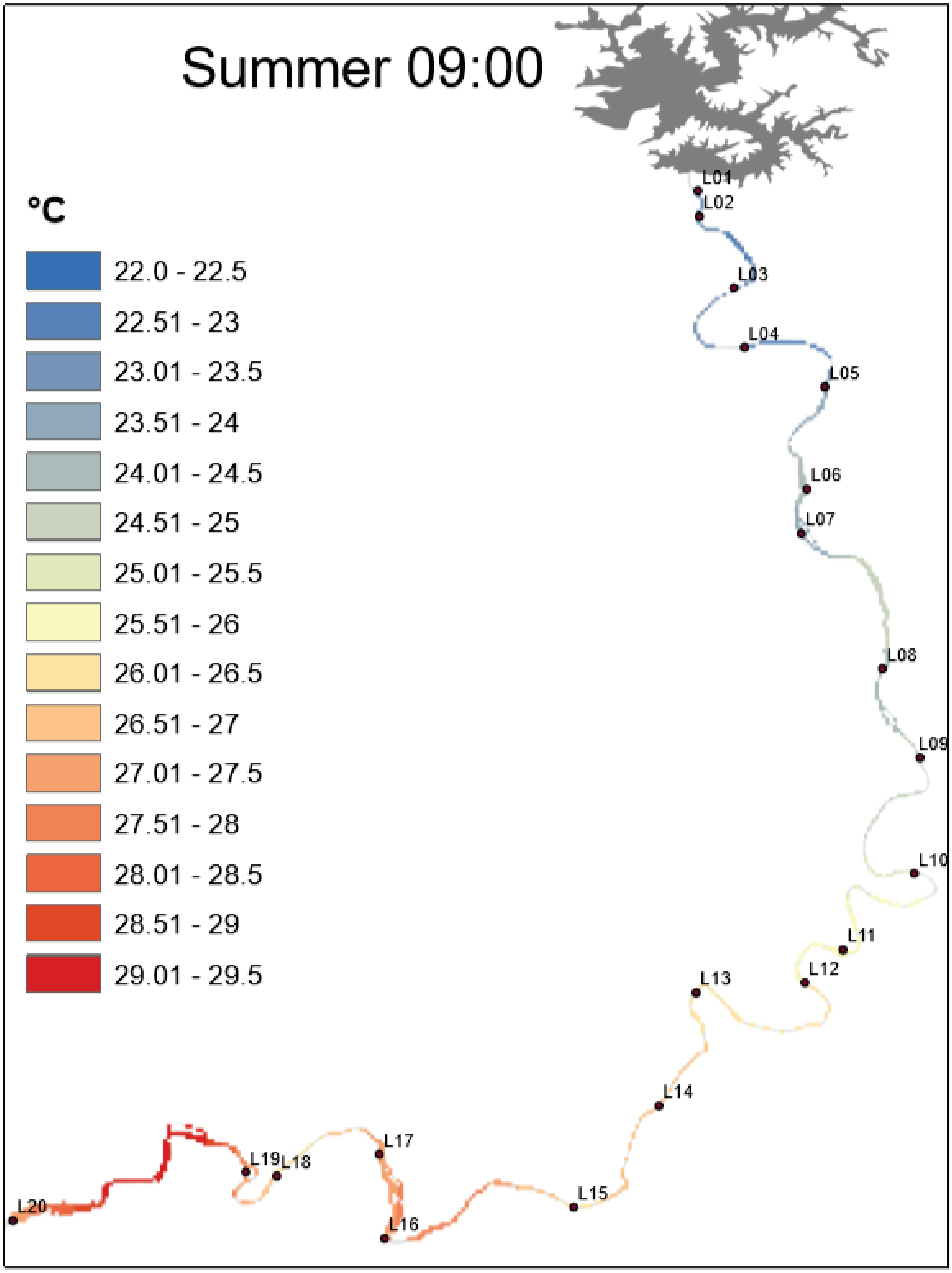

Summer 09:00
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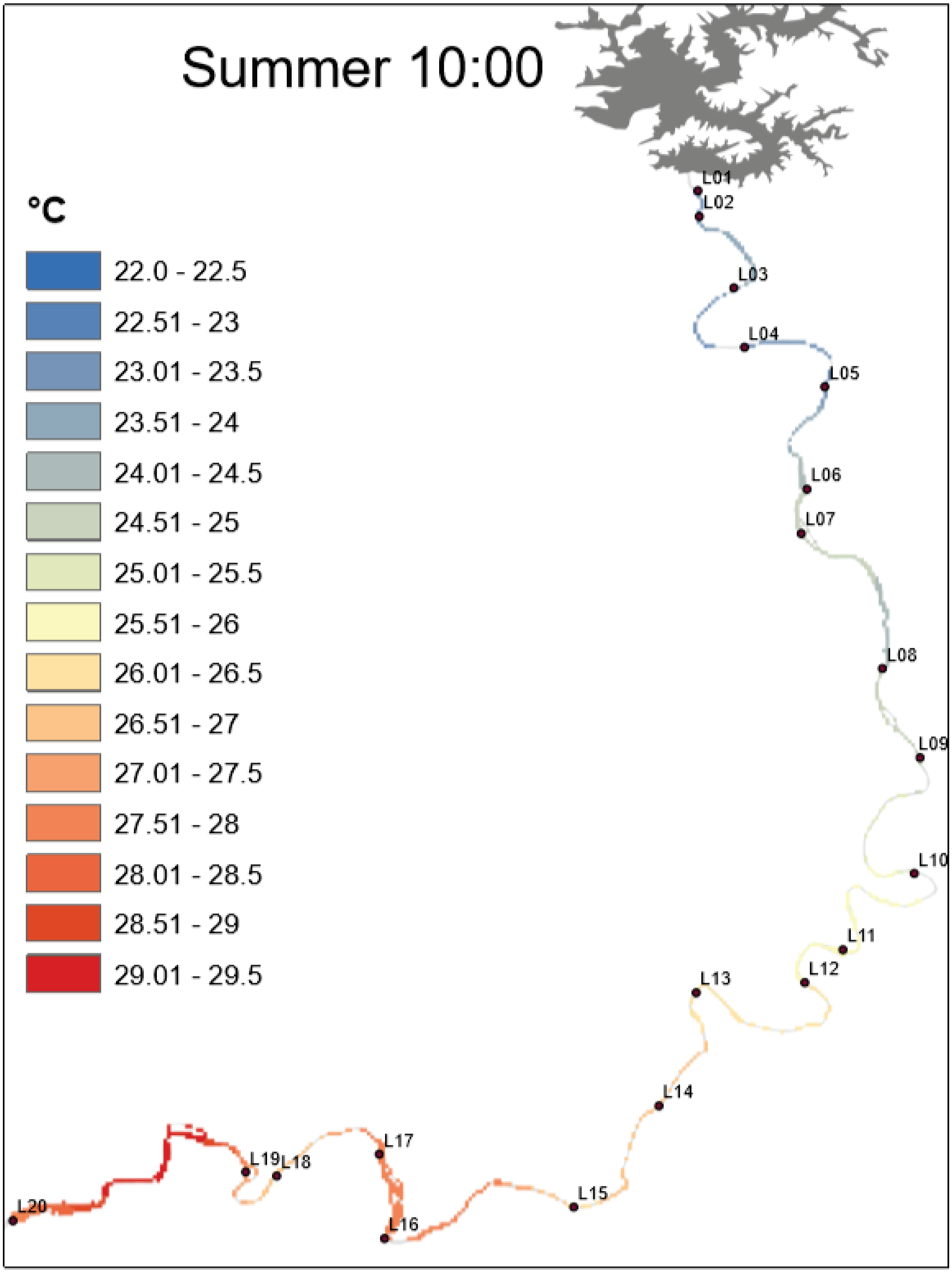

Summer 10:00
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23.01 - 23.5
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24.01 - 24.5
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27.01 - 27.5
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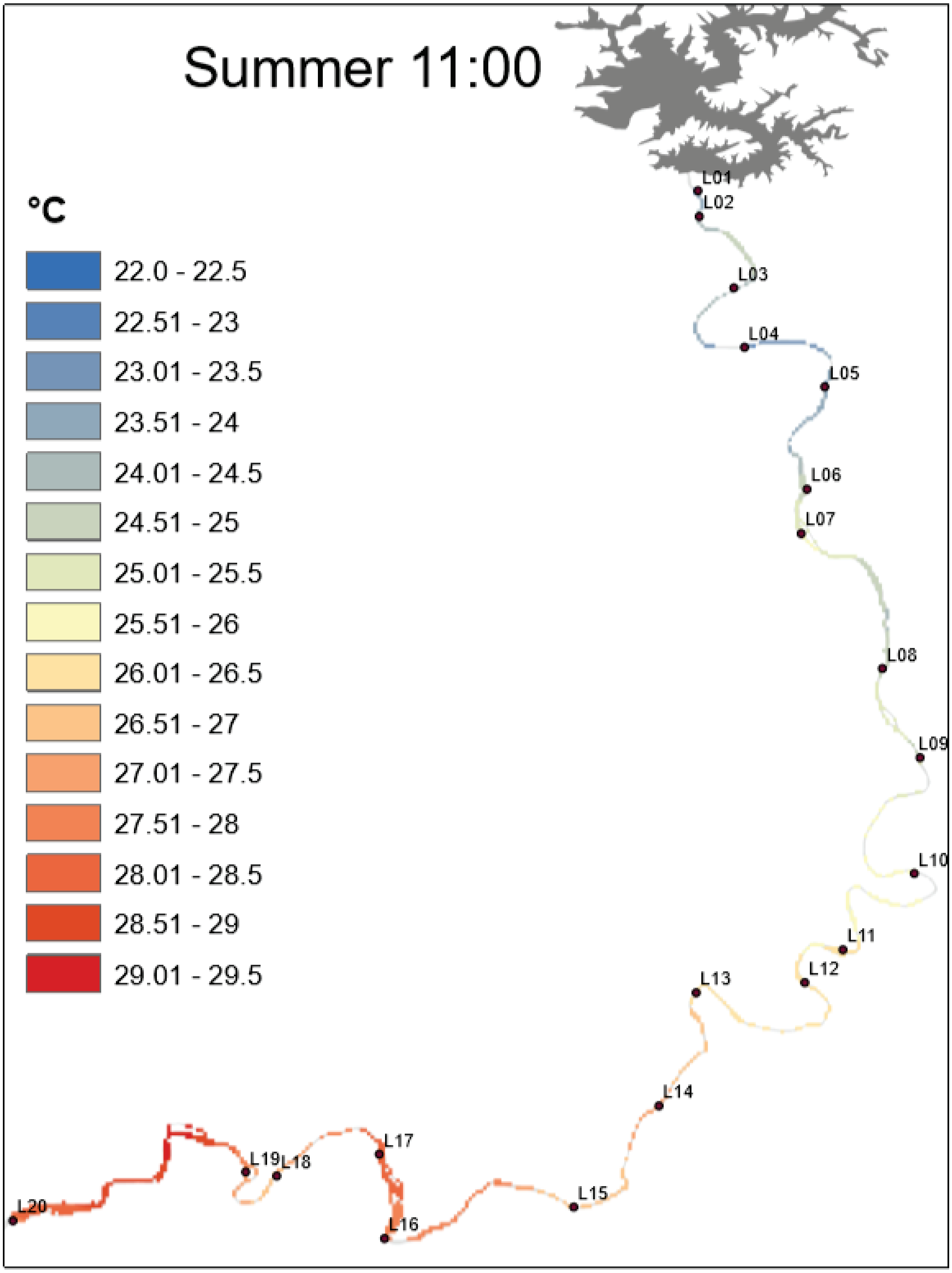

Summer 11:00
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25.01 - 25.5
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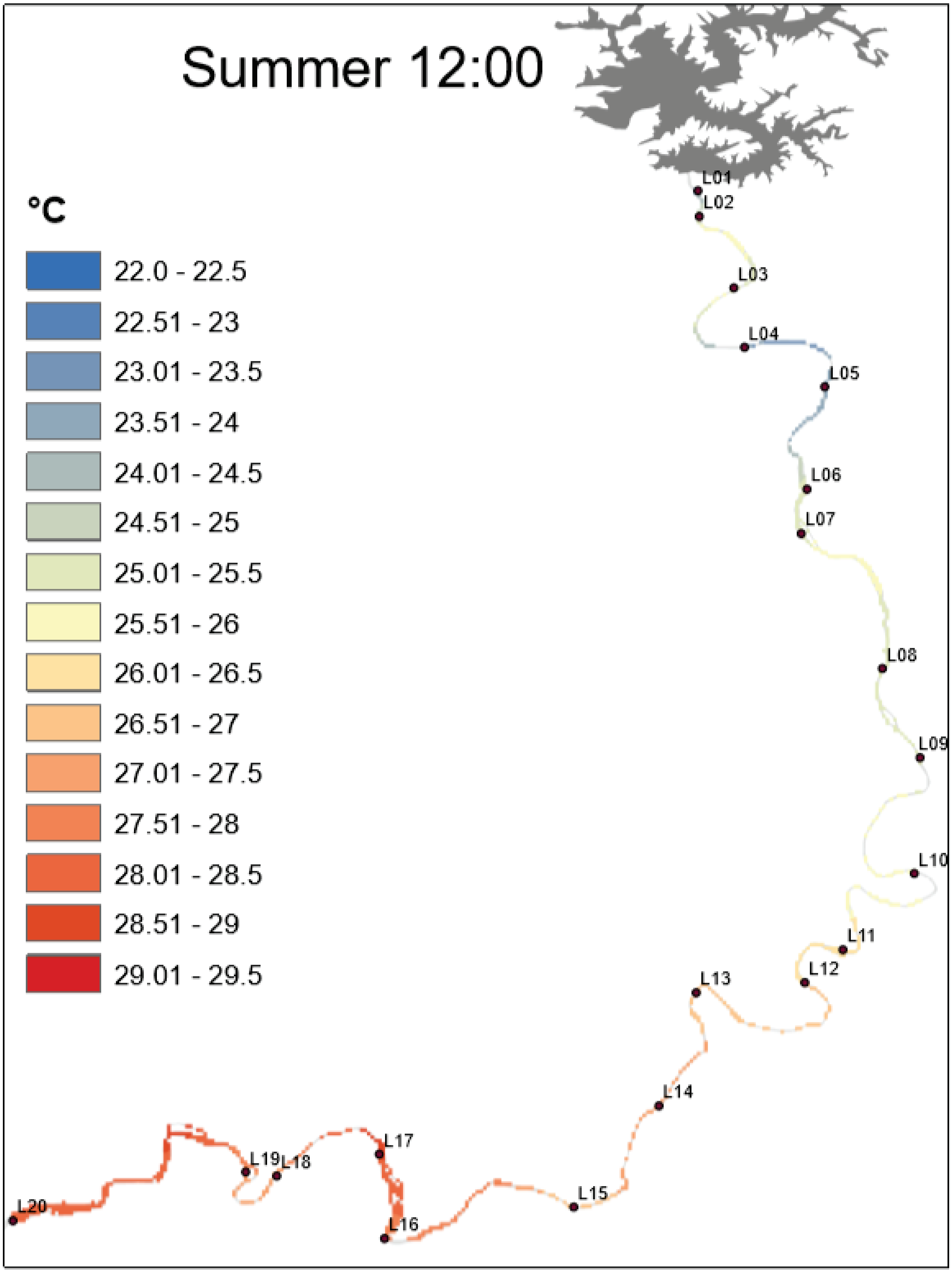

Summer 12:00
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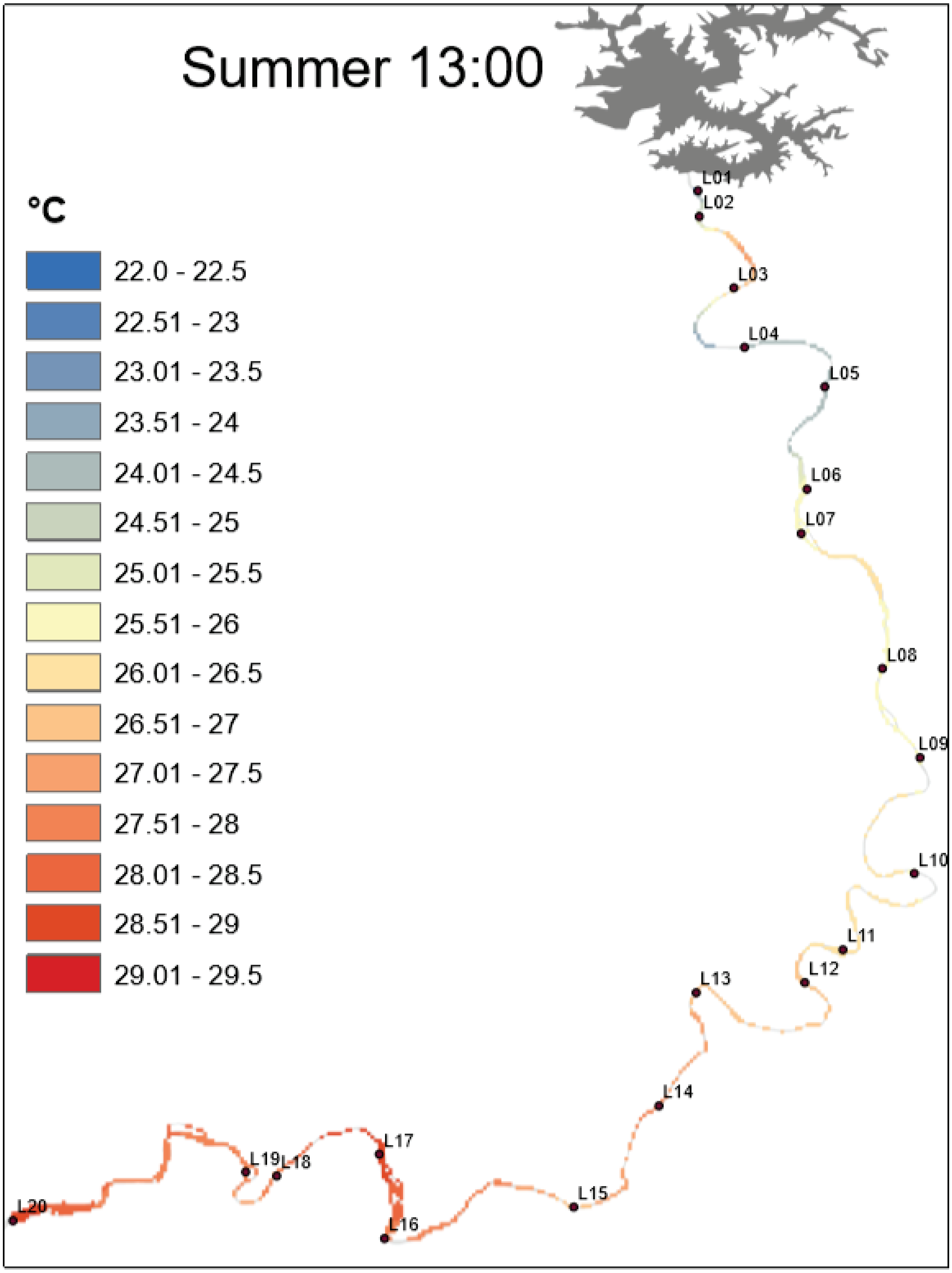

Summer 13:00
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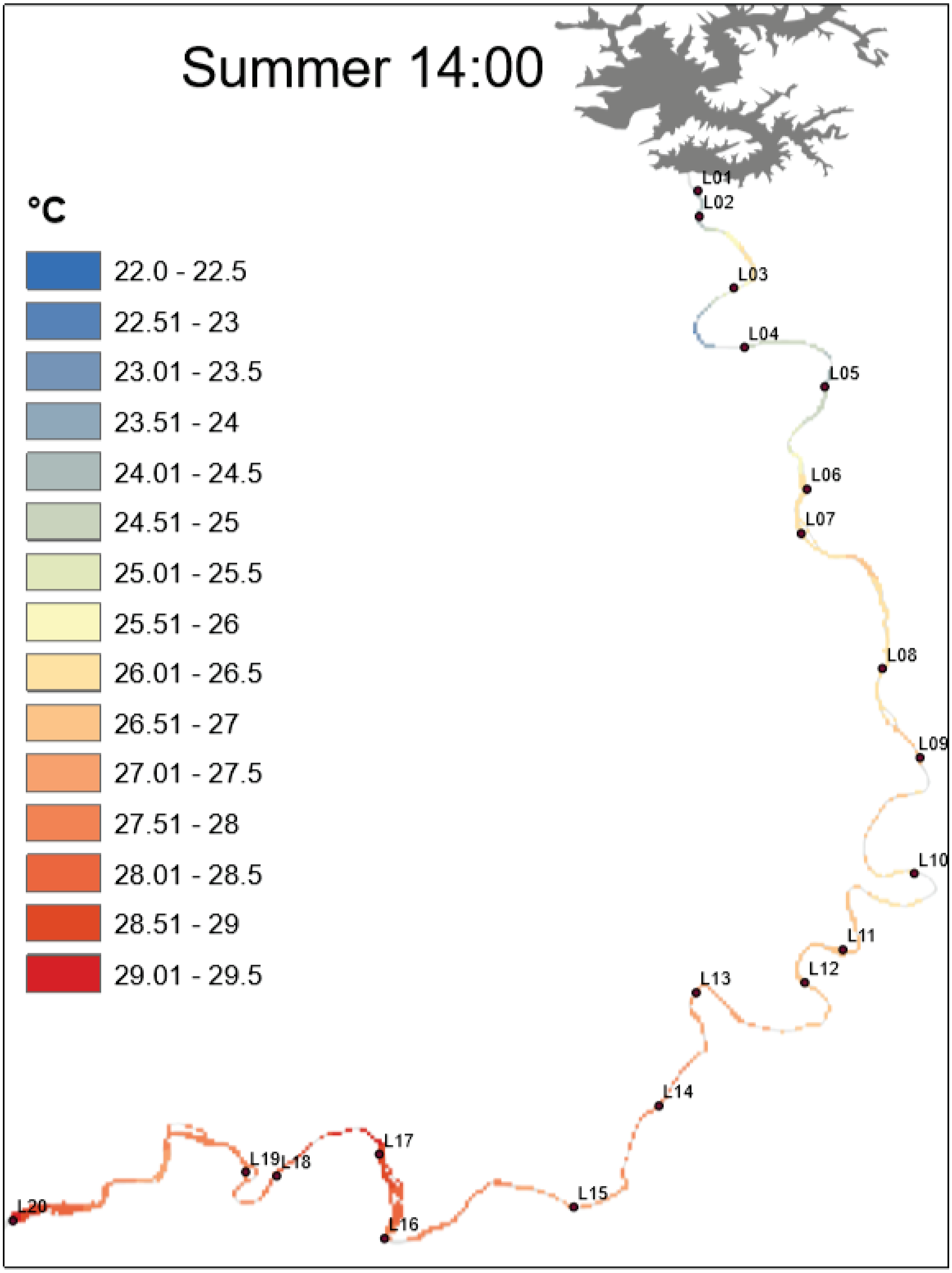

Summer 14:00
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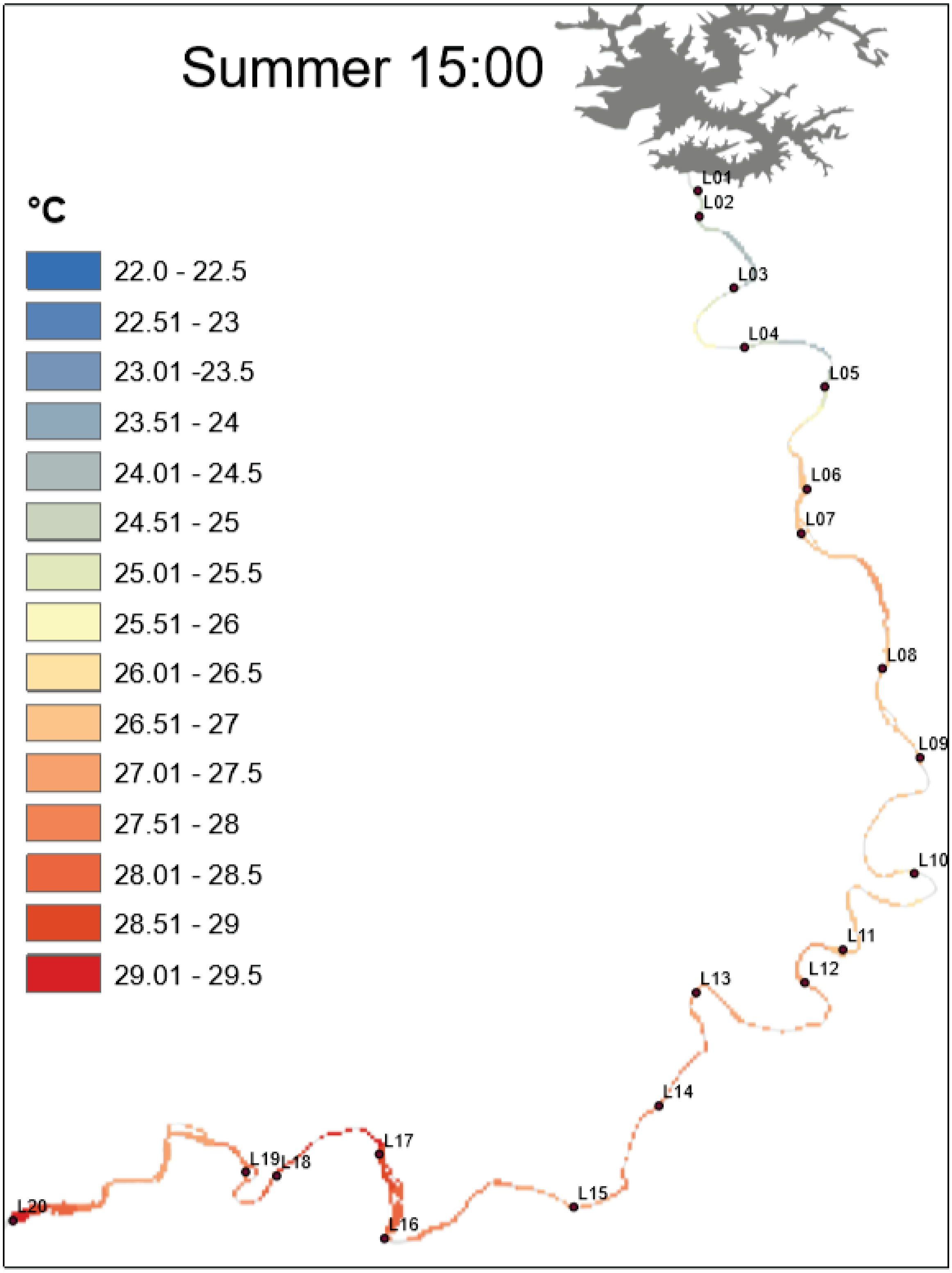
Summer 15:00
°C
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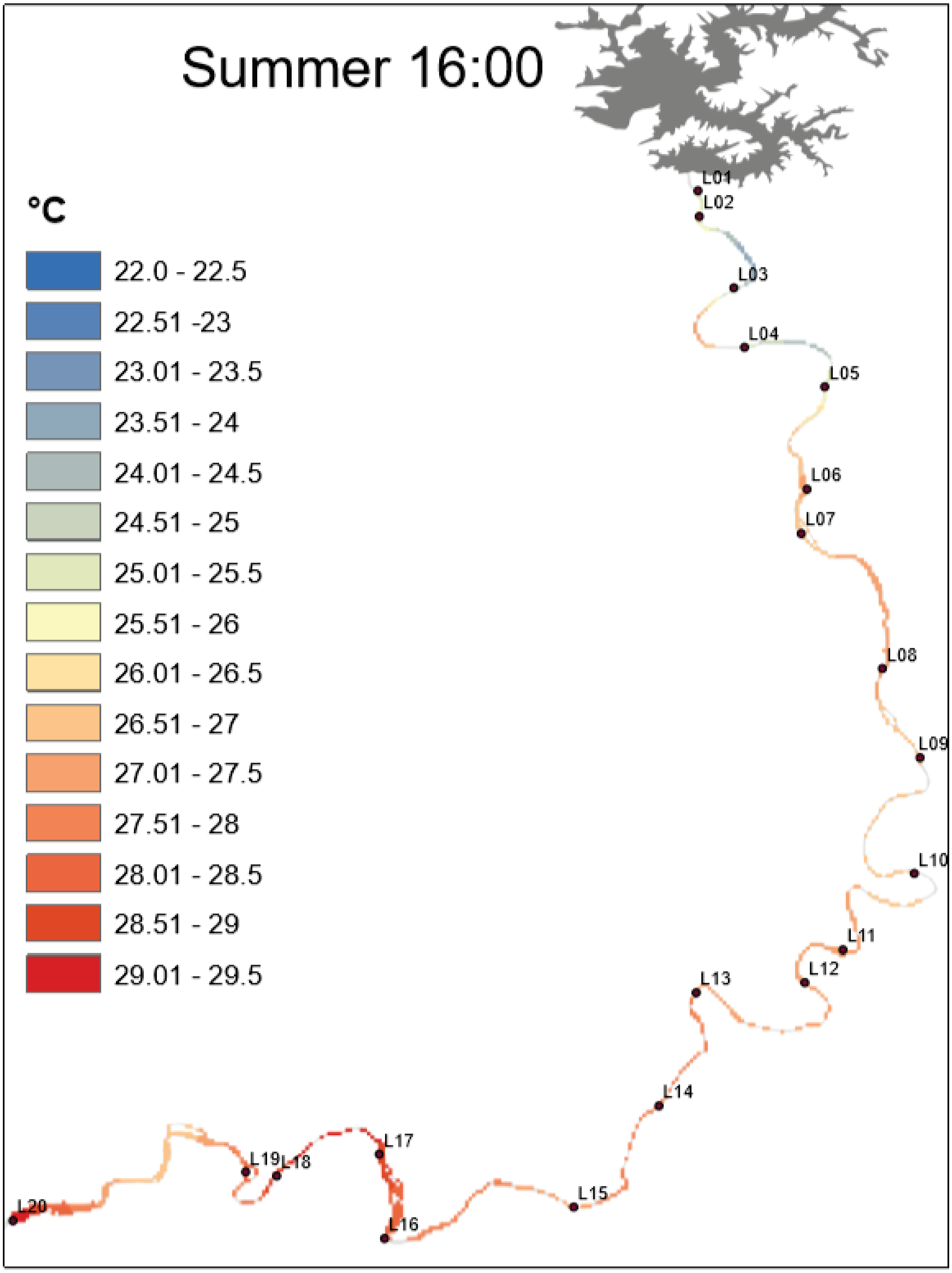
Summer 16:00
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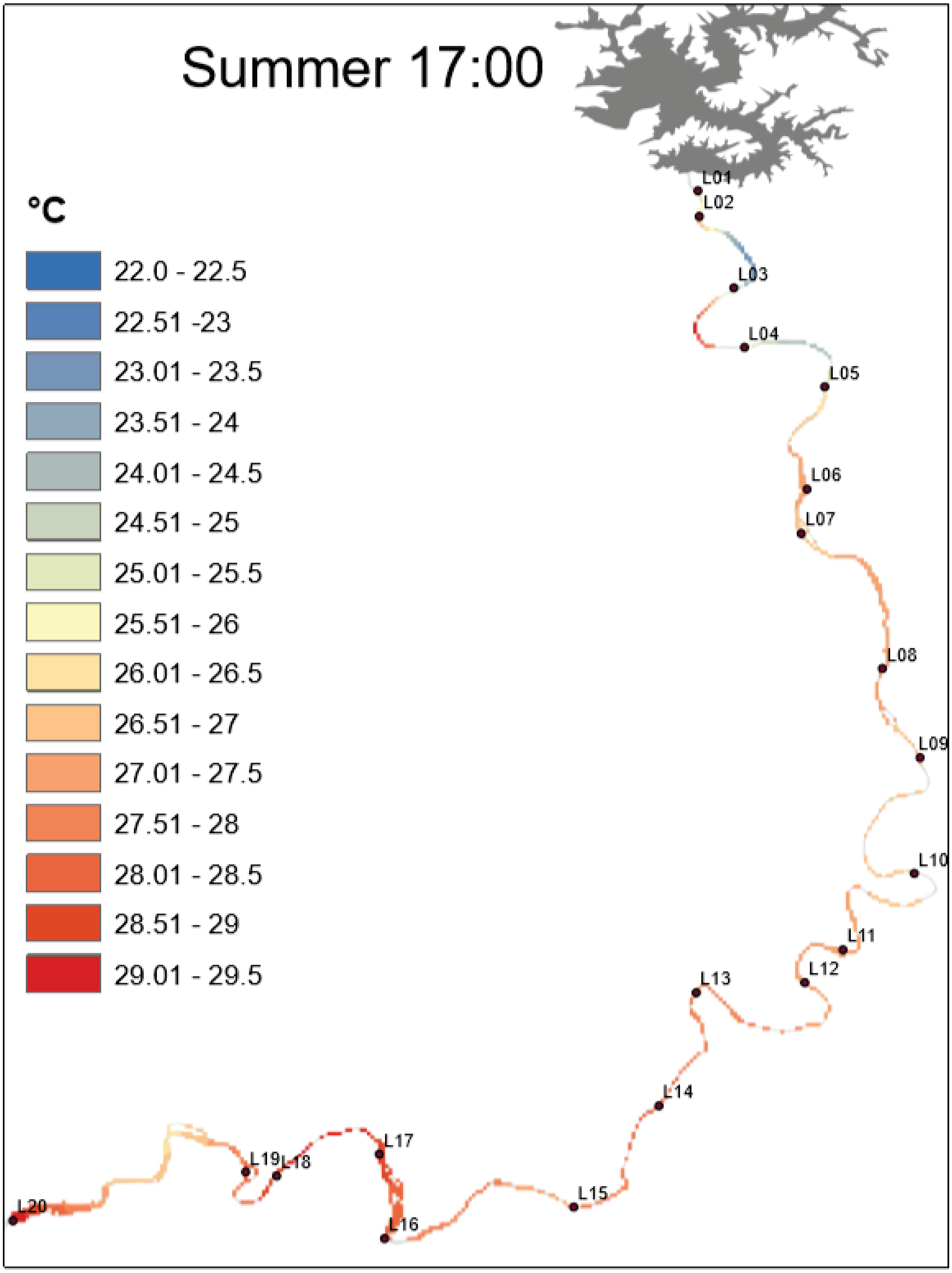
Summer 17:00
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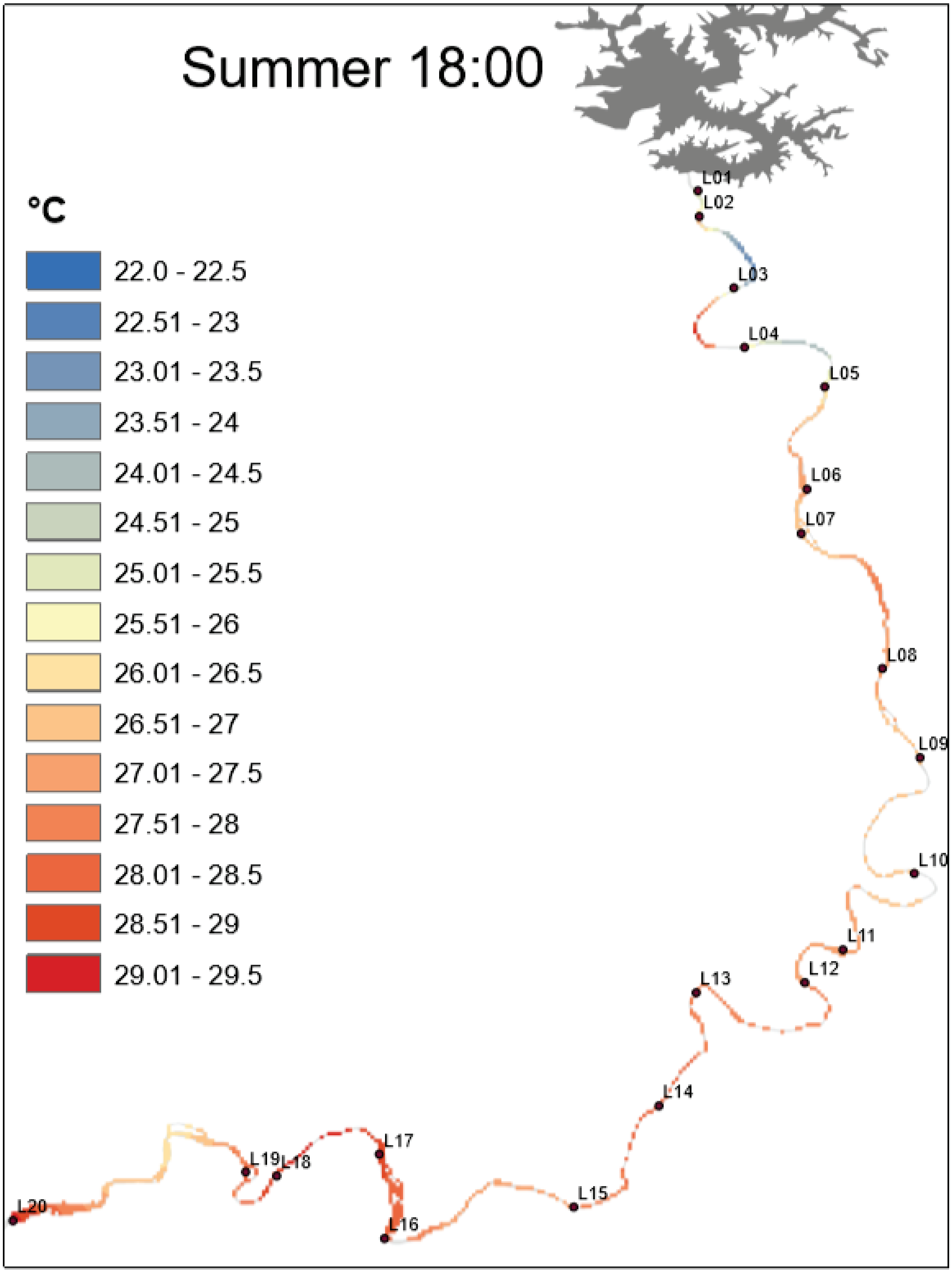
Summer 18:00
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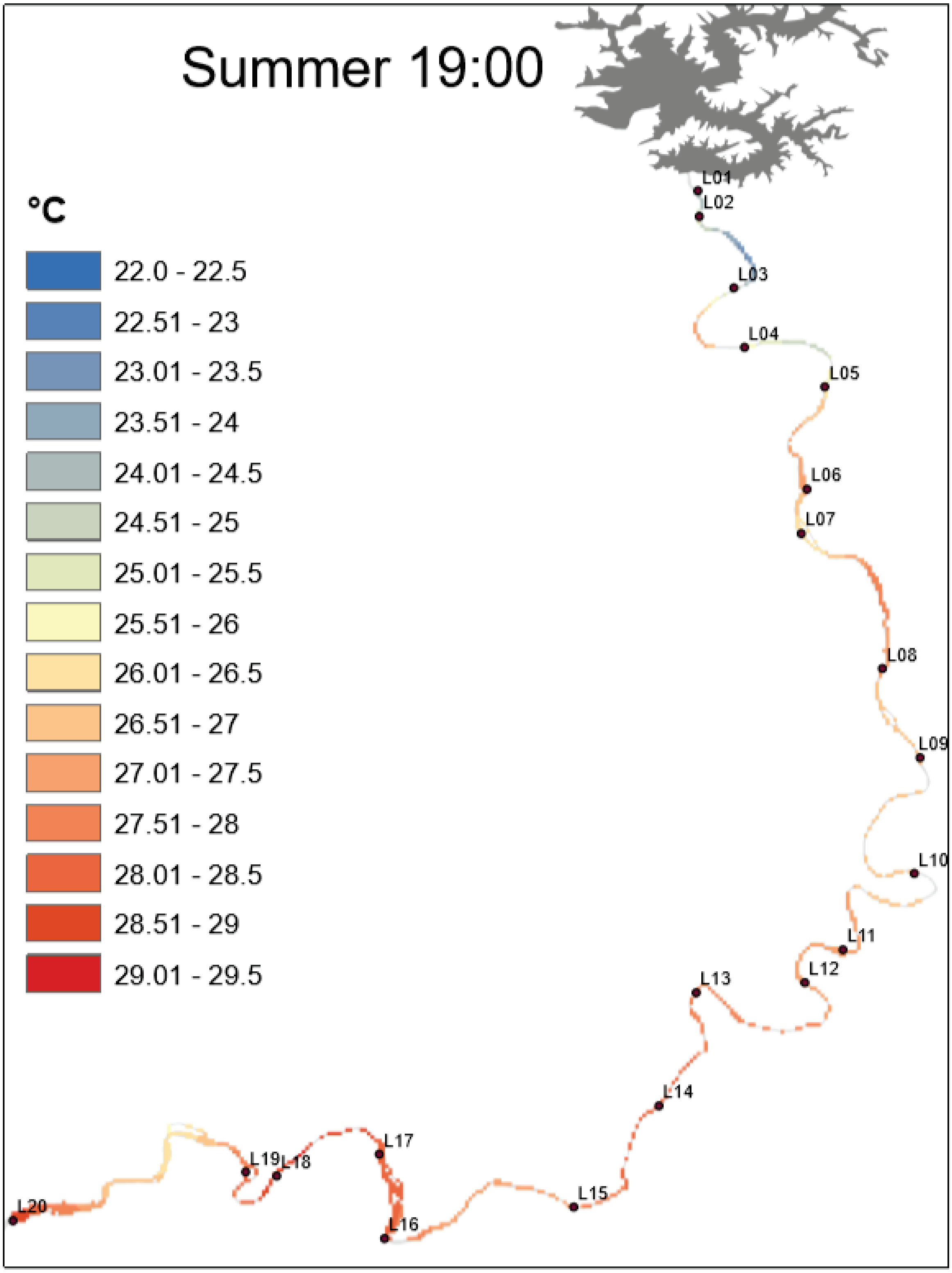
Summer 19:00
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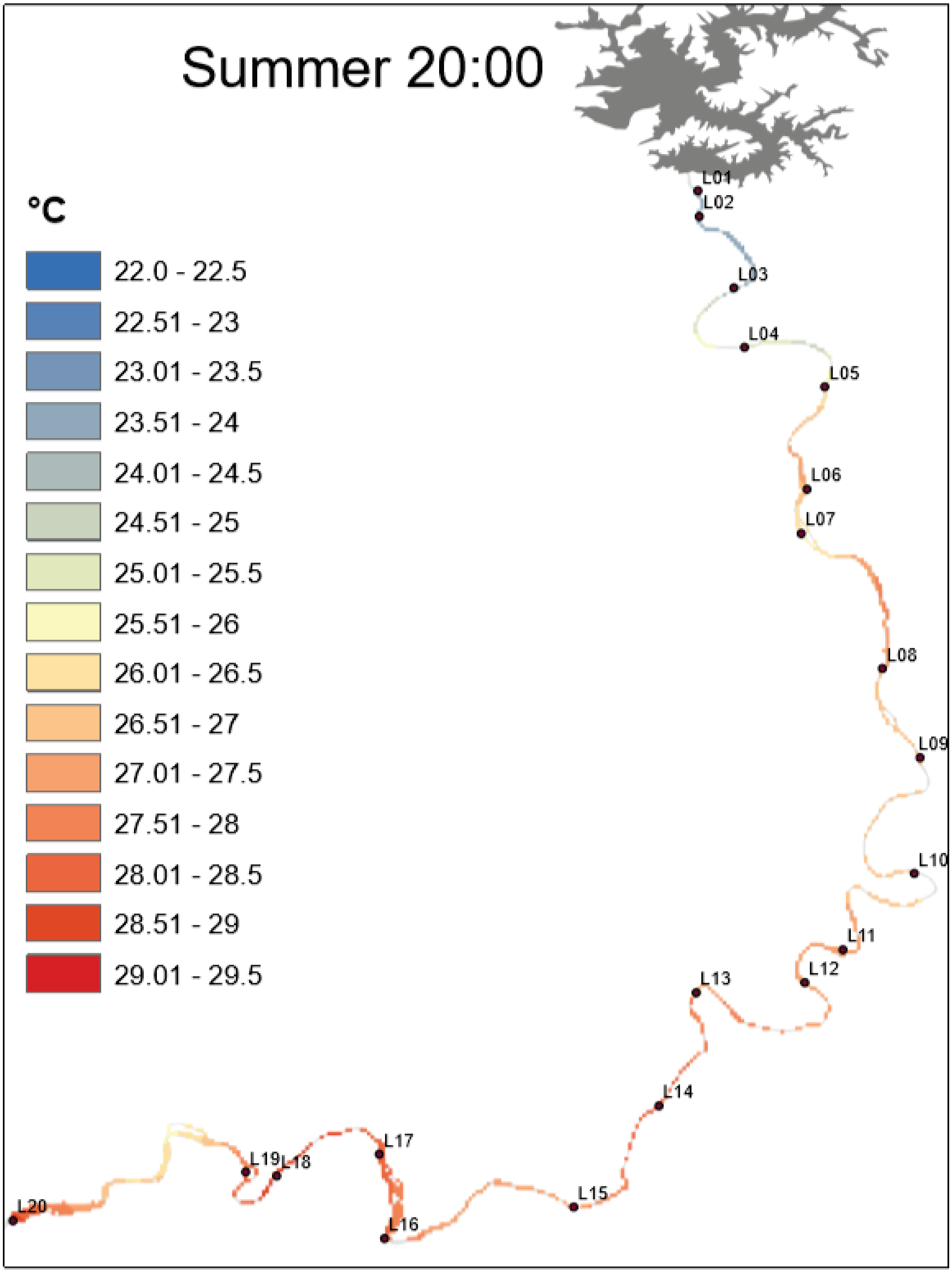

Summer 20:00
°C
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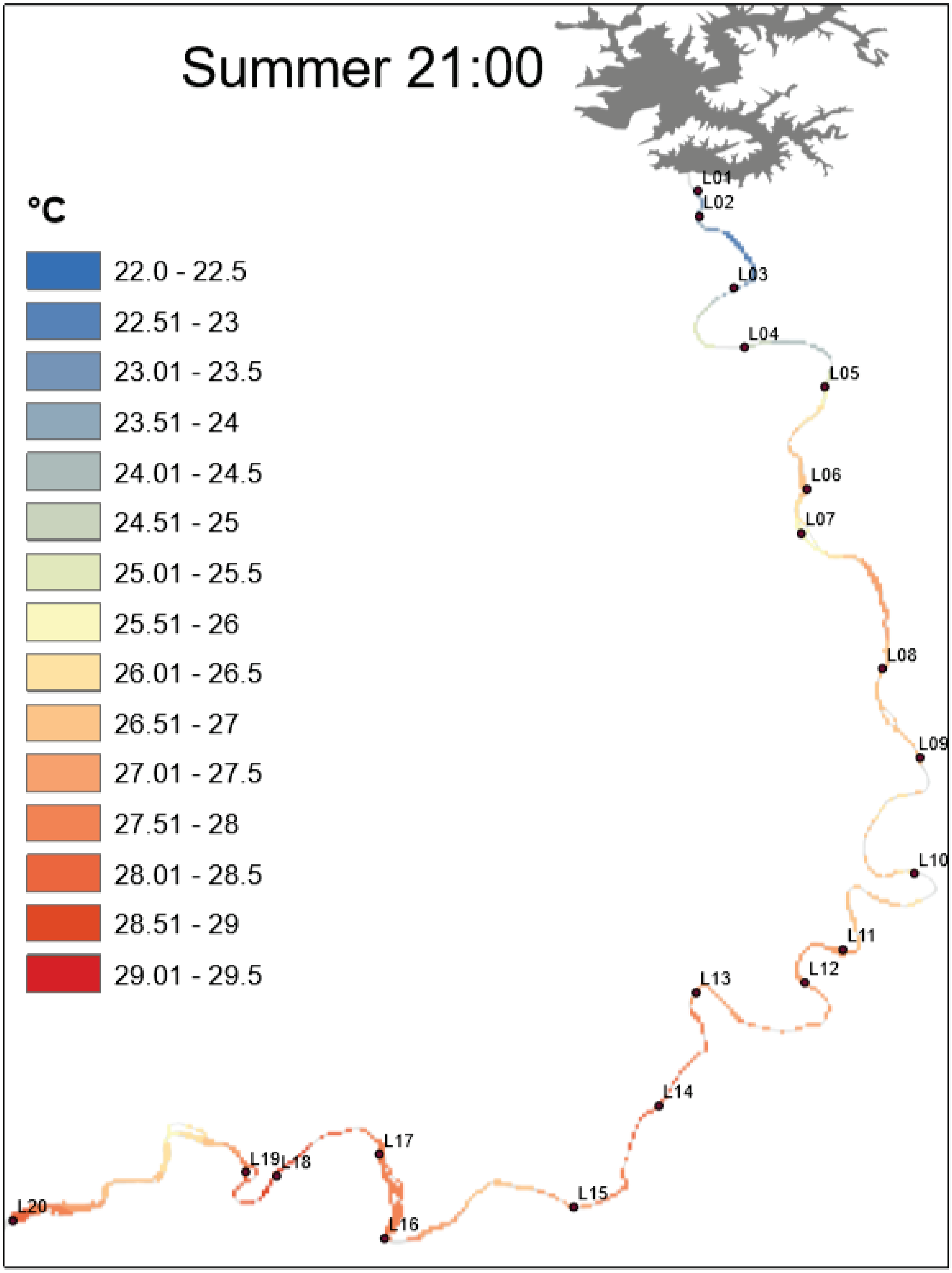
Summer 21:00
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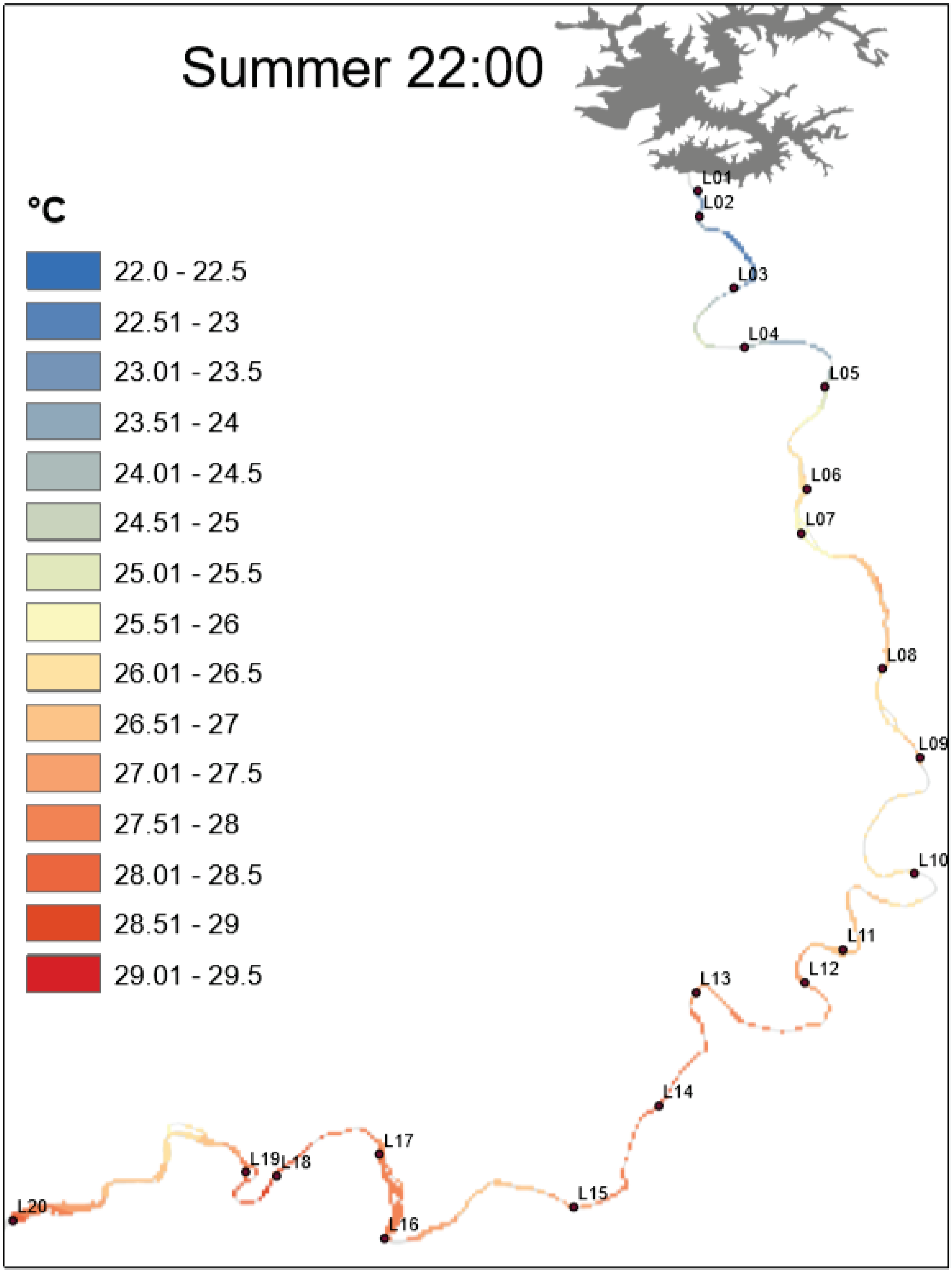
Summer 22:00
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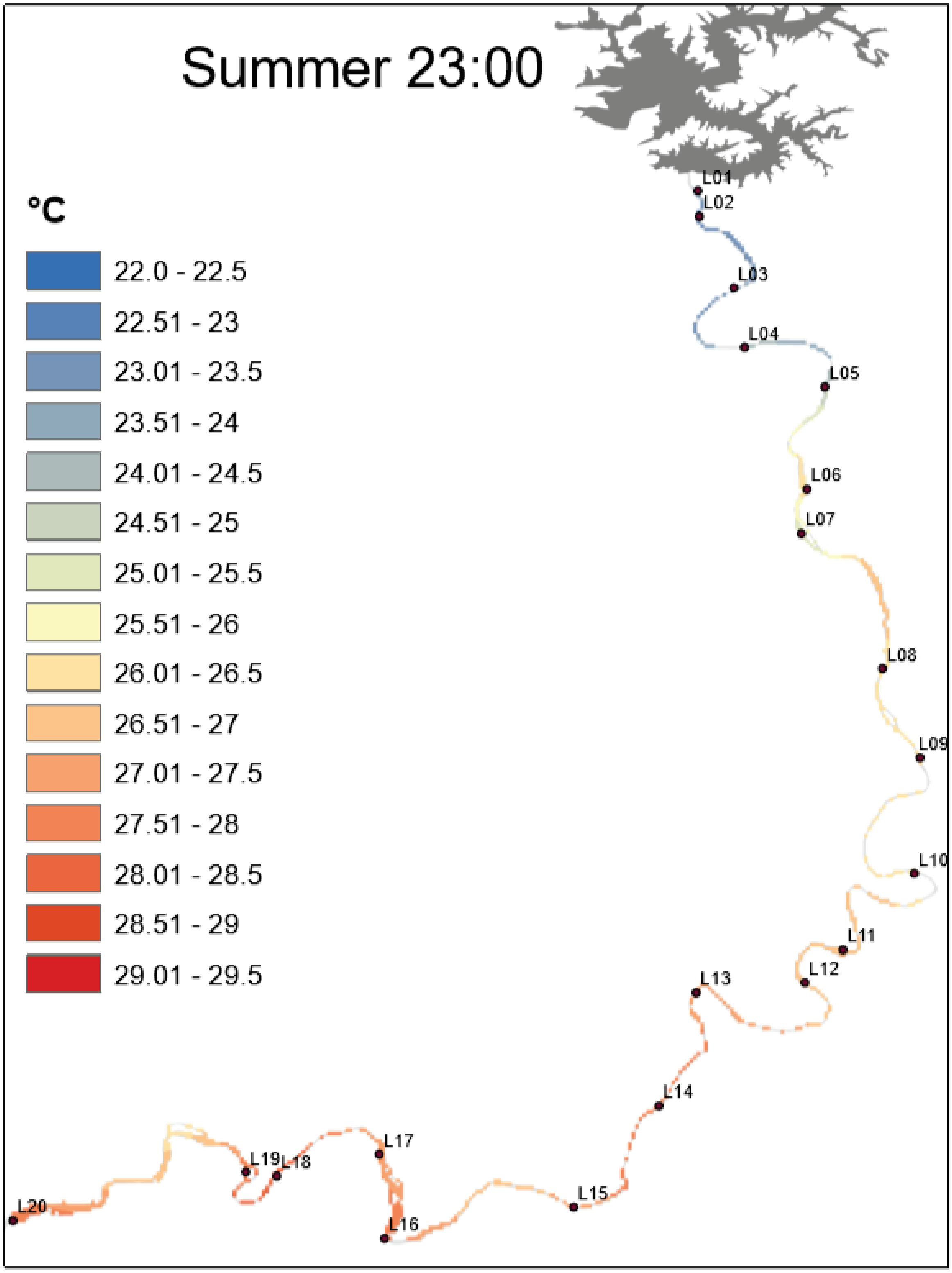


Figure 2.9. Temperature maps generated using interpolated data from 20 loggers along the river for an average day of each season. Each map represents the average temperature per hour.

