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Lake Champlain
Basin Program

TECHNICAL REPORT NO. 116

Conservation of the Lamoille River Mudpuppy (*Necturus maculosus*) Population Using Translocation and Monitoring (Mudpuppy Translocation)



May 2026

Prepared by: Vermont Fish & Wildlife
Mark Ferguson

For:
The Lake Champlain Basin Program and NEIWPCC

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Executive Summary

The mudpuppy (*Necturus maculosus*) is an aquatic salamander native to lower sections of Lake Champlain tributaries and portions of the lake. Due to concerns for the long-term viability of Vermont populations, the Vermont Fish & Wildlife Department undertook an effort to establish a novel subpopulation in the Lamoille River upstream of the Arrowhead Mtn. Dam. The goals of this project were to: (1) trap and relocate 50 to 150 mudpuppies from the native Lamoille River population and relocate them to the upstream release area; and (2) following their release, track the movements of a subset of these individuals fitted with radio transmitters.

Mudpuppies were trapped in March and April of 2022 and 2023, using wire mesh minnow traps with widened opening and baited with minnows. Twenty-four traps were placed in three separate areas along the south shoreline, with eight traps in each array. Traps were checked every 24 hours, mudpuppies removed, and bait replaced before resetting them back in the river. Captured mudpuppies were measured (weight, total length, snout-to-vent length), implanted with PIT tags if large enough, and photographed before being released at the relocation site. Sex was determined for adults. Eighteen of the animals were implanted with radio transmitters (six in 2022 and twelve in 2023) and released with the others so that their movements could be followed until early December.

Capture/relocations for each year were 114 in 2022 and 20 in 2023 (shortened trapping period) for a total of 134. Catch per unit of effort averaged much higher in 2022 than in 2023. The slightly cooler water temperatures in 2023 may have lowered catch rates, although other natural variables were also likely factors. Within-year catch rate appeared to have been influenced, at least in 2022, by river flow rate and water temperature, with highest catches general occurring when water temperature was 2 – 6^{o}C and following a high flow event. Overall, sex ratio was fairly even (0.47M:0.53F).

Tracking effort began later in 2022 than in 2023 due to the longer first trapping season. Early post-relocation movement was notable and showed considerable variation among individuals in 2023, with some released mudpuppies moving temporarily into both impounded (downstream) and rapid (upstream) waters. The length of river/impoundment occupied by all live mudpuppies combined over this early period was about 1.7 km. This was followed by a period of shorter movements, sometimes both upstream and downstream by the same individual. Individuals that had previously migrated farthest into the impoundment and rapid waters moved back towards the release site. Each animal eventually settled into an area within which little movement was detected until October 25 to November 17, when at least two of the remaining live mudpuppies moved a distance greater than 50 m. Similarly, mudpuppies tagged in 2022 showed no summer movement until September 30 (earliest individual movement). Of the 18 mudpuppies that received transmitters, data indicated that at least seven were still alive at the conclusion of their first tracking season.

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1 Project Introduction

The mudpuppy (*Necturus maculosus*) is considered a rare species in Vermont, with a Natural Heritage conservation status rank of S2 and designation as a high priority Species of Greatest Conservation Need in the Vermont Wildlife Action Plan (Vermont Fish and Wildlife Department 2015). Based on review of available data from the basin, the Vermont Endangered Species Committee indicated concern in 2019 about long-term population viability in Vermont streams as well as interest in ensuring that mudpuppies remain a vital part of the Lake Champlain Basin aquatic fauna. A mudpuppy conservation strategy identified for implementation by the Vermont Fish and Wildlife Department (VFWD) is to establish a separate subpopulation upstream of the known inhabited reach of the Lamoille River. This would provide a "refugium" for the species that is not exposed to stressors that arise downstream and would add resiliency to the overall Lamoille River population. This could also provide a source for restoration if the downstream population suffers a decline in the future.

Most Lake Champlain tributary observations of Mudpuppies (Lamoille, Winooski, Missisquoi, and Poultney rivers) have resulted from post-treatment nontarget mortality surveys of the Lake Champlain sea lamprey control program. Outside of these reports, our understanding of population demographics has been hampered by the difficulties of surveying this species. Early attempts (2001-2004) at capturing mudpuppies with minnow traps in several Lake Champlain tributaries had very limited success (Lyttle and Staats 2002, Lyttle and Staats 2003, Lyttle and Staats 2004). However, minnow traps set in the Lamoille River in the spring of 2006 captured two mudpuppies, while baited hooks set to capture lake sturgeon there in May 2002 caught nine mudpuppies (Lyttle and Staats 2002). These observations indicated the Lamoille population could be larger than those found in other Vermont streams where mudpuppies had been recorded. A University of Vermont (UVM) graduate study was conducted 2008-2010 to assess mudpuppy capture methods and abundance in the Lamoille River. This work validated the use of baited minnow traps during early spring as an effective capture method, with over 160 individuals trapped over two years. This represented a 10-fold greater success rate compared with the 2001-2004 multi-stream Champlain Basin trapping (Chellman 2011; Chellman et al. 2017). Capture rates were highest following precipitation events in spring (late March – early April), during periods of higher river flow when water temperatures were 3 – 6^{o}C.

The goal of the current project was to establish a novel mudpuppy sub-population by trapping and translocating 50 to 150 mudpuppies in 2022-2023 from below Peterson Dam on the Lamoille River and moving them upstream of the Arrowhead Mtn. impoundment. Methods were based on those used in the UVM study (Chellman et al. 2017), with trapping efforts limited to late March – April. This work followed on the heels of a VFWD pilot effort in the spring of 2020, which demonstrated the UVM methodology to be successful with 36 individuals captured in a one-week period. Almost all translocated mudpuppies were marked with passive integrated transponders (PIT tags) so they can be identified during future assessments within the relocation area. This study was not designed to determine the status of the population downstream of Peterson dam. A small tissue sample, however, was collected from the tailfin of each mudpuppy to provide material for any future genetic study within that reach, including estimation of population size. A subset of captured mudpuppies was fitted with radio transmitters prior to release and investigators used telemetry equipment to locate these animals for assessment of survival and movement (Bodinof 2010).

The VFWD Project Manager/QA Officer was responsible for project development and implementation. This included procurement of materials and equipment, preparing for field operations, hiring staff, organizing VFWD volunteers, carrying out fieldwork (trapping, taking measurements, animal care, PIT tagging salamanders, releasing animals, radio tracking), data collection and management, and data analysis. Other VFWD staff assisted with field preparation, trapping, data collection, animal care, radio tracking, and data analysis. A Vermont Center for

Ecostudies biologist performed surgeries for radio transmitter implantation and assisted in one day of radio telemetry.

2 Tasks Completed

Task 1: Develop a QAPP
Objective: Describe quality assurance procedures that will maintain project performance.

A QAPP was completed March 12, 2021, and approved by EPA.

Task 2: Acquire equipment and materials; prepare for radio tagging.
Objective: Prepare equipment and materials for mudpuppy trapping and tagging.

Necessary equipment and materials were acquired to conduct several activities, including mudpuppy trapping, body measurement, PIT tagging, tissue sampling and storage, transport and care of animals, surgical implantation of radio transmitters, and tracking of transmitters. Various preparations of supplies were conducted prior to use, such as separating and freezing bait, testing radio transmitters before implantation, assembling traps, and preparing outdoor holding tanks for mudpuppies.

Task 3. Capture, mark, and relocate mudpuppies.
Objective: Develop a novel population of mudpuppies upstream of Arrowhead Mt. Dam.

Trapping occurred in the springs of 2022 and 2023 to meet or exceed the target number of captured and relocated mudpuppies (minimum 50, maximum 150). A total of 134 individuals were trapped and relocated. All trapping was conducted downstream of Peterson dam. Captured animals were brought back to the Sandbar Wildlife Management Area facilities where there were measured, PIT tagged (if meeting the minimum snout to vent length (SVL) of 150 mm), and photographed. Following processing, mudpuppies were released into the Lamoille River at the relocation area.

Figure 1: Trap location downstream of Peterson dam and release site at bridge at upper end of Arrowhead Mtn. Lake.

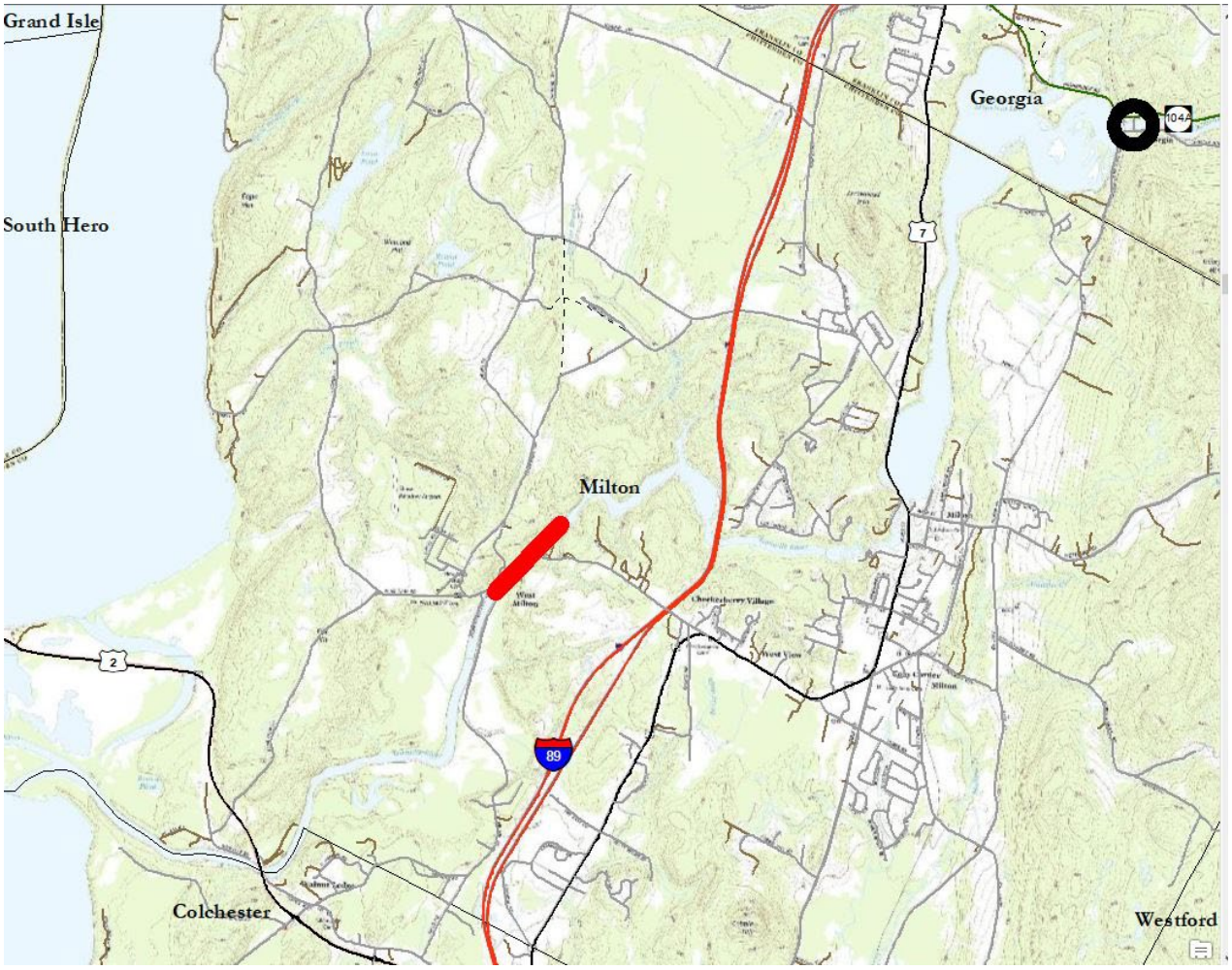

Figure 2: Map of trapping section (red polygon) and relocation site (black circle) on the Lamoille River.

Task 4: Fit a subset of individuals with radio tags.
Objective: Track the movement and survival of individuals after translocation.

Radio transmitters were surgically implanted in 18 mudpuppies during the 2022 and 2023 trapping periods. This was within the range indicated in the workplan (10-20). Post-surgery, these animals were held in captivity until deemed healthy and ready for release by the biologist conducting the implantations. Prior to release, transmitter signals were tested with the receiver to ensure detectability. This was repeated following release at the relocation site. All transmitters were detected.

Figure 3: (a) Mudpuppy in induction solution; (b) surgical implantation procedure; (c) post-surgery outdoor holding tanks.

Task 5: Track movements of radio tagged mudpuppies
Objective: Track movement and survival of individuals after translocation.

Transmitter locations were tracked on approximately a weekly basis during 2022 and 2023 following the end of trapping until river ice began to form in the area occupied by tagged mudpuppies (December). Locations were assessed by kayak, allowing more accurate estimation than triangulation from the streambank. Coordinates were determined using a GPS unit. Observational notes were also taken, such as noticeable change in transmitter position, lack of detection, and description of the area searched. Water temperature, time of detection, and length of search period were also recorded. Survivorship was not directly determined, but assessed based on movement, lack of movement during periods when mudpuppy activity would be expected, and, in some cases, location and other factors.

Task 6: Quarterly and Final report
Objective: Provide quarterly reports and final report on project objectives, study area, methods, photos, maps, and results.

Quarterly reports were produced for the period of October 2020 through June 2024. The draft final project report was submitted on 5/31/2024.

3 Methodology

Trapping
In early spring of 2022 and 2023, 24 baited minnow traps were set in the Lamoille River downstream of the Peterson dam where a population exists. We used the same area as the UVM study (Chellman 2011). A similar pilot trapping project we conducted in 2020 indicated that this was still a successful area for mudpuppy trapping. The 16.5 x 7.5 inches cylindrical traps were made of ¼-inch galvanized steel mesh with an inward-facing conical entrance at each end. These were tied to shore and arranged in three linear arrays, with eight traps per array (Fig. 4). Traps were checked every 48 hours (24 traps x 48 hrs = one trapping event), mudpuppies removed, and fresh bait added before replacing the traps in the river. This provided a maximum of 84 samples per week (24 x 3.5) with zero or more mudpuppies collected in each. The trapping start and end dates were determined based on water temperature, precipitation events, and other factors. Chellman et al. (2017) found that mudpuppy trap success was greatest when water temperatures were 3 – 6°C, accounting for over half their captures, with capture rate declining rapidly above that range and dropping to near zero when above 10°C. Water temperature was monitored near the trapping locations in mid-March 2022 and traps were deployed on March 15 when it rose above 0°C. Trapping in 2023 was initiated on March 18 based on trapping results of 2022, which suggested a slightly later start date could be used. Trapping continued in 2022 through the end of April, when trapping success had dropped to 1.5 mudpuppies per trapping event over a six-event period, and water temperature had risen above 6°C. Trapping in 2023 concluded when there were enough mudpuppies for transmitter implantation and the number of translocated individuals was nearing the workplan's maximum allowance. Ending trapping as early as possible allowed investigators to shift efforts to radio tracking to capture early post-release movements. Data collected and recorded on the standardized form included personnel, dates when traps were set and checked, water temperature at each date, times when first and last traps were reset, observations of precipitation within past 48 hours, gauge flow (obtained from USGS gauge information, https://waterdata.usgs.gov/monitoring-location/04292500/#parameterCode=00065&period=P7D&showMedian=false), and number of mudpuppies captured by each specific trap. See Appendix VI for the field data form.

