Common Carp Assessment in Six Mile Creek
Annual Report: June 2014 - February 2015

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MINNEHAHA CREEK
WATERSHED DISTRICT

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Purpose

To determine the abundance, seasonal movements, and recruitment patterns of common carp (*Cyprinus carpio*) in the Six Mile Creek Subwatershed to enable development of carp control strategies for restoration of the Six Mile Creek Subwatershed.

Background

Site overview

The Six Mile Creek Subwatershed is predominately agricultural and parkland, but is presently facing increasing urban development pressure. Located in the southwest corner of the Minnehaha Creek Watershed District (MCWD), it spans roughly 27 square miles and encompasses a chain of 17 lakes (Piersons, Marsh, Wassermann, Carl Krey, Kelzer's, Church, East Auburn, West Auburn, Steiger, Sunny, Zumbra, Stone, North Lundsten, South Lundsten, Turbid, Parley, & Mud) and dozens of unnamed ponds and wetlands (Figure 1). This system flows north from Piersons Lake and eventually drains into Halsted's Bay of Lake Minnetonka.

Water quality in the Six Mile Creek Subwatershed is variable, but many lakes are highly degraded and devoid of healthy native submersed plant communities. Additionally, several lakes currently fail to meet state nutrient standards and are classified as impaired for excess nutrients (phosphorus). Because internal loading was identified as a significant driver of in-lake phosphorus concentrations, common carp assessment and management was recommended (Wenck Associates 2013).

Common carp research & management approach

The introduction of the common carp to Minnesota waters in the 1880s was one of the greatest ecological threats to befall our shallow lake ecosystems. Being long-lived, mobile, and extremely fecund, the common carp has come to dominate the fish biomass in many lakes in the Upper Midwest (Sorensen & Bajer 2011). Common carp disrupt shallow lake ecosystems by uprooting submersed native vegetation, causing changes to food-webs, and often negatively impacting water quality by increasing turbidity and nutrient loading (Bajer et al. 2009; Weber & Brown 2009). In deeper, thermally-stratifying lakes, carp have also been shown to decrease water clarity and reduce submersed aquatic plant growth, but their impact on nutrient cycling is less straightforward (Bajer & Sorensen 2015).

Efforts aimed at improving water quality are typically futile until densities of adult carp can be sustainably reduced. Unfortunately, reducing carp densities in a sustainable manner has proven very difficult due to their complex life history. Adult carp exploit outlying predator-free wetlands for breeding where young carp often thrive and colonize connected waters which can rapidly counteract adult carp removal efforts (Bajer & Sorensen 2010; Sorensen & Bajer 2011; Osborne 2012; Koch 2014). Nevertheless, recent studies conducted by the Sorensen Laboratory are revealing a possible way forward for carp control in many watersheds. This management approach typically has three components; (1) identifying carp nurseries and suppressing recruitment, (2) quantifying adult carp abundance and reducing existing biomass, and (3) understanding movement patterns to identify management units and inform potential barriers.

First, the source(s) of juvenile carp (i.e. recruitment) must be identified, isolated, remediated, and/or eliminated (Bajer & Sorensen 2010; Bajer et al. 2012). Remediation may be possible if the carp nurseries can be restored to support healthy native fish communities comprised of species that consume carp eggs and young (e.g. bluegill sunfish; Silbernagel & Sorensen 2013). Alternatively, recruitment locations may be isolated from the main lakes so adults cannot reach them to breed, or if isolation is not feasible, these areas can potentially be drained or killed regularly. Second, adult carp must be removed in numbers large enough to make a meaningful difference to ecosystem function. Fortunately, this is often possible because adult carp tend to aggregate during winter months where they may be targeted by commercial seining if the bottom is free of obstacles. The use of radio-tagged 'Judas' fish can increase the success rate of such seining efforts (Bajer et al. 2011). Adult carp may also form springtime spawning aggregations which can be targeted, trapped, and removed. Third, carp movement between connected systems must be defined, and when appropriate, obstructed. Identification of possible carp sub-populations can be used to delineate management units. Presently, the behavior of adult carp is too poorly understood to predict when and where they will move across any particular watershed. Consequently, it is necessary to collect detailed site-specific demographic data on common carp to develop sustainable control strategies.

Summary of Research Findings—June 2014 to February 2015

Deliverable 1: Estimates of adult common carp abundance in all accessible lakes

Methods

Adult common carp abundance was estimated by conducting standardized electrofishing surveys in each accessible lake to determine the catch per unit effort (CPUE; see table 1). CPUE measurements estimate the number of fish in a population based on the number sampled per hour, corrected by known estimates of electrofishing efficiency from similar locations (Bajer & Sorensen 2012). In lakes where multiple surveys were conducted, 95% confidence intervals were generated as a measure of precision. Carp biomass (kg/ha) was estimated by multiplying abundance estimates by the average weight of carp in each lake and then dividing by lake surface area.

During the course of electrofishing surveys, all carp sampled were also marked with external plastic T-bar anchor tags (Hallprint co., Australia) before being released. Having these tagged fish in the system may allow for the calculation of supplemental mark-recapture population estimates if enough tagged fish are recaptured.

Results

Carp biomass estimates in the Six Mile Creek Subwatershed ranged widely from 37 to 1,093 kg/ha (Table 2). Nine of the 15 accessible lakes surveyed were above 100 kg/ha; a threshold in which carp are known to become ecologically damaging in shallow lakes (Bajer et al. 2009). Notably, the carp population in Halsted's Bay was estimated to contain 65,225 (55,803-74,646) individuals with a biomass of 1,093 (935-1,251) kg/ha based on four surveys. This exceeds the damaging threshold tenfold and is the highest biomass ever observed by the Sorensen Lab. In addition to Halsted's Bay, carp biomass was very high in Lakes Mud, Parley, W. Auburn, E. Auburn, Turbid, and Wassermann ranging from 250 to 480 kg/ha. Carp biomass was moderate (91-177 kg/ha) in N. Lundsten, S. Lundsten, Steiger, Stone, and Zumbra. Carp biomass was low (≤63 kg/ha) in Piersons, Sunny, and Kelzer's. It should be noted that biomass estimates for N. Lundsten, S. Lundsten, Sunny, Stone, and Kelzer's are based on two or less surveys and should be validated with additional electrofishing surveys to confirm catch rates. The details for all abundance and biomass estimates are reported in Table 2 for all 15 accessible lakes.

During the course of all electrofishing surveys conducted across the subwatershed, 964 common carp were tagged with T-bar tags and released. To date, only 7 tagged fish have been recaptured. This low recapture rate does not allow for the statistical computation of supplemental mark-recapture estimates. Additional recaptures may allow for these complimentary estimates in a subset of the study lakes in the future.

Deliverable 2: Information on the seasonal distribution and movement patterns of adult carp

Methods

The seasonal distributions and movement patterns of adult carp across the Six Mile Creek Subwatershed were determined by implanting carp with radio-tags and manually bi-angulating their locations once per month. In fall of 2014, 102 of the 120 proposed radio-tags were implanted in carp throughout the subwatershed. Tagged fish were distributed as follows: Halsted's Bay (n=15), Mud (n=15), Parley (n=15), E. & W. Auburn (n=15), Wassermann (n=15), Piersons (n=10), Steiger (n=10), and Zumbra (n=7). Each tagged carp was given a unique fish identification number ranging from 1 to 120. In spring of 2015, additional radio-tags will be implanted in Sunny Lake (n=3) and Lundsten Lakes (n=15) to circumvent possible overwinter mortality in these shallow lakes.

In addition to tracking the radio-tagged carp, movement patterns may also be elucidated by recapturing carp previously tagged with T-bar tags during routine electrofishing surveys. As discussed above, 964 carp have been sampled across the subwatershed, tagged with T-bar tags, and released.

Results

To date, all of the radio-tagged carp have been tracked once per month for four months (See Figures 2-15). Each month, the majority of carp have been located within the lakes in which they were originally tagged. Carp movement has however been documented between Lakes Mud and Parley, East and West Auburn Lakes, as well as Halsted's Bay and adjacent bays of Lake Minnetonka. More specifically, within one month of being tagged, 9 of the 15 carp tagged in Mud Lake were located in Parley Lake in November of 2014 and 7 of the 15 carp tagged in Parley Lake were located in Mud Lake (Figure 12). From December 2014 to the present, all carp tagged in both Mud and Parley Lake have been located in Parley Lake (Figures 12-13). Movement between East and West Auburn Lakes was less frequent, with only 1 of 15 tagged fish moving between these lakes during the 4 month tracking period (Figure 6). Additionally, up to 20% of carp tagged in Halsted's Bay have been located in adjacent bays within Lake Minnetonka any given month (Figures 14-15). To date, we have only been unable to locate one radio-tagged carp (Fish ID no. 1); the missing carp was originally tagged in Halsted's bay and is assumed to be at large in greater Lake Minnetonka.

In addition to radio-tagged carp moving between lakes, there have also been strong seasonal patterns in the spatial distribution of carp within lakes. Specifically, wintertime aggregations of carp have formed in all but one of the study sites (i.e. Steiger Lake; Table 3). The timing of formation of these aggregations has ranged from as early as November in Piersons Lake to as late as February in Halsted's Bay. These aggregations have contained as many as 100% of radio-tagged carp in some lakes (i.e. Parley, W. Auburn, E. Auburn, Wassermann, & Zumbra), whereas in other lakes (i.e. Halsted's Bay, Piersons), multiple aggregations comprised of roughly 30-60% of tagged fish have been observed. Notably, all of the carp tagged in Mud Lake moved into Parley Lake to form one large aggregation that has persisted from the beginning of December 2014 until the present. The timing and locations of these winter aggregations can inform adult carp removal efforts via targeted winter seining by commercial fisherman. It should be noted that radio-tagged fish have only been monitored over the winter season and there is likely seasonal and annual variation. Important springtime spawning movements will be documented in 2015 and 2016. These spawning movements will be vital to understanding and identifying management units and may also inform fall sampling locations targeting young carp (see deliverable 3 below).

In addition to radio-tagged carp moving within and between lakes, carp marked with T-bar tags have also been observed moving between lakes. Specifically, one carp tagged in North Lundsten Lake was subsequently recaptured in West Auburn Lake two days later and one carp tagged in Mud Lake was later recaptured in Halsted's Bay.