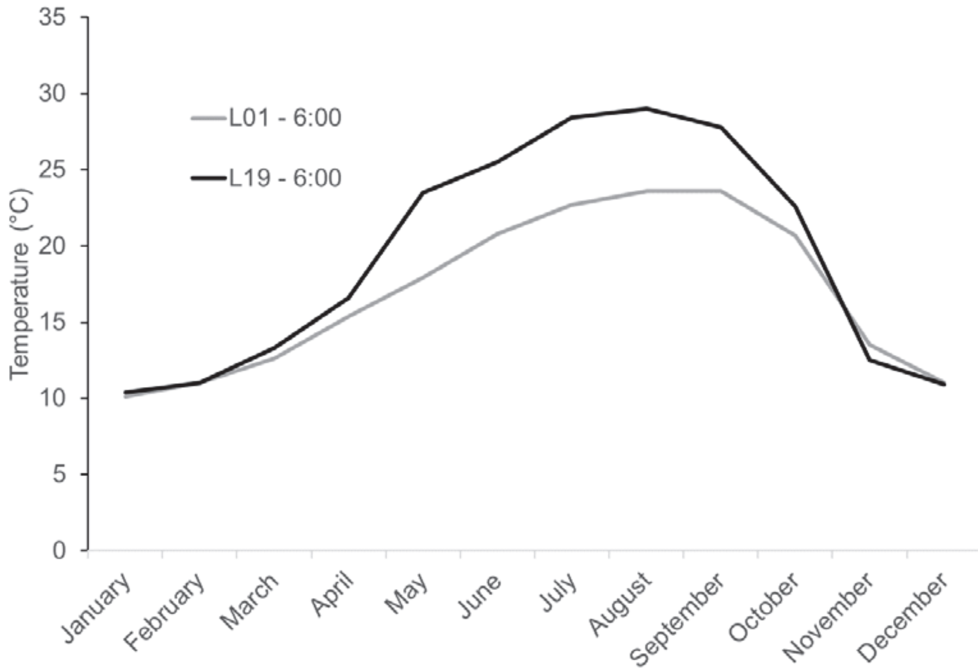
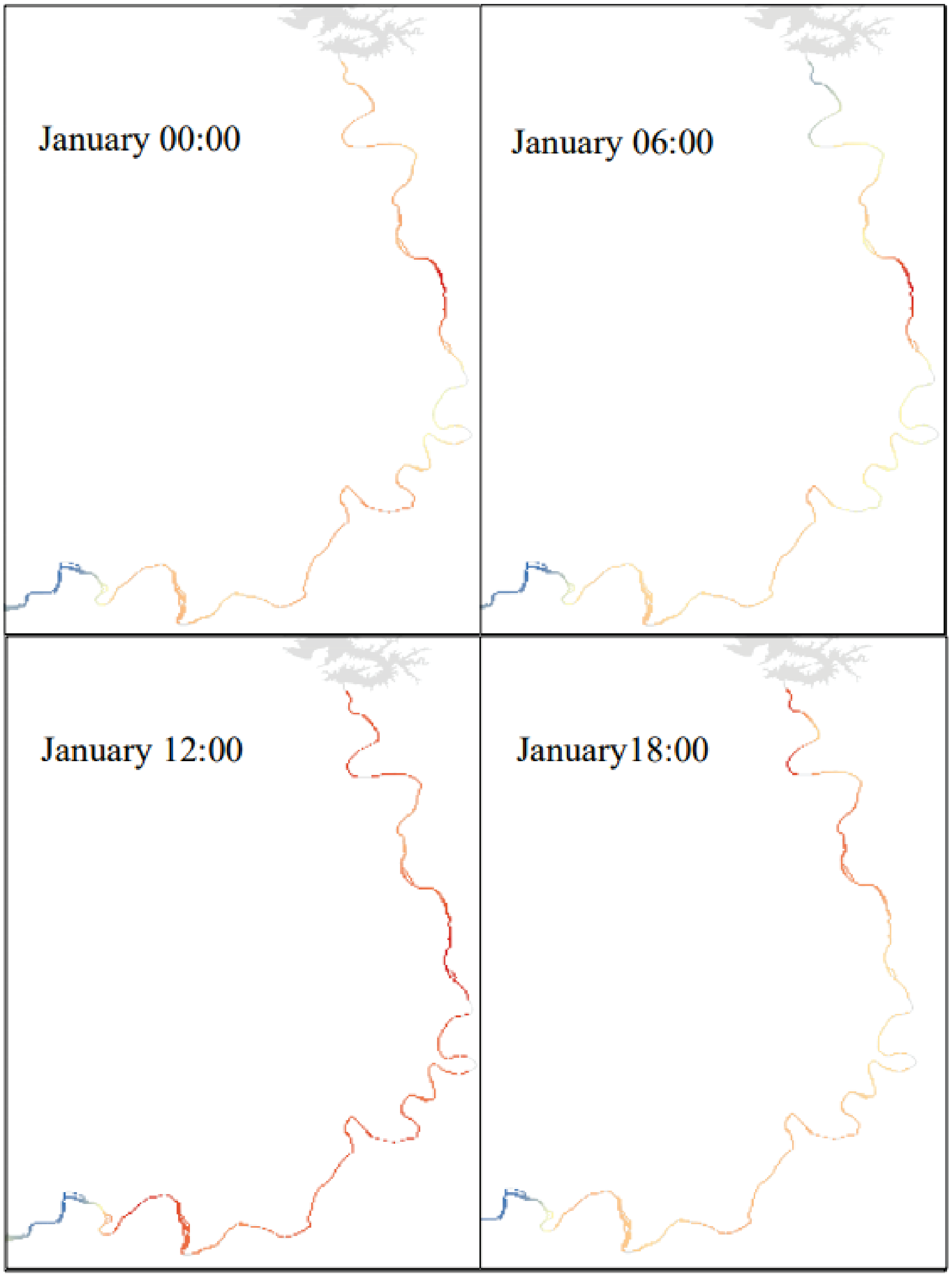
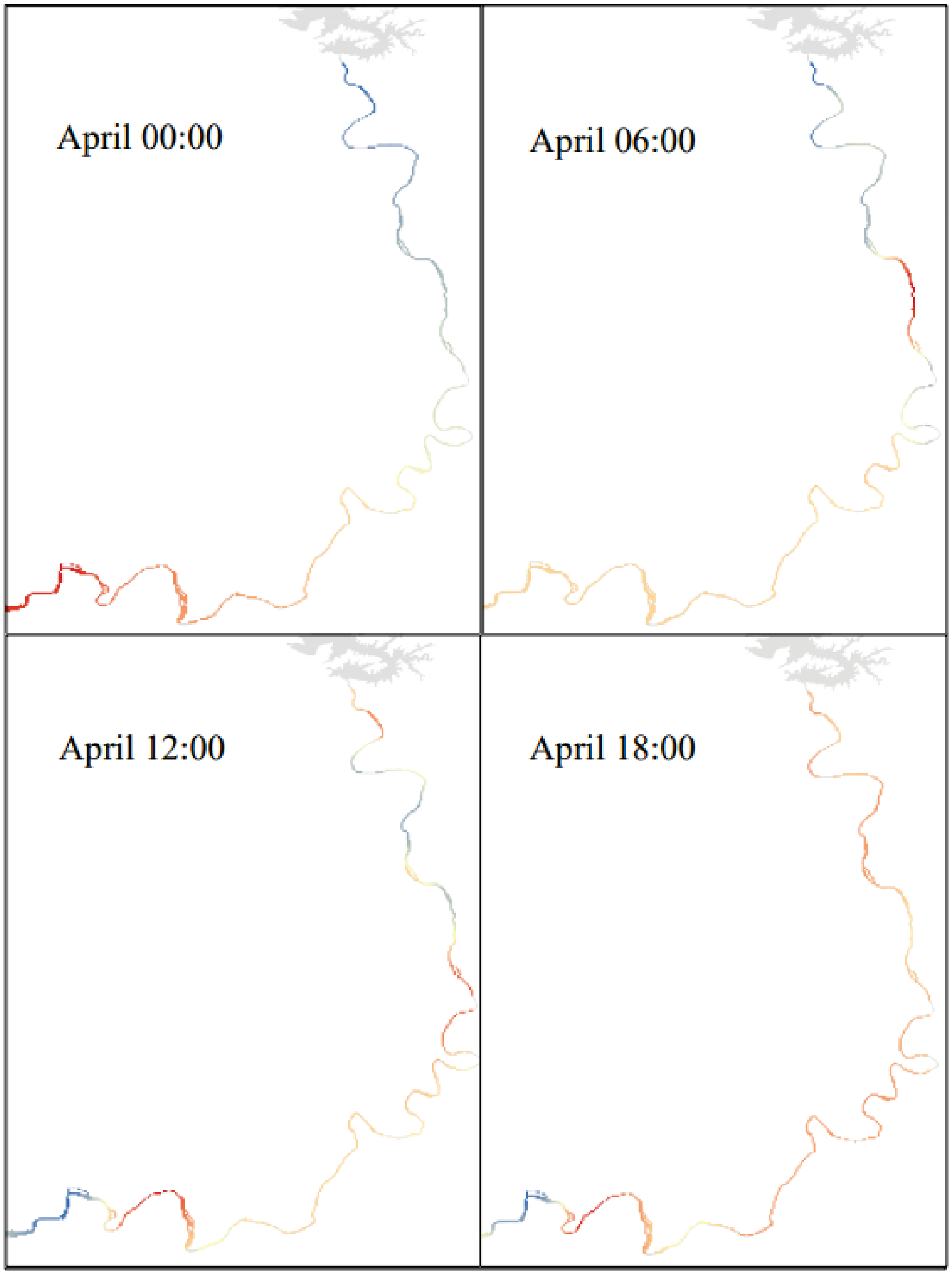
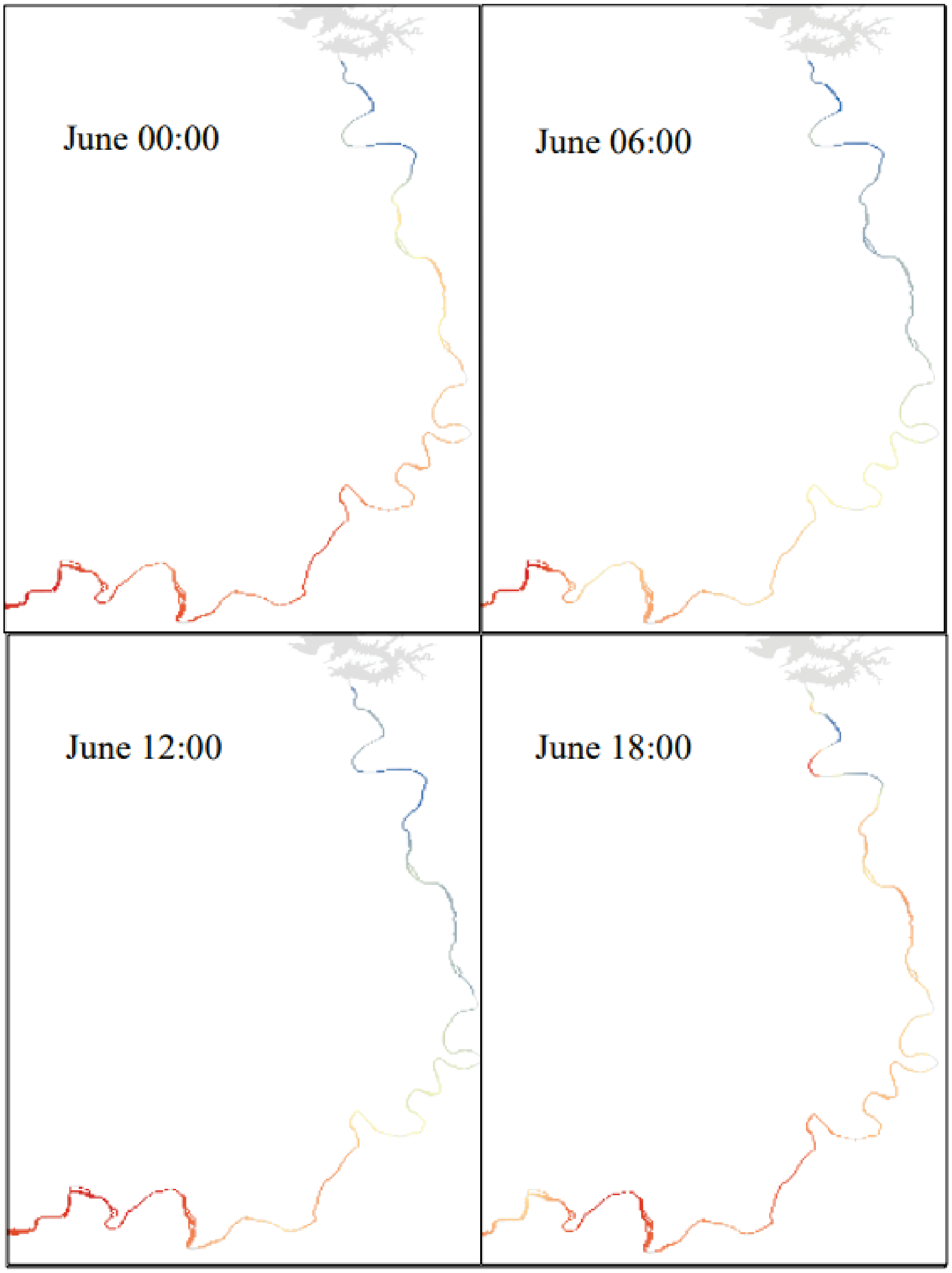
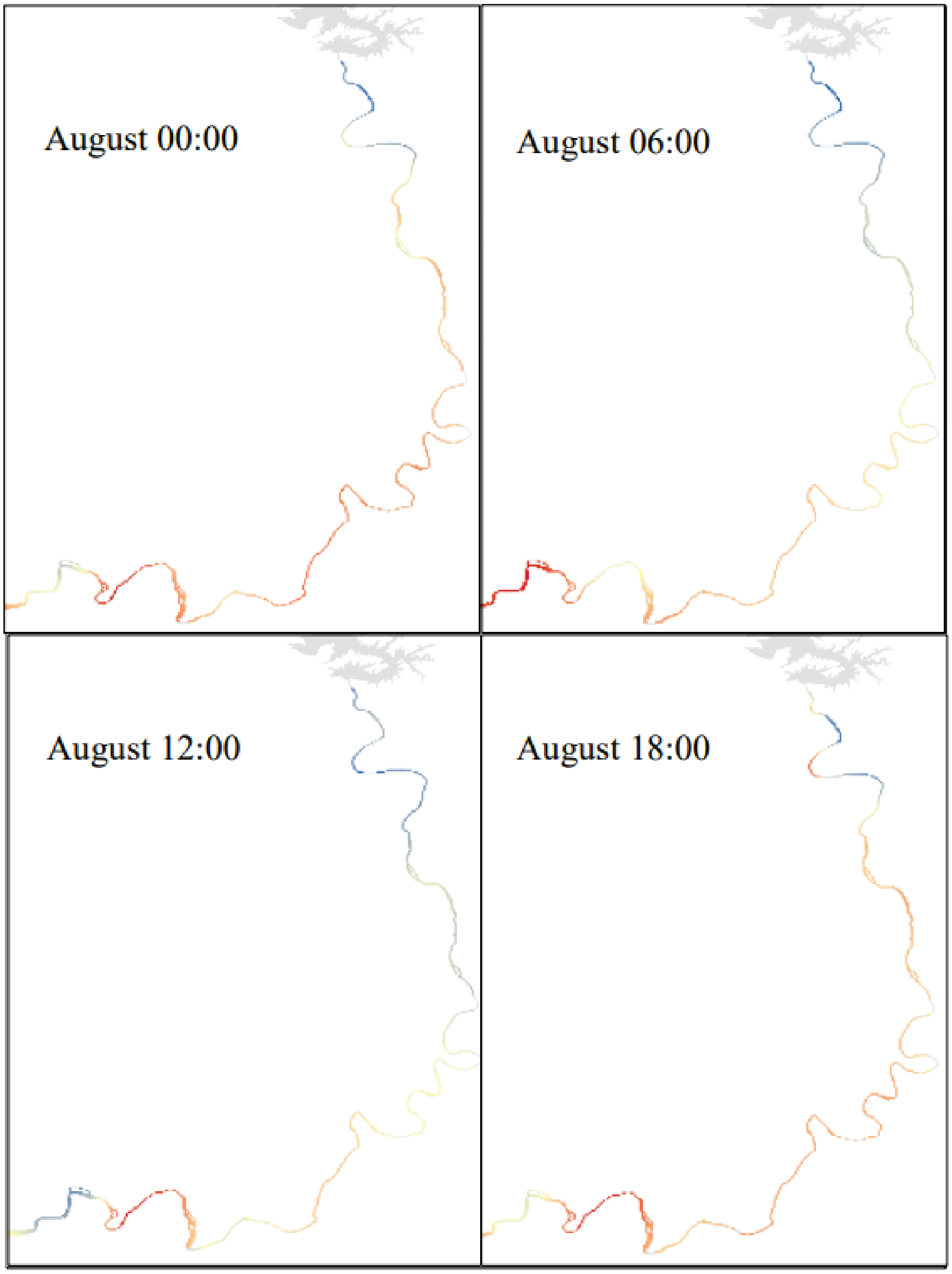


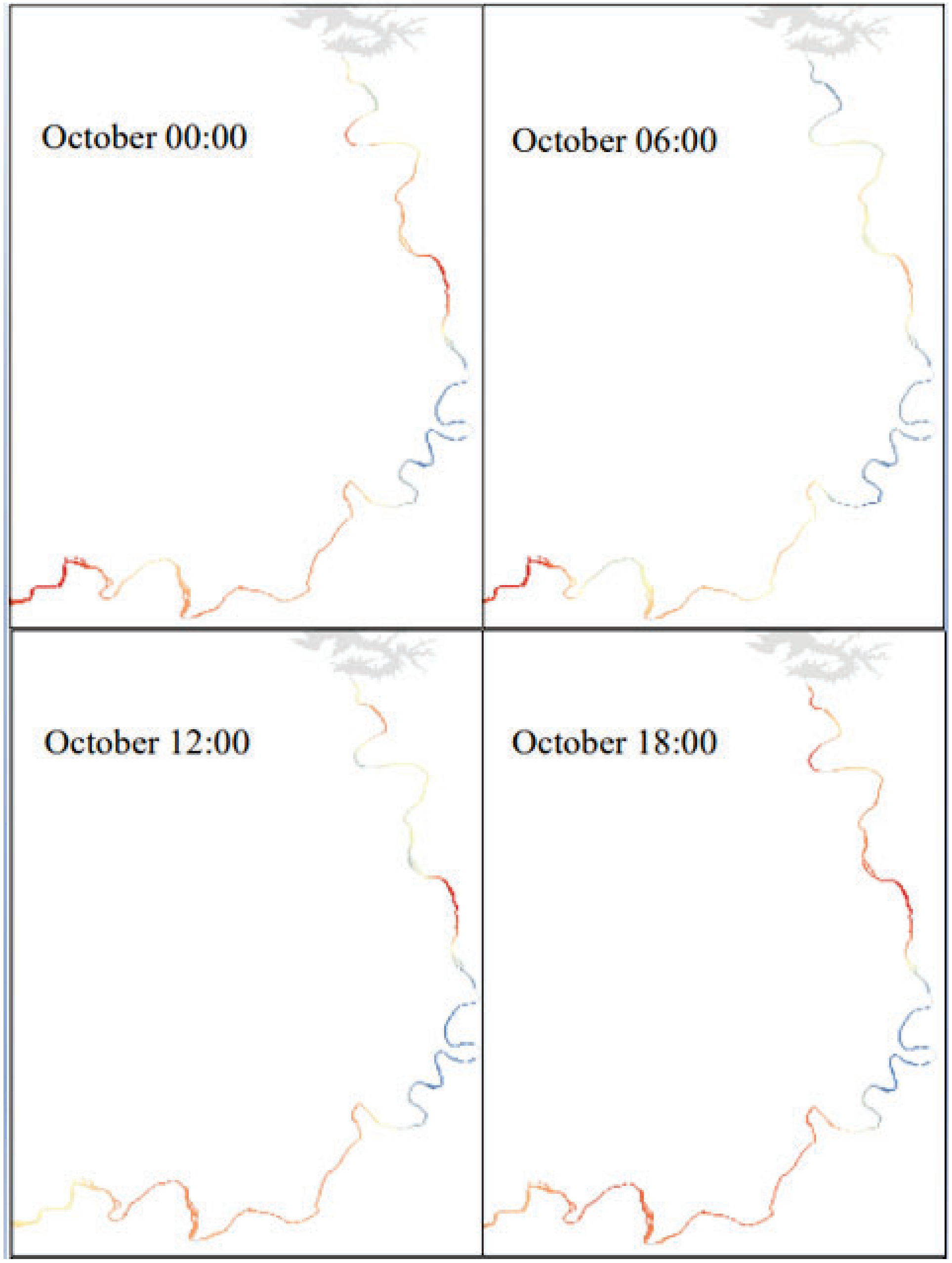
Figure 2.10. Average monthly temperatures over the course of 2019-2020 for loggers LO1 and L19 on the Tallapoosa River.


January 00:00
January 06:00
January 12:00
January18:00


April 00:00
April 06:00
April 12:00
April 18:00


June 00:00
June 06:00
June 12:00
June 18:00


August 00:00
August 06:00
August 12:00
August 18:00


October 00:00
October 06:00
October 12:00
October 18:00

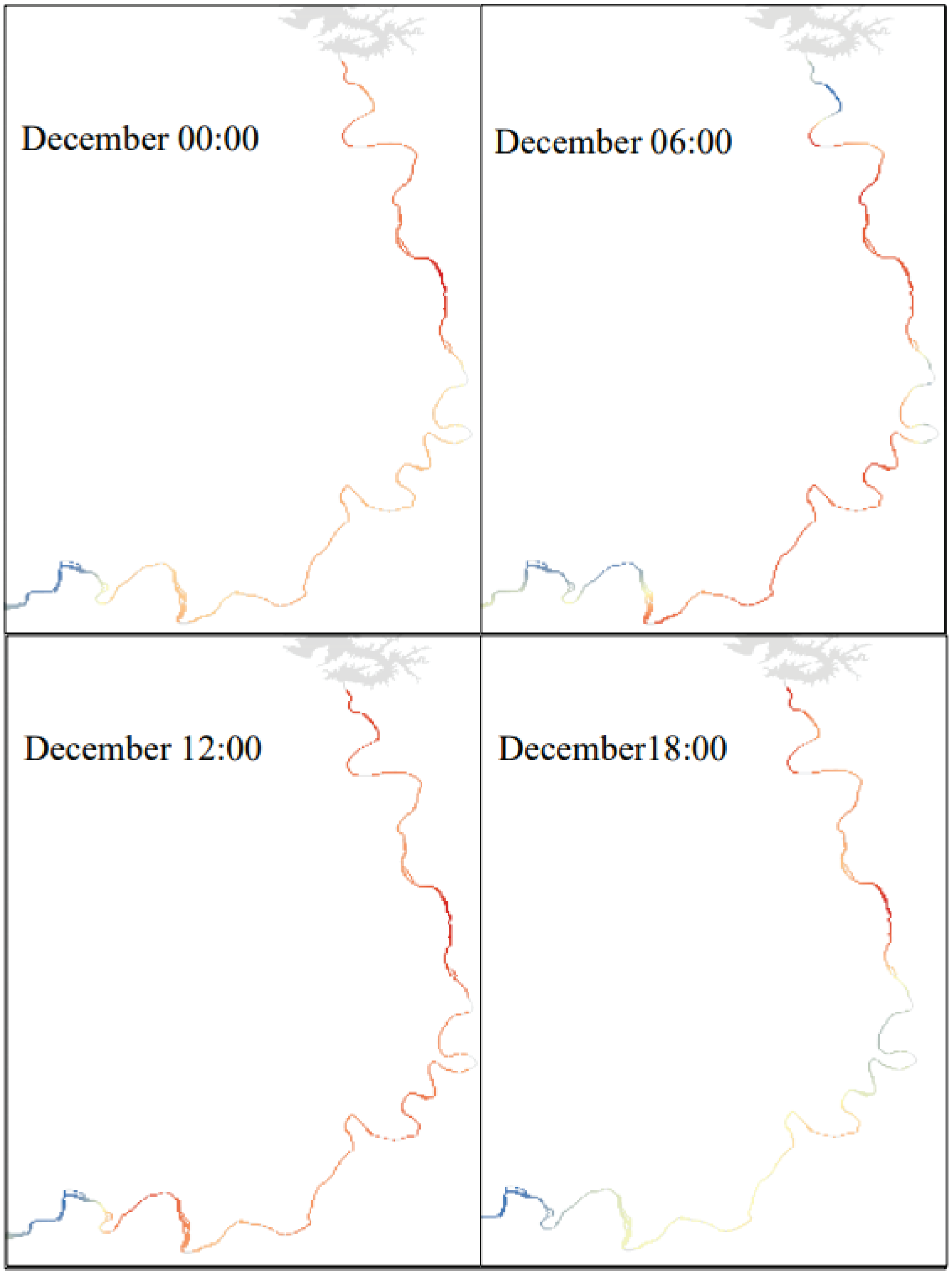


Figure 2.11. Relative change in temperature every six hours along the Tallapoosa River for six different months. Each panel shows the warmest water in red and the coolest water in blue.

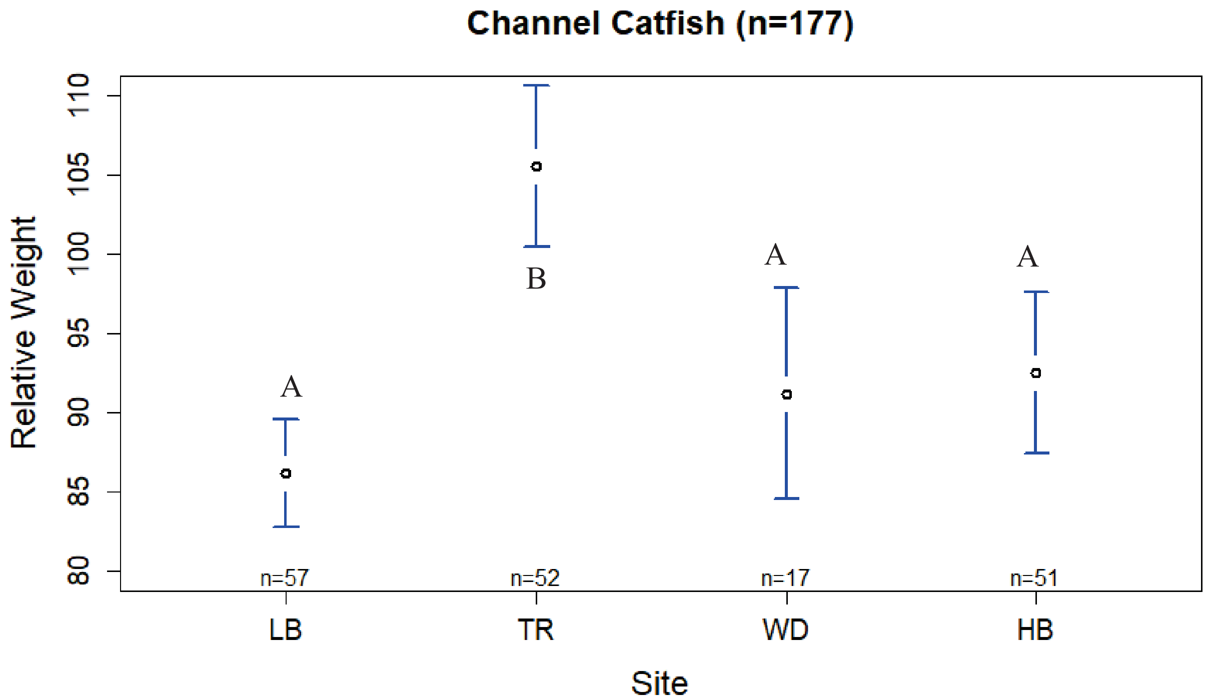


Figure 3.1. Relative weights of Channel Catfish collected from four sites on the Tallapoosa River, Alabama. Sites are LB=Lee's Bridge, TR=tailrace, WD=Wadley, and HB=Horseshoe Bend. Sites with different letters were significantly different based on an ANOVA with a Tukey's test for pairwise comparisons. The sample size for each species is above its name on the x-axis, and the total number of individuals across sites is in parentheses next to the species name.

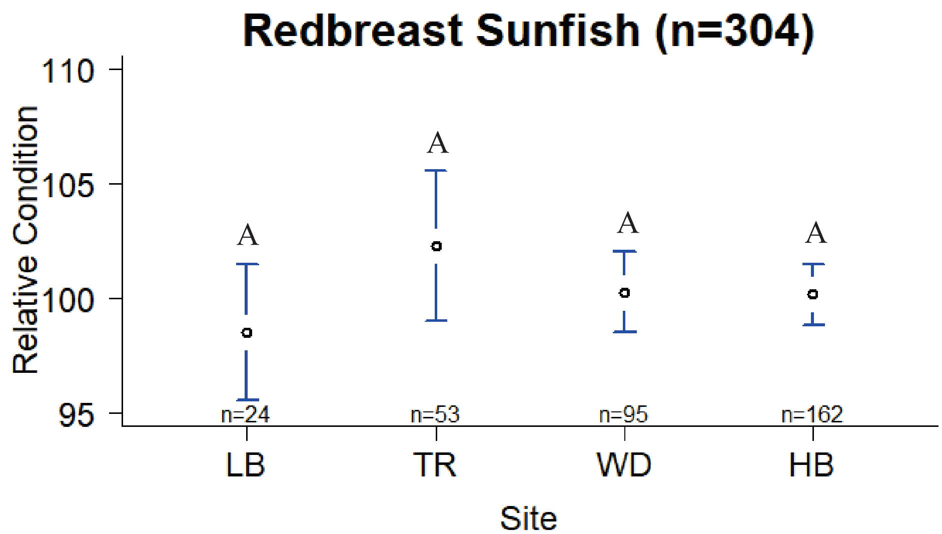


Figure 3.2. Condition factor of Redbreast Sunfish collected from four sites on the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sites with different letters were significantly different based on an ANOVA with a Tukey's test for pairwise comparisons. The sample size for each species is above its name on the x-axis, and the total number of individuals across sites is in parentheses next to the species name.

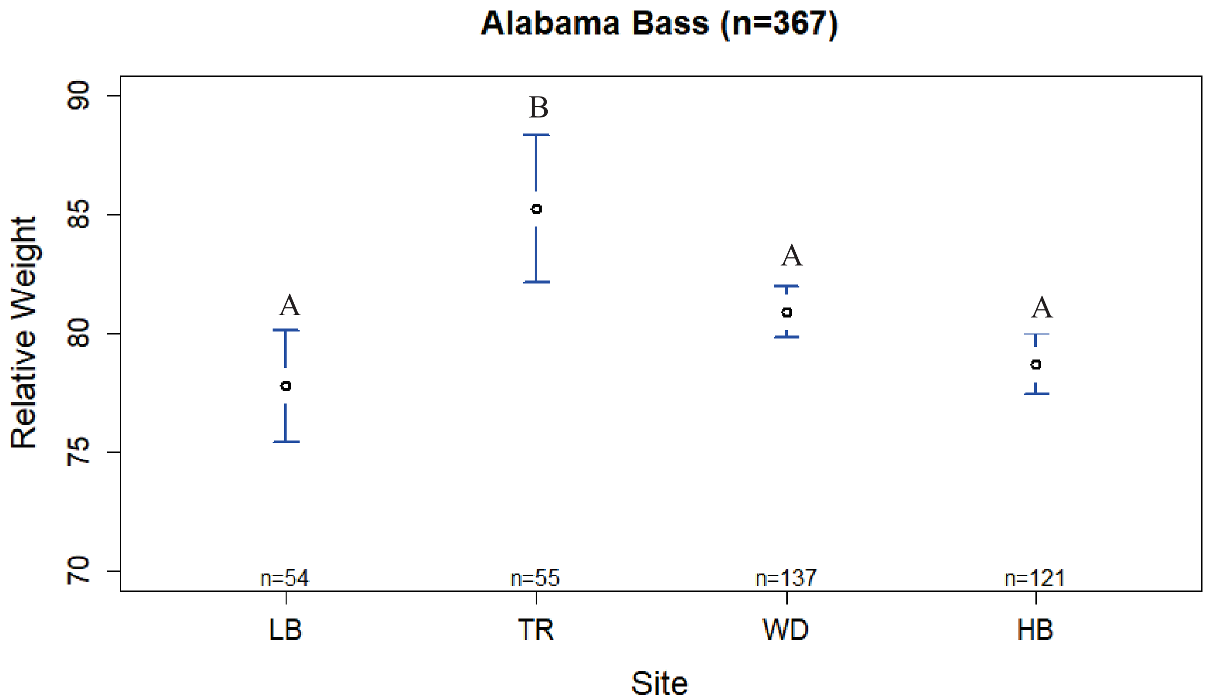


Figure 3.3. Relative weights (mean + 95% CI) of Alabama Bass collected from four sites on the Tallapoosa River, Alabama. Sites with different letters were significantly different based on an ANOVA with a Tukey's test for pairwise comparisons. Sites are as defined in Figure 3.1. The sample size for each species is above its name on the x-axis, and the total number of individuals across sites is in parentheses next to the species name.

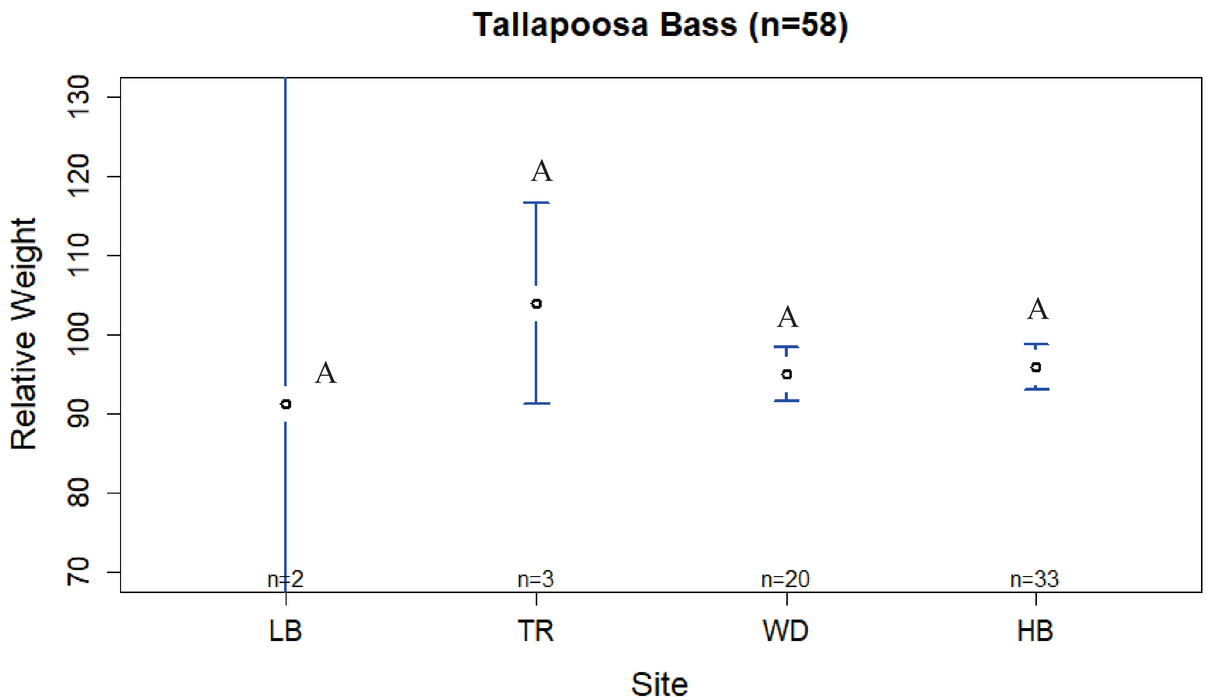


Figure 3.4. Relative weights of Tallapoosa Bass collected from four sites on the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sites with different letters were significantly different based on an ANOVA with a Tukey's test for pairwise comparisons. The sample size for each species is above its name on the x-axis, and the total number of individuals across sites is in parentheses next to the species name.

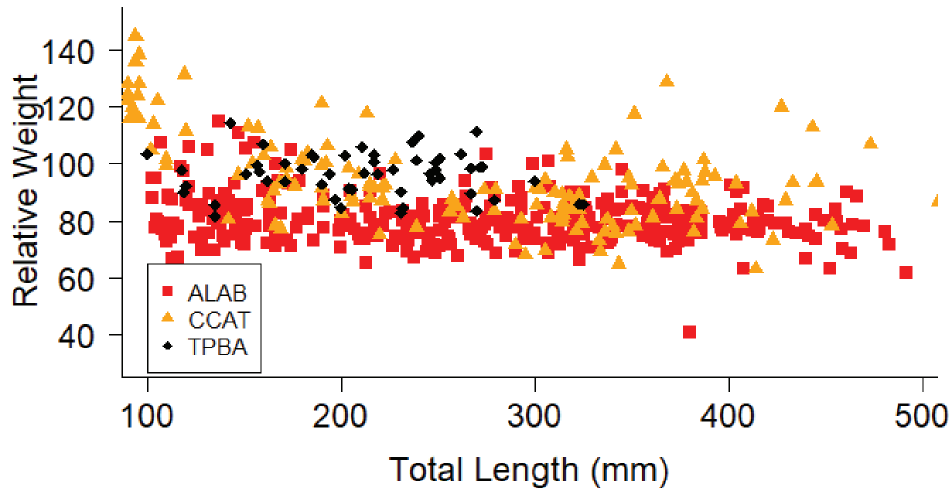


Figure 3.5. Plot of relative weight and total length (mm) of target species collected from the Tallapoosa River. Species are: Alabama Bass (red squares), Channel Catfish (orange triangles), and Tallapoosa Bass (black diamonds).

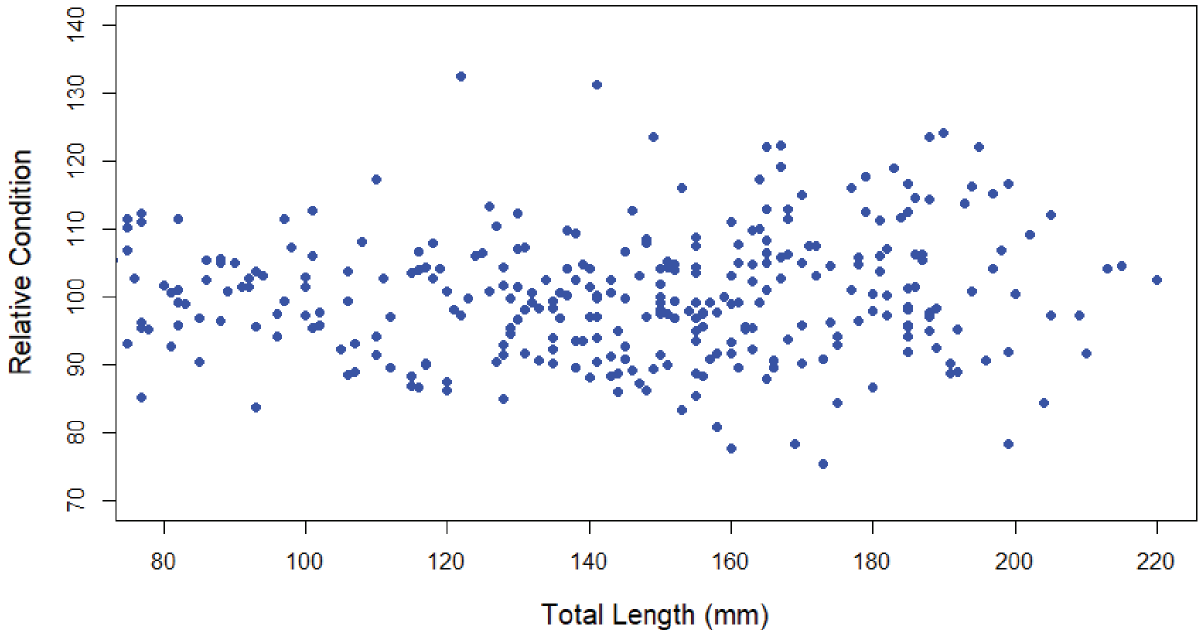


Figure 3.6. Relative condition of Redbreast Sunfish collected from the Tallapoosa River, Alabama by total length.

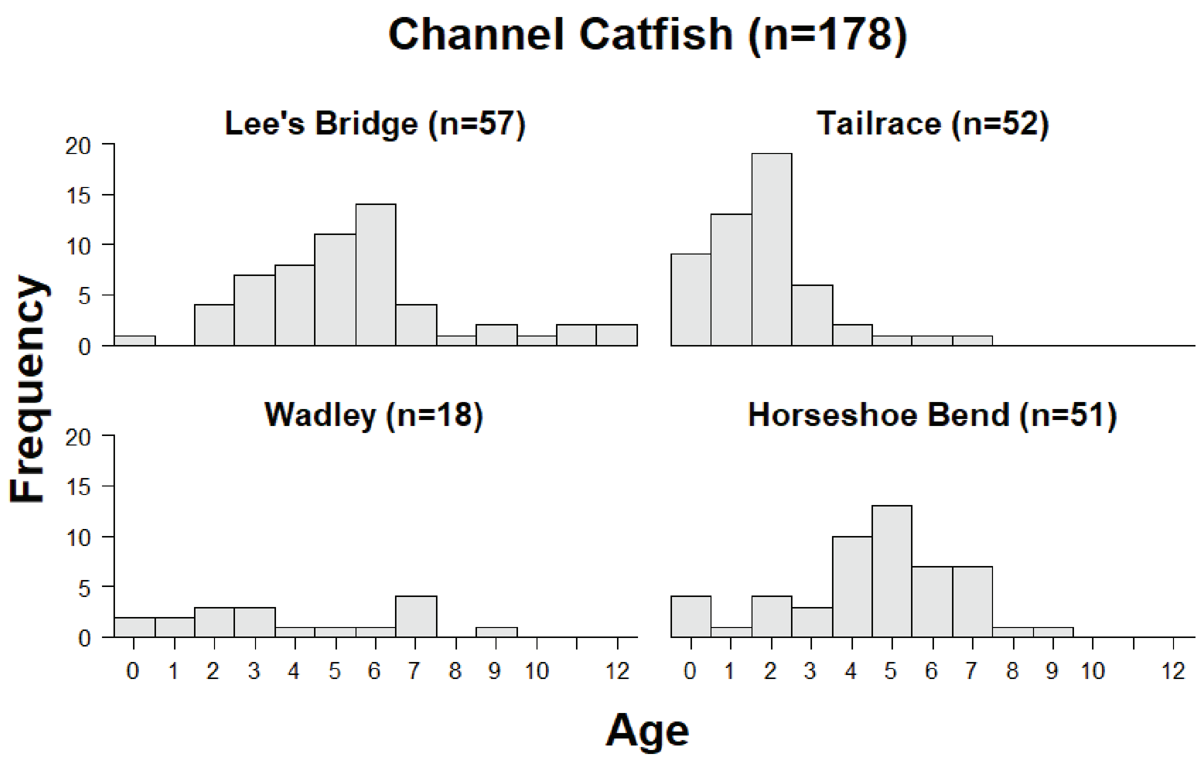


Figure 3.7. Age-frequency distributions of Channel Catfish from four sites on the Tallapoosa River, Alabama. Sample sizes are in parentheses following each site name.

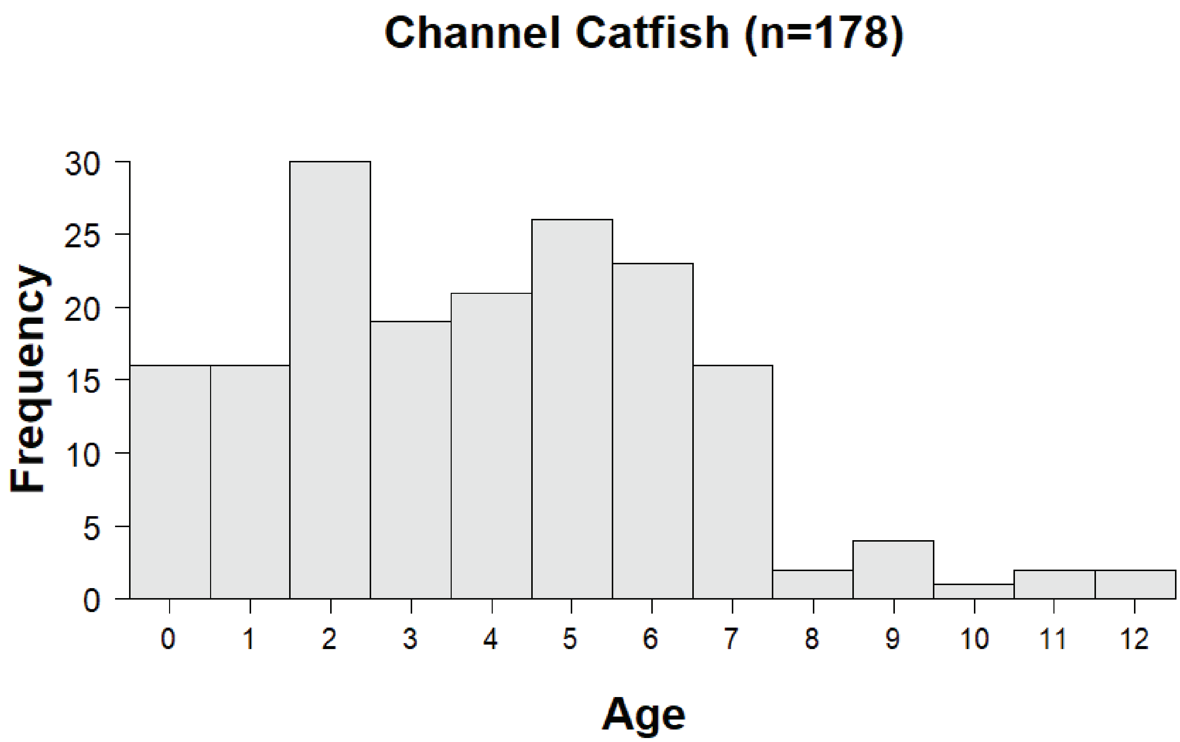


Figure 3.8. Age-frequency distribution of Channel Catfish from the Tallapoosa River, Alabama. Sample size is in parentheses.

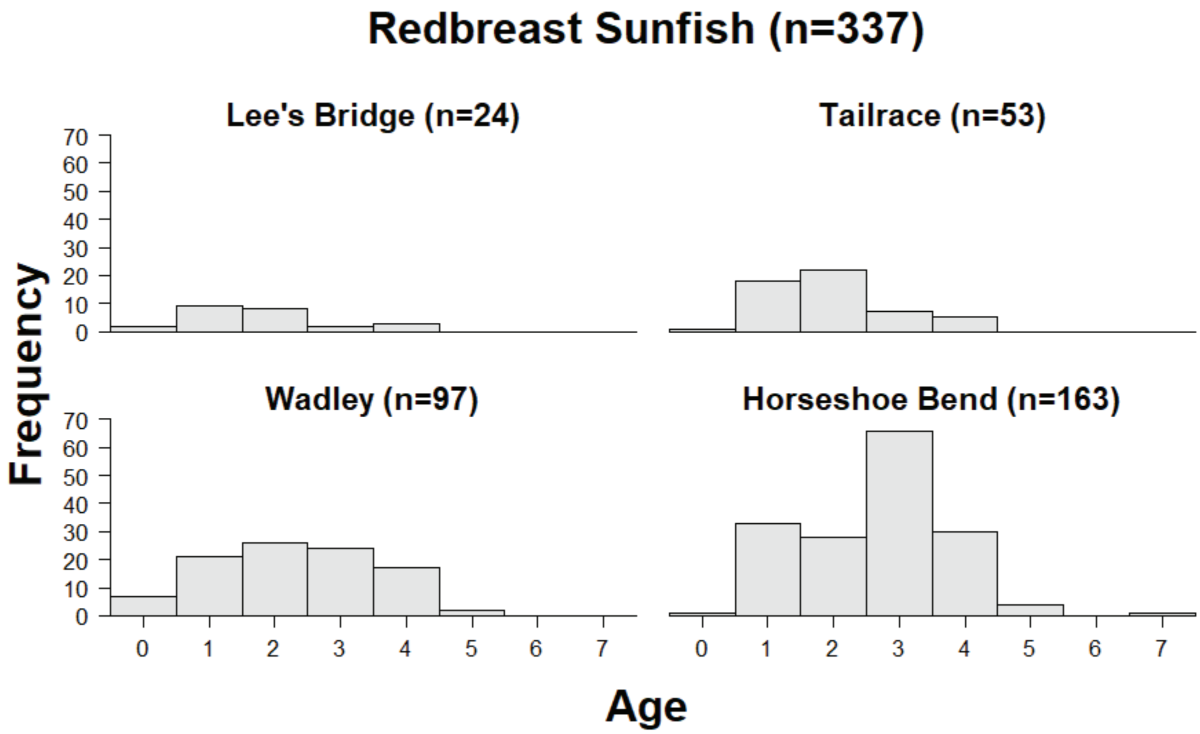


Figure 3.9. Age-frequency distributions of Redbreast Sunfish from four sites on the Tallapoosa River, Alabama. Sample sizes are in parentheses.

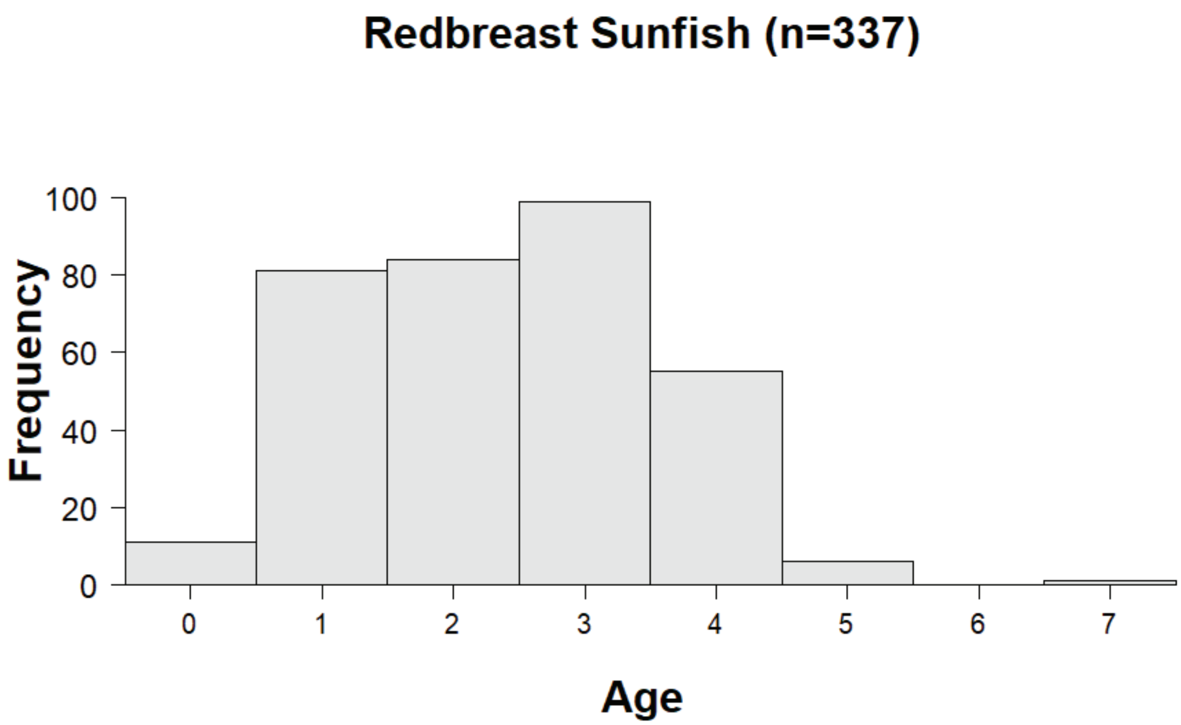


Figure 3.10. Age-frequency distribution of Redbreast Sunfish from the Tallapoosa River, Alabama. Sample size is in parentheses.