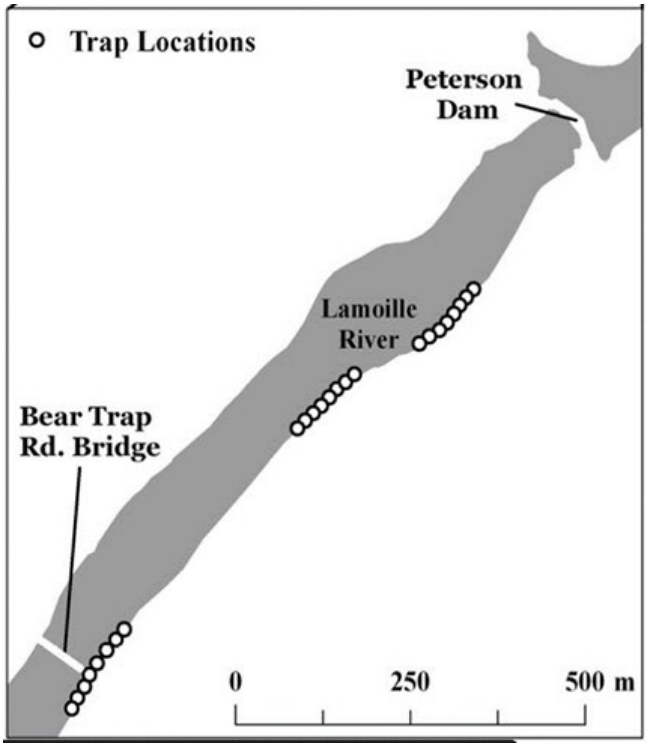

Figure 4: Trap array locations on the Lamoille River, downstream of Peterson Dam.

Mudpuppy data collection

All captured mudpuppies were transferred to five-gallon buckets with fresh water and aerators. After all traps were checked, animals were taken to the Sandbar Wildlife Management Area where data was collected indoors. Information collected and recorded during mudpuppy processing included total body length, SVL, weight, and sex. Lengths were measured to the nearest 5 mm on a wooden board with an embedded meter stick. Weight was recorded to the nearest 5 grams by placing the mudpuppy in a plastic zip-lock bag and hanging this from a handheld spring scale. The scale was tared between measurements. Sex was determined in adult mudpuppies by inspecting the cloaca; in males, the cloaca is conspicuously swollen and has paired papillae at the posterior end through winter and early spring; in females, the cloaca has no evident swelling or papillae (Chellman et al. 2017). The sex of sub-adult mudpuppies could not always be determined. Photographs were taken of each mudpuppy processed. Following data collection, 134-kHz Biomark PIT tags (12.5 mm in length and 2.03 mm in diameter) were injected (Biomark MK25 injector) laterally into the base of the tail on all mudpuppies > 150 mm SVL, following the methodology of Chellman et al. (2017). Each PIT tag has a unique number, which was recorded on the data sheet. These tags will enable easy identification of individuals if they are recaptured in the future (e.g., trapping efforts to assess survival). To accommodate future genetic studies that may arise, a small V-shaped tissue clip (< 0.5 cm2) was removed from the dorsal side of the tail of each mudpuppy using surgical scissors that had been disinfected with a bleach solution, then ethyl alcohol. Each tissue sample was stored individually in 95% ethyl alcohol in a clean 20 mL glass VOA vial with a polypropylene and PTFE lined cap. Each tissue vial included a label with the following information: species, collector, date, preservative, PIT tag number, total length, and water body.

Release

Following data collection and PIT tagging, mudpuppies were translocated the same day to a site at the head of Arrowhead Mtn. Lake where the habitat transitions from riverine to lacustrine. This site has ample rocky habitat, a requirement for mudpuppy shelter and reproduction. Water

temperature was taken during release events. Mudpuppies that received radio transmitters were held an additional day prior to release.

Radio transmitter implantation
A subset of translocated mudpuppies were implanted with radio transmitters (F1170, Advanced Telemetry Systems) for the purpose of tracking their movements within the river following release. Transmitters weighing approximately 4.0 g were only placed in animals weighing greater than 100 g so that the unit represented no more than 5-7% of the body mass, as recommended for tag burden (Dervo et al. 2010). Each tag transmits a signal at a unique frequency, making it identifiable when detected. With pulse rate set at 30 per minute (ppm), the transmitter batteries were rated to last up to 441 days. Transmitters were deployed in both 2022 and 2023, with the goal of using 2022 results to guide the 2023 methodology. All animals were examined for signs of recent trauma or poor health (e.g., open wounds, missing or discolored gills) prior to selection for transmitters. Prior to and after implantation, mudpuppies were held in cold river water in 5-gallon buckets with aerators. In 2022, to reduce potential stress to these animals, we did not inject PIT tags. After observing the excellent recovery of mudpuppies following surgery, we decided to include PIT tagging for those receiving radio transmitters in 2023. Radio transmitter implantation was performed by a wildlife biologist experienced with this procedure for another salamander species. A full description of the transmitter implantation process can be found in reports in Appendix IV.

Tracking
Tracking movements of radio-tagged mudpuppies using telemetry methods began following the end of each trapping season. Tracking was generally conducted about once per week until cold water temperatures began to form surface ice in the search area. We had initially intended to estimate the locations of animals using radio telemetry from the shore or nearby roads, based on direction and strength of signals (triangulation). However, the detectable signal distance in 2022 proved to be much less than expected, often not reaching halfway across the river. Kayaking was quickly added as a way of accessing the signals from all points on the river. This proved a better method than shoreline triangulation, as the strongest signal was easily determined when directly underneath the boat. All the reservoir downstream of the release site was accessible by kayak, as was riverine habitat up to about 0.8 km upstream. Upstream of that reach, another 0.8 km of the north shoreline was walked on several visits when attempting to find missing transmitters. In October 2022, the 10.9-km reach from below Fairfax Falls dam to the downstream point of the routine search area was canoed by two observers to locate signals of missing transmitters. All tracking data was recorded on a standardized form (See Appendix VI). Information collected for each tracking day included date, observers, start and end time of tracking, and water temperature. For each transmitter detected, recorded information included transmitter frequency/channel, time of observation, location of strongest signal, and other pertinent observations (e.g., strength of signal, noticeable change of location). Movement data was reviewed following the end of a tracking season (December) to determine whether each animal was alive or dead on each date of observation. The death of an animal was indicated by one of the following: (1) the transmitter signal originated from a location up on the riverbank; or (2) The transmitter signal moved into an area of the impoundment with no evident flow and there were no signs of movement from subsequent tracking efforts. For one transmitter, observation of a likely predation event provided additional information.

4 Quality Assurance Tasks Completed

The overall goal of the project is to capture 50-150 mudpuppies in the Lamoille River and relocate them above the Arrowhead Mt. Dam and radio-track 10-20 of these animals to evaluate post-relocation survival and movement. The project data-quality objective is to collect and document

data that describes demographic characteristics of captured mudpuppies and the movements of these animals following translocation.

- Field data sheets were fully completed during each day of data collection. Data sheets were unique (one per day) and identifiable by date. The form from each data collection event was reviewed at the end of that field day for completeness and correctness.
- After specimen data were entered into an Excel database, length and weight data were checked for accuracy using the original data sheets.
- For tissue samples, data fields were pre-printed on the labels to be included in the tissue vials to ensure all required information was recorded and stored with the sample. Each tissue sample (one per mudpuppy) was taken, the label filled out, and both placed in a new vial with ethanol and a lid before data collection began for the next mudpuppy. This ensured that tissue sample information was for the mudpuppy being processed and there was no unintended mixing of the labels or tissue samples.
- Each PIT tag was scanned prior to injection and that unique identification number recorded on the same data sheet as the body measurements. Following injection, the tag was again scanned while in the mudpuppy to ensure it is detected and matches the recorded number.
- After being entered into an Excel spreadsheet, radio-tracking data was checked against the original datasheets. Tracking data was mapped and inspected for location accuracy.
- When three transmitters were not detected in 2022, efforts were made to find these tags by canoeing an additional 9.0 km of river upstream of the release site.
- Personnel were trained in trapping, data collection, and radio-tracking methods to ensure consistency.
- All data were recorded on standardized forms developed for this project. Each data sheet is uniquely identifiable by date. No information was recorded for tissue sampling other than on labels, but this information will not be used in the current study.
- Radio transmitter channel and signal frequency were recorded on the same data sheet as trapping, morphometric, and PIT-tag information. Tracking data, recorded on a separate form, could thus be linked with other data for an individual.
- All datasheets were scanned (.pdf) at the end of each field day; original paper copies were filed in a cabinet in the Project Manager’s office. Scanned copies are stored on a laptop computer and a government network system, which is backed up daily. Excel spreadsheets are stored on the same laptop and network system. Data storage on the Vermont government network system will be permanent.
- Inspection and maintenance of all equipment was conducted in accordance with manufacturer instructions. Regular maintenance and testing for some equipment was part of the daily protocol. For example, traps were inspected for damage prior to being set in the river each day and the spring scale was tared between measurements. A malfunctioning thermometer was immediately replaced.
- Traps and other equipment were only used for this project on the Lamoille River during the project period. All equipment had a drying period of several months prior to and following each field season to prevent the spread of invasive aquatic species. The kayak used for telemetry work was checked carefully for presence of aquatic invasive species prior to and following use on the river and its use was restricted to the relocation area for the duration of the project.

- The VFWD Project Manager is responsible for organization and oversight of data generation, processing, and storage so that the data will be documented, accessible and secure for the foreseeable time period of its use.
- LCBP Project Officer, Meg Modley, conducted a quality assurance check in the field on March 21, 2022.

5 Deliverables Completed

Table 1: List of project deliverables and dates of completion.

Task Title	Objective	Deliverable	Date Completed
Develop a QAPP	Describe quality assurance procedures that will maintain project performance.	Approved QAPP	March 2021
Acquire equipment and materials; prepare for radio-tagging	Prepare equipment and materials for mudpuppy trapping and tagging.	List of equipment obtained (photos), documentation of trapping and tagging team training and expertise to ensure readiness for radio-tagging	March 2022 March 2023
Capture, mark, and relocate mudpuppies	Develop a novel population of mudpuppies upstream of Arrowhead Mt. Dam.	Relocate 50 to 150 mudpuppies; capture attempts type, date, results and photos; marking description and photographs	April 2022 April 2023
Fit a subset of individuals with radio-tags	Track the movement and survival of individuals after translocation.	Documentation of # of mudpuppies radio-tagged, description of process and photographs. Positive detection of location and movement of mudpuppies	March 2022 April 2023
Track movements of radio-tagged mudpuppies	Track movement and survival of individuals after translocation.	Successful detection of radio-tagged mudpuppies using telemetry methods; maps of detection and movement over time	December 2022 April 2024
Quarterly and Final report	Provide quarterly reports and final report on project objectives, study area, methods, photos, maps, and results.	Quarterly and final reports	May 2024

Equipment and materials

Table 2 provides a list of necessary supplies either purchased or already available for use. Photos are provided in Appendix I.

Trapping	**Measurement**	**Tissue Sampling**	**Surgery**
Crayfish traps	Weighing scale	Surgical scissors	Sterile saline solution
Bait canisters	Metric measuring board	Sterile disposable gloves	MS-222
Rope	Holding tub	Vials	Chlorhexidine wipes
Bait - golden shiners		Alcohol wipes	Fine surgical scissors
Dip nets	**PIT tagging**	Ethanol	Probes
Boat hook	PIT tags	Bleach	Needle clamps
Thermometer	Injectors	Tweezers	Scalpels
Data sheets	Tag reader	Plastic trays	Absorbable sutures
GPS unit	Towels		Non-absorbable sutures
Basic tools		**Tracking**	Forceps
Hand warmers	**Transport**	ATS R410 radio receiver	Oxygen tank and aerator
Ice cleats	5-gallon buckets	3-element antenna	Holding tank
Flotation with rope	Aerators	Headphones	Radio transmitters
Measuring tape	Batteries	GPS unit	Flat scale
		Compass	Gauze pads
		Kayak and paddle	Chlorhexidine solution
		Life vest	Spatula
			Shelf liner for bedding
Other minor supplies were also purchased or available to facilitate tasks including, but not limited to, waterproof paper for data forms, a camera for taking photographs, and plastic bags/containers for conducting measurements.			

Table 2: Equipment and supplies listed by task. Some items served more than one use.

Trapping and Relocation

2022

Traps were first set on March 15, with water temperature at 0.5°C. All 24 traps remained active until they were removed from the river on April 30 (6.0°C). Accounting for traps that came open while deployed (= not set), this resulted in 545 trap sets during 23 trapping events. Only three traps caught no mudpuppies throughout the season. Two of these were located in the upstream array closest to Peterson dam, while the third was within the middle array (Fig. 4). The highest catch per unit effort (CPUE = number of mudpuppies caught/number of trap sets) for a single trap was 0.783 (n=18), while the lowest non-zero value was 0.043 (n=1). The greatest capture success by far was seen in the most downstream array (8 traps in each array), with an average CPUE of 0.35, more than twice that of the other two arrays combined. The most upstream array produced the fewest captures. Only two trapping events resulted in zero captures, one of which

was the final day. The average CPUE for all traps combined was 0.214. Captures and CPUE for individual traps from 2022 and 2023 are provided in Appendices II(a) and (b).

Captures increased dramatically when an increase in river flow rate coincided with the water temperature rising from 0.5 to 2.0°C. Over six mudpuppies were captured daily for five consecutive trapping events under these conditions from March 21-29, totaling 60 animals. The greatest CPUE (> 0.20) for all traps combined were observed when water temperatures were about 2 – 6°C (Table 3). A second peak in captures (n=17) was seen later in the season (April 10) when flows peaked again and the water temperature dropped (Fig. 5, Appendix II(a)). Towards late April, however, even increased flow rate and dropping water temperatures did not trigger an increase in captures.