Deliverable 3: Identification of sources of juvenile carp across the watershed

Relative abundance of young-of-the-year common carp

Methods

In order to assess the distribution and abundance of young-of-the-year carp (YOY; carp spawned that year), we conducted standardized trap-net surveys across the subwatershed. Trap-nets (also known as fyke nets or hoop nets) are a common type of sampling gear used to survey fishes in the littoral zone of lakes (e.g. panfish and YOY fishes). Trap-nets consist of a long section of net (30 ft x 3 ft wall) staked close to shore that leads out to an underwater frame that further directs fish through a series of hoops and funnels until they are 'trapped' in the rear of the net. Five nets are set around the perimeter of each lake and are left in place overnight for approximately 24 hours. These surveys are conducted in August or September, when YOY fishes are large enough to sample, but before water temperatures cool. These surveys are important because they capture YOY common carp, one-year-old carp, and many other native fish species. Identifying areas with a high abundance of young carp is critical for understanding and managing common carp populations at a watershed scale as these areas have been shown to provide a source of young carp that may disperse across long distances.

Results

Trap-net surveys targeting juvenile common carp were completed in August and September of 2014 in 14 of the 15 accessible lakes discussed above with the exception of Halsted's Bay due to threat of transporting zebra mussels *(Dreissena polymorpha)*. Trap-net surveys were also conducted in numerous other connected wetlands and ponds including: Crown College Pond, Big SOB Lake, Yetzer's Pond, Lake #2 (Carver Park Reserve, S of Grimm Road), Shady Pond (Carver Park Reserve, downstream of Sunny Lake), and Marsh Lake (Table 1). Additionally, a gill net survey was conducted in Carl Krey's Lake because trap-netting was not feasible. Of all of the locations sampled, YOY carp were only captured in three locations: 1 YOY (0.2 per net) in Mud Lake, 4 YOY (1.0 per net) in Crown College Pond, and 99 YOY in Big SOB Lake (19.8 per net). Additionally, one-year-old carp were also sampled in 2 locations: 2 in Shady Pond (0.67 per net) and 2 in Carl Krey's Lake (gillnet; Table 4). These systems are now of special interest and concern. Follow-up surveys in 2015 and 2016 will be conducted to confirm presence of young carp and to assess annual variation in catch rates.

Historical patterns of carp recruitment via ageing analysis

Methods

In order to elucidate historical trends in common carp recruitment, we conducted an aging study in Parley Lake, Mud Lake, and Halsted's Bay. In November of 2014, at least 50 common carp were sampled via electrofishing in each lake, removed from the system, and frozen for subsequent analysis following established protocols for common carp outlined in Bajer and Sorensen (2010). More specifically, in winter of 2014-15, the asterisci otoliths (i.e. ear bones) were extracted, embedded in epoxy, and sectioned using a slow speed saw. Annual growth rings were counted using a compound microscope by two independent readers.

Next year, the U of MN will sample carp for age determination from additional locations within the Six Mile Creek Subwatershed. These locations will be determined in conjunction with MCWD staff. Lakes Wassermann, Auburn, and Lundsten are of particular interest.

Results

In total, 162 common carp were collected for age determination in Parley Lake, Mud Lake, and Halsted's Bay (n=54 per lake). All of these samples were aged by two independent readers and consensus (± 1 year) was reached for 153 carp (n=51 per lake). The age structure of common carp was similar across all three lakes (Figure 16). This information, coupled with evidence of carp movement between these lakes, supports the notion that Parley-Mud-Halsted's should be viewed as a single management unit. Notably, Parley Lake appears to contain a higher abundance of younger carp relative to the other lakes downstream, suggesting that fish may originate from nursery areas connected to Parley Lake (i.e. Big SOB & Crown College Pond; Figure 16). Additionally, the age structure of common carp in Parley-Mud-Halstead's combined also reveals some striking trends in historical recruitment. Specifically, dating back to the 1960s, there have only been a few strong year classes (i.e. 1990, 1991, & 2002; Figure 17). These 3 year classes account for 63% of all carp sampled from the three lakes. In many other years there was little to no recruitment identified. This is encouraging from a control perspective as continuous recruitment would present management challenges.

Tentative Management Recommendations

The overarching aim of the common carp assessment in the Six Mile Creek Subwatershed is to develop a rigorous scientific understanding of the carp in this system to develop sustainable control strategies. After seven months of data collection, it is presently premature to definitively outline management units and strategies. Nevertheless, based on our current understanding of the common carp population(s), we can suggest some plausible strategies.

Tentative management units

Based on the abundance estimates, movement data, size structures, and age structures of common carp sampled throughout the Six Mile Creek Subwatershed, it is clear that there are multiple sub-populations and consequently multiple management units. The degree of connectivity between tentative sub-populations is however presently unclear and will become better understood after two full years of tracking radio-tagged carp.

At this point in the study, data suggest that carp inhabiting Lakes Parley, Mud, and Halsted's comprise a single population and also that carp can and do move between Lundsten and Auburn Lakes. Based on low catch rates of common carp in Lakes Stone, Zumbra, Sunny, and Steiger, it appears that these lakes may comprise one or more separate management units. The degree of connectivity between Piersons Lake, Wassermann Lake, and downstream lakes is presently unclear.

Strategies to suppress recruitment

Given the fecundity of adult female carp (2-3 million eggs per large female), suppression of recruitment is the cornerstone of long-term carp management. Although a few tentative carp nurseries have been identified in the Six Mile Creek Subwatershed (i.e. Big SOB lake, Crown College Pond, Carl Krey Lake, and Shady Pond), more data on springtime spawning migrations of adult carp, the distribution and abundance of young carp, and the age structures of additional carp populations is necessary to inform the feasibility of recruitment suppression and possible management strategies.

Strategies to reduce the biomass of adult carp

After carp recruitment is better understood and ongoing recruitment is under control, it is reasonable to remove adult carp with the intention of reducing carp biomass below damaging levels. Because low numbers of adult carp (i.e. <100 kg/ha including measurement error) have not been shown to inflict significant ecological damage and their removal is likely to be expensive, it critical to understand the distribution, abundance, and biomass of adult carp throughout the subwatershed to efficiently target management efforts. Although our current estimates are only based on one season, it appears that there are locations that both warrant and do not warrant adult carp removal. Locations that will very likely require adult carp removal efforts include Halsted's Bay, Mud Lake, Parley Lake, Auburn Lakes, and Wassermann Lake. Due to fluctuating water levels in 2014, it was difficult to sample North and South Lundsten Lakes with an electrofishing boat, so additional surveys are required to refine estimates of carp abundance. Additional surveys are also necessary to confirm low estimates of carp density in several locations (e.g. Lakes Piersons, Steiger, Sunny, Zumbra, & Stone). It appears that carp do form winter aggregations in most of the study lakes, so under-ice seining will likely be a viable management strategy depending on substrate conditions. Trapping and removal of springtime spawning migrants may be another viable management strategy depending on spring carp movement patterns.

Progress & Future Plans

The U of MN has completed all tasks as outlined in the Project Scope. Specifically, the U of MN has completed electrofishing surveys to estimate adult carp abundance in at least 7 study lakes (n=15), implanted radio-tags in 102 carp across the Subwatershed, completed four rounds on monthly tracking, conducted trap-net surveys in relevant study lakes, ponds, and wetlands (n=21), and completed an aging study in one of the proposed management units. Details of plans for the 2015 field season for each deliverable are outlined below.

Deliverable 1: Estimates of adult common carp abundance in all accessible lakes

Up to 3 additional electrofishing surveys will be conducted in each lake that was surveyed in 2014 (n=15; see table 1). Lakes that were surveyed the fewest number of times in 2014 and lakes which had the highest variability in common carp catch rates will be prioritized (i.e. North Lundsten, South Lundsten, East Auburn, Sunny, & Stone).

Because estimated common carp abundance and biomass is very high in some of the Six Mile Creek study lakes (i.e. Wassermann, Parley, Mud, & Halsted's Bay), it would be beneficial to verify our abundance estimates that are based on catch per unit effort measurements with supplemental mark-recapture estimates. Because we have already marked hundreds of carp with T-bar tags in these lakes, supplemental mark-recapture estimates could be readily calculated if enough tagged carp could be resampled. This may be possible via contracting commercial fishermen to seine these lakes under the ice. Although these efforts would be beyond the Project Scope, we are interested in seeking additional funding and/or reallocating some research funds to support this additional data collection.

Deliverable 2: Information on the seasonal distribution and movement patterns of adult carp

In spring of 2015, we will implant additional radio-tags in Sunny Lake (n=3), North Lundsten Lake (n=8), and South Lundsten Lake (n=7) which will bring the total to 120 radio-tagged fish in the system. We will also replace any radio-tags that were lost due to fish mortality. We will continue tracking all radio-tagged carp once per month. If time permits, we will obtain higher resolution tracking data during the spring spawning season in order to identify spawning habitat and thus inform where to conduct additional trap-net surveys if needed.

Deliverable 3: Identification of sources of juvenile carp across the watershed

In order to assess annual variation in the distribution and catch rates of juvenile carp, a second trap-net survey will be conducted in each location that was sampled in 2014 (n=21; see table 1). Additionally, some new locations may also be sampled; the locations of new survey sites will be determined based on springtime spawning movements of adult carp and on the results of winter dissolved oxygen sampling. Of special interest are the three ponds adjacent to Wassermann Lake, Auburn Marsh (S. of West Auburn Lake), Church Lake, and Sink Hole Pond (along Six Mile Creek just S. of Hwy 5).

A second aging study will be conducted to complement the aging study that was completed for Parley-Mud-Halsted's Bay. The location of this aging study has yet to be determined, but it will contain samples from at least three lakes located in the upstream half of the subwatershed (e.g. Wassermann Lake, Auburn Lake, & Lundsten Lake).

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Table 1. Overview of study design -- Attributes of study lakes in the Six Mile Creek Subwatershed and available sampling data collected by the University of Minnesota. X's denote sampling that has occurred in 2014, O's denote sampling proposed for 2015, asterisks (*) denote radio-tags that will be implanted in spring of 2015, and double asterisks (**) denote sampling conducted by MCWD staff.

Location	Surface Area (ac)	Max Depth (ft)	Electrofishing Survey	Trapnet Survey	Aging Study	Radio Telmetry (# of Tags)	Winter Dissolved Oxygen**
Halsted's Bay	552	30	X		X	15	
Mud	144	6	X	X	X	15	X
Parley	257	19	X	X	X	15	
Crown College	6	3		X			
Big SOB	7.5	25	O	X			X
Yetzer's Pond	12	2		X			
N. Lundsten	114	7	X	X	O	8*	X
S. Lundsten	77	9	X	X	O	7*	X
Turbid	40	35	X	X			
Lake #2	36	N/A		X			
W. Auburn	145	80	X	X	O	7	
E. Auburn	148	40	X	X	O	8	
Shady Pond	0.5	>5		X			X
Sunny	48	N/A	X	X		3*	X
Zumbra	193	50	X	X		7	
Stone	99	30	X	X			
Steiger	166	37	X	X		10	
Kelzer's	21	34	X	X			X
Church	16	54		O			X
Carl Krey	50	16		X			X
Wassermann	164	41	X	X	O	15	
N. Wassermann Pond	6	27		O			X
S. Wassermann Pond	13.3	27		O			X
W. Wassermann Pond	6.5	18		O			X
Marsh	143	5		X			X
Piersons	297	40	X	X		10	

Table 2. Attributes of study lakes, catch rates of common carp, and resulting estimates of common carp abundance and biomass in the Six Mile Creek Subwatershed.

