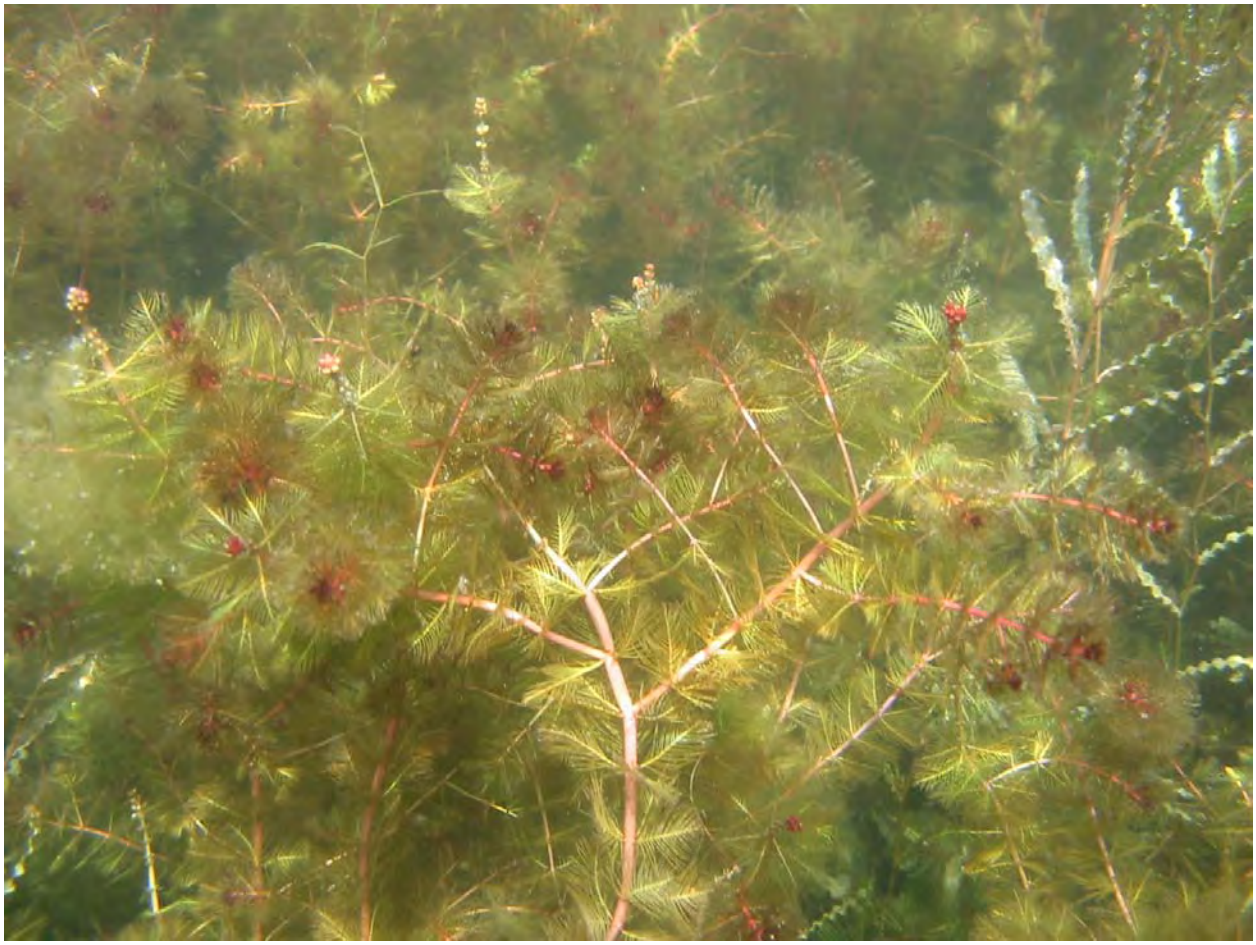
EURASIAN WATERMILFOIL SURVEY OF THREE RESERVOIRS IN THE LOWER CLARKS FORK RIVER, MONTANA: I. RESULTS OF THE FIELD VEGETATION SURVEY



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Eurasian Watermilfoil Survey of Three Reservoirs in the Lower Clarks Fork River, Montana: I. Results of the Field Vegetation Survey

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In 2008, the Lower Clark Fork Eurasian Watermilfoil Task Force issued a request for proposals to survey the Lower Clark Fork River reservoirs of Cabinet Gorge, Noxon Rapids, and Thompson Falls for the presence of Eurasian watermilfoil. Our proposal was selected from those submitted.

We divided the project into three tasks:

Task 1. Survey Current Aquatic Vegetation Community

We generated a grid of points over the entire system from Cabinet Gorge Dam to Thompson Falls Dam. These points were displayed using software on a notebook computer or handheld computer allowing navigation to each point. At each point, the depth was recorded. If the depth was less than 40', we recorded the plant species present from one rake toss. If no plants were found on the first rake toss, then one more rake toss was made to ensure that plants were not present at that site. Estimates of acreage for species of interest were based on the number of points at which the species are present and the size of the sample grid for each reservoir.

At each reservoir, 6 samples of each species of *Myriophyllum* were collected for genetic analysis. Samples were photographed digitally with the sample number, and subsamples shipped to Dr. Ryan Thum of Grand Valley State University, Dr. Vipaporn Phuntumart of Bowling Green State University, and Dr. Mark Welch of Mississippi State University for analysis. Three separate analyses were done to verify results. Each subcontractor used a different approach to develop the genetic identities of the samples. Each sample also had pressed specimens and a digital photo for future analysis.

Task 2. Eurasian Watermilfoil Littoral Survey

Eurasian watermilfoil was mapped using a combination of hydroacoustic sensing (e.g., a high-end depth finder), visual observation, and rake throws to locate plant beds. This technique offers finer-resolution point mapping to outline locations of Eurasian watermilfoil beds. While outlining beds sounds simple, particularly considering the ease with which terrestrial weeds can be mapped; this technique is in fact extremely difficult to do with submersed plants growing in 20 to 30 feet of water depth. The entire shoreline circumference of all three reservoirs was patrolled to find Eurasian watermilfoil infestations. Locations of curlyleaf pondweed (*Potamogeton crispus* L.) and flowering rush (*Butomus umbellatus* L.) were also mapped. We visually estimated the density of these areas as sparse or scattered (occasional plants, not forming a bed), moderate (less than 50% cover in the infested area), or dense (greater than 50% cover in infested area).

Boat launches are areas of particular concern. Boat launches were monitored closely for the presence of Eurasian watermilfoil, and plants mapped by location using a GPS. Incidental locations of Eurasian watermilfoil and other species of concern were noted for the distribution maps.

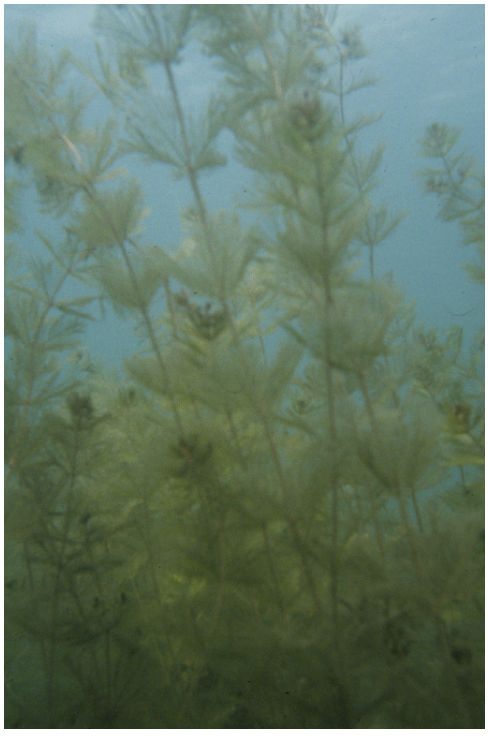
Task 3. Morphological and Genetic Analysis of *Myriophyllum* species.

The samples were collected as part of Task 1 and will be analyzed by the three labs discussed above. Since these results are still pending, we will report on the genetic and morphological analysis in a separate report.

For each reservoir, we report the summary of the point intercept survey and the shoreline survey.

Invasive Species Surveyed

Curlyleaf pondweed. Curlyleaf pondweed (*Potamogeton crispus* L.) is a nonnative invasive aquatic plant introduced to North America in the mid-1800's. A native of Eurasia, Africa and Australia, it is now found in North, Central, and South America (Catling and Dobson 1985). It grows submersed, rooted to the bottom, and forms a dense surface canopy. A member of the Potamogetonaceae family, it is distinguished by alternate ovate leaves that are curled or "crisped" and have minute teeth on the edge. While it does form viable seeds, reproduction and over-summering are predominantly by vegetative turions that are formed in the leaf axils (Madsen and Crowell 2002). Management is predominantly by the herbicides diquat and endothall, though other options are available (Madsen and Crowell 2002). It is imperative that management occurs before the formation of turions, if long-term control is the goal.



Eurasian watermilfoil. Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a nonnative invasive submersed aquatic plant. Growing submersed in 20 or more feet of water, it is rooted to the bottom yet forms a dense surface canopy. An evergreen perennial, it overwinters as a green shoot. While the plant produces viable seed, reproduction and spread is almost entirely by stem fragment (Madsen and Welling 2002, Madsen 2005). The plant forms fragments ("autofragments") in the fall through stem abscission, these autofragments have

abundant starch to aid in long-term survival. This is a key form of spread within and between lakes. Fragments formed by mechanical breakage are also viable. A native of Eurasia, it was introduced in multiple locations in North America in the 1940's (Madsen 2005). Management is predominantly by the herbicides diquat, endothall, 2,4-D, triclopyr, and fluridone; though other control techniques are available (Madsen 2005). Management with herbicides can be done selectively with a number of products (Getsinger et al. 1997, Parsons et al. 2001, Madsen et al. 2002). Overwinter drawdown has also been demonstrated to be effective. Several native species of *Myriophyllum* are found in North America that may be easily confused with Eurasian watermilfoil, including northern watermilfoil (*Myriophyllum sibiricum* Komarov) and whorled watermilfoil (*Myriophyllum verticillatum* L).

Flowering rush. Flowering rush (*Butomus umbellatus* L.) is a nonnative invasive aquatic plant to North America. It can grow both submersed and emergent leaf stages in depths up to 15 feet. Introduced to the Great Lakes region in the 1930's, it has spread across the northern US and southern Canada to Montana, Idaho, and Washington (Lui et al. 2005, USDA 2008). Flowering rush has been largely ignored until recently, so there is little published information on its management. Significant nuisance populations have established elsewhere, including on Flathead Lake in Montana.

Methods and Materials

Cabinet Gorge Reservoir

Cabinet Gorge Reservoir was surveyed using a point intercept method (Madsen 1999), with points established in a regular grid pattern with an interval of 150m. A total of 334 points were surveyed on August 9-10 2008 (Figures 1a, 1b). Points were distributed from the dam at the lower end of Cabinet Gorge Reservoir to the end of navigation at the upper end of the reservoir. At each point, the depth was recorded. If the depth was less than 40', we recorded the plant species present from one rake toss. If no plants were found on the first rake toss, then one more rake toss was made to ensure that plants were not present at that site. Any additional species visible at the point were also recorded.

On August 15, we surveyed the entire shoreline of Cabinet Gorge Reservoir. We mapped the locations of Eurasian watermilfoil and other invasive species of concern. We attempted to outline any beds or areas of dense plants.

Noxon Rapids Reservoir

Noxon Rapids Reservoir was surveyed using a point intercept method (Madsen 1999), with points established in a regular grid pattern with an interval of 250m. A total of 487 points were surveyed on August 11, 13 (afternoon), and 14 (Figures 2a, 2b, 2c). Points were distributed from the dam at the lower end of Noxon Rapids Reservoir to the end of navigation at the upper end of the reservoir. At each point, the depth was recorded. If the depth was less than 40', we recorded the plant species present from one rake toss. If no plants were found on the first rake toss, then one more rake toss was made to ensure that plants were not present at that site. Any additional species visible at the point were also recorded.

From August 16-19, we surveyed the entire shoreline of Noxon Rapids Reservoir. We mapped locations of Eurasian watermilfoil and other invasive species of concern. We attempted to outline any beds or areas of dense plants. In the end, we opted to record each segment of shoreline as having dense, moderate, or scattered infestations of either Eurasian watermilfoil, curlyleaf pondweed, or flowering rush.

Thompson Falls Reservoir

Thompson Falls Reservoir was surveyed using a point intercept method (Madsen 1999), with points established in a regular grid pattern with an interval of 150m. A total of 40 points were surveyed on August 13 (morning) (Figure 3). Points were distributed from the dam at the lower end of Thompson Falls Reservoir to the end of navigation at the upper end of the reservoir. At each point, the depth was recorded. If the depth was less than 40', we recorded the plant species present from one rake toss. If no plants were found on the first rake toss, then one more rake toss was made to ensure that plants were not present at that site. Any additional species visible at the point were also recorded.

Results and Discussion

Cabinet Gorge Reservoir

Point Survey. Of all the 334 points observed, 21.3% had some plant species present (plant cover, Table 1). The dominant species were elodea (15.9%), coontail (14.7%), and the invasive curlyleaf pondweed (10.7%). For all points observed over 40', the deepest extent of plants observed was at 24', so we arbitrarily set the maximum depth of the littoral zone at 25' (Figure 4). A cumulative depth distribution chart of Cabinet Gorge Reservoir indicates that approximately 40% of the reservoir is 25' or less deep, the maximum depth of the littoral zone (Figure 5). While habitats 5' or less are less common, the depths from 5' to 25' are fairly evenly distributed (Figure 6).

Within the littoral zone, elodea was the dominant plant (38.1%), followed by coontail (35.3%) and curlyleaf pondweed (25.2%). Eleven other native species are represented in the plant community (Table 2). Curlyleaf pondweed was the dominant invasive plant (25.2%), followed by Eurasian watermilfoil (15.1%). Flowering rush was not found at any point, but was observed scattered about the lake (see below). The littoral community averaged 1.7 species per point, with

1.3 species per point being native and 0.4 species per point invasive exotics. Plant cover averaged 51.1% of littoral points.