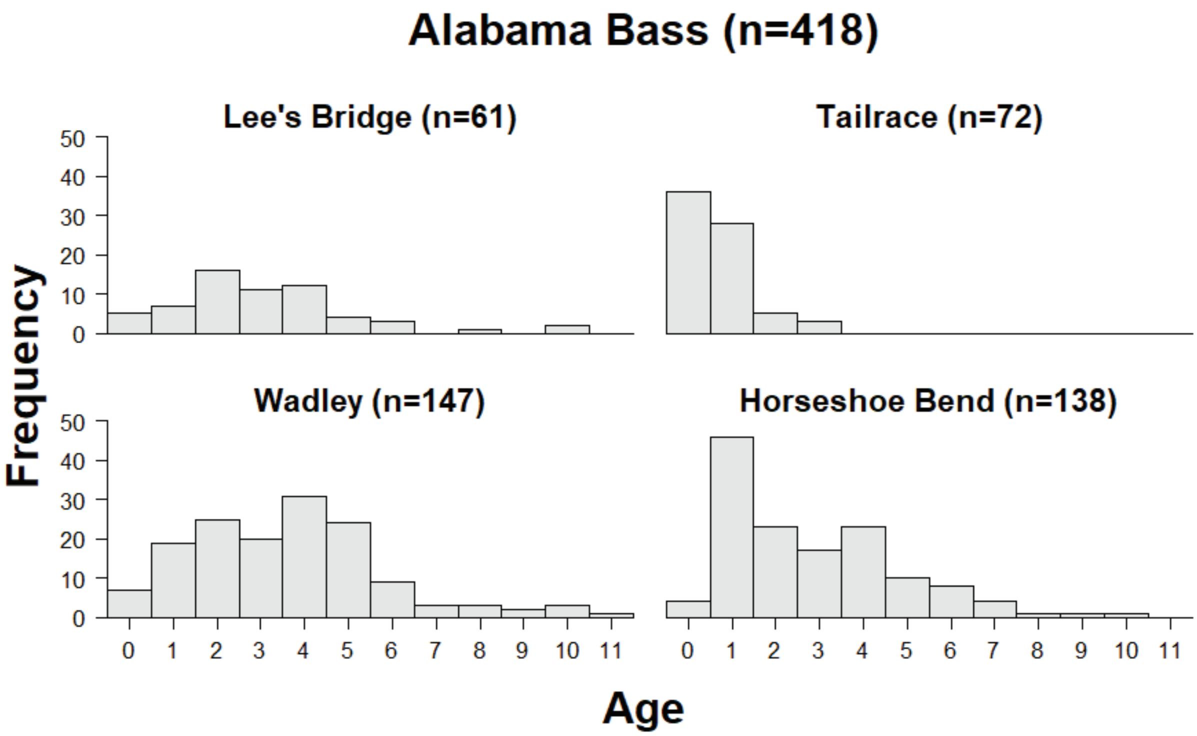


Figure 3.11. Age-frequency distributions of Alabama Bass from four sites on the Tallapoosa River, Alabama. Sample sizes are in parentheses.

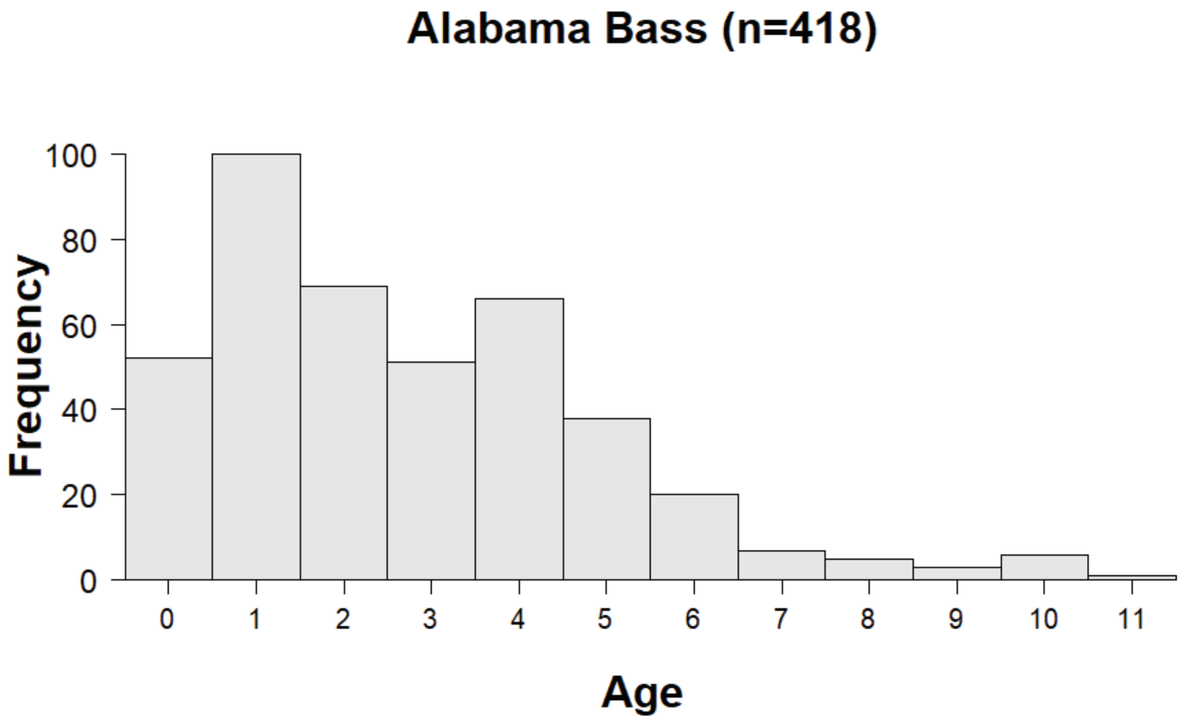


Figure 3.12. Age-frequency distribution of Alabama Bass collected from the Tallapoosa River, Alabama. Sample size is in parentheses.

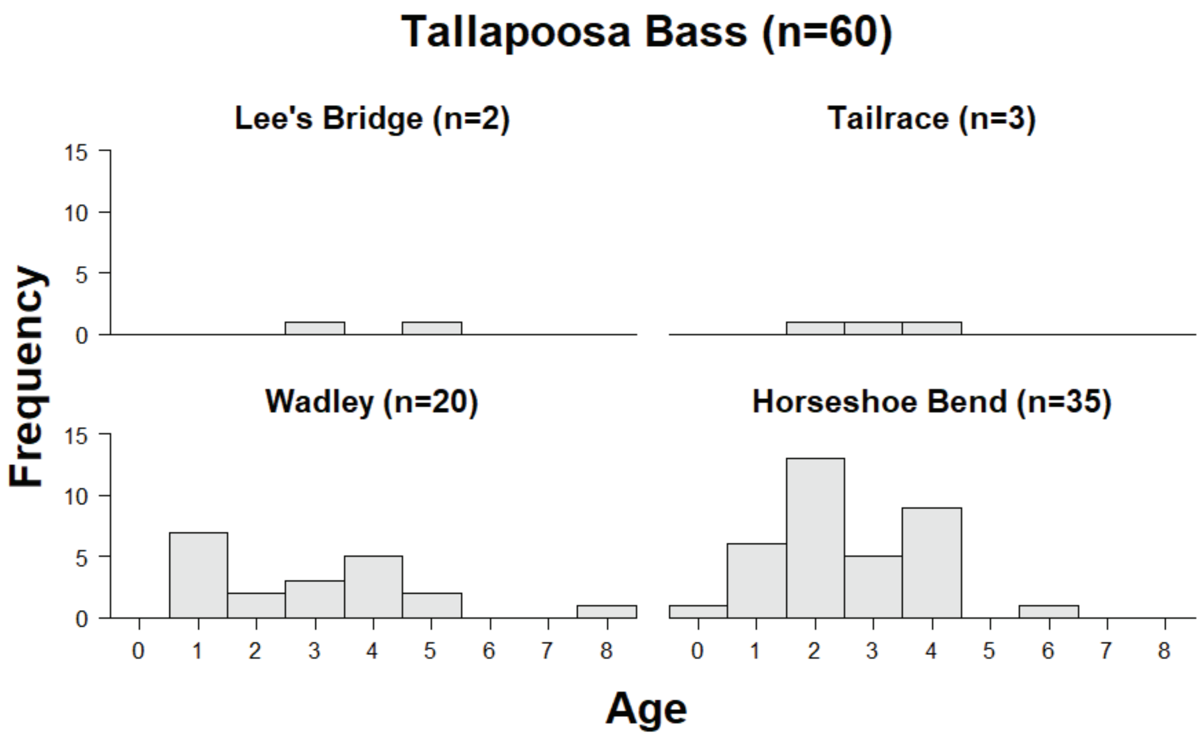


Figure 3.13. Age-frequency distributions of Tallapoosa Bass collected from four sites on the Tallapoosa River, Alabama. Sample sizes are in parentheses.

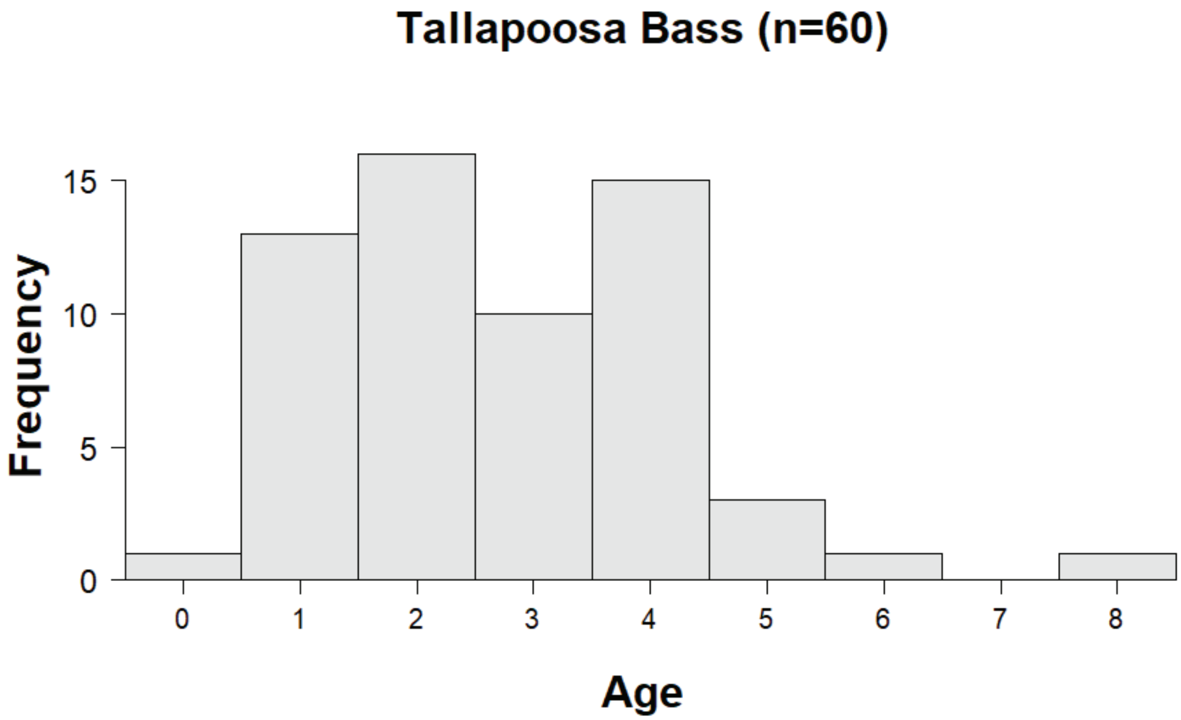


Figure 3.14. Age-frequency distributions of Tallapoosa Bass collected from the Tallapoosa River, Alabama. Sample size is in parentheses.

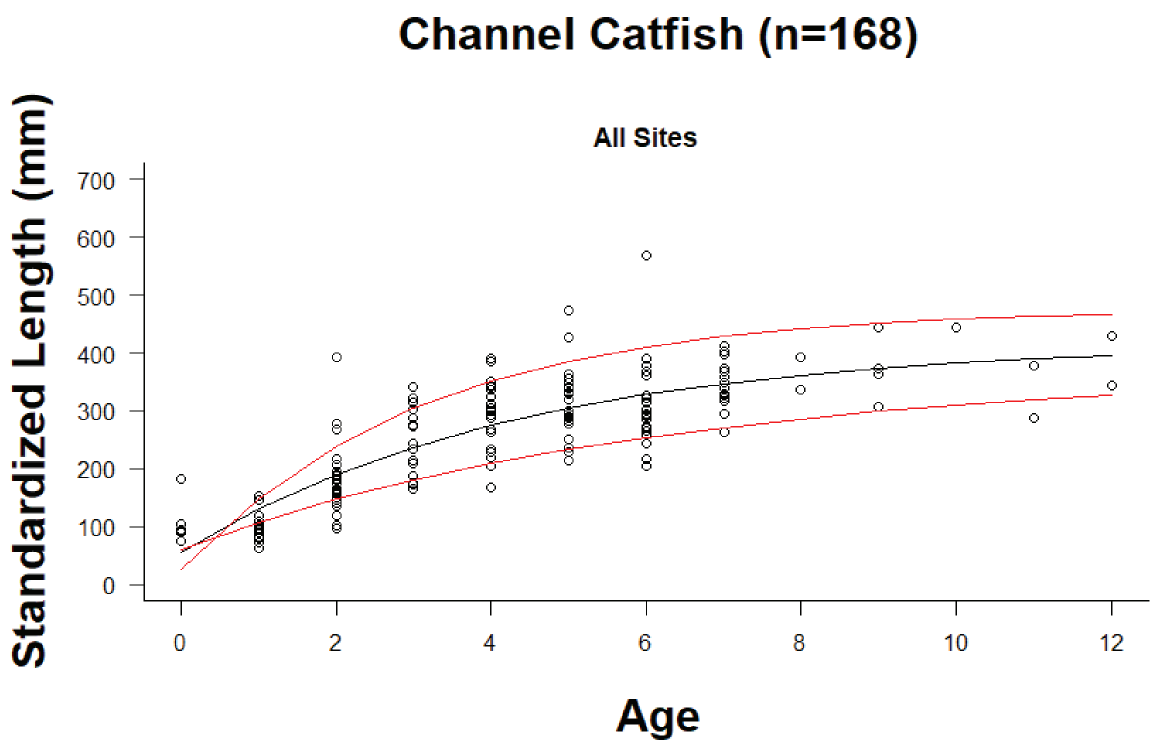


Figure 3.15. von Bertalanffy growth curve for Channel Catfish collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

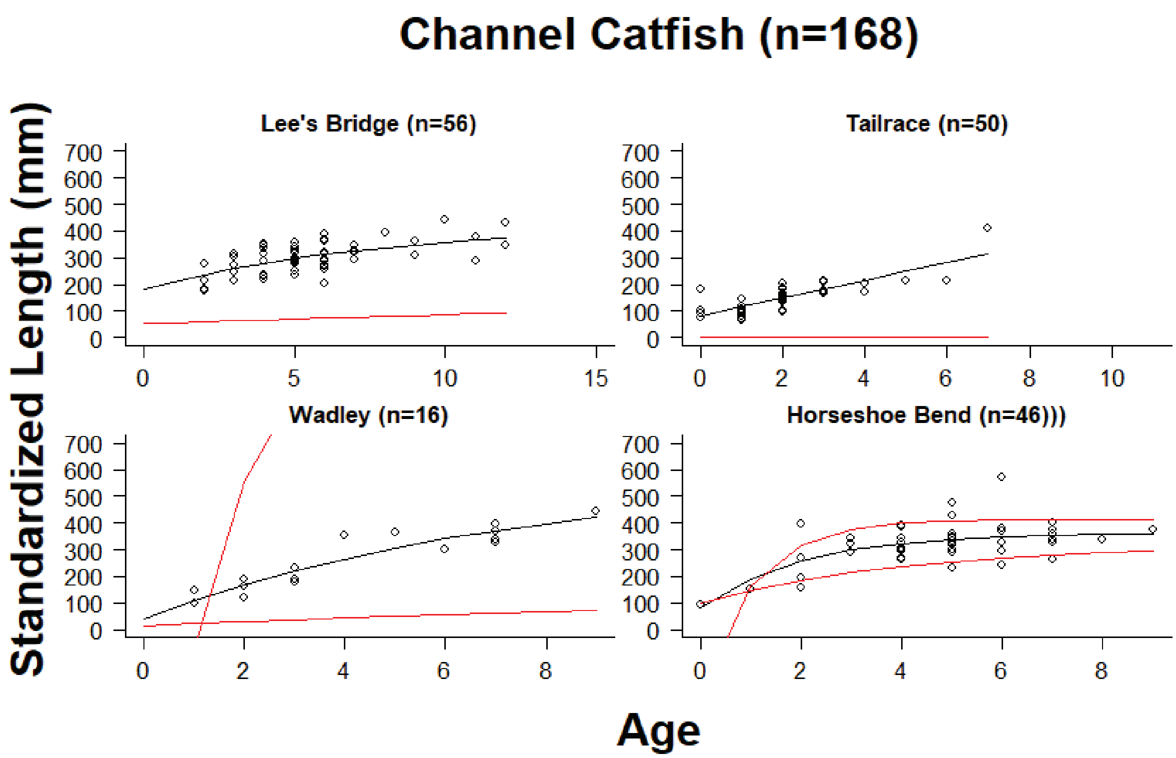


Figure 3.16. von Bertalanffy growth curves for Channel Catfish collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

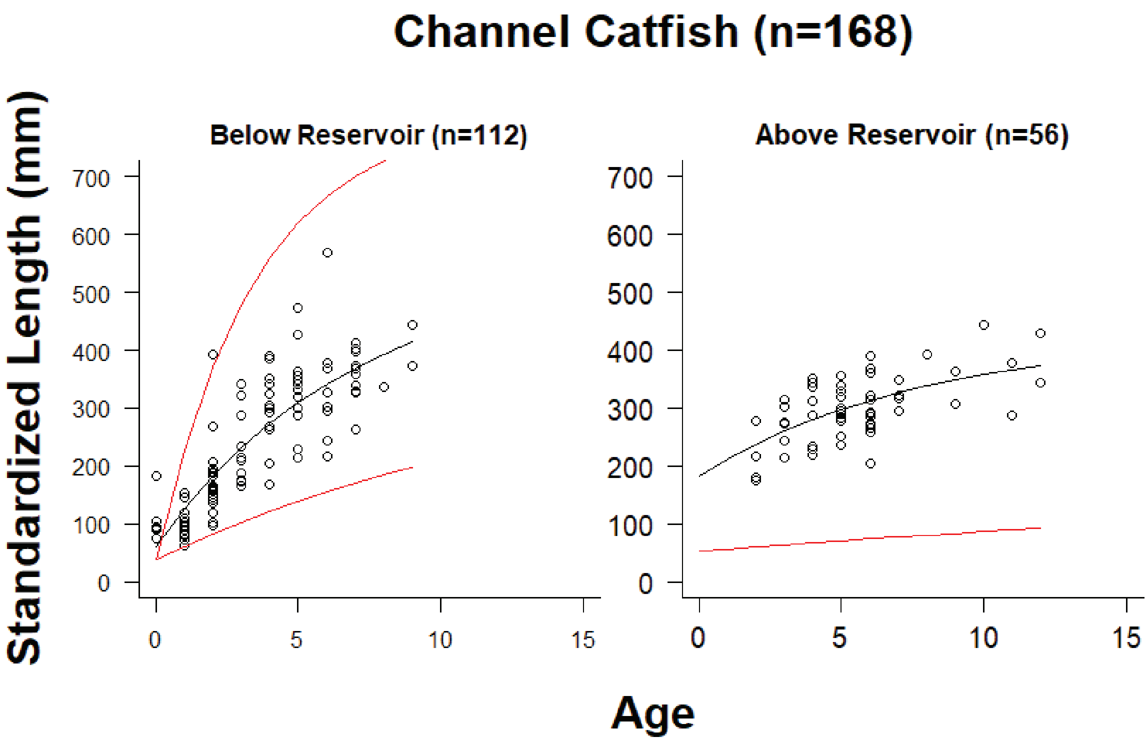


Figure 3.17. von Bertalanffy growth curves for Channel Catfish collected from above and below R.L. Harris Reservoir on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

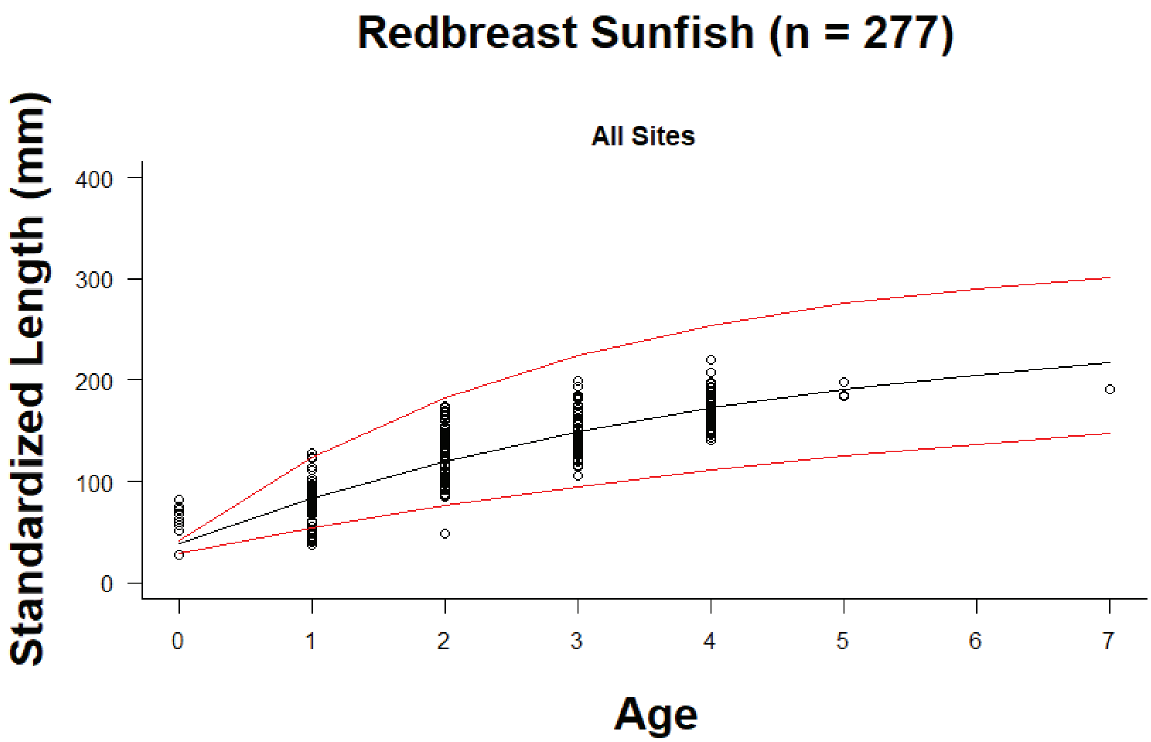


Figure 3.18. von Bertalanffy growth curve for Redbreast Sunfish collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

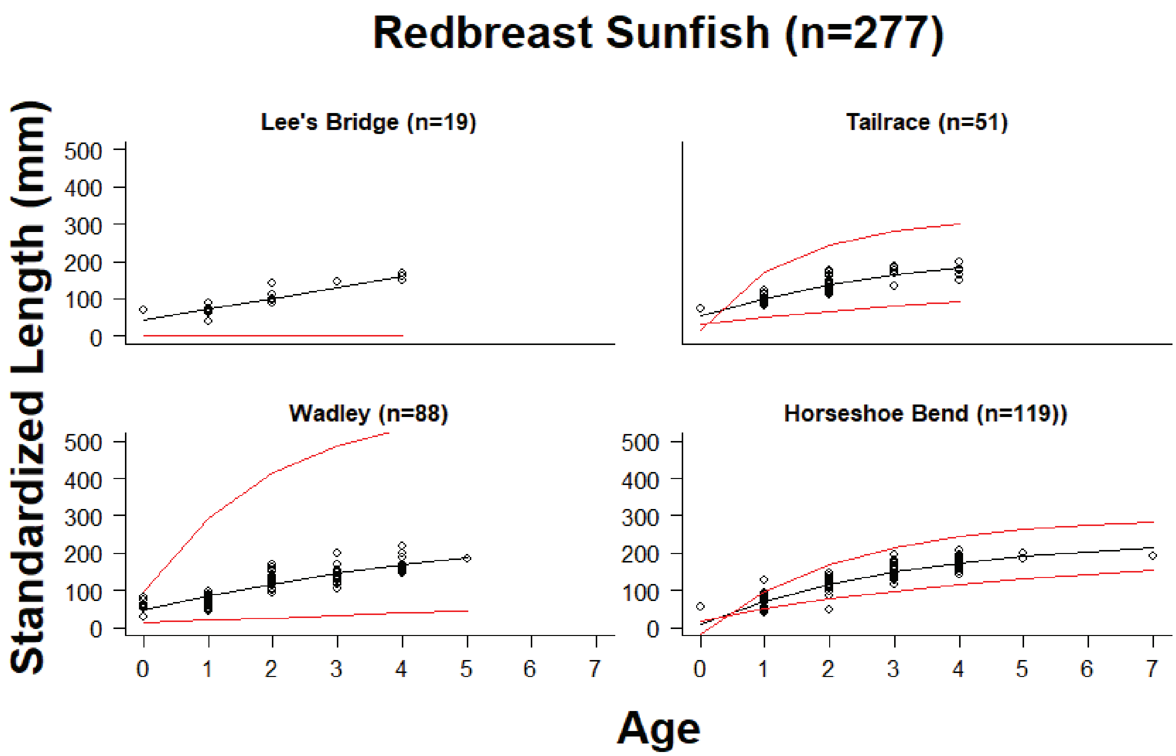


Figure 3.19. von Bertalanffy growth curves for Redbreast Sunfish collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

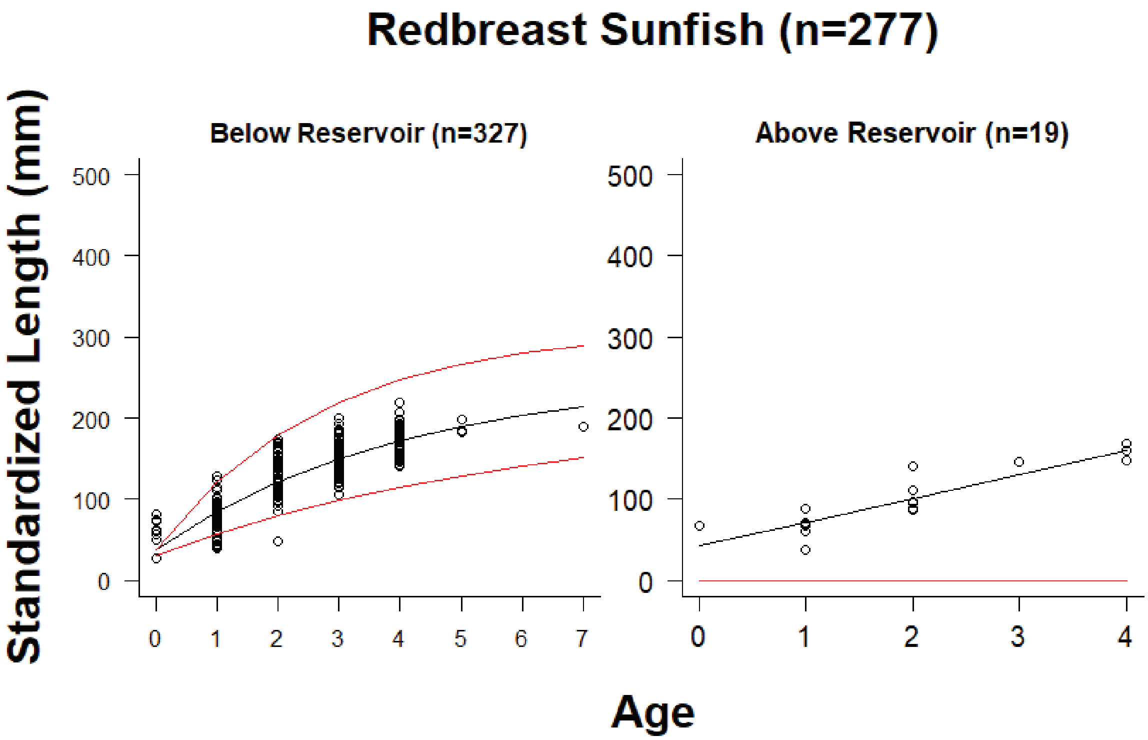


Figure 3.20. von Bertalanffy growth curves for Redbreast Sunfish collected from above and below R.L. Harris Reservoir on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

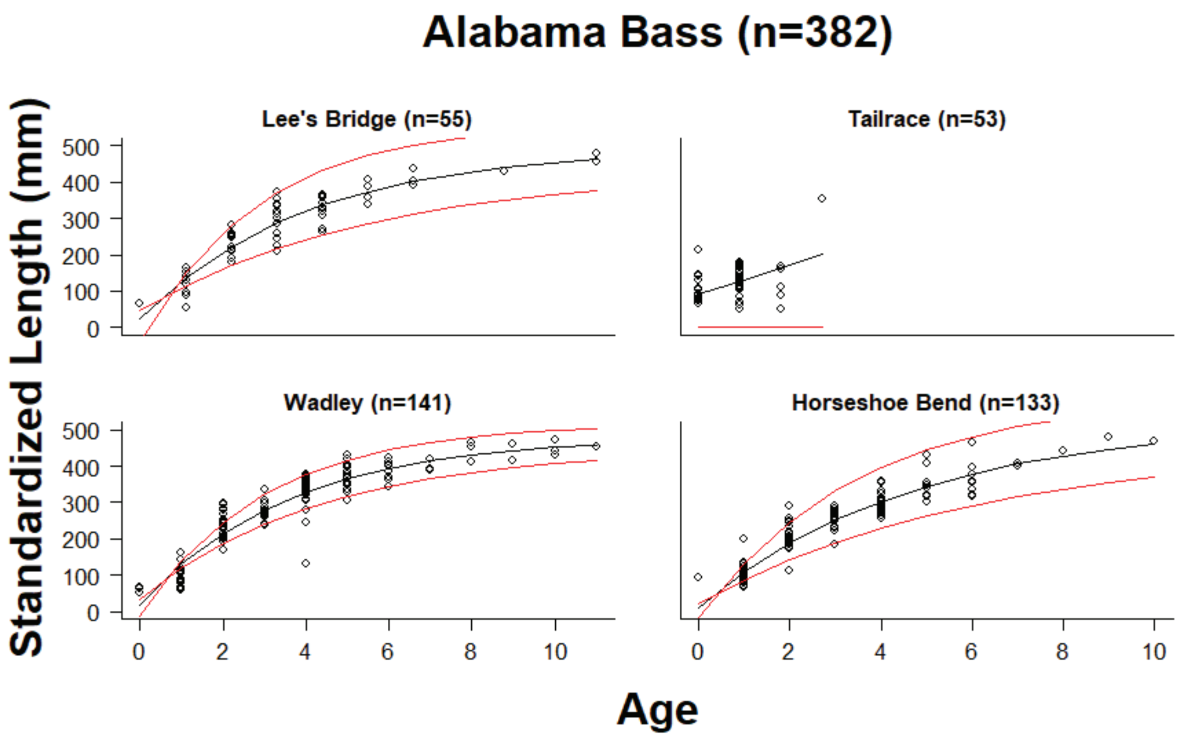


Figure 3.21. von Bertalanffy growth curves for Alabama Bass collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

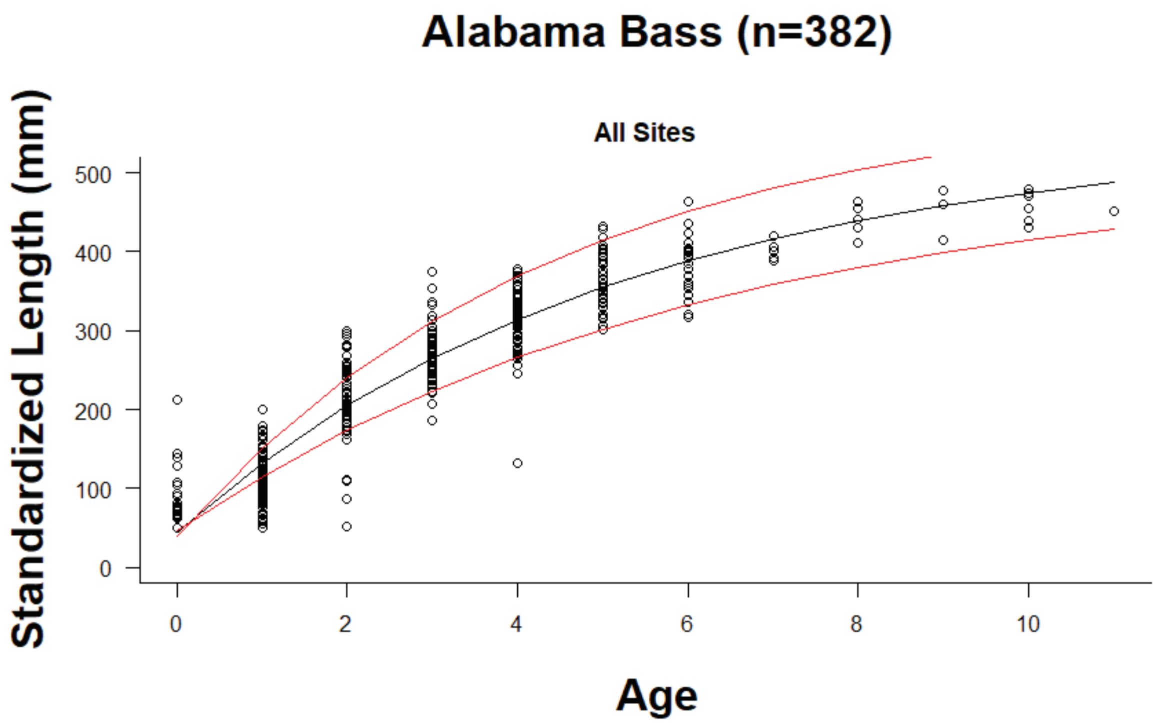


Figure 3.22. von Bertalanffy growth curves for Alabama Bass collected from all four Tallapoosa River, Alabama sites combined. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

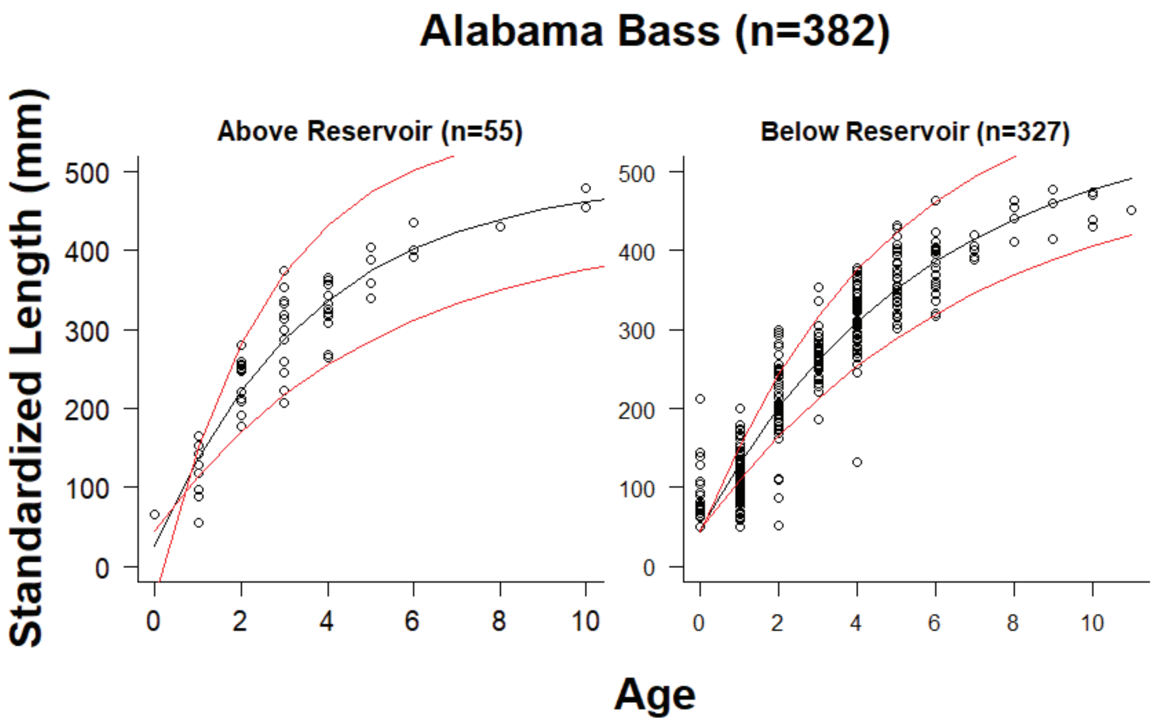


Figure 3.23. von Bertalanffy growth curves for Alabama Bass collected from above and below R.L. Harris Dam on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

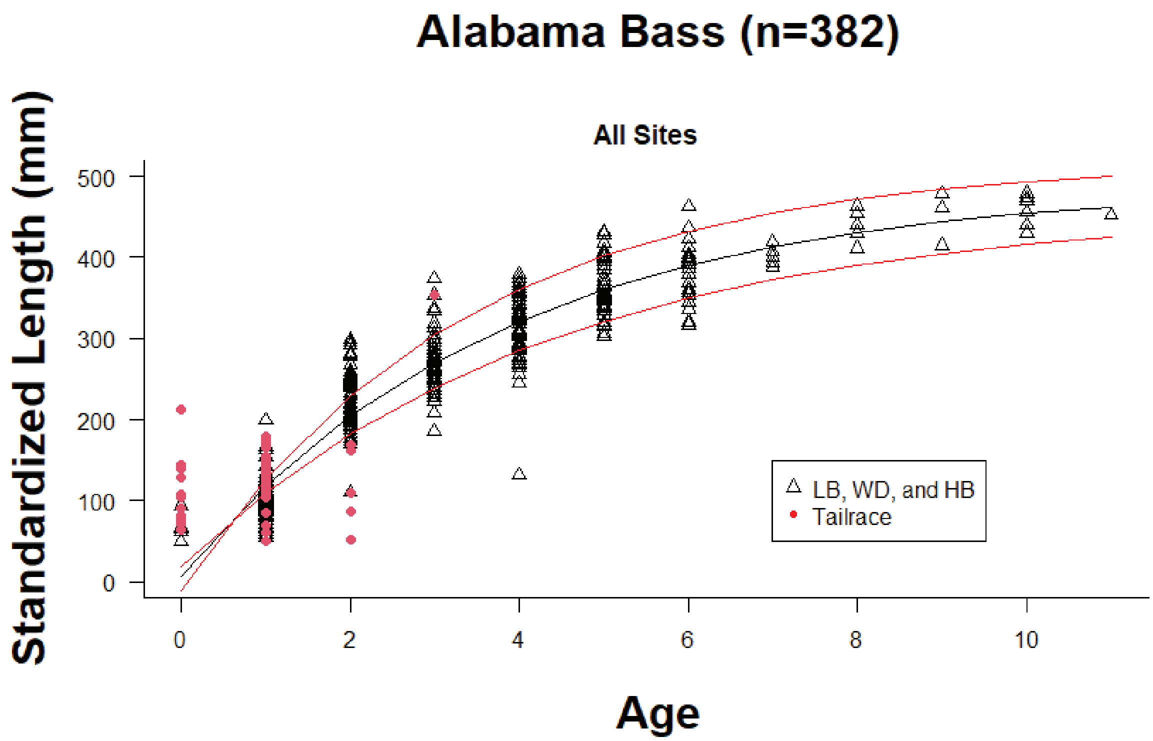


Figure 3.24. von Bertalanffy growth curve for Alabama Bass collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

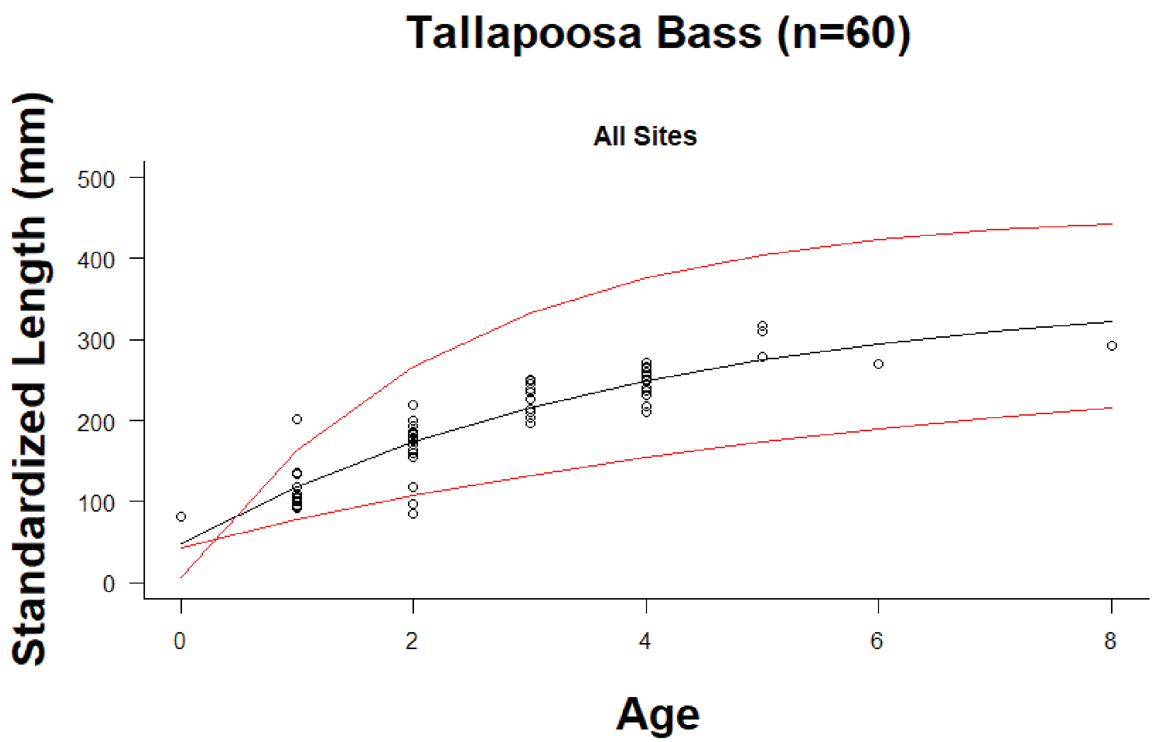


Figure 3.25. von Bertalanffy growth curve for Alabama Bass collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

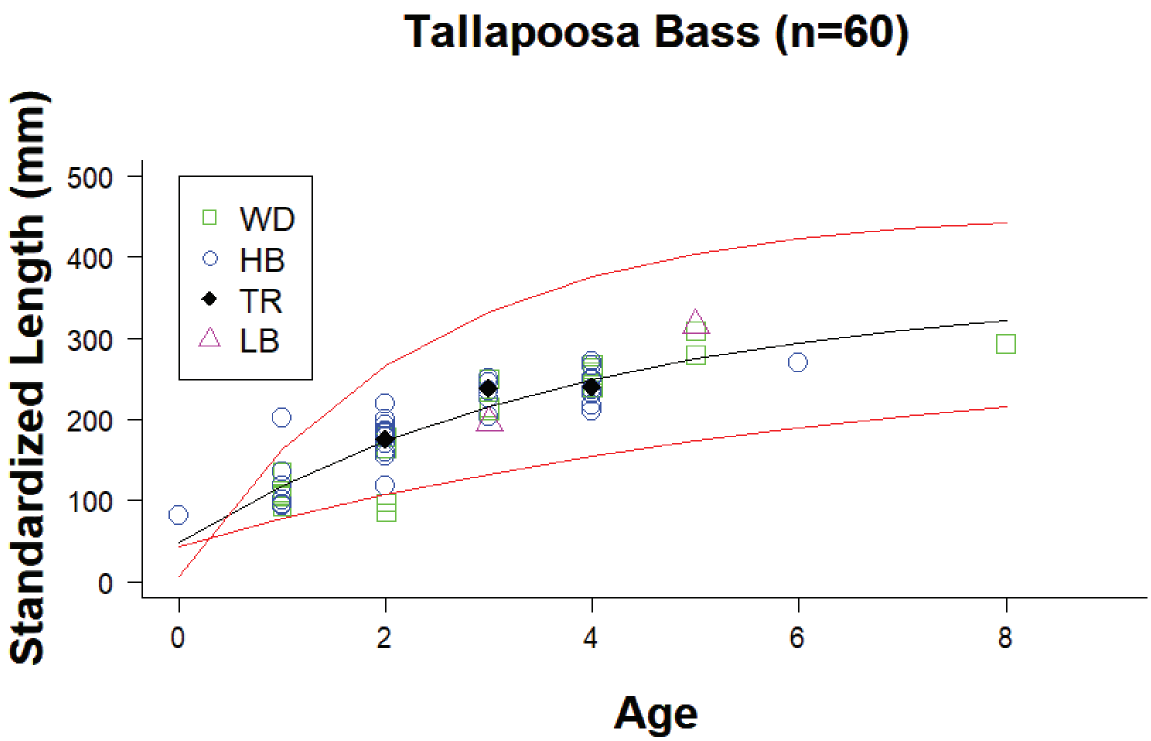


Figure 3.26. von Bertalanffy growth curve for Tallapoosa Bass collected from four sites on the Tallapoosa River, Alabama. Length was standardized to the last observed annulus using the direct proportion method. Red lines represent the estimate ± 1.96 times the standard error.

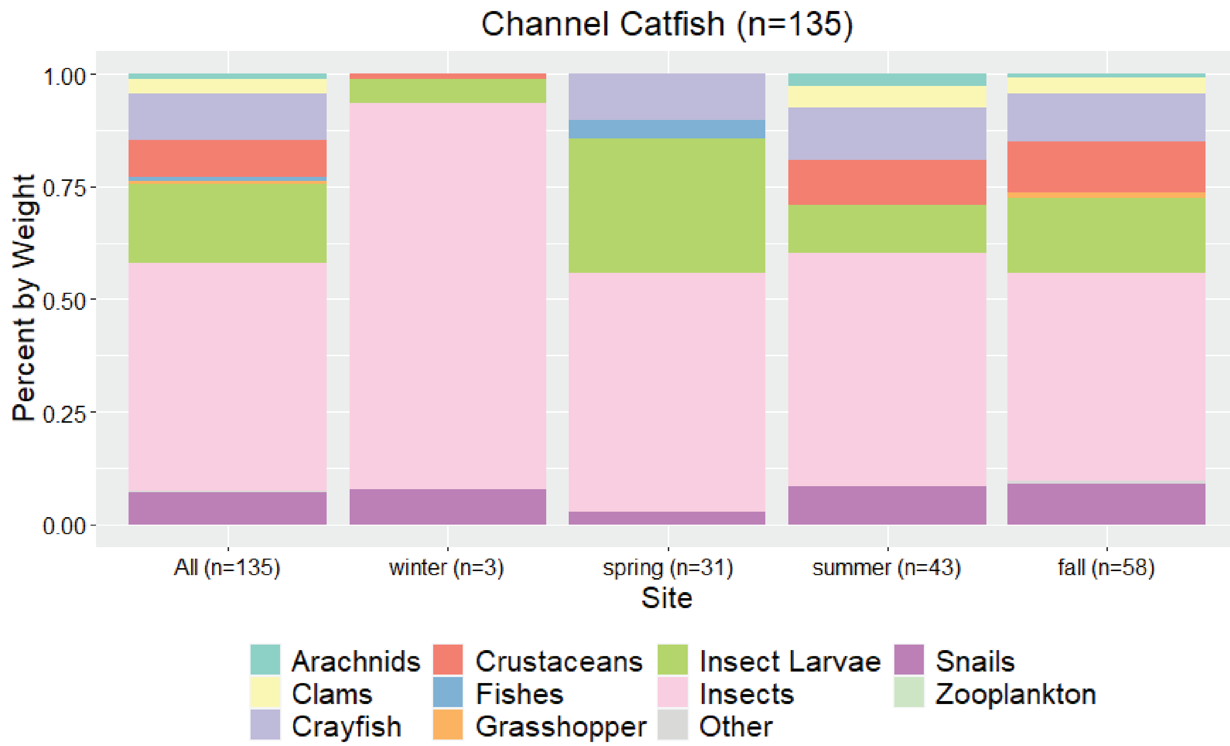


Figure 3.27. Diet composition (average percent by weight) overall and by season for Channel Catfish collected from the Tallapoosa River, Alabama. Sample sizes are in parentheses.

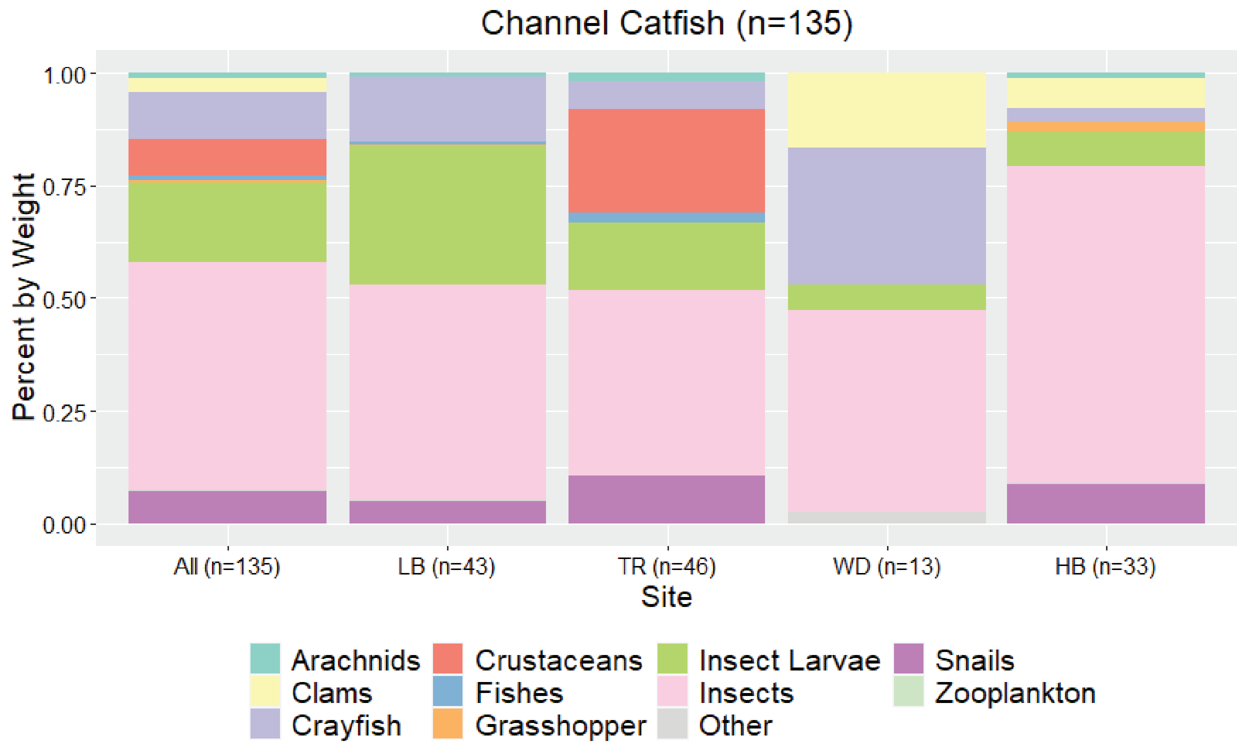


Figure 3.28. Diet composition (average percent by weight) overall and by site for Channel Catfish collected from the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sample sizes are in parentheses.

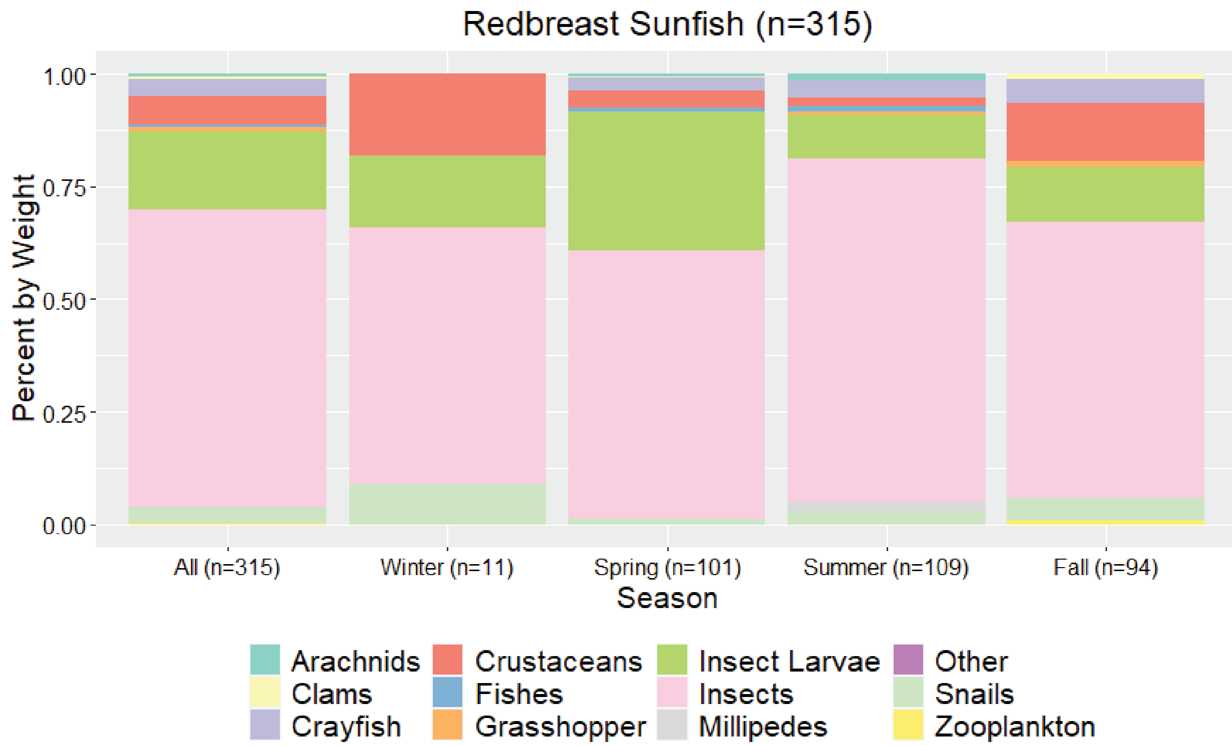


Figure 3.29. Diet composition (average percent by weight) overall and by season for Redbreast Sunfish collected from the Tallapoosa River, Alabama. Sample sizes are in parentheses.