Lake Name	Area (ha)	# of Surveys	CPUE (SE) (# / hr)	Density (# / ha)	Abundance N, mean (95%CI)	Average Weight (kg)	Biomass (kg/ha)
Halsted's Bay	223.4	4	61.3 (4.6)	292.0	65,225 (55,803-74,646)	3.7	1,093 (935-1,251)
Mud	37.6	6	22.7 (5.2)	110.0	4,138 (2,325-5,951)	3.9	428 (241-616)
Parley	104.4	6	26.2 (13.4)	126.5	13,203 (11,647-14,758)	3.5	444 (392-496)
North Lundsten	43.7	2	18.3 (9.2)	89.5	3,910 (191-7,630)	2.0	177 (9-345)
South Lundsten	29.9	1	8.3 (NA)	42.4	1268 (NA)	2.3	97 (NA)
West Auburn	53.8	3	27.0 (3.1)	130.1	7,002(5,458-8,547)	1.9	250 (195-306)
East Auburn	46.9	3	31.6 (12.6)	151.7	7,120 (1,644-12,596)	1.8	280 (65-495)
Turbid	16.2	2	25.3 (2.1)	122.4	1,981 (1,674-2,288)	3.1	378 (319-436)
Wasserman	66.0	4	33.1 (5.2)	159.1	10,494 (7,309-13,679)	3.0	480 (334-625)
Piersons	120.1	5	3.1 (0.7)	17.7	2,119 (1,380-2,859)	3.3	59 (38-79)
Stieger	67.1	4	8.2 (3.3)	41.7	2,799 (760-4,838)	3.2	135 (37-234)
Sunny	19.4	1	2.4 (NA)	14.3	279 (NA)	2.6	37 (NA)
Zumbra	89.4	4	7.5 (1.8)	38.3	3,426 (1,967-4,885)	2.5	94 (54-135)
Stone	39.3	1	3.8 (NA)	20.7	813 (NA)	4.4	91 (NA)
Kelzer's	8.0	1	2.1 (NA)	13.1	105 (NA)	4.8	63 (NA)

Table 3. Summary of winter aggregation occurrence and timing in the Six Mile Creek study lakes.

Location	November 2014	December 2014	January 2015	February 2015
Halsted's Bay				X
Mud				
Parley		X	X	X
W. Auburn			X	X
E. Auburn	X	X	X	X
Zumbra			X	X
Steiger				
Wassermann		X	X	X
Piersons	X	X	X	X

Table 4. Catch rats of young-of-year (YOY) and age 1 carp from standardized trap-net surveys conducted in Six Mile Creek. Asterisk (*) denotes catch rates from gill net survey.

Location	Catch Rate YOY Carp (# / Net)	Catch Rate Age 1 Carp (# / Net)
Mud	0.2	0
Parley	0	0
Crown College	1.0	0
Big SOB	19.8	0
Yetzer's Pond	0	0
N. Lundsten	0	0
S. Lundsten	0	0
Turbid	0	0
Lake #2	0	0
W. Auburn	0	0
E. Auburn	0	0
Shady Pond	0	0.67
Sunny	0	0
Zumbra	0	0
Stone	0	0
Steiger	0	0
Kelzer's	0	0
Carl Krey	0	2.0*
Wassermann	0	0
Marsh	0	0
Piersons	0	0

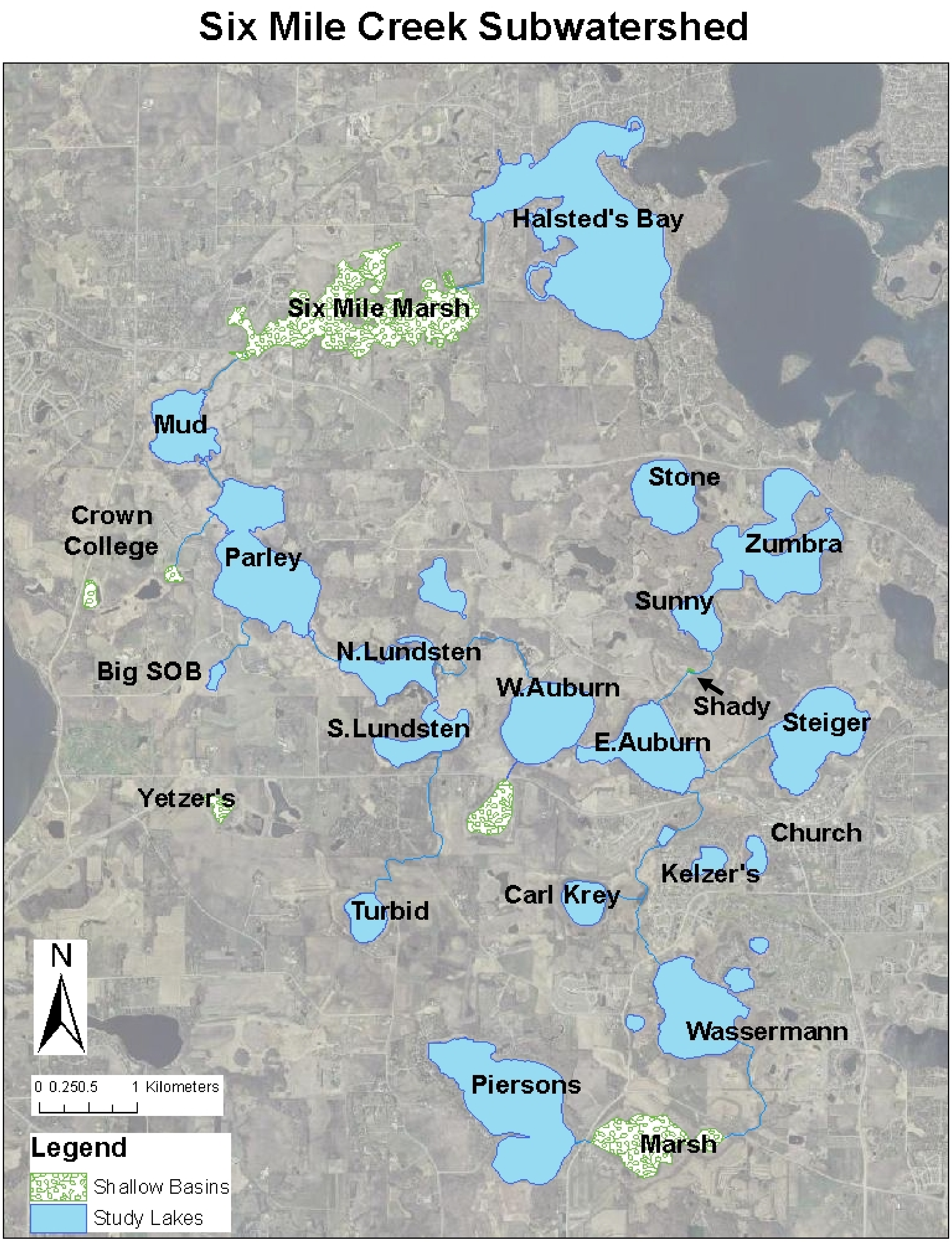

Figure 1. Overview map of Six Mile Creek Subwatershed.

Lake Piersons Common Carp Locations -- November & December 2014

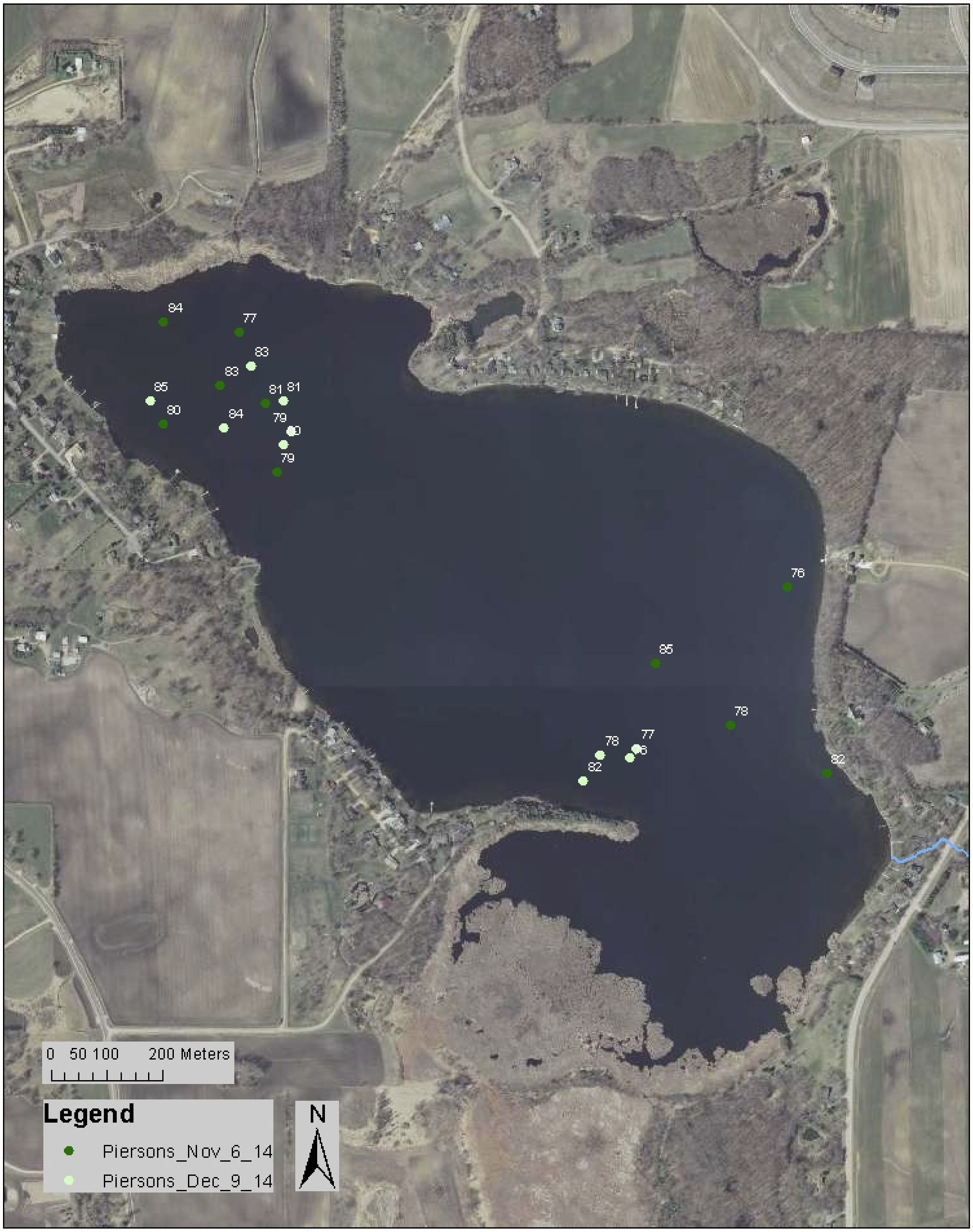

Figure 2. 2014 monthly locations of common carp originally radio-tagged in Piersons Lake (Dark Green=November, Light Green=December). Individual carp are labeled with unique fish identification numbers (White).

