2007

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Introduction

Ensuring passage of native fishes in the pooled portions of the Upper Mississippi River System (UMRS) is necessary for maintaining the ecological integrity of the river and surrounding ecosystems (Holland et al. 1984, Wilcox et al. 2004). Modified management of locks and dams in addition to the construction of fish passage devices at potential barriers will likely improve opportunities for long-range movement of migratory species as well as facilitate local movement of non-migratory fishes (Wilcox et al. 2004). However, improving fish movement by increasing connections between navigation pools also may enhance the ability for invasive fish species such as Asian carps to invade novel reaches (Kolar et al. 2005). Thus, the construction of taxa-selective barriers (e.g., strobes, bubble curtains) at key conduits may be necessary to reduce the rate and extent of movement of these nuisance species while still facilitating the passage of natives (Kolar et al. 2005).

Before fish passage improvements and selective barriers are planned and implemented in the UMRS, a strong understanding, building on existing knowledge (e.g., Holland et al. 1984, Ickes et al. 2001), of the interactions between environmental conditions and fish movement is needed. A baseline by which responses to improvements are measured also is necessary. This report summarizes preliminary results of a prototype monitoring system for fish with surgically implanted ultrasonic transmitters above and below Lock and Dams 19, 22, and 26 of the UMRS as part of a broader project quantifying movement of fishes among Pools 20-26 and continuing through to the open river and the Chain of Rocks canal.

We designed the research primarily around Lock and Dams 22 and 26 to determine how a series of stationary logging hydrophones emplaced in the UMRS could be used to quantify the frequency and extent of movement of common fishes. Further, we could begin to use this system to test the null hypothesis that movement is unaffected by structures. If true, then the distribution of sonically tagged fishes would become fully mixed some time following the initial effort. If false, then fish would not move across the structures, remaining isolated on either side of each. Of course, the final analysis will be more complex given the effects of factors such as river conditions, season, and changing sample size (e.g., as transmitters are added and others expire).

Preliminary Objectives

- Emplace a prototype ultrasonic monitoring array around potential barriers in the UMRS
- Surgically implant common native and non-native fishes with ultrasonic transmitters above and below barriers
- Quantify frequency and extent of movement
- Refine methodology and experimental design

Goals

- Determine the effects of lock and dam complexes on the movement of fishes under differing river conditions
- Set baseline conditions before implementation of fish passage improvements

- Develop framework for basinwide monitoring network for fishes
- Provide management guidance for fishes in the UMRS

Approach

System

The monitoring system currently emplaced in the UMRS, including the open Mississippi River, the Missouri River, and the Illinois River (Figure 1), consists of stationary, data-logging, omnidirectional hydrophones (model VR2, Vemco; Figure 2) that are used to detect individually unique ultrasonic transmitters implanted in fishes. These receivers must be retrieved and downloaded manually. VR2 loggers were initially affixed to navigation buoys with the hydrophone pointing down. To avoid damage or loss due to navigation, ice, flotsam, and vandalism, we began submerging receivers on anchored concrete stands with the hydrophone oriented up. These stands could either be retrieved with a grappling rig (Figure 3) or by using a (far more expensive) Sonardyne acoustic release and pop-up buoy system (Figure 4). The grappling hook rig was lowered to the riverbed near the stand and was dragged until it snagged a retrieval wire between the stand and an anchor (Figure 3). The acoustic release system, which is still present on some receivers, is affixed to the stand and when an acoustic signal is sent to it, it releases a pop-up buoy which rises to the surface and allows the stand to be retrieved (Figure 4). The pop-up system, however, is about twice as costly as the VR2 unit it is used to retrieve.

The submerged concrete bottoms of stands were often buried by shifting bedload. Thus, we modified the stand configuration to consist of a series of rebar legs with the receiver mounted on top (Figure 5). These legs could be easily extracted from the river bed using chain to snag it and a boat-mounted davit and winch to lift it. To date, this modified stand system with either chain and hook grappling system or acoustic release retrieval has worked well, with all protoypes being retrieved successfully.

We also assessed the efficacy of using model VR3 receivers in the river. These receivers can be deployed and downloaded remotely using a surface modem. Two units were deployed in the vicinity of Lock and Dam 22. These units are costly, but reducing the need to retrieve these units would potentially save technical time in the field.

Ultrasonic transmitters that currently are implanted in fish are sized such that they do not typically exceed fish weight in water by 2-3%. River water is circulated over fish gills during surgery. Incisions are made ventrally, anterior to the anal opening. The incision areas are disinfected with betadine. All surgical utensils are sanitized in 70% ethanol. A scalpel and curved hemostats are used to insert the tag and avoid damage to organs. The transmitter is pushed down and away from the incision site to alleviate any added stress on the wound. Incisions are closed with monofilament sutures attached to a curved cutting needle using simple interrupted sutures, as documented by Summerfelt and Smith (1990). The incision and sutures also are sealed with cyanoacrylate resin to prevent infection and to hold the wound and suture knots together securely. Immediately following the surgical procedure, fish are placed in a recovery tank supplemented with oxygen and released after normal swimming occurs.

Locations

We focused our effort on movement above and below Lock and Dam 22 (Figure 6) and Lock and Dam 26 (Figure 7), although we have placed other receivers above and below Lock and Dam 19 (Figure 8) and at Swan Lake in the Illinois River (Figure 9).

During March 2006 at Lock and Dam 22, three receivers were placed above and three below the structure (Figure 6) ensuring full detection at each site. During early October 2006 at Lock and Dam 26, four receivers were installed above and three below the structure (Figure 7). In that same area, another receiver is currently in the Missouri River, one is found in the approach to the shipping canal connected to Lock and Dam 27, and two are present upstream of the Chain of Rocks lowhead dam (Figure 7). Passage occurs when a fish released on one side of the structure is detected on a VR2 receiver on the opposite side. Of course, the fish has to move some distance (typically about 0.5 miles) beyond the structure to be detected. Ultrasonic noise and obstructions from navigation currently prohibit placement of VR2s closer to the structures. Thus, it is possible that fishes only moving a short distance through structures might not be detected.