	2022			2023			Both		
Water temp	**Mudpups**	**Checks**	**CPUE**	**Mudpups**	**Checks**	**CPUE**	**Mudpups**	**Checks**	**CPUE**
33	7	47	0.149				7	47	0.149
34				2	47	0.043	2	47	0.043
36	**41**	**94**	**0.436**	2	48	0.042	**43**	**142**	**0.303**
37				1	23	0.043	1	23	0.043
38	19	48	0.396	**12**	**72**	**0.167**	31	120	0.258
40	16	71	0.225	3	23	0.13	19	94	0.202
41	6	24	0.25				6	24	0.25
42	10	47	0.213				10	47	0.213
43	5	70	0.071				5	70	0.071
44	2	24	0.083				2	24	0.083
45	3	24	0.125				3	24	0.125
46	3	24	0.125				3	24	0.125
47	1	24	0.042				1	24	0.042
48	2	24	0.083				2	24	0.083
All	117	545	0.215	20	213	0.094	137	758	0.181

Table 3: Catch per unit effort by water temperature.

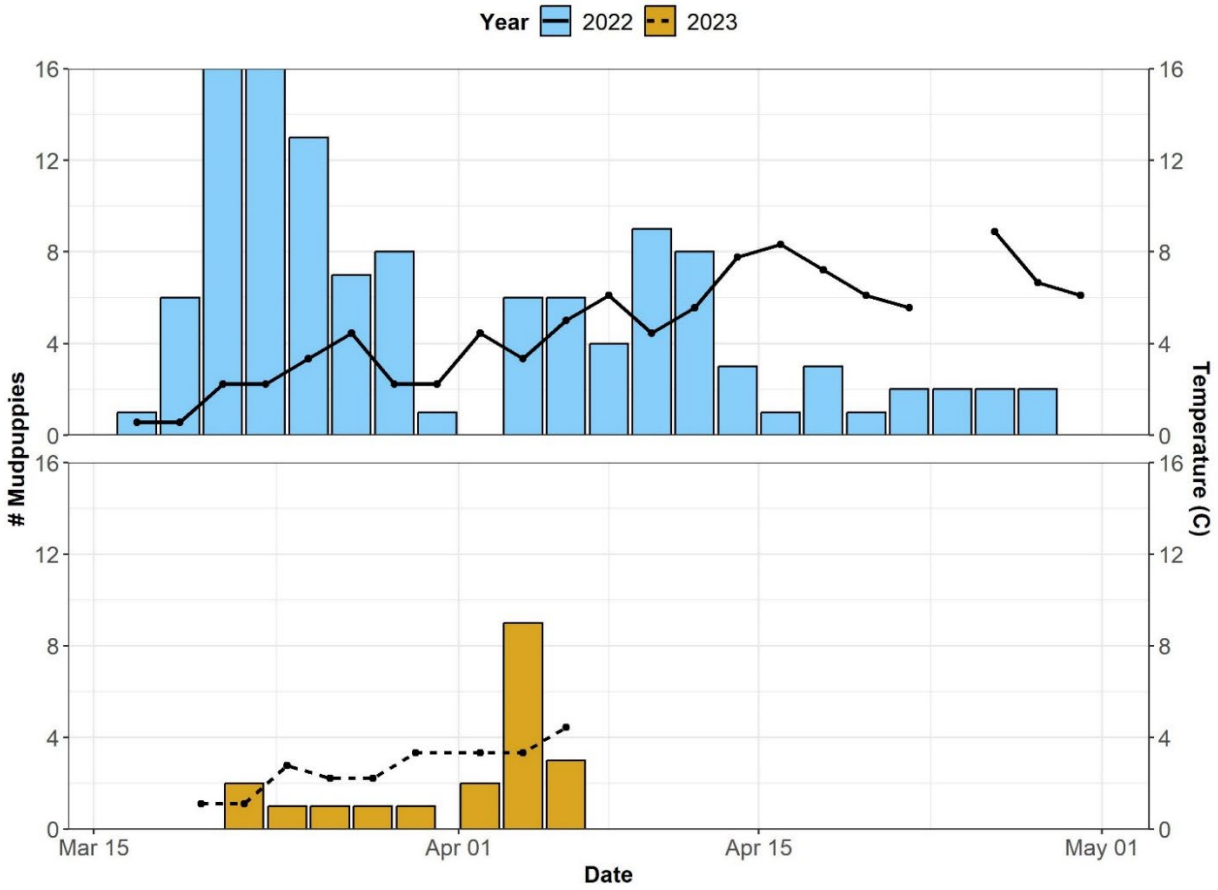

Figure 5: Mudpuppy captures in 2022 and 2023 by date with temperature data.

Through the trapping period, a total of 117 mudpuppies were captured and 114 of these later relocated to the release site. Three mudpuppies that were left in a trap on March 27 for later radio transmitter implantation escaped. The minimum target number to be relocated (50) was reached by the fifth trapping event (March 25). Of the total captured and relocated, 52 were male, 53 were female, and nine were either juvenile or too small for us to be certain of sex. Body measurements and related data for both years are provided in Appendix III. Size and weight values by sex were similar (both years combined) (Figures 6 and 7). Male SVL ranged 155 to 250 mm ($\bar{x}$ = 209.3 mm, SD = 20.3 mm) and weight ranged 55 to 205 g ($\bar{x}$ = 136.6 g, SD = 34.4 g). Female SVL was 155 to 265 mm ($\bar{x}$ = 206.6 mm, SD = 21.8 mm), and weight ranged 75 to 260 g ($\bar{x}$ = 131.9 g, SD = 39.8 g). The nine juveniles had SVL of 145 to 175 mm ($\bar{x}$ = 157.8 mm, SD = 10.6 mm), and weights of 45 to 85 g ($\bar{x}$ = 62.2 g, SD = 13.0 g). For all mudpuppies, SVL ranged 145 to 265 mm ($\bar{x}$ = 204.0 mm, SD = 24.5 mm) and weight ranged 45 to 260 g ($\bar{x}$ = 128.6 g, SD = 40.8 g).

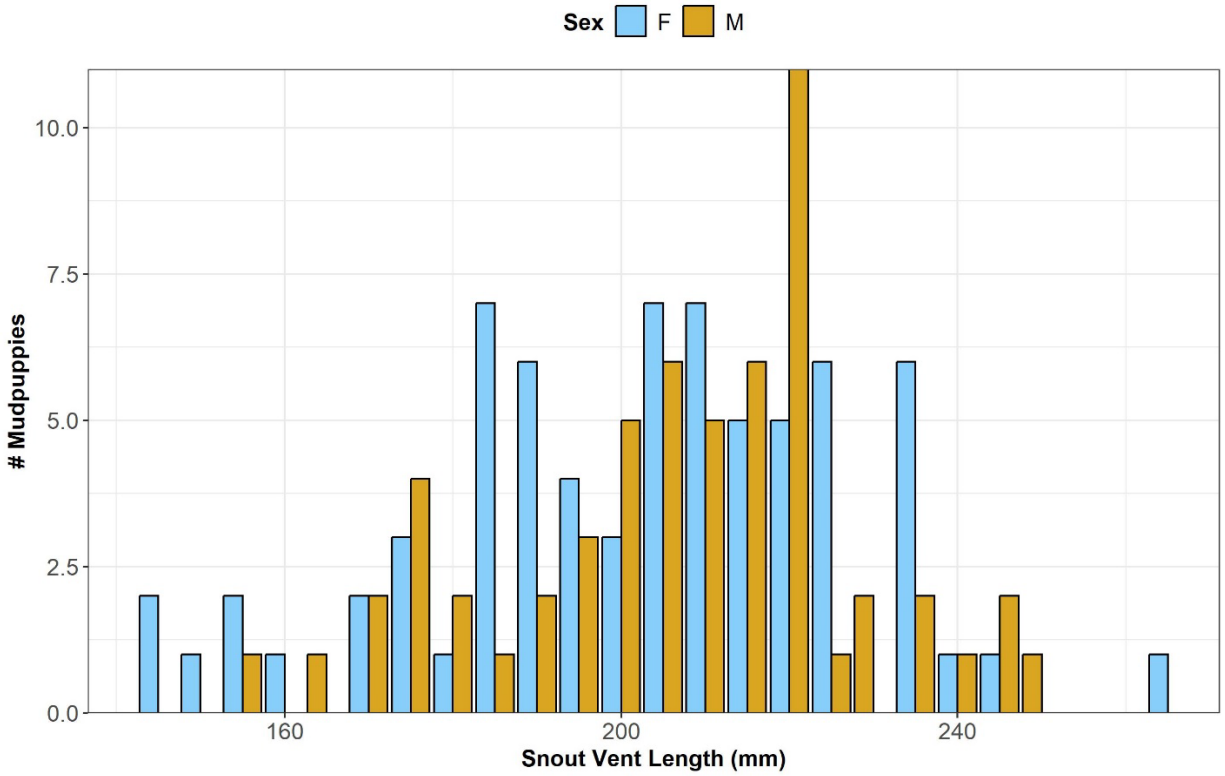

Figure 6: Distribution of mudpuppy catch by sex and SVL.

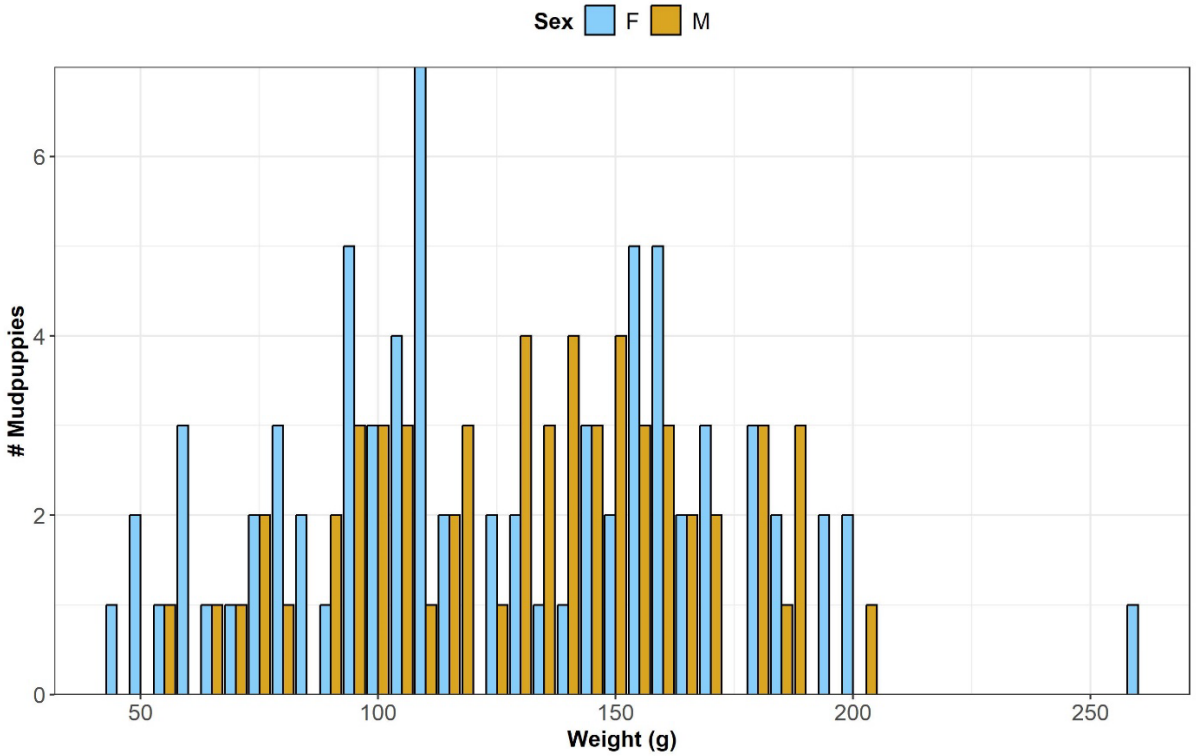

Figure 7: Distribution of mudpuppy catch by sex and weight.

2023

The maximum number of animals to be translocated in this project was set at 150, 114 of which were captured in 2022. To accommodate our interest in beginning tracking of radio-tagged

individuals as soon as possible, the 2023 trapping season focused on obtaining mudpuppies for transmitters and was much shorter in duration than that of 2022. Traps were first set on March 18 (water temperature 1.0°C) and removed from the river on April 6, for a total of nine trapping events (214 trap sets). Twenty mudpuppies were captured, after which trapping ended and tracking efforts began. The total number of captures for the two years combined was 134.

Trapping success during the early part of the 2023 season was drastically lower than that experienced in early 2022. Only 11 mudpuppies were captured in the six trapping events of March of 2023 (CPUE = 0.042), while 61 (CPUE = 0.433) were captured during the same date range in 2022 (Table 3). The capture rate may have been affected by cooler water temperature during this period compared to 2022 (Fig. 5). Shelf ice along the banks persisted in March 2023, something we did not observe in 2022. The average temperature during the six late-March trapping events was 2.8°C (SD = 1.1°C) in 2022 but only 2.0°C (SD = 0.8°C) in 2023, almost a degree Celsius lower. Given that Chellman et al. (2017) found trapping was most effective between 3 and 6°C, this difference could have affected overall captures. The relationships of water temperature and flow to different capture rates were not apparent in 2023 due to overall low daily captures, with nine of the 20 mudpuppies caught on a single date.

Of the total captured in 2023, five were male, 11 were female, and four were either juvenile or too small to be certain of sex. Total length for all captured individuals ranged 205 – 330 mm ($\bar{x}$ = 282.8 mm, SD = 33.9 mm), SVL ranged 145 to 235 mm ($\bar{x}$ = 193.0 mm, SD = 26.0 mm), and weight ranged 55 to 195 g ($\bar{x}$ = 130.5 g, SD = 41.6 g). Means were not calculated by sex or maturity due to the small sample size.

Radio-tagging

Transmitters were implanted in six mudpuppies on March 30, 2022 (four males, two females) and in 12 more on March 29 and April 5, 2023 (four males, eight females) for a total of 18 transmitters released at the relocation site (Appendix III). We attempted to tag both sexes each year, with size and availability affecting the resulting sex ratio of these animals. The average size was expectedly greater than that of all captured mudpuppies since there was a minimum body weight requirement for implantation. SVL averaged 210.6 mm (SD = 19.8 mm) and weight averaged 147.8 g (SD = 29.6 g). All implantations appeared to be successful prior to release, with no signs of reduced health or fitness. For a complete account of the radio-tagging procedure, see Appendix IV.

Tracking by Telemetry

2022 transmitter tracking

Tracking of the six radio-tagged mudpuppies was initiated on June 29 and continued on an approximate weekly basis (range of 5 – 9 days between visits for consecutive weeks) to December 5. There were six missing visits during July – September due to personnel availability or weather/river conditions. Search effort was concentrated on a 2.1-km reach of river and impoundment (0.8 km upstream and 1.3 km downstream of release site) during routine visits, as this could all be accessed by kayak. Additional efforts were made on two September dates to find missing transmitters in the 0.8-km stretch upstream of the kayaked area. An extensive search to locate missing transmitters was conducted on October 25, 2022, by canoeing the 10.9-km reach from Fairfax Falls downstream to the downstream point of the routine search area (Fig. 8).