Lake Piersons Common Carp Locations -- January & February 2015

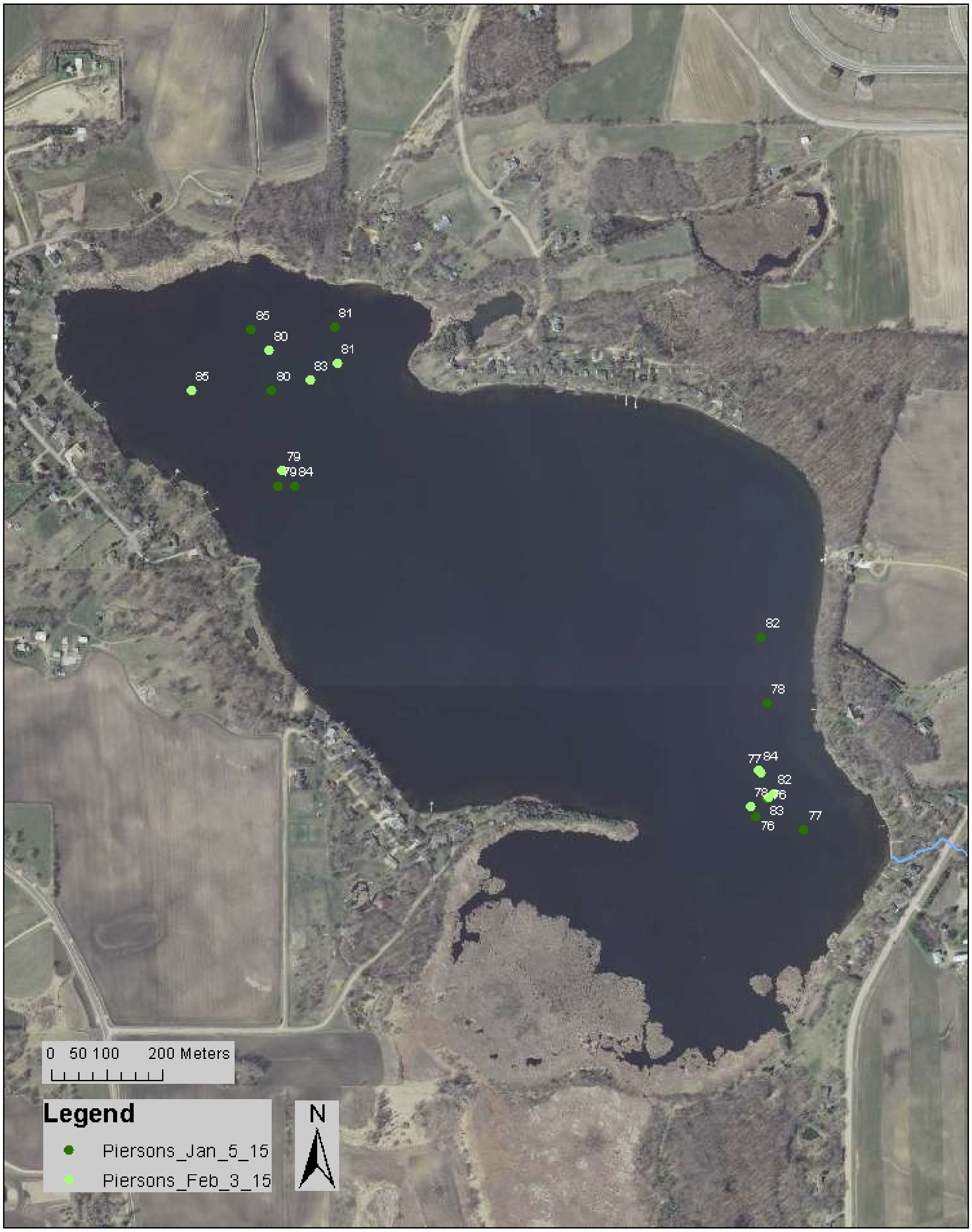

Figure 3. 2015 monthly locations of common carp originally radio-tagged in Piersons Lake (Dark Green=January, Light Green=February). Individual carp are labeled with unique fish identification numbers (White).

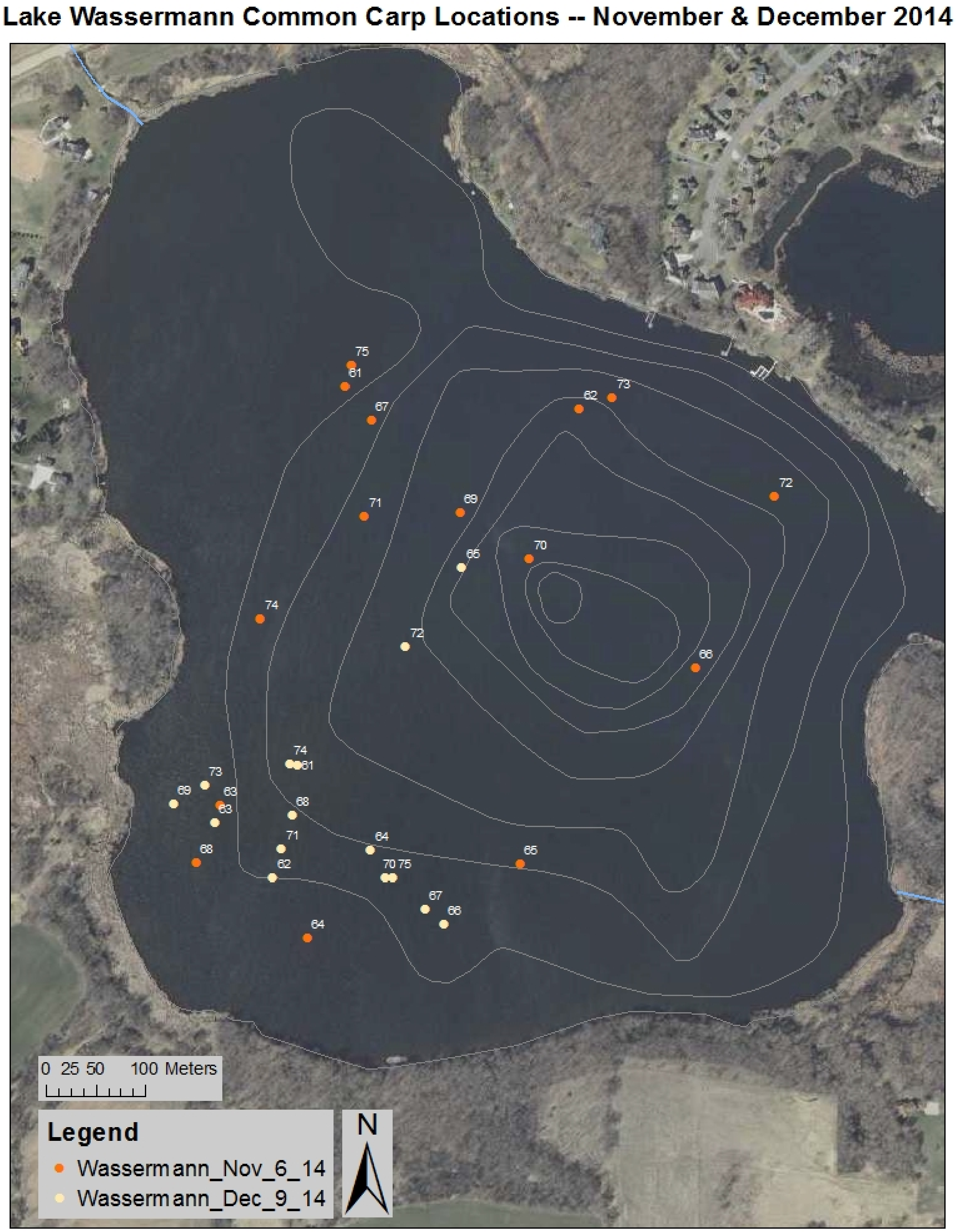

Figure 4. 2014 monthly locations of common carp originally radio-tagged in Lake Wassermann (dark orange=November, light orange=December). Individual carp are labeled with unique fish

identification numbers (White).

