

Evaluation of Fish Passage Following Installation of a Rock Arch Rapids at Lock and Dam #1, Cape Fear River, North Carolina

2013 Annual Report

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INTRODUCTION

Construction of the rock arch rapids fishway at the first lock and dam (LD-1, river kilometer (rkm) 97) on the Cape Fear River was completed in November 2012. This design has been determined to successfully pass fish (USACE 2010), although no known studies have been published and the design has never been used along the Atlantic coast or for anadromous species. Therefore, the primary objective of this study is to evaluate the passage of fish at LD-1 through the rock arch rapids; fish passage locking procedures did not occur there in 2013. A second objective is to evaluate fish passage at lock and dam 2 (LD-2, rkm 149) and lock and dam 3 (LD-3, rkm 186) where fish passage locking procedures continued in the spring of 2013. This report provides preliminary results through July 2013, the study will continue through July 2014.

METHODS

Tagging

We tagged striped bass *Morone saxatilis*, American shad *Alosa sapidissima*, and flathead catfish *Pylodictis olivaris* with sonic transmitters in 2013 (Table 1). The transmitters emit a unique identification code that can be detected with manual and stationary telemetry receivers. The striped bass and flathead catfish tags remain active for nearly two years while the American shad tags remain active for four to five months.

We internally implanted transmitters into 49 striped bass in the lower Cape Fear and Northeast Cape Fear rivers; the North Carolina Division of Marine Fisheries (NCDMF) assisted with electrofishing. Downstream of LD-1, we used electrofishing to capture additional striped bass along with American shad and flathead catfish; the North Carolina Wildlife Resources Commission (NCWRC) assisted on certain days. At this location, we internally implanted transmitters into 14 striped bass and 20 flathead catfish and gastrically implanted transmitters into 25 female and 25 male American shad.

The NCDMF internally implanted 20 striped bass in 2012 and 11 individuals in 2013 in the Lower Cape Fear and Northeast Cape Fear rivers (Table 1). These individuals were captured either by hook and line or electrofishing.

Receivers

Together with NCDMF, we installed stationary telemetry receivers to monitor tagged fish passage at each lock and dam and their migrations throughout the Cape Fear River system (Figure 1). Multiple receivers were installed at LD-1 to determine when fish arrived at the structure, how long they remained downstream, and how many successfully passed (Figure 2). We installed a

receiver 0.4 rkm downstream of the dam, a receiver on the downstream end of each side of the rock arch rapids (0.1 rkm downstream of dam), and one receiver 0.1 rkm upstream of the dam. In addition, the NCDMF had a receiver installed 0.3 rkm downstream of the dam, in the lock chamber to monitor potential passage during occasional boat or maintenance locking procedures, and immediately upstream of the dam. At both LD-2 and LD-3, we installed one receiver downstream (downstream of dam = 0.4 rkm at LD-2, 0.5 rkm at LD-3), in the lock chamber, and upstream (upstream of dam = 0.1 rkm at LD-2 and LD-3). We installed additional receivers between the three lock and dams and upstream of LD-3. The NCDMF has additional receivers installed downstream of LD-1 in the Cape Fear River, along with receivers in the Black, Northeast, and Brunswick rivers.

Fish Passage

We calculated the percentage of upstream fish passage at each lock and dam as the number of tagged fish detected upstream of the structure divided by the number of tagged fish available to pass the structure, multiplied by 100. Tagged fish were available for passage if they were detected at a receiver immediately (i.e., ≤ 0.5 rkm) downstream of a structure. We only included an individual once in the total available and passage numbers at each lock and dam (e.g., excluded multiple upstream passes). Fish tagged at LD-1 that migrated downstream shortly after tagging (“fallback”) were only included as an available individual if they migrated back to the structure.

RESULTS

Striped bass

A total of 43 striped bass were available for passage at LD-1, with nine individuals passing upstream for a passage rate of 21% (Table 2). Striped bass first arrived at LD-1 in the second week of April and the most available individuals occurred in the second week of May (Figure 3). The most striped bass passed LD-1 in April, although there were no discernible patterns with river conditions such as gage height and water temperature (Figure 4). Seven of nine striped bass passed LD-2 and all seven of these individuals reached and passed LD-3.

Striped bass displayed a variety of patterns upon reaching and passing the lock and dams (Table 2, Figure 5). A few striped bass reached LD-1 and passed rapidly (Figure 5 A), but others were delayed in their passage for variable time periods (Figure 5 B); the duration from reaching to passing LD-1 ranged from 0.2 to 15.9 days (Table 2). For individuals that did not pass LD-1, some migrated back downstream shortly after arriving at the structure (Figure 5 C) while others remained near the structure for extended periods (Figure 5 D). While a higher proportion of striped bass passed LD-2 and LD-3, some passed rapidly (Figure 5 A) and others appeared to be delayed for long periods (Figure 5 B). Overall, fish migrated rapidly through reaches that did not contain a lock and dam (e.g., Figure 5 A, B).

Most striped bass migrated downstream in mid to late-May as fewer individuals were detected downstream of LD-1 (Figure 3). Certain individuals, in particular those that migrated upstream of LD-1, migrated downstream in early June. Eight of the nine individuals that migrated upstream of LD-1 were detected migrating downstream of LD-1. The remaining individual was detected migrating downstream at the next upstream receiver (rkm 111) but not at LD-1.

American shad

A total of 32 American shad were available for passage at LD-1, with 16 individuals passing upstream for a passage rate of 50% (Table 2). American shad were first available at LD-1 towards the beginning of March, but passage only occurred between April 1 and May 1 (Figure 6). However, there were no distinct patterns with passage and river conditions (Figure 4). Fourteen American shad were available for passage at LD-2, with five passing upstream (Table 2). All five of these individuals reached LD-3 and passed upstream (Table 2).