Fish

To date, fish have been typically captured using either set or drifted 2- and 3-inch gill nets. We began quantifying effort (hours of each set) during fall 2006. A few tags were available during spring 2006 and thus we began implanting them in fish at Lock and Dam 22 during March 2006. We continued tagging as transmitters became available and completed tagging at this site by October 2006. About 25% of fish were tagged and released above the structure; the remainder was tagged below it. We did this with the expectation that any barrier effect would be more likely for fish moving upstream. Thus, we wanted to increase our power to detect upstream movement by increasing our sample size of fish at the downstream location. Target fish were silver carp, paddlefish, shovelnose sturgeon, and white bass. A related project quantifying movement of Asian carps also contributed tags for use in bighead carp. We also conducted pilot work to assess the feasibility of tagging skipjack herring. Survival of skipjack was poor and we decided to explore other options for tracking their movement. Our goal was to initially tag about 5 individuals per species above the structure and 15 individuals per species below the structure.

Tags became available for research at Lock and Dam 26 during October 2006. We sought to capture and tag 45 paddlefish, 45 shovelnose sturgeon, 45 silver carp, 45 white bass, and 45 blue catfish, with 12 individuals per species released above dam and 33 below dam (225 fish total). Blue catfish were included because of their abundance in the vicinity of this structure, their unique benthic life history, and their economic importance. All methods were identical to those at Lock and Dam 22.

Analysis

Because this research is ongoing, formal statistical analysis is not yet possible. However, we do summarize the mean lengths (total or fork, depending on species) and numbers of fish tagged in this report. We also quantify the number of fish detected to date on VR2s and whether passage past a structure occurred. To place results in the context of river stage and perhaps water-level management at dams, we also provide stage data from the Hannibal, Missouri (Lock and Dam 22) and Alton, Illinois (Lock and Dam 26) USGS gages.

Results

Flow was elevated during spring 2006; open river conditions occurred at both structures with the Hannibal gage being elevated due to the high spring flow (Figure 10). Gates were probably open at Lock and Dam 22 during much of this time. With excess water coming from higher reaches, Pool 26 was managed as a tilt, with water being passed through the downstream dam at a faster rate than the upstream dam to reduce water levels in the lower reach, thereby exposing the flood plain and facilitating growth of moist soil vegetation (Figure 10; Garvey et al. 2003). Thus, gates at Lock and Dam 26 also were likely open during much of this time, even though water levels at this gage were relatively low.

Although we did not quantify effort during spring 2006, we expended about 145 net hours at Lock and Dam 22 and 600 hours at Lock and Dam 26 to capture fish for transmitter implantation.

During spring through fall 2006, we successfully captured and implanted transmitters in most of the intended individuals above and below Lock and Dam 22 with the exception of paddlefish, which were rarely caught (Table 1). During spring through early fall 2006, individuals tagged below the structure in Pool 24 were frequently detected on VR2 receivers within that pool (Table 1). Conversely, with the exception of the Asian carps, individuals tagged above the structure in Pool 22 were never detected by receivers in that pool (Table 1). During spring through early fall, only one silver carp and one bighead carp, both tagged in Pool 22 above the dam, moved through the structure; movement occurred during the elevated flow period in spring (Figure 10) and was downstream for both fish. Further, another bighead carp tagged below the structure in Pool 24 was detected at a VR2 in Pool 26 during that spring (Figure 10). Field tests of two remotely downloadable VR3 units determined that they were not feasible for use in river environments. It was impossible to remain in proximity to these units in sufficient time to download the data. We are currently trading these two units with Vemco for several additional VR2 units with wireless downloading capability.

During fall 2006, we succeeded in tagging about two-thirds of the intended fish. Most species were successfully tagged, again with the exception of paddlefish both above and below the structure and white bass below the structure (Table 1). Detection rates were again higher for fish tagged below the dam than above the dam. A silver carp and blue catfish, both tagged in Pool 26 in fall 2006, moved into the open river below the structure shortly after they were tagged (Figure 10).

Sizes within species differed between pools, with individual paddlefish, silver carp, and shovelnose sturgeon being shorter on average at downstream sites (Table 2). Tag lives depend on the size and species of fish. Batteries within tags implanted in Asian carps in spring 2006 at Lock and Dam 22 have expired (Table 3). Tags implanted within white bass at this site will expire before spring 2007 (Table 3).

Although the receiver array cannot provide information about fine-scale individual daily movement, it can provide some information about the average directionality of movement. By first averaging the distance of VR2 detections from the release point for each individual fish and then averaging across individuals at each reach, we generated an average, species-specific distance moved (Table 4). For all fish, net movement was downstream, with the highest average movement being 9.8 miles for bighead carp released in Pool 24 (Table 4). This high average was driven by the one bighead carp that moved from Pool 24 to below Lock and Dam 26.

Summary

With the exception of the VR3 units, the combination of ultrasonic transmitters and submerged VR2 receivers worked well in detecting the downstream movement of fishes. We are unsure why the VR2s above each dam were less likely to detect resident fishes, although there is a chance that these individuals also moved downstream out of the area shortly after tagging. Still, given the high detection rate (66%) below each dam, these fish should have been detected as they moved through the structure and into the adjacent lower reaches. To ensure that the system is working well above each dam, it would be wise to increase the number of receivers deployed both directly above the dams as well as incrementally upstream.