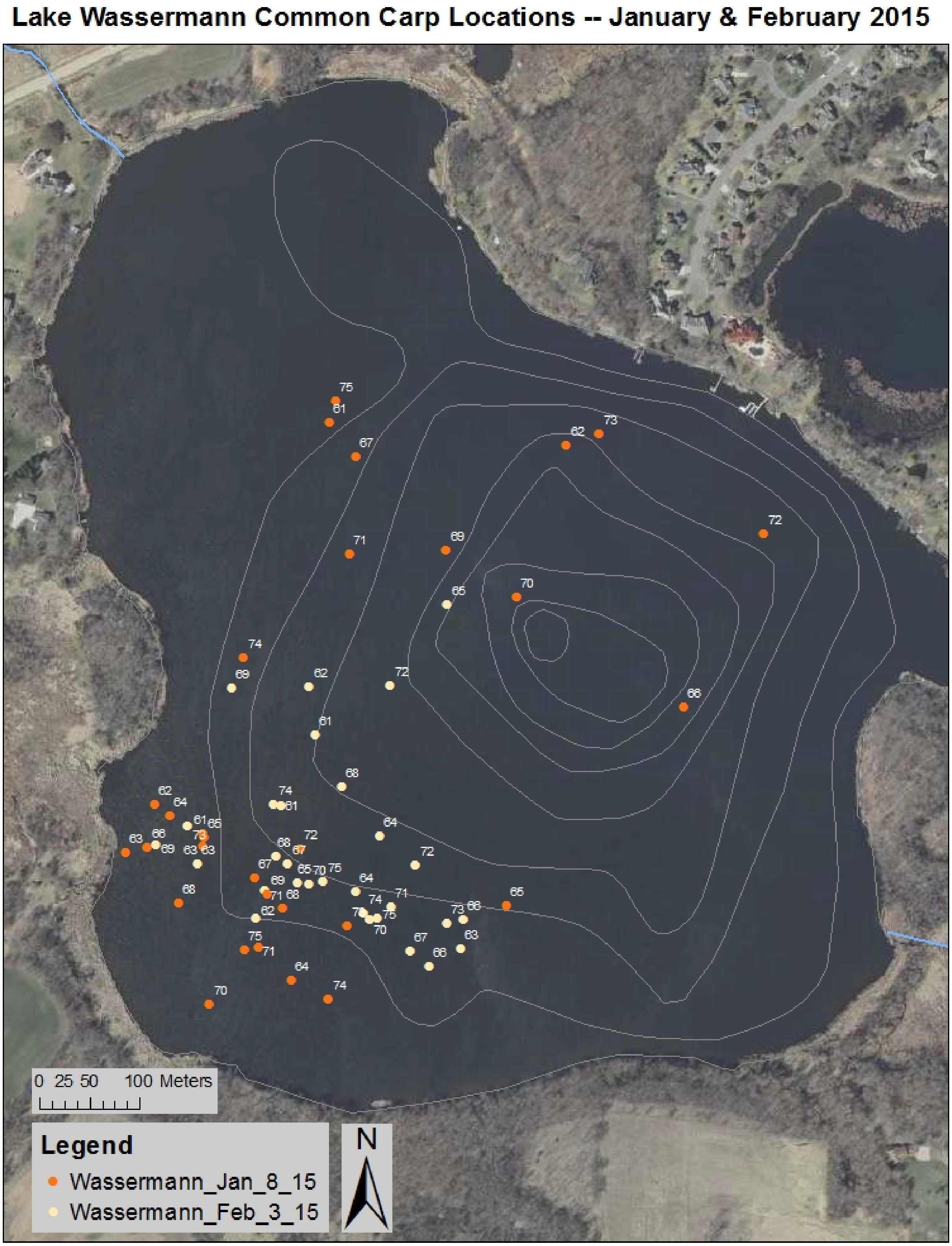

Figure 5. 2015 monthly locations of common carp originally radio-tagged in Lake Wassermann

(dark orange=January, light orange=February). Individual carp are labeled with unique fish identification numbers (White).

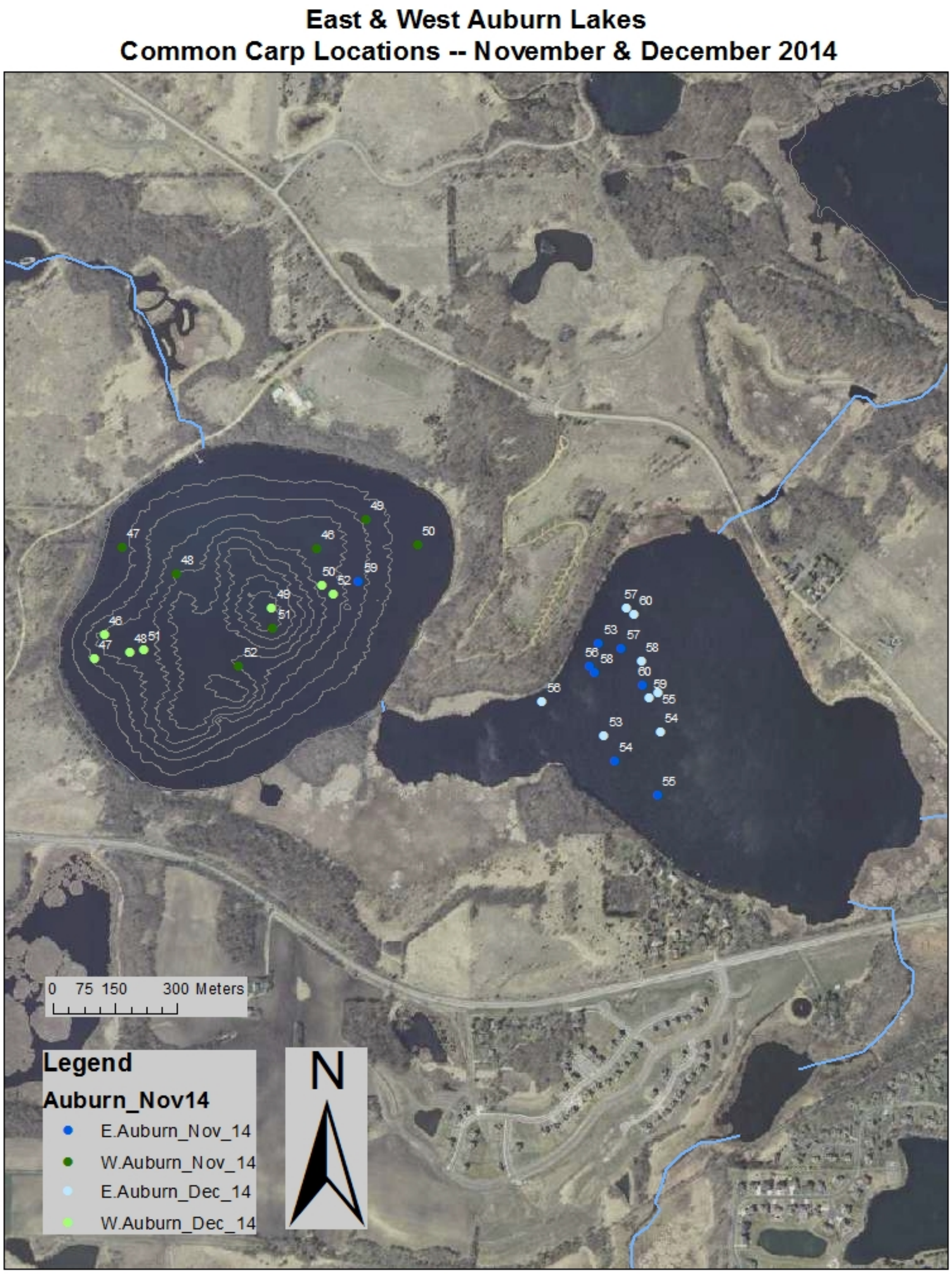

Figure 6. 2014 monthly locations of common carp originally radio-tagged in East and West Auburn Lakes (dark blue=November locations of fish tagged in East Auburn, light

blue=December locations of fish tagged in East Auburn, dark green=November locations of fish tagged in West Auburn, light green=December locations of fish tagged in West Auburn). Individual carp are labeled with unique fish identification numbers (White).

East & West Auburn Lakes
Common Carp Locations -- January & February 2015

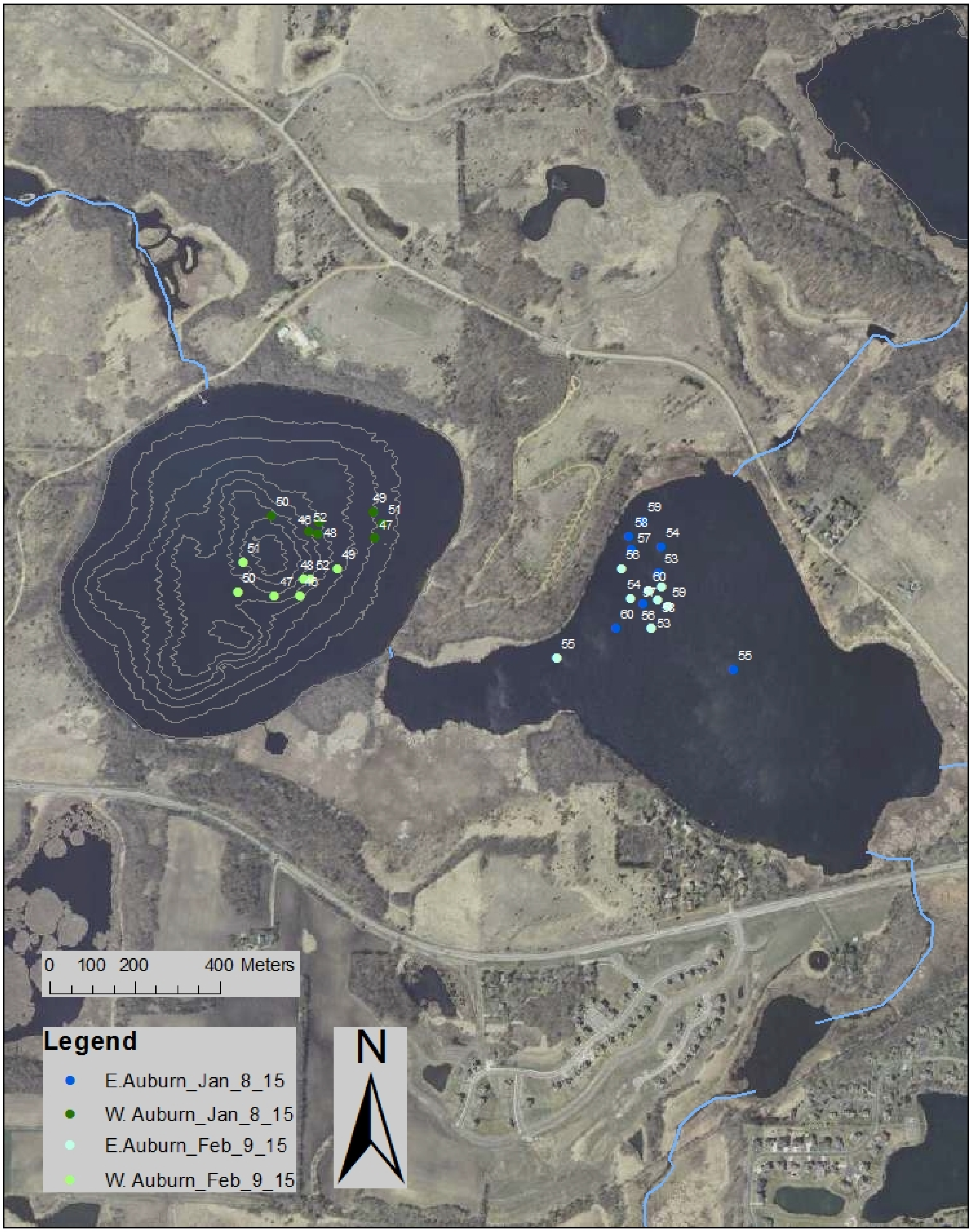

Figure 7. 2015 monthly locations of common carp originally radio-tagged in East and West Auburn Lakes (dark blue=January locations of fish tagged in East Auburn, light blue=February locations of fish tagged in East Auburn, dark green=January locations of fish tagged in West

Auburn, light green=February locations of fish tagged in West Auburn). Individual carp are labeled with unique fish identification numbers (White).