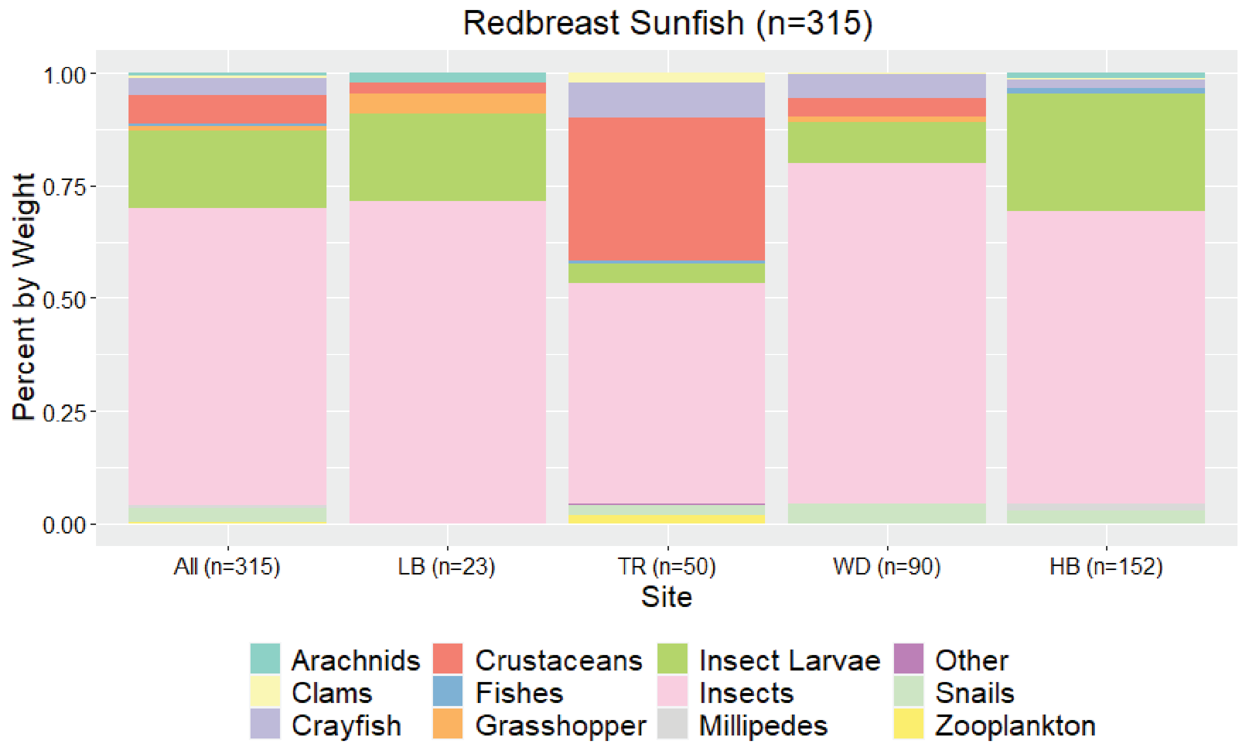


Figure 3.30. Diet composition (average percent by weight) overall and by site for Redbreast Sunfish collected from the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sample sizes are in parentheses.

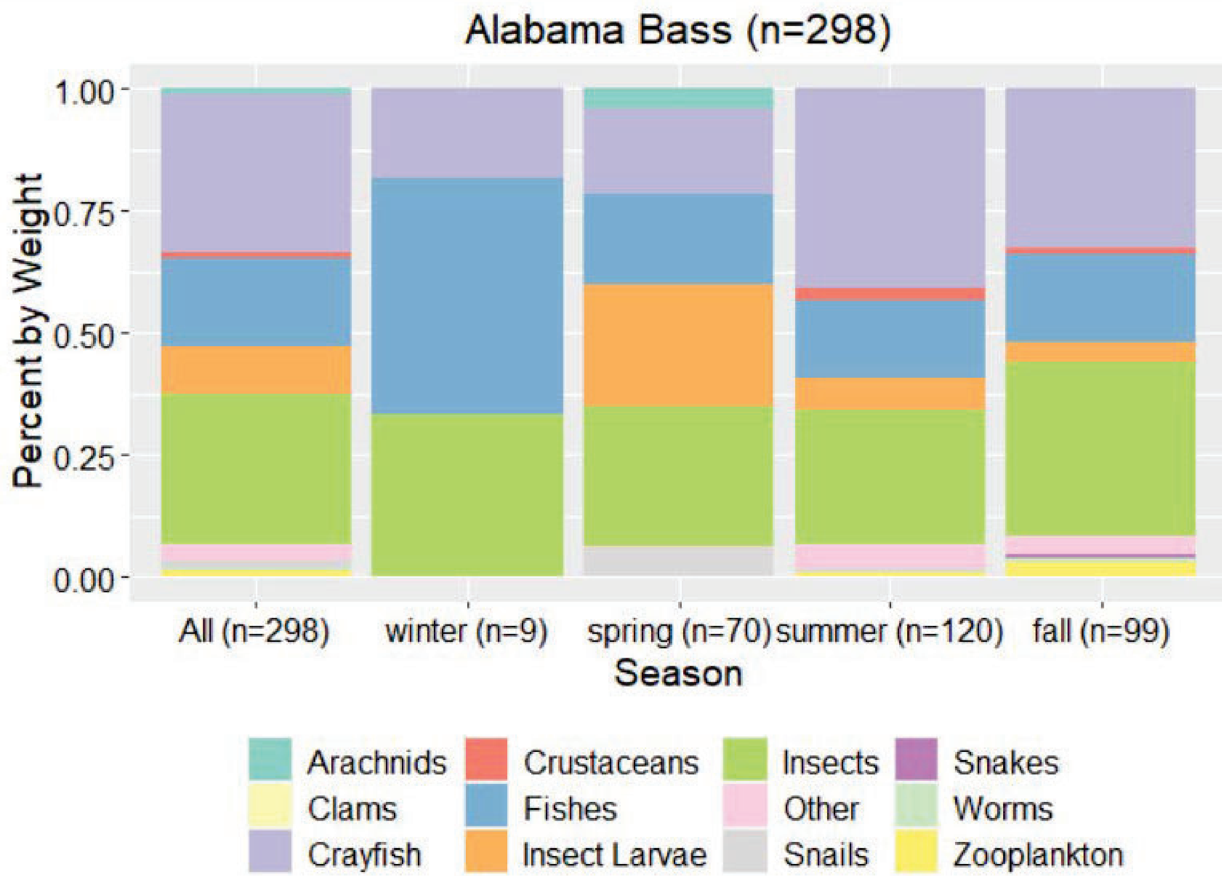


Figure 3.31. Diet composition (average percent by weight) overall and by season for Alabama Bass collected from the Tallapoosa River, Alabama. Sample sizes are in parentheses.

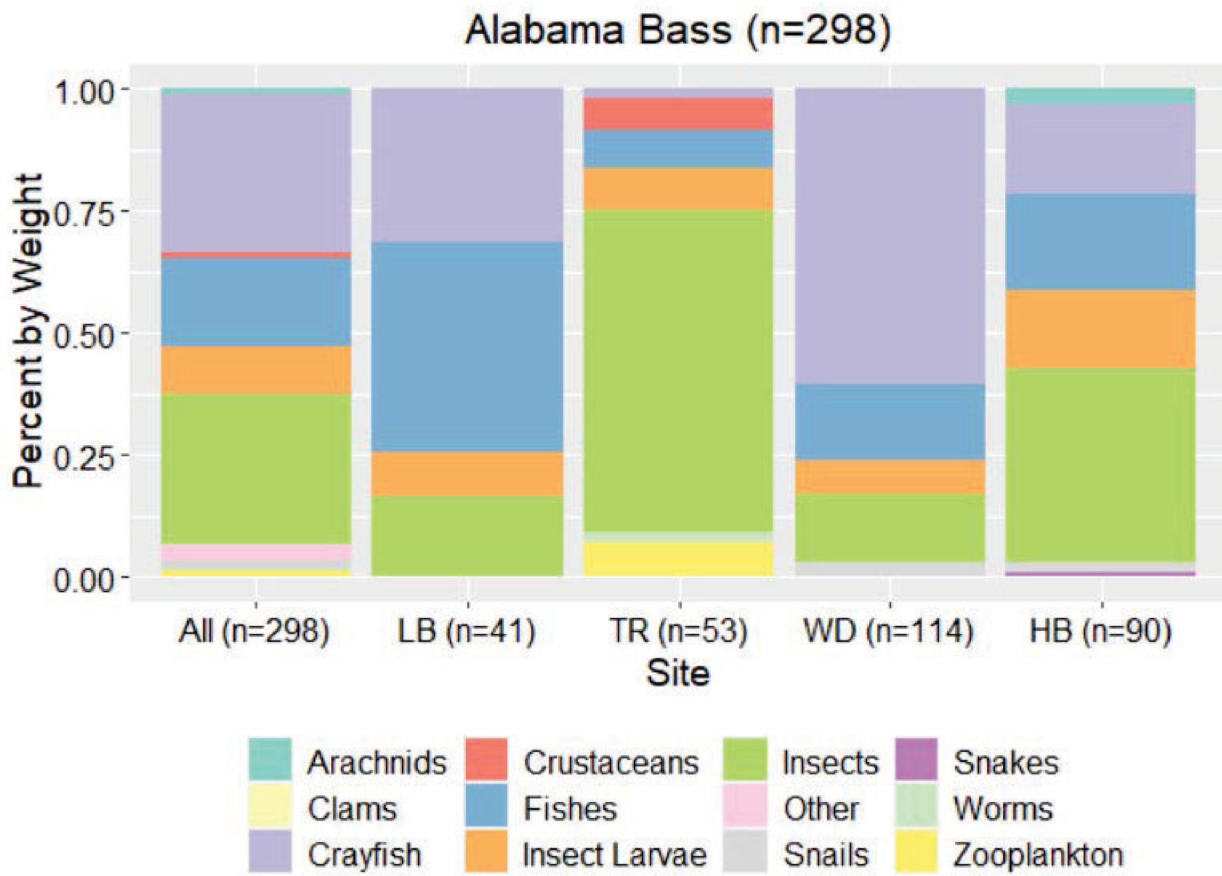


Figure 3.32. Diet composition (average percent by weight) overall and by site for Alabama Bass collected from the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sample sizes are in parentheses.

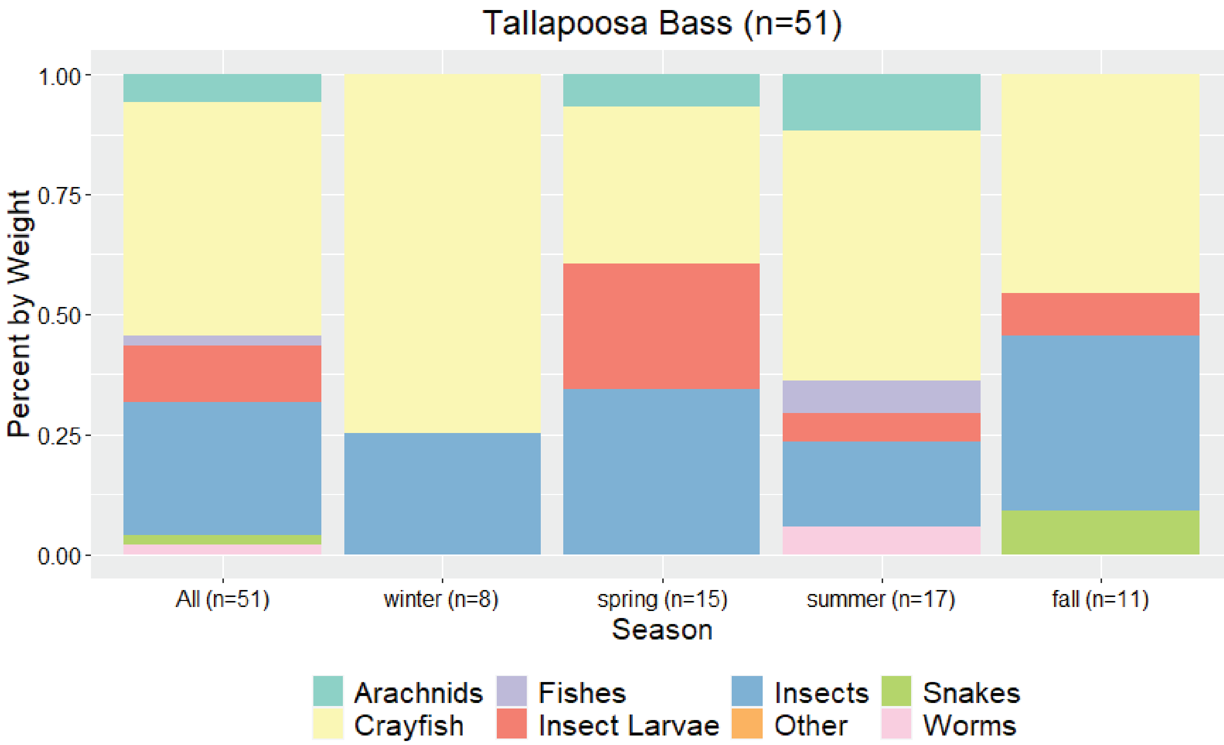


Figure 3.33. Diet composition (average percent by weight) overall and by season for Tallapoosa Bass collected from the Tallapoosa River, Alabama. Sample sizes are in parentheses.

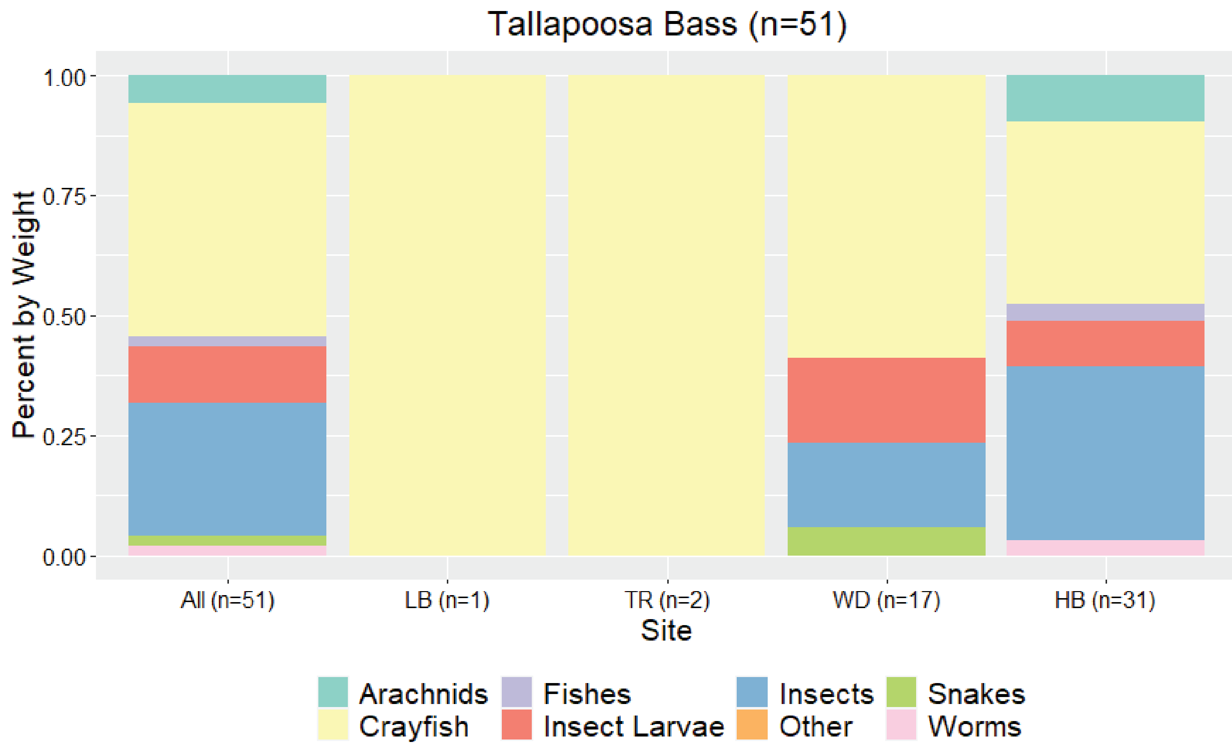


Figure 3.34. Diet composition (average percent by weight) overall and by site for Tallapoosa Bass collected from the Tallapoosa River, Alabama. Sites are as defined in Figure 3.1. Sample sizes are in parentheses.

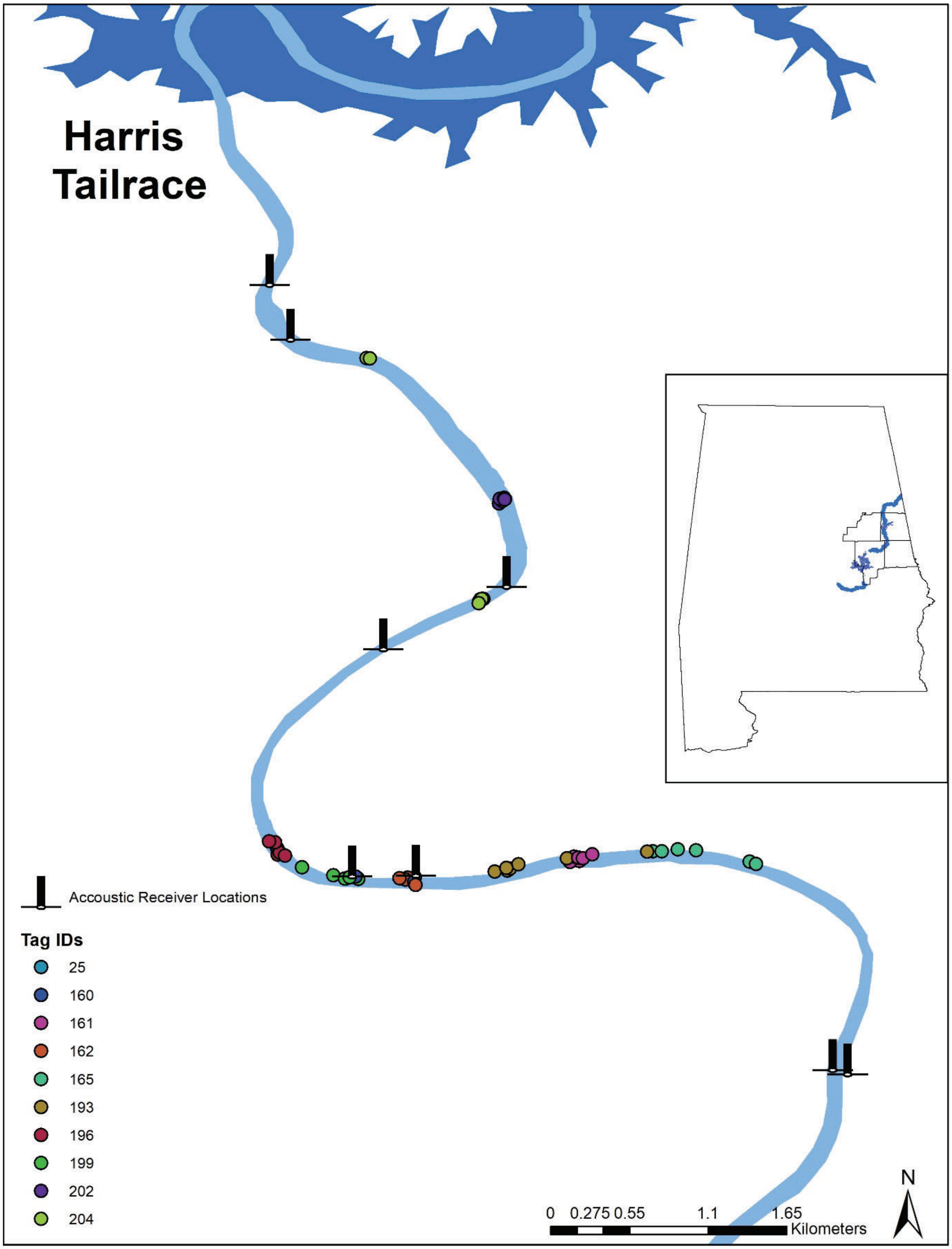


Figure 3.35: Map of each detected fish's position (maximum signal strength) during each manual tracking effort.

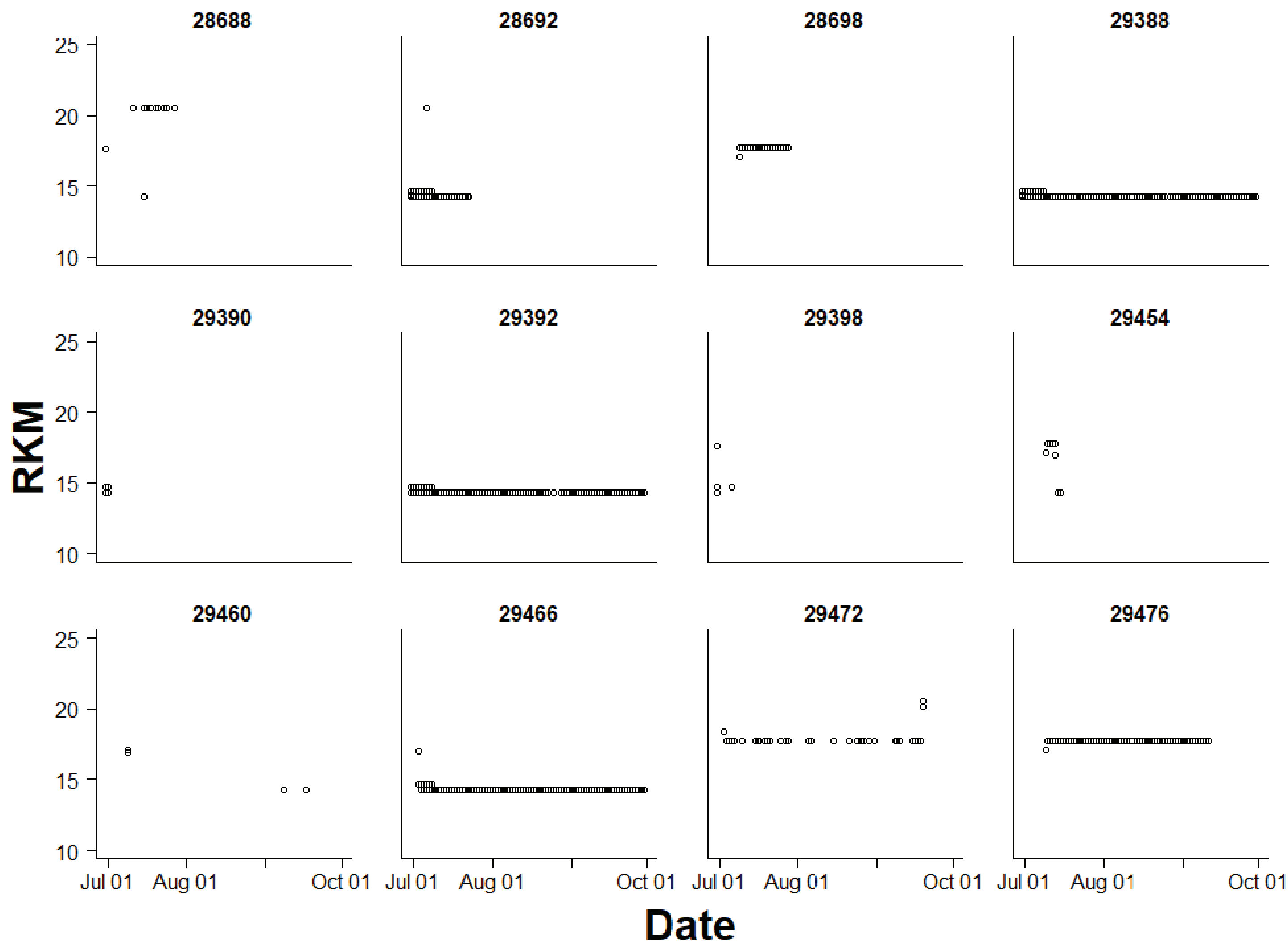


Figure 3.36. Graph fish position (RKM) by date for each fish detected by a stationary acoustic array in the Tallapoosa River, Alabama. RKM zero was set at the furthest downstream receiver located at the Wadley site.

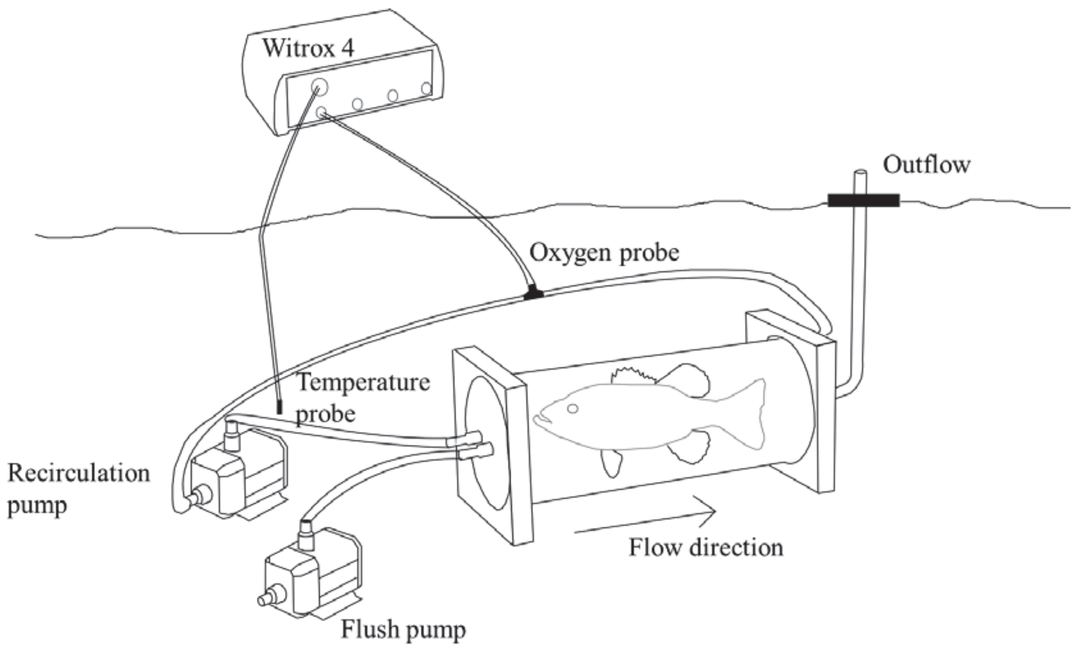


Figure 4.1a. static respirometry system.

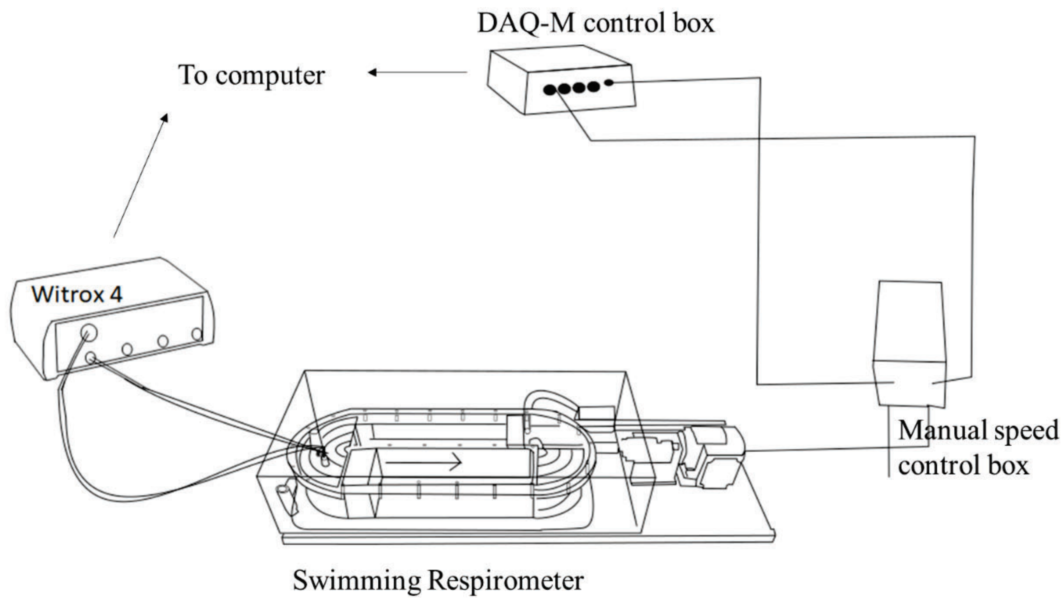


Figure 4.1b. swimming respirometer.

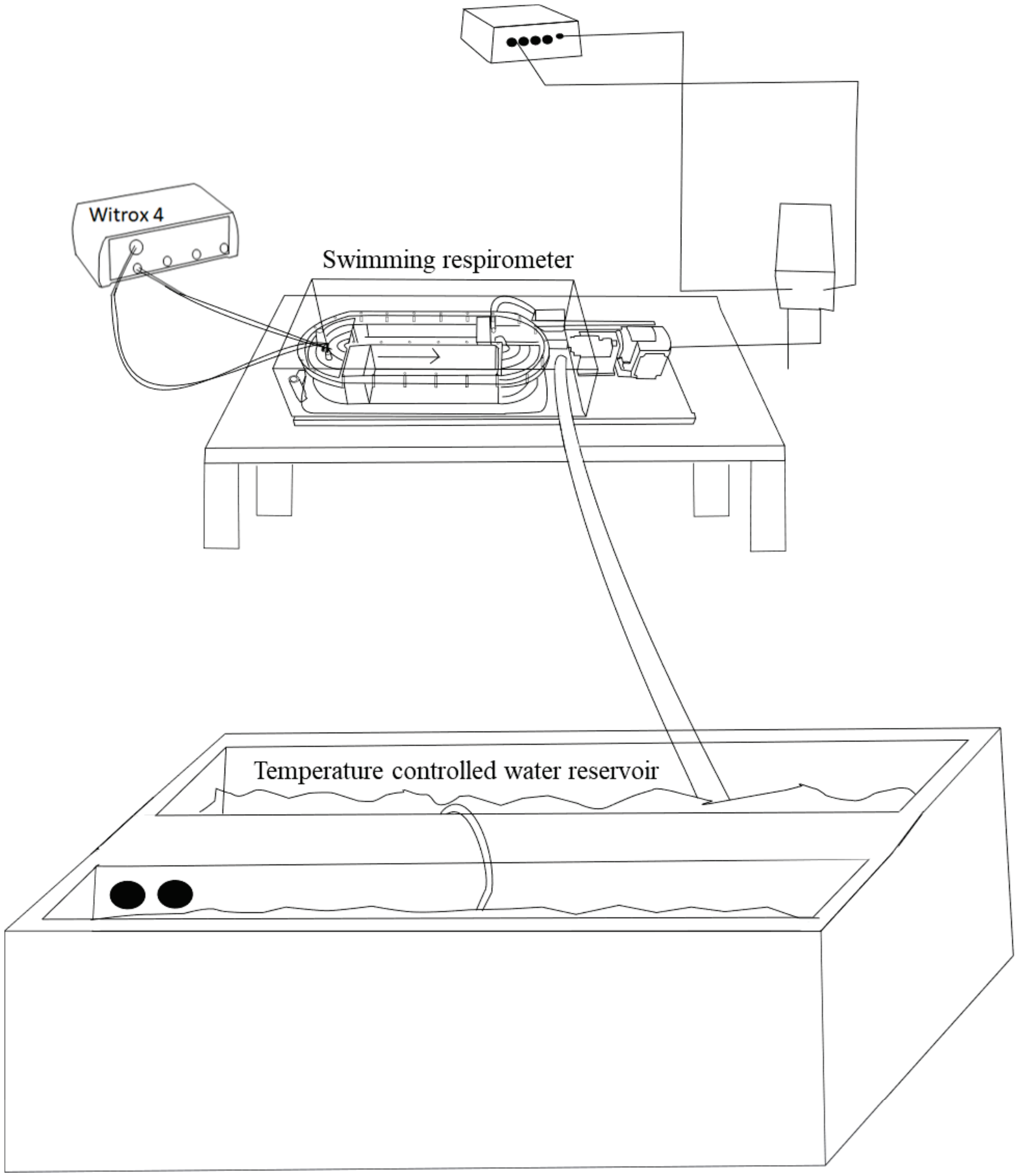


Figure 4.1c. Set up of water exchange with the swimming respirometer.

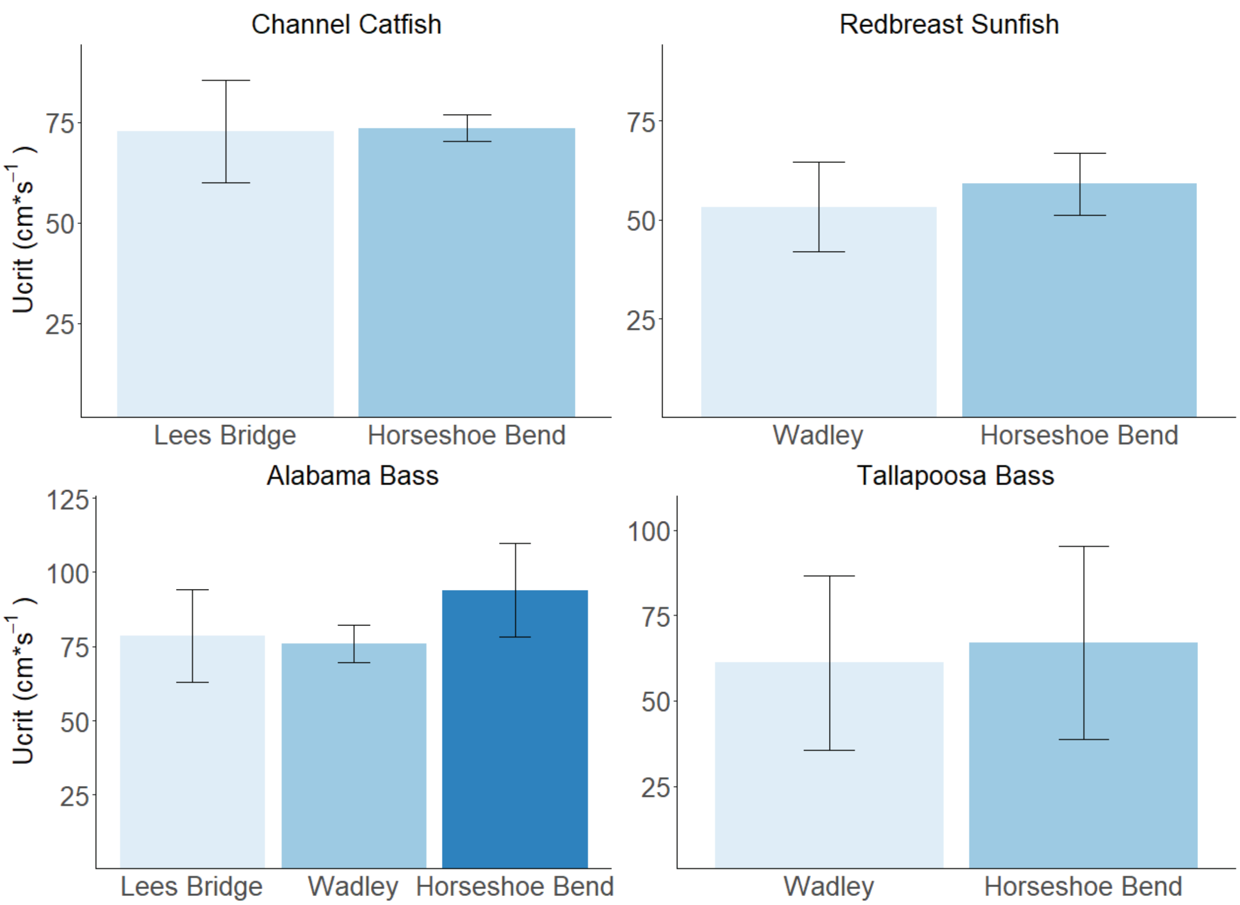


Figure 4.2. Critical swimming speed of each species based on capture location.

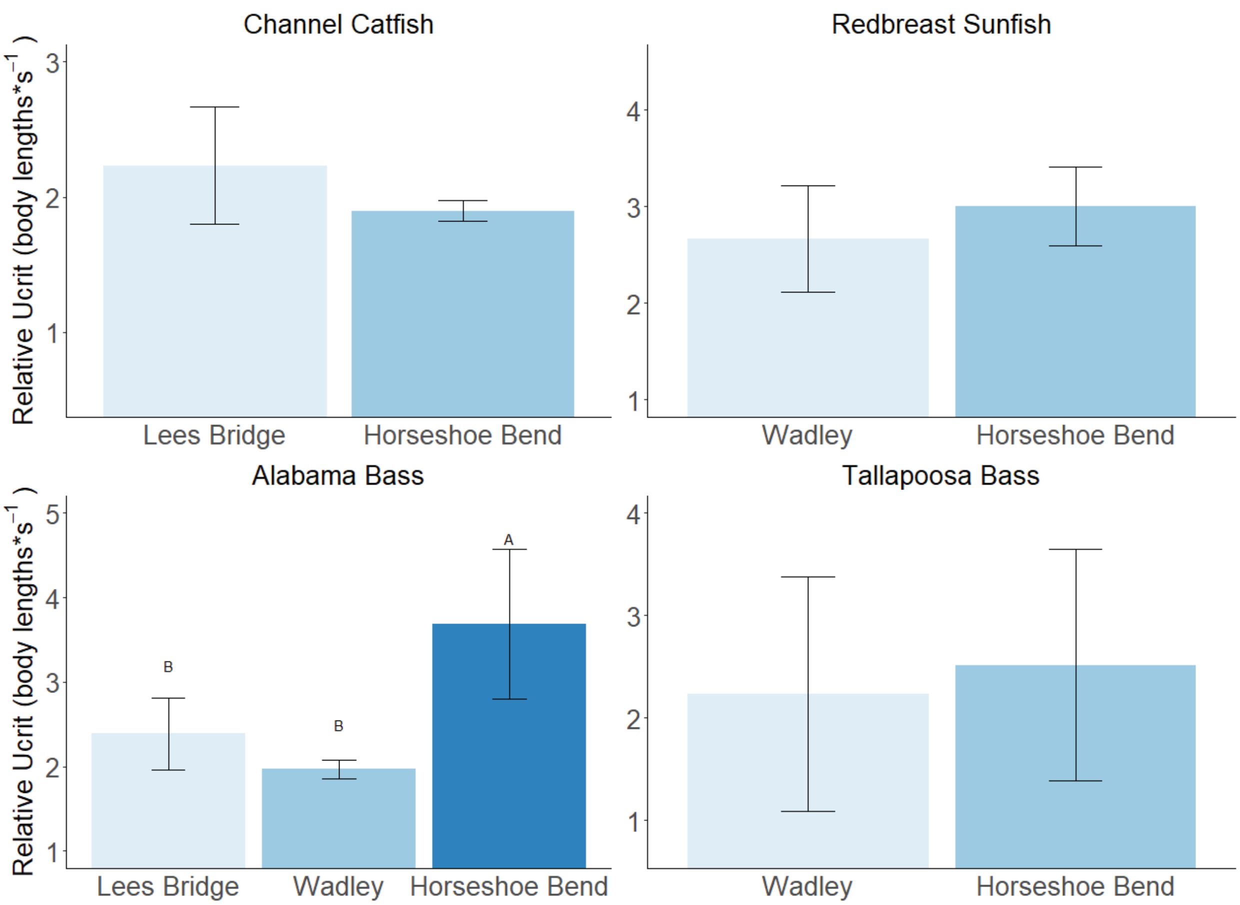


Figure 4.3. Relative U_{crit} of four species by collection site. Bars with different letters above them indicate values that differed significantly among sites within a species. All bars represent standard error.

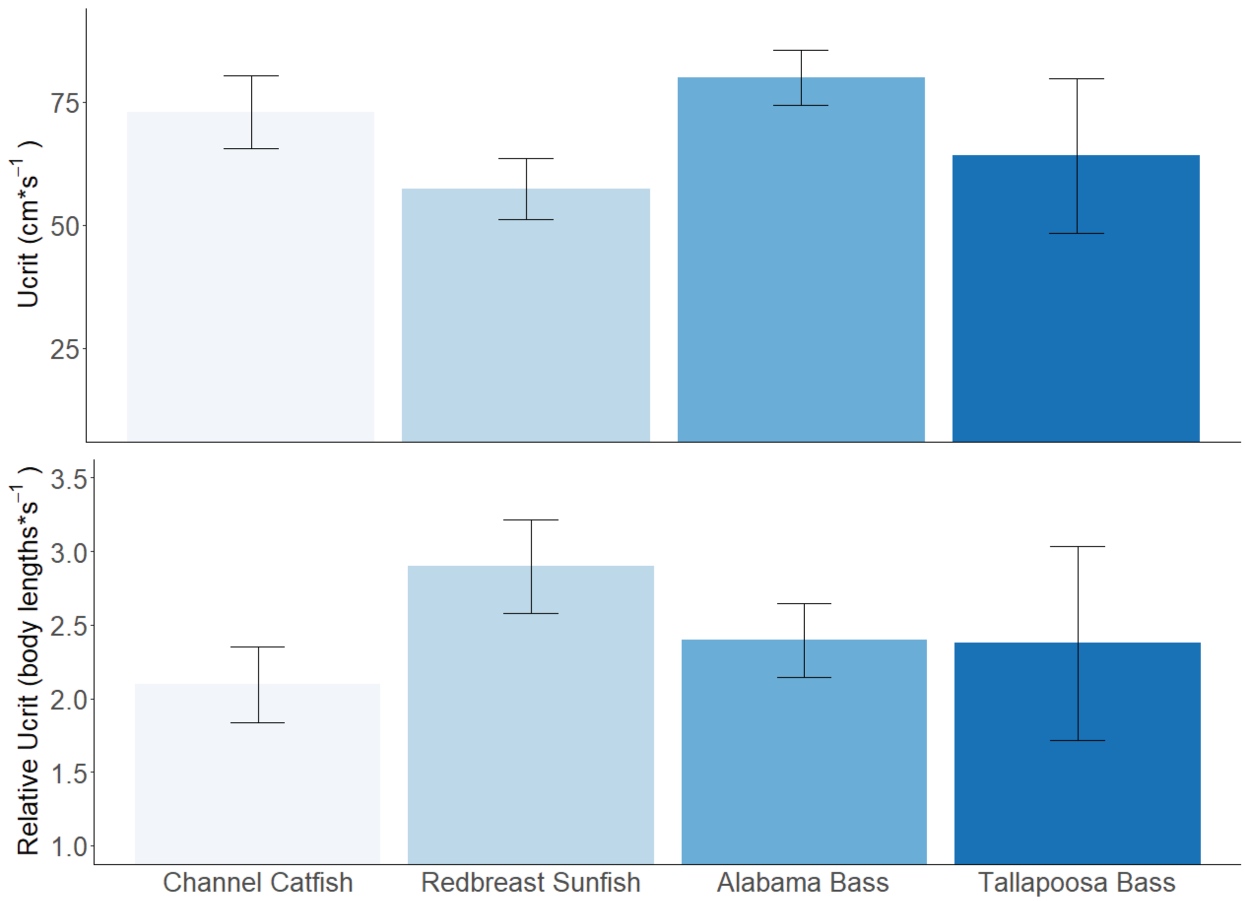


Figure 4.4. Average U_{crit} for each species with standard error bars (top) and average relative U_{crit} for each species collected from all sites with standard error bars (bottom).

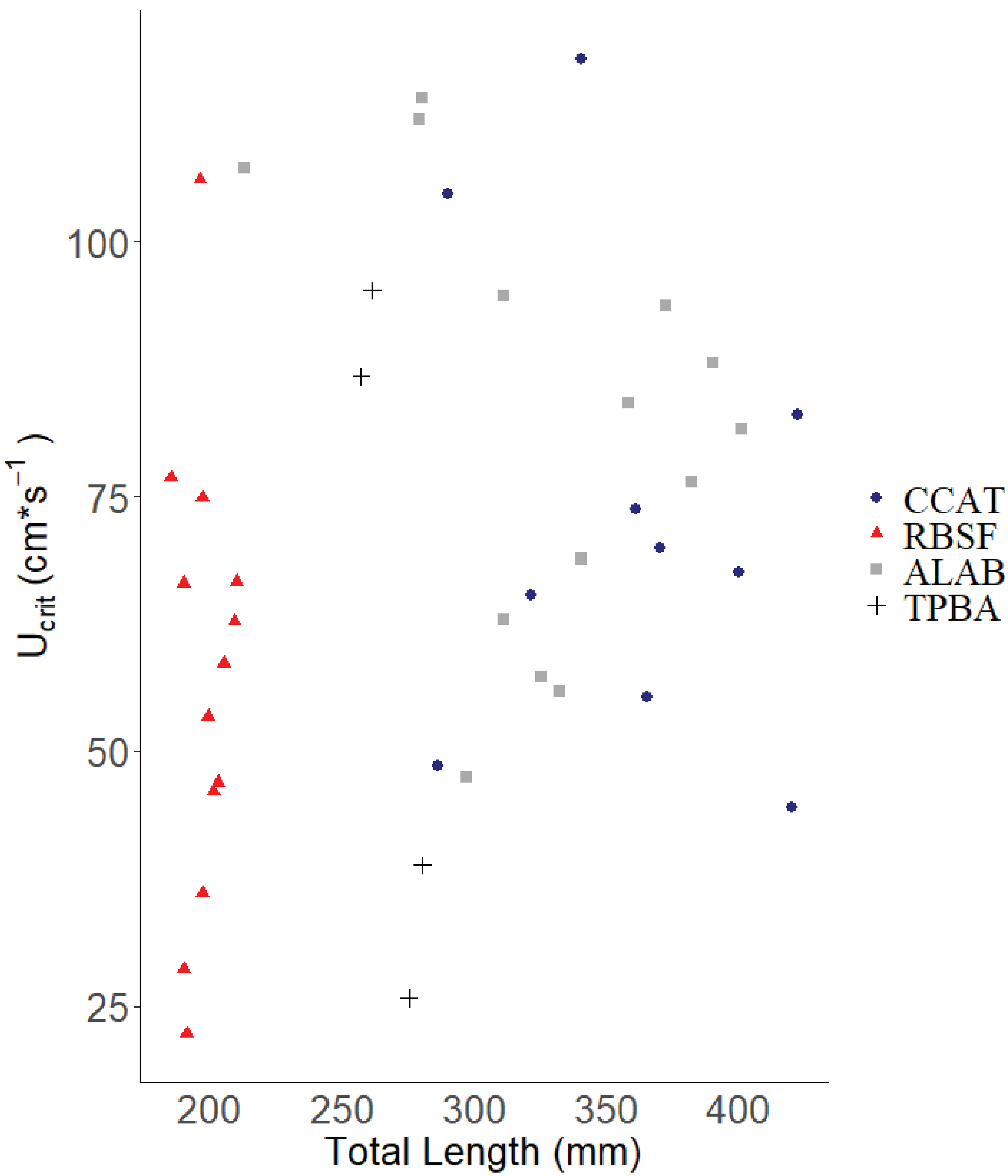


Figure 4.5. Plot of total length and U_{crit} for all species and locations.

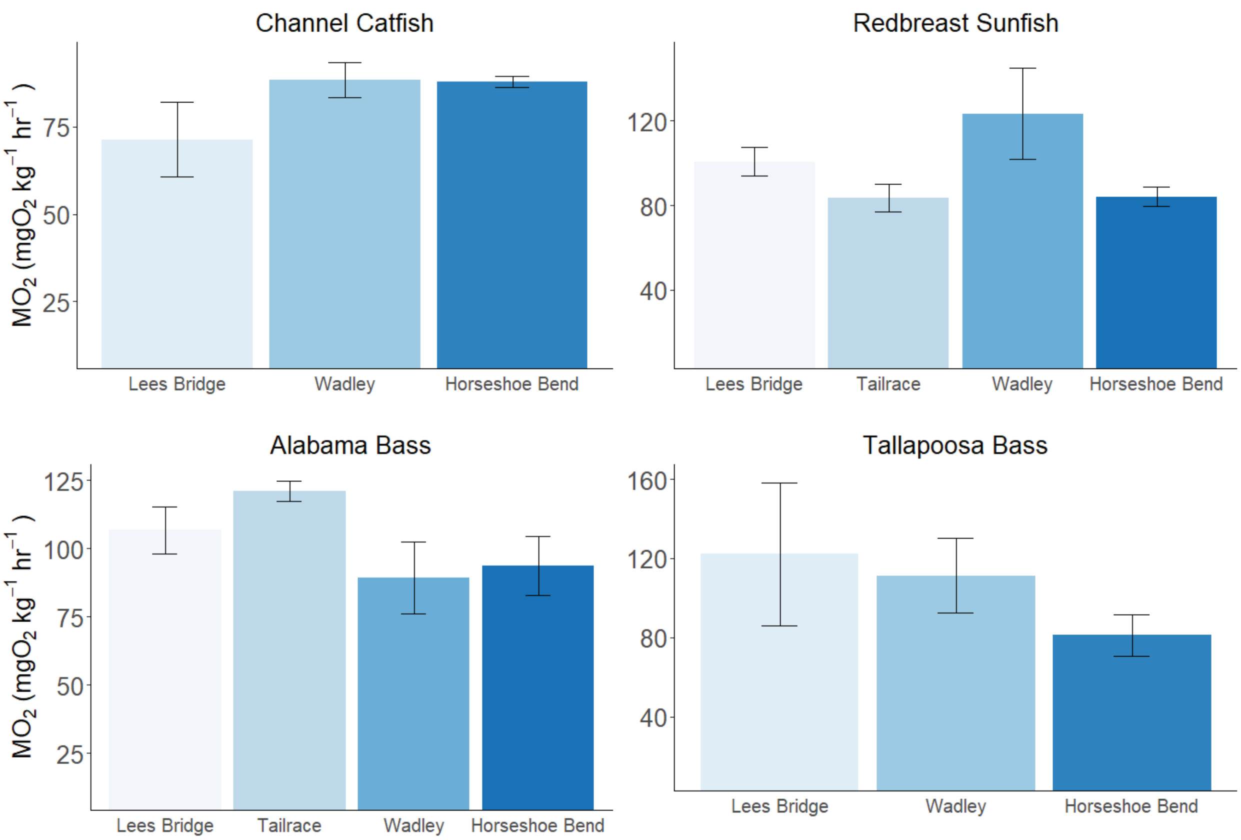


Figure 4.6. Average SMR for each species across sites at 21 C. Error bars are SE. There were no differences across sites.

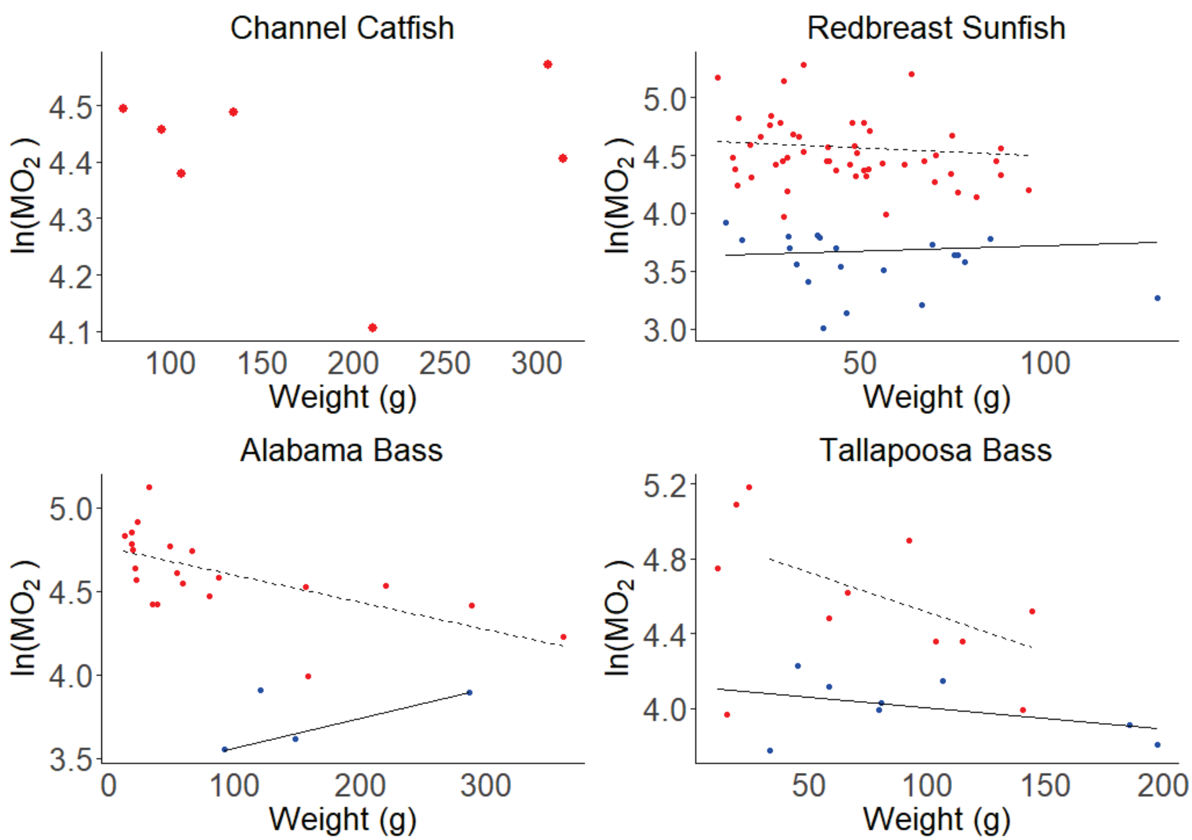


Figure 4.7. Respiration rate as a function of weight for each target species. Blue dots are fish tested at 21 C while red dots are fish tested at 10 C.