The major obstacle to the receiver system was retrieval and downloading. Retrieval problems appear to have been largely alleviated with the combination of modified submerged stands and a grappling rig. The highest probability of retrieval was ensured by the addition of the acoustic release and pop-up buoy. But the cost may be prohibitive except for the receivers collecting the most critical data (i.e., those near the dams). Download time (> 30 minutes per unit) is burdensome because the current VR2 system has very slow data transfer rates. However, Vemco has overcome this technological limitation; VR2 units manufactured in early 2007 will be equipped with Bluetooth data transfer capability at little extra cost. Thus, as VR2s are either replaced or new ones deployed, the technical time required to download data after retrieval will be curtailed. In summary, the monitoring system is technologically sound and produces multi-species information about movement with little apparent species-specific bias.

At this juncture, it is difficult to render conclusions about species-specific patterns and the impact of the structures and season on movement. Out of 224 fish tagged, only five individuals were detected moving through a lock and dam. All but one of these fishes were non-native Asian carps. Movement was predominately downstream rather than upstream and occurred across short distances for most fishes. A flood pulse did occur during spring. However, most fishes were not tagged until fall when flow was lower, thereby preventing us from determining the impact of water-level operations at dams on fish movement.

We recommend continuing this effort across multiple years to bracket the impact of environmental variability (e.g., temperature and discharge) and water-level management at dams on the movement of these common UMRS fishes. To improve detection rates, we recommend increasing VR2 coverage, particularly above both lock and dam complexes. Due to limited battery life, the transmitters in several fishes have either expired or will expire before spring 2007 when high water and upstream reproductive migrations are anticipated. Thus, it would be beneficial to increase the number of tagged individuals before spring 2007; we will return to Lock and Dam 26 during February through March 2007 to tag the remainder of fishes. It would be instructive to increase our sample size of fishes during this same time at Lock and Dam 22.

We do not know how the dams affect behavior of resident fishes relative to the open river. We recommend emplacing an open river "control" in the Middle Mississippi River near Chester, Illinois. In this system, we would enhance an existing pallid sturgeon VR2 system and implant transmitters in the same complement of common UMRS fishes. From this, the pattern and extent of movement of fishes in this unobstructed system can be compared simultaneously with those counterparts in the pools.

We currently know little about the effect of lock chambers on the passage of fishes. We plan on affixing a VR2 receiver in the lock chamber of Lock and Dam 26 to determine how frequently fish successfully move through this structure.

After some experience with these data, it is clear that statistical analysis of these data will be complex given the changing number of fish at large and their non-random movement within pools and between pools and the open river. We suggest developing a spatially explicit simulation model to predict average movement of fish in the hypothetical absence of the lock and dam structures (or installation of fish ladders). Data from the open river could be used to parameterize this model. From this, a "null model" of movement would be generated for the fishes in the UMRS and compared to the actual observed movement. Significant deviations between the model expectations for position of fishes at any given model time step and the observations could be analyzed statistically using many different methods (i.e., the simplest being a chi square) and would provide insight into the impact of dam operations, season, year, etc. on movement patterns among species.

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Table 1. Number of fish ultrasonically tagged and then later detected by VR2 receivers in Pools 22, 24, 26 and the open river below Lock and Dam 26 Mississippi River.

Pool	Species	Detected	Tagged	Proportion
22	Bighead carp	5	5	1.00
	Paddlefish	0	1	0.00
	Silver carp	4	5	0.80
	Shovelnose sturgeon	0	5	0.00
	White bass	0	5	0.00
24	Bighead carp	4	5	0.80
	Paddlefish	1	1	1.00
	Silver carp	11	15	0.73
	Shovelnose sturgeon	13	19	0.68
	White bass	17	19	0.89
26	Blue catfish	4	12	0.33
	Paddlefish	0	3	0.00
	Silver carp	7	12	0.58
	Shovelnose sturgeon	1	12	0.08
	White bass	1	10	0.10
Open	Blue catfish	15	27	0.56
	Silver carp	17	31	0.55
	Shovelnose sturgeon	22	33	0.67
	White bass	1	4	0.25

Table 2. Mean lengths of species sampled in Pools 22, 24, 26 and the open river below Lock and Dam 26 Mississippi River.

Species	Capture Pool	N	Mean	Std
Bighead carp[a]	22	5	917	69
	24	5	915	95
Blue catfish[a]	26	12	607	63
	Open	27	602	92
Paddlefish[b]	22	1	1219	.
	24	1	1257	.
	26	3	1156	197
Silver carp[a]	22	5	859	47
	24	15	831	145
	26	12	686	60
	Open	32	601	64
Shovelnose sturgeon[b]	22	5	686	13
	24	19	646	54
	26	12	649	37
	Open	33	641	36
White bass[a]	22	5	342	31
	24	19	337	27
	26	10	369	33
	Open	4	351	27

[a]total length (mm)

[b]fork length (mm)

Table 3. Individual fish sampled, surgically tagged, and released in Pools 22, 24, 26 and the open river below Lock and Dam 26 Mississippi River.