American shad also displayed variable patterns upon reaching and passing the lock and dams (Table 2, Figure 7). A few individuals passed LD-1 relatively quickly (shortest = 2.2 days), but on average fish were downstream longer (mean = 18.4 days) before passing (Table 2, Figure 7 A, B). For individuals that did not pass LD-1, some remained downstream for extended periods (Figure 7 C). However, others were only downstream of LD-1 for short periods but were never observed migrating downstream (Figure 7 D); these individuals may have died naturally or were harvested. Individuals that passed LD-2 and LD-3 tended to do so promptly (Table 2, Figure 7 A), but others remained downstream of LD-2 for prolonged periods (Figure 7 B). Similar to striped bass, American shad migrated rapidly through reaches that did not contain a lock and dam (Figure 7 A, B).

The number of available American shad downstream of LD-1 decreased after mid-April and most individuals appeared to have emigrated by early June (Figure 6); remaining individuals may have died but their transmitters were still detected. Only one of 16 fish that passed upstream of LD-1 was detected passing downstream of LD-1.

Flathead catfish

A total of 20 flathead catfish were available for passage at LD-1 by the end of May, with 16 individuals passing upstream for a passage rate of 80% (Table 2, Figure 8). Flathead catfish passage numbers steadily increased throughout May; two individuals passed in mid-June (Figure 8). Flathead catfish tended to pass LD-1 when water temperatures were warmer, but there was no distinct pattern with gage height (Figure 4). Ten flathead catfish were available for passage at LD-2, with 9 passing upstream (Table 2). Five flathead catfish passed LD-3 but we were unable to determine the total number available for passage, as the receiver downstream of LD-3 was inaccessible during June and July visits.

Flathead catfish displayed slightly different patterns when reaching and passing lock and dams (Table 2, Figure 9). The duration from reaching to passing LD-1 for their first time ranged from 3.4 to 29.4 days (Table 2). Certain individuals rapidly passed all three lock and dams (Figure 9 A) while others were downstream at different structures for longer periods (Figure 9 B). Some individuals passed and then returned to downstream of LD-1 after a short time period (Figure 9 C) and at least three individuals passed LD-1 upstream and downstream multiple times. For the four individuals that did not pass LD-1, three were near the structure for an extended period (Figure 9 D) but one was only downstream for a few days. Individuals passed LD-2 between 0.1 and 18.1 days, but we were unable to determine their duration downstream of LD-3. Flathead catfish did tend to migrate rapidly through reaches without lock and dams (e.g., Figure 9 A, B).

By the middle to end of June, few flathead catfish were downstream of LD-1 (Figure 8). Flathead catfish were detected at all three lock and dams at the end of July. However, some individuals appeared to be migrating downstream (e.g., Figure 9 A).

DISCUSSION

All three species passed upstream through the rock arch rapids at LD-1 and also at the other two lock and dams. Agencies have set 80% passage of American shad and striped bass as the success criterion at LD-1. Both American shad (50%) and striped bass (21%) did not meet this criterion in 2013; however, 80% of flathead catfish did pass the structure. American shad tended to remain downstream for extended periods prior to passing, suggesting a hesitancy to enter the fishway or difficulty in passing. Certain striped bass passed through rapidly, indicating they are capable of passing efficiently. However, others striped bass apparently experienced delays and a large proportion did not pass. Flathead catfish were most effective at passing LD-1 and certain individuals passed through the structure multiple times.

Previous telemetry studies evaluated LD-1 passage via fish locking procedures. Our 2013 results for American shad (50%) were comparable to previous studies. Moser et al. (2000) found 18-61% passage at LD-1, CZR Inc. (2004) determined 25% passed, and Smith and Hightower (2012) reported 65% passage. However, striped bass passage rates at LD-1 in 2013 (21%) were lower than the 61% determined by CZR Inc. (2004) and 77-86% found by Smith and Hightower (2012).

Passage at LD-1 did not appear to be influenced by river conditions. We expected more fish to pass under high flow conditions as water would be deeper across the rock arch rapids and possibly less turbulent. However, we did not observe an apparent relationship between passage and flow despite having a variety of flow conditions in the spring of 2013. Water temperature influenced the arrival of the three species, but did not appear to influence when fish passed LD-1.

Passage and delays at LD-1 may have been influenced by other factors. It is possible that individuals could pass through the structure but remained downstream to spawn or feed. Handling and tagging fish may induce stress and influence migratory behaviors. Most tagged American shad migrated downstream ("fallback") for variable distances and time periods. While we only evaluated individuals that returned to LD-1, it is possible they behaved differently than fish there were not handled or tagged. In separate NCWRC electrofishing surveys, American shad captures were higher at LD-2 and LD-3 than LD-1 in 2013; captures were higher at LD-1 in previous years. Striped bass NCWRC captures were highest at LD-1 in 2013. It is also possible that recreational and commercial fishing influenced tagged individuals, especially American shad, either through harvest or stress from catch and release.

Passage results were variable between studies at the other two lock and dams. We found 36% of American shad passed LD-2 and 100% passage at LD-3, while Moser et al. (2000) found 33% at LD-2 and Smith and Hightower (2012) determined 85% passed LD-2 and 64% passed LD-3. In 2013, 78% of striped bass passed LD-2 and 100% passed LD-3. Smith and Hightower (2012) found 75-100% passed LD-2 but only 44-50% passed LD-3. We determined that the duration downstream of LD-2 and LD-3 prior to passing was comparable or shorter than at LD-1 for all three species.