Depths of less than 1 foot were devoid of vegetation. Vegetation was common at depths from 1 to 12 feet, with vegetation less frequent beyond 12 feet (Figure 7). Curlyleaf pondweed was found predominantly between 3 and 12 feet deep (Figure 8). Eurasian watermilfoil was found between 1 and 11 feet deep, with scattered individuals found in deeper water (Figure 9).

Based on the number of points for a given species found in Cabinet Gorge Reservoir, we estimated that there was 195 acres of curlyleaf pondweed, 117 acres of Eurasian watermilfoil, and 0 acres of flowering rush (Table 7).

Mapping of Invasives. We surveyed the shoreline of Cabinet Gorge Reservoir, but found little in the way of dense plant growths of either curlyleaf Pondweed or Eurasian watermilfoil. Curlyleaf pondweed was found in scattered locations in both the lower (Figure 10a) and upper (Figure 10b) halves of the reservoir, with somewhat higher occurrence in the upper half. Dense congregations of points would form a bed of moderate density. This would be consistent with Noxon Rapids Reservoir being the source for curlyleaf pondweed.

Eurasian watermilfoil was much less common in Cabinet Gorge Reservoir than curlyleaf pondweed. Eurasian watermilfoil was found as sparse collections of plants in the lower (Figure 11A) and upper (Figure 11b) halves of the reservoir; but the general trend was for Eurasian watermilfoil to be more abundant in the upper half of the reservoir. None of these occurrences were categorized as dense or even moderately dense beds.

Noxon Rapids Reservoir

Point Intercept Survey. For all 487 points surveyed, 18.4% had some plant species present at that location (Table 3, Total plant cover). The dominant plant was elodea (10.1%), followed by sago pondweed (8.2%), leafy pondweed (6.8%), and coontail (6.4%). A plot of total number of species at the point versus the point's depth indicates that the deepest occurrence of plants in Noxon Rapids Reservoir was also 24', so we arbitrarily set the maximum extent of the littoral zone at 25' (Figure 12). A plot of cumulative distribution of depths indicates that less than 30% of the reservoir would be littoral habitats (Figure 13). The distribution of depths within the littoral zone is fairly evenly distributed (Figure 14).

Within the littoral zone (< 25'), 68.2% of points had vegetation (Table 4), which provides a significant amount of habitat for fish. Dominant species include elodea (37.7%), sago pondweed (30.8%), leafy pondweed (25.4%), and coontail (23.9%). Species richness is high, with an average of 2.25 species per point. Native plant richness was 1.91 species per point. Invasive species were still a relatively small component of the community, with an average of 0.35 exotic species per point. Eurasian watermilfoil was found at 12.3% of littoral points. Curlyleaf pondweed was more common, at 20.0%. Flowering rush was only found at 2.3% of points.

Vegetation was prevalent in all depths out to 15 feet, common out to 20 feet, and present to 24 feet (Figure 15). Flowering rush was found in depths from 1 to 14 feet (Figure 16). Eurasian

watermilfoil was found in depths of 5 to 16 feet, with an optimal depth of 8 to 11 feet (Figure 17). Curlyleaf pondweed was found in depths from 2 to 16 feet, with an optimal range of 4 to 11 feet (Figure 18). Note that all points within the 4 to 6 foot depth range had curlyleaf pondweed.

Based on the number of points observed for a given species, we estimated that there were 401 acres of curlyleaf pondweed, 247 acres of Eurasian watermilfoil, and 46 acres of flowering rush (Table 7).

Mapping of Invasives. Noxon Rapids Reservoir had substantially more of all three invasive plants than Cabinet Gorge Reservoir. While there were a few dense beds, much of the reservoir shoreline had a thin band (from 3 to 10 feet wide) of invasive plants ranging from scattered to dense. Curlyleaf pondweed, for instance, was found as scattered plants in much of the lower third, and as a dense band downstream of the North Shore boat launch (Figure 19a). In the middle third (Figure 19b), curlyleaf pondweed was found as a dense to scattered band, predominantly along the northern and/or eastern shores; depending on the orientation of the channel (the right-hand shore traveling downstream) (Figure 19b). In the upper third, this narrow shoreline band continues, again predominantly on the northern and/or eastern shore; with the exception of Finley Flats. At Finley Flats, a dense bed of curlyleaf pondweed was intermixed with native plants species. Eurasian watermilfoil was found in four dense beds in the lower portion of Noxon Rapids Reservoir (Figure 20a). One large bed was found in the basin adjacent to the dam, just north of the two islands (Rock Island). This bed is perched on a submerged island. The second bed is also perched on a submerged island, at the junction of Marten Creek with the main reservoir arm, but towards the eastern shore. The third dense bed, mixed with curlyleaf pondweed, is downstream of North Shore boat launch. The last bed is upstream of North Shore boat launch. Otherwise, Eurasian watermilfoil was found as scattered plants or as a component of the dense band of plants along each shore. The densest collections of Eurasian watermilfoil are in the lower third of the reservoir. In the middle third, Eurasian watermilfoil was found in dense to scattered bands along the shoreline (Figure 20b). Eurasian watermilfoil was found as only scattered plants along the eastern shore in the downstream portion of the upper third (Figure 20c). Flowering rush was found mixed in the bands of plants along the shore, except for a few small dense patches in the lower third of the reservoir (Figure 21a). Flowering rush was most dense in the lower third (Figure 21a). Flowering rush was found as scattered plants along the northern or eastern shore of the middle third (Figure 21b). These scattered plants continued along this shore in the upper third of the reservoir, with some plants also found along the edge of the dense plant beds at Finley Flats (Figure 21c).

While these plants are widely distributed in the reservoir, the total acreage is actually relatively small.

Thompson Falls Reservoir

Point Intercept Survey. For the forty points recorded, 42.5% had some plant species present (Total plant cover, Table 5). Of these, the dominants were elodea and curlyleaf pondweed (both at 32.5%), followed by coontail and northern watermilfoil (both also at 20%). No Eurasian watermilfoil was found; flowering rush was observed at 12.5% of points. A plot of number of species per point versus depth (Figure 22) indicates that the deepest plant found was in 11 feet of

water. Water clarity was good, and would allow deeper colonization; so we maintained the convention of the other two reservoirs and defined the maximum depth of the littoral zone as 25'. The cumulative depth distribution plot demonstrates that most of the reservoir (over 65%) would be classified as littoral zone using this definition (Figure 23). Within the littoral zone, the depth range of habitats is very uneven (Figure 24). Very little habitat is available for plant colonization from 12 to 23 feet due to the steep-sloping walls of the submerged old river channel, which may explain the relatively shallow distribution of plants in an otherwise clear reservoir.

Within the littoral zone, the dominant species are elodea (48.2%) and curlyleaf pondweed (42.8%), followed by coontail (29.6%) and northern watermilfoil (29.6%, Table 6). No Eurasian watermilfoil was found in Thompson Falls Reservoir. Flowering rush was found at 18.5% of the littoral points. A total of nine species were found in the littoral zone, with 63% of the sites colonized by some plant. The average number of invasive plant species per point was 0.67, the average number of native species per point was 1.56, and the average number of species per point was 2.22.

The depth distribution of vegetated sites indicates that all sites 11' or less was colonized, and no sites over 11' were colonized (Figure 25). Twenty-three percent of sites at 11' or less were colonized by flowering rush (Figure 26). Curlyleaf pondweed colonized 90% of sites from shore to 8' deep (Figure 27).

Based on the number of points found for a given species, we estimated that there are 77 acres of curlyleaf pondweed, 0 acres of Eurasian watermilfoil, and 28 acres of flowering rush (Table 7).

Mapping of Invasive Plants. Dense clumps and individual plants of flowering rush were scattered around Thompson Falls Reservoir (Figure 28). Curlyleaf pondweed was widespread in Thompson Falls Reservoir (Figure 29). Eurasian watermilfoil was not found in Thompson Falls Reservoir.

Conclusions

1. While curlyleaf pondweed, Eurasian watermilfoil, and flowering rush are widespread in these reservoirs, the total acreage is not extensive. Only four dense beds of Eurasian watermilfoil were found in Noxon Rapids Reservoir, with several areas of moderate to scattered plants. Cabinet Gorge had even fewer areas of Eurasian watermilfoil, located mostly in the upstream portion of the reservoir.

2. Cabinet Gorge had extensive native vegetation, particularly in the upstream half. Scattered to moderate density of curlyleaf pondweed and Eurasian watermilfoil was found. Only a few plants of flowering rush were found.

3. Noxon Rapids Reservoir had prolific growth of native vegetation in the littoral zone, particularly in the downstream two-thirds. Moderate to dense curlyleaf pondweed was found throughout most of the reservoir, often as a narrow band along the shore. Only four dense beds of Eurasian watermilfoil were found in Noxon Rapids Reservoir, with several areas of moderate to scattered plants. Flowering rush was found in a few dense clumps, but not large beds such as are found in Flathead Lake. Flowering rush was found scattered along the shoreline throughout the reservoir.

4. Thompson Falls Reservoir had prolific growths of a few native plant species. While no Eurasian watermilfoil was found, dense growths of both curlyleaf pondweed and flowering rush were found.

Recommendations

1. We recommend aggressive management of Eurasian watermilfoil, curlyleaf pondweed, and flowering rush. Eurasian watermilfoil is widely known as a deleterious invasive aquatic plant. Curlyleaf pondweed is not as well known as Eurasian watermilfoil, but it has been demonstrated to be a deleterious invasive plant. Flowering rush is only recently becoming recognized as an invasive plant species, with significant nuisance populations forming in Flathead Lake, MT.

2. Attempting to map beds and scattered plants is extremely tedious and yields only fair accuracy. Plants well below the surface are difficult to see, and easily missed. We would recommend finer-scale point intercept surveys in the littoral zone, with a maximum depth of 30'. I would recommend a grid size of 100 m for Cabinet Gorge and Noxon Rapids Reservoirs, and 50 m for Thompson Falls.

Acknowledgements

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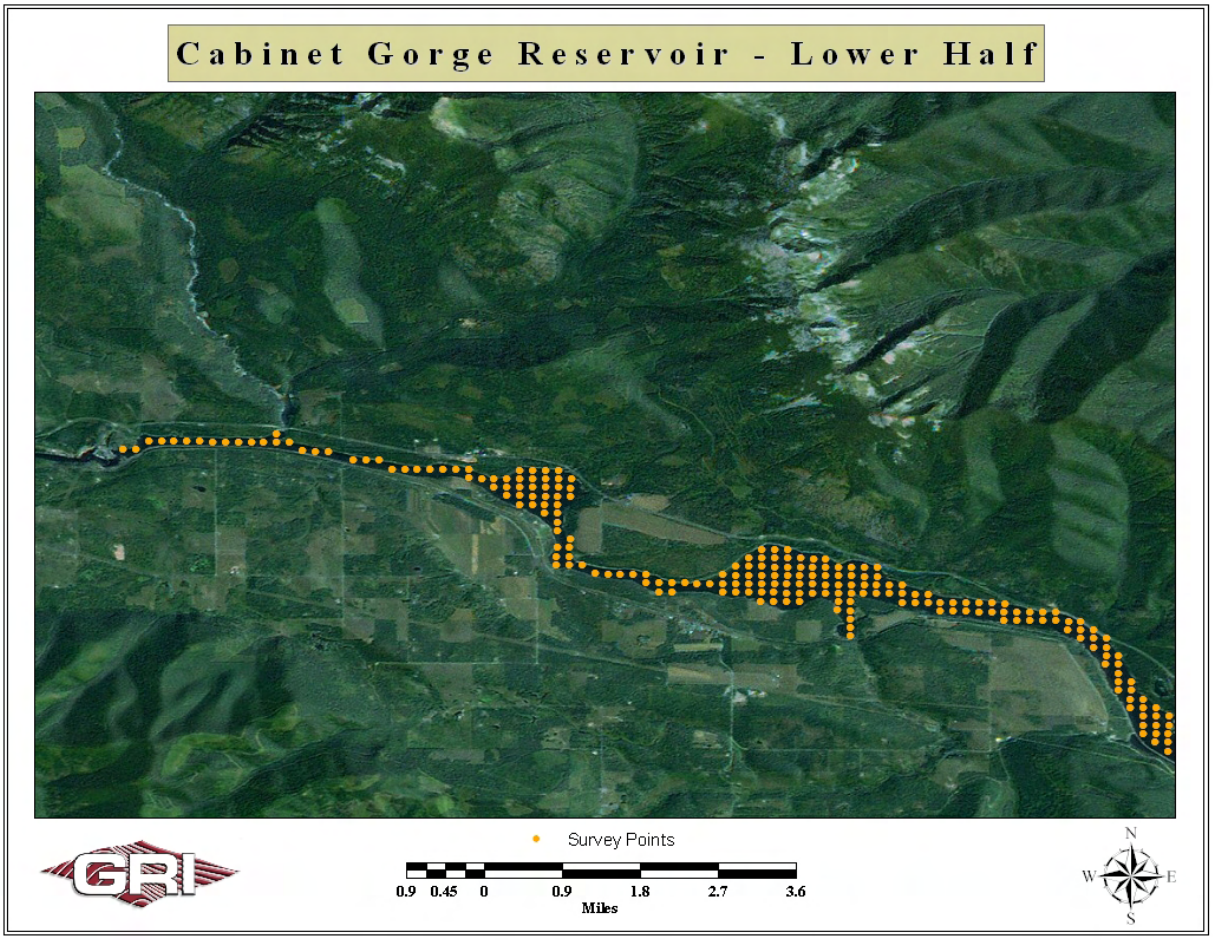

Figure 1a. Points surveyed in the lower half of Cabinet Gorge Reservoir.