Release Location	Species	Release Date	Length	Tag ID	Tag Life	Remaining Tag Life
22	bighead	1-May	940	1011	211	Expired
			950	1012	211	Expired
			853	1014	211	Expired
			1002[a]	1016	211	Expired
			840	1017	211	Expired
	paddle	11-Oct	1219	196	211	164
	shovelnose	24-May	691	1007	366	179
			671	1024	366	179
			699	1026	366	179
			695	1032	366	179
			674	1034	366	179
	silver	29-Mar	790	1006	211	Expired
			901[a]	1013	211	Expired
			903	1015	211	Expired
			840	1019	211	Expired
			860	1020	211	Expired
	whitebass	11-Oct	305	125	130	83
			336	126	130	83
			377	127	130	83
			370	128	130	83
			321	133	130	83
24	bighead	1-May	1007	1010	211	Expired
			950[a]	1018	211	Expired
			990	1025	211	Expired
			800	1027	211	Expired
			830	1029	211	Expired
	paddle	5-Oct	1257	180	211	158
	shovelnose	11-May	735	1005	366	166
			703	1028	366	166
			517	1031	366	166
			694	1033	366	166
			678	1035	366	166
			661	1037	366	166
			650	1038	366	166
			655	1039	366	166
			675	1040	366	166
		12-May	715	1030	366	167
			622	1036	366	167
		2-Oct	588	203	366	310
			609	204	366	310
		3-Oct	620	200	366	311
			598	201	366	311
		4-Oct	638	197	366	312
			612	198	366	312

24 (continued)			700	199	366	312
			596	202	366	312
	silver	22-Apr	820	1001	211	Expired
			960	1002	211	Expired
			845	1003	211	Expired
			860	1004	211	Expired
			923	1008	211	Expired
			940	1009	211	Expired
		25-May	540	1021	211	25
			862	1022	211	25
			605	1023	211	25
			910	1576	211	25
			920	1592	211	25
			920	1596B	211	25
			583	1596D	211	25
			950	1598B	211	25
		2-Oct	.	183	211	155
	whitebass	3-Oct	338	165	130	75
			336	166	130	75
		4-Oct	.	160	130	76
			315	161	130	76
		5-Oct	319	162	130	77
			.	163	130	77
			319	164	130	77
		6-Oct	367	154	130	78
			318	155	130	78
			324	156	130	78
			378	157	130	78
			410	158	130	78
			327	159	130	78
		9-Oct	321	119	130	81
			323	120	130	81
			341	121	130	81
			352	122	130	81
			309	123	130	81
			327	124	130	81
26	bluecf	17-Oct	620	1608	339	298
			640	1609	339	298
			536	1610	339	298
			630	1612	339	298
			619	1614	339	298
			565	1616	339	298
			560	1618	339	298
			579[a]	1619	339	298
		19-Oct	595	1611	339	300
			685	1613	339	300
		20-Oct	738	1615	339	301
			512	1617	339	301
	paddle	19-Oct	1295	1517	211	172
			1016	1565	211	172

26 (continued)			.	1606	211	172
	shovelnose	19-Oct	695	1664	366	327
			690	1670	366	327
		23-Oct	677	1653	366	331
			666	1654	366	331
			630	1655	366	331
			623	1656	366	331
			610	1657	366	331
			624	1658	366	331
			704	1659	366	331
			650	1660	366	331
			593	1661	366	331
			628	1667	366	331
	silver	17-Oct	657	1555	211	170
			656	1556	211	170
			850	1557	211	170
			655	1558	211	170
			660	1560	211	170
			652	1562	211	170
		18-Oct	677	1559	211	171
			649	1561	211	171
			695	1563	211	171
			756	1564	211	171
			657[a]	1566	211	171
		19-Oct	665	1604	211	172
	whitebass	17-Oct	398	1702	130	89
		18-Oct	303	1737	130	90
			331	1742	130	90
		19-Oct	384	1707	130	91
			374	1712	130	91
			392	1732	130	91
		20-Oct	359	1714	130	92
			350	1717	130	92
		24-Oct	408	1731	130	96
			390	1736	130	96
27	bluecf	26-Oct	511	1620	339	307
			633	1621	339	307
			490	1622	339	307
			918	1623	339	307
			508	1649	339	307
		27-Oct	550	1625	339	308
		31-Oct	659	1627	339	312
			787	1629	339	312
			611	1631	339	312
			544	1644	339	312
			541	1646	339	312
			512	1647	339	312
			522	1648	339	312
			610	1651	339	312
		1-Nov	567	1624	339	313

27 (continued)			573	1645	339	313
			537	1650	339	313
			562	1652	339	313
		2-Nov	557	1626	339	314
			622	1628	339	314
		2-Nov	600	1630	339	314
			632	1638	339	314
		2-Nov	686	1640	339	314
		3-Nov	654	1637	339	315
			610	1639	339	315
			583	1641	339	315
			674	1643	339	315
	shovelnose	26-Oct	629	1662	366	334
			655	1663	366	334
			646	1665	366	334
			614	1666	366	334
			625	1668	366	334
			669	1669	366	334
			642	1686	366	334
			659	1689	366	334
			672	1690	366	334
			629	1692	366	334
			624	1693	366	334
			604	1695	366	334
			606	1696	366	334
		31-Oct	643	1671	366	339
			610	1672	366	339
			629	1673	366	339
			635	1674	366	339
			658	1675	366	339
			653	1677	366	339
			656	1678	366	339
			670	1680	366	339
			627	1681	366	339
			578	1683	366	339
			681	1684	366	339
			619	1687	366	339
			622	1691	366	339
			742	1694	366	339
			675	1697	366	339
		1-Nov	716	1676	366	340
			610	1679	366	340
			608	1682	366	340
			679	1685	366	340
			575	1688	366	340
	silver	25-Oct	576	1526	211	178
			568	1528	211	178
			844	1530	211	178
		26-Oct	590	1539	211	179
			595	1540	211	179

		550	1541	211	179
		710	1567	211	179
		698	1568	211	179
		656	1570	211	179
		573	1572	211	179
		568	1574	211	179
		554	1599	211	179
		567	1600	211	179
		575	1601	211	179
		568	1602	211	179
		679	1603	211	179
		543	1605	211	179
		526	1607	211	179
	30-Oct	554	1531	211	183
		563	1533	211	183
		672	1535	211	183
		599	1537	211	183
		668	1542	211	183
	31-Oct	565	1532	211	184
		597	1534	211	184
		564	1536	211	184
		585	1538	211	184
		600	1593	211	184
		566	1595	211	184
		577	1597	211	184
		591	1598D	211	184
	2-Nov	583	1579	211	186
whitebass	26-Oct	367	1721	130	98
		381	1722	130	98
		332	1723	130	98
	2-Nov	325	1727	130	105

[a]moved through structure (see Figure 10)

Table 4. Mean movement (miles upstream or downstream) of species within each point of release within Pools 22, 24, 26 and the open river below Lock and Dam 26 Mississippi River. Negative movement is downstream; positive is upstream.