Evaluation of fish passage at the Cape Fear River lock and dams will continue in 2014. We will tag additional fish, allowing us to increase our sample size and monitor fish passage under different environmental conditions and potentially a modified rock arch rapids. We will also examine striped bass and flathead catfish tagged in 2013 that return in 2014. These individuals will have no handling and tagging effects and we can compare their passage efficiency between years.

REFERENCES

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- Smith, J. A., and J. E. Hightower. 2012. Effect of low-head lock and dam structures on migration and spawning of American shad and striped bass in the Cape Fear River, North Carolina. *Transactions of the American Fisheries Society* 141:402-413.
- USACE. 2010. Environmental assessment: Rock arch rapids fish passage, Cape Fear River above Wilmington, NC, lock and dam no. 1. US Army Corps of Engineers, Wilmington District, Wilmington, North Carolina.

TABLES

Table 1. Sample size, length, and tagging periods and location for American shad, flathead catfish, and striped bass.

Species	n	Length (mm)			Tagging			
		Mean	SE	Range	Dates	Year	Location	Organization
American shad	50	488	6.0	391 - 565	2/25 - 3/28	2013	CF LD-1	NCSU
Flathead catfish	20	746	29.3	532 - 980	4/11 - 5/21	2013	CF LD-1	NCSU
Striped bass	49	649	9.3	509 - 791	1/22 - 2/15	2013	Lower CF, NECF	NCSU
Striped bass	14	608	21.2	510 - 754	4/3 - 5/15	2013	CF LD-1	NCSU
Striped bass	20	667	17.5	522 - 823	1/14 - 2/2	2012	Lower CF, NECF	NCDMF
Striped bass	11	681	19.0	563 - 764	1/19 - 2/4	2013	Lower CF, NECF	NCDMF

Table 2. Upstream passage efficiency and rates of striped bass, American shad, and flathead catfish at three lock and dams on the Cape Fear Rivers.

	Passed	Available	Efficiency	Duration to Passage (Days)		
				Mean	SE	Range
LD-1						
Striped bass	9	43	21%	4.1	1.62	0.2 - 15.9
American shad	16	32	50%	18.4	2.57	2.2 - 36.8
Flathead catfish	17	20	80%	9.1	1.85	3.4 - 29.4
LD-2						
Striped bass	7	9	78%	5.2	4.08	0.1 - 29.5
American shad	5	14	36%	3.0	0.85	0.8 - 4.9
Flathead catfish	9	10	90%	5.8	2.40	0.1 - 18.1
LD-3						
Striped bass	7	7	100%	5.5	4.12	0.2 - 29.7
American shad	5	5	100%	4.9	2.25	0.3 - 12.3
Flathead catfish	5

FIGURES



Figure 1. Stationary telemetry receivers located in the Cape Fear, Black, and Northeast Cape Fear rivers used to monitor tagged fish migrations and passage at lock and dams.