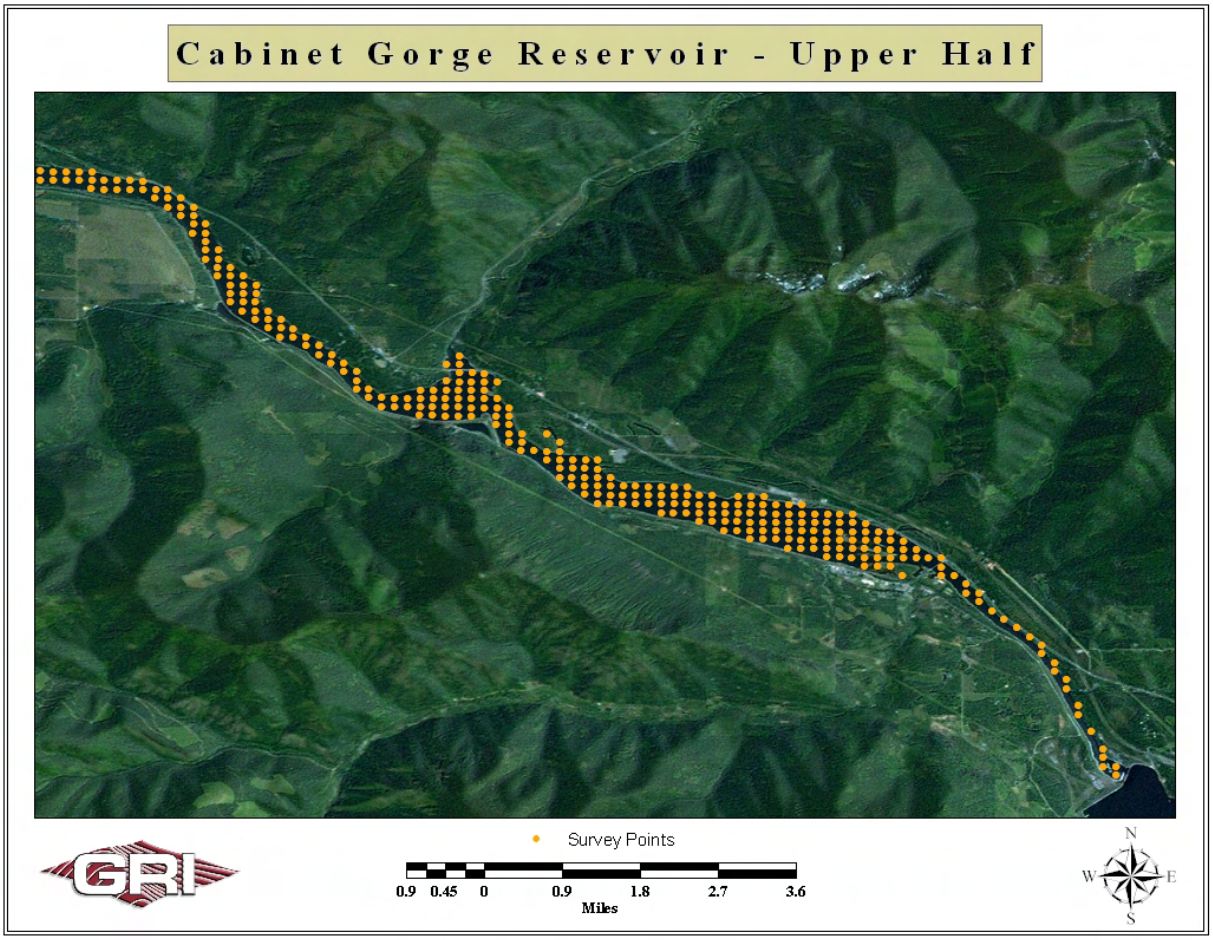

Figure 1b. Points surveyed in the upper half of Cabinet Gorge Reservoir.

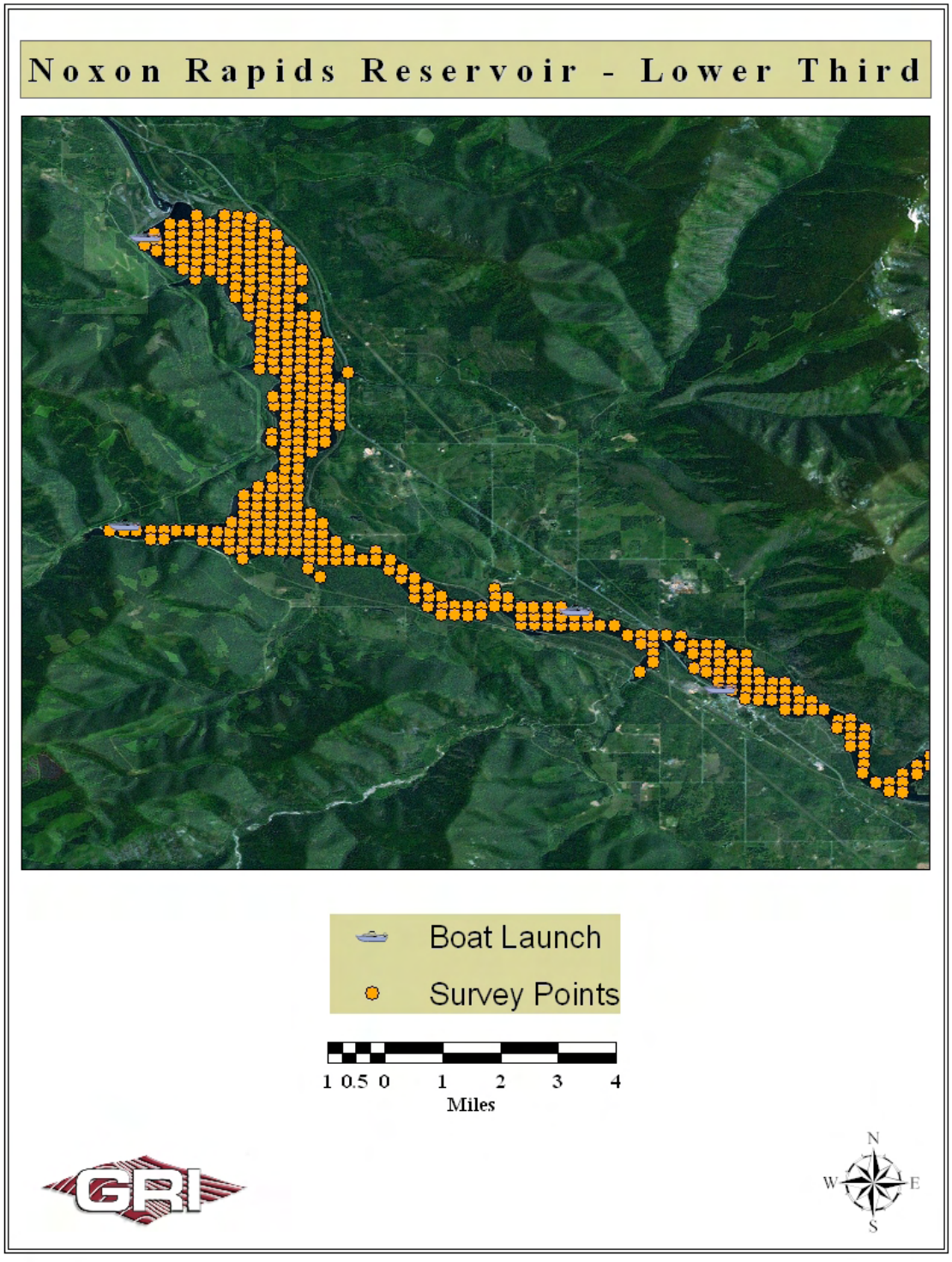

Figure 2a. Survey points from the lower third of Noxon Rapids Reservoir.

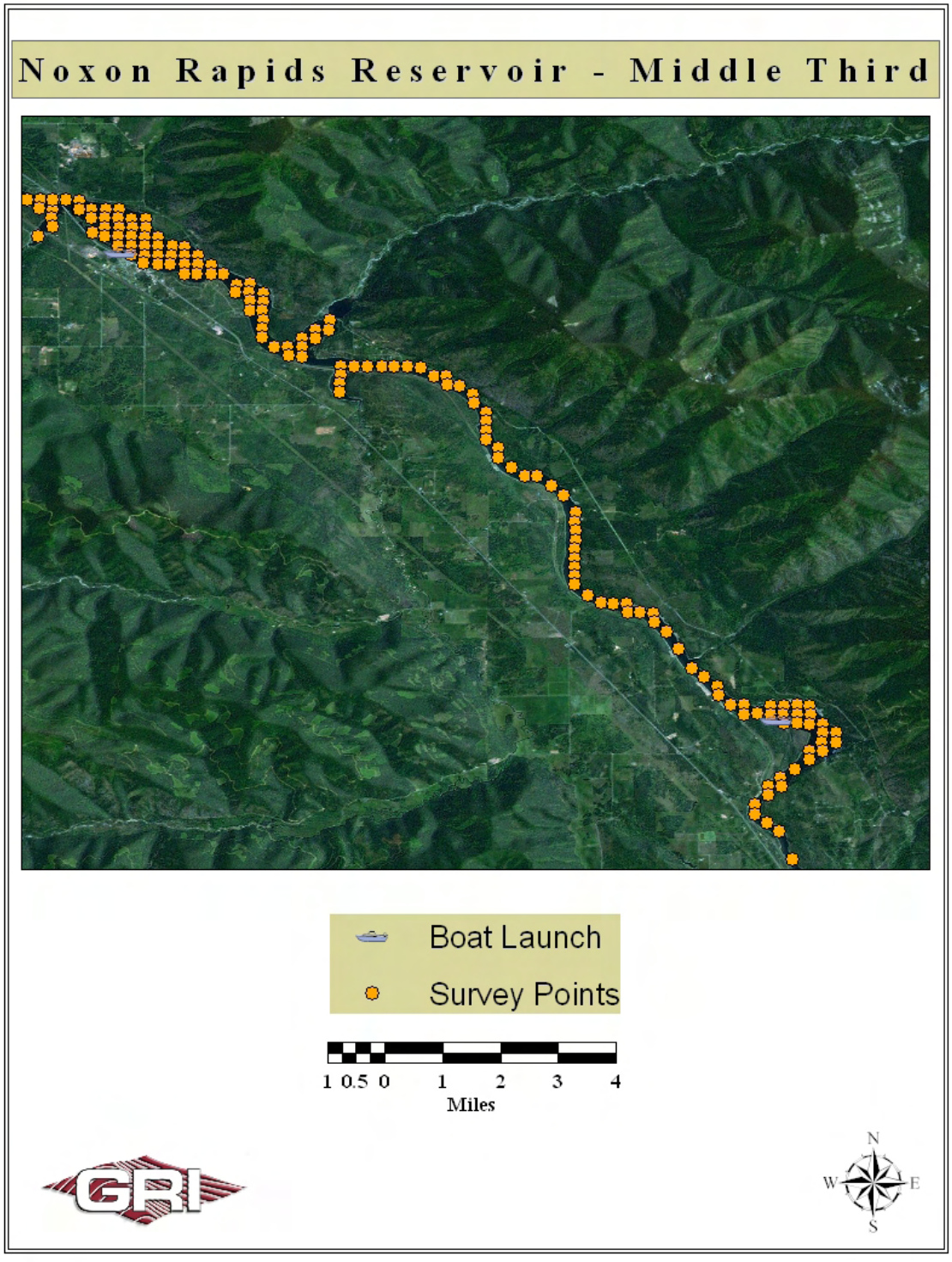

Figure 2b. Survey points from the middle third of Noxon Rapids Reservoir.

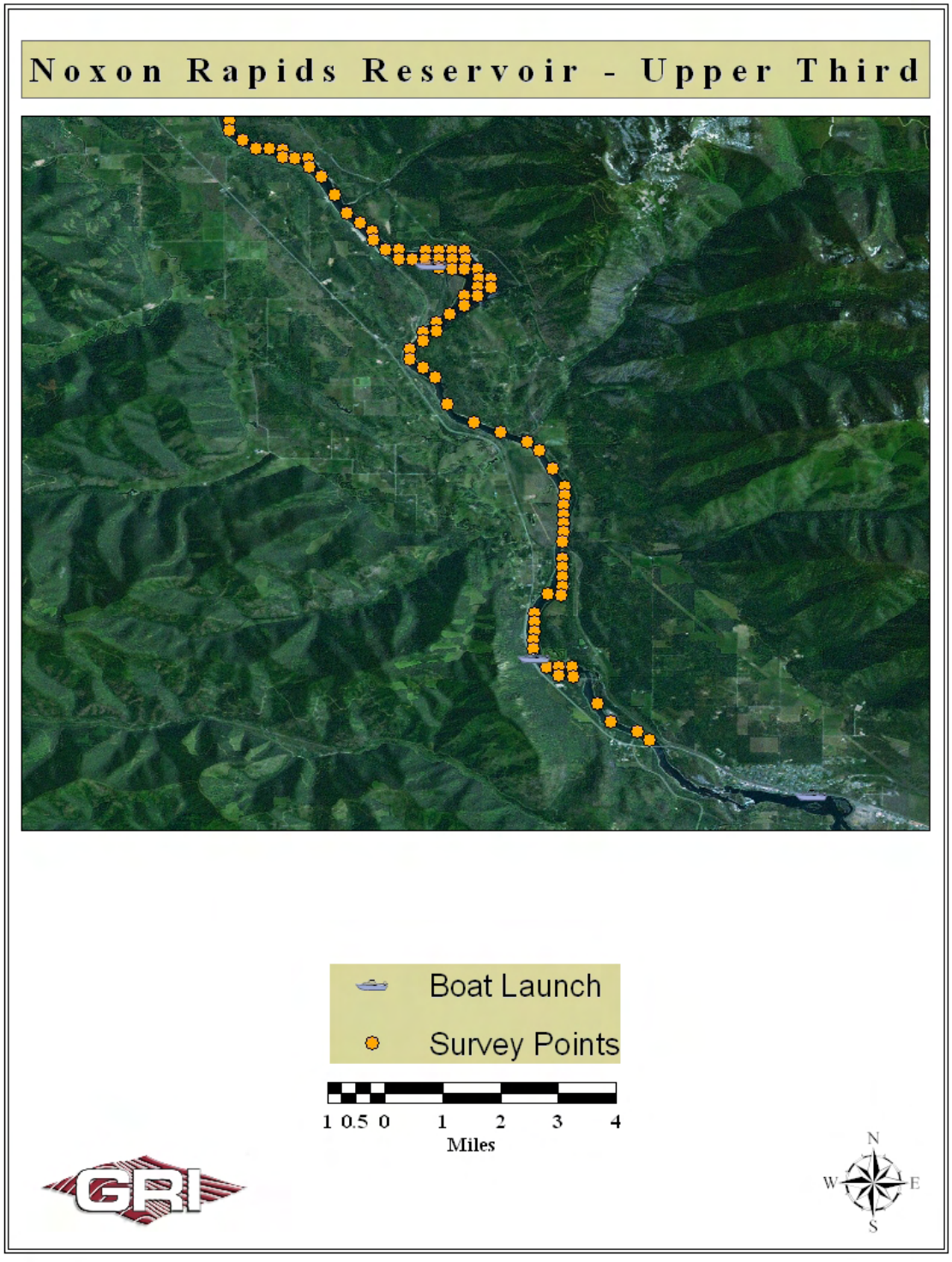

Figure 2c. Survey points from the upper third of Noxon Rapids Reservoir.