Pool of Release	Species	Mean	Std	N
22	Bighead carp	-0.06	0.12	5
	Silver carp	-0.03	0.12	4
24	Shovelnose sturgeon	-0.34	1.07	13
	White bass	-1.30	1.51	17
	Bighead carp	-9.80	19.74	4
	Silver carp	-0.48	0.84	11
26	Shovelnose sturgeon	0.00	.	1
	White bass	-0.58	.	1
	Blue catfish	-0.11	0.32	4
	Silver carp	-0.01	0.04	7
Open	Shovelnose sturgeon	-0.13	0.32	22
	Blue catfish	-0.03	0.21	15
	Silver carp	-1.11	4.10	17

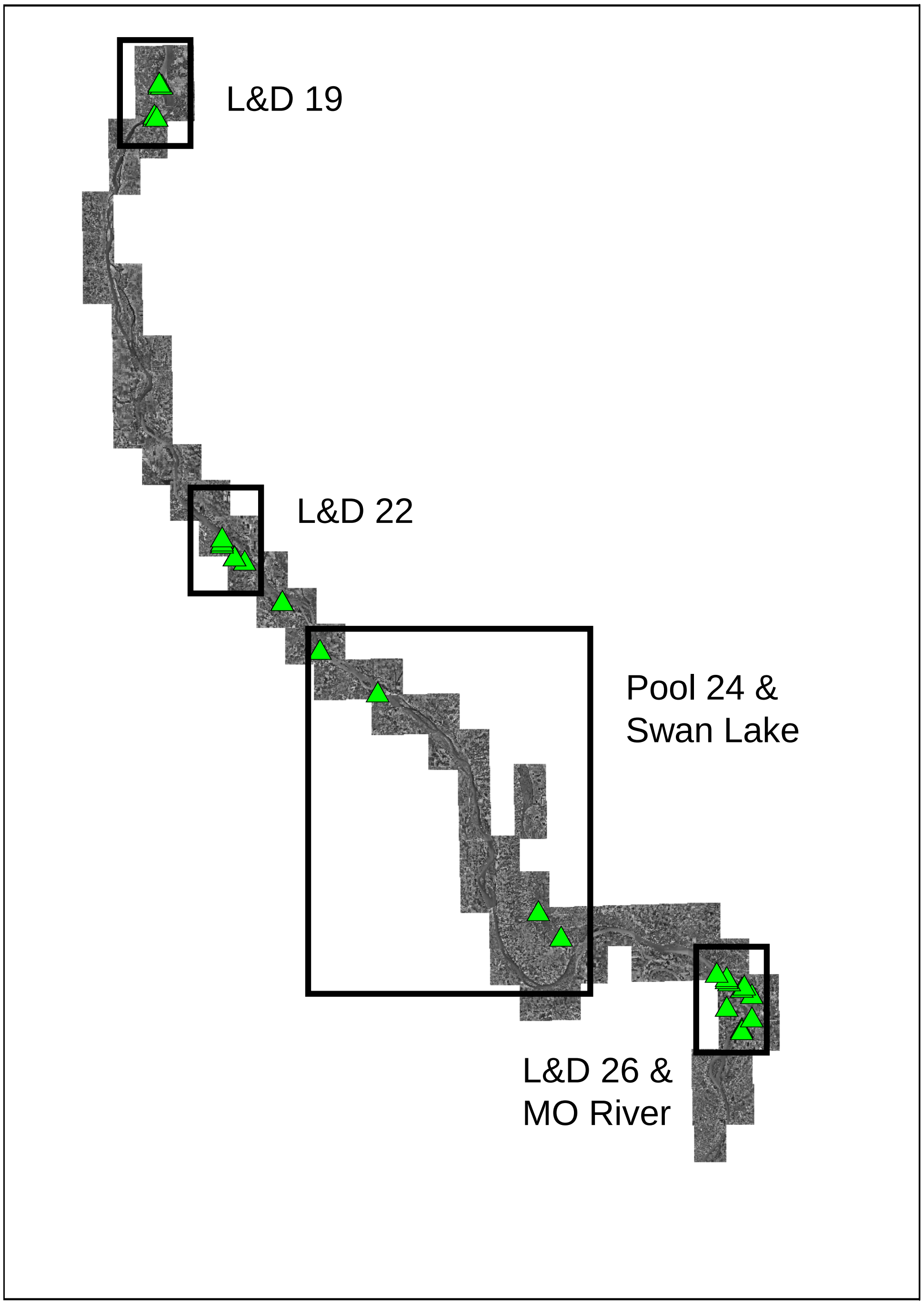


Figure 1. Current locations of the VR2 receivers (green triangles) in the Upper Mississippi River System. Areas in boxes are depicted in other figures.