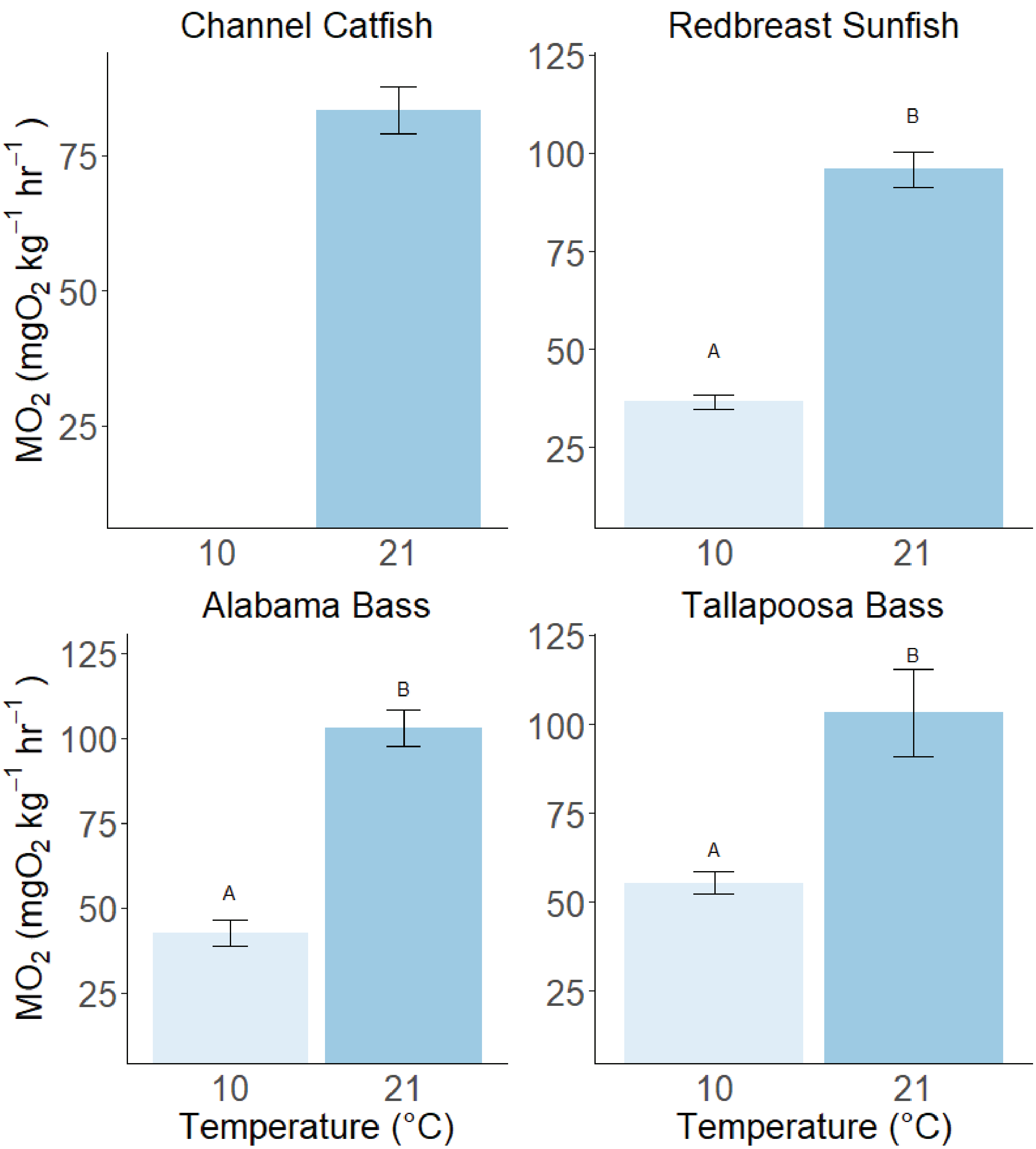


Figure 4.8. Average SMR for each species at 10 and 21 C with standard error bars.

mind when comparing the largest and smallest individuals AMR and SMR.

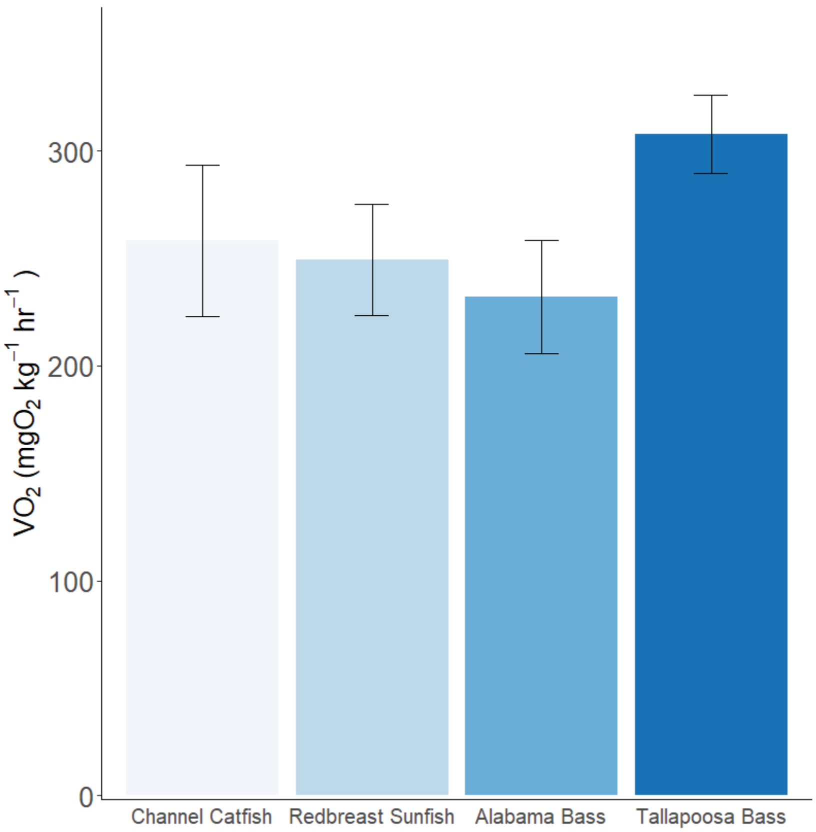


Figure 4.9. Average (± 1 SE) maximum AMR for each species combined across sites.

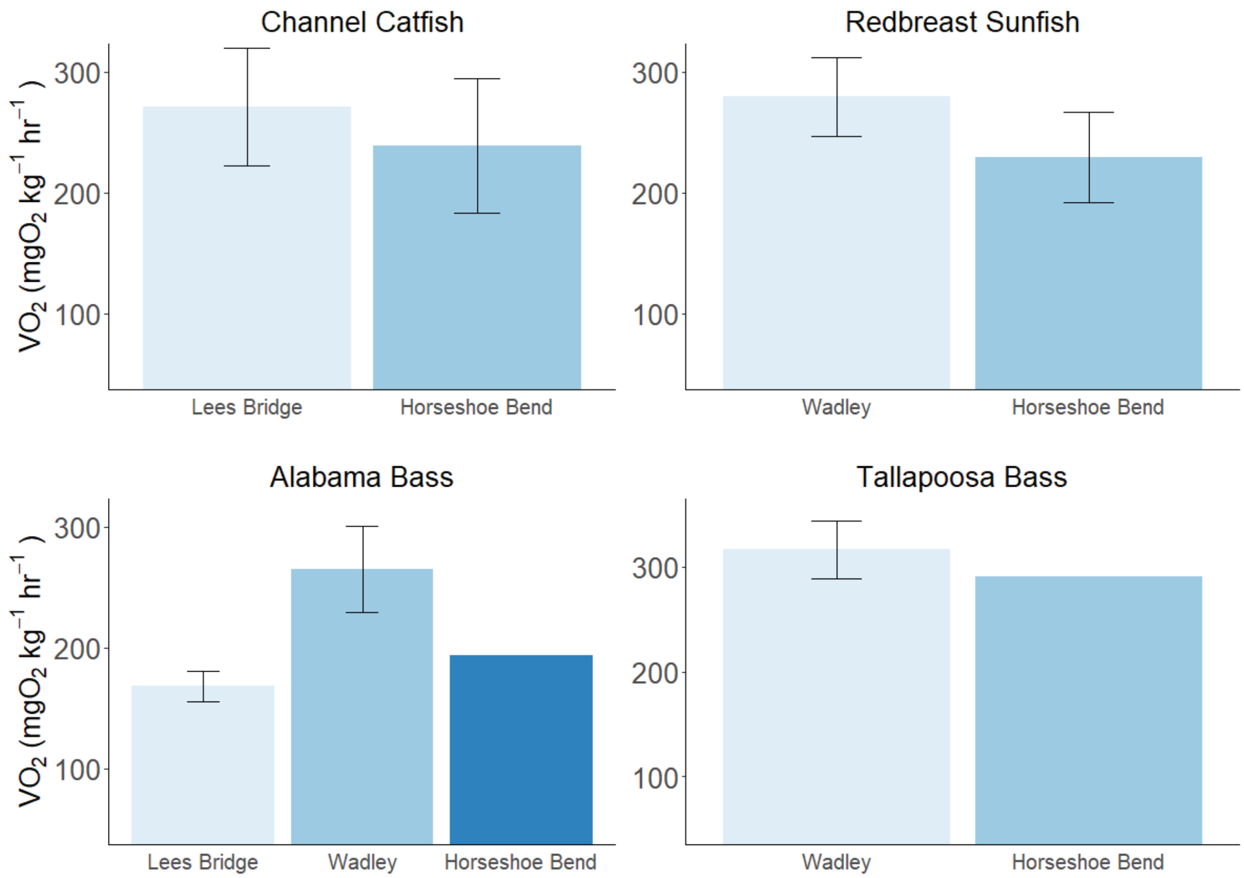


Figure 4.10. Average (± 1 SE) maximum AMR for each species collected at all sites. Some samples were unusable for AMR analysis due to equipment failure leading to a single individual Alabama Bass and Tallapoosa Bass being tested at Horseshoe Bend.

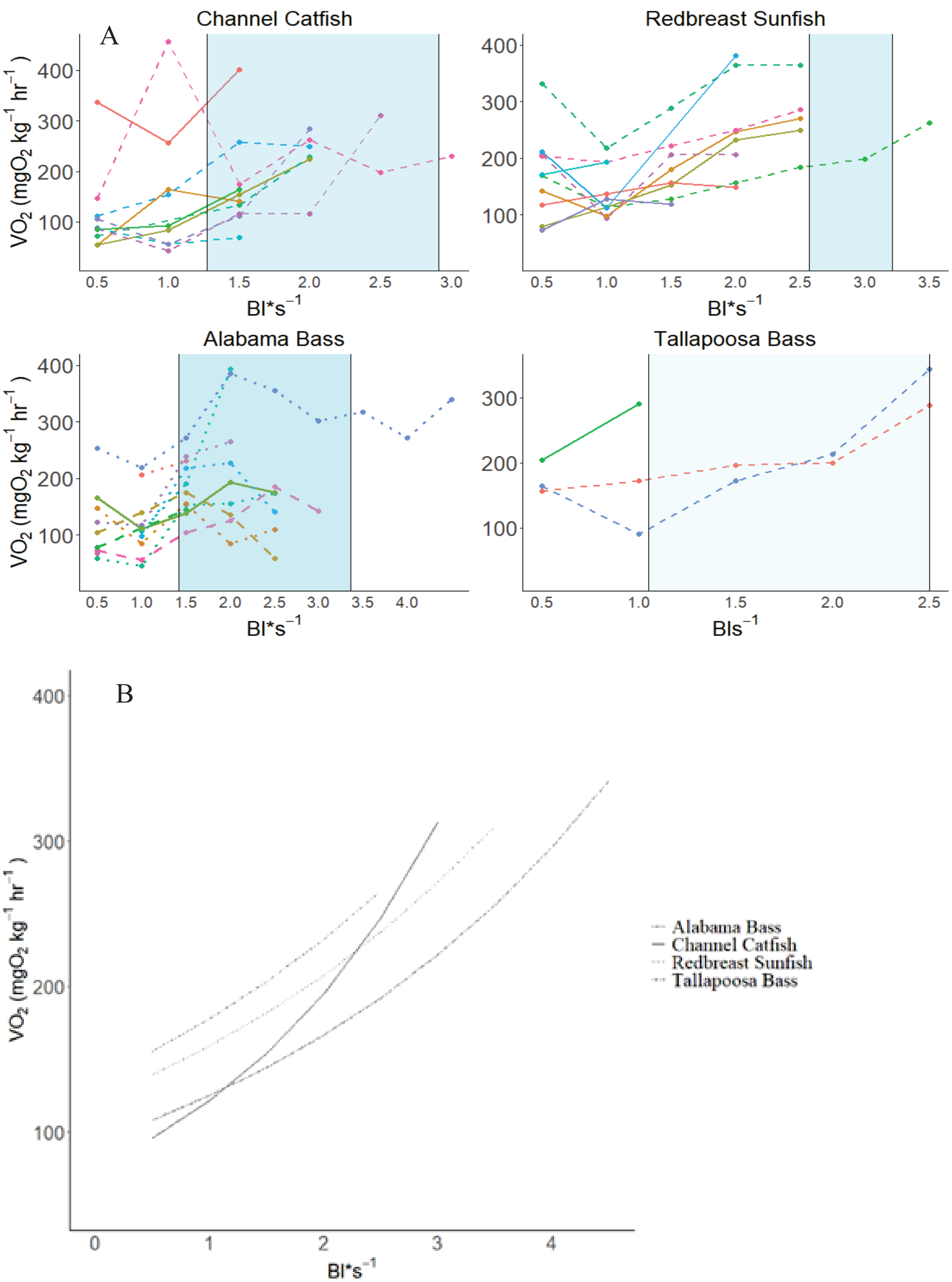


Figure 4.11. Active metabolic rate as a function of relative swimming speed ($Bl*s^{-1}$). Blue shaded areas indicate ±1 standard deviation of species average U_{crit}. B shows the predicted value of VO_2 based on relative speed. Models were derived from fish used in U_{crit} trials (1 measure per fish per speed). The best model was a logarithmic model (lny) (Channel Catfish r^2 = 0.26, 4.3296 + 0.4722x; Redbreast Sunfish r^2 = 0.26, 4.8042+0.2667x; Alabama Bass r^2 = 0.25, 4.5415 + 0.28715x; Tallapoosa Bass r^2 = 0.32, 4.9132+0.2683x)

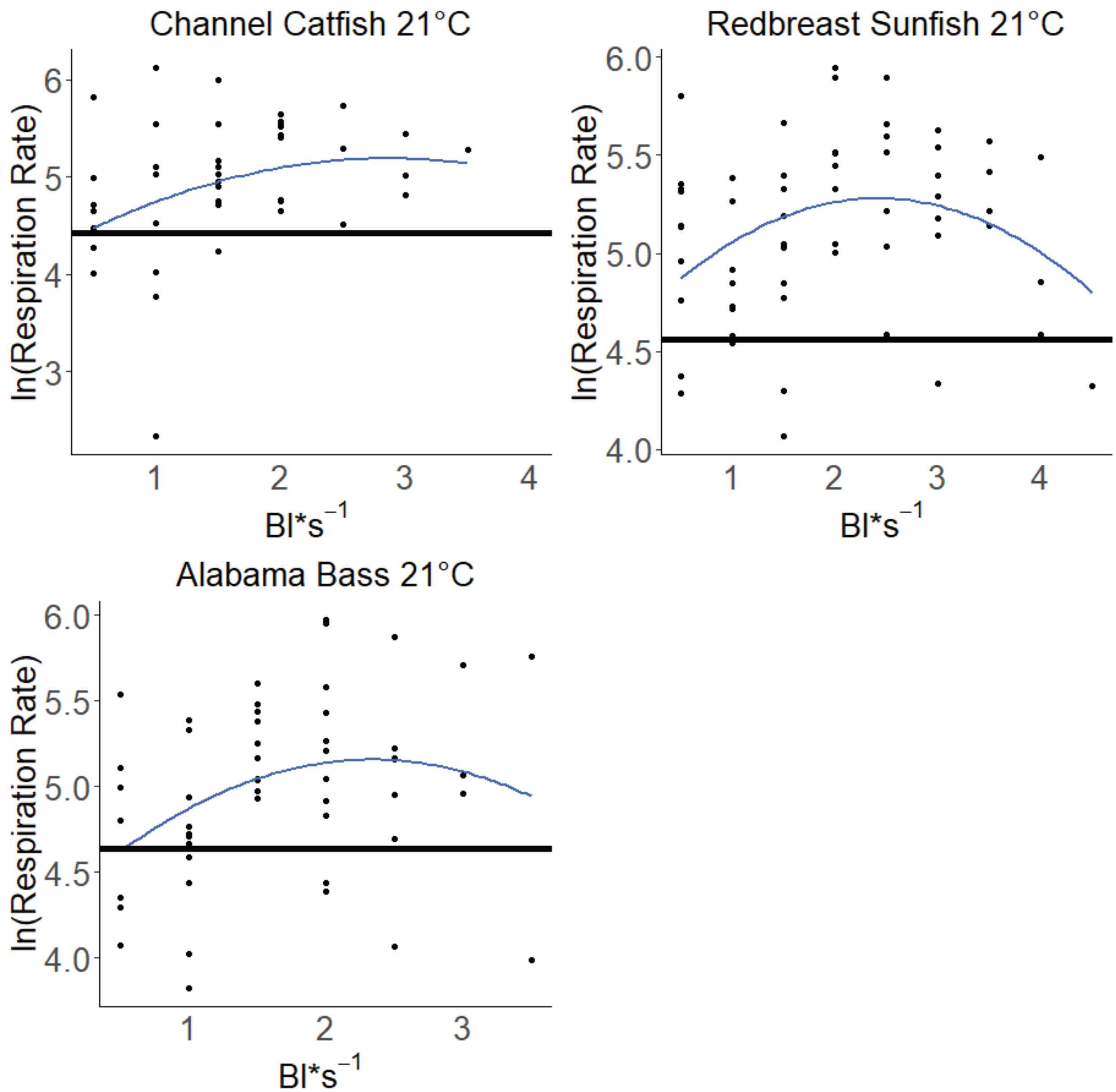


Figure 4.12. Active metabolic rates (black dots) and average standard metabolic rates for each species. The area between the second order polynomial line (blue line) and the average SMR (black line) represents the average Scope for Metabolic Activity for the species at 21°C.

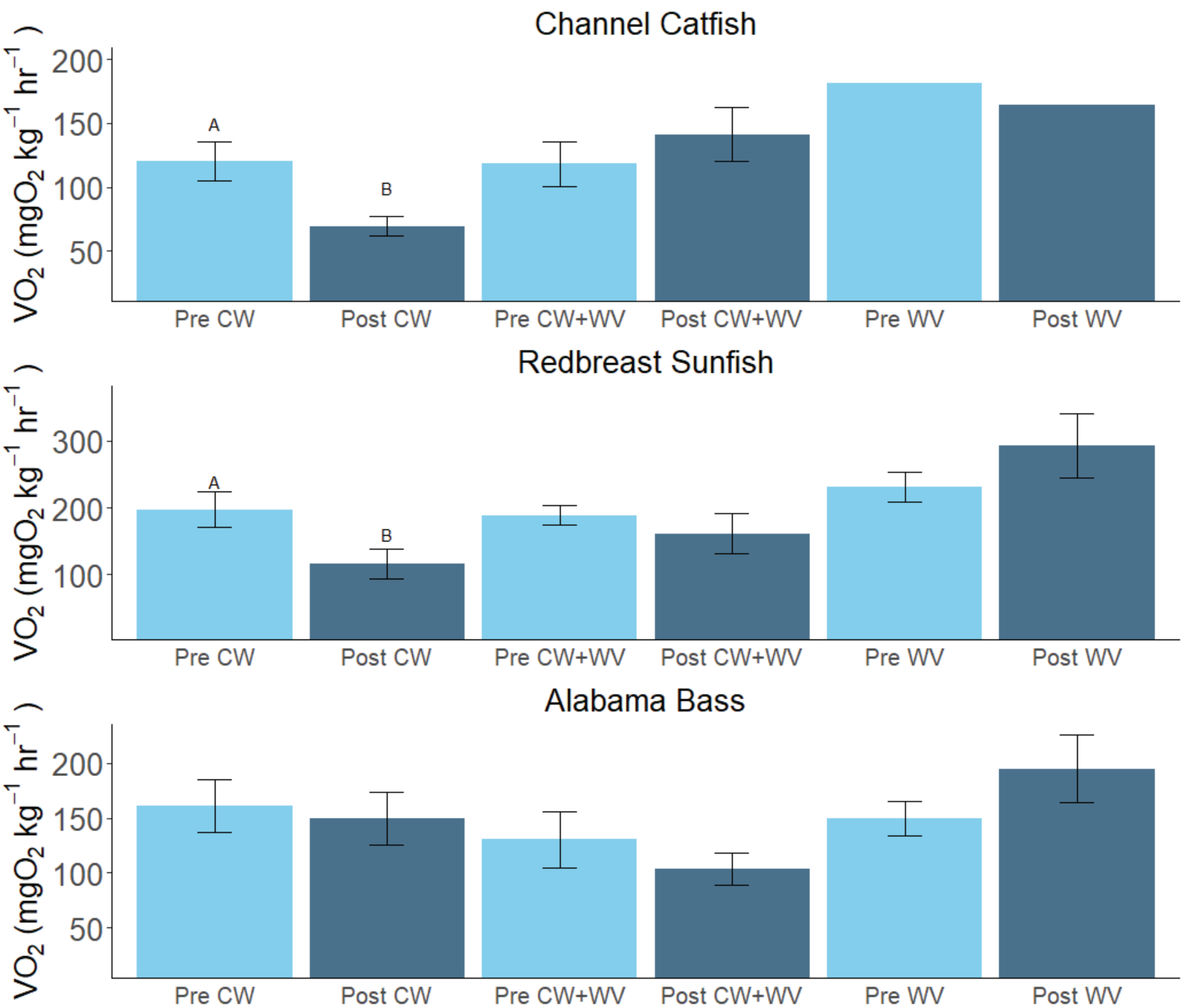


Figure 4.13. Mean respiration rates before and after water exchanges. Letters denote significant changes in rates after water exchange.

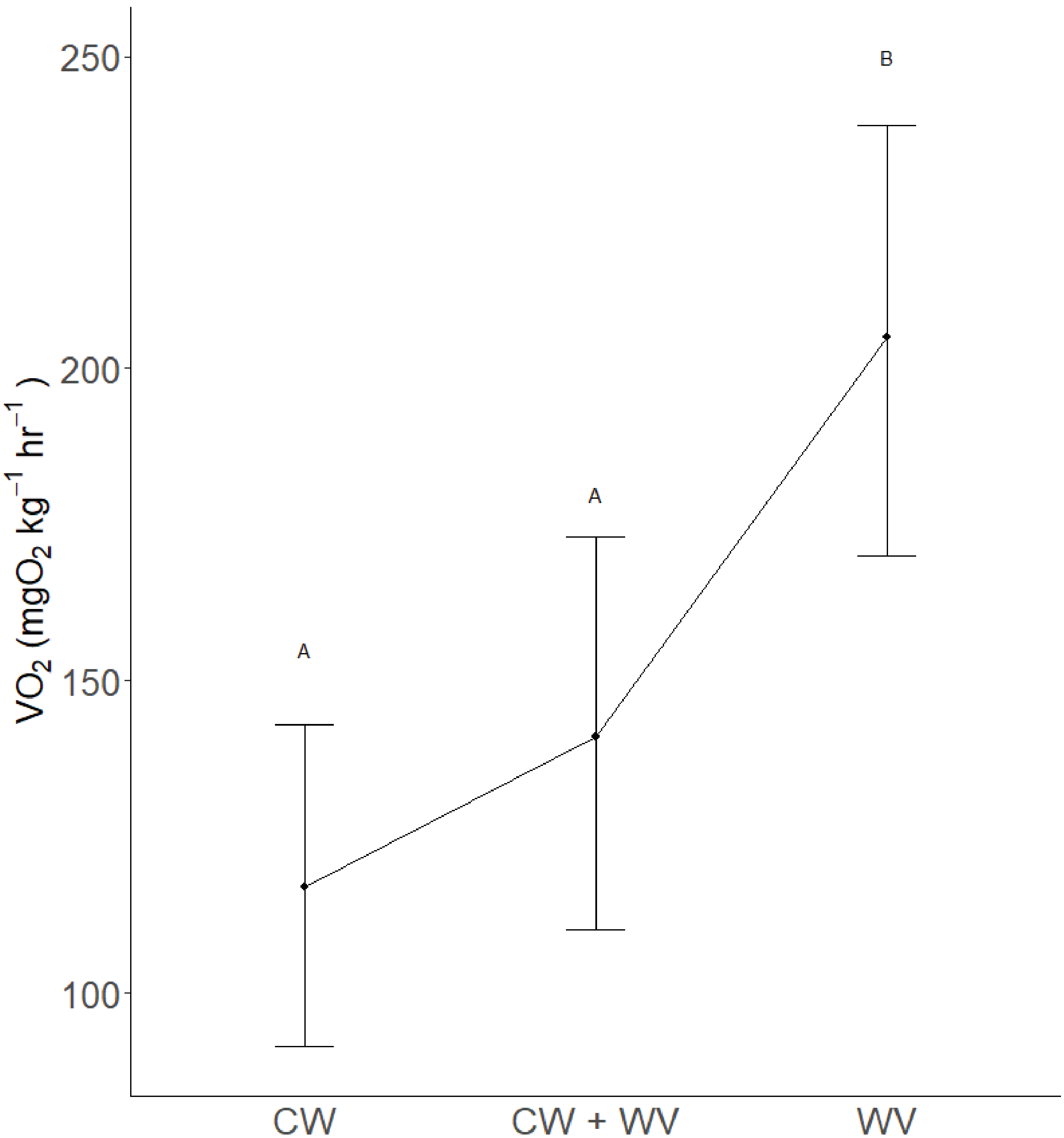


Figure 4.14. Mean respiration rates after water and velocity changes for all fish with 95% confidence intervals.

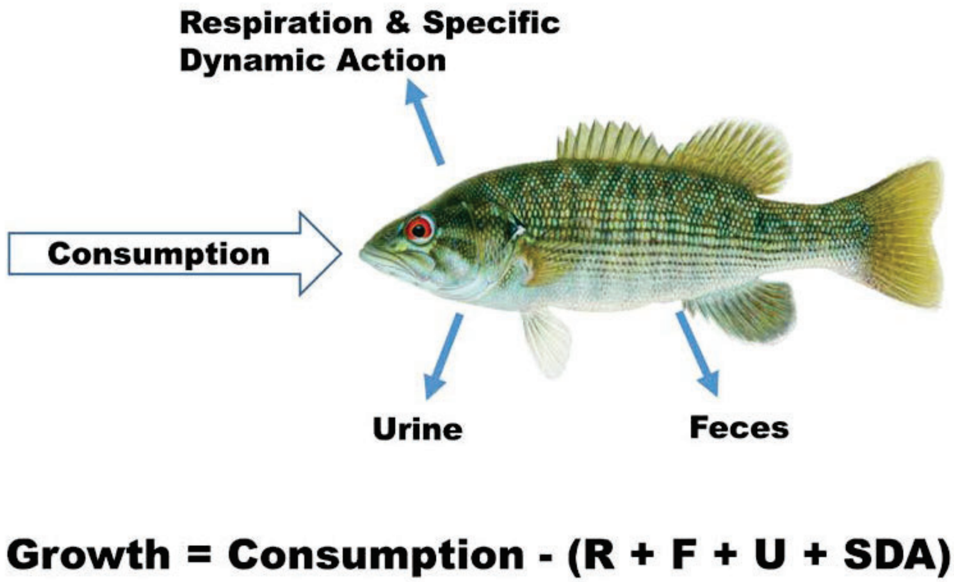


Figure 4.15. A graphical representation of a typical bioenergetics model of the growth of a fish.

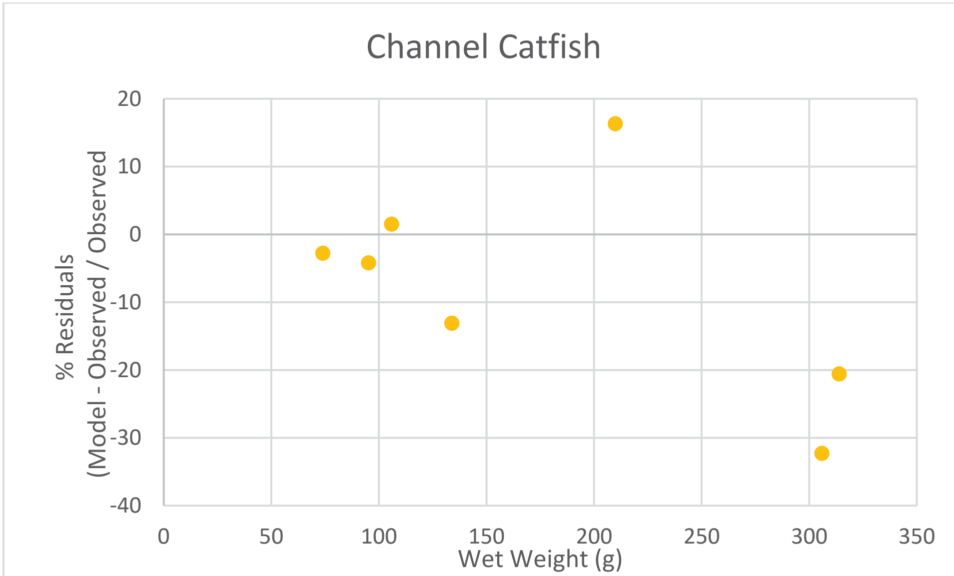


Figure 4.16. Relative accuracy (measured as percent residuals) of modeled respiration rates versus our quantified measurements as a function of fish weight for Channel Catfish.

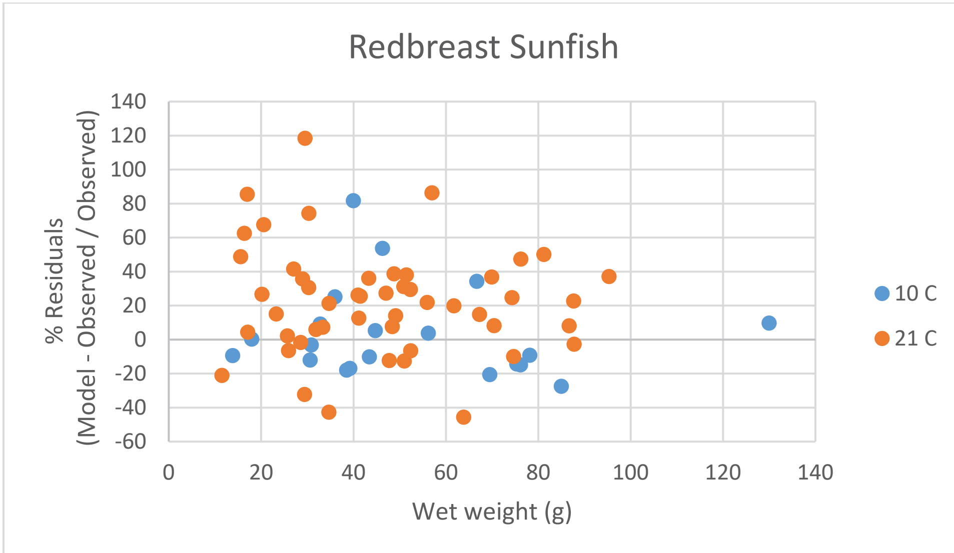


Figure 4.17. Relative accuracy (measured as percent residuals) of modeled respiration rates versus our quantified measurements as a function of fish weight for Redbreast Sunfish.

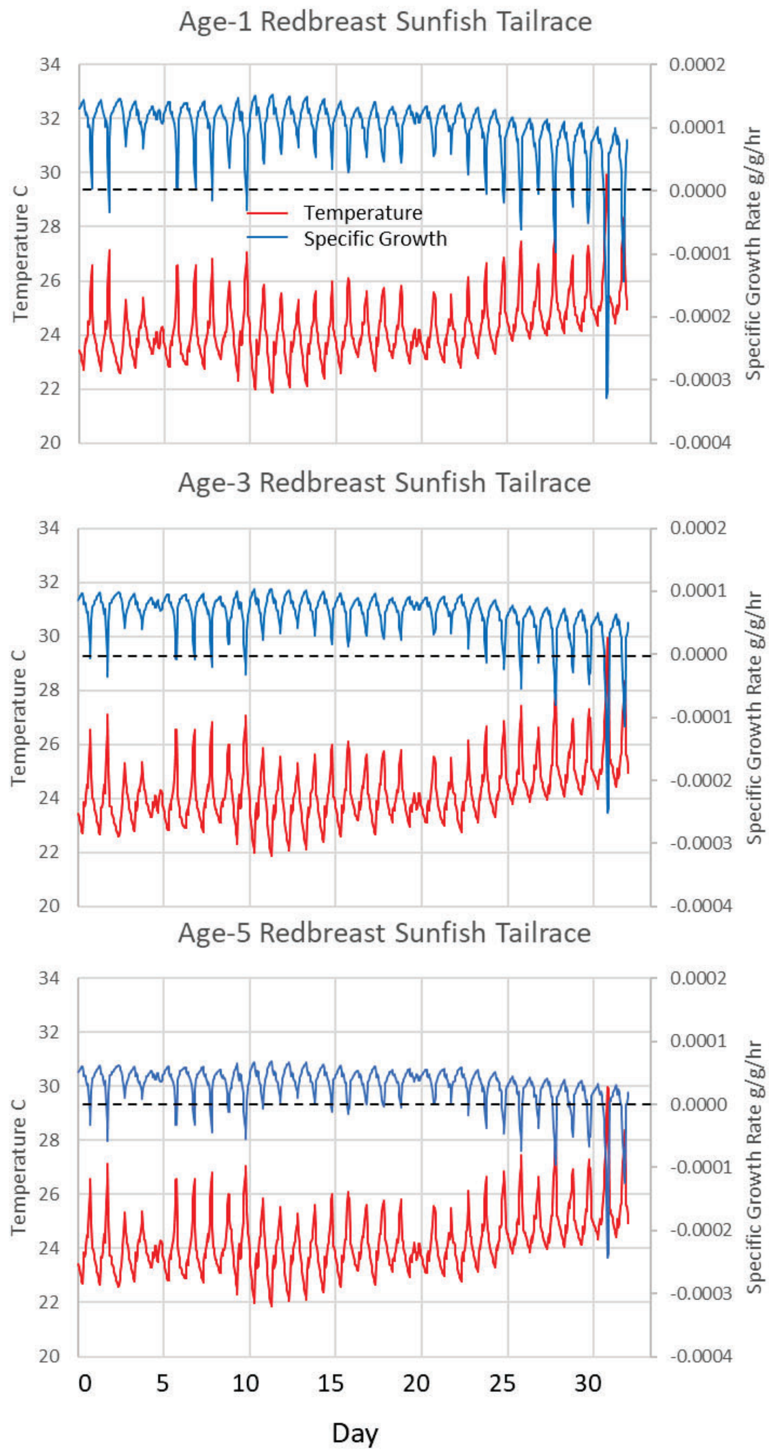


Figure 4.18. Simulated specific growth rate (blue lines, left axis) for Redbreast Sunfish in the tailrace for a 1-month period (July 15- August 15). Temperatures used in the simulations are given by the red lines (right axis).

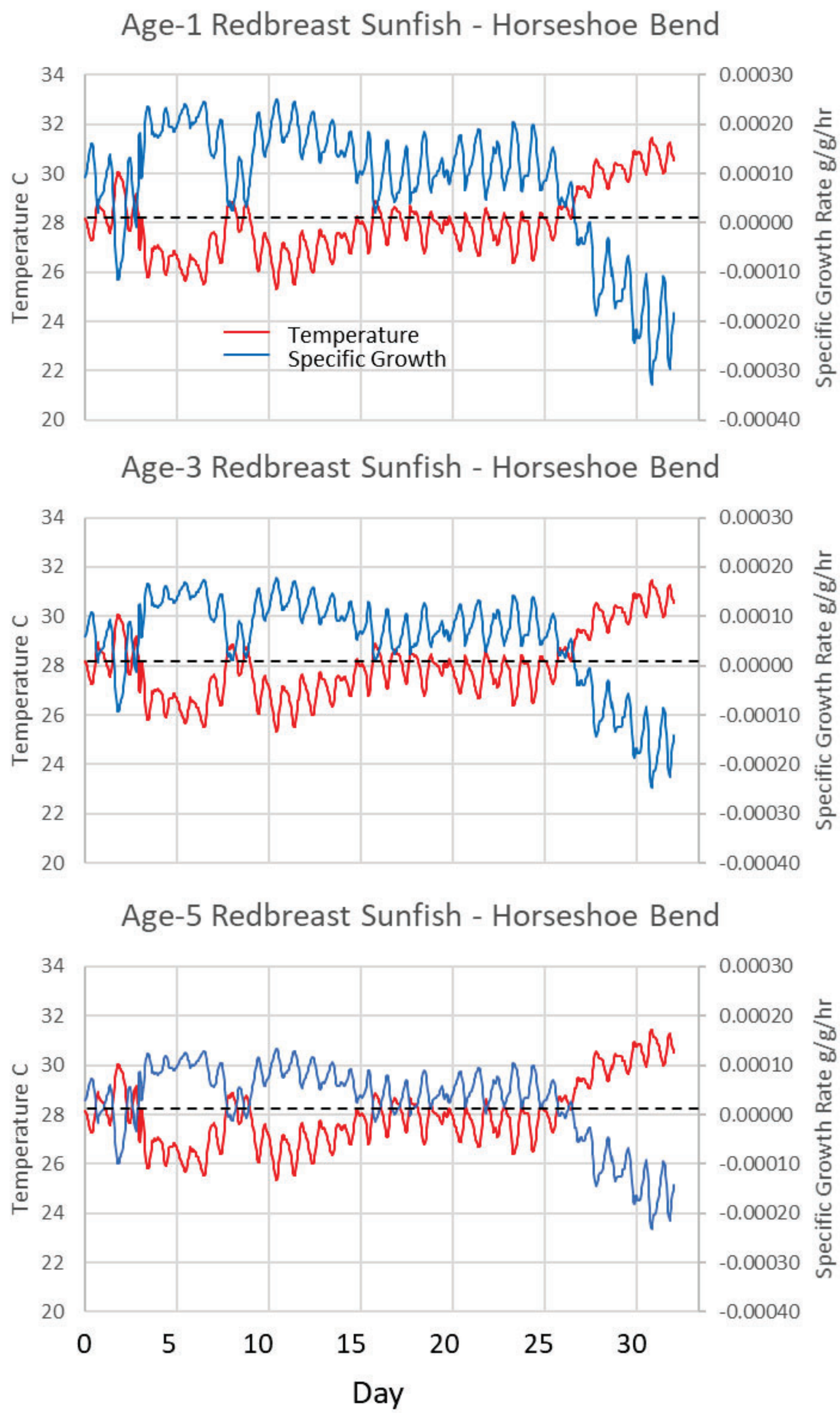


Figure 4.19. Simulated specific growth rate (blue lines, left axis) for Redbreast Sunfish at Horseshoe Bend for a 1-month period (July 15- August 15). Temperatures used in the simulations are given by the red lines (right axis).

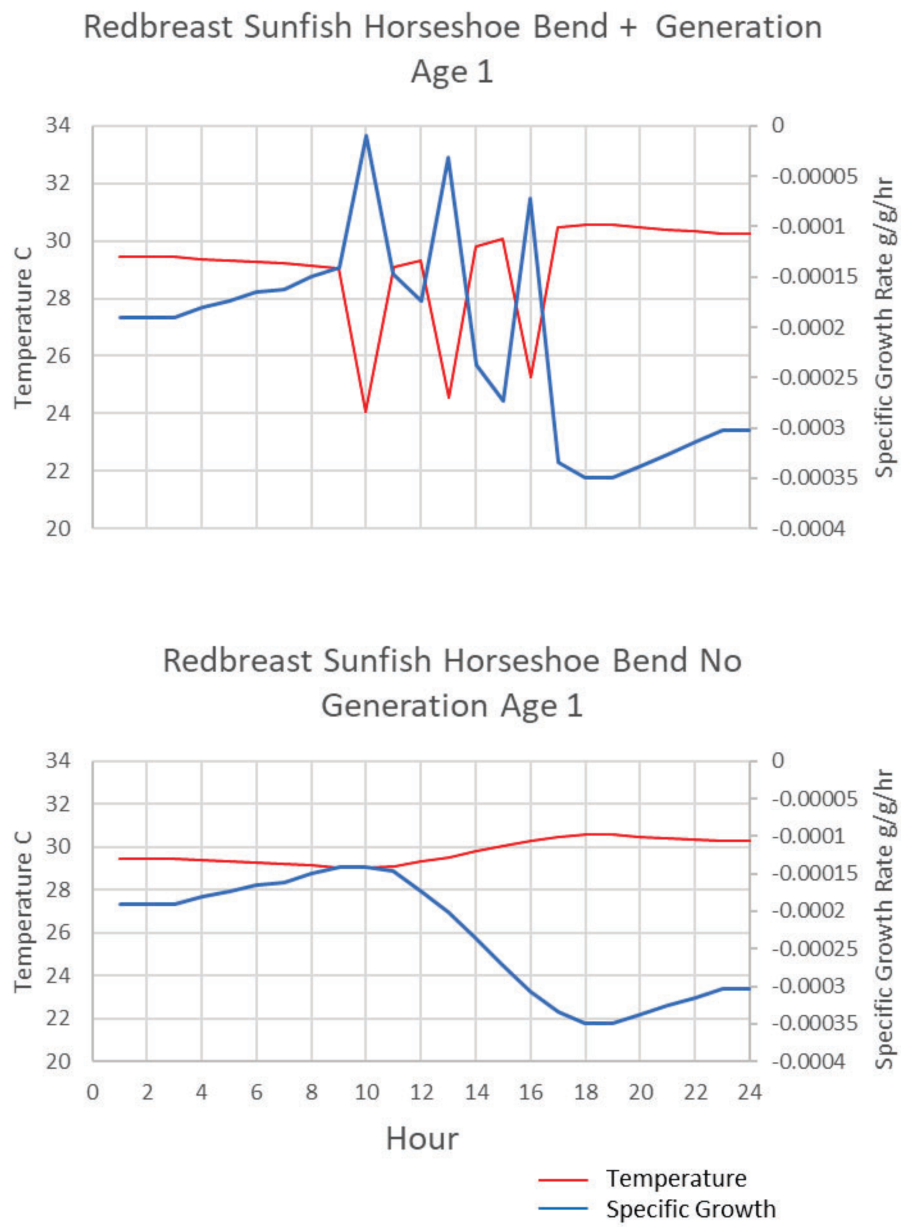


Figure 4.20. Specific growth rate of Age-1 Redbreast Sunfish (blue lines, right axis) modeled for a 24-hour period either with 3 pulse/generation events (top panel) or without generation (bottom panel). Temperatures (red line, left axis) and flow rates were derived from August at Horseshoe Bend.

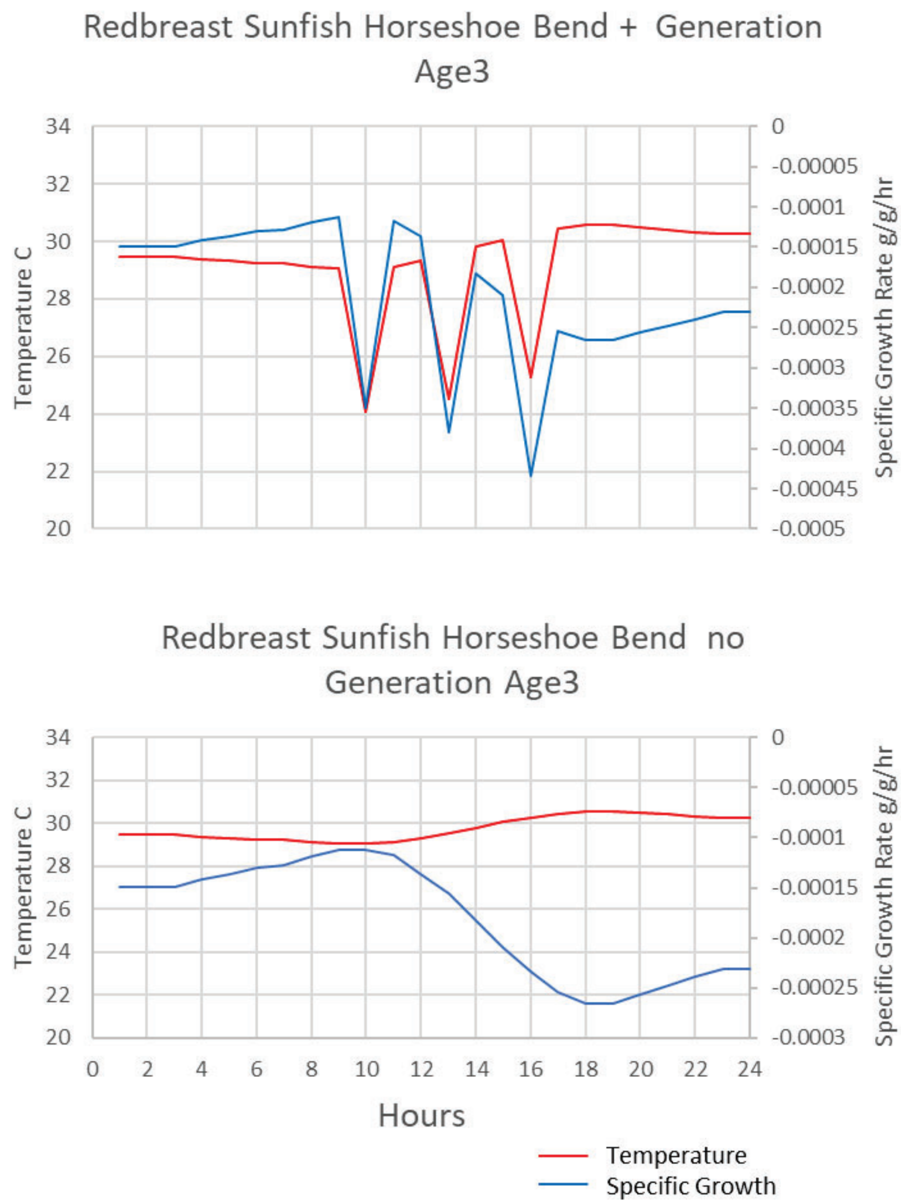


Figure 4.21. Specific growth rate of Age-3 Redbreast Sunfish (blue lines, right axis) modeled for a 24-hour period either with 3 pulse/generation events (top panel) or without generation (bottom panel). Temperatures (red line, left axis) and flow rates were derived from August at Horseshoe Bend.

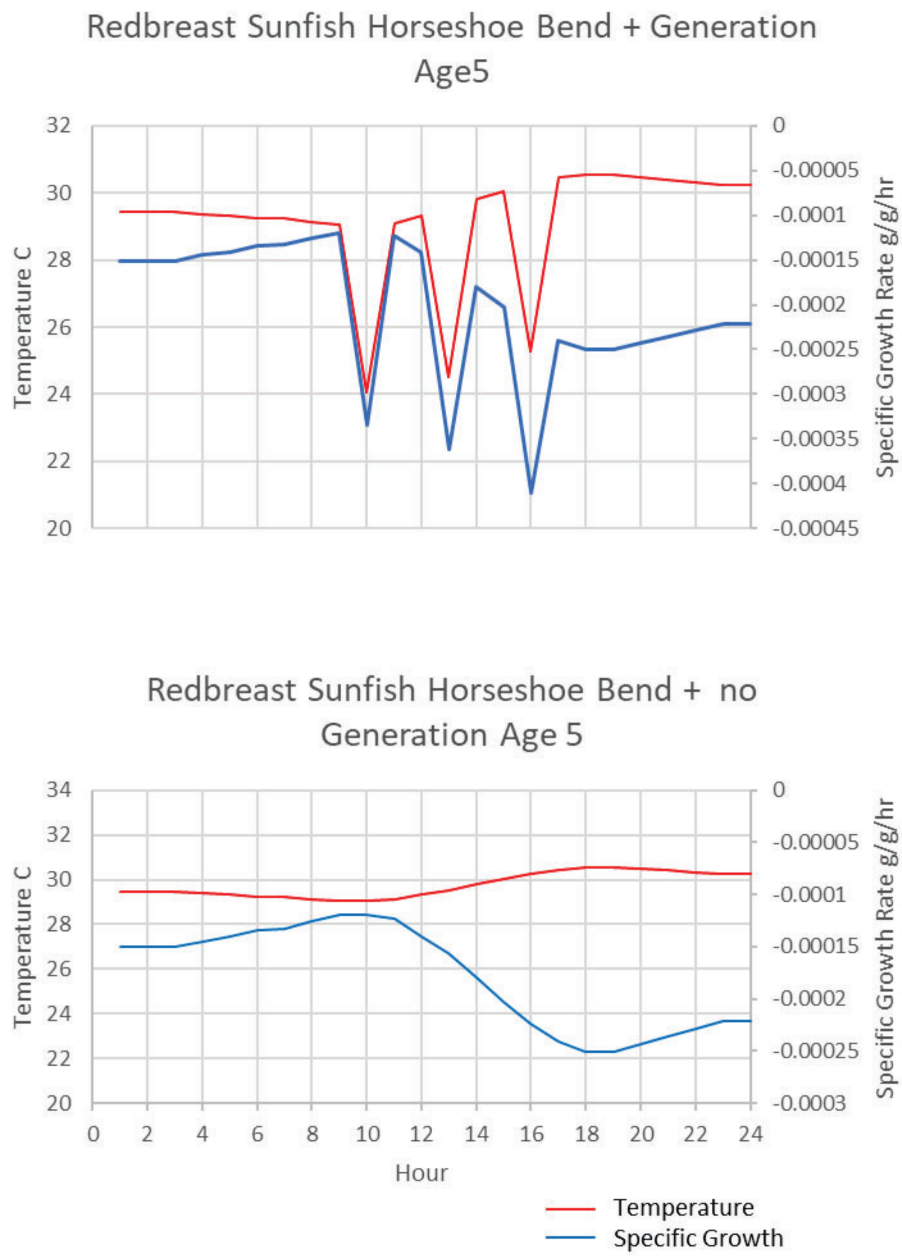


Figure 4.22. Specific growth rate of Age-5 Redbreast Sunfish (blue lines, right axis) modeled for a 24-hour period either with 3 pulse/generation events (top panel) or without generation (bottom panel). Temperatures (red line, left axis) and flow rates were derived from August at Horseshoe Bend.

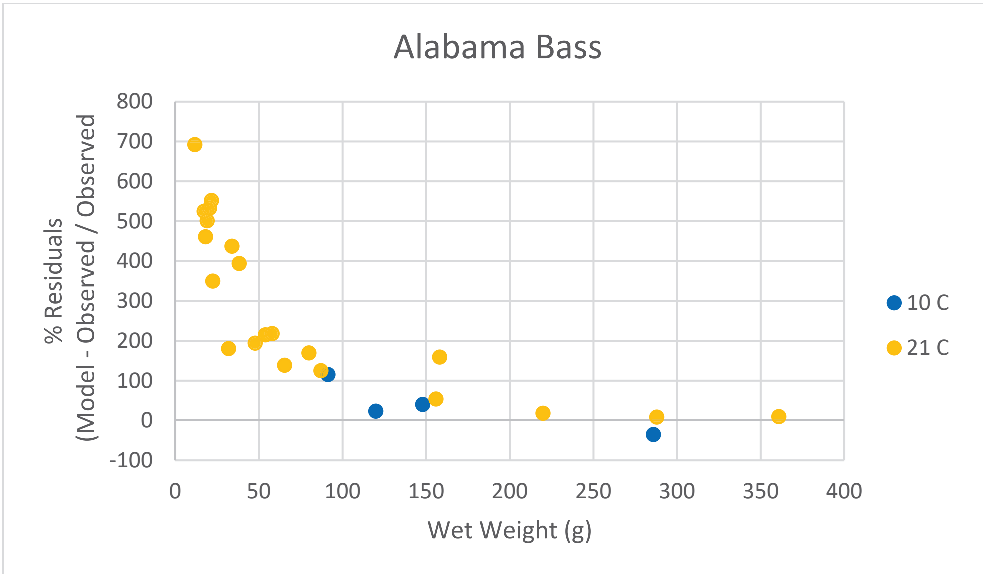


Figure 4.23. Relative accuracy (measured as percent residuals) of modeled respiration rates versus our quantified measurements as a function of fish weight for Alabama Bass.