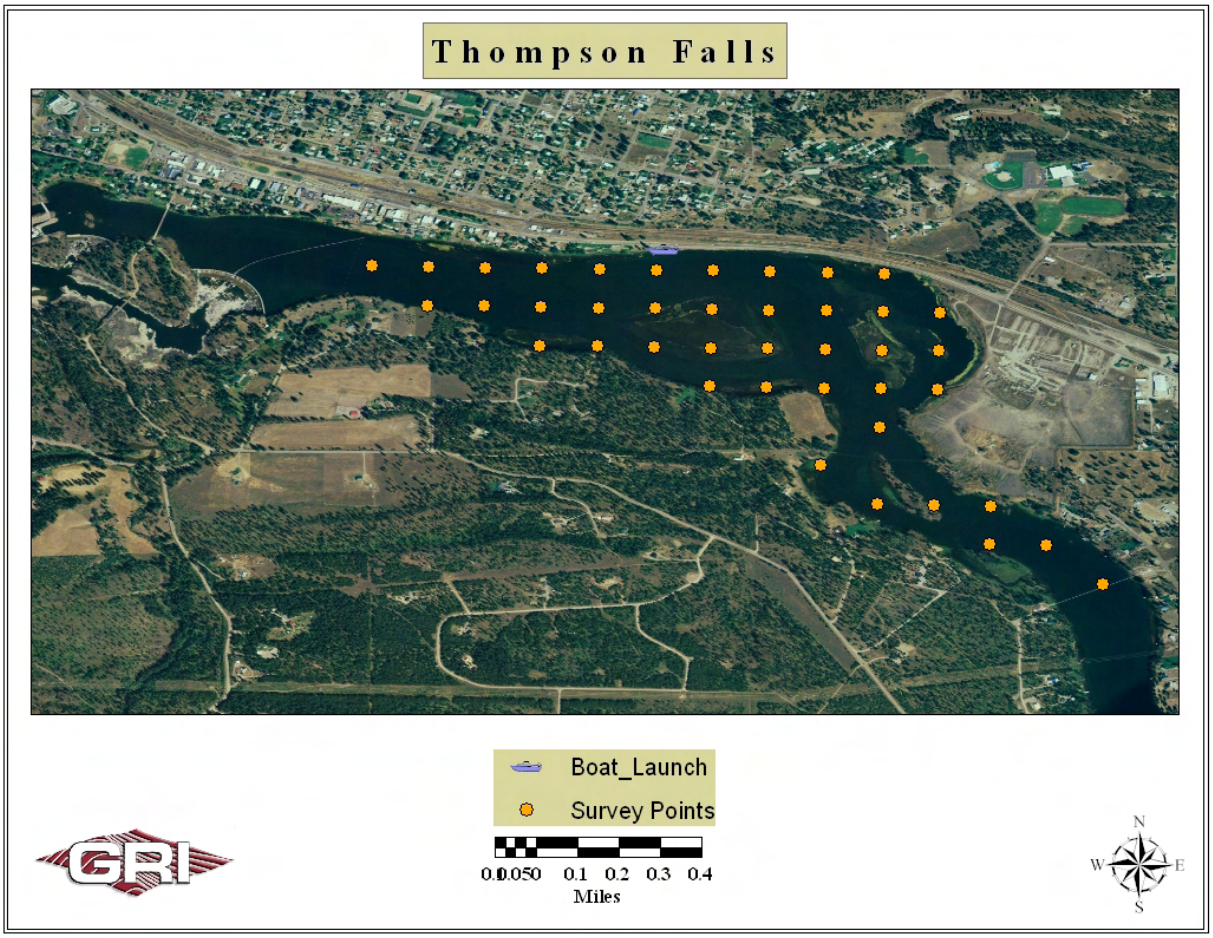

Figure 3. Survey points for Thompson Falls Reservoir.

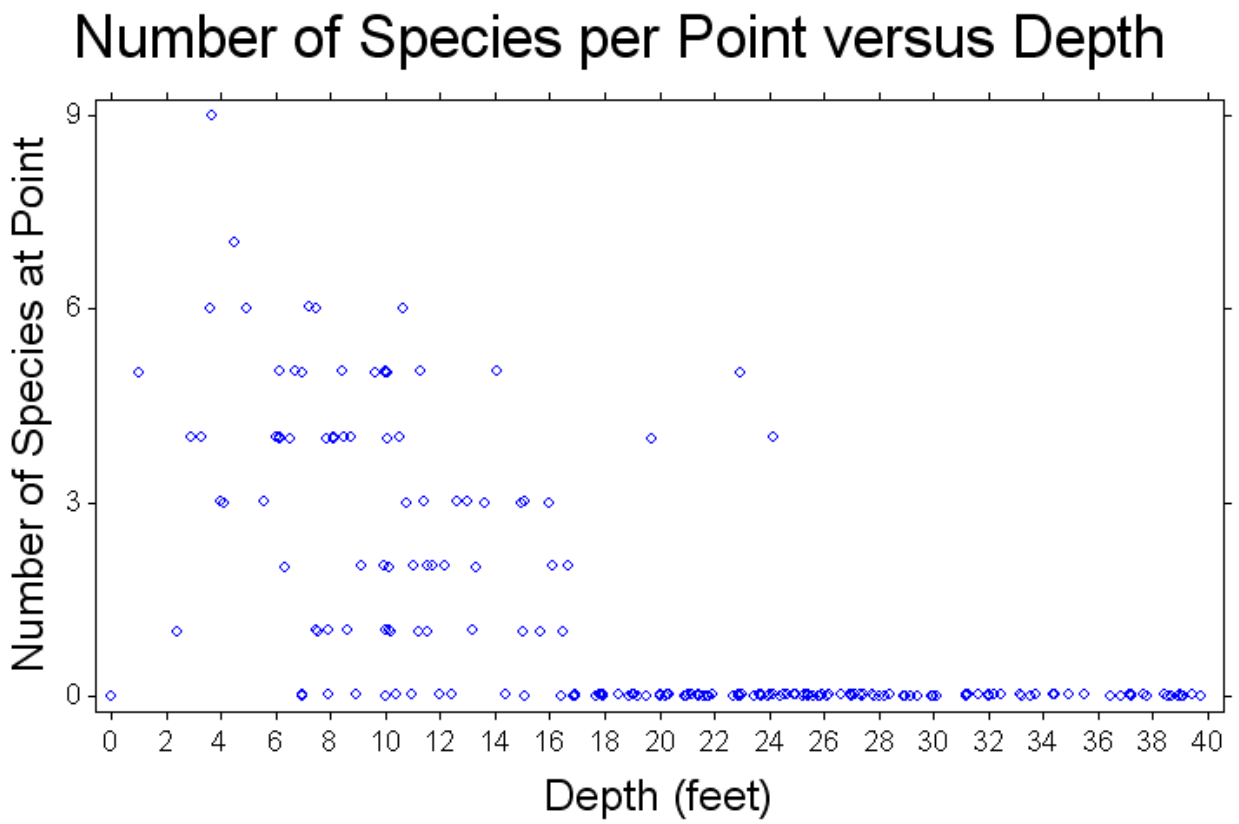

Figure 4. Plot of the number of species per point versus depth in feet for all points less than 40' deep in Cabinet Gorge Reservoir. The deepest point with plants was 24', so we arbitrarily assigned a depth of 25' as the maximum extent of the littoral zone.

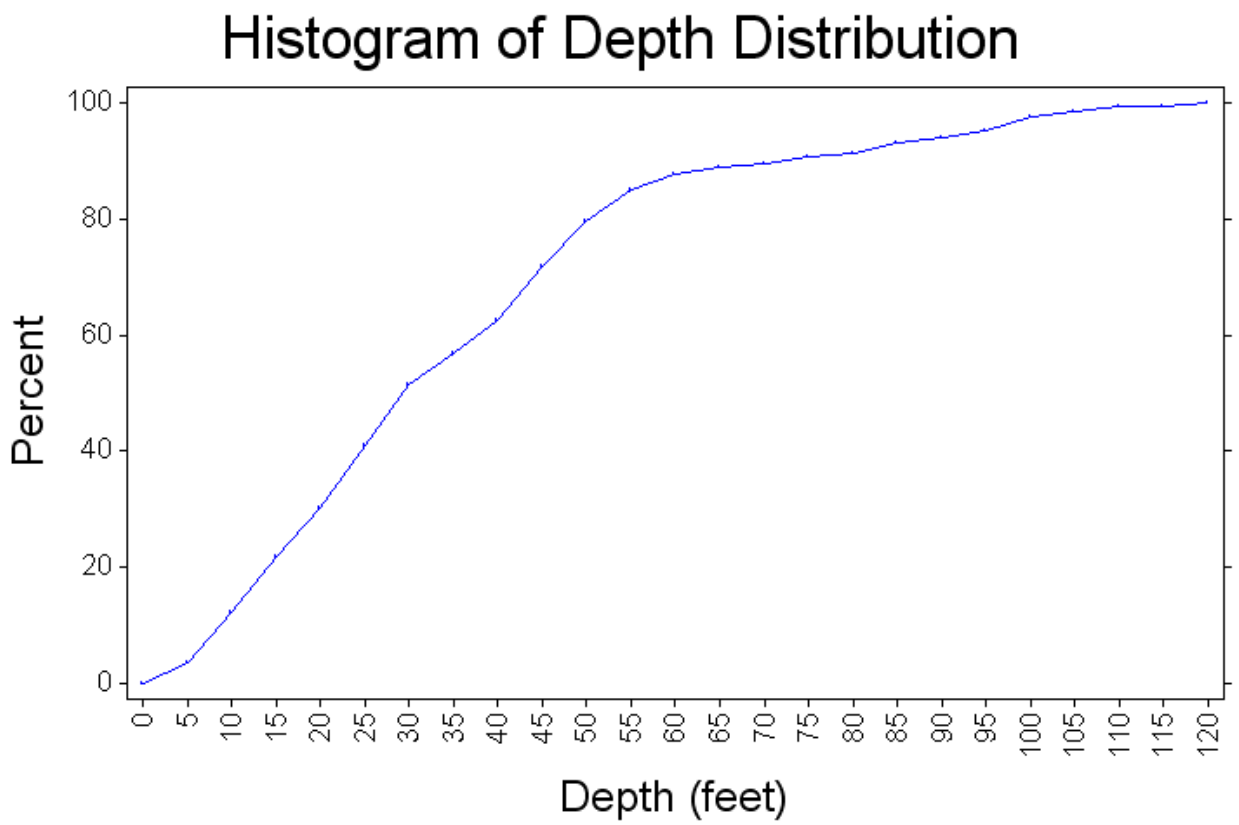

Figure 5. Cumulative distribution of depths of all points surveyed in Cabinet Gorge Reservoir.

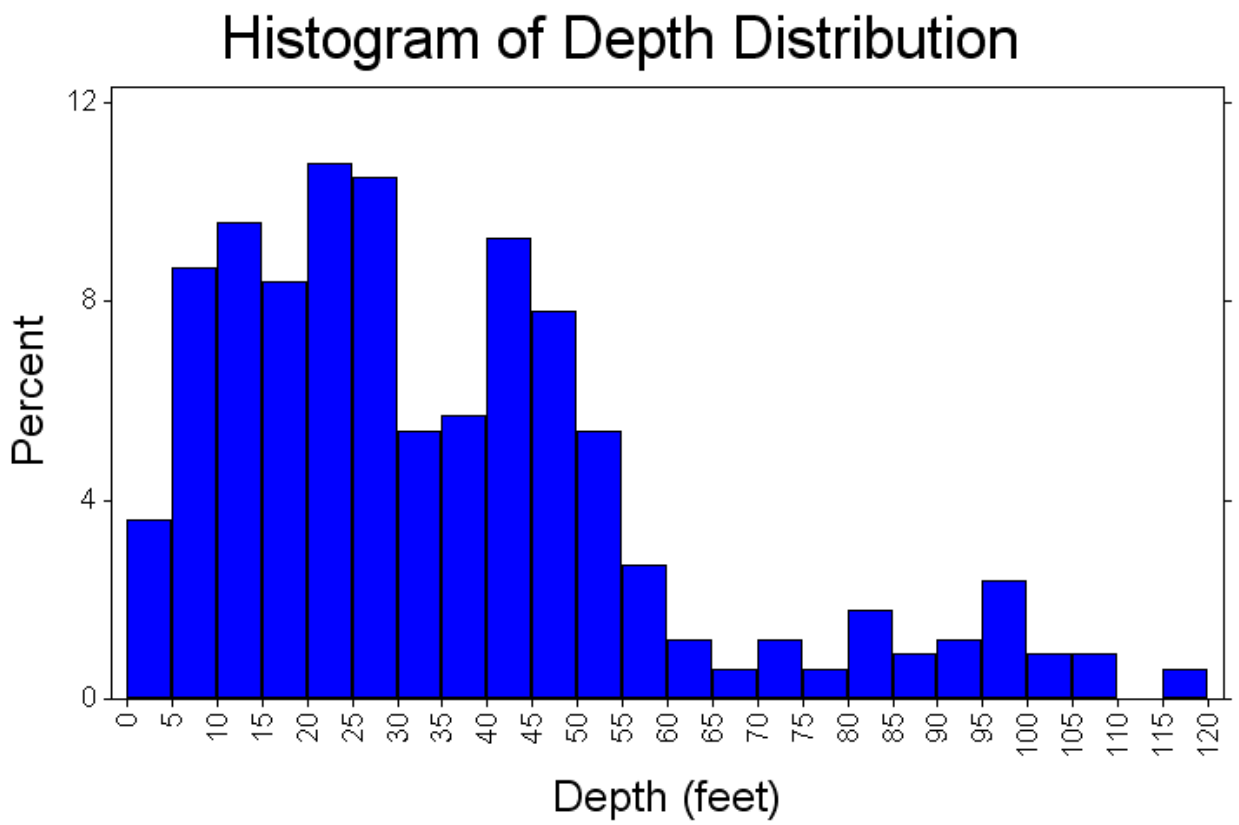

Figure 6. Histogram of depth distribution in Cabinet Gorge Reservoir.