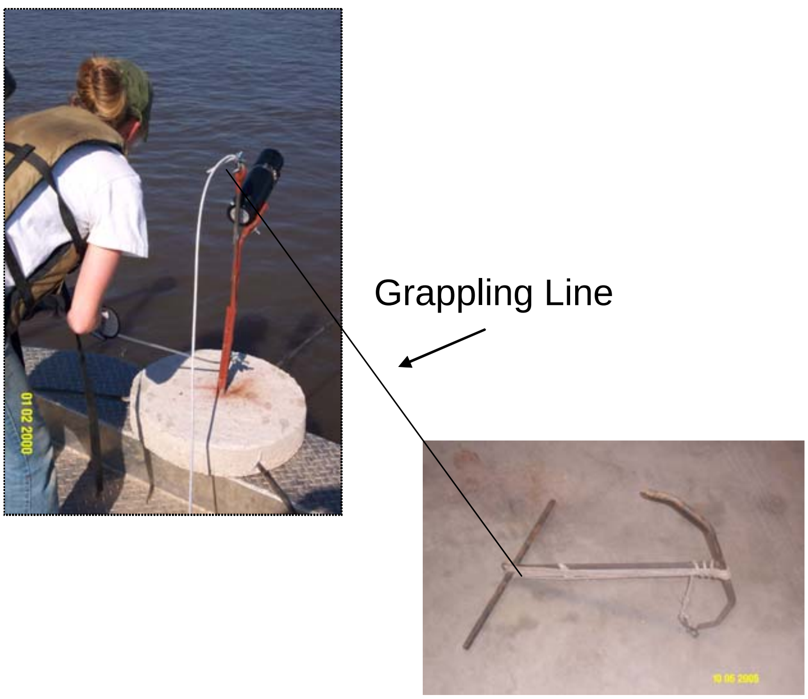


Figure 2. VR2 stationary logging hydrophone (above) and original stand plus anchor (with VR2 attached; below).

Figure 3. Rig used to grapple line between anchor and stand (see Figure 2).

Figure 4. Sonardyne acoustic release system with pop-up buoys.

chain.

Figure 5. Modified stand configuration with VR2 attached and hooks for retrieval with a chain.

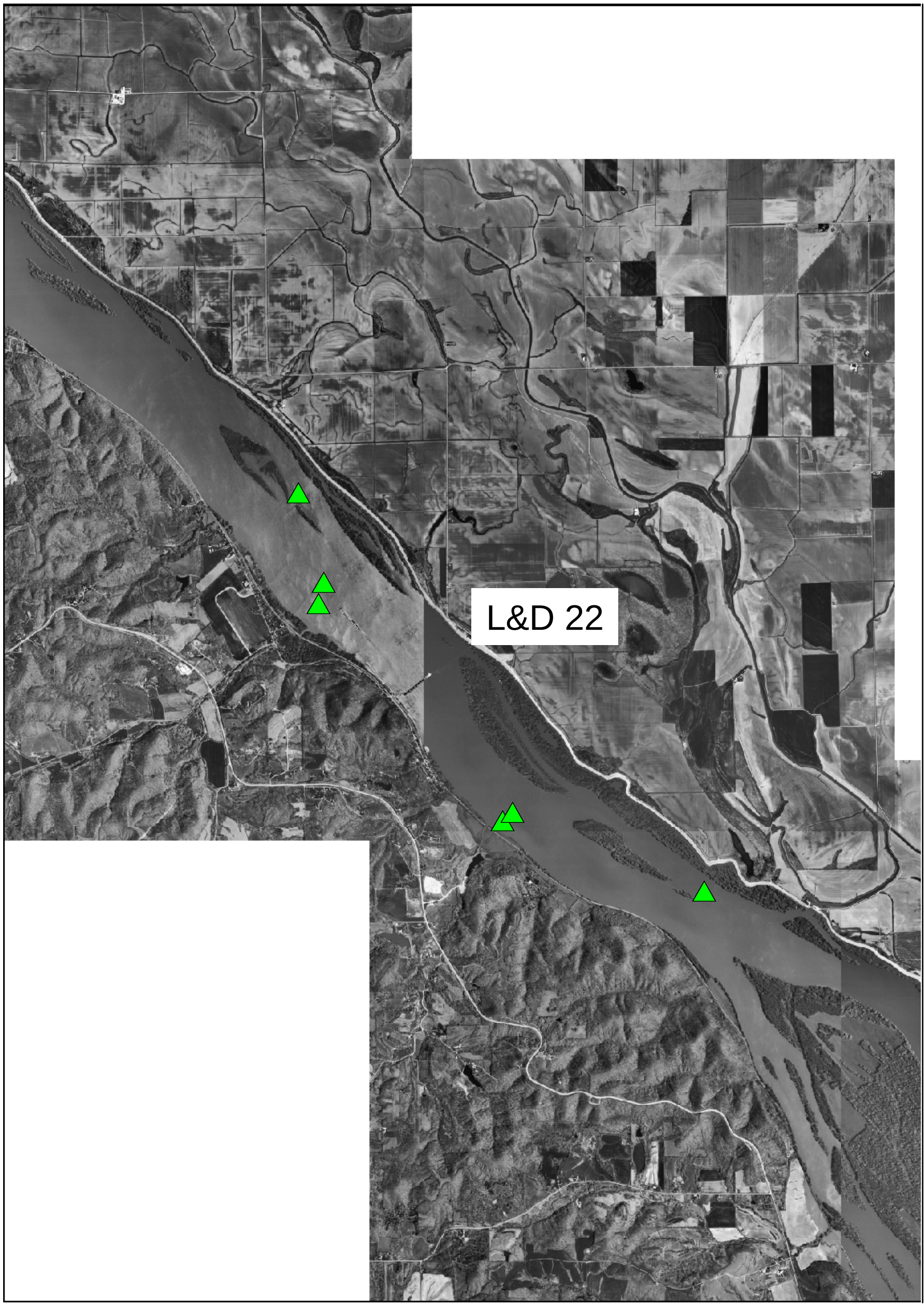


Figure 6. VR2 locations (green triangles) in the vicinity of Lock and Dam 22, Upper Mississippi River.