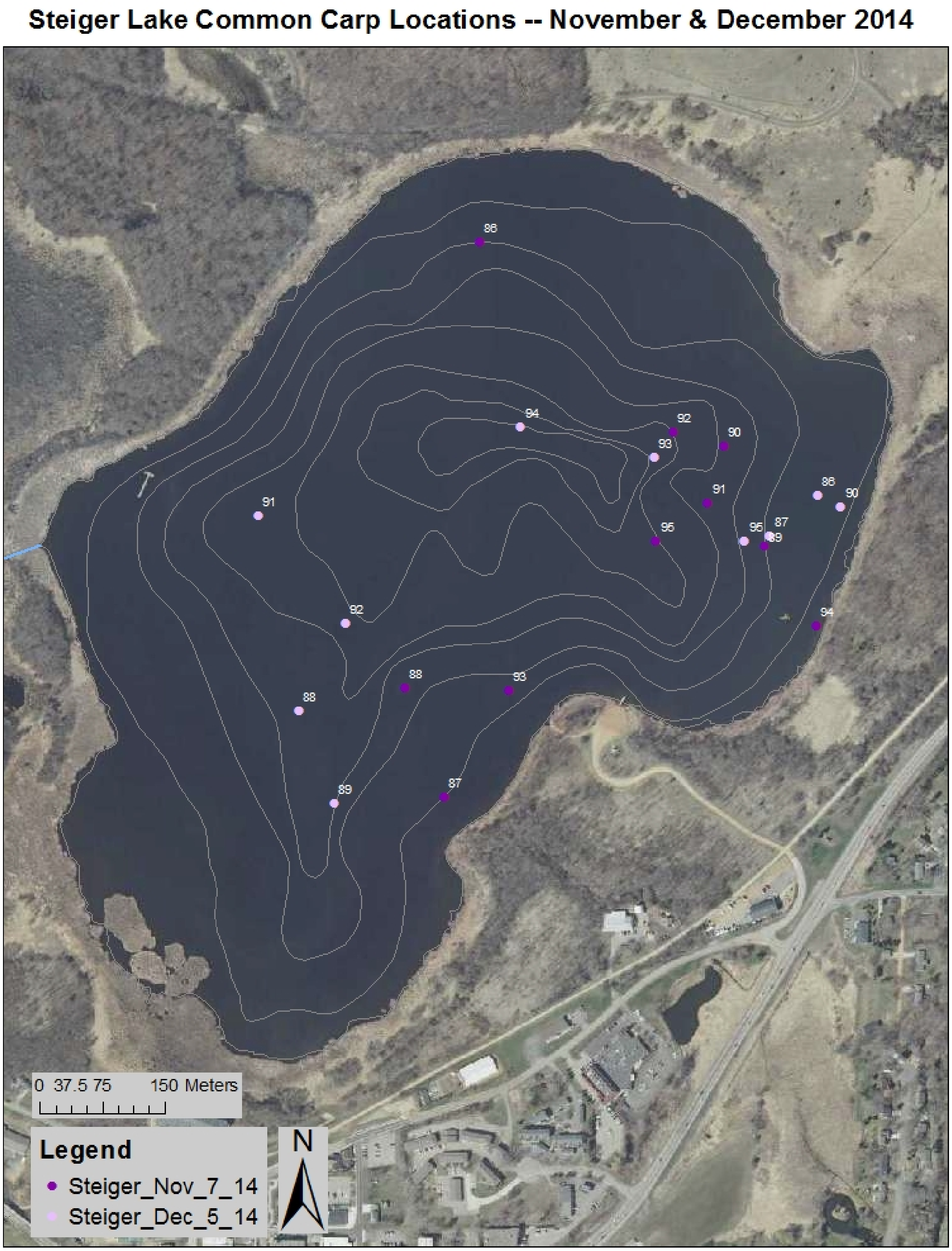

Figure 8. 2014 monthly locations of common carp originally radio-tagged in Steiger Lake (light purple=November, dark purple=December). Individual carp are labeled with unique fish identification numbers (White).

Steiger Lake Common Carp Locations -- January & February 2015

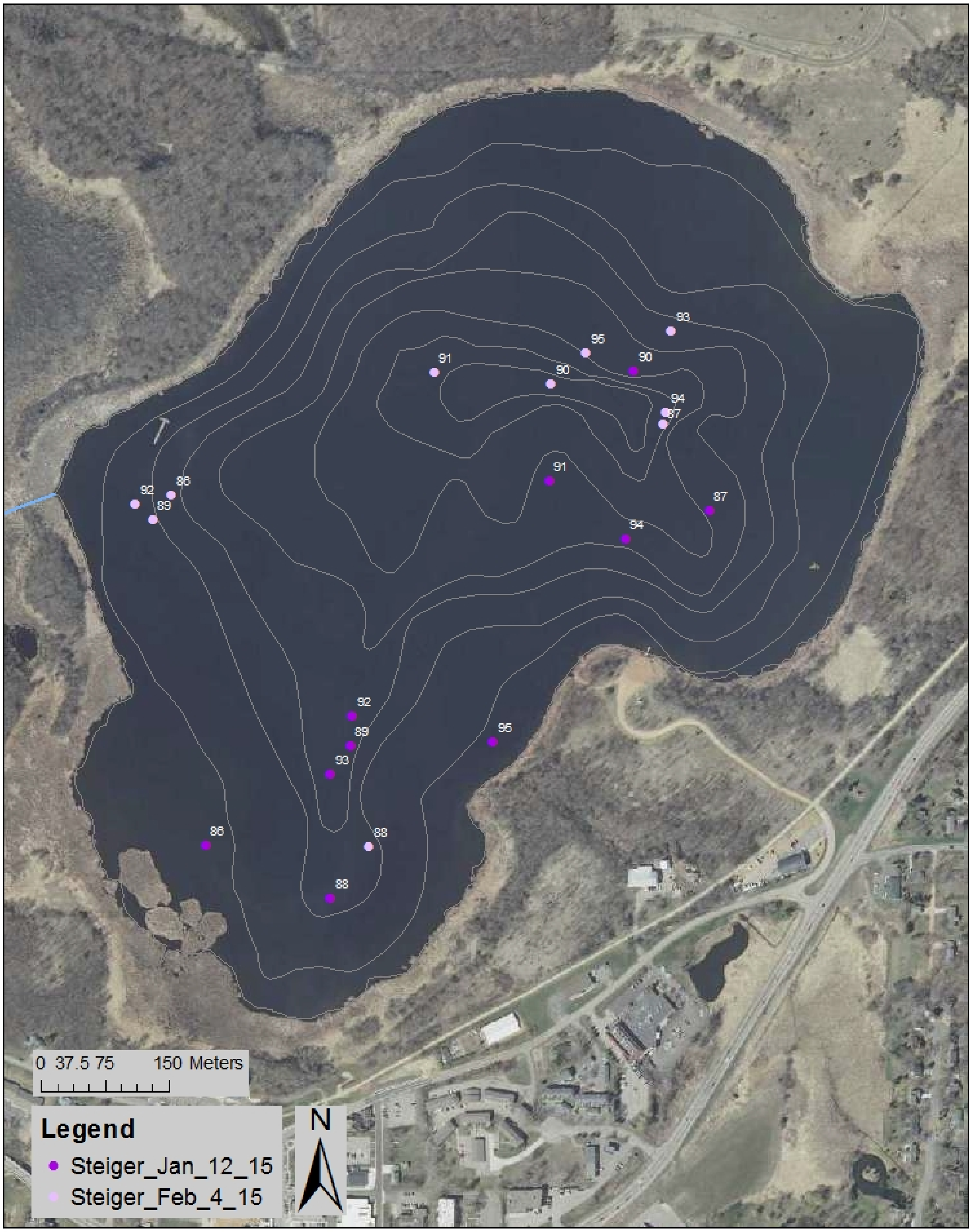

Figure 9. 2015 monthly locations of common carp originally radio-tagged in Steiger Lake (light purple=January, dark purple=February). Individual carp are labeled with unique fish identification numbers (White).

Lake Zumbra Common Carp Locations -- November & December 2014

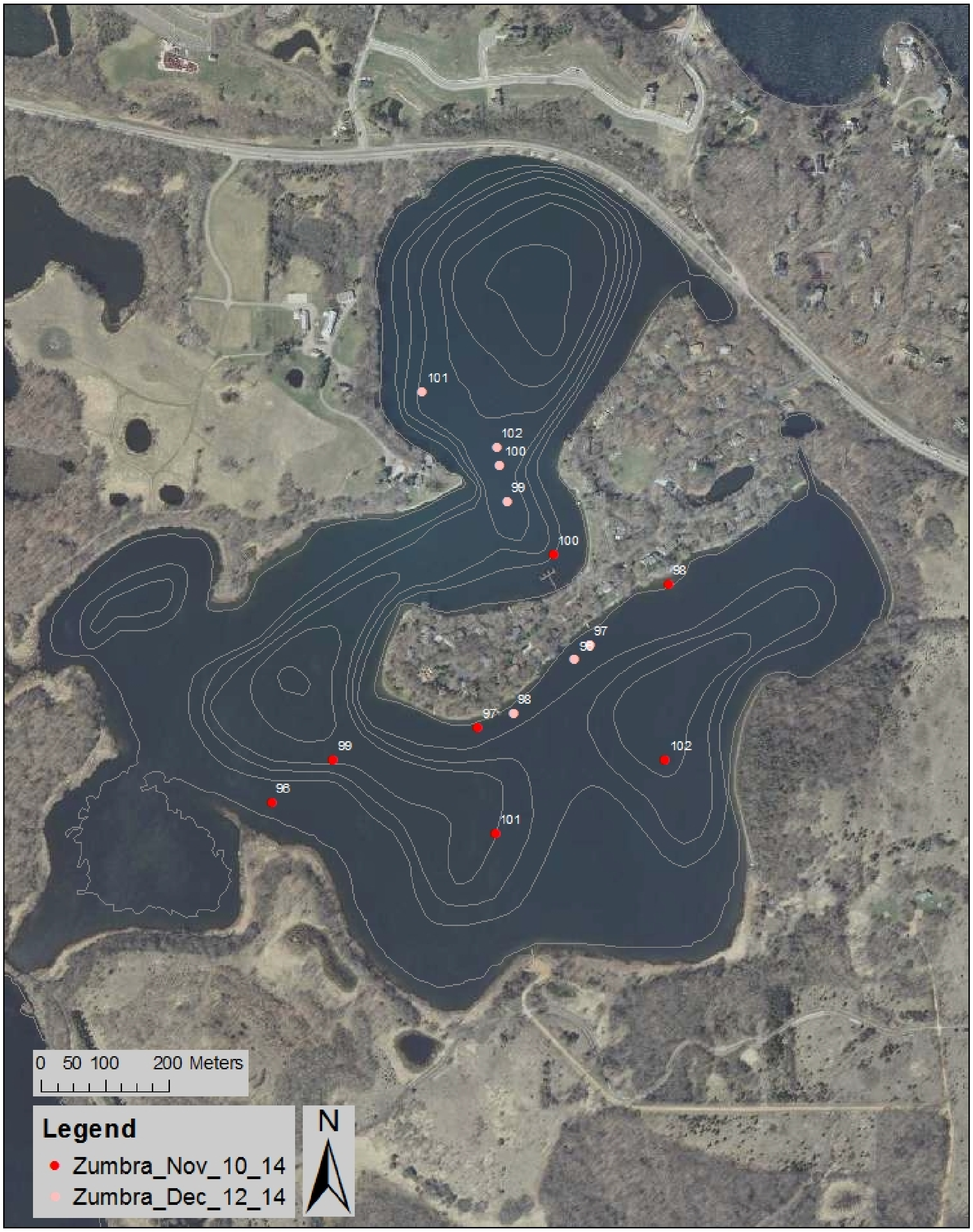

Figure 10. 2014 monthly locations of common carp originally radio-tagged in Lake Zumbra (dark red=November, light red=December,). Individual carp are labeled with unique fish identification numbers (White).