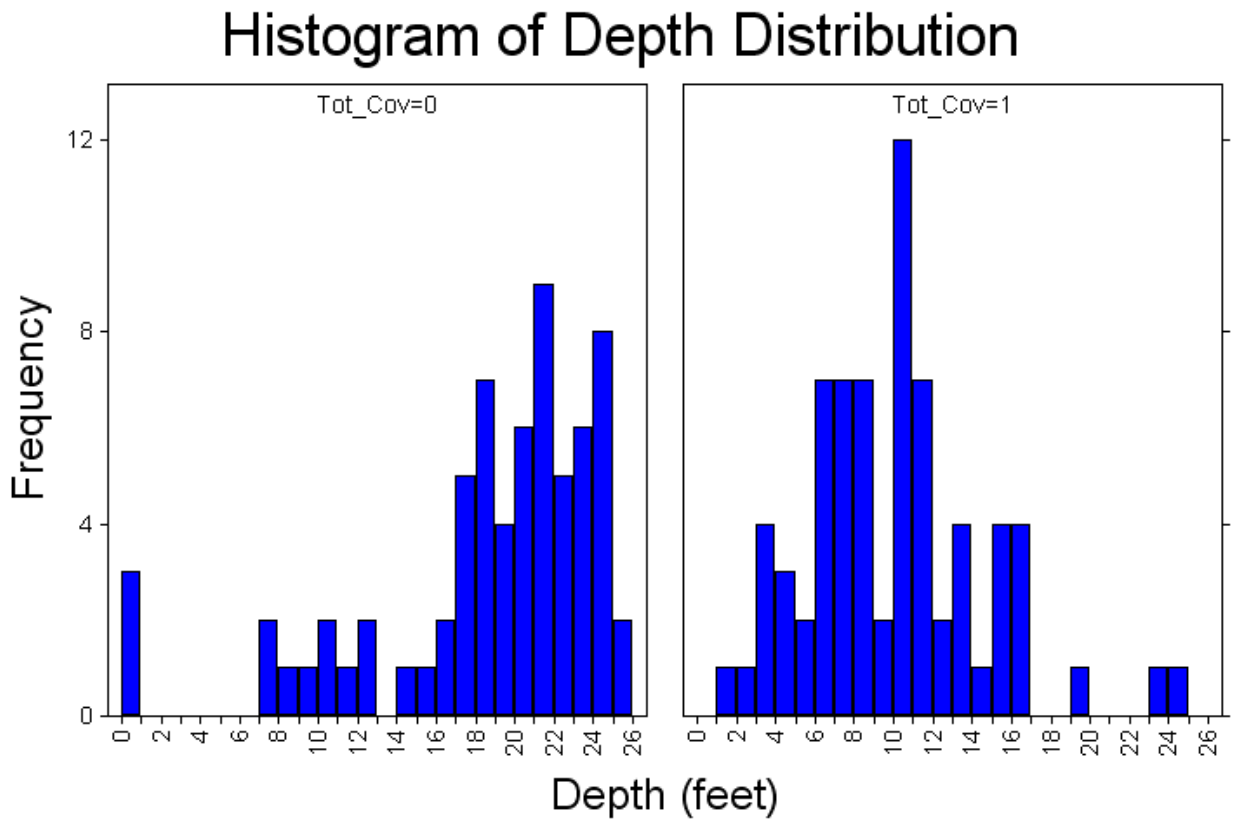

Figure 7. Depth distribution of sites without (Tot_Cov=0, left) and with (Tot_Cov = 1, right) vegetation in Cabinet Gorge Reservoir.

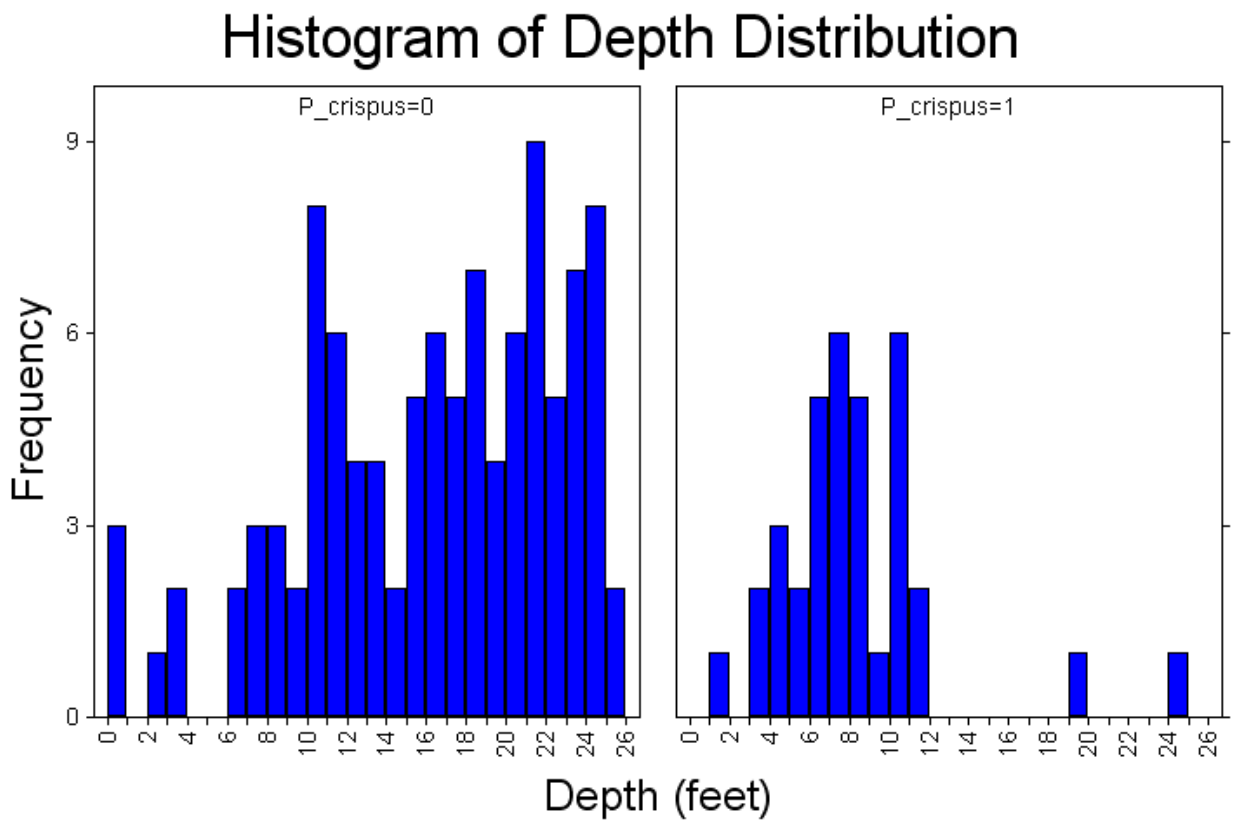

Figure 8. Depth distribution of curlyleaf pondweed (P_crispus=1, right) in Cabinet Gorge Reservoir.

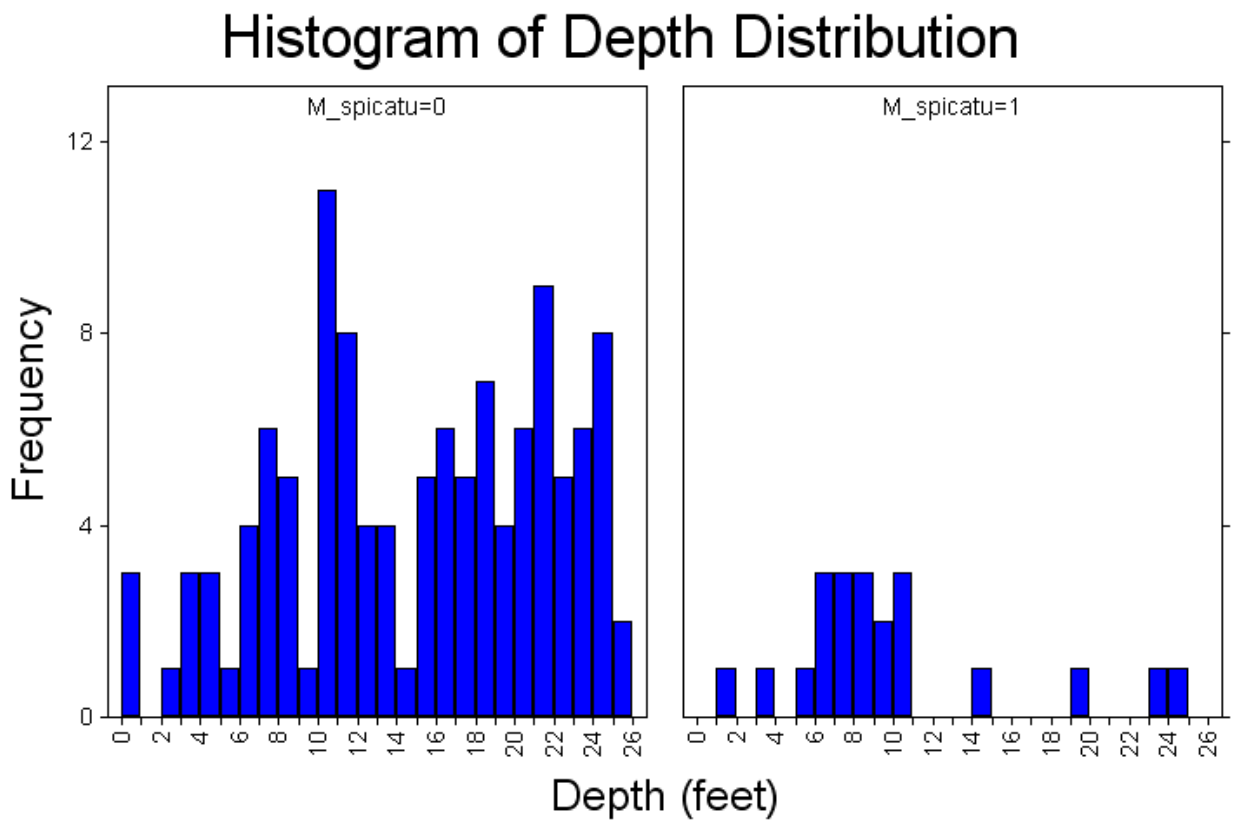

Figure 9. Depth distribution of Eurasian watermilfoil (M_spicatu=1, right) in Cabinet Gorge Reservoir.

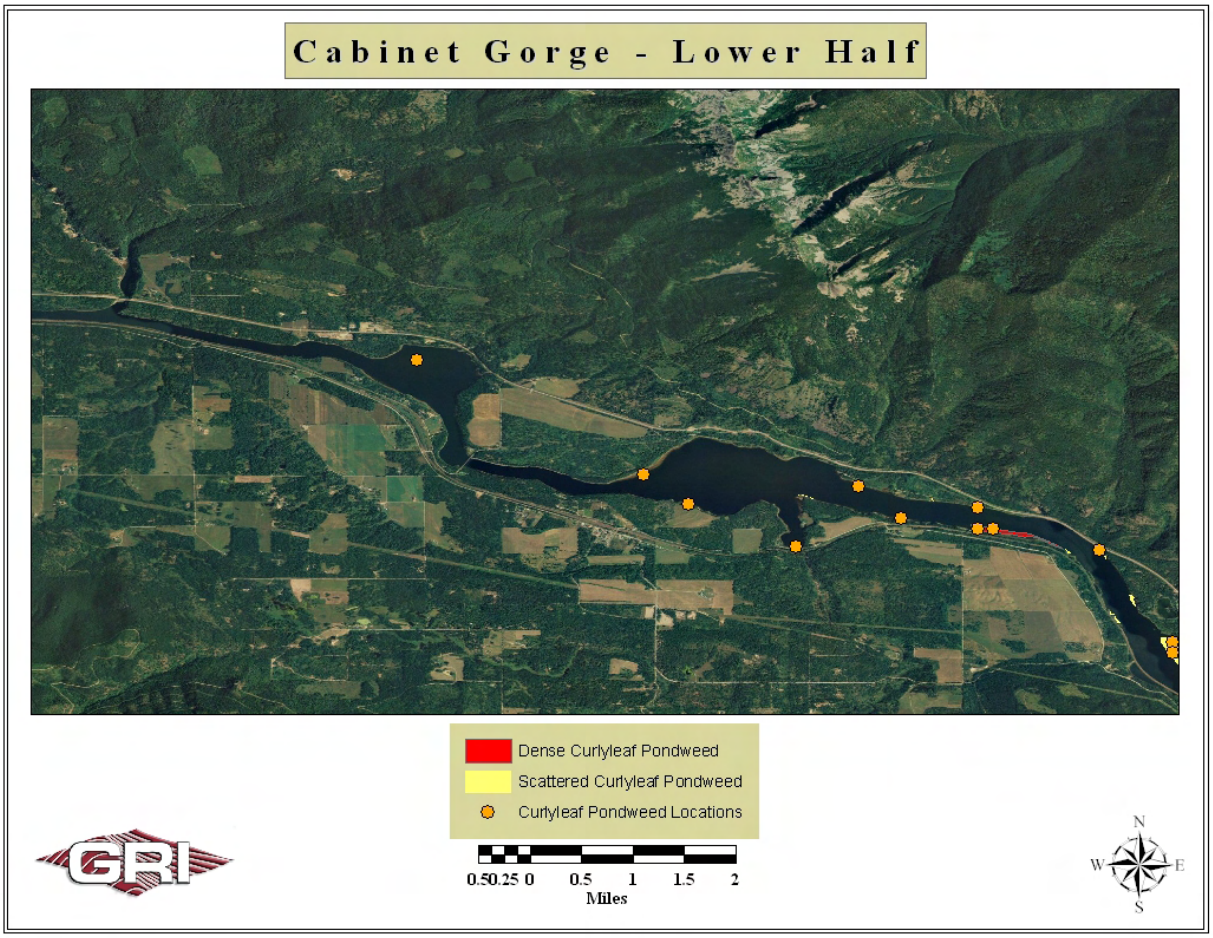

Figure 10a. Curlyleaf pondweed in the lower half of Cabinet Gorge Reservoir. Red areas are dense beds of curlyleaf pondweed, yellow areas are scattered zones of curlyleaf pondweed, and points are grid points at which curlyleaf pondweed was observed.