APPENDIX E

STAKEHOLDER COMMENT TABLES

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
Comments below were received following the Initial Study Report filing on April 10, 2020[1]			
Federal Energy Regulatory Commission (FERC) Note: footnotes included in the original letter have been omitted from this table	6/10/2020 20200610-3059	During the ISR Meeting, Alabama Power requested that stakeholders provide downstream flow alternatives for evaluation in the models developed during Phase 1 of the Downstream Release Alternatives Study. Stakeholders expressed concerns about their ability to propose flow alternatives without having the draft reports for the Aquatic Resources and Downstream Aquatic Habitat Studies, which are scheduled to be available in July 2020 and June 2020, respectively. It is our understanding that during Phase 2 of this study, Alabama Power would run stakeholder-proposed flow alternatives that may be provided with ISR comments, as well as additional flow alternatives that stakeholders may propose after the results for the Aquatic Resources and Downstream Aquatic Habitat Studies are available. Please clarify your intent by July 11, 2020, as part of your response to stakeholder comments on the ISR.	The intent was clarified in our July 10, 2020 letter to FERC (Accession No. 20200710-5122).
FERC		In addition, we recommend that the modeling for Alabama Power's Aquatic Resources Study and Downstream Aquatic Habitat Study,[4] as well as any Phase 2 assessment(s) include all the downstream flow release alternatives identified and evaluated as part of the Downstream Flow Release Alternatives Study. The results of all the modeling for the Aquatic Resources Study and Downstream Aquatic Habitat Study should be included in the final study reports and filed with the Updated Study Report, due by April 12, 2021.	Alabama Power is evaluating the impacts to aquatic resources and aquatic habitat as part of Phase 2 of the Downstream Release Alternatives Study.
David Bishop (only the portion of the letter that pertains to aquatic resources has been included in this table) (highlighted portion of letter pertains to this study)	6/11/2020 20200611-5005	We have noticed a large amount of bank erosion and tree loss in the years since the dam was built. A corresponding widening and shallowing of the stream with warmer water resulting in fewer fish has been noted by many who fish the river. I feel that responsible and constant release would mimic the pre-dam flow and allow the river to recover to its natural state. I am also concerned that raising the winter pool of the lake will result in more flooding, erosion, loss of property and life downstream. Also, public access is limited to only two points above Lake Martin and below Wadley. This needs to be remedied so that more people may enjoy the river. FERC can take the lead and make sure that those of us downstream can enjoy our river as before.	Comment noted. The Downstream Release Alternatives Study investigated alternative flow scenarios and how they would affect these resources, and the Operating Curve Feasibility Analysis Study assessed the effects of a change in winter pool on downstream flooding.
Alabama Rivers Alliance (ARA)	6/11/2020 20200611-5114	There is significant stakeholder concern over the temperature of releases from Harris, and ARA understands that analysis of the effects of temperatures will be included in the forthcoming Aquatic Resources Study Report.[9] This concern stems from the scientific literature documenting the	Auburn University assessed the effects of temperature change and flows on specific growth of Redbreast Sunfish. Swimming respirometer trials assessed fish

[1] Accession No. 20200410-5084

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
Note: footnotes included in the original letter have been omitted from this table (highlighted portion of letter pertains to this study)		ecological consequences of cold-water pollution from hydroelectric dams[10] and decades of research on Harris indicating "thermal alteration and generation frequency negatively affect the occupancy of most fish species below the dam."[11] As additional study and analysis of the thermal regime progresses and is reported in the Aquatic Resources Study, ARA recommends that *temperature and flows be considered in tandem* during this analysis because "both discharge and temperature must be simultaneously considered for the successful implementation of environmental flow management below dams."[12]	response to simultaneous increases in water velocity and decreases in water temperature.
ARA		Unfortunately, neither the Aquatic Resources Study Plan nor the Draft Water Quality Report contemplate the study of any potential remedial actions to adjust water temperatures in line with unregulated reaches of the Tallapoosa. Licensee has acknowledged that once an issue has been identified with water temperatures, it plans to study technologies that can address the thermal regime.[17] Due to the available evidence of low temperatures impacting both colonization and persistence of fishes and the downstream macroinvertebrate community[18] and the sizeable stakeholder concern, ARA urges thorough study of the infrastructure enhancements available for implementation at Harris to control release temperatures. A variety of temperature management strategies exist, including multi-level intake structures, floating intakes, and reservoir destratification approaches using pumps and submerged weirs, as well as operational adjustments in the timing and volume of releases.[19]	Alabama Power will evaluate infrastructure enhancements that may be needed as a solution to any temperature problems described in the results of the studies.
ARA		Despite the past decades of disruption, studies performed during the ILP and a reinvigorated adaptive management approach can shape a new framework for creating positive ecological responses below Harris. As the USGS Open-File Report on adaptive management of flows from Harris states, "[i]f flow and thermal alteration from the dam can be modified toward improving natural resource objectives, adaptive management processes and long-term monitoring could further reduce uncertainty related to biotic response to new Federal Energy Regulatory Commission licensing requirements."[27]	Comment noted.
ARA		We appreciate that Licensee was willing fifteen years ago to enter into a collaborative process with stakeholders and to voluntarily operate the Harris project according to an adaptive management plan known as the Green Plan,[28] the purpose of which "was to reduce effects of peaking operations on the aquatic community downstream."[29] The Green Plan was a starting point for adaptive management, but evidence suggests it has	Comment noted. The Downstream Release Alternatives Study investigated several different alternatives to the Green Plan and how those scenarios could affect downstream aquatic resources. Auburn University's analysis on the effects of flow and temperature on fish growth is one of the variables being considered in the

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
		not improved conditions for aquatic life. The most recent published literature demonstrates that although "[h]abitat availability for fishes increased under the Green Plan management…improved conditions did not improve recruitment processes for species of interest."[30] Further, "results indicate that the Green plan did not meet the stakeholder objective to restore and maintain macroinvertebrate community composition similar to unregulated reaches within the regulated portions of the river."[31] Since beginning adaptive management and the Green Plan roughly fifteen years ago, no actual adaptation or iteration has occurred. This relicensing and the studies now underway provide an opportunity to iterate, adapt, and improve flows and subsequent impacts on downstream aquatic life, recreation opportunities, erosion and sedimentation, and water quality. In order to make the refinements contemplated by a full adaptive management process, a wide variety of flow scenarios should be studied, and "[c]ontinuing adaptive management in tandem during the FERC relicensing process would be advantageous to include a specific assessment of long-term objectives of all stakeholders."[32]	decision to maintain Green Plan operations or to alter operations at Harris Dam.
ARA		A. Until Aquatic Resources and Aquatic Habitat Study Reports Are Available, It Is Premature to Ask Stakeholders to Specify All Flow Alternatives to Model Commenters, stakeholders, and FERC staff have encouraged Licensee to examine a broad range of flows throughout the ILP.[33] Currently, licensee is studying two possibilities other than its current flow regime and its prior flow regime. The Draft Downstream Release Alternatives Phase 1 Report filed by Licensee assesses impacts to operational parameters (*e.g.*, generation, reservoir levels, flood control) under three flow scenarios: (i) the current Green Plan pulsing regime that has been in effect since 2005 through a voluntary adaptive management process; (ii) the pre-Green Plan regime with no intermittent flows between peaks, which occurred from 1983 to 2004; and (iii) a continuous minimum flow of 150cfs, which is the equivalent daily volume of the current Green Plan pulses and has never been physically implemented and studied. A fourth release scenario, the alternative/modified Green Plan, will be evaluated in Phase 2 of the study, once results from the Aquatic Resources Study are available to shape the design of an altered Green	Based on FERC, ARA, and EPA's recommendation to modify the Downstream Release Alternatives study, Alabama Power evaluated the following additional downstream flow scenarios: • A variation of the existing Green Plan (GP) where the Daily Volume Release is 100% of the prior day's flow at the USGS Heflin stream gage, rather than the current 75%; • A hybrid Green Plan that incorporates both a base minimum flow of 150 cfs and the pulsing laid out in the existing Green Plan release criteria; • 300 cfs continuous minimum flow (CMF); • 600 CMF; • 800 CMF; • 300 CMF + GP; • 600 CMF + GP; and • 800 CMF + GP.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
		Plan.[34] The two alternatives that have never been implemented—a continuous minimum flow of roughly an equivalent volume and altering the timing of the existing Green Plan releases— are effectively different flavors of the existing release scheme, though studying those modifications may yield important insights into improving flows. The summary of the Initial Study Report meeting reflects that Licensee desires "to hear from stakeholders now" regarding alternative flow scenarios stakeholders would like to have modeled,[35] despite no draft Aquatic Resources Study or Aquatic Habitat Study reports being available. The downstream release alternatives, aquatic resources, water quality, and aquatic habitat reports are all deeply interrelated, and without at least draft reports of the fisheries studies, stakeholders should not be required to propose alternative flow scenarios until more information is available. Indeed, Licensee itself acknowledges that the results from the Aquatic Resources Study are needed to design the fourth flow scenario it plans to model.[36] Those same results will also inform what variety of inputs stakeholders suggest. In fact, the logical time to propose additional flow scenarios is after Licensee has "analyze[d] the effects of each downstream release alternative on other resources, including water quality… downstream aquatic resource (temperature and habitat), wildlife and terrestrial resources, threatened and endangered species, recreation, and cultural resources," which will be accomplished by Phase 2 of the study.[37] At a minimum, stakeholders should be equipped with the draft fisheries studies showing the current status of aquatic resources before being required to list all alternative flows to be studied.	Alabama Power met with HAT 3 following distribution of the Draft Aquatic Resources Study Report and Draft Downstream Aquatic Habitat Report. No additional downstream release alternatives were requested by stakeholders.
Dana Chandler in letter filed by Carol Knight (only the portion of the letter that pertains to aquatic resources has been included in this table)	6/11/2020 20200611-5148 On the ISR	Chandler adds the Tallapoosa River was once the habitat for more species of mollusks than any other Alabama river. Of course, many of these are now gone because of the inconsistent river flow, among other reasons.	Comment noted.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
Wayne Cotney in letter filed by Carol Knight (only the portion of the letter that pertains to aquatic resources has been included in this table) (highlighted portion of letter pertains to this study)	6/11/2020 20200611-5148 On the ISR	He remembers when the bridge was built at Horseshoe Bend and when folks kept boats tied to the banks up and down the river. Fishing was a way of life—and a way of feeding one's family—during those days. Those days are long gone, for several reasons, including but not limited to erosion and "fast water" that comes from up the river.	Comment noted.
John Carter Wilkins in letter filed by Carol Knight (only the portion of the letter that pertains to aquatic resources has been included in this table) (highlighted portion of letter pertains to this study)	6/11/2020 20200611-5148 On the ISR	In the past, he says that he could catch a mess of yellow cats, but now he is lucky if he catches one. Bullfrogs used to be so plentiful that he could frog gig at night, but not he might see one frog if he goes out at night. The land and the wildlife are no longer what they were. To him, that is the greatest shame of all.	Comment noted.
Comments highlighted in blue were filed with comments on the Initial Study Report but were directed towards the Draft Downstream Aquatic Habitat Study Report. Because temperature was analyzed as part of the Aquatic Resources Study, all temperature analyses were moved to the Final Aquatic Resources Study Report.			
Alabama Department of Conservation and Natural Resources (ADCNR) Note: footnotes included in the original letter have been omitted from this table	6/11/2020 20200611-5152 On the ISR	On page 18, section 3.2.4 Water Temperature of Draft Downstream Aquatic Habitat Report, temperature change data is primarily depicted in averages. It is important to remember that like dissolved oxygen declines, only one significant sudden temperature change event can stress or kill aquatic species. In addition, temperature highly influences dissolved oxygen levels in aquatic environments and significant dissolved oxygen declines and extreme temperature fluctuations can often coincide. For water temperature data, maximum and minimum values, and how long those values persist (hours) would better explain the fluctuation in temperature changes occurring in a regulated river. Providing detailed reporting of minimum and maximum values at hourly intervals especially when water temperatures reach critical spawning	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. An appendix to the Final Aquatic Resources Study Report will include 15-minute line plots of water temperature and sensor depth for each level logger. In addition, Auburn University conducted respirometry trials to determine the effect of temperature and flow regimes on fish respiration and energy expenditure. The effects of rapid temperature and flow fluctuations on specific growth rate of Redbreast Sunfish were also analyzed with a bioenergetics model. Results provide

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
		ranges (15-25°C) in the spring are required to fully understand what is occurring. For example, if water temperature rise during the spring reaches a fish species thermal spawning cue but then suddenly decreases due to generation, disruption of spawning success can occur. Decreased and varied downstream water temperatures, as a result of project operations, can negatively impact downstream aquatic fauna. The impacts of water temperatures on the aquatic environment have been well-documented in peer-reviewed literature (Travnichek and Maceina 1994; Bowen *et al.* 1998; Andress 2002, Craven *et al.* 2010; Irwin *et al.* 2010; Goar 2013; Early and Sammons 2015). A component of varied downstream water temperatures downstream of regulated waterways, includes rapid sudden changes in water temperatures. These rapid changes can cause serious stress responses in some fishes in captivity and in the wild that are otherwise healthy, even leading to mortality (Jenkins et al. 2004). Limits of tolerance and ability to tolerate changes in temperature are influenced by the previous thermal histories of individual fish as well as species characteristics (Carmichael et al. 1984). Sudden temperature changes of greater magnitude, either upward or downward, are very stressful and should be avoided. The magnitude of change that aquatic species can tolerate will depend on the species, the life history stage in consideration, previous thermal history, and the initial conditions. The literature-based temperature requirement for fish information provided by the ongoing Aquatic Resources Study should provide useful details on various Tallapoosa River system fish species temperature tolerances. In addition, the comparison of temperature data in regulated and unregulated portions of the study area in the ongoing Aquatic Resources Study should provide additional insight into this topic. The Aquatic Resources Study results in conjunction with downstream flow data, water quality data and downstream habitat data from the initial study reports must be fully evaluated to assess potential impacts to the aquatic resources of the system. For these reasons it is important to provide median, minimum and maximum daily and hourly water temperature fluctuations in this section, in addition to the provided means. Median site data should be included into Tables 3-5 and 3-6. Provide Figure line plots of 15-minute water temperature data collected for each site, similar to page 29, Figure 4-2 line plots of 15-minute water temperature data collected by ADEM on the Tallapoosa River of the Draft Water Quality Study Report.	insight on the effects of dam releases on age-1, -3, and -5 Redbreast Sunfish. Auburn University analyzed temperature in an unregulated site (Heflin; 2018-2020) and three regulated sites (the Harris Dam tailrace, Malone, and Wadley; 2000-2018); however, the ability to compare the unregulated and regulated data directly was limited due to the limited amount of data for Heflin and a variety of variables that could contribute to the differences between the unregulated and regulated river. These variables are described in Auburn University's Final Report, Appendix D of the Final Aquatic Resources Study Report.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
ADCNR		On page 18, section 3.2.4 Water Temperature of Draft Downstream Aquatic Habitat Report, in the discussion on water temperature, explain how the temperature change range is lower at the dam, in comparison to sites 1 and 3 miles downstream. Explain what processes might cool the water moving downstream before warming them again.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. Mean daily water temperature fluctuations near the dam (0.4 miles downstream) are within one standard deviation of the mean fluctuations measured one and 3 miles downstream (i.e., essentially the same).
ADCNR		On Page 19, Figure 3-8 of Draft Downstream Aquatic Habitat Report, provide standard deviation bars for the average monthly temperature data points.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. This figure was revised and included in the Final Aquatic Resources Study Report.
ADCNR		On page 20, Figure 3-9 of Draft Downstream Aquatic Habitat Report, provide standard deviation bars for the average daily temperature fluctuation.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. This figure was revised and included in the Final Aquatic Resources Study Report.
ADCNR		On page 21, Table 3-5 of Draft Downstream Aquatic Habitat Report, in addition to mean, minimum and maximum provided, provide the median (°C) for each site and standard deviation of the means.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. This information has been included in the Final Aquatic Resources Study Report.
ADCNR		On page 22, Figure 3-10 of Draft Downstream Aquatic Habitat Report, provide standard deviation bars for the average hourly temperature fluctuation.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. Standard deviation is included in a table.
ADCNR		On page 22, of Draft Downstream Aquatic Habitat Report, provide an additional graph similar to Figure 3-10 that depicts the maximum hourly water temperature fluctuation (Delta T) from May 2019 to April 2020. This graphic will better represent the unnatural, harsh conditions subjected to aquatic fauna frequently below Harris Dam.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. The maximum hourly temperature fluctuations are provided in a table.
ADCNR		On page 23, Table 3-6 of Draft Downstream Aquatic Habitat Report, provide map site numbers from Figure 2-1, in addition to the included miles below Harris dam.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. A revised figure has been included in the Final Aquatic Resources Study Report.
ADCNR		On page 23, Table 3-6 of Draft Downstream Aquatic Habitat Report, in addition to mean, minimum and maximum numbers provided, provide the median (°C) for each site and standard deviation of the means.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
			This information has been included in the Final Aquatic Resources Study Report.
ADCNR		On page 32, section 4.0 Discussion and Conclusions of Draft Downstream Aquatic Habitat Report, it states "*It is also worth noting that river flows during August and September of 2019, typically the warmest months of the year, were well below normal which could have resulted in greater daily and hourly temperature fluctuations than normal.*" This statement as presented does not seem accurate. Explain how a warm water unregulated river, without a dam, would decrease in temperature as it moves downstream. In many instances rainwater (runoff) in the summer will warm streams and tributaries, thus warm runoff increases temperatures in the creeks in some instances, particularly during afternoon storms when ambient air temperatures have peaked for the day. Additionally, since the Harris dam discharge is below the surface water at 30-40 feet deep, changes to the stratification of the reservoir, would be more pronounced in higher flow, than lower flow years. Reservoir stratification is affected more by higher inflows, than low inflows, especially when discharge occurs from the metalimnion or hypolimnion. Downstream temperature changes should not be significantly different if a thermocline is present, which occurs annually at Harris Reservoir, and persists into September. The statement above requires additional explanation including mechanisms that would cause greater hourly temperature fluctuations than normal during low flow. Provide a reference to a Figure in document illustrating river flows during this time period and provide a specific instance that supports this statement. Clarify whether this statement is referring to tailrace flows or tributary inflows to the tailrace. Significant differences between large tributaries and tailrace temperatures even during atypical river flow scenarios in warmer months may be indications that the regulated reach is significantly altered compared to the natural temperature regime of the river system. Under a new FERC license agreement, R.L. Harris Hydroelectric Project will operate under various weather conditions throughout the issuance period of the license. We maintain our request that when evaluating impacts on downstream water quality (including water temperature) due to project operations, that methods to mitigate the unnatural water temperature variability be fully assessed to minimize impacts to the aquatic resources.	All temperature data and analyses were moved to the Final Aquatic Resources Study Report. The intent was not to imply that a warm water unregulated river decreases in temperature as it moves downstream. During periods of very low flow, shallow water areas such as shoals can warm or cool much faster than deep areas such as pools. A figure was added to the discussion section of the Final Aquatic Resources Study Report to illustrate this concept.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
ADCNR	6/11/2020 20200611-5152	On page 11, section 4.1 of Initial Study Report, "*i.e.*" ("that is") should be changed to "*e.g.*" ("for example"). The alternative/modified Green Plan operation downstream release alternative will be evaluated as part of Phase 2. Results from the other three scenarios as well as from the Aquatic Resources Study are needed to design the alternative to be studied. Downstream Aquatic Habitat Study and Recreational Evaluation Study results should be included in footnotes in order to fully evaluate and recommend an alternative Green Plan to be modeled and evaluated as a downstream release alternative. Without the ability to fully evaluate the Aquatic Resources Study, Downstream Aquatic Habitat Study and Recreational Evaluation Study results at this time, ADCNR recommends multiple base flow scenarios calculated from available aquatic inflow and base flow records and guidelines representative for the tailwaters downstream to the Horseshoe Bend with Pre-Green Plan, Green Plan and Modified Green Plan be modeled during the evaluation process. All operational changes to downstream releases should evaluate methods for how these flows could be provided while maintaining state dissolved oxygen guidelines and a natural temperature regime, at all times for the sustainable benefit of aquatic resources.	Alabama Power is evaluating a range of alternatives identified in FERC's August 10, 2020 letter to Alabama Power.
ADCNR		On [page 21, section 7.1] of Initial Study Report, it states, "Questions have also been raised regarding potential effects the Harris Project may have on other aquatic fauna within the Project Area, including macroinvertebrates such as mollusks and crayfish. Alabama Power is investigating the effects of the Harris Project on these aquatic species and is performing an assessment of the Harris Project's potential effects on species mobility and population health." There are currently records of mussel species Under Review for federal listing with substantial 90-day findings that occur and occurred historically in the Tallapoosa River and its tributaries. Alabama Spike (*Elliptio arca*) and Delicate Spike (*Ellipto arctata*) are currently state protected species and Under Review by United States Fish and Wildlife Service (USFWS) with a substantial 90-day finding. Threatened and Endangered Species study plan states in the methods that additional species of concern may be added at the request of USFWS and/or ADCNR if determined to be appropriate. Please provide details on what specific mollusks and crayfish species will be evaluated. A list of state protected species currently being evaluated during the relicensing process is recommended.	Existing information on mollusks and crayfish upstream and downstream of the Project are detailed in the Desktop Assessment (Section 2.0) of the Final Aquatic Resources Study Report.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
Charles H Denman (highlighted portion of letter pertains to this study)	6/11/2020 20200611-5174	Harris Dam additional studies suggested A general review of historical materials ie newspapers, and other records dealing with the proposals for constructing the Dam. Including comments and conditions provided in initial permitting. With the goal being to determine if the dam has achieved the original benefits expected. Perhaps a score card. A pre vs post Dam analysis of down stream impacts. Including flooding,erosion and habitat changes to flora and fauna. 1. Flooding :storm runoff model comparing 25,50 and 100 year 24 hour storm events. 2. Erosion : utilizing available remote sensing materials to compare river channel and islands size and shape today and pre dam. 3. Plants: utilize remote sensing materials to map flag grass and invasive plant communities to compare changes from pre Dam. 4. Fisheries: review available materials from locals in the community, fish and game and other resources to determine what effect the Dam has had on down stream fish types and numbers.	The Recreation Evaluation Study used angler interviews to assess the fishery downstream of Harris Dam.
Donna Matthews (highlighted portion of letter pertains to this study)	6/12/2020 20200612-5018	#2 Proposed: A New Study of the downstream river using historic images overlaid onto current imagery 5.15 (e) 1. Erosion is a significant and persistent concern. Erosion is problematic for landowners and flora & fauna in and around the river. 2. To my knowledge, this type of GIS comparison using historic data to impact effects of release effects downriver have not been done. 3. At the initial licensing there was no post dam data to compare to compare to the historic data. 4. This is a simple and inexpensive study, using readily available data 5.0(b) 1. The study should look at and provide change	See Alabama Power's response filed July 10, 2020 (Accession No. 20200710-5122).

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
		analysis for: a. Analysis of the river bank contour along its length through time. Free flowing rivers are elastic, moving silt and sedimentation from side to side and down its length. A river serving as a channel should show deviations from historic patterns. b. Any changes in river bank elevation c. Provide image overlays of historic data onto current imagery with the intent to discover what the data show about the effects of a dam on the downstream river and can be a tool to evaluate effect of future changes made to flow patterns. d. Begin construction of a detailed GIS map with information relating fish populations, (and a whole host of other parameters) in 3D. That is, not only presence/absence of species along the river length, but presence (where data are available) of species during different decades in time. There are numerous possibilities. e. APC can gather additional, (say scaled to 1:6000 or the highest resolution feasible) imagery to overlay on the historic public images available at 1:20000. This would provide a baseline for future studies. At our fingertips are 80 years of data. 2. This GIS modeling tool can also be applied to provide opportunity for interagency contribution towards building the most accurate picture of aquatic and other life of the Tallapoosa. Creating the realization of and expounding upon the treasures of the Tallapoosa River is something all parties (APC and stakeholders above/below the dam) can rightly be proud of.	
Environmental Protection Agency (EPA)	6/12/2020 20200612-5079	Additionally, EPA requests the inclusion of both adaptively managed flow scenarios and adaptive management as an outcome. The state-of-the-science on environmental flows includes adaptive management as a key feature for the protection of aquatic life. The evaluation could examine how monitoring would be used to evaluate the success of the flows, and any potential adjustments that may be needed over time. The EPA submitted resources that supports this request in March 2019.	Comment noted.

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
Comments below were received following the Draft Aquatic Resources Study Report filing on July 28, 2020[1]			
ADCNR	8/28/2020 filed by email On the Draft Aquatic Resources Study Report	On page 2, section 1.1 Study Background of the Draft Aquatic Resources Report, it states "*Alabama Power prepared this draft report to support the relicensing process and to fulfill the requirements of the FERC-approved Aquatic Resources Study Plan. The draft report is comprised of two components: 1) results of the desktop assessment used to compile the possible effects of dam operations and 2) progress and results to date of Auburn University's research on the literature requirements of target species located in the Tallapoosa River below Harris Dam, an analysis of existing temperature data below Harris Dam, fish community sampling and evaluation, and respirometry tests and bioenergetics modeling of fish.*" With some of the requirements from the FERC approved Aquatic Resources Study Plan completed and nearly half of the requirements remaining incomplete, it would be beneficial to provide a summary table or paragraph indicating which requirement components from the Study Plan are completed and which requirements will be provided in the Final Aquatic Resources Report. If modifications to any FERC approved Aquatic Resources Study Plan requirements were made, provide a notification and explanation in the report for the modifications. If any of the requirements are provided in one of the other Study Reports, provide a reference to the material or add to the appendix of the report. The Study Plan indicates that the bioenergetics model requirement would be released April 2021 following the Draft Report and are excluded from the following list. Remaining FERC approved Aquatic Resources Study Plan requirements ADCNR identified include: o Identify aquatic species and populations whose presence and/or sustainability within the Study Area may have been affected by the Harris Project. Describe the factors affecting their presence and sustainability. o Comparison of Temperature Data in Unregulated Portions of the Study Area (i.e., Newell and Heflin). o Results of the temperature data analysis will be compared to the temperature requirements of target species (see Section 4.2.1) to determine how those species may be affected by baseline operations. o Auburn University and Alabama Power will perform field sampling to characterize the current fishery in shallow water habitats in the Study Area. Wadable, shallow water habitats will be sampled using a	The remaining study plan components have been included in the Final Aquatic Resources Study Report. Auburn University determined that the 30+2 method was not feasible at the study sites but found that boat and barge electrofishing equipment were effective at reaching shallow habitat. Deep and shallow water habitats were not analyzed separately but were both incorporated into analysis to provide an overall picture of community structure in the Tallapoosa River.

[1] Accession No. 20200728-5120

Commenting Entity	Date of Comment & FERC Accession Number	Comment – Aquatic Resources	Alabama Power Response
		standardized protocol known as the 30+2 method (O'Neil et al. 2006). Data from ADEM's 2018 fish surveys in the Tallapoosa River may be used to supplement collections by Auburn University and Alabama Power. (If supplementing this data for shallow water sampling include data in the report or in an appendix and discuss results). o Deep and shallow fish survey sampling should include common metrics such as abundance, diversity, evenness, etc. and calculated for each study reach (Recommend a similar basin calibrated IBI calculation for comparison to previous studies (Bowen *et al.* 1996; O'Neil *et al.* 2006; Irwin 2019)).	
ADCNR		Throughout the Draft Aquatic Resources Report, utilize one term to represent Harris Reservoir for consistency purposes (For example, different terms identified were, Harris Reservoir, Harris Lake, Lake Harris). In addition, when discussing unregulated sites make sure to specify if they are upstream or downstream of Harris Reservoir to assist with site orientation within the Tallapoosa River system.	"Harris Reservoir" is being used to refer to the impoundment. Reference site locations have been specified.
ADCNR		On page 1, section 1.1 Study Background of the Draft Aquatic Resources Report, it states "Monitoring conducted since initiation of the Green Plan has indicated a positive fish community response and increased shoal habitat availability (Irwin et al. 2011); however, little information exists characterizing the extent that the Green Plan has enhanced the aquatic habitat from Harris Dam downstream through Horseshoe Bend." Recent reporting of fish community monitoring indicates that fish densities in the regulated river downstream of Harris Dam have been depressed when compared to unregulated sites (Irwin et al. 2019).	Information has been added to this paragraph.
ADCNR		On page 5, section 2.3.1 Tallapoosa River Basin of the Draft Aquatic Resources Report, it states, "Three of these, Gulf Sturgeon (Acipenser oxyrinchus desotoi), Alabama Sturgeon (Scaphiryhnchus suttkusi), and Alabama Shad (Alosa alabamae) are considered extirpated from the TRB." Change to "Three of these, Gulf Sturgeon (Acipenser oxyrinchus desotoi), Alabama Sturgeon (Scaphiryhnchus suttkusi), and Alabama Shad (Alosa alabamae) are hypothesized to be extirpated from the TRB due to dams on the Alabama River main stem restricting upstream migration and movement for spawning (Freeman et al. 2005). Ongoing studies by ADCNR are utilizing traditional collection methods in addition to environmental DNA detection to determine species status in the Mobile Basin. This research will assist in determining the extent and potential for sturgeon and shad to pass through navigational locks." For Alabama Sturgeon, USFWS concluded at the time of listing (74 FR 26488 26510;	Alabama Power has incorporated this information into the Final Report.

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		June 2, 2009) that the lower Coosa and Tallapoosa Rivers were not occupied at the time of listing. Results of recent collections of environmental DNA (eDNA) from water samples have detected the species in the Alabama River from below Robert F. Henry. Although most eDNA detections were from areas below the first passage barrier on the Alabama River (Claiborne lock and dam), there were eDNA detections past two passage barriers (Pfleger et al. 2016). The last specimen was collected from the Alabama River on April 3, 2007 (Rider et al. 2011). Another specimen was observed below Robert F. Henry Lock and Dam on April 23, 2009; however, ADCNR biologists were unable to net the fish (Rider et al. 2010). Gulf Sturgeon at Claiborne Lock and Dam were detected both by eDNA and by sonic tag (Rider et al. 2016) and by eDNA below Robert F. Henry (Pfleger et al. 2016). Only two individuals of Alabama Shad have been caught in the Alabama River since impoundment, one in 1993 below Claiborne lock and dam and one in 1995 below Miller's Ferry lock and dam. The last specimen of Alabama Shad to be captured from the Coosa River was in 1966 (Boschung, 1992), and no Alabama Shad have been caught in the Tallapoosa River in the last decade (Freeman et al., 2001). Since 2010, the US Army Corps of Engineers in cooperation with ADCNR has been conducting voluntary conservation locking measures to provide potential fish passage during the spring spawning season at Claiborne and Millers Ferry lock and dam. The detection of Alabama and Gulf sturgeon eDNA above these hydro projects could indicate the potential for fish to pass through these navigation locks. If fish passage occurred at Robert F. Henry dam similarly to other lower lock and dams, sturgeon and shad could potentially gain access to the Lower TRB. However, further study is needed to determine the correct path of passage and to what extent.	
ADCNR		On page 5, section 2.3.1 Tallapoosa River Basin of the Draft Aquatic Resources Report, it states "An estimated 15 mussel species occur or have occurred within the TRB (Table 2-2)." Johnson et al. (2002) results state, "Twenty unionid mussel species and one species of corbiculid clam, Corbicula fluminea, were collected within the Tallapoosa River drainage during this survey (Table 1). This, combined with an additional 12 species that have been documented historically (Table 1) yields a total of 33 bivalve species." Williams et al. (2008), reports 36 total mussel taxa from the Tallapoosa River system (page 46, Table 4.2 of Williams et al. 2008). In addition to these reports, The University of Michigan Museum online records database contain an Alabama Hickorynut (Obovaria unicolor)	The list of mussel species was updated using the sources provided by ADCNR. Available state/federal conservation status, GCN, and sub-basin occurrence information were reported in tables when available. Results of mollusk surveys conducted for the Threatened and Endangered Species Study have been included in the Final Threatened and Endangered Species Study Report. Comparison of presence and abundance to results of Johnson (1997) would be difficult due to likely dissimilar sampling methods and levels of effort.

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		specimen (UMMZ 107539) record from the Tallapoosa River, Randolph County, B. Walker Collection, that is not included in Johnson et al. 1997 or Williams et al. 2008 historical species list and should be added, pending current museum verification inquiry. Update the historical mussel species list, basin occurrence, and state/federal conservation status, accordingly in this summary section and Table 2-2. In addition to State Species of Greatest Conservation Need (GCN) status, provide if any species are state protected in Alabama Regulations 2019-2020 Invertebrate Species Regulation 220_2_.98 handbook or are currently under review for federal listing by United States Fish and Wildlife Service (USFWS) with substantial 90 day findings. ADCNR has records of 40 mussel species based on current and historical records from the Tallapoosa River system (includes separating Alabama Orb (Cyclonaias asperata) and Tallapoosa Orb (Cyclonaias archeri) and adding O. unicolor) (Gangloff and Feminella 2007; Gangloff et al. 2009; Johnson 1997, Johnson et al. 2002; Singer and Gangloff 2011; Storey et al. 2003; Williams et al. 2008). Change title to Freshwater Mussel Species of the Tallapoosa River Basin or add aquatic gastropods to Table 2-2 with no title change. If any mollusk surveys have been completed for the Threatened and Endangered Species Harris relicensing project, include and discuss results in the Final Aquatic Resources Report. Tributaries and mainstem river sections surveyed for the project should indicate any mollusk reduction or loss of species presence and abundance observed compared to Johnson (1997) or other notable mollusk survey studies. ADCNR Natural Heritage Database includes records of Alabama Spike (Elliptio arca) from Sandy Creek an eastern tributary to the Middle Tallapoosa in 2002 (Singer and Gangloff 2011). This record should be included in the Final Aquatic Resources Report.	
ADCNR		On page 5, section 2.3.1 Tallapoosa River Basin of the Draft Aquatic Resources Report it states, "One species, the Georgia Pigtoe (Pleurobema hanleyianum), is considered extirpated from the TRB." This information appears to be inaccurate, Johnson 1997; Johnson et al. 2002; Williams et al. 2008 and November 11, 2010 USFWS Georgia Pigtoe (Pleurobema hanleyianum) federal register listing (75 FR 67512 67550) do not include the Tallapoosa River as a known historical river system for Georgia Pigtoe. Two Pleurobema species with historical records in the Tallapoosa River system include Southern Clubshell (Pleurobema decisum) and Ovate Clubshell (Pleurobema perovatum). Provide a correction or information	Revised in the Final Report. Georgia Pigtoe was removed from the list of species occurring in the Tallapoosa River Basin.

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		supporting historical records of Georgia Pigtoe (Pleurobema hanleyianum) in the Tallapoosa River system.	
ADCNR		On page 5, section 2.3.1 Tallapoosa River Basin of the Draft Aquatic Resources Report, provide paragraph discussing aquatic gastropod species within the Tallapoosa River System. In addition, provide a similar table to Table 2-2 for aquatic gastropods or add aquatic gastropods to Table 2-2. Utilizing Johnson (1997) and ADCNR Natural Heritage Database records for this list in addition to any other recent studies or collections is recommended.	A paragraph and table summarizing gastropods in the Tallapoosa River Basin were added and a link to the Alabama Regulations 2019-2020 Invertebrate Species Regulation 220_2_.98 handbook was provided in the text.
ADCNR		On page 5, section 2.3.1 Tallapoosa River Basin of the Draft Aquatic Resources Report it states, "An estimated nine crustacean species in the Upper and Middle TRB have been reported in ADCNR's Natural Heritage Database (Table 2-3)." Eleven species are reported in Johnson (1997). Include this study information and provide explanations for any discrepancies between the different numbers and species lists (basin location may account for variations). Update species lists accordingly to reflect findings. In addition to State GCN status, provide if any species are state protected in Alabama Regulations 2019-2020 Invertebrate Species Regulation 220_2_.98 handbook.	Six crustacean/crayfish species were reported in Johnson (1997), four of which were in the Upper and Middle TRB. There were eleven gastropods found in the study. A link to the Alabama Regulations 2019-2020 Invertebrate Species Regulation 220_2_.98 handbook was provided in the text.
ADCNR		On page 7, Table 2-1 of the Draft Aquatic Resources Report add a sub basin occurrence column similar to the invertebrate species Tables 2-2 through 2-4 for consistency and further examination. For example, ADCNR is only aware of Lepisosteidae records in the lower Tallapoosa basin of the system. This information would be useful in a table format when evaluating Harris studies. In addition, separating conservation status columns into federal conservation status (including currently under review for federal listing by USFWS with substantial 90-day findings), state GCN status and state protected in Alabama Regulations 2019-2020 Protected Nongame Species Regulation 220_2_.92 (a).	State rank and state protection status have been added to Table 2-1. A link to Alabama Regulations 2019-2020 Protected Nongame Species Regulation 220_2_.92 (a) was provided in the text.
ADCNR		On page 7, Table 2-1 of the Draft Aquatic Resources Report add new species identified in the Auburn University fish sampling list from Appendix B page 7 Results Section. These additions include, Blueback Herring (Alosa aestivalis) and Snail Bullhead (Ameiurus brunneus).	Alabama Power has incorporated this information into the Final Report.
ADCNR		On page 18, section 2.3.2, of the Draft Aquatic Resources Report, remove, "Unfortunately, widespread negative attitudes toward the…" and replace with "Evidence of anglers not harvesting small bass under 13 inches reduced the effect of the imposed limit"	This sentence was modified to better paraphrase the original authors' interpretation.

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ADCNR		On page 18, section 2.3.2, of the Draft Aquatic Resources Report, it states, "Black Crappie were found in large numbers in the Harris Reservoir and exhibited much better growth and size structure than crappie (Pomoxis spp.) in the river, which was attributed to more abundant habitat and forage availability in the reservoir (Hartline et al. 2018)." Provide where "in the river" is referring to.	Revised in the Final Report.
ADCNR		On page 18, section 2.3.2, of the Draft Aquatic Resources Report, include a statement specifying that ADCNR standardized sampling includes only a few popular game species at Harris Reservoir. It is important to note that other popular fisheries exist in Harris Reservoir, such as Flathead Catfish (Pylodictis olivaris), Blue Catfish (Ictalurus furcatus), Channel Catfish (Ictalurus punctatus), Redear Sunfish (Lepomis microlophus), Bluegill Sunfish (Lepomis macrochirus), and White Bass (Morone chrysops).	Revised in the Final Report.
ADCNR		On page 19, section 2.3.2, of the Draft Aquatic Resources Report, change "…stable or a slightly rising elevation for a period of 14 days to increase the spawning success of these species." to "…stable or a slightly rising elevation for a period of 14 days to provide improved conditions for spawning and hatching success."	Revised in the Final Report.
ADCNR		On page 19, section 2.3.3, of the Draft Aquatic Resources Report, it states, "The following is a chronologically ordered synopsis of available information pertaining to aquatic resources in the Tallapoosa River downstream of Harris Dam." This statement needs to be reworded to state, "The following is a chronologically ordered synopsis based on Alabama Power Company's (APC) interpretation of selected relevant and historic information pertaining to aquatic resources in the Tallapoosa River System. Since the APC synopsis provided has not been through a scientific journal peer review process, there is a potential for bias or misinterpretation of the author(s) specific findings or conclusions." ADCNR has significant issues regarding how some of the studies were represented. In addition to an APC synopsis provided, if a peer-reviewed technical journal, master's thesis, doctoral dissertation or unpublished report discussed in this section include abstracts, include in an appendix of the Final Aquatic Resources Report, similar to page 20 of section 4.0 Publications in Appendix E, Volume 1 of the June 2018 R.L. Harris Hydroelectric Project Pre-Application Document or within the report prior to the APC synopsis. We reserve the right to continue providing comments on the included synopses and provide additional sources of information to include for consideration during the continued Final	The sources used in this literature review were chosen due to their relation to the geographic scope of the Harris Project. Abstracts from the sources summarized in the Aquatic Resources Desktop Assessment are available online and can be found by searching for the titles of the sources.

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		Aquatic Resources Report commenting and adaptive management plan process.	
ADCNR		On page 21, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Travnicheck and Maceina (1994) APC synopsis, provide a few statements regarding details of which specific species of catostomid (suckers) decreased in relative abundance.	Revised in the Final Report.
ADCNR		On page 21, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Johnson (1997) APC synopsis, add that in the Upper Tallapoosa tributaries Alabama Spike (Elliptio arca) was collected.	Revised in the Final Report.
ADCNR		On page 22, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Johnson (1997) overview summary, "Southern Rainbow (Villosa iris)" should be changed to "Southern Rainbow (Villosa vibex)".	Revised in the Final Report.
ADCNR		On page 22, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Johnson (1997) APC synopsis, there are several aquatic gastropod species missing from this summary that are listed in the paper. Update missing species provided in Johnson (1997). ADCNR has records of eight species of aquatic gastropods historically present in the TRB, minus Physella sp. species. Physella taxonomy is currently undetermined. There could be one species or up to three species of Physella present in the TRB, pending further investigation. Rock Fossaria (Fossaria modicella) is now Galba modicella. Any Fossaria that were found in Johnson (1997) are recognized as G. modicella. Pointed Campeloma (Campeloma decisum) does not occur in the Mobile Basin. Any Campeloma that were found in Johnson (1997) are recognized as Cylinder Campeloma (Campeloma regulare). Including specific tributary names of collections is recommended.	The summary of this paper only involves the portion of the TRB pertaining to the Harris Project. Other species of gastropods in the TRB can be referenced in the gastropod table. Scientific names have been updated in the Final Report.
ADCNR		On page 23, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Freeman et al. (2001) APC synopsis, provide the ten species investigated in this study. Include in the overview summary, that during summer, lower and more stable flows occurred at the regulated site which favored later spawning fish. Five of six species that spawn in the spring were less abundant at flow regulated sites compared to the upper unregulated sites.	It is unclear which ten species are being referred to, as there are more than ten species included in the publication. The last sentence of this comment was incorporated into the summary.
ADCNR		On page 23, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Irwin and Belcher (1999) APC synopsis, include how many Flathead Catfish were tagged and stocked and additional potential causes for why no tagged Flathead Catfish were reported.	The authors concluded that no tagged Flathead Catfish were reported due to migration out of the area or lack of fishing effort. The typical implication of a low number of tagged fish is a large population of that species. This conclusion was removed from the

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			desktop assessment as it was not a conclusion derived by the authors and language was revised clarify that the author of the original paper arrived at these conclusions.
ADCNR		On page 24, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Sakaris (2006) APC synopsis, remove "surprisingly".	This was paraphrased from the paper which reported results as "unexpectedly lower." Replaced "surprisingly" with "unexpectedly" to remain consistent with the conclusions of the original author.
ADCNR		On page 25, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Irwin et al. (2011) APC synopsis, provide IBI score overviews similar to Bowen et al. (1996) summary section. Remove one of the "be" after "Lipstick Darter may be be maintaining" and add Green Plan prior to "flow regulation" in this sentence.	IBI scores were displayed in a graph in the original paper and exact values are not available.
ADCNR		On page 26, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Irwin et al. (2011) APC synopsis, reword, "…but Tallapoosa Darter seemed to be reproducing and faring well downstream of the dam." excluding "seemed to be" and "faring well".	Language was paraphrased from the original study: "*Etheostoma tallapoosae* appears to be in reproductive condition in the regulated reaches and in general seem to be persisting well below the dam."
ADCNR		On page 27, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Earley (2012) APC synopsis, it states, "Cortisol had no substantial effect of growth…" It is important to remember that no substantial effect does not correlate to no effect. Physiological stressors for both species showed altered stress response at the regulated site on the Tallapoosa River compared to the reference site. This difference was possibly due to the non-natural flow regime measured at the regulated site.	Alabama Power agrees that although the changes in cortisol do not appear to be affecting growth, the stress responses of fish differ between the regulated and unregulated river.
ADCNR		On page 27, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Goar (2013) APC synopsis, rewrite overview to state, "Age-0 Redbreast Sunfish (Lepomis auratus) were collected at two regulated flow sites on the Tallapoosa River downstream of R.L. Harris Dam, at one unregulated flow site above Harris Reservoir, and an unregulated tributary stream of the Tallapoosa River downstream of R.L. Harris Dam. Overall daily growth rate and incremental growth rate varied among years and was higher at regulated sites than unregulated sites, although overall model fit was modest. Hatch frequency was higher and occurred earlier in unregulated sites compared to hatching in regulated sections. In laboratory experiments, results suggested that simulated high flows and decreased water temperatures similar to those measured on the regulated portion of the Tallapoosa River negatively affect daily growth rates and survival of Channel Catfish (Ictalurus punctatus) and Alabama	Revised in the Final Report. The author stated that the overall model fit was poor, which was clarified in the summary.

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		Bass (Micropterus henshalli). Mortality was highest and daily growth lower in treatments with decreased water temperatures. Older fish displayed higher daily growth rates and decreased mortality and were not as susceptible to the negative effects of simulated high flows and lower temperatures. These data suggest that growth and survival may be impacted more by fluctuations in temperature than flow."	
ADCNR		On page 28, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Sammons et al. (2013) APC synopsis, include statement that the short lifespan of Tallapoosa Bass "may have hindered the ability of residual analysis to identify relationships between hydrology and recruitment of this species."	Revised in the Final Report.
ADCNR		On page 28, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Sammons et al. (2013) APC synopsis, regarding rainfall and flows, Sammons et al. (2013) stated based on observations during sampling "that catch rates of age-0 fish of all three species was higher in the lower and upper reaches than in the middle reach, indicating that recruitment at the population-level is likely impacted in the middle reach."	Revised in the Final Report.
ADCNR		On page 29, Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Gerken (2015) APC synopsis, provide the ten species investigated in this study. Include in the overview summary, that HPUE was positively correlated to water temperature and negatively correlated to discharge for eight species of fish. Add that surveyed anglers targeted catfishes and black basses and reported catch rates of 2.0 fish per hour.	Variables correlated to HPUE were calculated overall but were only calculated individually for three species: Alabama Bass, Tallapoosa Bass, and Redbreast Sunfish. These correlations have been included.
ADCNR		On page 30, Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Kennedy (2015) APC synopsis, include that a total of 50 fish species were collected over the 22 sites sampled. Of these 50 species, 13 species were collected with a high enough frequency that permitted further analyses.	Revised in the Final Report.
ADCNR		On page 32, section 2.3.3 Tallapoosa River and Tributaries of the Draft Aquatic Resources Report, Irwin (2019) APC synopsis, provide IBI score overviews similar to Bowen et al. (1996) summary section. Note differences in metrics between studies.	Additional language has been added to the macroinvertebrate section. Standard deviation was high for some of the metrics calculated. Specific values were left out of the summary.
ADCNR		On page 33, Table 2-5 Summary of Findings from Studies in the Tallapoosa River Below Harris Dam, it should be noted that the findings are based on the interpretation of APC. Including the individual abstracts of the actual research reports would eliminate any potential bias and the possibility of misinterpreting the study results.	Abstracts are available online and can be found by searching for the titles of the sources.

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ADCNR		On page 33, Table 2-5 of the Draft Aquatic Resources Report, delete or rewrite table summary with major revisions. The majority of the brief summaries provided are either insufficient, incomplete and/or are not all inclusive of the research results or conclusions. Findings should point the reader to the actual research abstracts, which should also be included in this report.	The table has been updated with additional findings regarding comparisons of spawning and hatching between regulated and unregulated sites, presence/absence and decline of certain species, effects of temperature and flow on growth and survival, and habitat use during operation.
ADCNR		On page 35, 2.4 Summary section of the Draft Aquatic Resources Report, rewrite the first paragraph, accordingly, based on new species numbers and analysis after implementing ADCNR comments above. We recommend providing a more detailed summary of which specific aquatic species and populations (faunal shift changes) whose presence and/or sustainability within the Study Area have increased, decreased or remained stable since operation of the Harris Project and voluntary Green Plan implementation.	None of the individual studies summarized in the report span both pre- and post-Green Plan operations. However, many of them draw comparisons between regulated and unregulated reaches. The main focus of the 2.4 Summary section is to provide a general overview of the effects of Harris Dam on aquatic resources downstream. Sections 2.3.2 Harris Reservoir and 2.3.3 Tallapoosa River and Tributaries are more focused on species-specific information. Species numbers have been updated.
ADCNR		On page 35, 2.4 Summary section of the Draft Aquatic Resources Report, it states, " In the spring, Alabama Power coordinates with ADCNR to maintain Harris Reservoir at a stable or slightly rise in elevation for a two-week period to increase spawning success of sport fish species, including Largemouth Bass, Alabama Bass, and Black Crappie." Add "in the Harris Reservoir" after "Crappie". ADCNR appreciates this voluntary coordinated effort with APC to improve spawning success of sport fish species in the reservoir. It is great example of how stable spawning periods can be crucial to sport fish management and how cooperation among stakeholders can contribute to targeted natural resource positive outcomes.	Revised in the Final Report.
ADCNR		On page 37, section 3.2.1 of the Draft Aquatic Resources Report, it states, "There is little existing temperature data on the recently described Tallapoosa Bass and Alabama Bass species. Spotted Bass data are being gathered as a surrogate to Alabama Bass data since the two species are very closely related." If no specific data is obtained regarding temperature data for the Tallapoosa Bass, in addition to the information obtained on Alabama Bass, ADCNR recommends including as supplement, available temperature requirements of Redeye Bass (Micropterus coosae) and Shoal Bass (Micropterus cataractae). Auburn University has the perfect opportunity to study, and publish temperature requirements for Tallapoosa Bass, if there is nothing in the literature to use. Trying to use	See comments pertaining to Appendix B below.

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		"similar" species may not be accurate for the bioenergetics modeling trials.	
ADCNR		On page 38, section 3.2.2 of the Draft Aquatic Resources Report, it states, "Daily fluctuations of 10 °C were rare during both Pre-Green Plan and Green Plan operations. Overall, releases from Harris Dam could cause temperature decreases of 4 °C in the summer and 1-2 °C in the fall (see June 2, 2020 HAT 3 meeting summary in Attachment 2)." Specify what percentage of time yearly, monthly, daily and hourly, 2, 4, 6, 8 and 10 °C, changes occurred. Provide the time frame temperature changes described, are referring to in the text. For water temperature data, maximum and minimum values, and how long those values persist (hours) would better explain the fluctuation in temperature changes occurring in a regulated and unregulated river reaches. Providing detailed reporting of minimum and maximum values at hourly intervals especially when water temperatures reach critical spawning ranges (15-25°C) in the spring, is important to fully understand what is occurring to aquatic resources (See July 31, 2020, ADCNR page 18, section 3.2.4 Water Temperature of Draft Downstream Aquatic Habitat Report comments on temperature change). Provide mean, median, minimum and maximum hourly water temperature fluctuations in this section. A comparison of hourly changes between unregulated and regulated reaches will be critical in evaluating temperature impacts to natural resources.	See comments pertaining to Appendix B below.
ADCNR		On page 38, section 3.2.2 of the Draft Aquatic Resources Report, it states, "A direct comparison of temperatures between unregulated and regulated reaches will be included in the Final Aquatic Resources Study Report in April 2021". Explain why the unregulated temperature evaluation was not included in the Draft Aquatic Resources Report. In addition, this section indicates that temperature is less variable in the tailrace than at Wadley. The tailrace should theoretically receive the coldest and largest amount of discharge. Provide verification of this result and include an explanation of potential causes for this variation as you proceed further downstream of the discharge.	See comments pertaining to Appendix B below.
ADCNR		On page 38, section 3.2.3 of the Draft Aquatic Resources Report, it is unclear if this fish population includes shallow water habitat or only deep-water habitat analysis. The methods describe deep water sampling methods only. Specify which sites are shallow water and which are deep water. If any of ADEM's 2018 fish surveys in the Tallapoosa River will be used to supplement collections by Auburn University and Alabama Power, include data in the report or in an appendix and discuss results. Provide	See comments pertaining to Appendix B below.

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		deep and shallow fish survey sampling metrics such as numbers of each species collected, abundance, diversity, evenness, etc. and calculate for each study reach (Recommend a similar basin calibrated IBI calculation for comparison to previous studies (Bowen et al. 1996; O'Neil et al. 2006; Irwin 2019)). If selected monitoring sites were modified or changed, provide details on habitat and fish sampling differences observed between sites.	
ADCNR		On page 3, section 2.1 in Appendix B of the Draft Aquatic Resources Report, since data relevant to effect of temperature requirements for Tallapoosa Bass do not currently exist, ADCNR recommends including additional available temperature requirements of Redeye Bass (Micropterus coosae) and Shoal Bass (Micropterus cataractae).	Auburn University incorporated temperature requirement information suggested by ADCNR into their final report (reference emails dated November 24, 2020 and December 7, 2020 between Alabama Power and ADCNR as included in the Aquatic Resources Study Consultation record filed concurrently with this report).
ADCNR		On page 4, section 2.2 in Appendix B of the Draft Aquatic Resources Report, include an explanation or supporting sources for why extreme fluctuations in temperature in daily temperatures were defined as a 10 °C shift for this study. In addition to yearly, monthly and daily temperature shifts included, specify what percentage of time during hourly analysis, 2, 4, 6, 8 and 10 °C, changes occurred. For water temperature data, maximum and minimum values, and how long those values persist (hours) would better explain the fluctuation in temperature changes occurring in a regulated and unregulated river reaches. Providing detailed reporting of minimum and maximum values at hourly intervals especially when water temperatures reach critical spawning ranges (15-25°C) in the spring. This information is needed to fully understand what is occurring to aquatic resources (See July 31, 2020, ADCNR page 18, section 3.2.4 Water Temperature of Draft Downstream Aquatic Habitat Report comments on temperature change). Provide mean, median, minimum and maximum hourly water temperature fluctuations in this section. Provide more details on the noted periods of relatively higher variation during both pre- and post- Green Plan periods including how many times they occurred for each site. If temperature data is unavailable for a specific site, during a time period when other sites indicate high temperature variation, provide a caveat recognizing these specific key data range gaps with an explanation for the absence. For example, Tailrace 2000 Temp Range is unavailable for 10-12-month data, but Malone and Wadley both indicate high variation during this same time period. Unavailable temperature data gaps, during key high temperature variation events, has the potential to	The requested analyses would entail thousands of values. Auburn University will continue temperature analysis as described in the approved Aquatic Resources Study Plan, although the Auburn University team explored hourly changes as required for the temperature changes in the swim studies. Fluctuations as great as 10 °C were reported in Irwin and Freeman (2002) and were therefore defined as extreme fluctuations in this study. The temperature data show that some 6 °C changes occur close to the dam but only a very small fraction of the time. It is possible that fluctuations of 10 °C occur when an area becomes especially shallow with reduced flow, causing loggers to become influenced by more direct solar radiation and register higher temperatures. This happens occasionally to some of the USGS gages. Histograms were produced for some of these temperature changes. The comparison of water temperature in regulated and unregulated reaches incorporated 2018-2020 data from Heflin and is included in the Final report; however, statistical analysis was not used to compare temperatures in the unregulated and regulated river due to the short data record and the numerous biotic and abiotic differences between the Heflin site and sites downstream from Harris Dam. The

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		significantly reduce analyses of temperature changes and impacts occurring in the regulated reach. A comparison of yearly, monthly, daily and hourly changes between unregulated and regulated reaches will be critical in evaluating temperature impacts and providing details for Modified Green Plan flow scenario recommendations. Explain why the unregulated temperature evaluation was not included in the Draft Aquatic Resources Report and include this analysis in the Final Aquatic Resources Report.	draft report was submitted as a progress report, and as such, not all comparisons or data for the final report were available and thus some could not be included.
ADCNR		On pages 5-7, section 2.3 in Appendix B of the Draft Aquatic Resources Report, deep and shallow fish survey sampling should include common metrics such as abundance, diversity, evenness, etc. and calculated for each study reach (Recommend a similar basin calibrated IBI calculation for comparison to previous studies (Bowen et al. 1996; O'Neil et al. 2006; Irwin 2019)). Data from ADEM's 2018 fish surveys in the Tallapoosa River may be used to supplement collections by Auburn University and Alabama Power (If supplementing this data for shallow water sampling, include data in the report or in an appendix and discuss results). If selected monitoring sites were modified or changed, provide details on habitat and fish sampling differences observed between sites.	Deep and shallow sampling was integrated over entire transects but was not analyzed individually. Calibrating an IBI for this basin is beyond the scope of the contracted work. The Auburn University team does not consider it appropriate to insert the data they collected into an O'Neil IBI because data were not sampled using the same methods. Sites within the system are being compared using data collected by Auburn University with similar methods where possible.
ADCNR		On page 6, section 2.3 Sampling Methods in Appendix B of the Draft Aquatic Resources Report, include an explanation for why pulses were set at 25/sec (25 pps) for electrofishing sampling. Typically pulse rates of at least 60/s are used to collect scaled fishes, and 30 and below are used for non-scaled fishes such as catfish.	Initially, a lower setting was used to better ensure fish survival and was referenced in the draft progress report. After the first sampling trip, it became apparent that fish survival was consistent at a greater pulse rate, but fish survival was of less concern because the majority of sampled fish were being euthanized to be worked up in the lab.
ADCNR		On page 7, section 2.4 in Appendix B of the Draft Aquatic Resources Report, specify in the bioenergetics methods if data from individuals collected from all four sites will be pooled and/or analyzed for differences among fish species groups for each site.	Once data were collected across sites, a preliminary analysis determined whether there were metabolic differences among fish within species from the various study sites. The data are presented accordingly in the final report.
ADCNR		On page 10, section 3.3 in Appendix B of the Draft Aquatic Resources Report, ADCNR agrees with the assessment that an alternative site is necessary for the current upstream control site due to its closely linked dam operation characteristics. ADCNR requests input on site selection alternatives.	Auburn University explored whether to substitute the reference site upstream of Lee's Bridge with another unregulated site further upstream but could not find a suitable alternative. It was essential to find an alternative site where the same sampling methods could be used as the previous unregulated site. Auburn University continued to sample the original site upstream of Lee's Bridge as the unregulated site,

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			which yielded a diverse fish community with minimal influence of the dam. The habitat is riverine and water level only drops less than a meter during winter.
ADCNR		On page 10, section 3.3 in Appendix B of the Draft Aquatic Resources Report, provide methods for the electromyogram (EMG) telemetry data portion on page 5, section 2.3 section of the report.	Preliminary work determined that EMG tags did not provide a good representation of muscle activity. As such, CART (combined radio and acoustic) tags were used instead. Methods are provided in Auburn University's Final Report.
ADCNR		On page 15, Table 1. in Appendix B of the Draft Aquatic Resources Report, ADCNR recommends including additional available temperature requirements of Redeye Bass (Micropterus coosae) and Shoal Bass (Micropterus cataractae). Including details on spawning substrate preference, age at sexual maturity and maximum life expectancy of each species in this table would be beneficial.	Auburn University incorporated temperature requirement information suggested by ADCNR into their final report (reference emails dated November 24, 2020 and December 7, 2020 between Alabama Power and ADCNR as included in the Aquatic Resources Study Consultation record filed concurrently with this report). Given that the purpose of this table is to summarize temperature requirements of target species and surrogate species for bioenergetics models, other suggested parameters were not included.
ADCNR		On page 17, Table 3. in Appendix B of the Draft Aquatic Resources Report, provide common names column, and family column similar to page 7, Table 2-1 of the Draft Aquatic Resources Report, for consistency purposes. Include number collected for each species, instead of presence only. Include common metrics such as abundance, diversity, evenness, etc. and calculated for each study reach (For etc. ADCNR recommends including a similar basin calibrated IBI calculation for comparison to previous studies (Bowen et al. 1996; O'Neil et al. 2006; Irwin 2019)). Include a row indicating how many sampling trips the column data represents.	Appendix B was Auburn University's Progress Report that was submitted to Alabama Power and authored independently from the rest of the Draft Aquatic Resources Report. Inconsistencies between documents written by Alabama Power and Auburn University pertaining to subject matter or objective results were corrected. Common metrics such as diversity and catch-per-unit-effort are included in the final report. Auburn University is not comfortable with plugging data they gathered into an O'Neil IBI because data was not sampled using the same methods. Sites within the system were compared so Auburn University data could not legitimately be used in those IBIs.
ADCNR		On pages 22-30, Figures 2A-2C in Appendix B of the Draft Aquatic Resources Report, if temperature data is unavailable for a specific site, during a time period when other sites indicate high temperature variation, provide a caveat (blue shaded box with asterisks recognizing these specific key data range gaps) with an explanation for the absence. For example, Tailrace 2000 Temp Range is missing 10-12-month data, but	Absent data is evident in the figures. No changes were made.