Figure 11. 2015 monthly locations of common carp originally radio-tagged in Lake Zumbra (dark red=January, light red=February,). Individual carp are labeled with unique fish identification numbers (White).

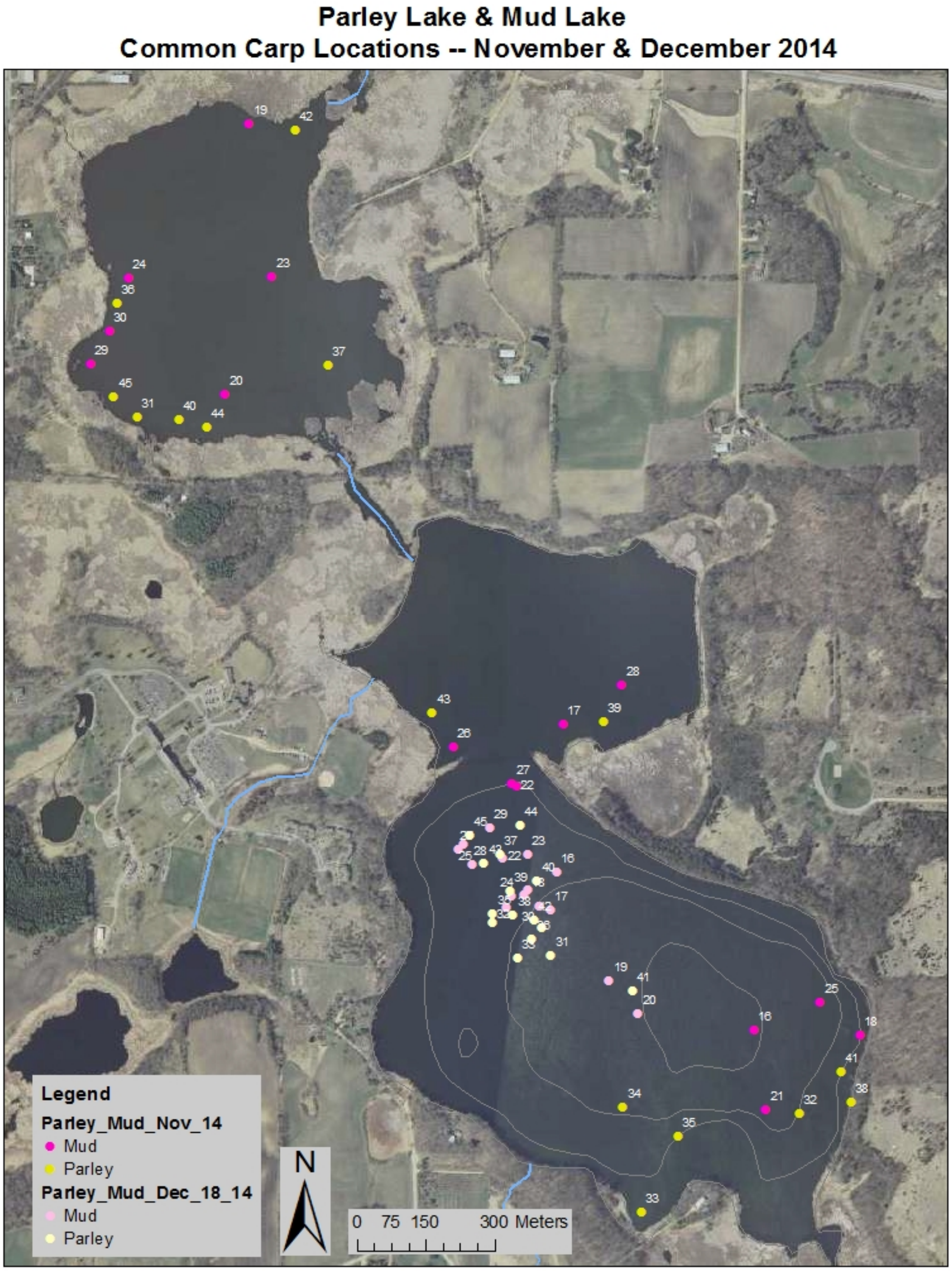

Figure 12. 2014 monthly locations of common carp originally radio-tagged in Parley and Mud Lakes (dark pink=November locations of fish tagged in Mud Lake, light pink=December locations of fish tagged in Mud Lake, dark yellow=November locations of fish tagged in Parley Lake, light yellow=December locations of fish tagged in Parley Lake). Individual carp are labeled with unique fish identification numbers (White).

Parley Lake & Mud Lake
Common Carp Locations -- January & February 2015

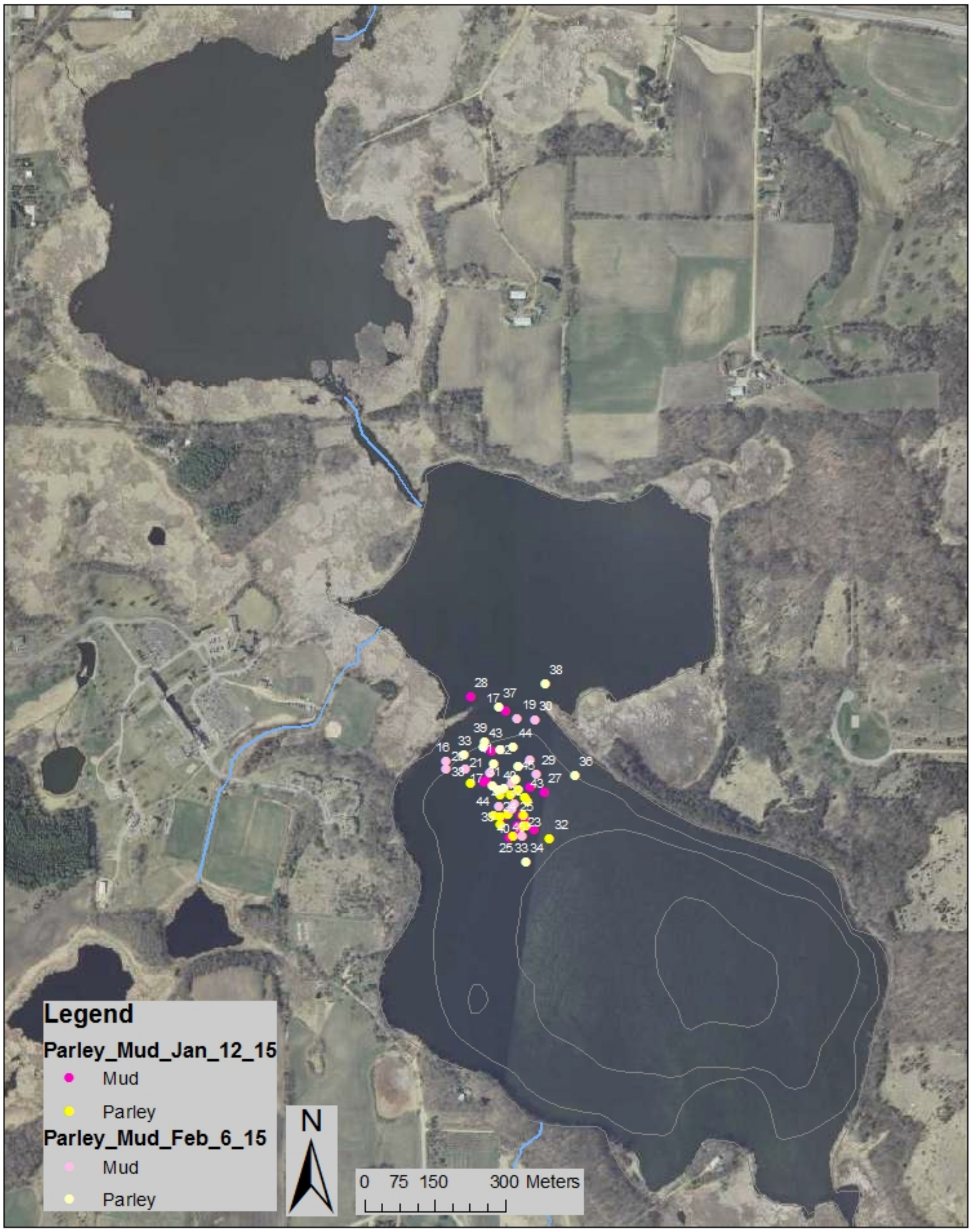

Figure 13. 2015 monthly locations of common carp originally radio-tagged in Parley and Mud Lakes (dark pink=January locations of fish tagged in Mud Lake, light pink=February locations of fish tagged in Mud Lake, dark yellow=January locations of fish tagged in Parley Lake, light yellow=February locations of fish tagged in Parley Lake). Individual carp are labeled with unique fish identification numbers (White).