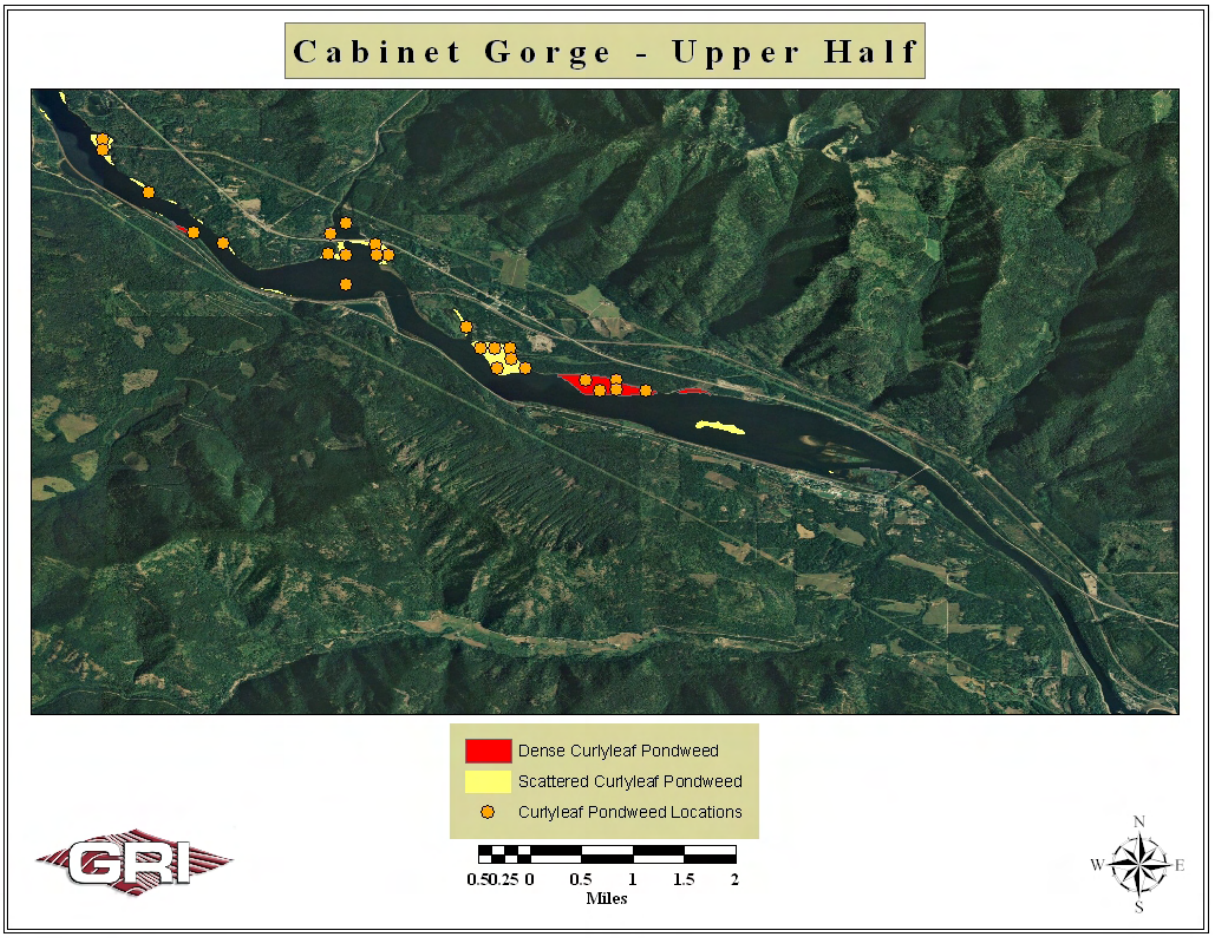

Figure 10b. Curlyleaf pondweed in the upper half of Cabinet Gorge reservoir. Red areas are dense beds of curlyleaf pondweed, yellow areas are scattered zones of curlyleaf pondweed, and points are grid points at which curlyleaf pondweed was observed.

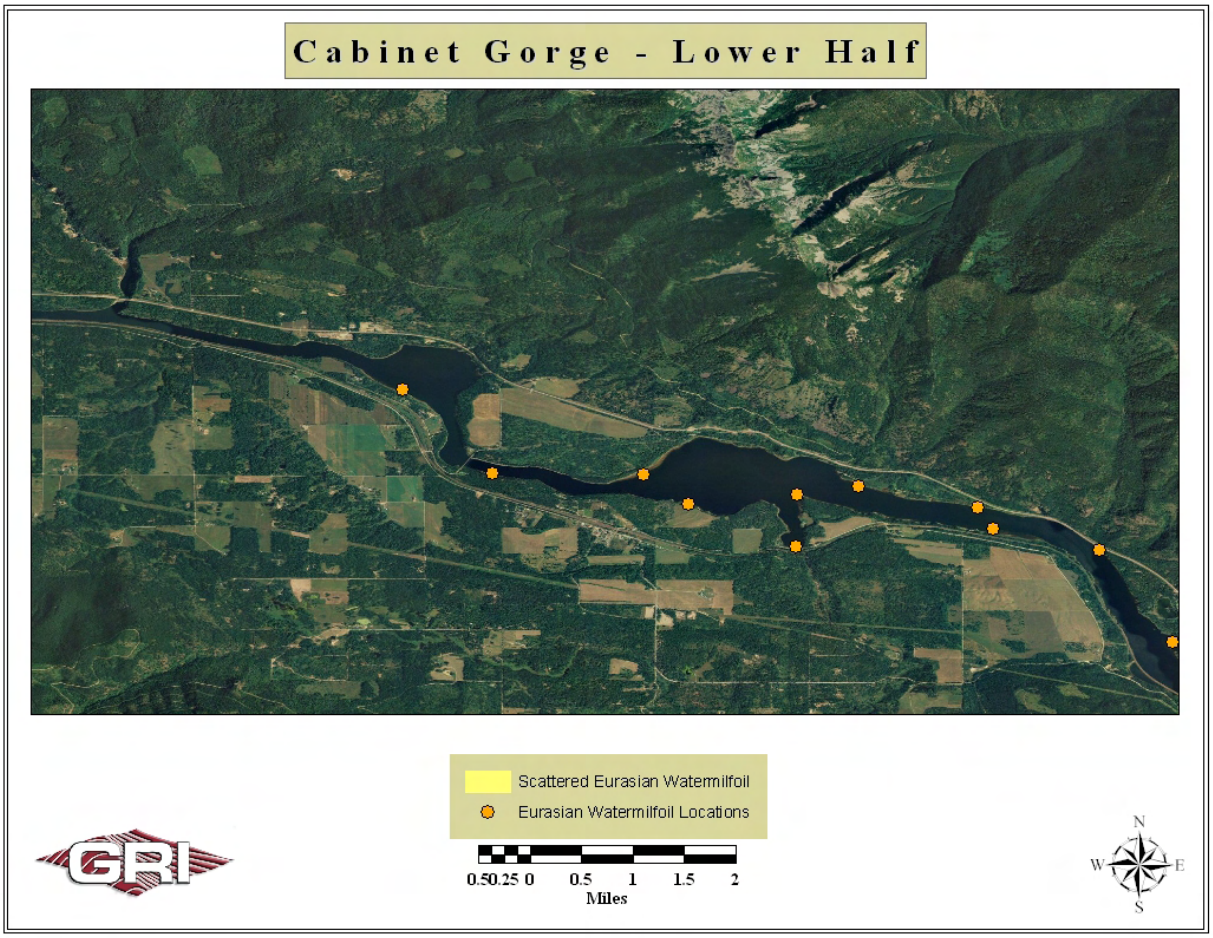

Figure 11a. Eurasian watermilfoil in the lower half of Cabinet Gorge Reservoir. Yellow areas are scattered zones of Eurasian watermilfoil, and points are grid points at which Eurasian watermilfoil was observed.

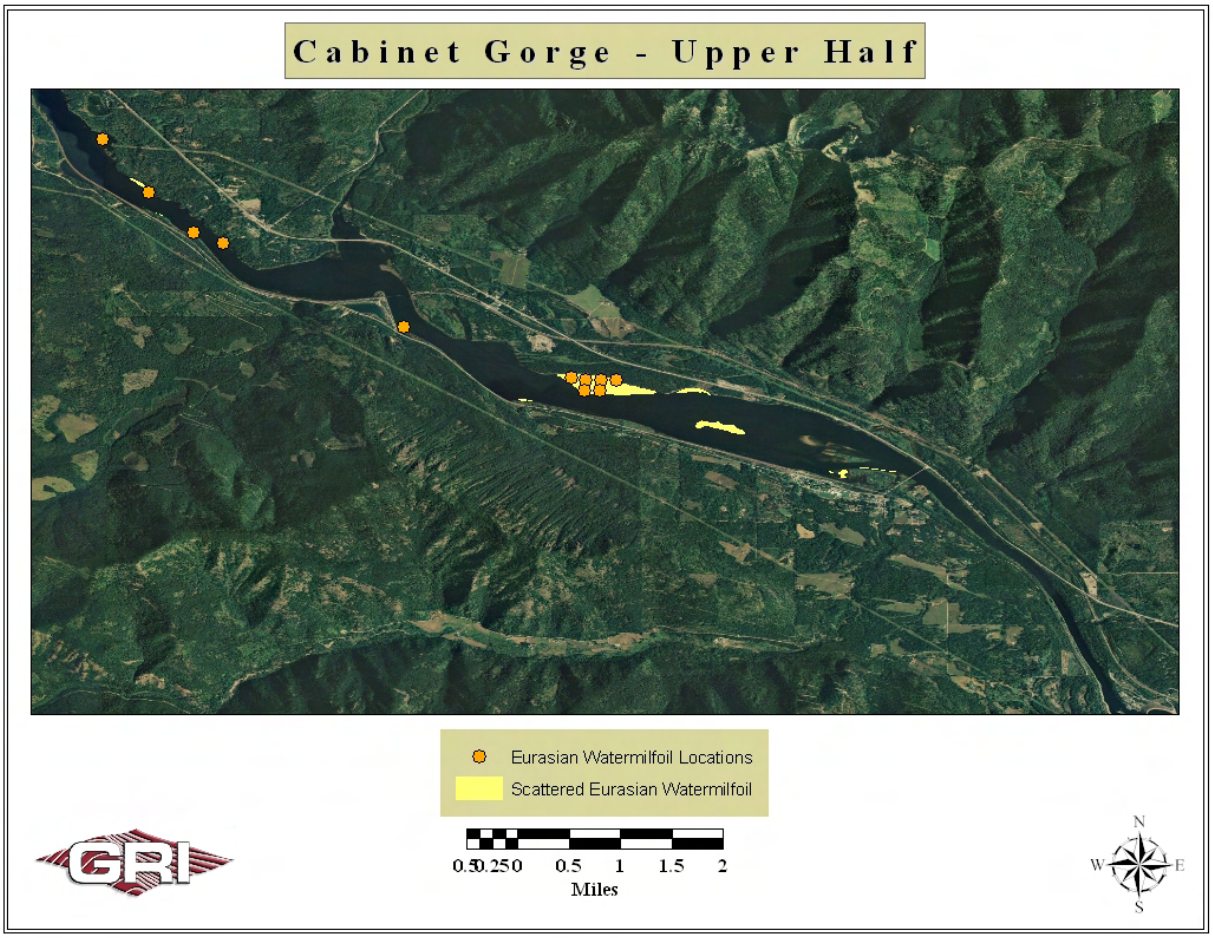

Figure 11b. Eurasian watermilfoil in the upper half of Cabinet Gorge Reservoir. Yellow areas are scattered zones of Eurasian watermilfoil, and points are grid points at which Eurasian watermilfoil was observed.