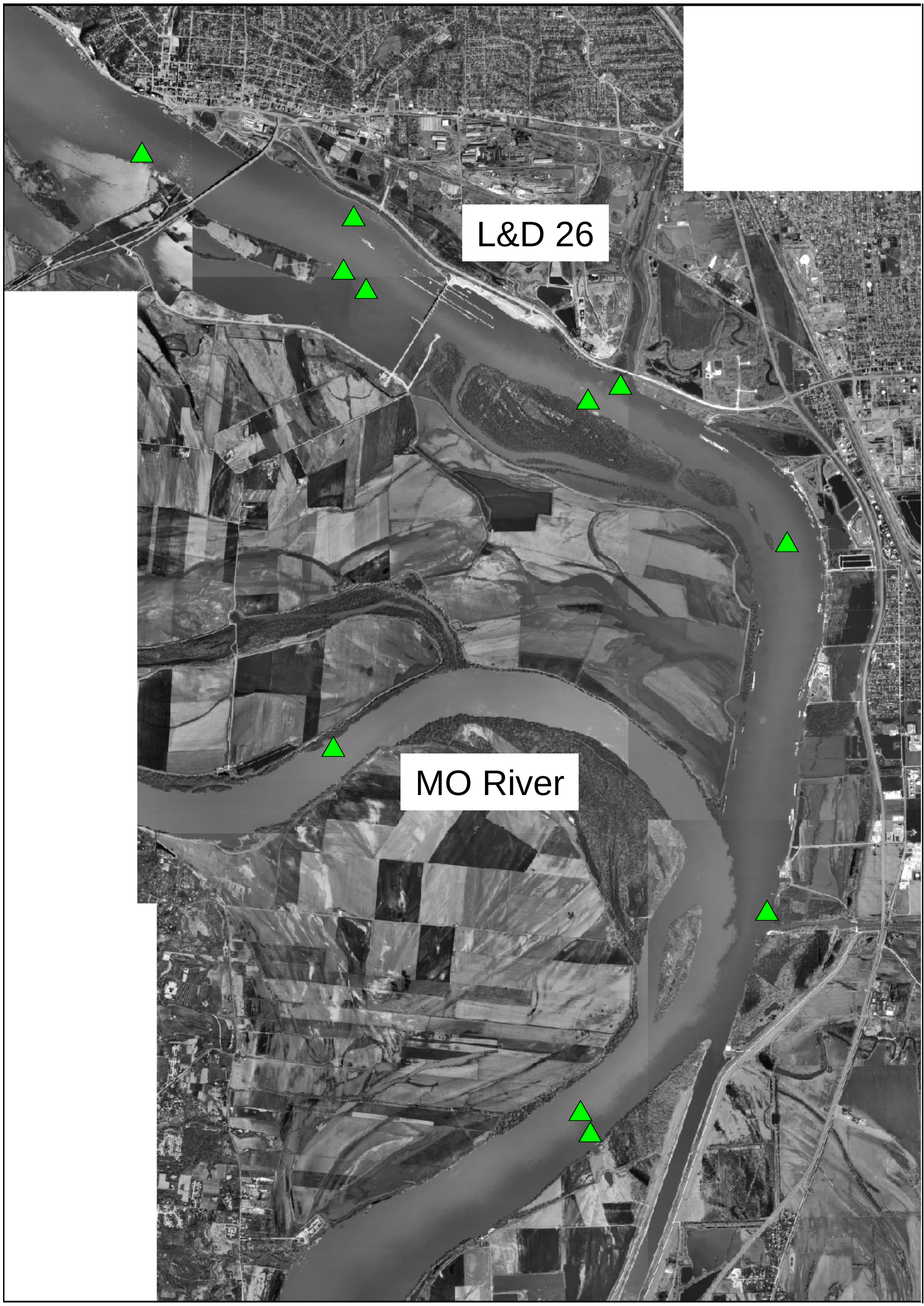


Figure 7. VR2 locations (green triangles) in the vicinity of Lock and Dam 26, Upper Mississippi River.