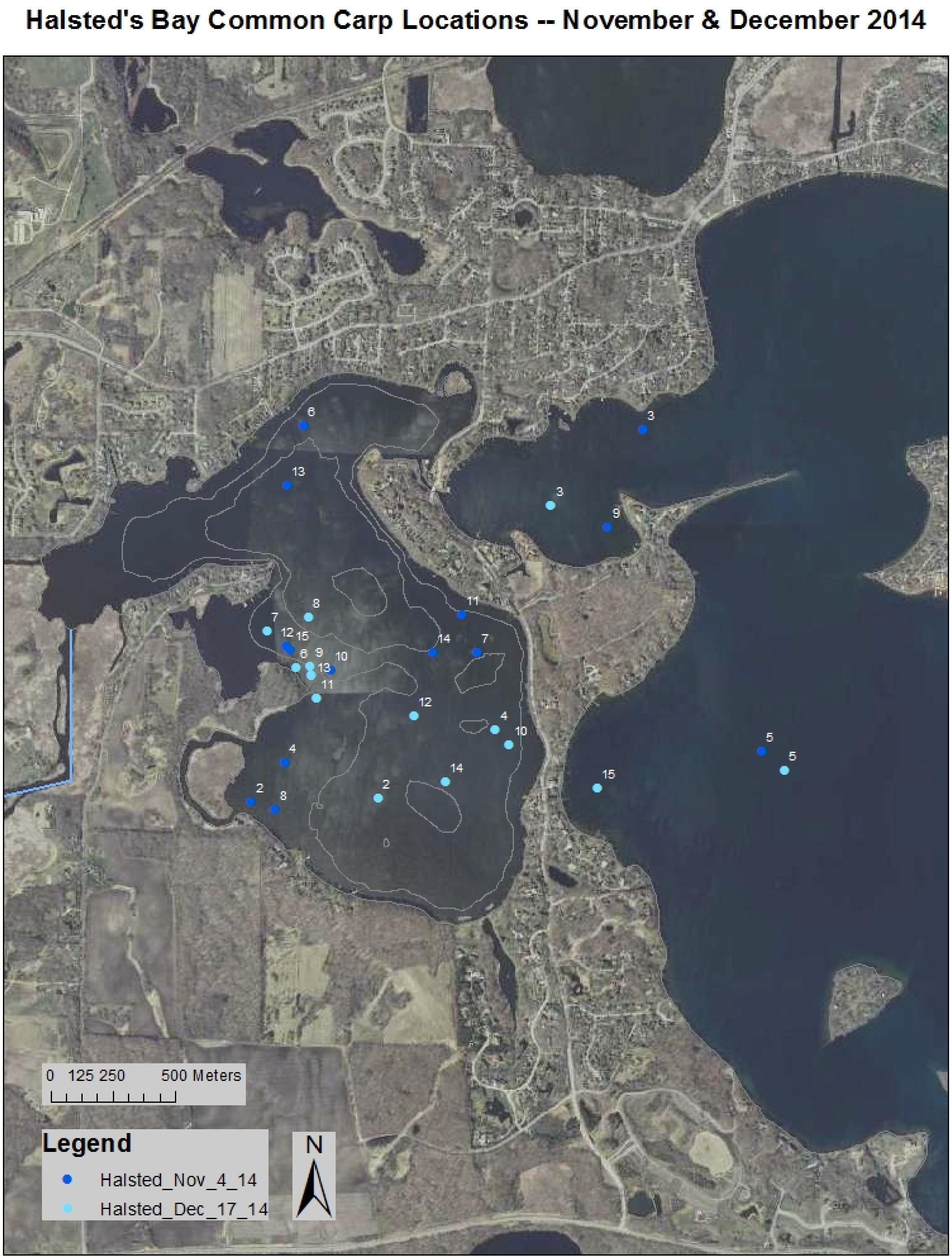

Figure 14. 2014 monthly locations of common carp originally radio-tagged in Halsted's Bay of Lake Minnetonka (dark blue=November, light blue=December). Individual carp are labeled with unique fish identification numbers (White).

Halsted's Bay Common Carp Locations -- January & February 2015

Figure 15. 2015 monthly locations of common carp originally radio-tagged in Halsted's Bay of Lake Minnetonka (dark blue=January, light blue=February). Individual carp are labeled with unique fish identification numbers (White).

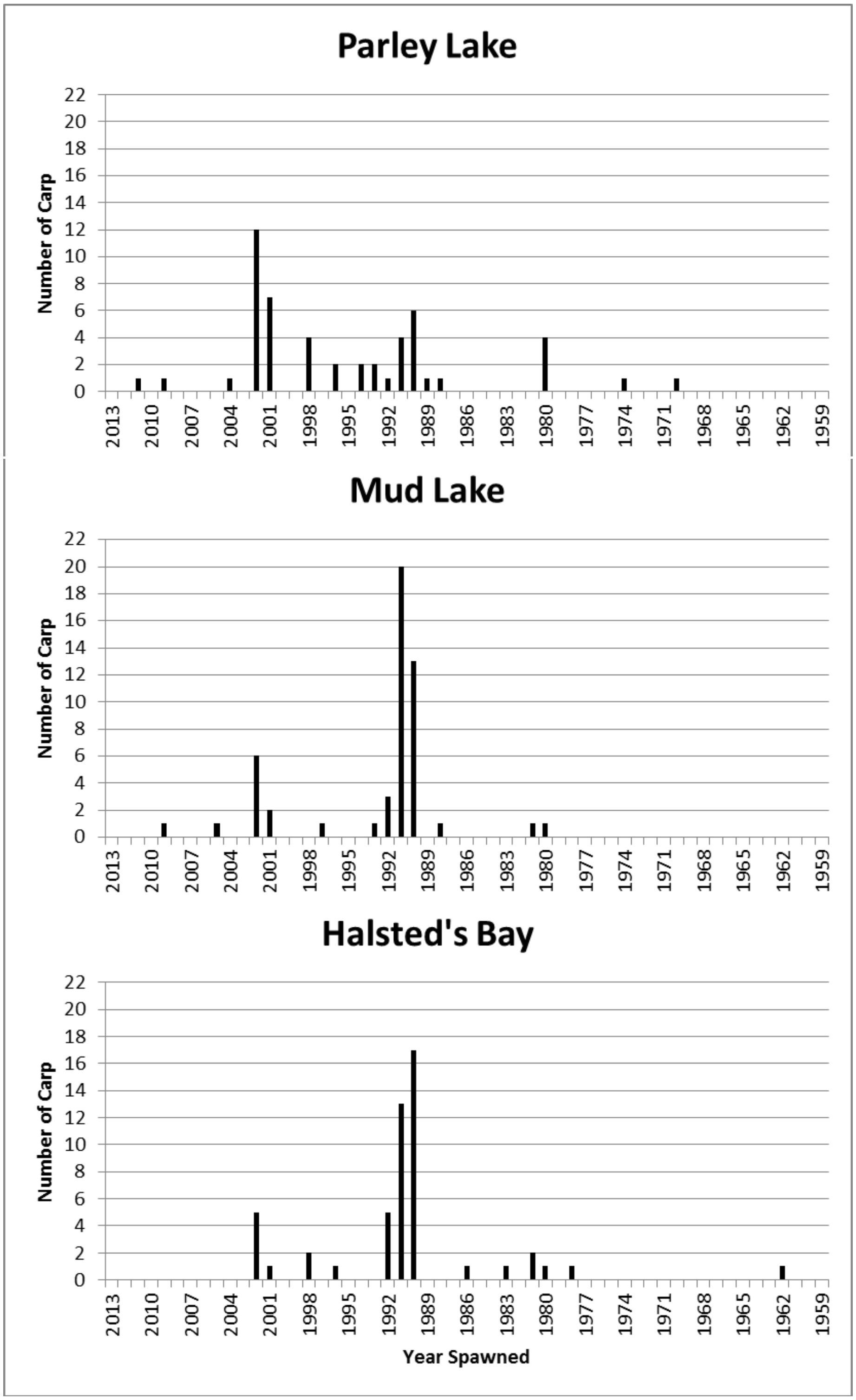

Figure 16. Age structure of common carp from Parley Lake (top, n=51), Mud Lake (middle, n=51), and Halsted's Bay of Lake Minnetonka (bottom, n=51).

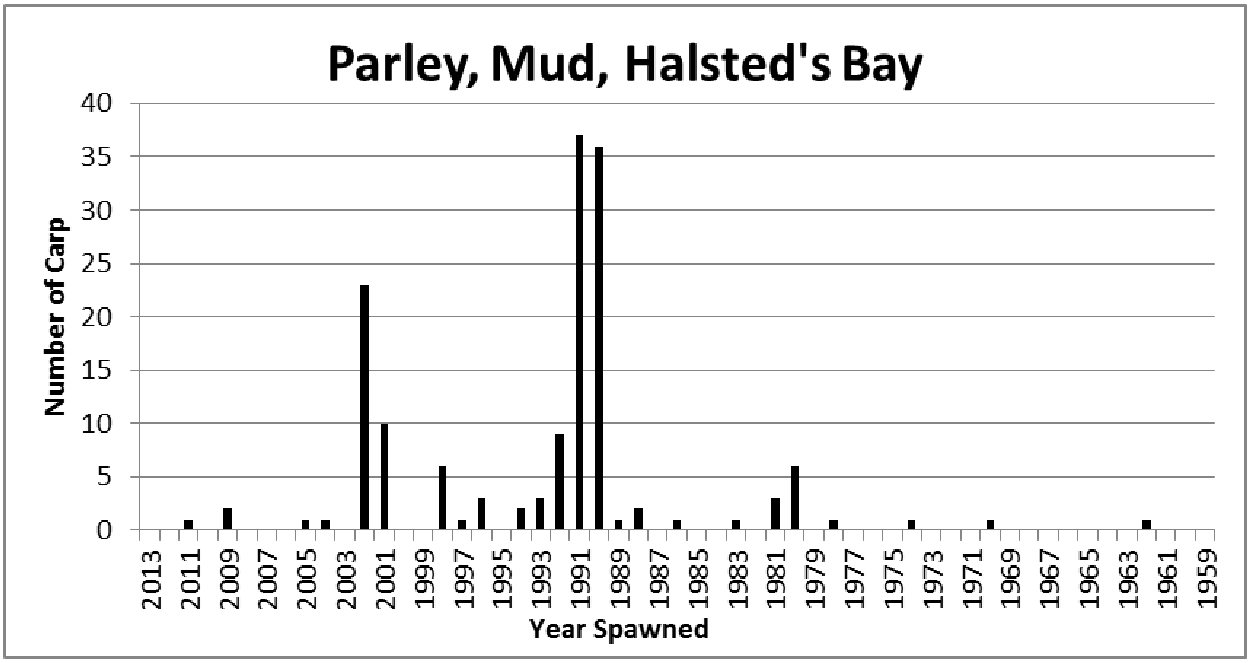

Figure 17. Age structure of common carp from Parley lake, Mud Lake, and Halsted's Bay of Lake Minnetonka combined (n=153).