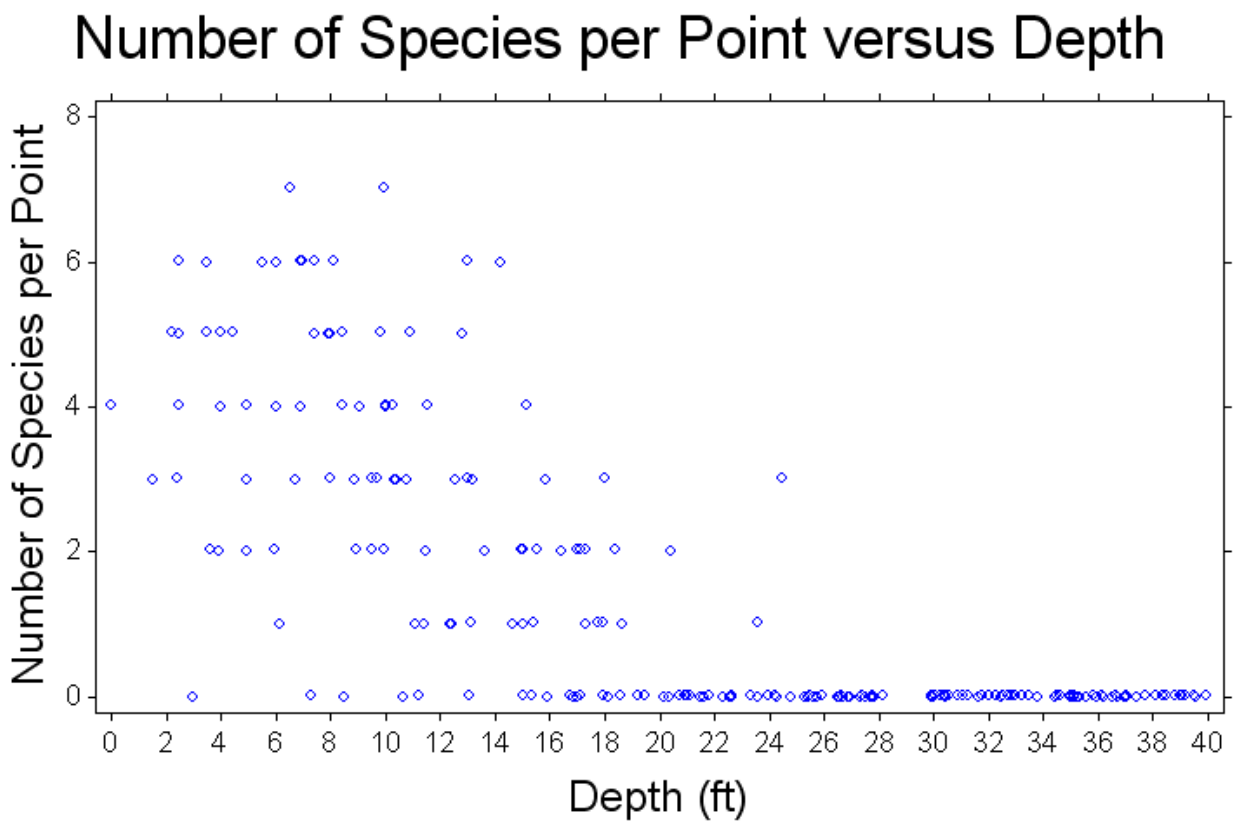

Figure 12. Plot of the number of species per point versus depth in feet for all points less than 40' deep in Noxon Rapids Reservoir. The deepest point with plants was 24', so we arbitrarily assigned a depth of 25' as the maximum extent of the littoral zone.

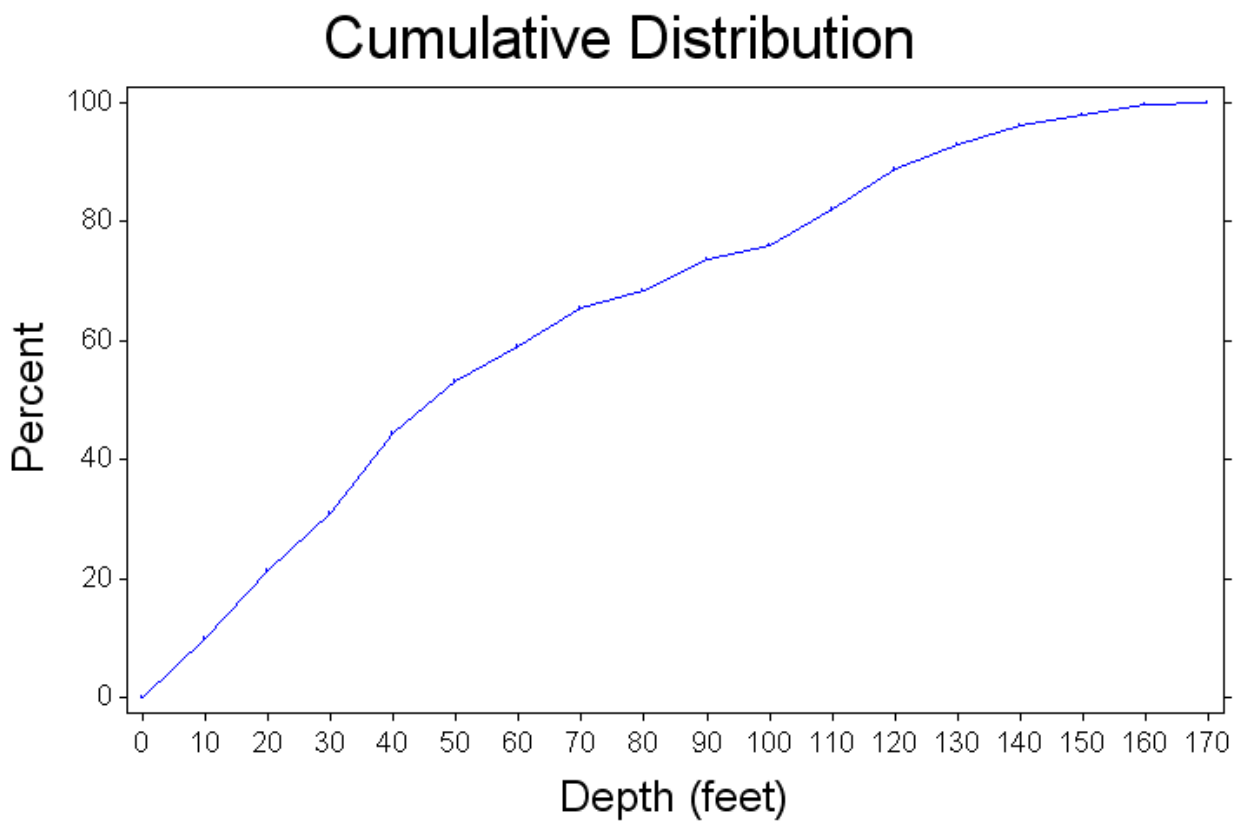

Figure 13. Cumulative depth distribution of points surveyed in Noxon Rapids Reservoir. Less than 30% of points were within the littoral zone (25').

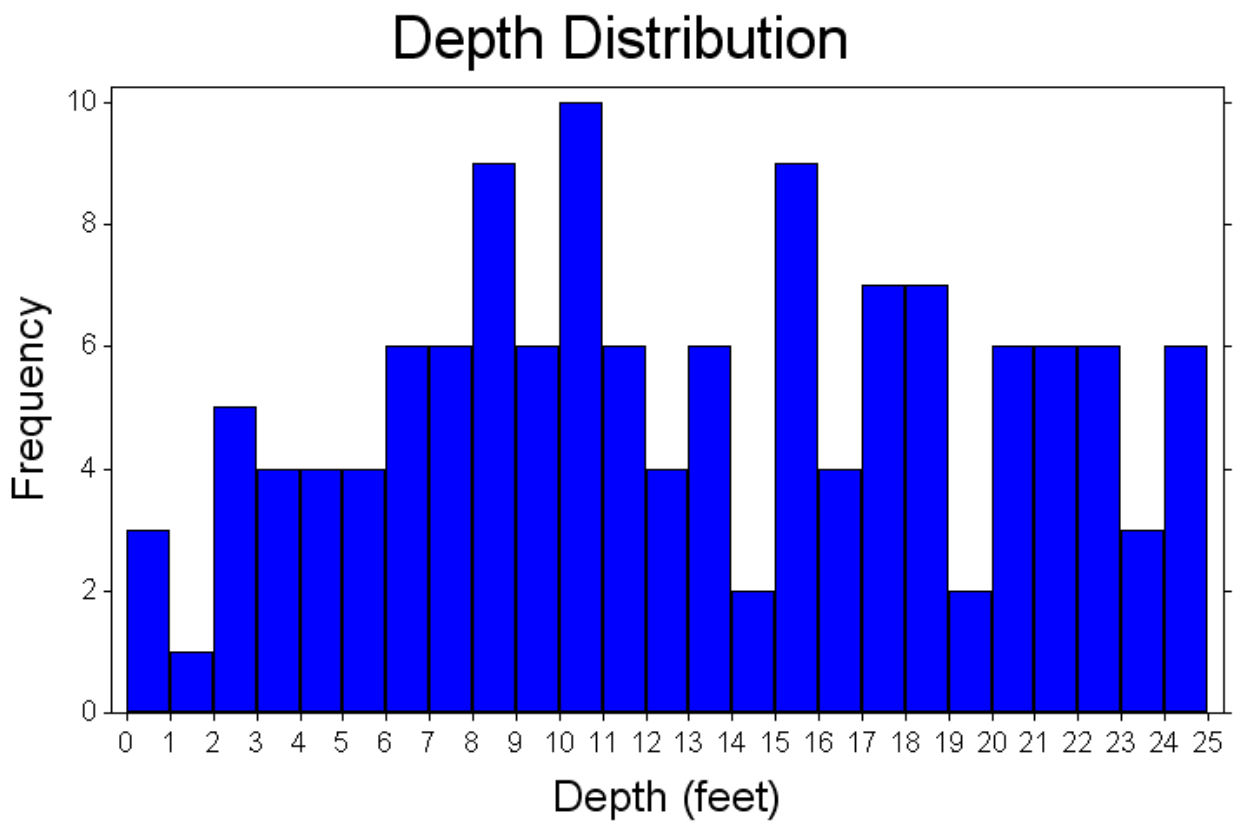

Figure 14. Distribution of depths within the littoral zone of Noxon Rapids Reservoir, based on 132 points.

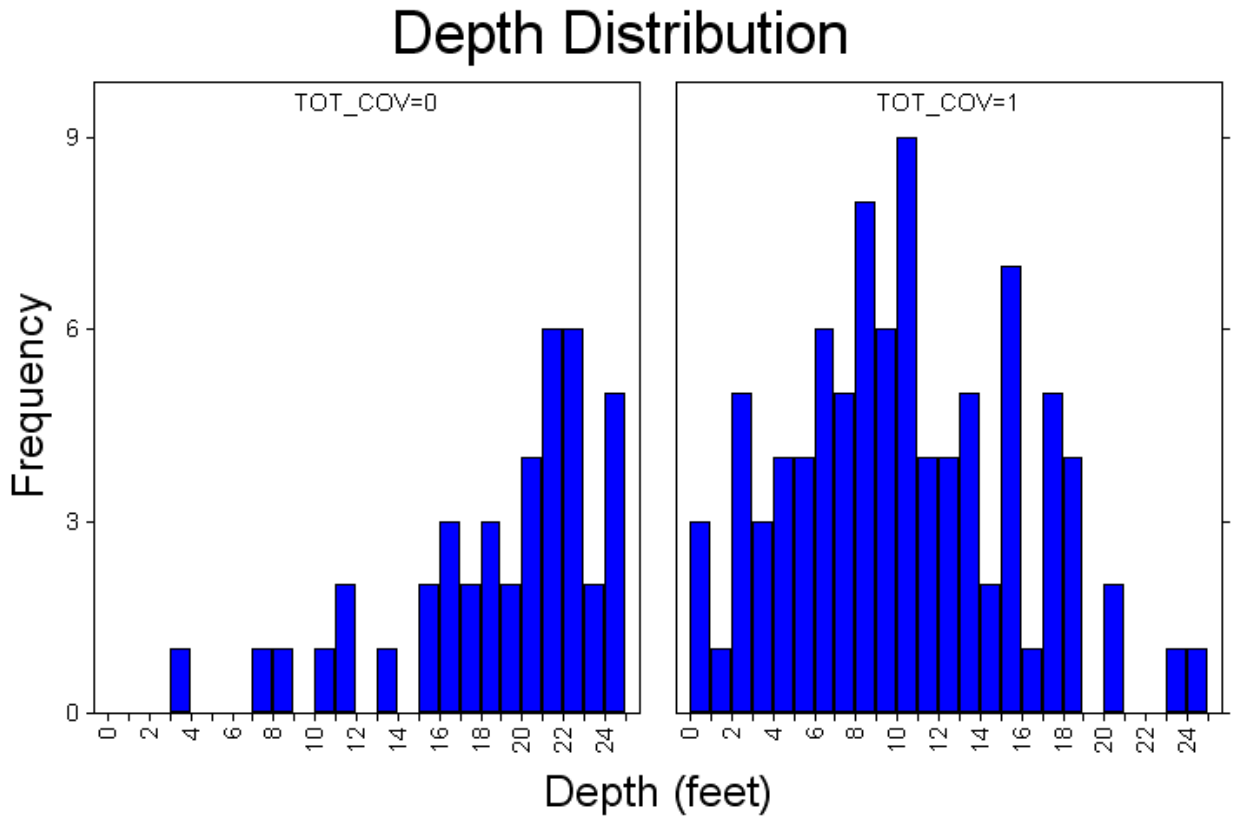

Figure 15. Frequency of occurrence of points without vegetation (TOT_COV = 0, left), and with vegetation (TOT_COV = 1, right) in Noxon Rapids Reservoir.