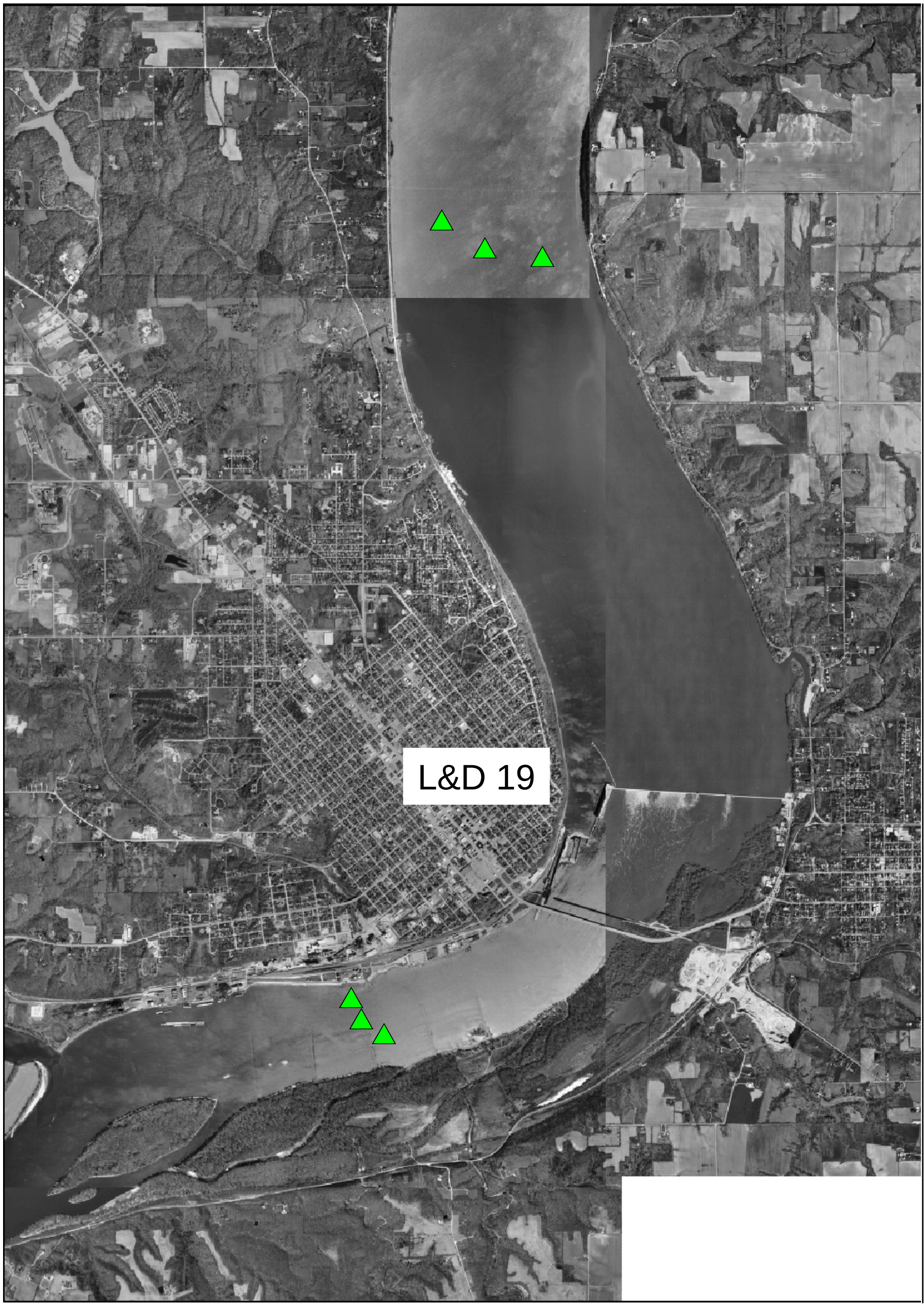
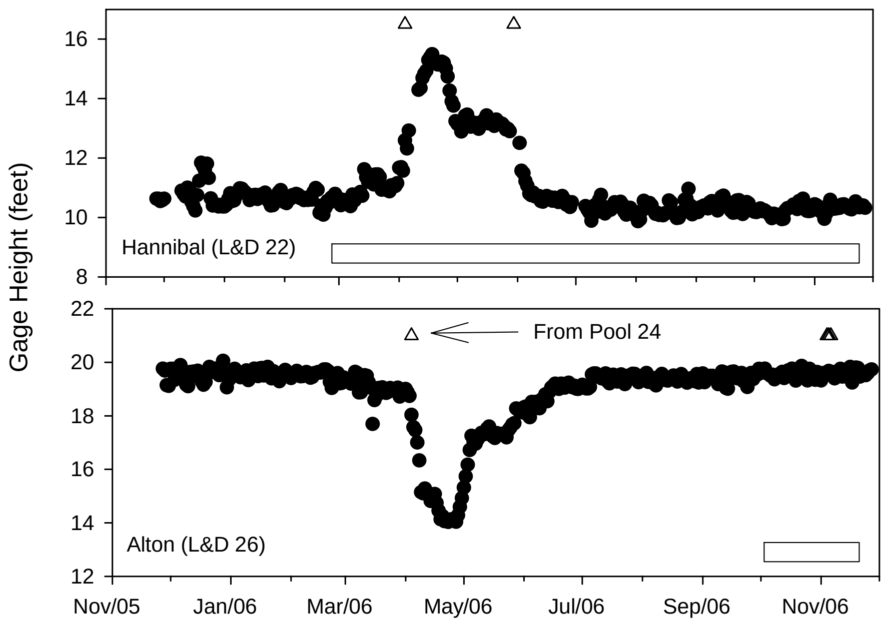


Figure 8. VR2 locations (green triangles) in the vicinity of Lock and Dam 19, Upper Mississippi River.

Figure 9. VR2 locations (green triangles) in the vicinity of Swan Lake, Illinois River.

A.



B.

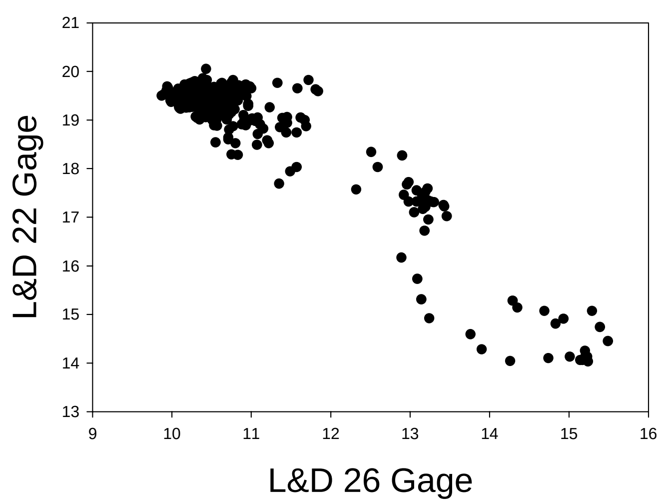


Figure 10. Daily water levels (feet) at the Alton and Hannibal USGS gages during fall 2005 through fall 2006. Panel A: Open triangles on each graph are days when a fish passed through either Lock and Dam 22 (top) or Lock and Dam 26 (bottom). Bars depict when transmittered fish were released and present at each location. Panel B: Relationship between water levels between gages. High water at the gage near Lock and Dam 22 typically occurred concurrently with low water at Lock and Dam 26. Gates were probably near open-river condition at both dams at this time (see text for explanation).