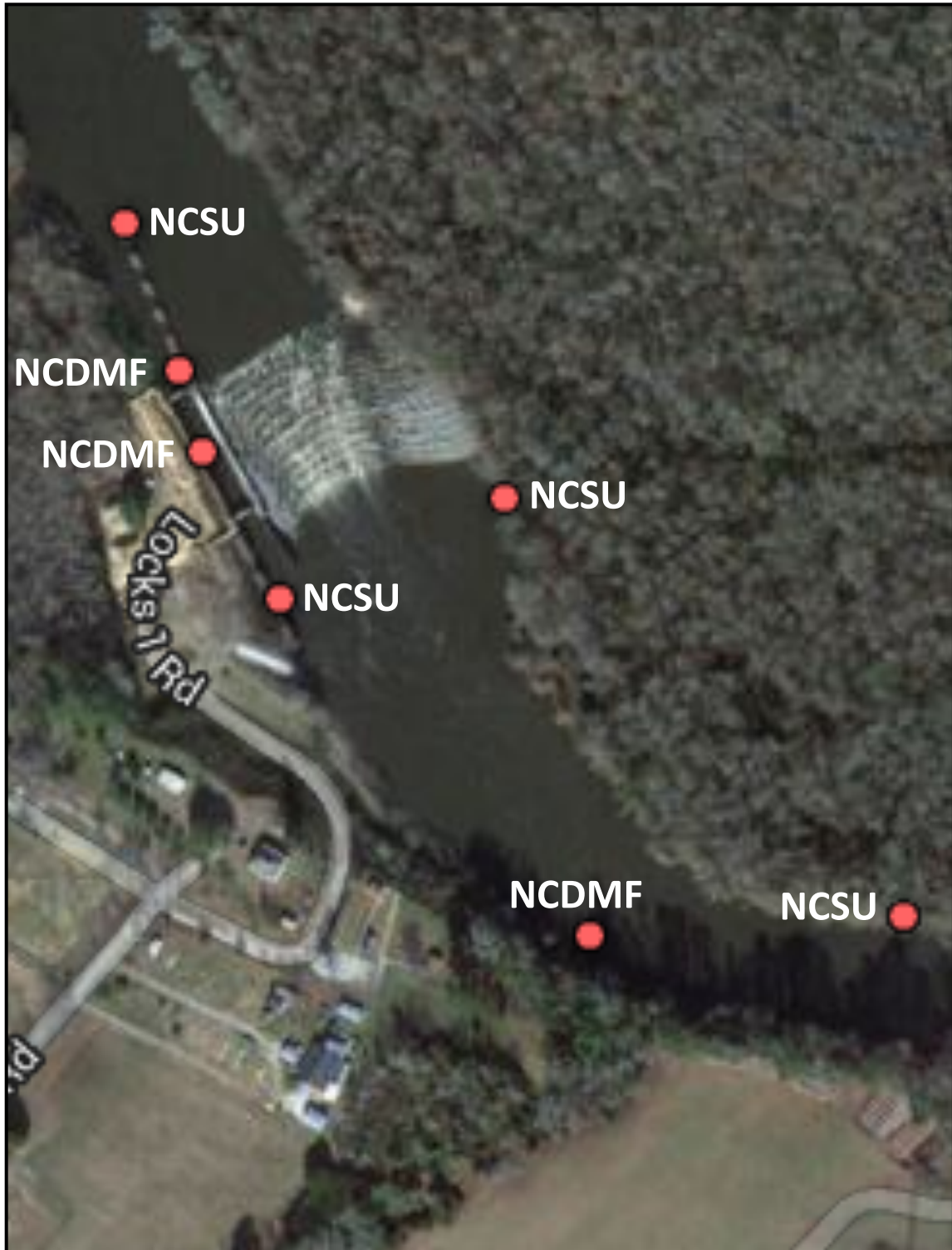


Figure 2. Stationary telemetry receivers located at the rock arch rapids fishways at LD-1 on the Cape Fear River. Receivers were used to determine when tagged fish arrived at the structure, how long they remained downstream, and their upstream passage efficiency.

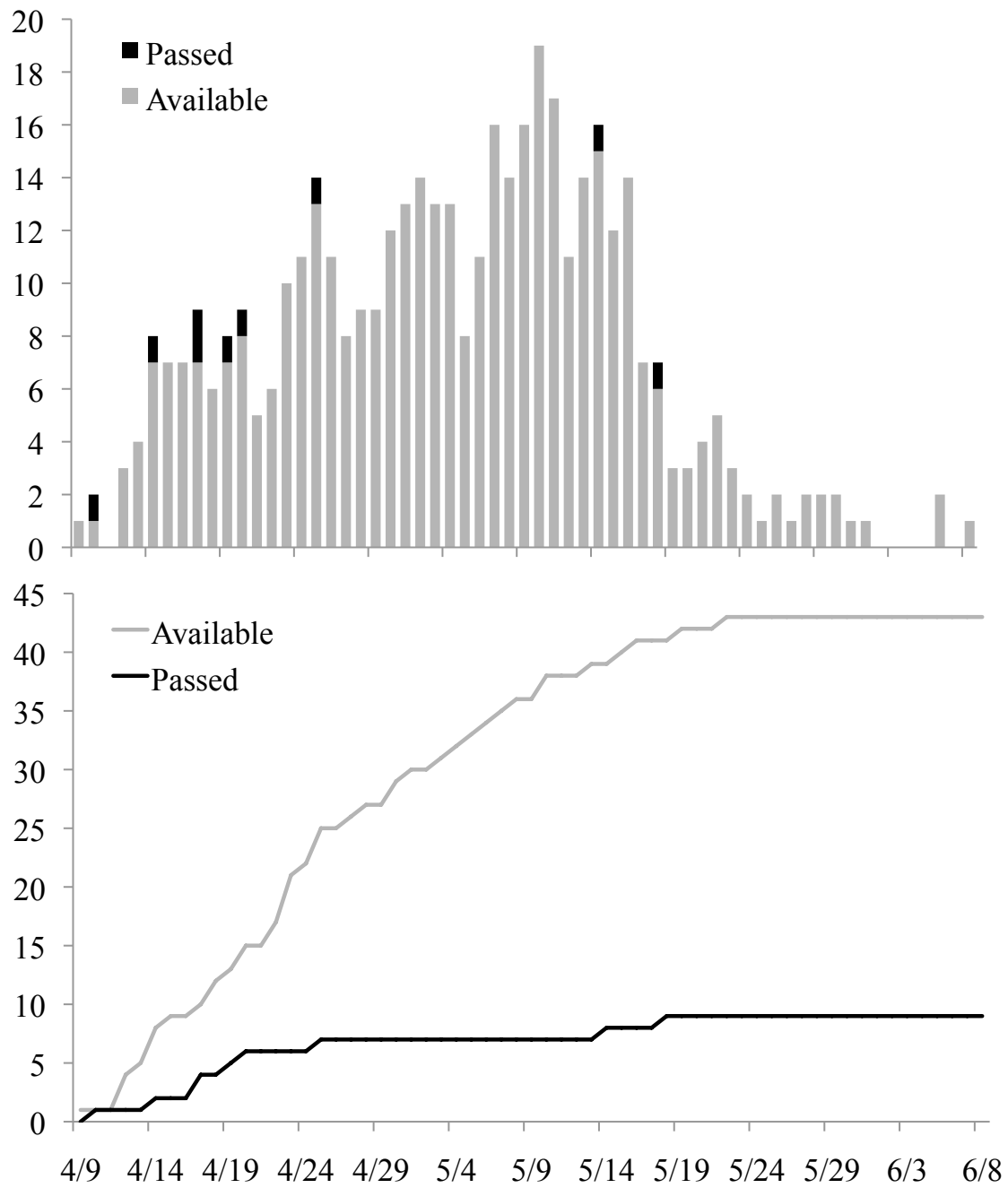


Figure 3. Daily (top) and cumulative (bottom) number of striped bass detected immediately downstream (available) and upstream (passed) of LD-1 on the Cape Fear River.