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		Malone and Wadley show high variation during this period. An additional notable missing data gap was observed in Figure 2B Malone 2003, months 3-5 data. Determining when, how often and how far downstream tailrace high variation temperatures were detected will be important information to have when evaluating temperature effects on aquatic resources.	
ADCNR		On page 36, Figure 6 in Appendix B of the Draft Aquatic Resources Report**,** label sites accordingly to site descriptions in the text (For example, label Upper Tallapoosa point as Lee's Bridge. Indicate which locations were substituted and provide alternative location on map.	Names and labels are used consistently in the Auburn University's Final Report. The reference site upstream of Lee's Bridge was not replaced.
ARA Note: footnotes included in the original letter have been omitted from this table (highlighted portion of letter pertains to this study)	8/28/2020 filed by email On the Draft Aquatic Resources Study Report	As part of the Downstream Fish Population Study described in Appendix B to the Draft Study (Auburn University's Progress Report), an assessment of the entire fish population below Harris is being conducted, and a subset of four target species are being studied more intensively.[1] For the non-target species, it is unclear exactly what the assessment entail. Will more information on non-target species be reported other than the presence/absence data contained in Table 3 of the Progress Report? We encourage Licensee to provide the "comprehensive characterization of aquatic resources" described in the approved Aquatic Resources Study Plan with careful attention paid to both target and non-target species.[2]	Common metrics such as abundance and diversity, were calculated. Non-target species are included in these analyses and results are included in Auburn University's Final Report.
ARA		Particularly because scant temperature data exists for two of the four target species (Tallapoosa Bass and Alabama Bass[3]) and a wide range in thermal minima and preferred temperatures has been reported in the literature for another target species (Channel Catfish[4]), we recommend a literature review of similar temperature data for at least some of the non-target species, including species the science indicates are most affected by Harris, such as Stippled Studfish, Blackspotted Topminnow, Black Redhorse, Blacktail Redhorse, Riffle Minnow, and Bullhead Minnow.[5]	Temperature data are not likely available for many of these non-target species and gathering these data is beyond the scope of the FERC-approved study plan. The target species were chosen in consultation with ADCNR because they are typical species of most rivers in the region, they are resilient species that can be transported to a laboratory for further study relatively easily, they are a mixture of habitat generalists (Alabama Bass) and riverine specialists (Tallapoosa Bass), and they are of interest to the public. No Stippled Studfish or Riffle Minnow were sampled during Auburn University's samples. Numbers and catch-per-unit-effort of other species are included in the final report by season and site.
ARA		Of the 38 fish species studied from 25 sites over a 12-year period and reported on in the U.S. Geological Survey's Open-File Report from 2019 ("USGS Report"), the four target species selected for the Downstream Fish Population Study are relatively more tolerant of flows from	Temperature data are not likely available for many of these non-target species and gathering these data is beyond the scope of the FERC-approved study plan. The target species were chosen in consultation with ADCNR due to the availability of temperature data,

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		Harris, though still clearly impacted. Figures B6 and B7 of the USGS Report show the estimated flow regulation effects on species-specific persistence and colonization, and it is clear that the target species are all in at least the top 50 percent of species that can withstand the current flow regime.[6] For example, the following Figure B6 of the USGS Report shows flow regulation effects on persistence for 38 species with the four target species highlighted. Certainly, the target species are game fish of particular interest to fishermen and recreationists on the Tallapoosa; however, they do not accurately represent the full spectrum of impacts suffered by fishes below Harris. As noted in the Aquatic Resources Study Plan, the goal of many stakeholders in this relicensing is to "protect and enhance the health of populations of game and non-game species of fish and other aquatic fauna."[7] To more comprehensively assess temperature and flow impacts on both game and non-game fishes, we recommend at least a literature review of temperature data for some of the more impacted species mentioned above.	because they are characteristic of stream species with respect to temperature requirements, and because they are of interest to the public.
ARA		Table 4 of Auburn University's Progress Report shows the number of each target species that have been run in static and swimming respirometry at either 10℃ or 21℃, but it does not show which sites the fishes tested were collected from (regulated vs. unregulated sites). For instance, which sites were the five Channel Catfish shown as tested in the swimming respirometer in Table 4B collected from? To fully understand the effects of a Harris-sized release that combines increased flow with decreasing temperature, fishes from unregulated reaches that are not acclimated to the effects of Harris should be subjected to simulated conditions. Just as the published bioenergetics model for a lentic population of Channel Catfish mentioned in Auburn's Progress Report may not be applicable to a model of the same species in a lotic environment, a bioenergetics model of Tallapoosa Bass from the Malone site, which experiences large fluctuations in daily flows, may be different than the model of Tallapoosa Bass in an unregulated reach that sees natural flows. To fully understand the energy-balance simulations provided by the bioenergetics model, it would be helpful to know if fishes from regulated or unregulated reaches were used to create the model.	Auburn University's final report clarifies these details. Preliminary analyses determined if there were metabolic differences within species across the study sites. If no differences were found, fish were combined across sites for water exchange trials.

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ARA		As part of the intermittent flow static respirometry portion of the bioenergetics modeling, target fish species are being tested at two temperatures, 10℃ and 21℃.[8] We seek to understand why those particular temperature values are being used for the static respirometry. The value of 10℃ aligns with the lowest thermal minima of any target species on Table 1 of the Progress Report. The value of 21℃ lines up with ideal spawning temps for two of the target species on Table 1. The temperature range data provided by Licensee for 2000-2018 in Figure 2B regularly shows temperatures reaching 10℃ in most every year. However, since this data is only for March through October of each year, with winter water temperatures not available, it is likely that lower water temperatures are present below Harris. The need for winter temperature data was noted by the Auburn research team as a take-home point during its June 2020 presentation to HAT-3.[9] Records from the USGS gages at Wadley and Heflin shows winter water temperatures significantly below 10℃.[10] Additional winter temperature data may need to be taken into account as part of the static respirometry portion of the bioenergetics modeling. At a minimum, rationale for the temperature values chosen for the static respirometry would be helpful to stakeholders and should be included in the final report.	10 °C and 21 °C are well established temperatures for measuring standard metabolic rate of fish from regions like this one. Lower temperatures would require respirometry trials extending over periods as long as 3-4 days in order for fish to measurably reduce dissolved oxygen levels in water. Such trials would include day and night periods, drastically complicating interpretation of results. In addition, the focus is less on winter temperatures and more on summer temperatures, when the largest temperature fluctuations occur.
ARA		In Section 3.3 of the Auburn University Progress Report, the authors discuss the possibility of adding an alternative "control" site, either another site upstream of the Harris reservoir or an unregulated tributary. The current control site at Lee's Bridge "appears to be more closely linked to dam operations than previously thought," and that particular site is not yielding the requisite number of one of the target species, Tallapoosa Bass, to have a sufficient dataset. [11] We fully support establishing one or more alternative control sites further upstream of Harris or, ideally, in the unregulated tributaries that are the least influenced by dam operations. An unaffected control site is necessary for the study, and if the Lee's Bridge site is not an appropriate control site, another should be identified and established.	Auburn University explored alternatives to the reference site upstream of Lee's Bridge with another unregulated site further upstream but could not find a suitable alternative. Finding an alternative site where the same sampling methods could be used as the previous unregulated site was essential. Auburn University continued to sample the original site upstream of Lee's Bridge as the unregulated site, which yielded a diverse fish community with minimal influence of the dam. The habitat is riverine and water level only drops less than a meter during winter.
ARA		Based on extensive studies surveying a wide variety of fishes and macroinvertebrates below Harris, and based on the preliminary findings contained in the Draft Report, we believe enough evidence exists of the temperature impacts created by the hypolimnetic releases from Harris to justify beginning discussion of the options available to remedy the current	Comment noted.

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		thermal regime. The following is a brief summarization of some of the research pointing to ecological problems caused by low water temperatures: - Nesting success for Redbreast Sunfish was negatively related to both peaking power generation and depressed water temperatures (Andress 2002).[12] - Strongly fluctuating flows and decreased water temperatures negatively affect survival and early growth of age-0 Channel Catfish and Alabama Bass. Mortality was highest in treatments with decreased water temperatures, indicating that variation of the thermal regime could have significant impacts on survival of juvenile Channel Catfish and Alabama Bass. Daily growth rates were also lower in treatments with decreased water temperatures. Data also suggest that growth and survival may be impacted more by fluctuations in temperature versus flow variation (Goar 2013).[13] - Improving flow and temperature criteria from Harris could enhance growth and hatch success of sport fishes (Irwin and Goar 2015).[14] - Flow and temperature remain in a non-natural state in regulated reaches downstream of Harris, and the macroinvertebrate community in regulated reaches shows many dissimilarities to communities from unregulated river reaches (Irwin 2019).[15]	
ARA		Most recently, Chapter B of the USGS Report specifically links cold temperatures to ecological impact: "Although it has long been recognized that temperatures are altered below R.L. Harris Dam, specific inference regarding the influence on biotic processes has been lacking until this study, which clearly related colonization rates (that is, recruitment of a species to a site) to increased thermal energy in the river."[16] Thermal regimes and flows are intrinsically related, but at Harris, adjusting water temperatures may require a different set of infrastructure improvements than modifying flows due to the configuration of the intake structure. Licensee has stated it will examine options for temperature mitigation technologies once it has been determined that water temperature is a problem.[17] It will take time to analyze the cost-effectiveness of temperature control technologies such as floating intakes, multi-level intake structures, and different reservoir destratification	Alabama Power will evaluate infrastructure enhancements that may be needed as a solution to any temperature problems described in the results of the studies.

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		approaches. We believe that delaying this discussion and assessment can only prolong the relicensing, and we encourage FERC and Licensee to turn to this topic while the Aquatic Resources Study progresses. As the USGS Report notes, "changes in dam management have successfully mitigated for thermal effects,"[18] and thermal controls coupled with operational changes guided by adaptive management can bring about successful mitigation and ecological restoration on the Tallapoosa below Harris.	
Donna Matthews	8/28/2020 Filed by email On the Draft Aquatic Resources Study Report	Given the wide array of study data already available, it seems prudent to design studies built upon previously gleaned knowledge and understanding. This river has been studied for decades. It is known that regulation of rivers including erratic flows and induced temperature variations are detrimental to downstream aquatic life. I saw no mention of previous 'Wisconsin" Bioenergetic Studies in the literature review. If creation of a model adaped for this study is breaking new ground, how is it superior to previous methodologies of *in situ* fish and critter counts at various points along the river? What does it aspire to contribute to the knowledge of the aquatic life, in all its totality, of the Tallapoosa River? What information will it (Bioeneretic Model) provide that other study methods do not? What information is not collected from a bioenergetic study which might be present in biological monitoring studies? My understanding was the 20 or so level loggers set out last year were to record temp and flow data every 15 minutes. Are the level logger locations being used to collect fish samples for any of the studies? Since the locations of the level loggers are known, they become reference points from which to gather and study species of concern. Since the data comparing regulated/unregulated temperatures is retrospective sec (3.2.2) are there plans to collect temp and flow data at the study/collection sites? Looking for species of concern at these specific locations will provide clear baseline data available for future scientists. Constructing a new bioenergetics model to assess aquatic life seems excessive. Adding data to protocols for established aquatic biological	Auburn University's Final Report elaborates more on the purpose and use of the bioenergetics model. The "Wisconsin Bioenergetics Model is a standard modelling framework that has been tested and published numerous times. The model is extremely flexible, allowing for different input parameters to be used for different species or for individuals from different populations/locations, although the parameters must have been measured. Some parameters are already published; others were determined in Auburn University's studies, such as temperature, diet, metabolic rate, etc. Limitations of the "Wisconsin" bioenergetics model include the lack of models for Tallapoosa Bass and Redbreast Sunfish, that the Channel Catfish model parameters are from lentic systems, and that temperature and activity operate on a daily time step, rather than hourly. Respiration trials isolated the variables of temperature and water velocity to determine how they impact metabolic rate and growth without the influence of other variables. Temperature and activity rates measured from Auburn University's studies were used as inputs into a bioenergetics model to simulate how temperature decreases and water velocity increases from Harris Dam releases could affect specific growth rate of Redbreast Sunfish. Temperature was collected at the sites where fish were sampled, but fish were not sampled at the locations of the 20 level and temperature loggers

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		monitoring would appear to be the better use of resources and allow better comparison of data from years past going forward.	deployed by Kleinschmidt Associates. The purpose of these 20 loggers was to create a model of discharge and temperature of the river for other Harris relicensing studies and data are being used to determine how proposed changes to operations could potentially affect aquatic resources and other resources in the Tallapoosa River downstream of Harris Dam. Temperature was collected at the study/collection sites and discharge data at the sites is available in the Final Downstream Aquatic Habitat Report.

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These ADCNR comments below were received following the March 5, 2021 presentation of Auburn University's report titled "Using Bioenergetics to Address the Effects of Temperature and Flow on Fishes in the Harris Dam Tailrace" (Auburn's final report) to ADCNR; Alabama Power subsequently filed these comments and a response on June 15, 2021[1].			
Alabama Department of Conservation and Natural Resources (ADCNR)	4/02/2021 filed by email	ADCNR is providing these comments in addition to our Aquatic Resources Draft Report comments. Please note that responses to our initial comments are still pending, as Alabama Power Company (APC) noted they would be addressed in the Final Aquatic Resources Report. The remaining FERC approved Aquatic Resources Study Plan requirements that ADCNR identified include: • Section 4.2.2 of Study Plan, states, "Auburn will compare temperatures at regulated sites (i.e., Tallapoosa River from Harris Dam to Horseshoe Bend) to unregulated sites (i.e., Newell and Heflin)". Heflin temperature data is included in the Auburn University (Auburn) final report although not statistically analyzed and Newell temperature data, to date, has not been provided. • Section 4.2.3 of Study Plan states, "Auburn and Alabama Power will perform field sampling to characterize the current fishery in deep and shallow water habitats in the Study Area and in unregulated portions of the Tallapoosa River. Wadeable, shallow water habitats will be sampled using a standardized protocol known as the 30+2 method (O'Neil et al. 2006). Backpack electrofishing will consist of 10 efforts each in riffle, run, and pool habitats, with an additional 2 shoreline efforts. Non-wadeable, deepwater habitats will be sampled using boat and barge electrofishing under standardized protocols (O'Neil et al. 2014). Auburn will perform boat sampling quarterly for 7 events between fall 2018 and fall 2020 in reaches at varying distances downstream of Harris Dam, including sites in the tailrace, near Malone, Wadley, Horseshoe Bend, and at least one additional site on an unregulated reach. Auburn researchers may employ additional passive capture techniques as conditions warrant (e.g., hoop nets,	• Previous comments provided by ADCNR were addressed in the Final Aquatic Resources Report filed with FERC on April 12, 2021. • Water temperature data from the unregulated Heflin and Newell sites are provided in the Final Aquatic Resources report, along with comparisons to water temperature data from regulated sites. Given that Objective 1 of the Auburn did not yield specific temperature requirements, Auburn could not compare such requirements with temperatures at regulated or unregulated sites. Relative to statistical analysis for Heflin versus downstream sites, after careful consideration, Auburn determined that it would not be appropriate due to the types of environments represented in each area. Heflin is narrow, shallow, extremely turbid (in comparison to downstream sites) and has many more agricultural inputs relative to the size of the stream. This could potentially lead to higher productivity, sediment input, and increased turbidity. These differences lead to different thermal variables affecting water temperature at each of the sites. Without measuring a full suite of variables, the results of any statistical tests aimed at determining if upstream temperatures differ from downstream temperatures due solely to the presence of the dam would be tenuous.

[1] Accession No. 20210615-5110

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		minnow traps, etc.). Data from ADEM's 2018 fish surveys in the Tallapoosa River may be used to supplement collections by Auburn and Alabama Power." The non-wadeable, deepwater habitats sampling is included in the Auburn report and has been completed using boat and barge electrofishing under standardized protocols (O'Neil et al. 2014). To date, wadeable, shallow water habitat field sampling work has not been provided using a standardized protocol known as the 30+2 method (O'Neil et al. 2006). • Section 4.2 of Study Plan states, "Alabama Power and Auburn University (Auburn) will evaluate factors affecting fish populations in the Tallapoosa River below Harris Dam through field and laboratory studies. Although this study will include an assessment of the entire fish population, a subset of target species will be studied more intensively." Although stakeholders agreed on target species to focus on, it was also explained in the study plan that fish populations would be studied, not just the four species identified to be studied extensively with bioenergetics and other methodologies. To date, with the Final Aquatic Resources Report still pending, neither APC or Auburn has identified aquatic species and populations whose presence and/or sustainability within the Study Area may have been affected by the Harris Project.	• Auburn sampled both deep and shallow water habitat. As noted during a previous HAT3 meeting (March 31, 2021), the shallow-draft electrofishing boat was used in all habitats, including very shallow areas to deeper water areas, as well as wadable waters such as were sampled with by barge. • This was a change that was presented as a part of the June 2, 2020 presentation of the Auburn interim/progress report. No comments or concerns were provided in response to this change. The change was made in conjunction with stakeholders after joint field sampling was conducted where various habitats were evaluated. It was agreed that the Auburn sampling procedure covered more area than the standard 30+2 method, integrating both shallow water and deeper water habitats, while still providing data desired by stakeholders. Furthermore, Auburn University determined that the 30+2 method was not feasible at the study sites but found that boat and barge electrofishing equipment were effective at reaching shallow habitat. Deep and shallow water habitats were not analyzed separately but were both incorporated into analysis to provide an overall picture of community structure in the Tallapoosa River. Additionally, previous comments from ADCNR regarding the use of the 30+2 method were address in the Final Report filed with FERC on April 12, 2021.

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			• An assessment of the entire fish community along the gradient across the four sample sites was presented in Auburn's final report, as well as more detailed analyses for the target species. • Identification of aquatic species and populations whose presence and/or sustainability within the Study Area may have been affected by the Harris Project was mentioned as a goal of the Desktop Assessment in the Final Aquatic Resources Study Plan (Section 4.1) and was not within the scope of the Auburn proposal. Therefore, this information was not included in the Auburn's final report. Due to varying goals of studies summarized in the Desktop Assessment, no specific conclusions about the presence and/or sustainability of species and populations within the Study Area were drawn by Alabama Power, but conclusions of the authors of the studies were summarized in Section 2.3 and in Table 2-7 of the Final Aquatic Resources Study Report.
ADCNR		It is unclear if the fish population assessment in the Final Aquatic Resources will include shallow water sampling analysis and assessment of the entire fish population as stated in the Aquatic Resources Study Plan. The Auburn report only provides a deep-water fish population assessment and should be noted as such throughout the report and in conclusions. The methods describe deep water sampling methods only "boat and barge electrofishing under standardized protocols (O'Neil et al. 2014)". In conclusions and discussion, any comparisons to past fish population collections such as Swingle (1951), Irwin and Hornsby (1997) and Travnicheck and Maceina (1994), should specify that these are for deep water fish population comparisons only, not overall fish population and exclude shallow water analyses. Travnicheck and Maceina (1994), clearly separated collection methods, results and discussion into deep water and shallow water analyses	• The Auburn sampling did include shallow water habitat and fishes. Boat electrofishing is not limited to deep water. Barge electrofishing consisted of wadable sampling, and the shallow-draft electrofishing boat was used at three sampled sites in water that was only several inches deep. Unlike the prepositioned grid samples that had been used previously which sampled only very shallow water, the current Auburn samples include both shallow and deep water. Travnicheck and Maceina's (1994) choice of the term "deep water" to describe their boat electrofishing is relative to the grid samples. In

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		ADCNR comments in the initial scoping document specify that "The study plan uses the terms "fishery" and "fish populations" interchangeably, particularly in section 4.3. The index of biotic integrity (IBI) is intended to provide an index of river or stream health based on the fish population and is not intended to explain the "fishery". The methods indicate a fish population survey using IBI methodology, which does not give an indication of the current status of the "fishery"; therefore, we still recommend the term "fish population" be used instead of "fishery"." In addition, ADCNR has addressed its concern with the shallow water sampling data gaps in previous Draft Aquatic Resources comments and at several meetings.	their description they refer to water generally over 1 meter, suggesting that a proportion of their sampled habitat was shallower than 1 meter. • Travnicheck and Maceina (1994) collected 40 unique species using boat electrofishing in the regulated portion of the river that corresponds with the sites Auburn sampled. Auburn collected 54 species from that portion of the river, excluding hybrids. This difference could be due to a variety of factors but is likely the result of Auburn having more effectively sampled the entire area at a site (including both shallow and deep habitat). • Auburn's final report does not include the word "fishery." The use of the term "fishery" in the Final Aquatic Resources Study Plan was intended to refer to the fish community. • The Auburn proposal never included explicit shallow-water-only sampling. At early meetings where the sampling approach was discussed, Auburn explained the rationale for using boat electrofishing. There was concern that fishes important to fisheries and ecosystem function had not been adequately sampled in previous studies, and ADCNR staff in particular were interested in more comprehensive sampling. Due to differences in sampling protocol, the IBI developed by O'Neil et al. (2006) could not be used.

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ADCNR		If any of ADEM's 2018 fish surveys in the Tallapoosa River will be used to supplement collections by Auburn and APC for the Final Aquatic Resources Report, these data should be included in the report or in an appendix with a results discussion. Provide deep and shallow fish survey sampling metrics such as numbers of each species collected, abundance, diversity, evenness, etc. and calculate for each study reach (Recommend a similar basin calibrated IBI calculation for comparison to previous studies (Bowen et al. 1996; O'Neil et al. 2006; Irwin 2019). Including how many sampling trips and shocking hours for each trip were completed. At the March 5, 2021 meeting it was indicated that seasonal collection comparisons included variable numbers of collection trips. Providing the number of sampling trips and boat shocking hours for each site and season column is important.	• No ADEM or APC fish data were used to supplement collections by Auburn. • Sampling was site specific, so data represent the site, not individual habitat types (such as shallow versus deep). Habitat specific sampling was not part of the proposed work. Requested metrics (numbers of each species collected, diversity) were presented in the Auburn Report for each study site. Abundance is not an appropriate metric for these data, although relative catch-per-effort values are presented. Calculation of an IBI using the format of O'Neil et al. (2006) for comparison with data from the noted previous studies is not possible using the Auburn data. The Bowen et a. 1996 IBI was calculated using backpack electrofishing and seining and included DELT data that were not a part of the Auburn sampling protocol. • As presented in the methods (page 17), sampling was conducted every other month for 2 years, with 60 minutes of electrofishing on each sampling date at each site. • Fish sampling occurred bimonthly in January, March, May, July, September, and November. Seasons were defined on page 14 (spring=March-May; summer=June-August; fall=September-November; winter=December-February). Effort was six 600-second (10 minute) transects, for a total of 60 minutes of pedal time per site per sampling trip (page 17).

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ADCNR		On page 47 of the Auburn report, it states, "Overall trends in fish diversity upstream to downstream were similar between our findings and those of Travnichek and Maceina (1994), who found little evidence of river regulation effect on fish diversity." Failing to specify that this result from Travnichek and Maceina (1994) was for the deep-water fish populations only. Include that Travnicheck and Maceina (1994) results suggested that the effect of flow regulation on species richness and diversity of fishes in deep water habitats was negligible in the Tallapoosa River system downstream of hydroelectric facilities, but that flow regulation appeared to alter shallow water fish assemblages with species richness progressively increasing with distance from Harris Dam. Alteration in natural flow corresponded to decreased species richness, diversity and abundance of species inhabiting shallow water areas, particularly species classified as fluvial specialists. Remove, replace or provide caveats to conclusion statements regarding upstream to downstream fish composition to illustrate that results are for deep water fish population assessment only and include statements from past literature of both deep and shallow water fishery analyses. When discussing Auburn's deep water fish population collections in the discussion include that reporting of the shallow water fish community monitoring between 2006 and 2016 indicates that fish densities in the regulated river downstream of Harris Dam were depressed when compared to unregulated sites (Irwin et al. 2019).	• Again, the Auburn sampling was not restricted to deep water sampling, but rather comprehensively includes both shallow and deep areas within sites. Considering Travnichek and Maceina's (1994) deep water results, species diversity from upstream to downstream sites (their sites 1-5) was 2.90, 3.19, 3.21, 3.25, and 3.53, respectively (sites 1 and 2 were above Lake Harris, sites 3, 4, 5 were below Harris Dam, but above Lake Martin; sites 6 and 7 were not included here because they are below Thurlow Dam and thus outside of the Study Area). Considering Travnichek and Maceina's (1994) shallow water results, species diversity from upstream to downstream sites (their sites 1-5) was 1.98, 2.27, 2.05, 2.16, and 2.46, respectively. Auburn's diversity indices for the four sites (Lees Bridge, tailrace, Wadley, and Horseshoe Bend) were 2.80, 2.59, 2.88, and 2.49, respectively. Given these values, the statement that fish diversity differences were similar between Travnichek and Maceina (1994) and the Auburn study appears appropriate. The numbers of fluvial specialist species collected in Travnichek and Maceina's (1994) deep water sampling was 4, 10, 8, 4, and 6 at sites 1-5, respectively, and in their shallow water sampling these numbers were 13, 19, 10, 15, and 16, respectively. Numbers of fluvial specialists in the Auburn sampling, using the same designations as in Travnicheck and Maceina (1994), were 13 at Lees Bridge, 18 in the tailrace, 16 at Wadley, and 10 at Horseshoe Bend. Again, these numbers seem to support the conclusion that trends in fish

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			diversity were similar between Travnicheck and Maceina (1994) and the Auburn Report. Note also that Auburn's collections yielded 33-39 species across sites, compared with 19-30 at Travnichek and Maceina's (1994) sites. • Irwin et al. (2019) suggest that the shallow water catch rate of fish when sampled by prepositioned grids was lower in shoals between Harris Dam downstream to Horseshoe Bend relative to a site upstream (Heflin) and a tributary site (Hillabee Creek). While catch rates among sites and seasons were generated from Auburn's current sampling, they were not intended to correlate to density of fishes. Fish species richness reported in Irwin et al. (2019) upstream to downstream was 33 at Malone, 30 at Wadley, and 33 at Horseshoe Bend. In Auburn's report, species richness was somewhat higher in the tailrace, perhaps due to the barge sampling approach (38 species) with somewhat lower numbers of species collected by boat electrofishing downstream but similar to Irwin et al. (2019) with 35 species at Wadley and 33 at Horseshoe Bend.

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ADCNR		ADCNR appreciates the Auburn modification and removal of hybrid occurrences in the initial calculations of species diversity after ADCNR inquiries at the March 5, 2021 meeting. In addition, total species and total native-species categories should be included. Including non-native species, such as Blueback Herring (Alosa aestivalis) and Snail Bullhead (Ameiurus brunneus), into species totals and analyses without this delineation can inflate species numbers and make it difficult to fully assess native species diversity changes. A decline of native species may not be evident if only evaluating total species diversity. Hughes and Oberdorff (1999) recommend using native species over total number of species in order to exclude several species of non-native fishes, which are generally tolerant, invasive, and could detract from the responsiveness of analyses in impaired streams. Incidence of unhealthy individuals in a fish community in the form of DELT's (Deformities, Eroded fins, Lesions, and Tumors) is frequently used in IBI metrics to reflect the health and condition of the fish community. Hybridization between species is also indicative of highly disturbed habitats and sometimes combined with DELT evaluation scores in IBI's (Karr et al. 1986, O'Neil et al. 2006). In addition, past research of the Harris tailwater often includes fluvial and benthic species specialists into analyses. This is highly recommended for comparisons and have been metrics strongly correlated to regulated tailwater operations. Adjust any conclusion statements and comparisons accordingly after separating non-native species from total species in calculations. Fluvial and benthic native species categories should be included as well.	• Relatively few non-native fish, both species or individuals, were collected and should not alter species diversity index values substantially. • Blueback Herring have been introduced to systems outside their natural distribution due to their common use by anglers as bait; however, there is no obvious explanation at this time for the increased range of Snail Bullhead. At this time, the hypothesis for the increased range of Snail Bullhead appears to be via a natural process, river capture. Whether that actually makes this species a non-native species is not clear. • Collection of DELT information was not part of the sampling protocol. As mentioned previously, IBI sampling was determined to not be feasible after the filing of the Final Aquatic Resources Study Plan (May 13, 2019). • Five *Lepomis* hybrids were collected in the Auburn sampling- 3 in the tailrace, 1 at Wadley, and 1 at Horseshoe Bend. It would be difficult to attribute this to variation in stress levels among these habitats. • Consideration of fluvial specialists was included in response above.

ADCNR		On page 48 of the Auburn report, it states, "The proportion of cyprinids and catostomids in our sample were higher than in the 1996 rotenone sample and the combined contribution of the two families was similar to the 1951 sample (Irwin and Hornsby 1997)." Although proportionally this statement may be accurate, it is a deceiving conclusion to make regarding the overall density comparisons of cyprinids among studies. Catastomid overall catch numbers between these three studies (Swingle, 1951; Irwin and Hornsby,1997; Auburn Report) are fairly similar ranging between 26 and 66 individuals, cyprinids on the other hand went from ~928 individuals collected by Swingle (1951) to between 12 and 77 cyprinids per site in collections by Irwin and Hornsby (1997) and 2020 Auburn samples respectively. This is a dramatic decline of cyprinid abundance since 1951. It is also important to keep in mind when comparing Swingle (1951) data, that this study was attempting to monitor effects on the Tallapoosa River fish populations ~23 years post filling of Lake Martin and two other hydropower impoundments. Although Swingle (1951) fish collection data represent fish compositions closer to other southeastern U.S. unregulated large river fish population assessments in regards to Ictalurid and Cyprinid abundance/species richness, it was still a river that had already been impacted by fragmentation and regulated flows from dams and reservoirs downstream. Other studies including the Auburn Report 2020 deep water fish collection results (Irwin and Hornsby 1997, Travnichek and Maceina 1994) have indicated dramatic declines in Ictalurid diversity and abundance, post dam construction. Ictalurid diversity and abundance changes and comparisons to other studies should be included and discussed in more detail.	• Proportions of fish contributed by families is the appropriate measure for comparison here. • Unfortunately, no claims concerning fish density can be reached in these data sets. Perhaps an aerial measure could be generated from the rotenone sample, possibly by using the estimated area that was sampled, but given that it is a lotic system, even that would be quite tenuous. Furthermore, a rate-based sampling effort (i.e., electrofishing) cannot produce an aerial-based estimate (i.e., density). That is why the statement quoted here relative to proportions is the appropriate way to make any comparisons among studies. • It would be inappropriate to compare "catch numbers" between a rotenone sample and electrofishing. The rotenone studies consisted of a single sample at a single moment in time where the sampling that is conducted occurs at the point where the entire area can be sampled by nets. Electrofishing consisted of multiple samples collected across all habitats in a reach conducted in all four seasons and during two years. Making a comparison of effort-independent numbers would be misleading. • Conclusions about abundance cannot be drawn from Auburn's report or from Travnichek and Maceina (1994), given that electrofishing does not allow one to quantify absolute abundance. Furthermore, comparing diversity in catfishes between rotenone versus electrofishing sampling would be misleading, given that catfishes are typically difficult to collect with electrofishing, often requiring different approaches than standard electrofishing. The Auburn sampling did include collections of all the native Tallapoosa River Ictalurid species plus Snail Bullhead, which was not listed in Boschung and Mayden (2004) as occurring in this river.

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ADCNR		On page 48 of the Auburn Report, explain and discuss potential reasons why two important forage species (Threadfin and Gizzard Shad) are not present in the Harris Tailrace collections. These two species are the most dominant species for sportfish in Alabama rivers. Considering Blueback Herring have been introduced illegally to Martin Reservoir, and that they prefer cooler water over native clupeids, the dam could be offering suitable habitat to Blueback Herring, and negatively impacting native clupeids with the cold-water discharges. In addition, results indicate that no Tallapoosa Shiners were collected. Include how this result compares with other fish population studies in the Tallapoosa River system that utilized both deep or shallow water fish collection methodologies.	• This is an intriguing potential ecological explanation that would be great to pursue, but the available data simply do not allow testing it. It would require collection of different/additional data. Furthermore, given that only 2 Blueback Herring were collected (at Horseshoe Bend) from all the Auburn sampling, it is not likely that Blueback Herring has excluded *Dorosoma* from the system and particularly from the tailrace. Reasons for the lack of clupeids from the tailrace are not clear. Native clupeids were present at all other sites. • Auburn collections included 13 Tallapoosa Shiners from 3 of the 4 sites (more than Travnichek and Maceina 1994's deep [none collected at sites 1-5] or shallow [1 individual collected at their site 5], although sampling effort was greater in the Auburn study.
ADCNR		On page 47 of the Auburn Report, it states, "Overall values of H (i.e., species diversity) in their study (Travnicheck and Maceina, 1994) were slightly higher in 1994 compared to our study (2019- 2021) (3.53 compared to 3.07 respectively), though this change may be influenced by differences in sampling technique versus actual fish diversity differences." This statement is inaccurate. The 3.53 value included from Travnicheck and Maceina (1994) is the overall value of H for deep water sampling Site 5 only (68km downstream, Horseshoe Bend), not the overall value of H for the entire study. Either remove statement or correct using deep water H value means from sites 1-5 of Travnicheck and Maceina (1994). Note that collection sites 6 and 7 in Travnicheck and Maceina (1994) were below Thurlow Dam.	• The value of H (3.53) that was used from Travnichek and Maceina (1994) was the highest value reported for relevant sites (their sites 3-5) using similar sampling techniques, and it was slightly higher than the Auburn value across sites, which was 3.06. If H for all of the Travnichek and Maceina (1994) deep sampling at sites 3-5 are averaged (H=3.33), the value is still somewhat higher than the same value for the Auburn data (H=2.65). If the shallow water sites from Travnichek and Maceina (1994) are considered (H ranging from 2.05-2.46), the values become even more similar between studies.

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ADCNR		On page 21 and 47 of the Auburn Report, explain in greater detail the results of the diversity index, H. Considering all sites combined diversity index was 3.07, it is important to know how other sites compare and what is significant about the index when comparing across sites. Compare and contrast each site, to allow for inferences about site specific significance, and comparisons to other studies mentioned.	• It is not clear what is being requested here relative to significance of diversity index observations across sites. With a single value per site, no statistical tests are possible and therefore significance cannot be estimated or assigned. H values for each site are presented in Table 3.2.
ADCNR		On page 17 and pages 46-47, boat electrofishing was used at Lee's Bridge, Wadley, and Horseshoe Bend, while barge electrofishing was used at Tailrace. Since the report indicates that percids had a higher catch rate in the tailrace compared to other sites, this may be due to the difference in the sampling techniques. Include and discuss if barge electrofishing is more effective at catching smaller fish, such as darters, compared to boat electrofishing. In the discussion include how different methods of fish collection at various sites may bias sampling results. Provide and discuss any studies that compare catch rates from these two different methodologies.	• It is possible the barge may be better at allowing collection of darters given that the biologists/netters are wading in the water and are closer to the fish. • This could potentially be discussed but given that the two gears were not used simultaneously at any given site, biases cannot explicitly be identified relative to expected differences based on sampling gear alone. • Quantitative studies comparing biases of electrofisher types are limited and do not provide direct comparison of efficiency of barge and boat electrofishers. This lack of comparison is in part due to the fact that barge sampling is limited to wadable waters and boat sampling includes a more diverse combination of both deep and shallow areas.
ADCNR		Unregulated Heflin data was provided but not statistically analyzed. Include statements clarifying how three years of temperature data was unable to be statistically analyzed and why the Newell temperature data was not included . If the data was unable to be compared to the full regulated site data, a separate analysis could be completed for the same available time periods allowing for statistical evaluation comparisons. Regardless of the variables associated with the Heflin site, temperature was the main metric of interest in the study, and there is no reason not to conduct analyses at the Heflin site or Newell site. Certain statements made, such as air hitting loggers at Heflin, and the suspect data at Malone and Wadley where water	• Several analyses were presented for the Heflin data (Table 2.1, Figures 2.2, 2.3, 2.5), some of which were in response to previous comments. Although there was three years of Heflin data available (2018-2020), only May 2019 – April 2020 data were available for both Heflin and regulated sites. Temperature can vary greatly among years so statistical analysis using only one year of data would not be a reliable method of determining differences between the thermal regime of the unregulated and regulated Tallapoosa River.

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		temperature consistently exceeds air temperature could potentially be further examined with the addition of the Newell data. For example, during the March 5, 2021 meeting Auburn indicated that the Heflin water temperature data during winter was suspect. If data at Newell was analyzed, the researchers could distinguish whether the changes were due to logger malfunction, or the logger being exposed to air. In limited comparisons of unregulated and regulated temperature data included in the Auburn Report, it appears that the Heflin data included December to March months while the regulated site data excluded these December to March time periods. These time periods should either be fully analyzed for regulated sites as well or removed from the unregulated site data for equivalent comparison. ADCNR recommends fully evaluating all time periods, especially with initial indications that warmer water temperatures, compared to unregulated sites and downstream regulated sites, are being released into the tailwater during winter months. Explain how high temperature variation for a specific time period could be detected in the Tailrace and Wadley, but not at Malone (for example months 9-12 Figure 2.2, year 2015). As noted in our draft Aquatic Resources comments, if temperature data is unavailable for a specific site during a time period when other sites indicate high temperature variation, provide a caveat recognizing these specific key data range gaps with an explanation for the absence. For example, Tailrace 2000 Temperature Range is unavailable for 10-12-month data, but Malone and Wadley both indicate high temperature variation during this same time period. Unavailable temperature data gaps, during key high temperature variation events, have the potential to significantly reduce analyses of temperature changes and impacts occurring in the regulated reach. These limitations to the overall conclusions of temperature analyses should be included and discussed.	• Newell data have been included in the main body of the Final Aquatic Resources Study Report (filed April 12, 2021). Comparisons of water temperature at Heflin and Newell to water temperatures at regulated sites are also included in the Final Aquatic Resources Study Report. • Several analyses were presented for the Heflin data (Table 2.1, Figures 2.2, 2.3, 2.5), some of which were in response to previous comments. • It is not clear why water temperature exceeding air temperature represents a problem. Water retains temperature longer than air, often resulting in warmer water than air at night or in cooler weather. • Data for regulated sites were not always available and are therefore missing in some instances. Prior to 2019, there were no data for the noted time periods. River conditions (high/fast water) prevented collection of the data. This was a data gap that was identified early in the project and noted to stakeholders at HAT meetings. In response, Kleinschmidt deployed loggers to collect a single full year of data.
ADCNR		Explain how high temperature variation for a specific time period could be detected in the Tailrace and Wadley, but not at Malone (for example months 9-12 Figure 2.2, year 2015). As noted in our draft Aquatic Resources comments, if temperature data is unavailable for a specific site during a time period when other sites indicate high temperature variation, provide a caveat recognizing these specific key data range gaps with an explanation	• These data are derived from loggers deployed as part of the Downstream Aquatic Habitat Study and were not part of Auburn's study. The variation between sites can be due to the type of habitat in which the loggers were deployed. • The graphs clearly show where data are missing,

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		for the absence. For example, Tailrace 2000 Temperature Range is unavailable for 10-12-month data, but Malone and Wadley both indicate high temperature variation during this same time period. Unavailable temperature data gaps, during key high temperature variation events, have the potential to significantly reduce analyses of temperature changes and impacts occurring in the regulated reach. These limitations to the overall conclusions of temperature analyses should be included and discussed.	allowing readers/reviewers to interpret and draw conclusions. • The example from fall 2000 looks to be a case when loggers were likely out of the water. • It is not likely that this led to the potential to "significantly reduce analyses of temperature changes and impacts" given the relatively small number of occurrences. If substantial gaps occurred over the 19 years of data, this would be a concern, but they do not appear to have happened very often. • Other than the fall 2000 data, it is not clear what limitations to the overall conclusions are cause for concern and need to be discussed.
ADCNR		On page 12 of the Auburn Report it states, "Hourly data points were used to generate hourly and daily averages, minimum, and maximum temperatures through the year. This eliminated some variation but allowed for a consistent comparison of temperatures across years." Analyzing the temperature data in a way that "eliminates variation" in a study aimed at targeting the amount of "temperature variation" conflicts with the overall purpose. It is important to make sure that minimums and maximums that occur in the tailrace are not averaged or reduced. Provide Tables in addition to Figures similar to draft Water Quality Study Report Tables 4-9 and 4-10 for each year and site. In the draft Water Quality Study Report Tables 4-9 and 4-10 indicate that maximum temperature ranges reaching 29.35° C during generation and 35.60° C from the continuous downstream monitor for the 2019 monitoring period. Although the 2019 temperature data is not included in the Tailrace figures provided in Figure 2.2A of the Auburn Report, the maximum temperatures displayed do not seem to correlate with previous years. Explain how maximum temperature ranges from the continuous downstream monitor for 2019 are higher than the Auburn Report temperature range maximums included in Figure 2.2A for the	• In order to produce hourly data variation, which was requested in an 8/28/2020 comment, the data (which occurred in 15-minute values) had to be averaged within an hour to produce hourly data points for analysis. This aggregation did eliminate some variation, but the variation within an hour was also analyzed as requested. • The Draft Water Quality Study Report was developed by Alabama Power and performed independently of Auburn's study. Auburn University was chosen by Alabama Power in consultation with ADCNR to conduct studies for the Final Aquatic Resources Study Report and as experts on fisheries science were given the authority to present results as they deemed appropriate. • See previous responses. • It is not clear what comparison is being asked

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		tailrace. If they are at different locations or using different instrumentation, explain how they could differentiate so much in their temperature readings.	about here. Different habitats will result in different temperatures (i.e., pooling water vs flowing water/ shallow water vs deep water).
ADCNR		On page 13 of the Auburn Report it states, "Extreme fluctuations in temperature were rare (extreme fluctuations were defined here as a 10 C shift within a day; Malone: 0.61% days pre Green Plan, 0% days post-Green Plan, Wadley: 0% days pre-Green Plan, 0.57% days post-Green Plan, Heflin 0% 2018-2020) (Figure 2.3)." It is important to remember that like dissolved oxygen (DO) declines, only one significant low DO event or one single sudden and dramatic temperature change event can stress or kill aquatic species. In addition, temperature highly influences dissolved oxygen levels in aquatic environments and significant dissolved oxygen declines and extreme temperature fluctuations can often coincide. Extreme fluctuations in temperature should be noted in the results and the discussion. With potential negative effects to aquatic species from just a single event, the magnitude and number of individual extreme fluctuation events is important. As presented in Figure 2.3, the scales make discerning these number of events difficult. Proportionately overall it may be low but could still consist of many extreme temperature fluctuations. Consider providing additional or zoomed in y-axis excerpts for low percentage of overall time temperature data when it is difficult to discern in large y-axis scale figures.	• If an extreme temperature fluctuation is prolonged or consistently exceeds an organism's thermal tolerance, mortality may result. In addition, given the lack of temperature threshold/requirement findings for target species from Objective 1, interpretation of historical temperature data could not be done in that context. • Auburn included data in the report to allow readers/reviewers to interpret across a range of temperature variation events. Table 2.1 was provided in the report to allow for discrimination among data points that are difficult to discern on the figure. • The percentages are presented to allow for one to calculate the number of occurrences.
ADCNR		In figures 2.7B and 2.7C of the Auburn Report, it indicates that mean water temperatures were above mean air temperature at both Malone and Wadley. Provide how this was calculated and verification of this result and include a more detailed explanation of potential causes for how mean water temperatures could be above mean air temperatures and were outside of standard error or standard deviation ranges (specify in the Figures what the error bars represent).	• The referenced figures depict average monthly water and air temperatures, which were calculated from hourly data. • It is unclear what is meant by the request to verify the result. The results are provided. • In most cases the error bars overlap, so one cannot conclude whether air temperature is greater than or less than water temperature. Again, these are averaged values. It is possible that exposed rocks in the river channel absorb heat and transfer it to the water.

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ADCNR		In NOI, PAD, Scoping Document and Study Plans, ADCNR October 1, 2018 comments we recommended "that selected sampling sites closely mirror those of samples collected historically and with the ADEM water quality and fish survey sites. This will allow for an ease of comparison over time and among various data sets." ADCNR had agreed with the Draft Aquatic Resources assessment that an alternative site was necessary for the current upstream control site due to its closely linked dam operation characteristics. ADCNR had requested input on site selection alternatives. Please include in the report why this was determined unnecessary and provide any comparison limitations the original upstream control site might contribute. The Auburn Report states on page 6, "There is little habitat heterogeneity at this site which is dominated by sluggish, turbid water." and page 47,"Higher catch rates of clupeids above the reservoir were likely due to the high connectivity between the reservoir and the Lee's Bridge site." indicating remaining researcher doubts about Lee's Bridge as an adequate control site. In addition, on page 22 of the Auburn Report, it states that Lee's Bridge was not accessible by boat during the winter due to reservoir drawdown. Using the Foster's Bridge access area, ADCNR frequently collects brood stock from the shoals above Lee's Bridge during early spring when Harris is still at winter pool and accessibility issues have not been problematic during low water. Overall, ADCNR remains concerned that the lack of an adequate control site, could limit any strong conclusions when comparing data throughout the report.	• Identification of a true nonregulated control site is always problematic. Unfortunately, Lee's Bridge is influenced by the reservoir and may, therefore, not necessarily provide a true control for dam effects. However, sites even further upstream also pose problems. As stated in the November 5, 2020 HAT3 meeting, Auburn could not find an alternative sampling site further upstream that would allow them to continue sampling with the same methods. It was determined that this inconsistency would be more problematic than the operational influence, which was limited to a decrease of water level of ~1-2 feet during drawdown. The original Lee's Bridge site was still riverine in nature despite the seasonal decrease in water level and was therefore kept as the unregulated site. • It was not accessible by boat during the winter but was during the rest of the year. The choice was made for a location with consistent flow for fish (not necessarily boats) as would be expected in a natural lotic system. • There are several shoals above Lee's Bridge before the study site. These shoals are impassible in winter without a jet boat or air boat. • Despite the fact that the water level fluctuates ~1-2 feet through the year with the reservoir, as mentioned in the response to 16a, Lee's Bridge still is essentially riverine and was determined by Auburn to be the most suitable site to maintain sampling consistency.
ADCNR		On page 50 of the Auburn Report it states, "Based on the evidence in the literature combined with our telemetry data, it is clear that high flow from	• The report refers to displacement downstream, not laterally. Given that fish were located by telemetry regularly at individual sites, the data

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		peaking hydropower operation is not displacing Tallapoosa or Alabama Bass downstream." This is a strong statement that does not provide the a referenced literature citations or provide a caveat that this telemetry study only tracked sixteen total fish (n=3 Tallapoosa Bass and n=13 Alabama Bass) during a short three month period (August 1, 2020 to October 1, 2020) outside of spawning periods. Moreover, it appears these fish were only exposed to one hydrological event over 2,000 cfs (Wadley gage) towards the very end of the study period. The term "displacement" used for this study needs to be defined and the temperatures and flow event variation that occurred during the study when fish movement was observed need specifying. Additionally, the limitations to this tracking methodology should be recognized since the receivers set to detect longitudinal stream distance movements will not capture lateral movements that could be occurring between stationary acoustic receiver locations. At the March 5, 2021 meeting, ADCNR inquired on the reasoning behind specific months being chosen regarding the telemetry study. Auburn stated that late summer was chosen due to higher flows and temperature variation, but the correlating discharge flows during the telemetry study period were not provided. These are necessary to verify that the tagged fish were exposed to "higher flows and temperature variation". Even cited literature statements included on page 54 stating "Earley and Sammons (2015) manually tracked Alabama Bass and Redeye Bass near Wadley, Alabama and found that during pulses these fish tended to move laterally into tributaries or along the bank of the river and then returned to the main channel once the pulse subsided, suggesting fish choose to seek shelter during these events" contradict the conclusion that bass are not being displaced. Fish behavior observations by Martin (2008) indicated that increased flows caused disruption of spawning and nesting behavior. In the NOI, PAD, Scoping Document and Study Plans, ADCNR comments on October 1, 2018 recommended, "that field telemetry studies occur over a period of time such that tagged fish can experience a range of flows and seasonal variability to provide a full understanding of the varying conditions that occur during different flow types. Also, it should be noted that during spawning season some fish species (i.e., Redbreast Sunfish) may	support that fish were not displaced downstream. This is consistent with Laurie Earley's work (2012) where fish were similarly not displaced downstream (although they did move laterally during increased flow). Relative to flow events, data for the Malone gage reflect numerous discharge events exceeding 2,000 cfs, including one up to 17,000 cfs and numerous occurrences over 8,000 cfs during 1 August-1 October 2020. • The Auburn study looked at longitudinal movement and not lateral movement. • Evaluation of lateral movement was not proposed for study. • Data from the USGS gauge at Wadley indicates maximum daily discharge exceeded 2,000 cfs on 84 of 123 days between July 1 and October 31, 2020, with an average daily flow delta (daily max minus daily min) of 4,728 cfs. Average daily water temperature delta for the same period was 2.71 °C. These data are available on the web at https://bit.ly/3ijJz19 • Spawning times were not a part of this tracking work. • The reference is provided in the same paragraph (Earley and Sammons 2015)

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		not move as much throughout the system because they are using most of their energy for nest building, and parental care of eggs and fry." Provide what conditions the tagged fish were exposed to during the study and if any observed movements correlated to flow or temperature changes. Provide references for the "evidence in the literature", you are referring to in the Auburn Report telemetry statement above. Limitations to the overall conclusions of the telemetry study should be included and discussed.	
ADCNR		In the March 5, 2021 meeting, Auburn stated that the fish were likely in the two-river kilometer gaps between the acoustic receivers. This lack of data between receivers or instream movement during pulsing and high flow events is the reason the Study Plan requested EMG tags, "…the EMG tags will measure fish movement, including tail-beat frequency, to provide an in-situ measure of energy expenditures across the range of flow conditions experienced during baseline Harris Dam operations…" Include in the discussion why the original electromyogram (EMG) telemetry data methodologies which included "tail-beat frequency" were modified and what key data gaps this change might have created.	• EMG tags were intended to measure muscle movement, and when their use was proposed early on during this project, Auburn stated that they were being tested in controlled pond experiments to see whether they measured what was intended. Through these tests, Auburn found that EMG tags did NOT measure what was intended to be measured. This modification was presented in Appendix B of the July 28, 2020 Draft Aquatic Resources Report and the November 5, 2020 HAT 3 meeting. Relative to data gaps, if the reference is to spatial gaps, the same gaps would have existed had EMG tags been used as the gaps were a factor of the receiver array, not the tags used. If the reference is to gaps due to not measuring muscle activity, the data still provided evidence for a lack of downstream displacement but did not include evidence as to whether fish were actively swimming against the current versus seeking shelter from the flow.

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ADCNR		The Auburn Report bioenergetics model did not run a cold to warm scenario. When asked why impacts of cold to warm temperatures were not analyzed during the March 5, 2021 meeting, Auburn noted that the dam does not typically release warmer water into the river, so the analysis focused on warm to cold water transitions. The temperature data and analyses presented in the Auburn Report clearly show aquatic resources in the Harris tailrace are exposed to extreme changes in temperature both from warm to cold and cold to warm. After colder pulses in the summer or warmer pulses in the winter are discharged, water temperature fluctuations occur in both directions. Reasons for why this scenario was omitted even though fish in the tailrace are exposed to extreme temperature shifts from cold to warm, should be included in the discussion. Include in the discussion with supporting literature how physiologically taking fish from cold to warm temperatures is more detrimental than taking fish from warm to cold. The interaction of temperature and dissolved oxygen should also be included and note how it only takes one low DO event or only one drastic temperature change event to harm aquatic fish species. In addition, the Auburn Report does not specify how quickly temperature was changed in the lab chamber. This information should be included in the methods section	• A cold to warm scenario was never part of the proposed work nor was it requested by ADCNR. The cold to warm temperature shifts occurring during operation of the dam, would only occur during winter conditions when temperature fluctuations were found on average to only range 1-2 ℃, which is not an extreme temperature shift at these cold temperatures. Such fluctuations would be well within thermal tolerance and may improve swimming and growth conditions. • We disagree with the premise that there are extreme shifts from cold to warm in the Harris tailrace. Data collected in 2019 -2020 indicate the smallest daily fluctuations in water temperature occurred during the winter (Dec-Feb) months. • Auburn University's literature review of temperature requirement data yielded a variety of optimal ranges some of which were dependent on the temperature at which fish are accustomed or acclimated. The Auburn study was not designed to conduct a physiological temperature effects review of the literature or an evaluation of the effects of DO below Harris Dam on aquatic resources. • This information is included in the Auburn Report, on page 31 (~5-7 minutes).
ADCNR		On page 19 of the Auburn Report, provide length distribution by site so that relative weight results can be more discernable. Often, biologists do not compare relative weights below stock size, even though some equations allow for such to be accomplished (for instance 70mm Channel Catfish with Gabelhouse's equation (Gabelhouse 1984)). ADCNR does not typically calculate relative weights for fish below stock size for the selected	• Relative weights were calculated for fish that were within the size range across which the standard weight equation was generated. Fish sizes were not restricted within those ranges, nor were fish included that would have required extrapolation outside of that size range.