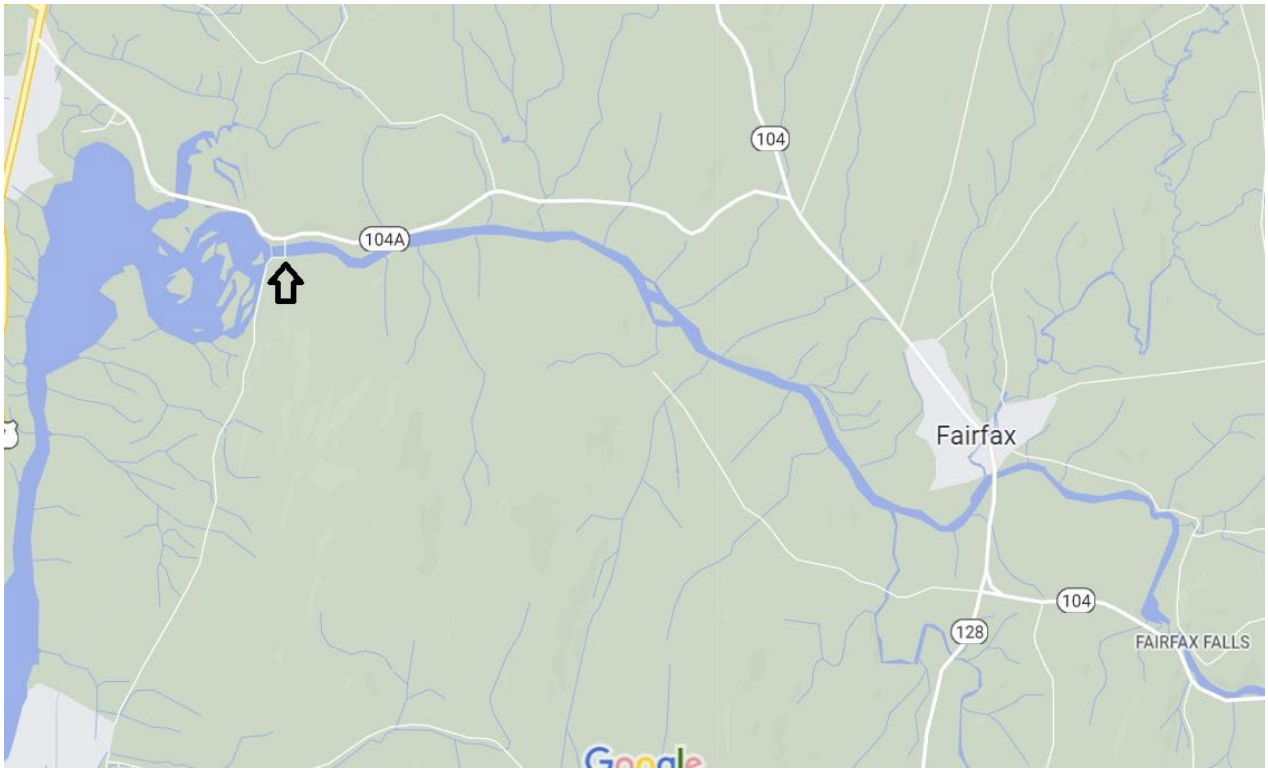

Figure 8: Reach of Lamoille River canoed on October 25, 2022 in attempt to locate missing transmitters. The dark arrow indicates the release site. Canoed reach began at Fairfax Falls just downstream of the dam.

Transmitters #01, #02, and #03 (all males) were detected in the first week of tracking. None of the other three transmitters (#00, #04, #05) were detected through the 2022 tracking season. While releasing additional radio-tagged mudpuppies on March 30, 2023, #02 was detected from the bank at the release site, near where it had last been observed. Subsequent efforts in 2023 (April 13 and 20) to find all six radio-tagged animals from 2022 were unsuccessful. This was 379 days since implantation, which is within the estimated 441-day battery life of transmitters. The product information page notes, however, that factors other than battery capacity may reduce life. Whether the transmitters were no longer within the search area or the batteries died is unknown.

No movement during summer months (June 29 through September 15) were detected. This was not unexpected, as trapping success and the species' activity have been reported to decrease during warmer times of the year (Bilak and Whiles 2021, Chellman et al. 2017). First observation of movement from summer locations occurred for mudpuppies #01 and #03 on September 30, when water temperature had dropped below 15°C for the first time in the tracking season. This also followed a September 18-28 rainy period which caused flow rates to increase dramatically, as high as about 5000 cubic feet per second (cfs) on the 20th (normal flow ~400 cfs). This raised the river level 3+ feet above normal. Chellman et al. (2017) reported much higher capture rates (also using minnow traps) following significant precipitation events, which also indicates greater mudpuppy activity. Based on observations of movements, #01, #02, and #03 were all considered to be alive through the last 2022 tracking date, December 5.

Figure 9 indicates recorded locations for all radio-tagged mudpuppies in 2022 that were considered alive at the time of detection. Two discrete areas were occupied by the three animals, one located just downstream of the release site in a transition zone between riverine and

impounded habitat, and the other upstream in shallower habitat along the north side characterized by boulder and large cobble.

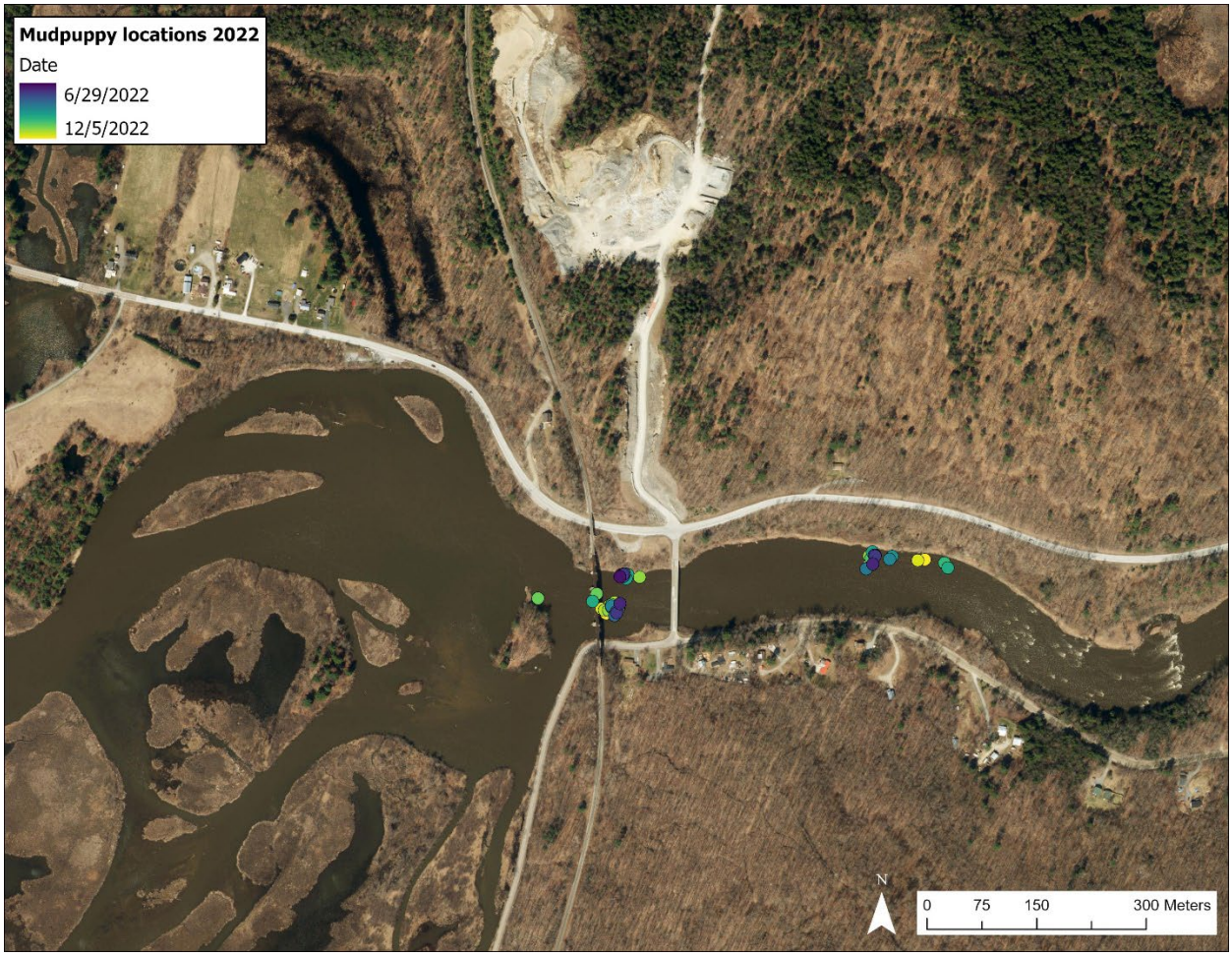

Figure 9: All recorded locations of mudpuppies considered alive at time of detection in 2022.

2022 individual transmitters

Movements of the three detected individual mudpuppies are shown in Figures 10(a-c). The accuracy error for point locations had a mean and median of 21 m. For this reason, we used 21 m as a minimum indicator of "true" movement. Calculated distances of less than this were not included in analysis. Telemetry data and calculated distances between points is provided in Appendix V.

#01 – This transmitter was located near the north shore 278 m upstream of the release site on June 30. No noticeable movement was observed again until September 30, when it was found just slightly farther upstream. It had moved slightly downstream again by October 12 before again moving upstream, detected on October 20. It was found 100 m back downstream on November 2. It remained fairly stationary until found 65 m upstream from the previous spot on November 29, where it remained through December 5. While this mudpuppy's movements were fairly small after June 30, it exhibited more directional changes (upstream/downstream) than other animals in this study. It was also the only mudpuppy in 2022 that settled in this area a long distance upstream from the release site. The final 2022 location of this mudpuppy was under a large boulder visible from the surface. Based on the detections, this mudpuppy appeared to consistently reside in shallow waters.

#02 – This mudpuppy was located very near the release site by the north bank on June 29. It remained at this location until detected on November 2 across the channel closer to the south bank, a movement of 44 m. Small movements were noted on several visits that followed, but it remained in a fairly small area in the southern half of the channel.

#03 – This transmitter was first detected on June 30 near the release site but out in the channel closer to the south shore. No movement was observed until September 30, when it had moved a short distance towards the middle of the river. It stayed within a small area until found on October 20 to have moved about 32 m downstream before moving back near the previous location a week later. It was detected on November 10 about 100 m downstream by a rocky island. On November 15, it had moved about 142 m upstream to a new area near the north shore release site. On November 24, it had moved back out to mid-channel and downstream, close to the June 30 position. It remained in this approximate location through December 5. This animal exhibited several directional changes (upstream/downstream), though fewer than #01.

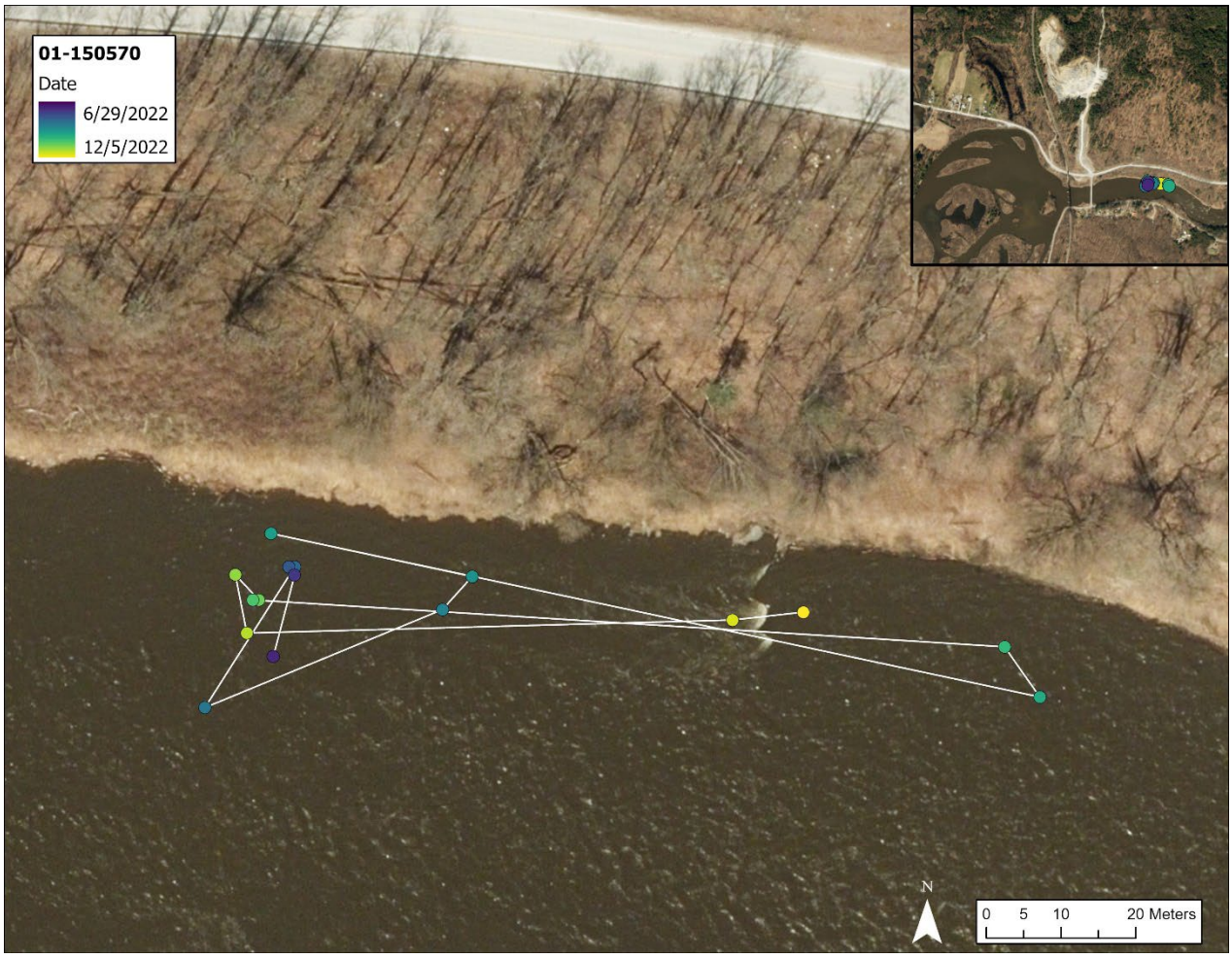

Figure 10(a): Recorded locations of radio-tagged mudpuppy #1 (frequency 150.570 MHz) in 2022.