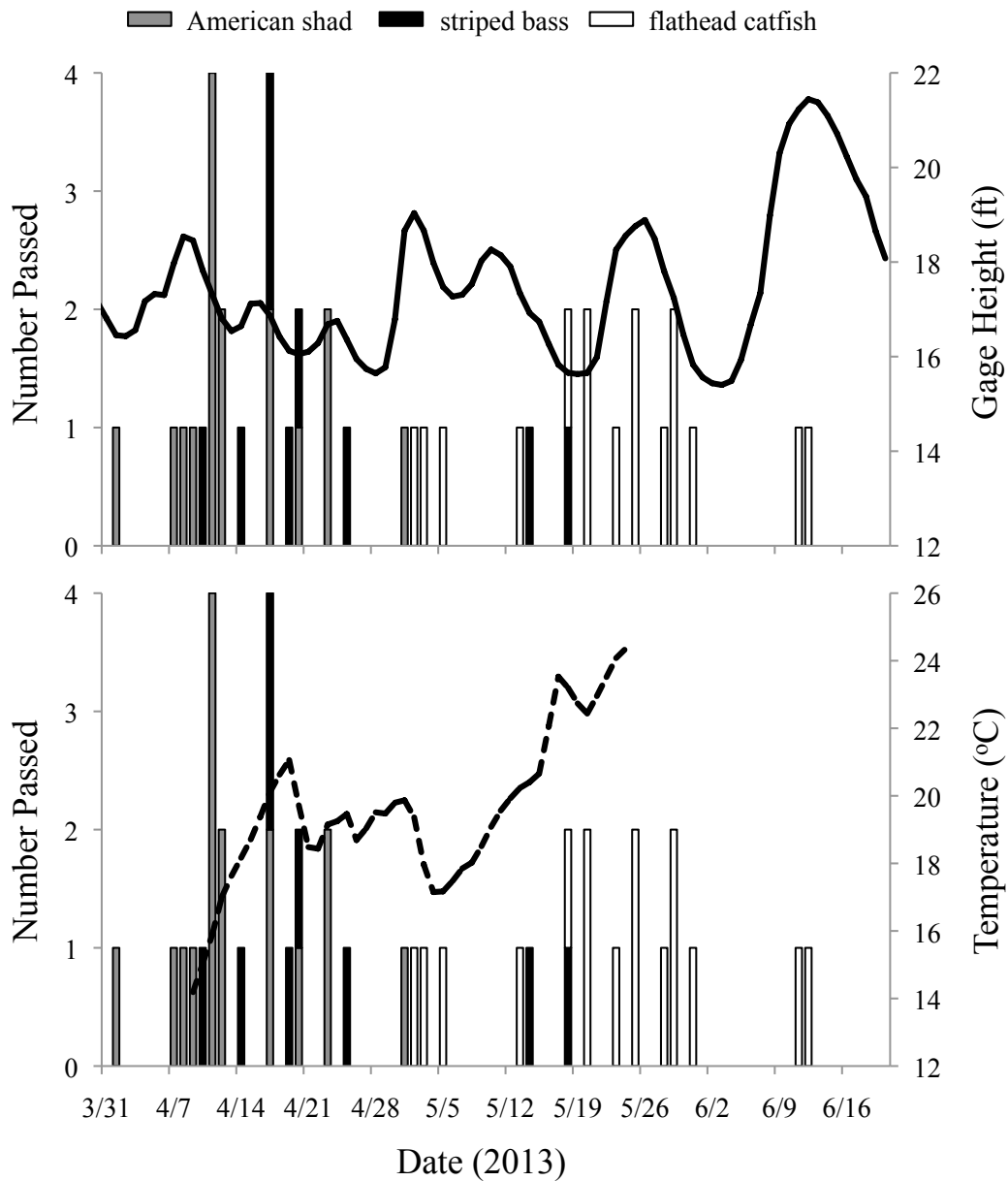


Figure 4. Daily number of American shad, striped bass, and flathead catfish that passed LD-1 on the Cape Fear River through the rock arch rapids compared to mean daily gage height (top) and water temperature (bottom).