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		study target game species. Some studies require determination of the minimum total length (TL) to be used in relative weight equation development to avoid inaccurate or imprecise weights for small fish. (Murphy et al. 1990, Bister et al. 2000). A minimum size threshold for relative weights should be considered. Describe the accuracy of the scale used to take weight measurements and if the scale was tared between measurements. This would allow for inferences on weight to be made for small catfish.	• Minimum total length was estimated based on the published and accepted minimum TL values from Gabelhouse as provided in the Fisheries Techniques (2012) chapter on Length, Weight, and Associated Indices by Neumann, Guy, and Willis (Chapter 14). Effects of fish size were considered within these published minima and maxima and found to not represent any bias (Figures 3.5, 3.6 in the report). For fish weighed in the lab that were less than 200 grams, the top-loading balance measured to the nearest 0.01 gram. For larger fish, a balance that weighed to the nearest 1 gram was used. Scales were tared between each fish.
ADCNR		On page 19 of the Auburn Report, it includes brief methods for calculating relative weights. Explain in detail how von Bertalanffy growth curves were derived. For example, explain if convergence criterion or model significance was met. Particularly, for some of the Channel Catfish and Redbreast Sunfish curves, theoretical maximum lengths are not plausible, and linear, instead of non-linear growth functions are evident. Having accurate growth estimates is important to be able to evaluate bioenergetics results. In addition, age agreement between multiple readers is important, and if agreement for each species is known, this information should be reported. Provide if Channel Catfish otoliths were sectioned with an isomet saw or hand sanded. Hand sanding is considered to be the most accurate method in order to see visible annuli and not distort the range of visible annular marks (Heidinger and Clodfelter 1987, Buckmeier et al. 2002). If photos are available for review of the sectioned otoliths, we suggest including these in the report since inter annular measurements were taken.	• Per Auburn, standard age-and-growth/population biology methods were used as has been the case with all work previously conducted and published by Auburn. • Otoliths were prepared using standard fisheries age-and-growth procedures. As in all fisheries age-and-growth work, hand sanding was used when necessary or if there was any doubt about annuli. Photographs are not generally included in such reports and would not be equivalent to viewing the otoliths through a microscope combined with digital image analysis systems.
ADCNR		On pages 22-25 and 48-49 of the Auburn Report. Provide the range and mean total length of fish at each site. In Figures 3.7, 3.11, 3.16, 3.21 it appears that older, larger Channel Catfish and Alabama Bass were much less abundant in the tailrace than at other sites. Include in the discussion, potential reasons why small Channel Catfish could be common in the	• The observed age range of Channel Catfish in the tailrace was age 0 – age 7. There may be fewer older Channel Catfish in the tailrace, but some are present. • A range of potential explanations exist, possibly

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		tailrace, with no adults present. Possible points to include and explore are the potential for immigration from tributaries, small fish passing through from Harris Reservoir or barge sampling bias allowing for more juveniles to be collected in the tailrace. A length frequency of target species by site is needed to compare collections, as age information is not adequate to discern the size structure of the samples by site.	including gear bias due to the barge versus boat electrofishing, the dam discharges, or a lack of suitable deep water habitat or velocity refugia, although none of these can be tested with existing data.
ADCNR		Figures 3.5 and 3.16 of the Auburn Report indicate that most of the Channel Catfish collected in the Tailrace were under 100mm, which is below stock size. This cohort of fish had obviously higher Wr values between 115-140. Include in the discussion if this could be a driving factor for the higher condition values observed in the Tailrace compared to other sites.	• The lack of larger Channel Catfish from the tailrace certainly could have contributed to the higher condition factors recorded there. Nothing presented in the Auburn Report is counter to this interpretation.
ADCNR		On page 51 of the Auburn Report, it states, "The first section of Objective 4 focused on measuring Ucrit of all the targeted species from the four study sites." According to Table 4.1 and Figure 4.2 this was not done and Ucrit was only measured for Channel Catfish at 2 of 4 sites, Redbreast Sunfish at 2 of 4 sites, Alabama Bass at 3 of 4 sites, and Tallapoosa Bass at 2 of 4 sites. Provide why Ucrit was not measured at the missing sites and why critical swimming speed was not measured for any fish collected from the Tailrace.	• This is due to timing of the Auburn Report deadline (i.e., prior to the completion of the funding period) combined with availability of fish within those timing constraints.
		Comparing Figures 4.2, 4.6 and 4.10 of the Auburn Report, it appears that there were additional fish from different sites used in the standard metabolic rate trials that were not used in the critical swimming speed trials or the active metabolic rate trials (For example, Channel Catfish from Wadley, Redbreast Sunfish from Lee's Bridge and Tailrace, Alabama Bass from Tailrace, Tallapoosa Bass from Lee's Bridge). Provide reasoning why fish from these locations were included in the SMR trials but not in the Ucrit or AMR trials.	• There are no additional fish that were not run. To avoid any potential biases, and to conduct this work in a statistically appropriate manner, Auburn used individual fish to estimate only one laboratory measure, that is, either for respirometry or critical swimming speed. Running individuals in both would bias the results of one or the other measure in a manner that could not be predicted. Size of fish largely determined which category (static versus swimming) the fish were placed in as the swimming respirometer can accommodate fish up to 400 mm while static respirometry was limited to fish under 250 mm.

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ADCNR		When presenting and comparing similar Figures throughout the Auburn Report, keep x and y axis on the same scale. Provide lines in figures at key data points for reference and assistance to the reader. Additionally, further correction is needed in the report as some Tables are listed as Figures.	• In any cases where the axes were on different scales among panels, that would have likely been done to minimize white space and make it easier to identify the distributions of the data. • These were typos. Hopefully the references to Tables 3.5, 3.6, and 3.7 as figures didn't cause any confusion.

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Comments below were received following the Final Aquatic Resources Study Report[1] and Updated Study Report[2] filings on April 12, 2021.			
Alabama Department of Conservation and Natural Resources (ADCNR)	5/27/2021 20210527-5024	Section 4.2.3 of Aquatic Resources Study Plan states, "Auburn and Alabama Power will perform field sampling to characterize the current fishery in deep and shallow water habitats in the Study Area and in unregulated portions of the Tallapoosa River. Wadeable, shallow water habitats will be sampled using a standardized protocol known as the 30+2 method (O'Neil et al. 2006). Backpack electrofishing will consist of 10 efforts each in riffle, run, and pool habitats, with an additional 2 shoreline efforts. Non-wadeable, deepwater habitats will be sampled using boat and barge electrofishing under standardized protocols (O'Neil et al. 2014). Auburn will perform boat sampling quarterly for 7 events between fall 2018 and fall 2020 in reaches at varying distances downstream of Harris Dam, including sites in the tailrace, near Malone, Wadley, Horseshoe Bend, and at least one additional site on an unregulated reach. Auburn researchers may employ additional passive capture techniques as conditions warrant (e.g., hoop nets, minnow traps, etc.). Data from ADEM's 2018 fish surveys in the Tallapoosa River may be used to supplement collections by Auburn and Alabama Power." The non-wadeable, deepwater habitats sampling is included in the Auburn report and has been completed using boat and barge electrofishing under standardized protocols (O'Neil et al. 2014). To date, wadeable, shallow water habitat field sampling work has not been provided using a standardized protocol known as the 30+2 method (O'Neil et al. 2006) and as of April 12, 2021 the licensee has expressed this missing component as a variance to the Aquatic Resources Study Plan. Of note, ADEM's 2018 fish surveys in the Tallapoosa River have not been used to supplement collections by Auburn or Alabama Power. APC's 2017, 30+2 survey data are briefly included and discussed in R.L. Harris Hydroelectric Project Pre-Application Document (PAD), Volume 1, Appendix E, but not included, referenced or discussed in the Aquatic Resources Final Report.	Alabama Power provided Auburn University's draft study proposal to ADCNR by email on Thursday, April 5, 2018. The draft proposal stated that fish sampling would be performed quarterly using electrofishing gear selected based on Auburn University's ability to access the tailrace. It was proposed that an electrofishing boat or an inflatable boat/electrofishing gear provided by Alabama Power would be used. Alabama Power, Auburn University, and ADCNR met to discuss the draft proposal, including sampling protocol, on April 24, 2018. A revised proposal reiterated that Auburn University would sample fish quarterly, specifically by standardized boat electrofishing sampling. Alabama Power provided Auburn University's revised proposal to ADCNR on Wednesday, August 1, 2018. Subsequent to the revised proposal, Auburn University expanded sampling to bi-monthly events and determined that boat-mounted electrofishing would not be feasible in the shallow habitat of the tailrace, and because there are non-wadeable areas of the tailrace, a barge electrofishing unit was used in the tailrace to sample both wadeable and non-wadeable habitat. The Final Aquatic Resources Study Plan[3] stated that wadeable, shallow water habitats would be sampled by the 30+2 method, but Auburn University had already determined after joint field sampling was conducted that boat and barge electrofishing could sample both deep pools and shallow shoal areas. Although the Initial Study Report[4] correctly describes the standardized sampling efforts as six, 10-minute sampling transects, it mistakenly does not list the deviation from standardized 30+2

[1] Accession No. 20210412-5745
[2] Accession No. 20210412-5737
[3] Accession No. 20190513-5093
[4] Accession No. 20200410-5084

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			sampling as a variance from the Final Aquatic Resources Study Plan, and the Initial Study Report meeting presentation[5] incorrectly reported that wadeable 30+2 sampling was being performed in addition to boat electrofishing. The change from the 30+2 method was presented as a part of the June 2, 2020 presentation of the Auburn interim/progress report. No comments or concerns were provided in response to this change. The Auburn sampling procedure covered more area than the standard 30+2 method, integrating both shallow water and deeper water habitats, while still providing data desired by stakeholders. Furthermore, Auburn University determined that the 30+2 method was not feasible at the study sites but found that boat and barge electrofishing equipment were effective at reaching shallow habitat. Deep and shallow water habitats were not analyzed separately but were both incorporated into analysis to provide an overall picture of community structure in the Tallapoosa River. Additionally, previous comments from ADCNR regarding the use of the 30+2 method were addressed in the Final Report filed with FERC on April 12, 2021 and Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021. [6] Auburn sampled bi-monthly to obtain representative samples from every season. The 2018 ADEM data was not gathered throughout each season and was collected using different methodologies, so comparing to Auburn's results would not be appropriate. There is no formal report of the 2018 ADEM data, so it was not included in the Desktop Assessment.

[5] Accession No. 20200512-5083

[6] Additional information has been provided in this response after its previous filing on June 15, 2021 (Accession No. 20210615-5110).

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			Alabama Power's 2017 data was already presented in the PAD and including it in the Final Aquatic Resources Report was not deemed necessary.
ADCNR		On page 30 of the PowerPoint presentation from the USR meeting on April 27, 2021, the licensee presented variances from the Final Aquatic Resources Study Plan. ADCNR noted that methodology modifications were made to the Final Aquatic Resources Study Plan without ADCNR and other stakeholder consultation or guidance. We are concerned that this variance highly reduces available collection data for shallow water fish populations in the Tailrace between 2017 and 2021 and that these data gaps and a fish population survey of <u>deep water only</u> are being used in summary statements to misrepresent the overall fish population status in the tailrace below Harris Dam. ADCNR has addressed its concern with the shallow water sampling data gaps in previous Draft Aquatic Resources comments (See P-2628-005 FERC ¶ 20200611-5152). If this issue was addressed in a timely manner, ADCNR and stakeholders could have provided approved shallow water methodology alternatives. The variance statements continue to state, that because the Study Plan was altered from a 30+2 sampling method (note without stakeholder input), that an index of biological integrity was not calculated, which further limits the ability of stakeholders to make easy comparisons to previous studies. It should be noted that the reason for not using the 30+2 method, Auburn and the licensee stated in the PowerPoint presentation during the USR meeting, "*that it was determined in the field to not be feasible/effective for sampling the sites.*" If this is true the licensee should explain the statement in PAD, Volume 1, Appendix E, page 7, which states, "*Alabama Power sampled fish communities in 2017 using standardize methods developed by the Geological Survey of Alabama (GSA) and ADCNR (O'Neil 2006.)…This sampling method is commonly referred to as the "30+2" method. Samples were collected at the Malone and Wadley sites along the Middle Tallapoosa in the spring and fall and the Upper Tallapoosa sites in July and October*." In addition, ADEM was able to successfully complete a 30+2 sampling method at Wadley in 2018. The licensee should state why both the 2017 and 2018 data were not used to supplement collections as requested in the Study Plan. This data should be included and discussed in the Final Aquatic Resources	Alabama Power's response concerning the use of the 30+2 method are provided above. ADEM's 30+2 sampling at Malone and Wadley was performed in September 2018, when water levels allowed for this method of sampling. The 30+2 method could not be utilized at these sites year-round. Alabama Power sampled sites within reaches historically referred to as "Malone" and Wadley" instead of specific sites at the Malone and Wadley bridges when conducting fish sampling. The IBI scores derived from Irwin et al. (2019) are presented in the PAD and are valid for comparison between sites and over time within that specific study. Although data were collected using methods consistently applied at each site and over time, collection methods used in Irwin et al. (2019) differed from Geological Survey of Alabama (GSA)'s IBI protocols and could not be compared to scores derived using those protocols or other studies using dissimilar protocols. Regarding the effects of Blueback Herring on native clupeid populations, this is an intriguing potential ecological explanation that would be great to pursue, but the available data simply do not allow testing it. It would require collection of different/additional data. Furthermore, given that only 2 Blueback Herring were collected (at Horseshoe Bend) from all the Auburn sampling, it is not likely that Blueback Herring has excluded *Dorosoma* from the system and particularly from the tailrace. Reasons for the lack of clupeids from the tailrace are not clear. Native clupeids were present at all other sites.

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		Study Report. Page 11 of the PAD, Volume 1, Appendix E, includes Figure 3-3 with IBI scores for 2005-2015 fish community samples at Upper Tallapoosa, Malone, Wadley and Hillabee Creek. In ADCNR's 6/11/20, Draft Aquatic Resources Study Report comments (See P-2628-005 FERC ¶ 20200611-5152), we requested the licensee to provide IBI score overviews from both Irwin et al. (2011) and Irwin et al. (2019) data. The licensee response stated that exact values were not available, that standard deviation was high for some of the metrics and that specific values were left out of the summary. Information on pages 6-11 of the PAD, Volume 1, Appendix E, contradict these response statements. For example, on page 7 of the PAD, Volume 1, Appendix E, it states in regards to the Alabama Cooperative Fish and Wildlife Research Unit (ACFWRU)(same data presented and analyzed in Irwin et al. 2019) sampling efforts from 2005 to 2015 that, "*IBI scores for the Upper Tallapoosa, Malone and Wadley sites appeared similar, with Hillabee Creek having consistently higher scores (Figure 3-3). The upper Tallapoosa site had an average score of 36 over the 11-year period, while the Malone and Wadley sites both have average scores of 35. Hillabee Creek had an average score of 43*." The PAD, Volume 1, Appendix E, clearly indicates exact scores are available and have been evaluated by the licensee (See pages 10-11, Table 3-3, Figure 3-2 and 3-3 of PAD, Volume 1, Appendix E). In addition, the licensee presents IBI scores they completed utilizing the "30+2" method in 2017 at Malone, Wadley and Upper Tallapoosa. On page 7 of the PAD, Volume 1, Appendix E, it states, "*IBI scores at the Middle Tallapoosa sites during the spring and fall ranged from 30 (poor) to 38 (fair). However, three of the four collections resulted in poor scores. Scores at upstream sites were 40 (fair) and 36 (fair) during the summer and fall respectively*". If the licensee has evaluated this fish population data set and calculated IBI's, ADCNR is requesting these analyses for review and that they be provided in the Final Aquatic Resources Study Report. In Section 4.2 of Study Plan states, "*Alabama Power and Auburn University (Auburn) will evaluate factors affecting fish populations in the Tallapoosa River below Harris Dam through field and laboratory studies. Although this study will include an assessment of the entire fish population, a subset of target species will be studied more intensively.*" Although stakeholders agreed on target species, it was also explained in the study plan that fish populations would be studied, not just the four species identified to be studied	Regarding the assessment of presence and sustainability, fish populations were studied using the boat and barge methods discussed, and identifying species and populations whose presence or sustainability within the Study Area may have been affected was never a goal outlined in the Auburn study proposal and outside the scope of the Auburn study. As described in the Final Aquatic Resources Study Plan, identifying species whose presence and/or sustainability within the Study Area may be affected by the Harris Project was a goal of the Desktop Assessment portion of the Aquatic Resources Study, which summarized findings and conclusions of available literature related to the Tallapoosa River downstream of Harris Dam.

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		extensively with bioenergetics and other methodologies. To date, the Final Aquatic Resources Report has not fully identified aquatic species and populations whose presence and/or sustainability within the Study Area may have been affected by the Harris Project. For one example among several, the Final Aquatic Resources Report should explain and discuss potential reasons why two important forage species (Threadfin, Dorosoma petenense and Gizzard Shad, Dorosoma cepedianum) are not present in the Harris Tailrace collections. These two species are the most dominant species for sportfish in Alabama rivers. Considering Blueback Herring have been introduced illegally to Lake Martin, and that they prefer cooler water over native clupeids, the dam could be offering suitable habitat to Blueback Herring, and negatively impacting native clupeids with the cold-water discharges. In addition, results indicate that few Tallapoosa Shiners (Cyprinella gibbsi) were collected and no Bullhead Minnow (Pimephales vigilax) were collected in the regulated sites. The dramatic decline of cyprinid abundance at regulated sites for both deep and shallow water surveys over the years is troubling and should have been included and discussed in overall Aquatic Resources USR meeting presentation (Swingle 1951; Irwin and Hornsby 1997, Travnicheck and Maceina 1994, Bowen et al. 1996, Irwin et al. 2011, Irwin et al. 2019). The Final Aquatic Resources Report lacks attention to individual species population trends outside of the target species and as a result provides a limited view of the overall fish population. The Final Aquatic Resources Report should include how survey results compare with other fish population studies in the Tallapoosa River system that utilized deep and shallow water fish collection methodologies and fully identify aquatic species and populations whose presence and/or sustainability within the Study Area may have been affected by the Harris Project.	
ADCNR		ADCNR disagrees with the summary statement by the licensee on page 30 of the PowerPoint presentation from the USR meeting on April 27, 2021 that "*boat sampling*" methodologies are "*effective at sampling shallow areas within study sites.*" Both boat and barge electrofishing equipment may collect shallow water fish species specialists but do not provide an equivalent result of a targeted shallow fish population survey comparison that shallow water pre-positioned area electrofishing grids (PAE) or 30+2 sampling method would provide. Similarly, a shallow water electrofishing grid or 30+2	Previous comments provided by ADCNR regarding the use of the 30+2 method and deep and shallow water sampling were addressed in the Final Aquatic Resources Report filed with FERC on April 12, 2021 and Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).

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		sampling method can collect deep-water fish species specialists but does not effectively sample deep water to provide reliable deep-water fish population results. The goal of the Study Plan was not to test new sampling methodologies, but to provide collection data that could be used to compare to previous collections that targeted either deep or shallow fish populations to fill in data gaps. The study plan clearly separated the two methods for this specific reason. In addition, barge electrofishing equipment may collect more shallow water fish species specialists than boat electrofishing, further complicating the ability to compare results among sites in the Auburn Report or to past collections using other methodologies. On page 17 and pages 46- 47 of the Auburn Report, boat electrofishing was used at Lee's Bridge, Wadley, and Horseshoe Bend, while barge electrofishing was used at Tailrace. Since the Auburn Report and page 28 of the PowerPoint presentation from the USR meeting on April 27, 2021, indicates that Lipstick Darter (Etheostoma chuckwachatte) (percids in Auburn Report) had a higher catch rate in the Tailrace compared to other sites, this may be due to the difference in the sampling techniques. A discussion if barge electrofishing is more effective at catching smaller fish, such as darters, compared to boat electrofishing is not included (Meador and McIntyre 2003). At minimum a discussion that includes how different methods of fish collection at various sites may bias sampling results should be included and translate to how overall results are presented to stakeholders (Bonar et al. 2009, Dolan and Miranda 2003, O'Neil et al. 2014). As presented, results are in sharp contrast to multiple shallow water species targeted studies in the tailrace (Travnicheck and Maceina 1994, Bowen et al. 1996, Irwin et al. 2011, Irwin et al. 2019, PAD June 2018 Appendix E) For example, Irwin et al. 2019 shallow water grid electrofishing results between 2006 and 2016 indicated benthic specialists in the Percidae family increased in abundance and diversity at sites progressively further downstream from the dam. In addition, all regulated sites had lower diversity and abundance when compared to unregulated sites. If the licensee is presenting the Auburn Report results as overall "Fish Community Results", without specifying that the methods are targeted for deep water fish populations only, then results are indicating even greater shallow water benthic species diversity and abundance declines in recent years and should be addressed at several collection sites downstream of the dam.	

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ADCNR		Due to this variance in methodology of the Final Aquatic Resources Study Plan, conclusions and discussion of fish population results, any comparisons to past fish population collections in ISR reports such as Swingle (1951), Irwin and Hornsby (1997) and Travnicheck and Maceina (1994), should specify that these are for deep water fish population comparisons only, not overall fish population and exclude shallow water analyses. Travnicheck and Maceina (1994) which the Auburn Report compares results to frequently, clearly separated collection methods, results and discussion into deep water and shallow water analyses.	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).
ADCNR		On page 28 of the PowerPoint presentation from the USR meeting on April 27, 2021, it states, "*Diversity was lower than Travnicheck and Maceina (1994), but overall trends in diversity upstream and downstream were similar*" This statement fails to specify that this result from Travnichek and Maceina (1994) and the Auburn Report was for the deep-water fish populations only. It should be included that Travnicheck and Maceina (1994) results suggested that the effect of flow regulation on species richness and diversity of fishes in deep water habitats was negligible in the Tallapoosa River system downstream of hydroelectric facilities, but that flow regulation appeared to alter shallow water fish assemblages with species richness progressively increasing with distance from Harris Dam. Alteration in natural flow corresponded to decreased species richness, diversity and abundance of species inhabiting shallow water areas, particularly species classified as fluvial specialists. Remove, replace, or provide caveats to conclusion statements regarding upstream to downstream fish composition to illustrate that results are for deep water fish population assessment only and include statements from past literature of both deep and shallow water fishery analyses. When discussing the Auburn Reports's deep water fish population collections in the discussion and in overall USR meeting summaries include that reporting of the shallow water fish community monitoring between 2006 and 2016 indicates that fish densities in the regulated river downstream of Harris Dam were depressed when compared to unregulated sites (Irwin et al. 2019).	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).
ADCNR		ADCNR appreciates modification and removal of hybrid occurrences in the initial calculations of species diversity after ADCNR inquiries at a March 5, 2021 meeting with Auburn PI's and the licensee. (See Attachment 1, page 1205, P-2628-005 FERC ¶ 20210412-5745). In	Relatively few non-native fish, both species or individuals, were collected and should not alter species diversity index values substantially.

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		addition, total species and total native-species categories should be included. Including non-native species, such as Blueback Herring (Alosa aestivalis) and Snail Bullhead (Ameiurus brunneus), into species totals and analyses without this delineation can inflate species numbers and make it difficult to fully assess native species diversity changes. A decline of native species may not be evident if only evaluating total species diversity. Hughes and Oberdorff (1999) recommend using native species over total number of species in order to exclude several species of non-native fishes, which are generally tolerant, invasive, and could detract from the responsiveness of analyses in impaired streams. Incidence of unhealthy individuals in a fish community in the form of DELT's (Deformities, Eroded fins, Lesions, and Tumors) is frequently used in IBI metrics to reflect the health and condition of the fish community. Hybridization between species is also indicative of highly disturbed habitats and sometimes combined with DELT evaluation scores in IBI's (Karr et al. 1986, O'Neil et al. 2006). In addition, past research of the Harris tailwater often includes fluvial and benthic species specialists into analyses. This is highly recommended for comparisons and have been metrics strongly correlated to regulated tailwater operations. Adjust any conclusion statements and comparisons accordingly after separating non-native species from total species in calculations. Fluvial and benthic native species categories should be included as well.	Blueback Herring have been introduced to systems outside their natural distribution due to their common use by anglers as bait; however, there is no obvious explanation at this time for the increased range of Snail Bullhead. At this time, the hypothesis for the increased range of Snail Bullhead appears to be via a natural process, river capture. Whether that actually makes this species a non-native species is not clear. Collection of DELT information was not part of the sampling protocol. As mentioned previously, IBI sampling was determined to not be feasible after the filing of the Final Aquatic Resources Study Plan (May 13, 2019). Five Lepomis hybrids were collected in the Auburn sampling- 3 in the tailrace, 1 at Wadley, and 1 at Horseshoe Bend. It would be difficult to attribute this to variation in stress levels among these habitats. Consideration of fluvial specialists was included in response 4a to comments filed by ADCNR on the Auburn University final report on 3/16/2021.
ADCNR		On page 48 of the Auburn report and on page 28 of the PowerPoint presentation from the USR meeting on April 27, 2021, it states, "*Relative contribution of centrarchids lower than 1996 rotenone sample; combined contribution of cyprinids and catostomids similar to 1951 rotenone sample*" Although proportionally this statement may be accurate, it is a deceiving conclusion to make regarding the overall density comparisons of cyprinids among studies. Catastomid overall catch numbers between these three studies (Swingle, 1951; Irwin and Hornsby,1997; Auburn Report) are fairly similar ranging between 26 and 66 individuals. Cyprinids, on the other hand, went from ~928 individuals collected by Swingle (1951) to between 12 and 77 cyprinids per site in collections by Irwin and Hornsby (1997) and Auburn Report samples, respectively. This is a dramatic decline of cyprinid abundance since 1951. It is also important to keep in mind when comparing Swingle (1951) data, that this study was attempting	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).

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		to monitor effects on the Tallapoosa River fish populations ~23 years post filling of Lake Martin and two other hydropower impoundments (i.e., Yates Lake and Thurlow Lake). Although Swingle (1951) fish collection data represent fish compositions closer to other southeastern U.S. unregulated large river fish population assessments in regards to Ictalurid and Cyprinid abundance/species richness, it was still a river that had already been impacted by fragmentation and regulated flows from dams and reservoirs downstream. Other studies including the Auburn Report 2020 deep water fish collection results (Irwin and Hornsby 1997, Travnichek and Maceina 1994) have indicated dramatic declines in Ictalurid diversity and abundance, post dam construction. Ictalurid diversity and abundance changes and comparisons to other studies should be included and discussed in more detail.	
ADCNR		If any of ADEM's 2018 fish surveys in the Tallapoosa River will be used to supplement collections by Auburn and APC as specified in the Aquatic Resources Study Plan, these data should be included in the report results and discussed. Data included in the licensee's PAD, Volume 1, Appendix E, document pages 6-11 should be included, referenced and discussed in the Final Aquatic Resources Study Report. Provide deep and shallow fish survey sampling metrics such as numbers of each species collected, abundance, diversity, evenness, etc. and calculate for each study reach (Recommend a similar basin calibrated IBI calculation for comparison to previous studies (Bowen et al. 1996; O'Neil et al. 2006; Irwin 2019)). Including how many sampling trips and shocking hours for each trip were completed. At the March 5, 2021 meeting it was indicated that seasonal collection comparisons in the Auburn Report included variable numbers of collection trips. Providing the number of sampling trips and boat shocking hours for each site and season column is important. Presenting only the Auburn Report deep water fish population results without including and discussing shallow water fish survey results presented in the PAD, Volume 1, Appendix E (plus additional supplementary material) in the Final Aquatic Resources Study Report and USR meeting conclusion statements is misleading to stakeholders in regards to the condition of overall fish population trends.	Auburn sampled bi-monthly to obtain representative samples from every season. The 2018 ADEM data was not gathered throughout each season and was collected using different methodologies, so comparing to Auburn's results would not be feasible. There is no formal report of the 2018 ADEM data, so it was not included in the Desktop Assessment.
ADCNR		There have been two other notable variances from the Aquatic Resources Study Plan that should have been included in the USR summary presentation. The first variance involves the adequate	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed

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		selection of an upstream control site. In NOI, PAD, Scoping Document and Study Plans, ADCNR comments from October 1, 2018 (See ADCNR, P-2628-005 FERC ¶ 20181002-5006) "*that selected sampling sites closely mirror those of samples collected historically and with the ADEM water quality and fish survey sites. This will allow for an ease of comparison over time and among various data sets.*" ADCNR had agreed with the Draft Aquatic Resources assessment that an alternative site was necessary for the current upstream control site due to its closely linked dam operation characteristics. ADCNR had requested input on site selection alternatives (See Attachment 2, page 18, ADCNR, P-2628-005 FERC ¶ 20210412-5745). Please include in the report why this was determined unnecessary and provide any comparison limitations the original upstream control site might contribute. The Auburn Report states on page 6, "*There is little habitat heterogeneity at this site which is dominated by sluggish, turbid water*" and page 47,"*Higher catch rates of clupeids above the reservoir were likely due to the high connectivity between the reservoir and the Lee's Bridge site*" indicating remaining researcher doubts about Lee's Bridge as an adequate control site. In addition, on page 22 of the Auburn Report, it states that Lee's Bridge was not accessible by boat during the winter due to reservoir drawdown. Using the Foster's Bridge access area, ADCNR frequently collects brood stock from the shoals above Lee's Bridge during early spring when Harris is still at winter pool and accessibility issues have not been problematic during low water. Overall, ADCNR remains concerned that the lack of an adequate control site could limit any strong conclusions when comparing data throughout the report.	with FERC on June 15, 2021 (Accession No. 20210615-5110).
ADCNR		The second variance involves the change from original electromyogram (EMG) telemetry tags to acoustic/radio (CART tags). The Aquatic Resources Study Plan requested EMG tags, "*…the EMG tags will measure fish movement, including tail-beat frequency, to provide an in-situ measure of energy expenditures across the range of flow conditions experienced during baseline Harris Dam operations…*". In the March 5, 2021 meeting, Auburn PI's stated that the fish were likely in the two-river kilometer gaps between the acoustic receivers. The lack of data between receivers or instream movement during pulsing and high flow events from CART tags is the reason for this initial request. The licensee should include in the discussion why the original electromyogram (EMG) telemetry data methodologies which	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).

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		included "tail-beat frequency" were modified and what key data gaps this change might have created. EMG tags could have provided data on how fish respond to increased flows and detected how tail-beat frequency corresponded to various flow conditions. The EMG tag variance was presented to stakeholders on page 23 of Initial Study Report (See P-2628-005 FERC ¶ 20200410-5084) but should still be included as an overall variance from the Study Plan in Aquatic Resources Final Report. It should be acknowledged that the change was a significant and critical loss to understanding in-situ target fish species movement in the tailrace. CART tag receivers were set to detect longitudinal stream distance movements and will not capture lateral movements or movements utilized between receivers to seek shelter due to flow changes.	
ADCNR		The Auburn Report bioenergetics model did not run a cold to warm scenario. During the HAT 3 meeting on March 5, 2021, ADCNR inquired on why the impacts of cold to warm temperatures were not analyzed. Auburn PI stated that "*the dam does not typically release warmer water into the river, so the analysis focused on warm to cold water transitions.*" (See Attachment 1, page 1205, P-2628-005 FERC ¶ 20210412-5745). During the HAT 3 meeting on March 31, 2021, Dr. Wright, an Auburn PI, stated that "*fish are typically more tolerant of sudden temperature decreases compared to sudden increases.*" The Auburn Report temperature analysis in addition to the Water Quality Report both clearly show aquatic resources in the Harris tailrace are exposed to extreme changes in temperature both from warm to cold and cold to warm. After colder pulses in the summer or warmer pulses in the winter are discharged, water temperature fluctuations occur in both directions. Scenarios at the time when reviewing the bioenergetics model draft study plan were severely limited and premature due to the unprovided and not statistically analyzed Aquatic Resources Study Plan, Section 4.2.2. Comparison of Temperature Data in Regulated and Unregulated Portions of the Study Area. The Aquatic Resources Study Plan states that "*Auburn will perform respirometry testing in a laboratory facility to determine the relative effects of temperature regimes on fish energy expenditures. This testing will include an assessment of the effects of "rapid" temperature change on respiration. Testing scenarios will be developed by HAT 3 <u>after the Initial assessment of temperature data (see Section 4.2.2)</u>.*" Note a large portion of the temperature analyses in various	This comment was addressed in Alabama Power's response provided to ADCNR on June 4, 2021 and filed with FERC on June 15, 2021 (Accession No. 20210615-5110).

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		study plans for the ISR were not released until 2021. For example, Heflin and Newell temperature data was not provided to HAT 3 until the Final Aquatic Resources Study was released on April 12, 2021 (See page 49 of Final Aquatic Resources Report, Attachment 2, P-2628-005 FERC ¶ 20210412-5745). Include in the discussion with supporting literature how thermal shock from abrupt changes in stream temperature caused by anthropogenic activities (both rapid warming and cooling) can result in serious sub-lethal and lethal consequences for resident fish, including increased susceptibility to predation, increased avoidance energy costs, and other negative effects (Beitinger 1974, Donaldson et al. 2008, Fry 1947, McCullough 1999, Todd et al. 2010) In this discussion include how physiologically subjecting fish from cold to warm temperatures is more detrimental than subjecting fish from warm to cold. The interaction of temperature and dissolved oxygen should also be included and note how it only takes one low DO event or only one drastic temperature change event to harm aquatic fish species.	
ADCNR		On page 5 of the USR meeting summary, Jason Moak with Kleinschmidt "*noted that Alabama Power is reviewing information that was submitted regarding temperature modifications at other hydropower projects. Jason M. added that the temperature regime of the Tallapoosa River has been well studied during the relicensing process and noted temperatures below Harris Dam are well within the required temperature range of target species presented in Auburn's report. Jason M. stated that the data shows the temperature regime of the river below Harris Dam is not much different from a warm-water fishery, as it averages over 20 degrees Celsius (℃) and closer to 25 ℃ at several locations downstream during the summer. Jason M. added that only a 2-3℃ difference exists in portions of the year when compared to unregulated sites like Heflin or Newell; therefore, there does not appear to be a strong case for making a temperature modification.*" These statements summarize the licensee's interpretation only, with many points that are in sharp contrast to the temperature analyses presented in the Water Quality Report, Aquatic Resources Report and synopses presented in pages 26-45 of the Final Aquatic Resources Study, several of which indicate temperature effects on aquatic resources below Harris Dam. It is important to note even with strong temperature	Alabama Power's analysis of the long-term record of water temperatures below Harris, comparisons with recent water temperature records from unregulated sites upstream of Harris, and the results of Auburn's review of fish temperature requirements contained in the Aquatic Resources Study Report support the referenced statements by Jason Moak of Kleinschmidt Associates. Alabama Power agrees that previous studies indicated some effects on aquatic resources from water temperature and/or flow, though many of those studies show both negative and positive effects depending on the species and life stage. Alabama Power notes that the intent of the Aquatic Resources Study was to supplement the research conducted prior to relicensing, specifically those studies conducted by U.S. Geological Survey (USGS) and summarized in the 2019 USGS report[7], and to fill information gaps identified by Alabama Power, ADCNR, and other stakeholders during the 2018-2019 development of study plans. Results of the Downstream Aquatic Habitat Study and Phase 2 Downstream Release Alternatives Study

[7] Available at: https://pubs.usgs.gov/of/2019/1026/ofr20191026.pdf.

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		effects indicated, that the Auburn Report is just one study among many concerning Harris Dam with many ADCNR review comments still unaddressed. Overall, ADCNR remains concerned that temperature and flow of the turbine releases has documented negative impacts on aquatic resources in the Tallapoosa River below Harris Dam resulting in a strong case for making both temperature and flow modifications below Harris Dam. Please see additional details below in the Downstream Release Alternatives Draft Phase 2 Report comment section, regarding our concerns with temperature analyses in the Final Aquatic Resources Study, Auburn Report, USR meeting summary statements and temperature inputs into the data modeling.	indicate that flow modifications – specifically a continuous minimum flow – would have beneficial effects on aquatic resources by providing a reduction in daily and sub-daily water temperature fluctuations.
ADCNR		ADCNR agrees with the licensee summary statement on page 29 of the PowerPoint presentation from the USR meeting on April 27, 2021, that the majority of the target species had "*insufficient sample sizes or models that did not accurately estimate respiration rates.*" These limitations highly reduced the overall conclusions that can be drawn from the Auburn Report bioenergetics results. The difficulty for Auburn PI's to obtain sufficient samples sizes and length distributions of the target species from study sites downstream of the dam for the Auburn Report bioenergetics study is concerning. A healthy natural unregulated river of that size, with the deep-water survey efforts deployed, would likely not have resulted in difficulties obtaining sufficient sample sizes and length distributions of the selected target species. Despite the limitations of the Auburn Report due to limited sample sizes, slightly decreasing growth rates modeled for only a short 24-hour time period (Auburn PI's note changes in growth have a multiplicative impact over longer periods) of age-3 and age-5 Redbreast Sunfish due to increased energy expenditure of swimming releases is alarming. Results from the Auburn Report laboratory swimming performance trials found that all target fish species were unable to maintain position in the open water column during single turbine generation without using burst swimming behaviors and must seek shelter when water velocity increases. In addition, the Auburn Report concluded that predicted velocities in the tailrace were greater than the measured Ucrit values for the target species and that the that high flow rates including that from Harris hydroelectric peaking generation can exceed the prolonged swimming capability of the target species. Fish forced to seek shelter at increased intervals requires energy expenditure as well. On page 61 of the Auburn	The essence of the statement in the first italicized quote in the ADCNR comment relates to models that could not be properly parameterized for this work. To fully parameterize the respiration functions for a new bioenergetics model for a species would require respiration measures across multiple temperatures and a relatively large range of fish size. In addition, the nature of this analysis requires estimates of the effects of activity rate (e.g., swimming) for multiple sizes of fish and at multiple (at least 2-4) temperatures. To do this entirely would have required more trials than would have been possible under the time constraints of the project, and all of these limitations were discussed repeatedly at every meeting during the planning phases of this project. It was originally thought that targeted measurements might allow for modification of existing models for closely-related species or in the case of Channel Catfish, using the existing model that was derived from lentic populations. Unfortunately, only the model for Redbreast Sunfish (modified from the existing Bluegill model) yielded respiration values that were acceptable relative to measured rates of specific respiration. These exact issues and caveats were addressed and presented at each stakeholder meeting that was conducted during the development of this work (at Wedowee Marine, at Auburn University). All of these early meetings included ADCNR personnel and everyone attending acknowledged that these were likely limitations of the proposed work.

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		Report, it states, "*Modeling growth and respiration rates of Redbreast Sunfish under temperature conditions experience both in the Harris Dam tailrace and further downstream at Horseshow Bend, suggests that water temperatures exceeds the optimal growth temperature for Redbreast Sunfish.*" The full optimal growth temperatures, growth rate and swimming performance results for just one target species, Redbreast Sunfish, coupled with the low sample sizes and length distributions of the target species point to both flow and temperature issues downstream of Harris Dam.	Relative to the first four sentences of the ADCNR comment, to the end of the underlined sentences: The comment concerning insufficient sample sizes is limited to only two aspects of the study-- the respirometry and the bioenergetics aspects of the work. Clearly, sample sizes for age-and-growth, diet analyses, and community composition were more than adequate. For the swimming challenges the size of fish was limited to those capable of reducing oxygen concentration in the swim chamber within an appropriate amount of time. Fish size limitations in that aspect of the research were due to logistics of requiring sufficiently large fish to be able to quantify measurable respiration and hence metabolic rates. For the static respiration measures, fish were limited to those that could fit into the chambers. Both of these caveats were discussed among stakeholders at early planning meetings for this work, which included participation by ADCNR representatives, with no concerns expressed. In the second portion of the comments, ADCNR expressed concern that the potential cost of swimming at higher velocities can have a multiplicative effect. As stated in the report, the projected differences in growth rate were very small and negative for age 3 and age 5 fish only at the higher temperatures used in the simulations. Measurements at cooler temperatures in the swimming respirometry trials indicated that decreased temperature can compensate for increasing metabolic demand caused by increased swimming. Simulations were not run for longer time periods because of concerns that shifts in habitat use by the fish during the higher velocities could not be accounted for. ADCNR's comment that refuge seeking has an energetic cost is almost certainly true. As velocity increases, fish would have to find appropriate refuge, likely moving toward the edge of the river or into the flow shadow of rocks or woody debris on the bottom. This refuge seeking is consistent with observations for Tallapoosa Bass made by previous researchers. The

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			movement required would be relatively small. In addition, there may be other costs such as reduced feeding. Unfortunately, shifts in habitat use or in the specific swimming speed of fish during periods of generation and non-generation could not be explicitly measured within the constraints of this study. In the original plan for the work, electromyographic tags were proposed as a potential measure of fish muscle activity to be correlated with respiration rates. After further testing, these tags were found to provide unusable information that could not be used to estimate exertion by the fishes. This was a caveat provided up front for the potential application of these tags. The last 2 sentences of ADCNR's comments suggest a potential misinterpretation of the 1 month modelling results. They suggest that only having a model for Redbreast Sunfish due to low sample size, the low sample size itself, and the effect of higher temperature on the specific growth of Redbreast Sunfish, together suggests that there are "temperature and flow issues". As stated above, sample sizes (i.e. catch rates) were not low or insufficient for most analyses. The number of respirometry trials (samples in this context) was the only place where samples were insufficient for fully parameterizing multiple bioenergetics models, which again was a goal that was clearly stated during the proposal development phase as being beyond the scope of the proposed work in this project. There is no evidence that dam operations significantly increase temperature of the downstream sites during late summer. In fact, as stated in the report, these results were similar to those modelled for conditions by other researchers in Saugahatchee Creek, an unregulated stream. Late summer is the period where weight loss might be expected for Redbreast Sunfish at downstream sites as predicted by the bioenergetics model simulations. The effects of interaction among increased swimming velocity and higher temperatures could potentially increase the negative effect on growth and is why late summer

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			downstream conditions were chosen to simulate. That said, it would be inappropriate to suggest that these simulations would indicate impact on the growth of Redbreast Sunfish without information on the habitat use and activity of these fish during generation releases.
ADCNR		On page 28 of the PowerPoint presentation from the USR meeting on April 27, 2021, the licensee includes two bullet points regarding body condition and fish size. These points fail to include page 49 of the Auburn Report statement, "*Based on this evidence, it appears that abundance and diet variation could be, in part, affecting the observed patterns of body condition in the tailrace.*" Goar et al. 2013 also hypothesized that lower fish densities at regulated sites may contribute to higher growth at early life stages of Redbreast Sunfish.	Comment noted. The Auburn study did not report differences in body condition of Redbreast Sunfish or relative weight of Tallapoosa Bass (although sample sizes of Tallapoosa Bass were low at Lee's Bridge and the tailrace). Lower densities in the tailrace is a plausible explanation for higher body condition of Alabama Bass in the tailrace, but not for Channel Catfish.
Environmental Protection Agency (EPA)	6/7/2021 20210607-5012 On USR	Baseline temperature data originally contained in the 4/2020 Downstream Aquatic Habitat Report Conclusions (page 64) Final Bioenergetics Study, using bioenergetics to address the effects of temperature and flow on fishes in the Harris Dam tailrace (page 1645). • More information is needed on fish temperature thresholds for future management of the system • Green plan data indicates temperature regimes have remained similar to pre-Green plan • High flow rates exceed capability of target species tested • Temperature and flow in the Tallapoosa River may affect growth (however, growth is positive for Redbreast sunfish in lower temperatures) • It is uncertain how flow and temperature interact in the Tallapoosa River for a broader array of species Comment: Based on the information summarized above, which is contained in the Aquatic Resources Report as well as information in the Draft Downstream Release Alternatives Report, an alternative modeled flow could reduce downstream temperature fluctuations, increase wetted perimeter, decrease wetted perimeter fluctuations and increase downstream DO. As stated above, providing a process through which stakeholders can provide input to determine an alternate CMF or ModGP flow could potentially result in a preferable alternative.	Comment noted.

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Michelle French	6/11/2021 20210611-5001	I am writing to request that your agency require Alabama Power and the Army Corps of Engineers make substantial changes to the Harris Dam/Lake Wedowee to better serve the citizens of Randolph, Clay, and Cleburne Counties. Harris Dam was conceived and designed, under the pretense of flood control and energy generation. Sadly, property owners below the dam are regularly flooded while the Tallapoosa River is suffering loss of fisheries and irregular water flows. Landowners have no confidence in the trustworthiness of the dam operations. Alabama Power gouges the local area on electric rates with less than stellar service. Please enforce upgrading and implementation of an update to the Army Water Control and redesigning and replacing the turbines at the dam. Thank you	Comment noted.
Alabama Rivers Alliance (ARA) Note: footnotes included in the original letter have been omitted from this table	6/11/2021 20210611-5070 On the USR	ARA disagrees with the statements of the Licensee's representatives contained in the Updated Study Report Meeting Summary that "the temperature regime of the river below Harris Dam is not much different from a warm-water fishery" and that "there does not appear to be a strong case for making a temperature modification". These comments represent Licensee's evaluation of the temperature data collected as part of the study prepared for this relicensing and not an overall scientific consensus. The Tallapoosa River below Harris has been rigorously studied over the past 25 years, and the Final Aquatic Resources Study, including Auburn University's bioenergetic modeling and temperature analysis, is only one of a number of studies. Based on prior extensive studies surveying a wide variety of fishes and macroinvertebrates below Harris and based on the water temperature concerns put forth by resource agencies, enough evidence exists of the temperature impacts created by the hypolimnetic releases from Harris to justify discussion of the options available to remedy the current thermal regime. The following is a brief summarization of the considerable research pointing to ecological problems caused by low water temperatures below Harris:	Alabama Power disagrees with ARA's position that "enough evidence exists of the temperature impacts created by the hypolimnetic releases from Harris to justify discussion of the options available to remedy the current thermal regime". Alabama Power's review of the long-term record of water temperatures below Harris, comparisons with recent water temperature records from unregulated sites upstream of Harris, and the results of Auburn's review of fish temperature requirements contained in the *Aquatic Resources Study Report* support the referenced statements by Jason Moak of Kleinschmidt Associates. Alabama Power filed the temperature data from 2000-2018 with its response to USR comments on July 12, 2021. Alabama Power agrees that previous studies indicated some effects on aquatic resources from water temperature and/or flow, though many of those studies show both negative and positive effects depending on the species, life stage, and metric. In addition, to our knowledge, none of the previous studies included an analysis and/or comparison of the temperature regime in the Tallapoosa River below Harris to reference sites. Alabama Power notes that the intent of the Aquatic Resources Study was to supplement the research conducted prior to relicensing, specifically those studies conducted by U.S. Geological Survey (USGS) and summarized in the 2019 USGS report, and to fill information gaps identified by Alabama Power, ADCNR,

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		• Nesting success for Redbreast Sunfish was negatively related to both peaking power generation and depressed water temperatures (Andress 2002). • Strongly fluctuating flows and decreased water temperatures negatively affect survival and early growth of age-0 Channel Catfish and Alabama Bass. Mortality was highest in treatments with decreased water temperatures, indicating that variation of the thermal regime could have significant impacts on survival of juvenile Channel Catfish and Alabama Bass. Daily growth rates were also lower in treatments with decreased water temperatures. Data also suggest that growth and survival may be impacted more by fluctuations in temperature versus flow variation (Goar 2013). • Improving flow and temperature criteria from Harris could enhance growth and hatch success of sport fishes (Irwin and Goar 2015). • Thermal spawning conditions for Channel Catfish occurred every year in unregulated reach but in only 7 out of 12 years in regulated river segment and occurred earlier in the year in regulated reaches (Lloyd et al. 2017) • Flow and temperature remain in a non-natural state in regulated reaches downstream of Harris, and the macroinvertebrate community in regulated reaches shows many dissimilarities to communities from unregulated river reaches (Irwin 2019). The detailed, long-term documented impacts on aquatic life due to excessively cold temperatures, temperature fluctuations, and flow fluctuations from the Harris project are at odds with the conclusions drawn by Licensee in the USR Meeting Summary and support the contention that temperature modifications are in fact needed. Most recently, the US Geological Survey's Open File Report from 2019 ("USGS Report") recaps the history of the biological studies and	and other stakeholders during the 2018-2019 development of study plans. The aquatic resources and water temperature data provided on the record will facilitate FERC's ability to review and conduct their own independent analysis of the temperature effects in the Tallapoosa River below Harris Dam, given Alabama Power's proposed operations and PME measures. Results of the Downstream Aquatic Habitat Study and Phase 2 Downstream Release Alternatives Study indicate that flow modifications – a continuous minimum flow – would have beneficial effects on aquatic resources by providing a reduction in daily and sub-daily water temperature fluctuations.

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		monitoring below Harris and firmly links water temperature to detrimental effects on fishes and macroinvertebrates below the Harris project. The USGS Report clearly points to an unnaturally cooler temperature regime as detrimental to aquatic species: "Our long-term metapopulation data provide evidence that suggests broadscale negative influences of the dam on species persistence and colonization parameters. Specifically, generation frequency and cool thermal regimes negatively affected fish persistence and colonization, respectively." Having broadly studied 38 fish species from 25 sites over a 12-year period below Harris, the authors of the USGS Report write: "Although it has long been recognized that temperatures are altered below R.L. Harris Dam, specific inference regarding the influence on biotic processes has been lacking until this study, which clearly relates colonization rates (that is, recruitment of a species to a site) to increased thermal energy in the river. In addition, our data indicate that there is no downstream recovery for colonization processes such that colonization rates did not increase with distance from the dam." Increasing thermal energy in the river, and thereby increasing colonization rates and recruitment, can only be achieved by adjusting the temperature of releases. The Final Aquatic Resources Report sourced significant amounts of historic temperature data from regulated and unregulated river segments, but "unregulated and regulated river temperatures were not compared statistically due to limited data from the Heflin gage and a variety of other variables that could contribute to temperature differences between the regulated and unregulated river." To enable a complete evaluation of thermal issues, all available water temperature data should be shared with stakeholders, including Licensee's historic temperature data provided to Auburn University. ARA has requested Licensee's 2000-2018 water temperature data referenced in Section 5.2.2 of the Final Aquatic Resources Report and used in Auburn's water	

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		temperature assessment. Licensee responded that its 2000-2018 temperature data will be filed with the Final License Application in November 2021. We request that all temperature data be made available to stakeholders as soon as possible since temperature has been a long-time area of concern.	
ARA		The Aquatic Resources Study Plan states that the goal of many stakeholders in this relicensing is to “protect and enhance the health of populations of game and non-game species of fish and other aquatic fauna.” The FERC-approved study plan describes an “assessment of the entire fish population” while noting that a subset of target species will be studied more intensively.” While Auburn researchers under contract with Licensee did some fish community sampling and reported those results in Appendix D, no portion of the Final Aquatic Resources Study Report has sufficiently assessed the impacts of flow regulation and temperature on non-game and non-target species. Population trends of non-target species are not discussed. No Index of Biology Integrity (IBI) scores were calculated to compare to prior studies. Variances in study methodology and control site selection were undertaken without adequate stakeholder input. In August 2020, ARA recommended in comments on the Draft Aquatic Resources Study that Licensee review temperature data for at least some of the non-target species. Particularly because scant temperature data exists for two of the four target species (Tallapoosa Bass and Alabama Bass) and a wide range in thermal minima and preferred temperatures has been reported in the literature for another target species, Channel Catfish, we suggested a literature review of similar temperature data for at least some of the non-target species, including species the USGS Report indicates are most affected by Harris, such as Stippled Studfish, Blackspotted Topminnow, Black Redhorse, Blacktail Redhorse, Riffle Minnow, Bullhead Minnow. No information on thermal requirements for non-target species has been included in the final report.	Temperature data are not likely available for many of these non-target species and gathering these data is beyond the scope of the FERC-approved study plan. The target species were chosen in consultation with ADCNR because they are typical species of most rivers in the region, they are resilient species that can be transported to a laboratory for further study relatively easily, they are a mixture of habitat generalists (Alabama Bass) and riverine specialists (Tallapoosa Bass), and they are of interest to the public. No Stippled Studfish or Riffle Minnow were sampled during Auburn University’s samples. Numbers and catch-per-unit-effort of other species are included in the final report by season and site. The IBI scores derived from Irwin et al. (2019) are presented in the PAD and are valid for comparison between sites and over time within that specific study. Although data were collected using methods consistently applied at each site and over time, collection methods used in Irwin et al. (2019) differed from Geological Survey of Alabama (GSA)’s IBI protocols and could not be compared to scores derived using those protocols or other studies using dissimilar protocols.

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ARA		A stakeholder process was begun in 2005 to evaluate and adjust flows, which culminated in the Green Plan, a process described as an adaptive management plan (AMP) by Licensee and other stakeholders. That painstaking and model-driven process consisted of years of stakeholder meetings, data collection, and evaluation. Yet the ultimate flow prescription that resulted was still a scientific "best guess' of what would benefit aquatic biota while meeting power generation requirements. After twelve years of research and monitoring, this flow hypothesis was disproved as to both fishes and macroinvertebrates: "Irwin and others reported an increase in shoal habitat persistence associated with the Green Plan; however, positive population responses have not ensued." But the failure of the AMP was not that its flow prescription did not achieve the desired biological outcome; the failure was that there was no mechanism to reevaluate and adjust operations based on the knowledge gained after the Green Plan was instituted. Adaptive management is by nature iterative, and no matter the flow scenario ultimately selected through this relicensing process, monitoring future ecological responses and preserving the flexibility to adjust operations based on system feedback is imperative. Especially because few of the alternative flow scenarios under consideration have been physically implemented and monitored, the flow regime arising from this relicensing process will be the next scientific "best guess." In the face of changing climatic conditions that are forecasted to accelerate over the next license term, Licensee and FERC should not write a static flow prescription into the next license but instead fashion a mechanism for monitoring and responsive change. Biologists studying the river below Harris have for decades been calling for iterative adaptive management of regulated rivers by allowing managers and scientists to address the uncertainty in predicting and measuring how river fauna will respond to flow-regime alterations." Licensee and stakeholders should not make the same mistake again and lock in a flow regime with no mechanism to adapt. One positive	Alabama Power has been participating in an adaptive management process since the implementation of the Green Plan in 2005. Data has been gathered since 2005 to evaluate the Green Plan flows. As part of the relicensing of the Harris Project, Alabama Power evaluated a number of downstream release alternatives and is proposing to implement an Aquatic Resources Monitoring Plan following the implementation of a continuous minimum flow.

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		example of adaptive management involving minimum flows in another Southeastern river, which resulted from a recent relicensing, that Licensee, FERC, and stakeholders can can look to is the Parr Hydroelectric Project (FERC No. 1894).	