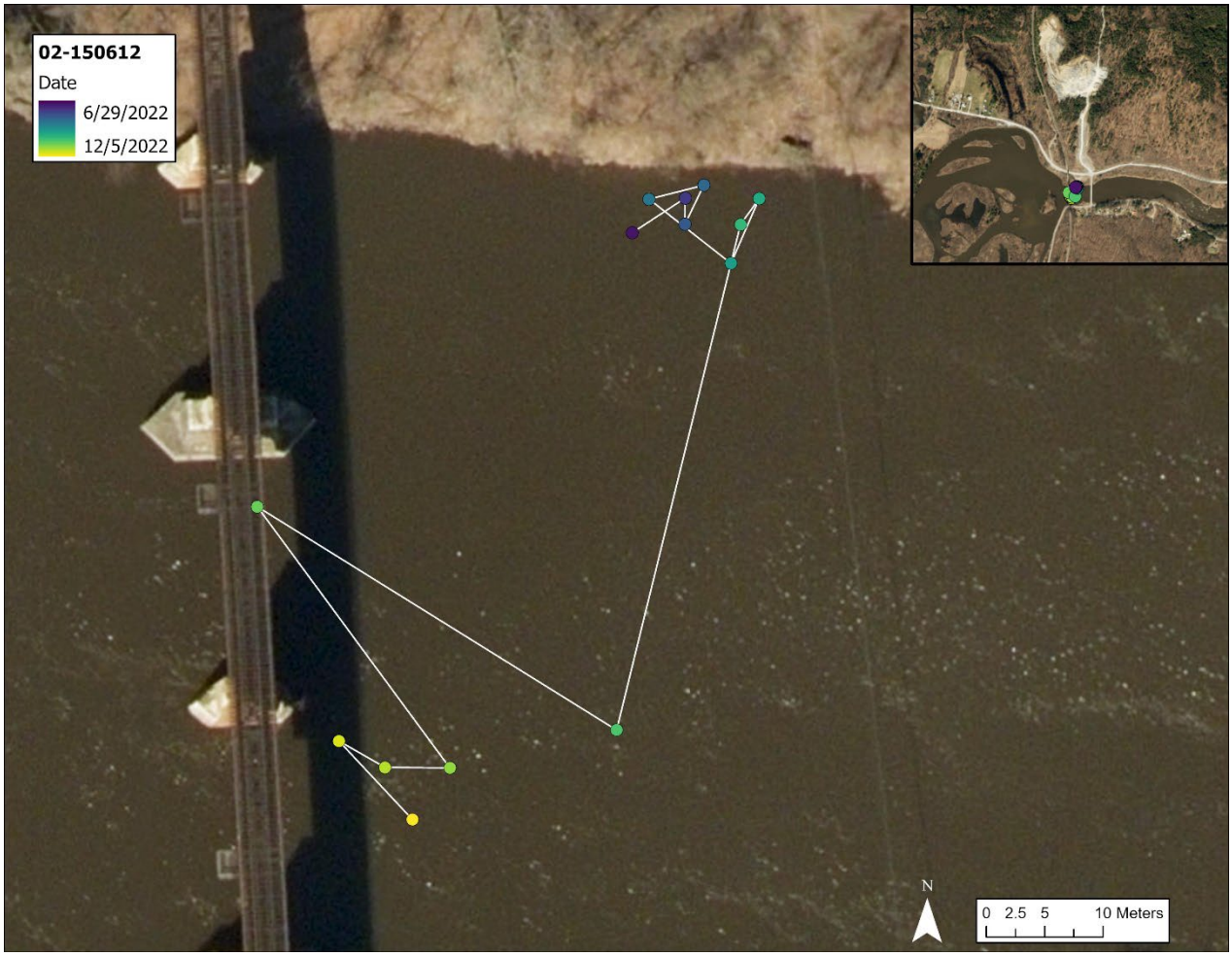

Figure 10(b): Recorded locations of radio-tagged mudpuppy #2 (frequency 150.612 MHz) in 2022.

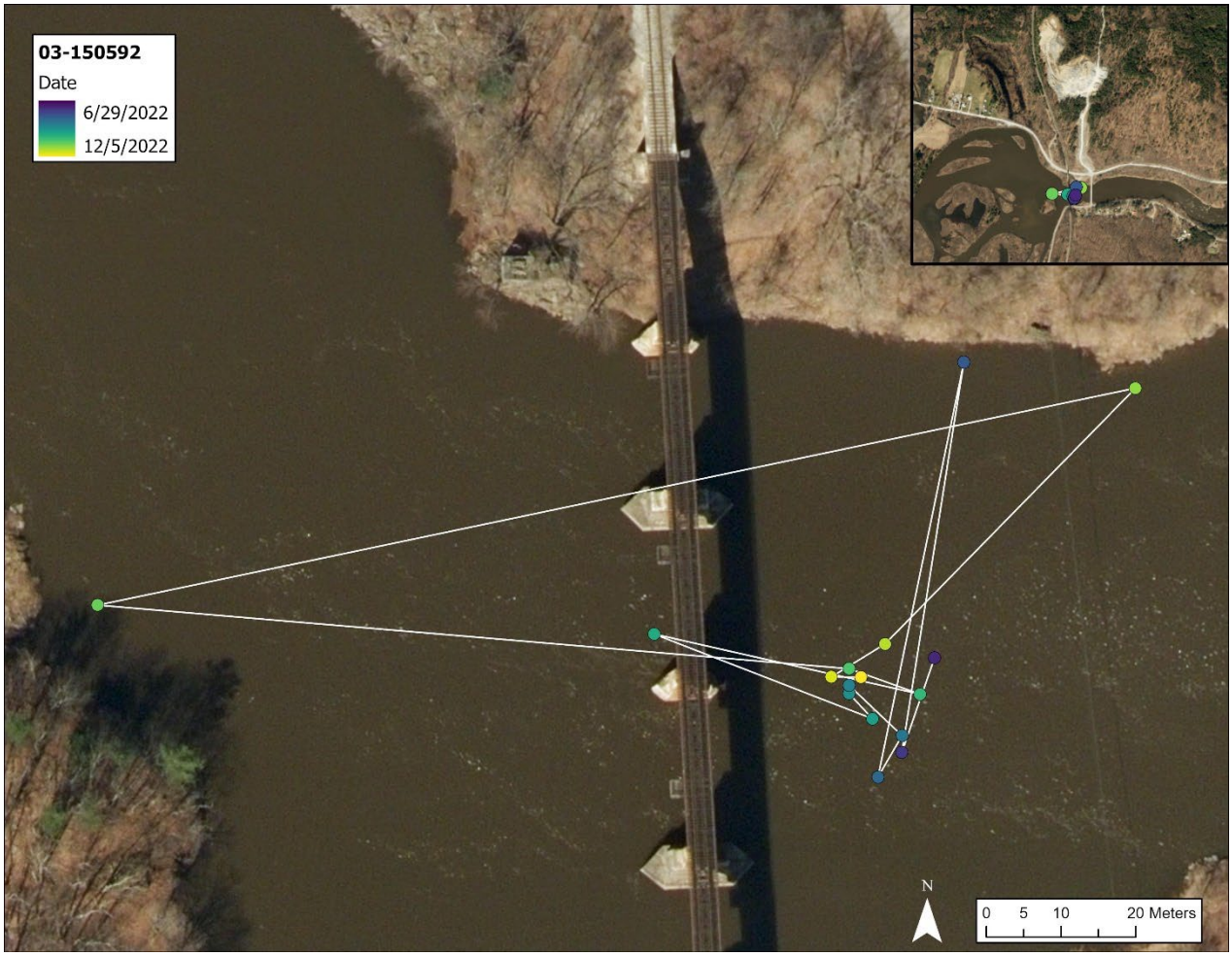

Figure 10(c): Recorded locations of radio-tagged mudpuppy #3 (frequency 150.592 MHz) in 2022.

2023 transmitter tracking

Tracking of the 12 radio-tagged mudpuppies was initiated on April 13 and continued on an approximate weekly basis (range of 5 – 10 days between visits for consecutive weeks) to December 1, 2023. Two weekly visits were missed in July and September due to personnel availability or post-flood river conditions. An additional visit was made on April 29, 2024. As in 2022, search effort was concentrated on a 2.1-km reach of river and impoundment accessible by kayak. All detections were made within this area. Additional efforts were made on three dates in April and May to find missing transmitters in the 0.8-mile stretch upstream of the kayaked area.

Ten of the 12 transmitters released in 2023 were detected in the initial attempt, with #06 and #11 (both female) not found throughout tracking efforts. One additional transmitter (#13, female) went missing and was not detected after April 28, but all nine of the remaining transmitters were detected through the end of 2023. Several transmitters went undetected for varying durations before being relocated, ranging from one to five visits (always consecutive). Eight of these nine transmitters were detected on April 29, 2024, over one year (390 – 397 days) following release.

Although detection of transmitters was high through the end of the 2023 tracking season (nine located), we could only be certain that four of the original 12 mudpuppies were still alive by December based on observed movements: #10, #12, #16, and #17. Two of these, #10 and #16, were determined to be alive based on the April 29, 2023, detections.

With the earlier start date of tracking than in 2022, we were able to observe early post-release movements of tagged animals. This is reflected well in the map of recorded locations for all radio-tagged mudpuppies in 2023 that were considered alive at the time of detection (Figure 11). A week after release, most of the detected animals were still near the release site. Within the following week, however, most had begun moving large distances. Interestingly, movements occurred in both directions, some into rapid, rocky habitat upstream and others into still, impounded waters well downstream. Such large movements and variation in direction and habitat indicate that these animals were either searching for appropriate or possibly familiar habitat or else simply dispersing from the release site. Behavior over the subsequent few weeks suggests the former, as those mudpuppies that had “explored” farthest upstream and those that had moved into the impoundment moved back towards the area of release. By June, large movements had ceased for all remaining live mudpuppies and they seemed to settle into small areas through the summer. This is similar to what was seen in 2022 and, if only point locations recorded after May 2023 are included (Fig. 12), the areas of occupation look very similar.

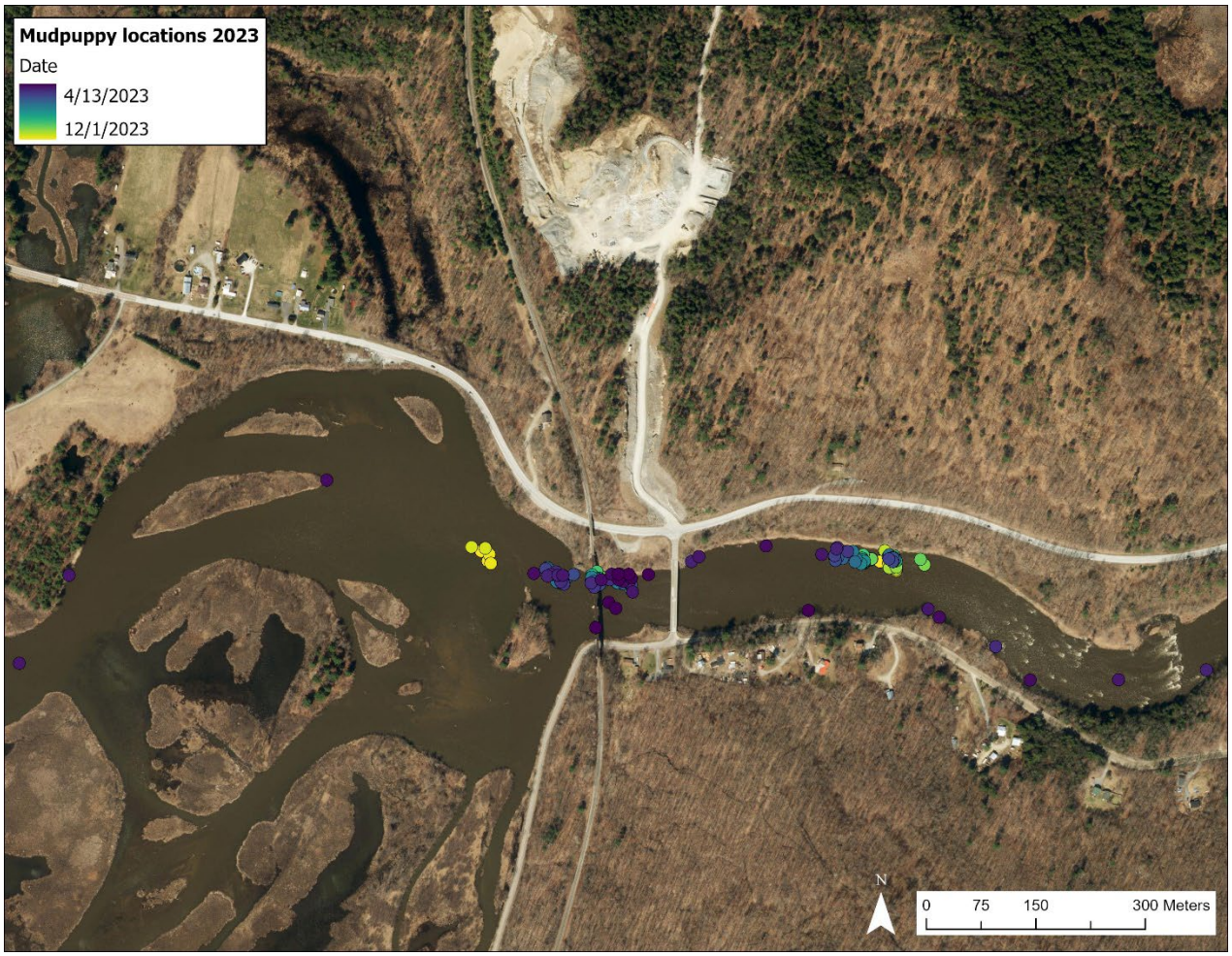

Figure 11: All recorded locations of mudpuppies considered alive at time of detection in 2023.