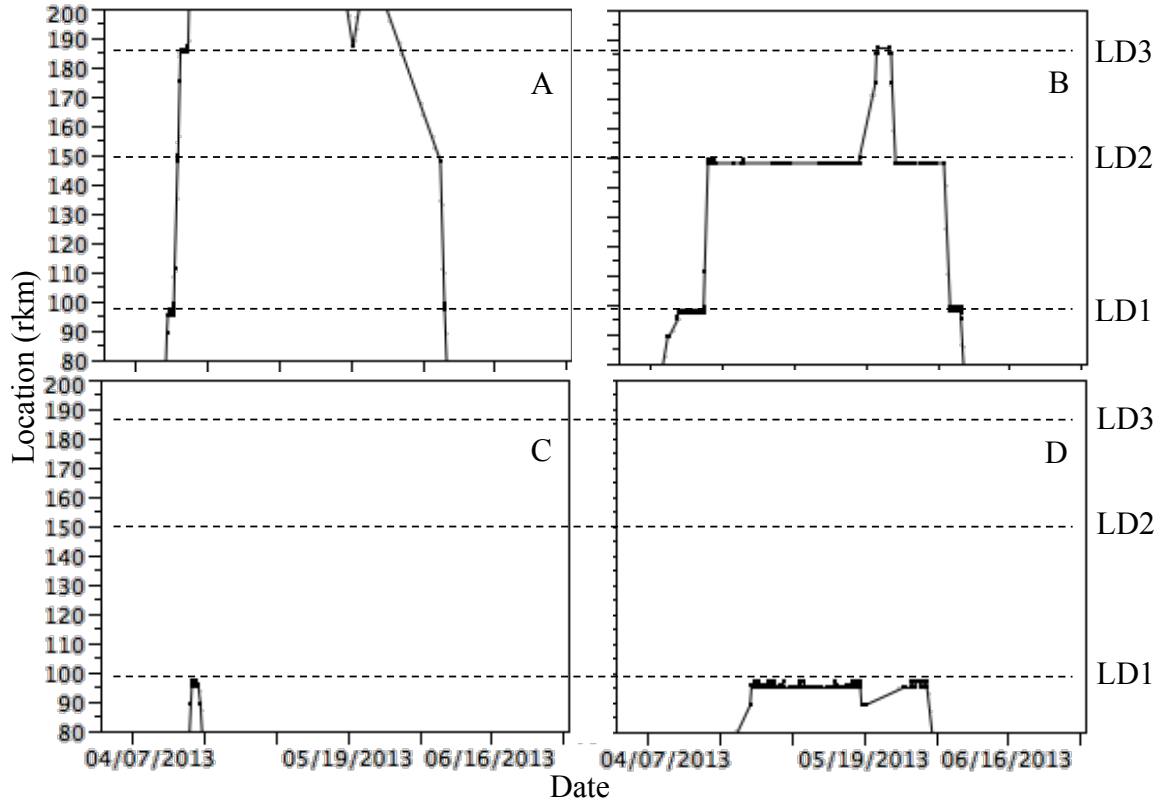


Figure 5. Examples of striped bass passage and behaviors upon reaching lock and dams (LD) on the Cape Fear River in 2013. Certain individuals passed promptly at both the LD-1 rock arch rapids and the LD-2 and LD-3 locks (A) while others appeared to be delayed downstream prior to passing (B). Some individuals reached LD-1 and promptly migrated downstream (C) but others remained near the structure for an extended period of time before migrating downstream (D).

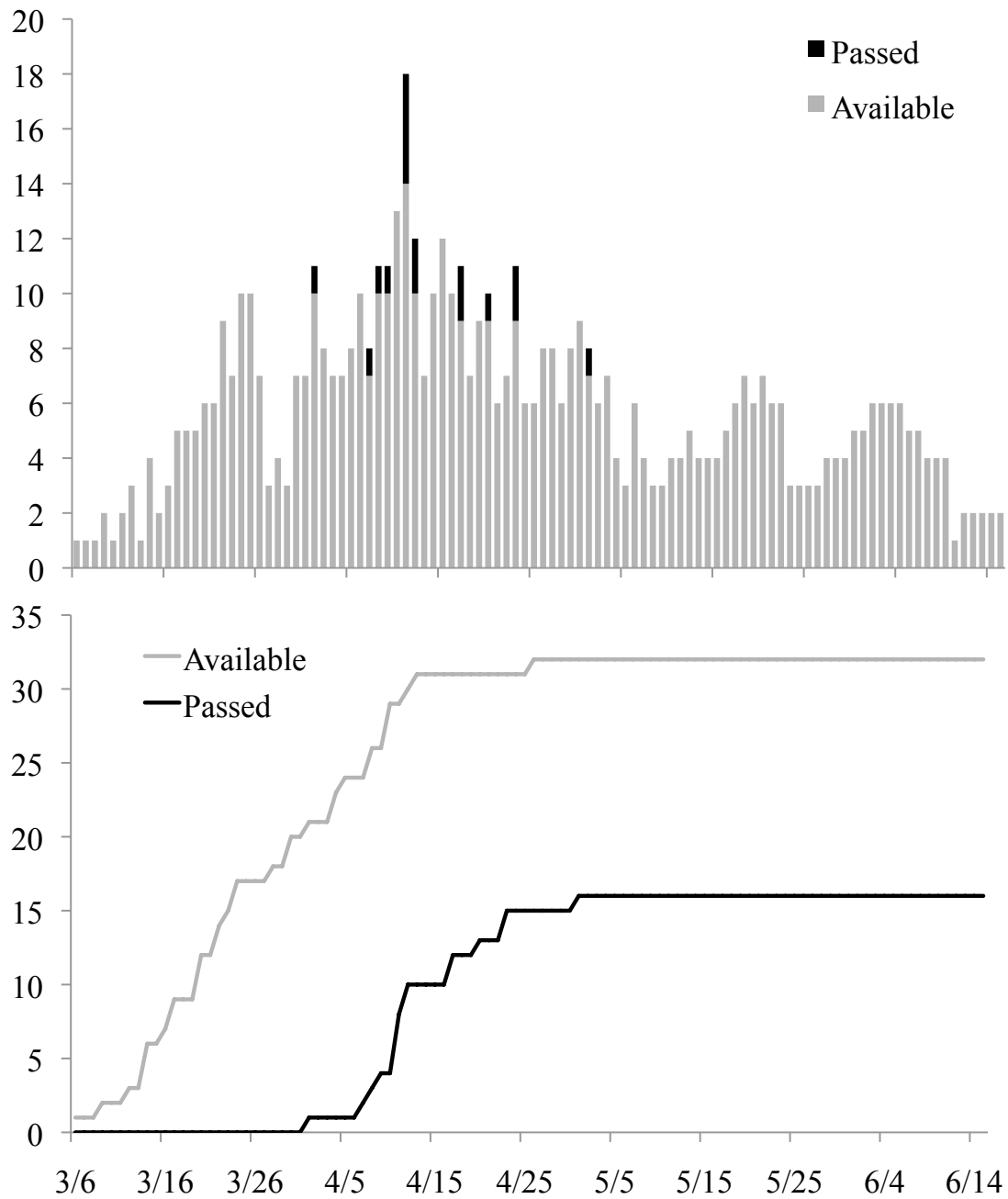


Figure 6. Daily (top) and cumulative (bottom) number of American shad detected immediately downstream (available) and upstream (passed) of LD-1 on the Cape Fear River.

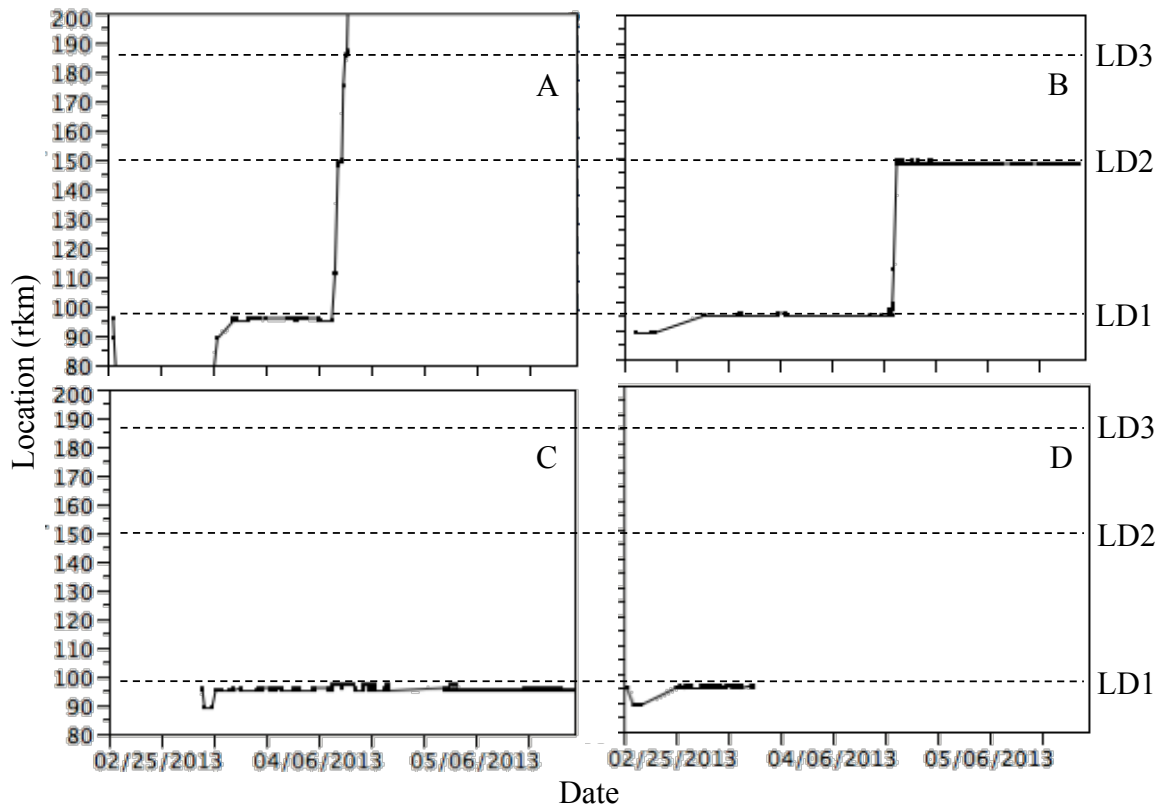


Figure 7. Examples of American shad passage and behaviors upon reaching lock and dams (LD) on the Cape Fear River in 2013. Certain individuals appeared to experience delays at the LD-1 rock arch rapids but passed rapidly at the LD-2 and LD-3 locks (A) while others appeared to be delayed downstream prior to passing at multiple sites (B). Some individuals reached LD-1 and remained near the structure for an extended period (C) but others were downstream of the structure and then no longer detected (D).