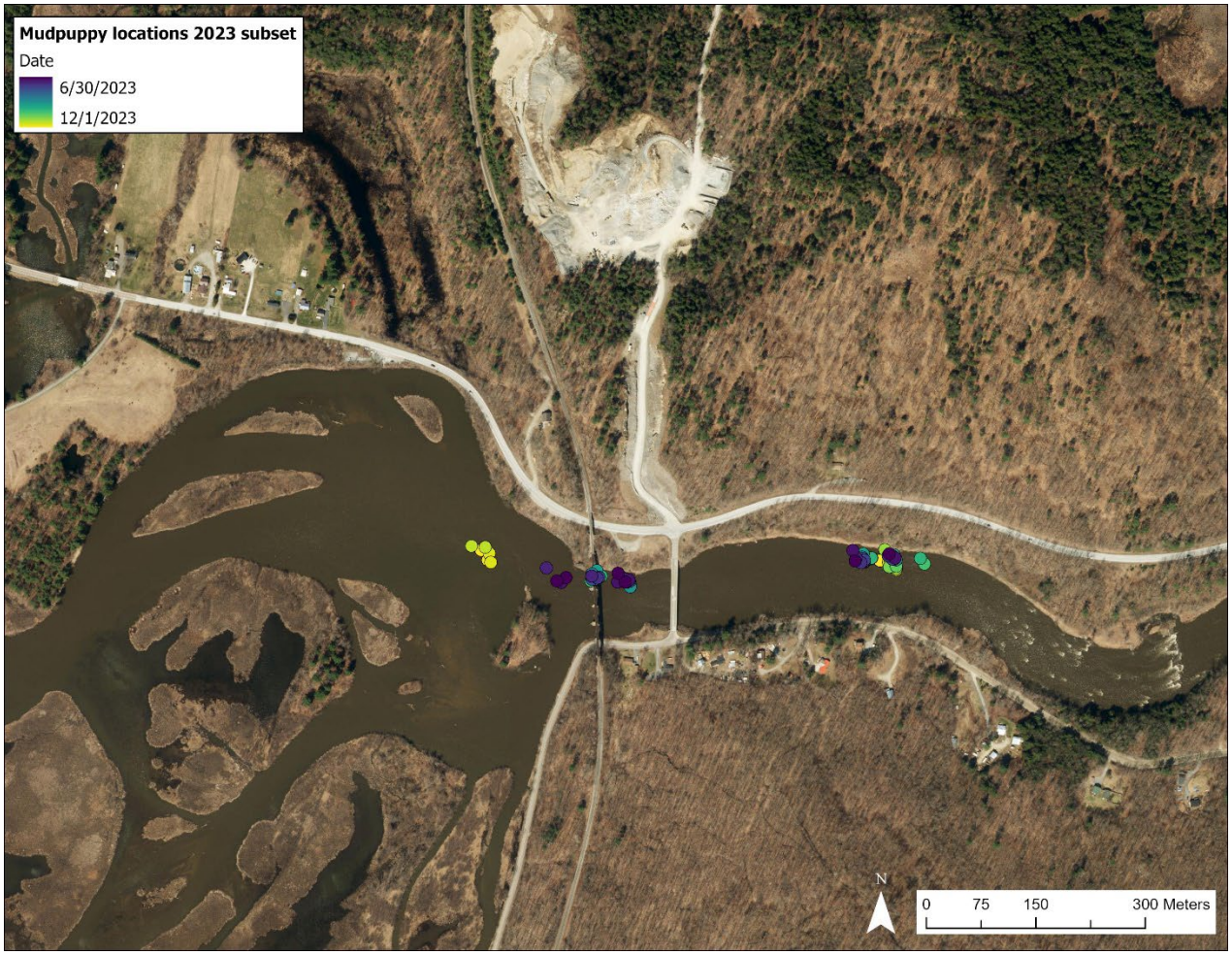

Figure 12: All recorded locations of mudpuppies considered alive at time of detection in 2023 after May 31.

2023 individual transmitters

Movements of individual mudpuppies are shown in Figures 13(a-h). Locations are presented only for dates when the mudpuppy carrying a transmitter was considered alive. All distances are straight line between GPS points. We did not attempt to adjust pathways to remain in the water, so actual mudpuppy movement distances would be expected to be greater than our values when a line between points traverses land. Calculated distances of less than 21 m were not included in our analysis. Telemetry data and calculated distances between points are provided in Appendix V.

#07 – This transmitter was detected April 13 about 200 m upstream of the release site along the south shore. By the following week (April 20) it had moved downstream about 285 m to a position near the north shore. On April 28, the signal was found slightly downstream of the RR bridge, where it remained for the duration of further tracking. On a subsequent visit, the signal origin was found to be a location up on the bank (an old bridge abutment). This animal was likely deceased on April 28 due to a predation event.

#08 – This signal was detected at a location along the north shoreline about 32 m upstream of the release site on April 13. The signal location did not change for the duration of our tracking efforts. On May 18, we discovered that the signal was emitting from up on the bank where there were several mammal burrow entrances. A mink had been observed on the shore at this location two weeks earlier. We concluded that this mudpuppy had been predated prior to April 13.

#9 – This transmitter was first detected on April 13, near the release site but across the channel nearer the south bank. It was not detected the next week, but was relocated on April 28 after it moved far into the impoundment, about 725 m from the previously detected location. By the next visit, May 5, it had moved 660 m back towards the river. It made small subsequent movements, staying in this general area, until July 13, when it was again found out in the impoundment and did not show signs of movement after that date. The mudpuppy had likely died by July 13.

#10 – The signal was detected very close to the release site on April 13. The mudpuppy then moved about 135 m downstream towards the impoundment (April 20) before returning to a location adjacent to the release site but towards mid-channel (April 28), where it remained through October 16. Not located on October 25, the signal was found again on November 17 about 205 m downstream at the impoundment/river interface, where a rocky island nearby suggests there may be rocky aquatic habitat in the area. The signal remained at this location through the final 2022 visit, December 1. On April 20, 2023, the mudpuppy had moved back upstream into the area it had settled in April 28 – October 16, 2022.

#12 – The signal was detected very close to the release site on April 13. The mudpuppy remained in this general area through April but was detected on May 5 about 288 m upstream near the north shore. Although small movements (<100 m) were detected on subsequent dates, the transmitter remained in this area through all subsequent visits.

#13 – The signal was detected very close to the release site on April 13. On April 20, it had moved 166 m upstream, still near the north shore. The following week (April 28) the transmitter had moved downstream about 95 m to a location near where the mink had been observed. The transmitter signal disappeared after this date and was not detected again.

#14 – The signal was detected close to the release site on April 13, but more towards mid-channel. One week later, it had moved upstream about 450 m and was located near the south bank shore. It remained in this vicinity until May 5, when the signal was detected about 525 m downstream on the north side of the river. The signal origin remained in this area until June 30, when it was found to be another 245 m downstream in the reservoir. Although the signal appeared to move one more time, slightly farther downstream into the lake, this mudpuppy was likely dead when the transmitter was detected on June 30. It is possible the mudpuppy died prior to this (as early as the May 5 observation), but this is not known.

#15 – The signal was detected very close to the release site on April 13. On April 28, it had moved downstream about 85 m to a location under the RR bridge. It remained in this general vicinity through July 13. On July 25, the signal was detected out in the reservoir but appeared to be moving, making the location difficult to pinpoint. In addition, occasional disturbances at the water surface were observed at the time, as might be made by a large fish. The transmitter could not be relocated again until September 4, when it was found farther downstream in a marshy inlet of the impoundment. This was the farthest location into the impoundment (about 1150 m from the release site) for a transmitter during this study. The transmitter did not move again through the end of tracking efforts. Based on observations and the detections that followed, this mudpuppy was likely predated by a large fish and the transmitter was being transported by the predator on July 25. The final transmitter location is likely where it was expelled.

#16 – The signal was detected close to the release site on April 13, but more towards mid-channel. One week later, the transmitter was in the impoundment, about 430 m from the previous location. The following week, it was 490 m farther downstream into the lake. On May 5, however, it had reversed direction and moved 930 m to riverine habitat upstream of the release site near the north shore. It had moved slightly by May 13, just downstream of the release site. It stayed in this vicinity through October 16, was not detected on October 25, then was relocated November 17 near a rocky island downstream of the RR bridge near where #10 was located on this date. Like #10, it stayed here through December 1 but was found to have moved by April 29, 2024, to the area it had occupied May 13 through October 16, 2023.

#17 – The signal was detected close to the release site on April 13, but more towards mid-channel. The following week, it had moved about 580 m upstream into fast water with cobble/boulder substrate near the south shore. Over the next two weeks, it continued moving upstream along the south side through rapid water another 225 m. This was the farther upstream any of the radio-tagged mudpuppies migrated, into waters that could not be reached by kayak and had to be accessed from walking the bank. One week later, May 13, the mudpuppy had moved back downstream along the south side about 290 m from the previous detected location and remained there the following week. It was detected near the north shore on May 25, about 190 m from the previous location. It remained in this general vicinity through December 1. It was not detected on April 29, 2024.

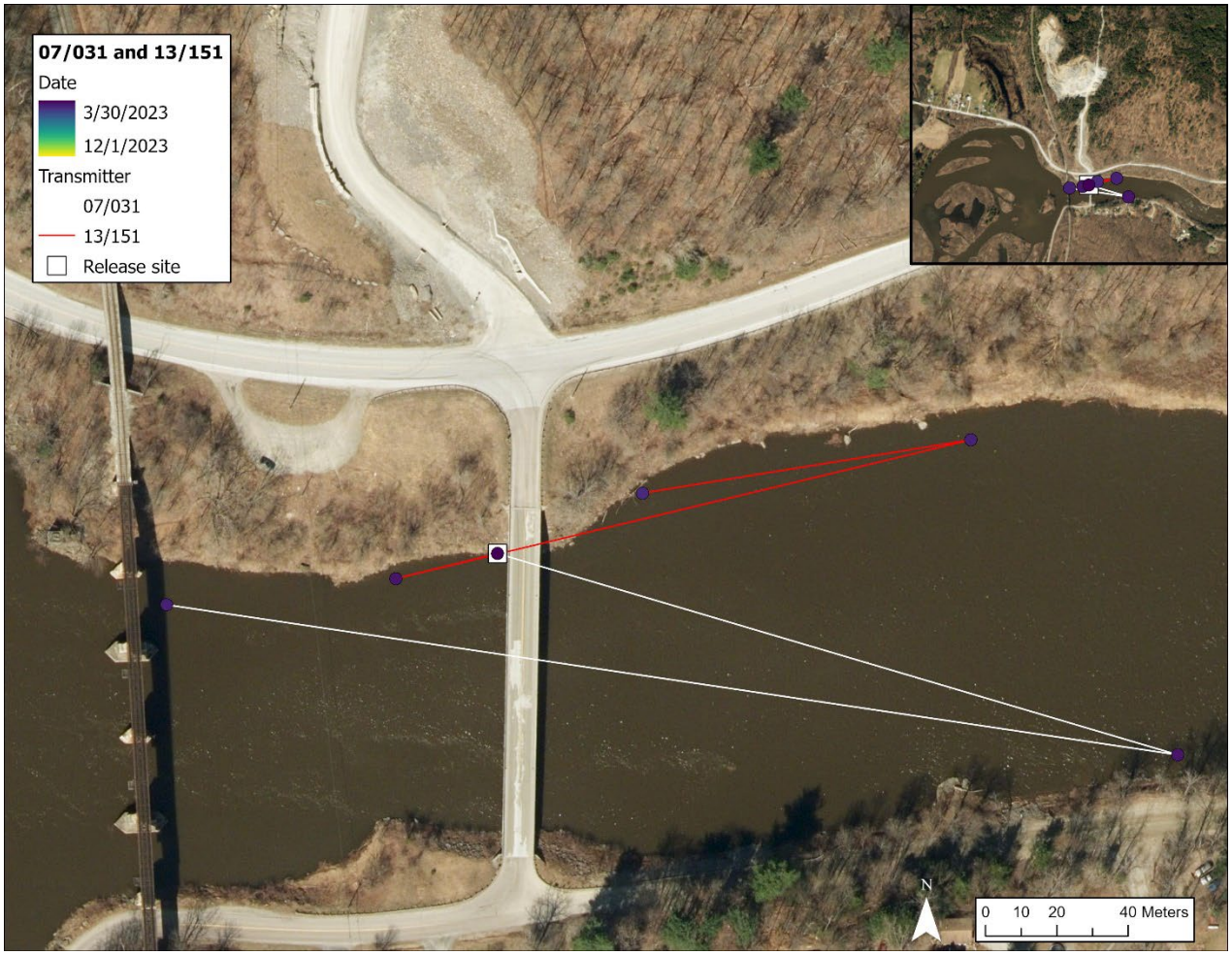

Figure 13(a): Recorded locations of radio-tagged mudpuppies #7 (frequency 150.031 MHz) and #13 (150.151 MHz) in 2023.

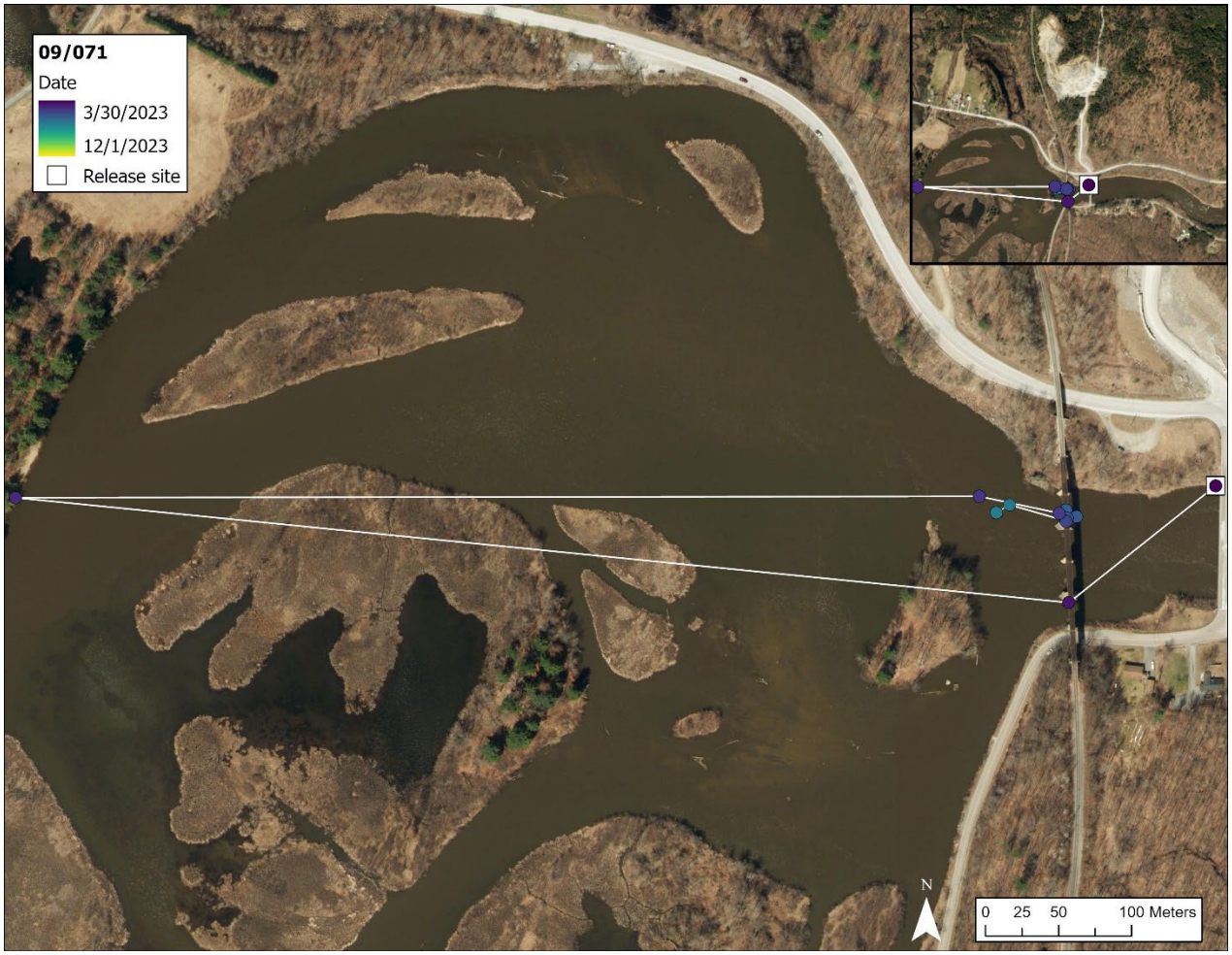

Figure 13(b): Recorded locations of radio-tagged mudpuppy #9 (frequency 150.071 MHz) in 2023.