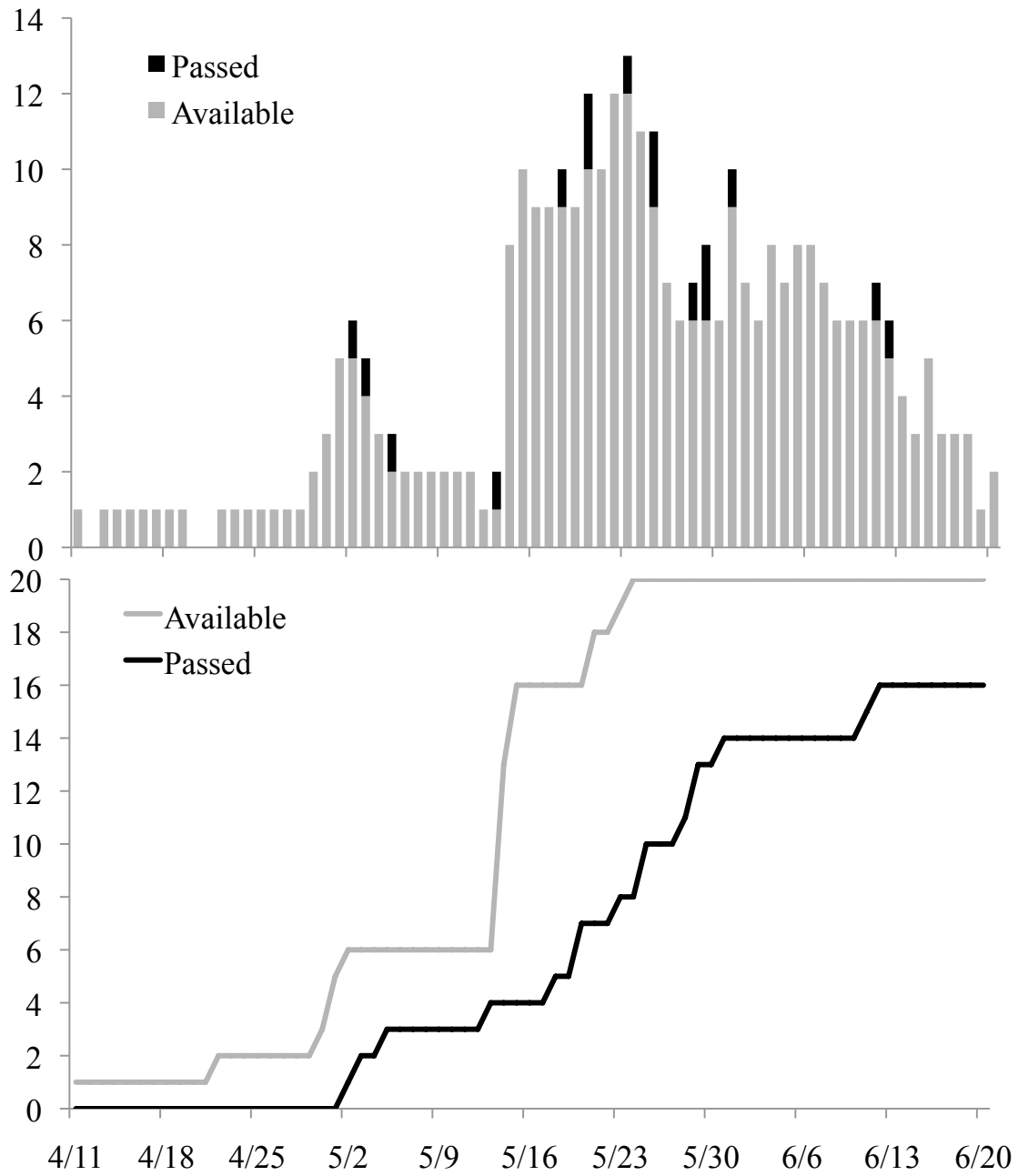


Figure 8. Daily (top) and cumulative (bottom) number of flathead catfish detected immediately downstream (available) and upstream (passed) of LD-1 on the Cape Fear River.

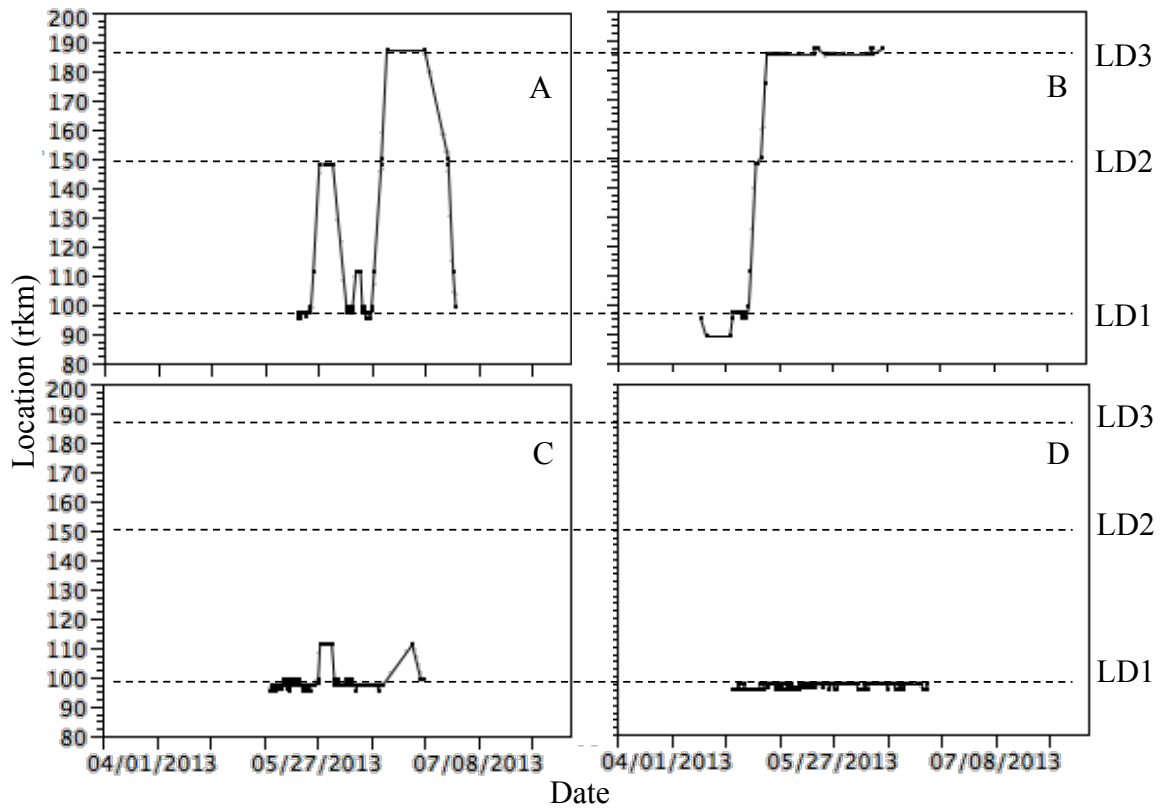


Figure 9. Examples of flathead catfish passage and behaviors upon reaching lock and dams (LD) on the Cape Fear River in 2013. Certain individuals passed promptly at both the LD-1 rock arch rapids and the LD-2 and LD-3 locks (A) while others appeared to be delayed downstream for variable periods prior to passing (B). Some individuals reached LD-1, passed, and then migrated back downstream until passing again (C) but a few individuals remained downstream and never passed (D).