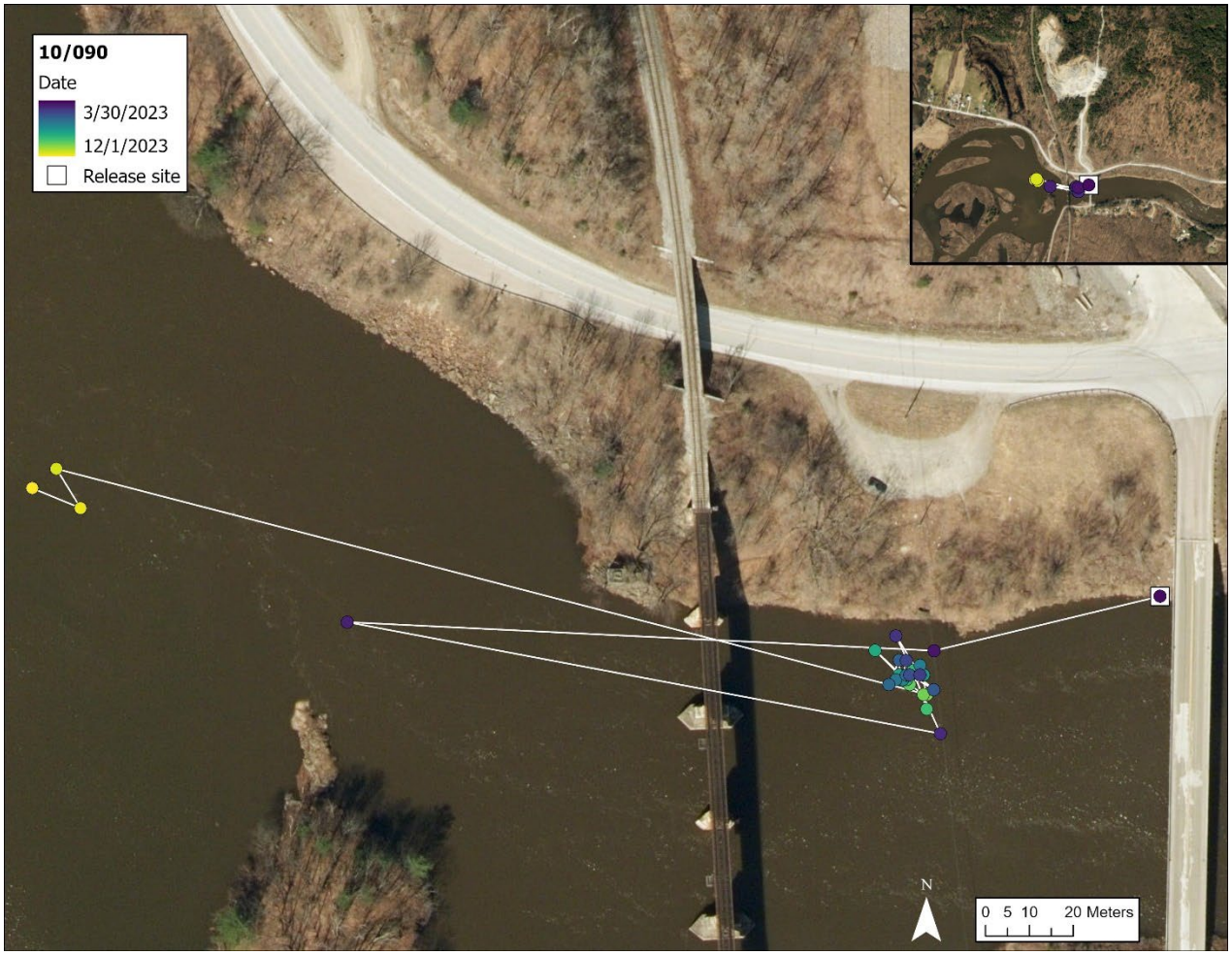

Figure 13(c): Recorded locations of radio-tagged mudpuppy #10 (frequency 150.090 MHz) in 2023.

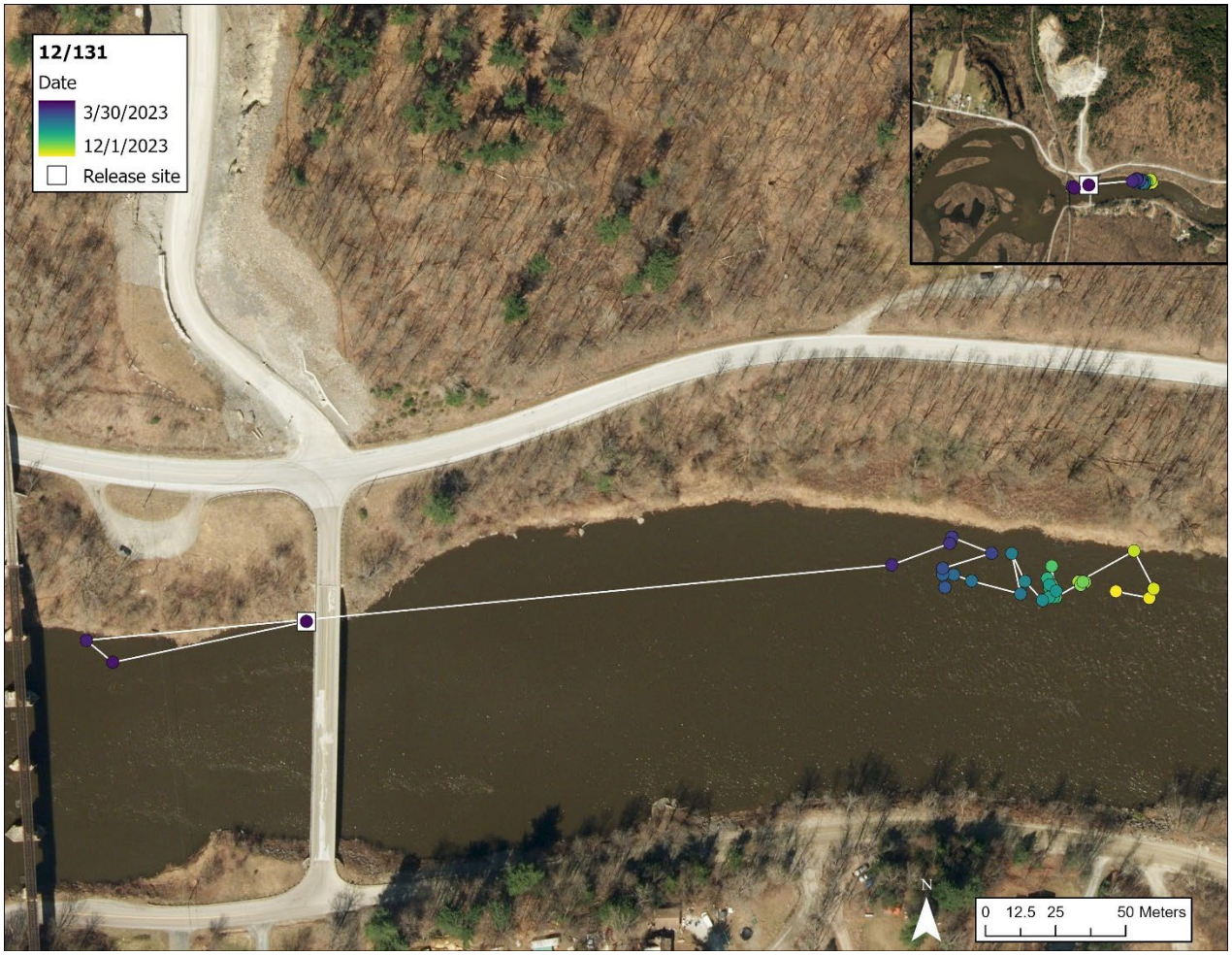

Figure 13(d): Recorded locations of radio-tagged mudpuppy #12 (frequency 150.131 MHz) in 2023.

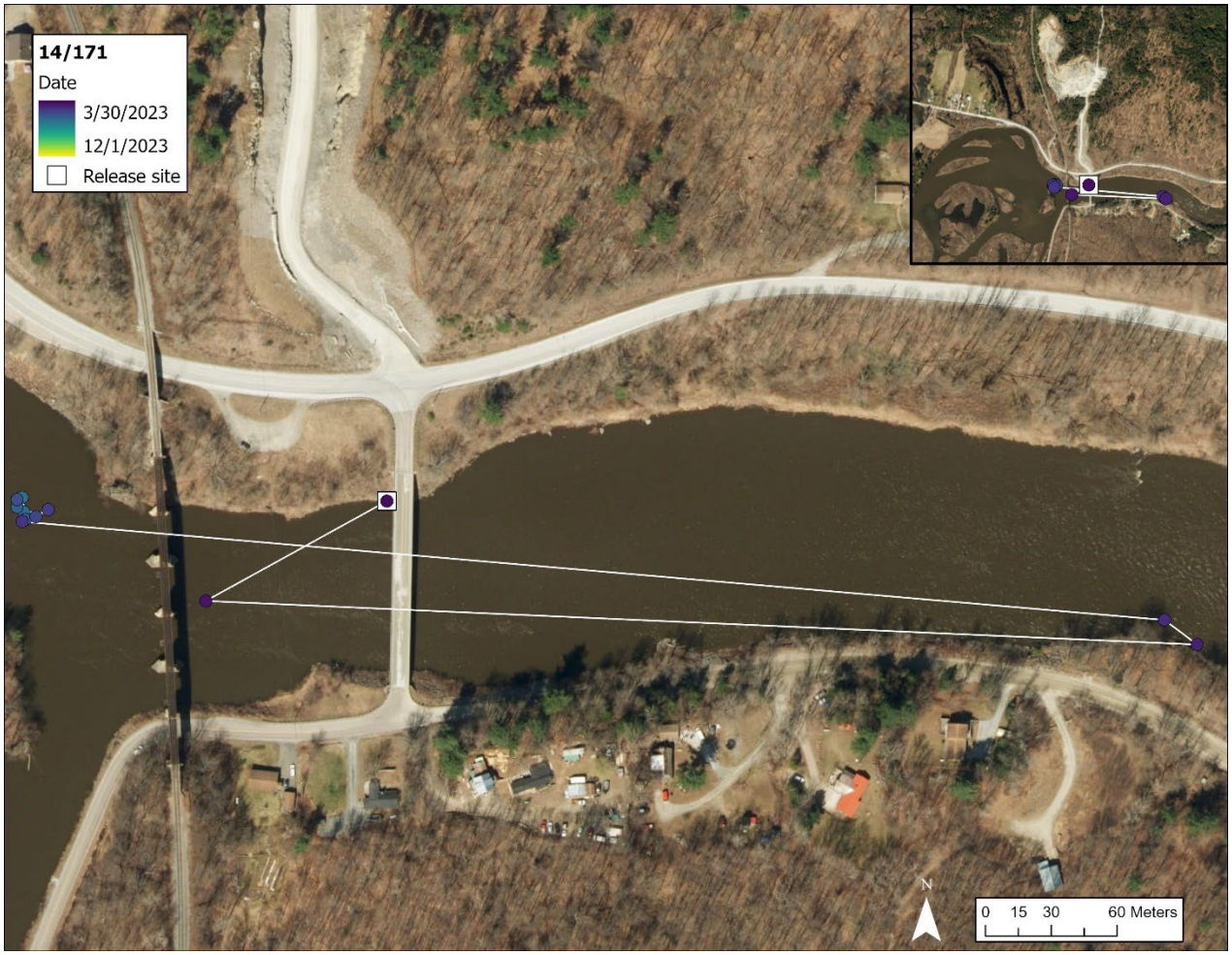

Figure 13(e): Recorded locations of radio-tagged mudpuppy #14 (frequency 150.171 MHz) in 2023.

Figure 13(f): Recorded locations of radio-tagged mudpuppy #15 (frequency 150.191 MHz) in 2023.

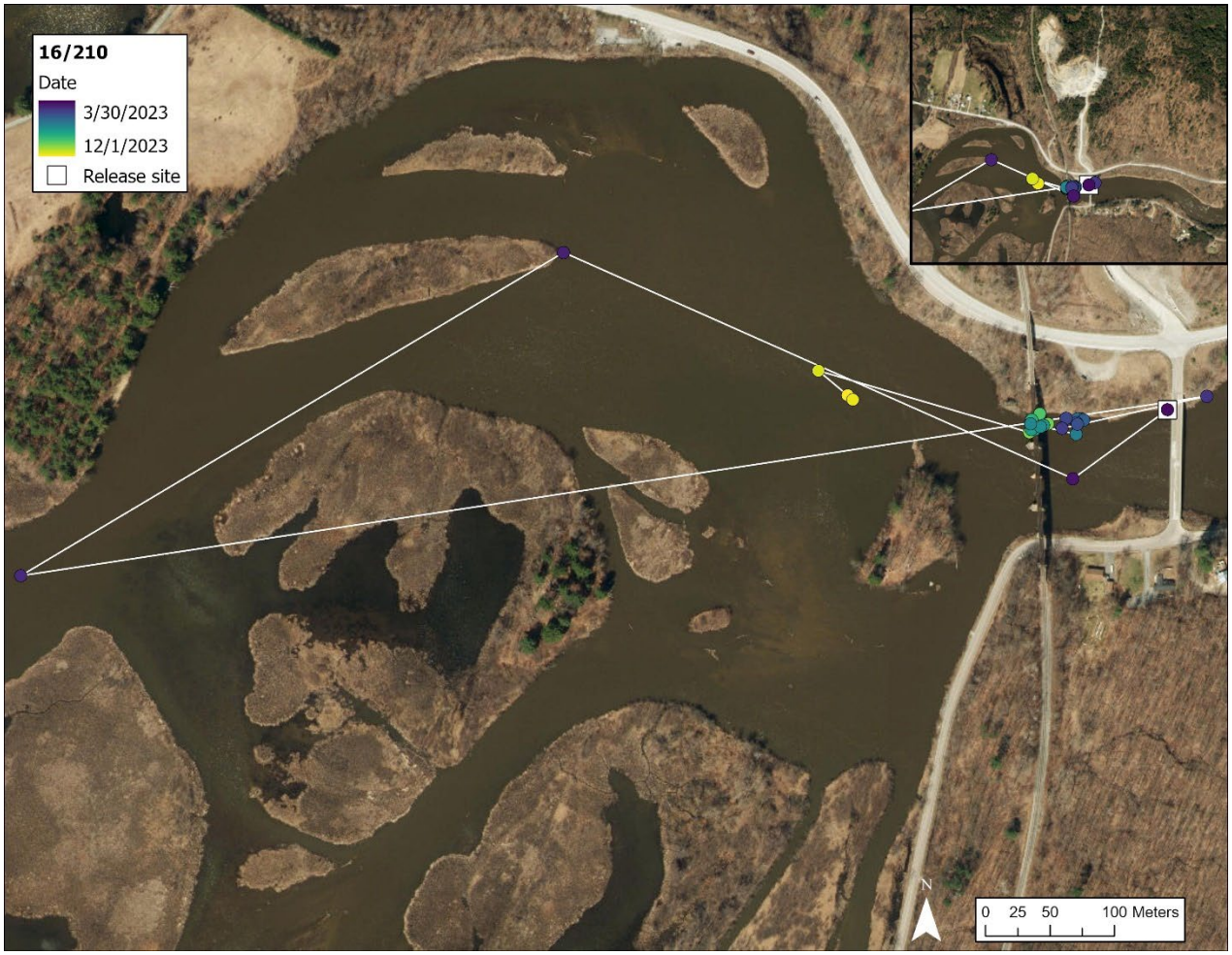

Figure 13(g): Recorded locations of radio-tagged mudpuppy #16 (frequency 150.210 MHz) in 2023.

Figure 13(h): Recorded locations of radio-tagged mudpuppy #17 (frequency 150.230 MHz) in 2023.

Tracking Summary:

Direct and indirect evidence of predation was observed for three of the 2023 radio-tagged mudpuppies. Both mammalian and fish predators were indicated. Whether this represents a normal survival pressure or is unique within this habitat upstream of the native population is not known, but it does represent a loss of at least 16.6% of our adult salamanders over less than 6 months. In addition, six transmitter signals went permanently missing not long after release of tagged mudpuppies (three in each year). Whether loss of transmitters is due to migration, highly mobile predators, subterranean signals, or some other explanation is not known. A probable factor is that the long-distance movements of mudpuppies observed in this study soon after release at the relocation site may not represent normal behavior and may have increased their exposure to predation. An encouraging observation was that two of the remaining live mudpuppies, #10 and #16, had moved back into previously occupied areas the following year. This suggests that movements may return to more normal patterns the year after relocation.

The period of greatest movement was in May (2023). After remaining fairly sedentary in summer months, movement began to increase again in the fall, primarily October and November (both years) (Fig. 14). The spring movements were likely influenced by post-translocation behavior as well as natural factors such as temperature, while the much shorter movements observed in the fall suggest a more normal pattern after the mudpuppies have acclimated to their new environment. During the trapping season, higher catch rates (which indicate mudpuppy

movement) were observed when the water temperature was within a particular range. Likewise, we found during tracking that the greater distance movements occurred within the lower range of all temperature readings (5 – 11°C) (Fig. 15). Again, however, this relationship is difficult to interpret because many of the water temperatures recorded within this range occurred in the early spring when translocation may have influenced movements. Since this greater movement occurred within a comparatively "warm" range that produced few captures for trapping (which suggested reduced movement), post-translocation behavior may have been a more significant factor than temperature, at least for large-scale movements.

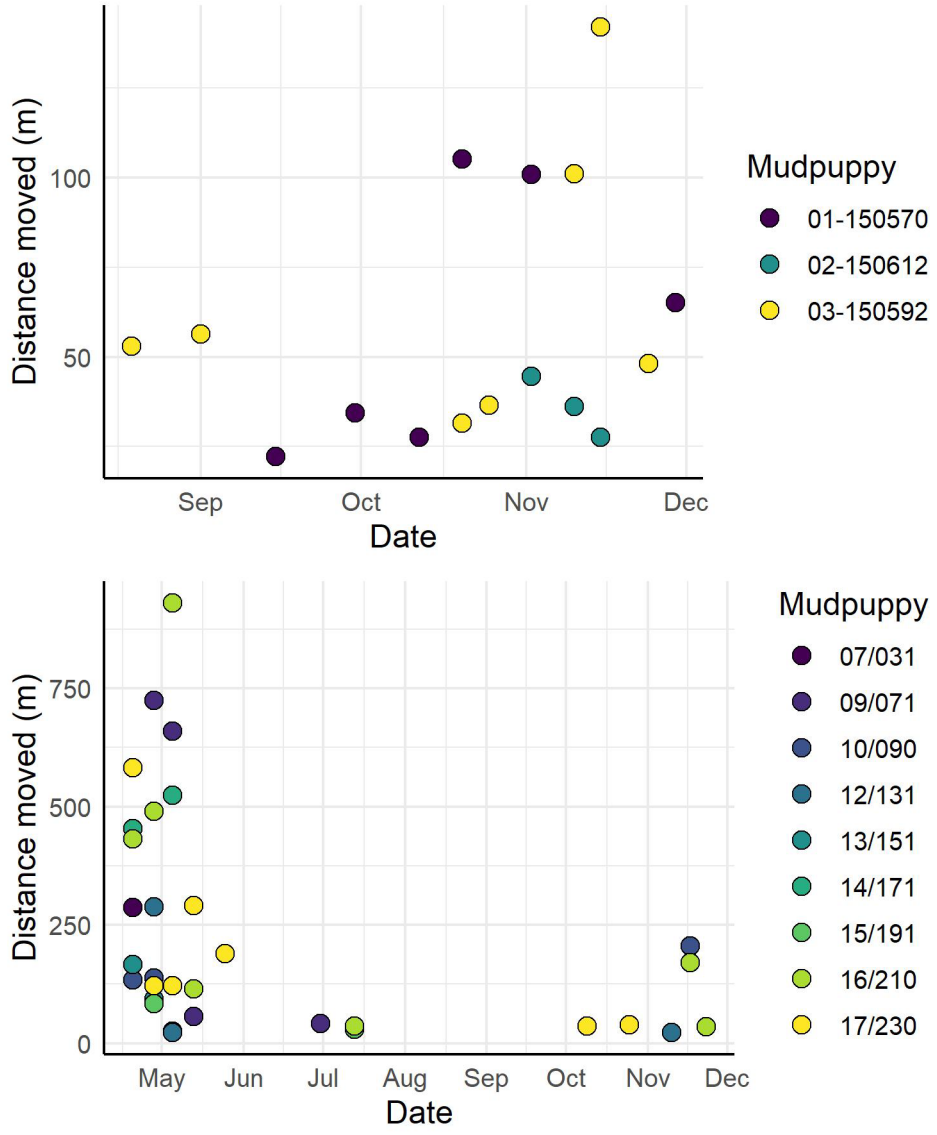

Figure 14: Movement distances for live radio-tagged mudpuppies by date in 2022 and 2023.

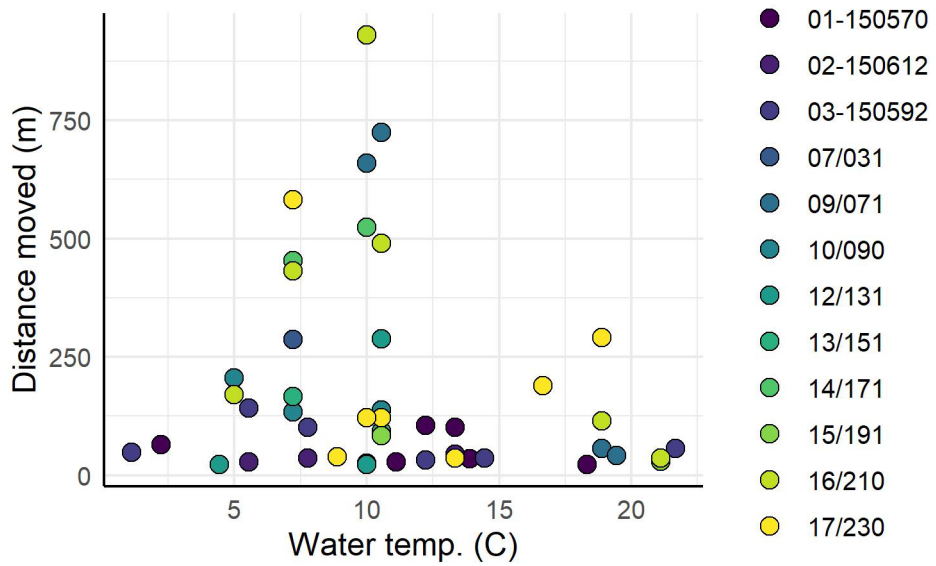

Figure 15: Movement distances and water temperatures for all live radio-tagged mudpuppies.

6 Conclusions

This project's approach of adopting the trapping techniques of Chellman et al. (2017) and concentrating effort on the late March/April period proved successful at maximizing catch rates and increasing efficiency. Water temperature and river flow appear to be important factors influencing capture rate. We found in 2022 that highest capture rates occurred within a temperature range of 2 – 6°C, particularly following high flow events, although when these conditions recurred in late April there was no noticeable increase in catch rate. Results from 2023 were less conclusive, indicating a lower threshold for higher catch rates of 3°C as in the Chellman et al. (2017) study. The difference in results between years supported that time of year alone cannot be depended on for accurately forecasting catch success.

Implantation of internal radio transmitters in mudpuppies has not been reported in publication but it proved to be a successful technique and we observed no stress or post-surgery ill effects in our study animals. However, we did not attempt to retrieve dead radio-tagged mudpuppies for examination so cannot rule out delayed mortality from the surgery. The use of transmitters with encased coiled antennae, as used in this study, is likely the best technique for this species. Although the expected detection range is less than for external antennae, the sealed antenna could reduce potential post-surgery complications. An externally mounted transmitter is not a practical option for aquatic salamanders, as it would be likely to detach more readily.

To the best of our knowledge, this is the first study report to include telemetry techniques for tracking mudpuppy movements. It is also unique in reporting post-translocation activity for this species. The natural dispersal tendencies of mudpuppies have not been reported to date, so this study represents a unique opportunity to track seasonal movements and determine whether translocated individuals are likely to remain at the release site.

Bodinof (2010) noted that long distance movements from release sites can result in increased mortality or predation. High site fidelity has been reported for many amphibian and reptile species but not specifically for mudpuppy, although Chellman (2011) reported evidence of small home range size in the Lamoille River. If mudpuppies do indeed exhibit high site fidelity, this could explain the long-distance movements observed soon after 2023 translocation, as adults attempt to find familiar ground. The return of individuals towards the release site following these early exploration/dispersal events suggests that the translocation release site may represent the

best available local habitat. The smaller movement distances observed in the fall, when cooling water temperatures triggered resumed activity, could indicate that these surviving individuals were settling into new home ranges. If so, a resulting return to more normal movement behavior could lessen exposure to mortality factors such as predation after the first year.

We observed a confirmed survival rate for both seasons combined of 38.9%, with 27.8% confirmed dead and 33.3% of unknown disposition. This is similar to what Bodinof (2010) reported for Ozark hellbenders after two years: 44% survival, 36% dead, and 20% unknown. Lu Zhang et al. (2018) reported an annual survival rate for reintroduced Chinese giant salamanders of 40 – 70%. Although the mudpuppy survival rate we observed is similar to that reported in studies of other aquatic salamanders, future efforts will be needed to ultimately determine whether this translocation study was successful.

7 References

Bilak, J.D., and M.R. Whiles. 2021. Minnow trap trotlines: a modified trapping design for mudpuppies. Herpetological Review 52(4): 760–764.

Bodinof, C.M. 2010. Translocation and conservation of hellbenders (*Cryptobranchus alleganiensis*) in Missouri. M.S. thesis, University of Missouri, Columbia. 25 p.

Chellman, I.C. 2011. Population demographics and genetic diversity of mudpuppies (*Necturus maculosus*). M.S. thesis, University of Vermont, Burlington. 92 p.

Chellman, I.C., D.L. Parrish, and T.M. Donovan. 2017. Estimating mudpuppy (*Necturus maculosus*) abundance in the Lamoille River, Vermont, USA. Herpetological Conservation and Biology 12(2):422-434.

Dervo, B., Skei, J.K., Berg, O.K., Kraabøl, M., Arnemo, J.M. and Dolmen, D. 2010. A comparison of external and internal attachments of radio transmitters on adult crested newts *Triturus cristatus*. Amphibia-Reptilia 31: 229-237.

Lyttle, M., and N. Staats. 2002. Mudpuppy (*Necturus maculosus*) sampling in the Lake Champlain drainage. Progress Report. U.S. Fish and Wildlife Service, Essex Junction, VT. 11 pp.

Lyttle, M., and N. Staats. 2003. Mudpuppy (*Necturus maculosus*) sampling in the Lake Champlain drainage. Progress Report. U.S. Fish and Wildlife Service, Essex Junction, VT. 15 pp.

Lyttle, M., and N. Staats. 2004. Mudpuppy (Necturus maculosus) sampling in the Lake Champlain drainage. Progress Report. U.S. Fish and Wildlife Service, Essex Junction, VT. 5 pp.

Vermont Fish & Wildlife Department. 2015. Vermont Wildlife Action Plan 2015. Vermont Fish & Wildlife Department. Montpelier, VT.

Vermont Fish & Wildlife Department. 2021. Status assessment of amphibians, reptiles, and fishes. Final Performance Report to the U.S. Fish & Wildlife Service. Vermont State Wildlife Grants Program. 7 p.

Zhang, L., H.X. Zhang, Q.J. Wang, I. Recchio, J. Krebs, D. Barber, and A.J. Kouba. 2018. Lessons learned from the reintroduction of the Chinese giant salamander. Global Reintroduction Perspectives: 2018. p.58-63.

8 Appendices

Appendix I Photos of Equipment and Materials
Shared via Google Drive with LCBP

Appendix II Trapping Data and Analysis

Appendix III Mudpuppy Data

Appendix IV Surgical Implantation Reports

Appendix V Telemetry and Distance Data

Appendix VI Field Forms