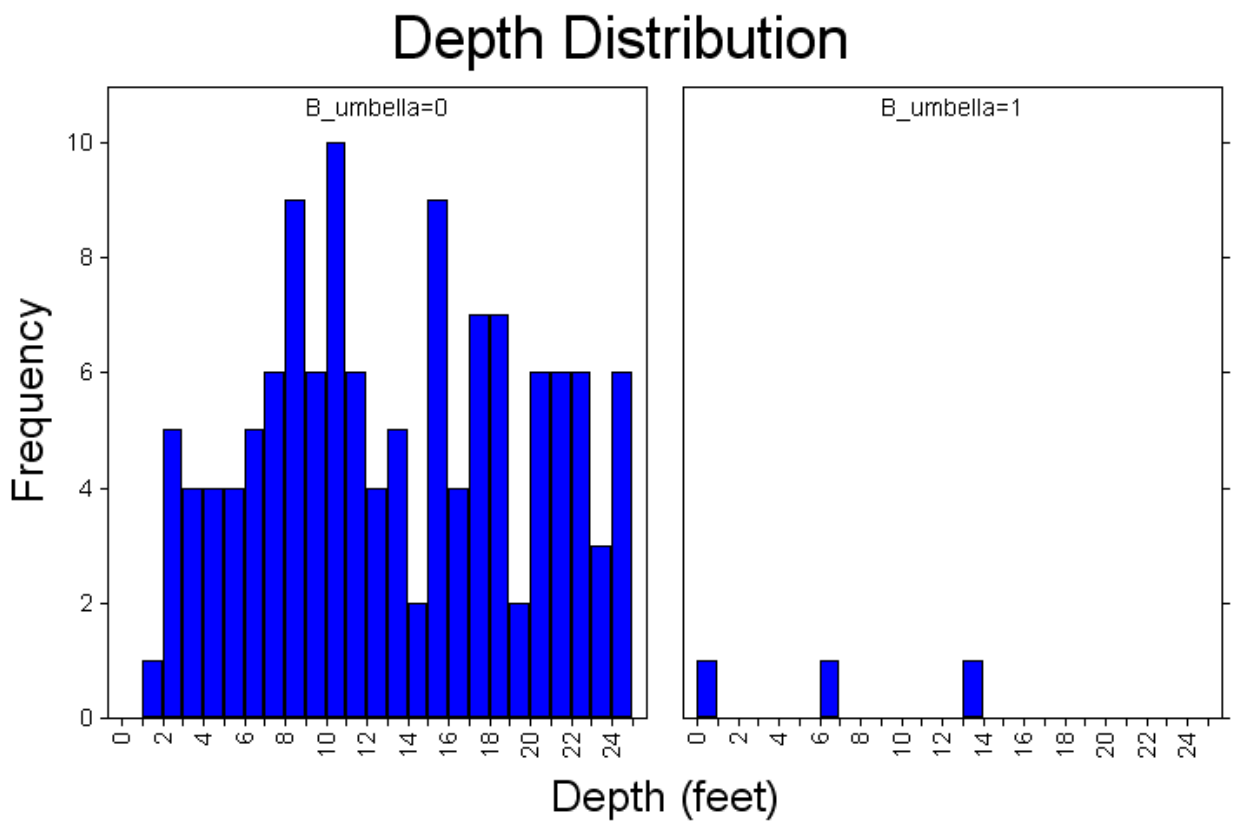

Figure 16. Frequency of occurrence of points without (left), and with flowering rush (code B_umbella=1, right) in Noxon Rapids Reservoir.

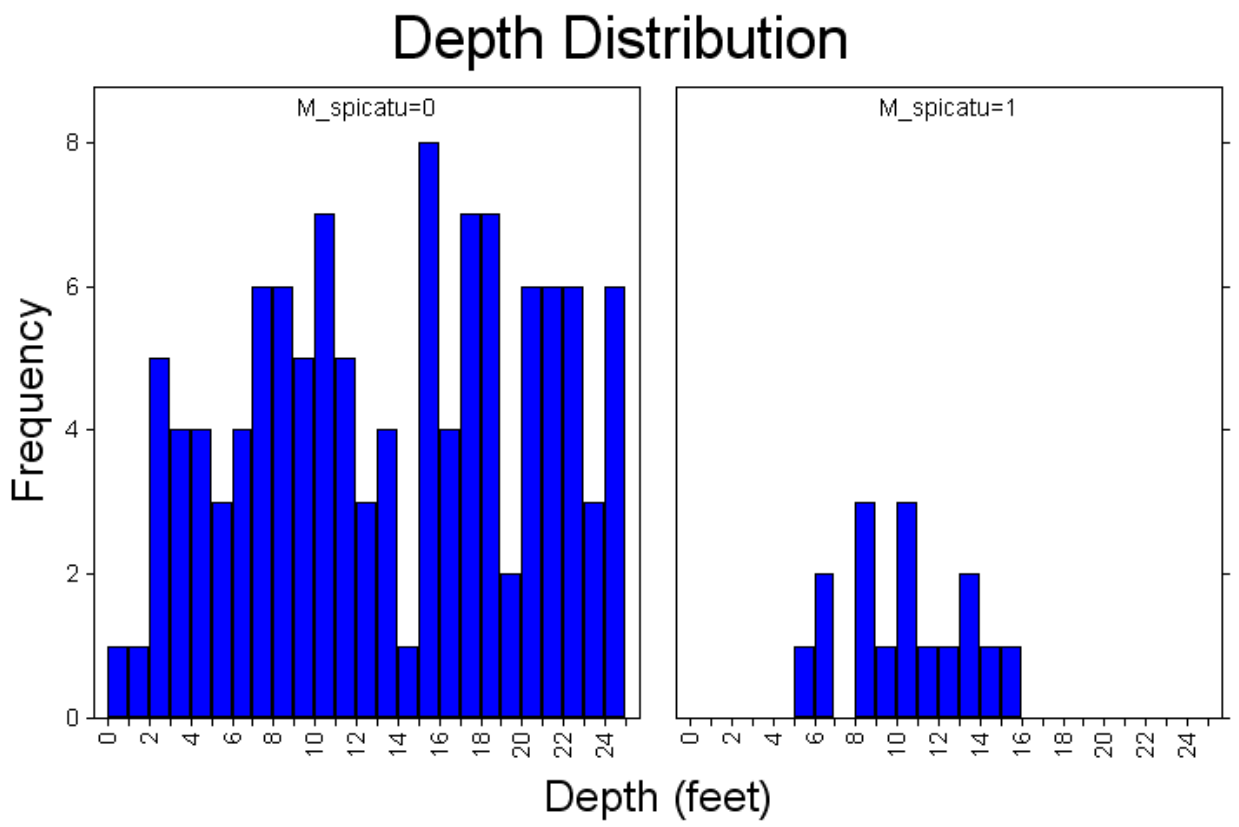

Figure 17. Frequency of occurrence of points without (left), and with Eurasian watermilfoil (code M_spicatu=1, right) in Noxon Rapids Reservoir.

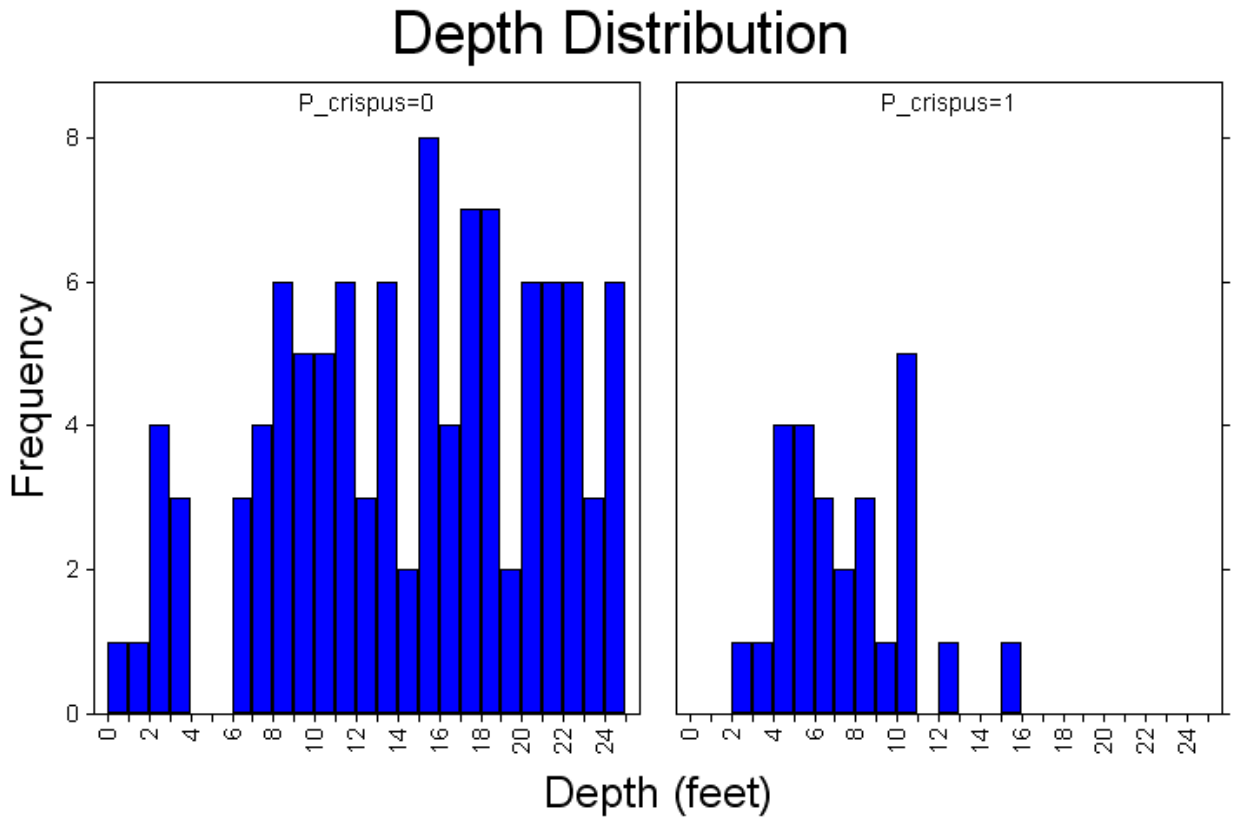

Figure 18. Frequency of occurrence of points without (left), and with curlyleaf pondweed (code P_crispus=1, right) in Noxon Rapids Reservoir.

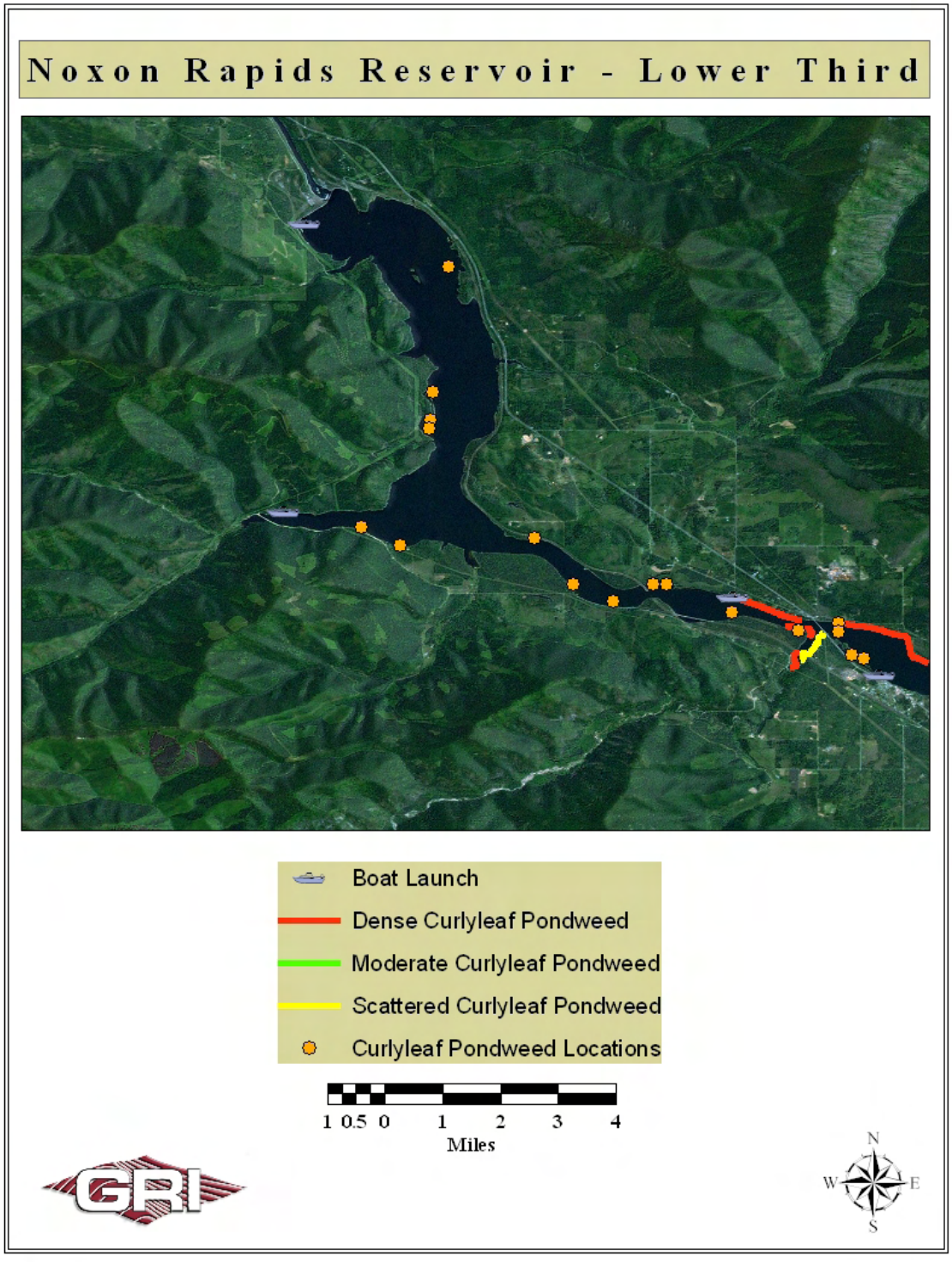

Figure 19a. Curlyleaf pondweed in the lower third of Noxon Rapids Reservoir. Red lines mark dense curlyleaf pondweed, green mark moderate curlyleaf pondweed, and yellow mark scattered curlyleaf pondweed. Points are curlyleaf pondweed locations from the point survey.

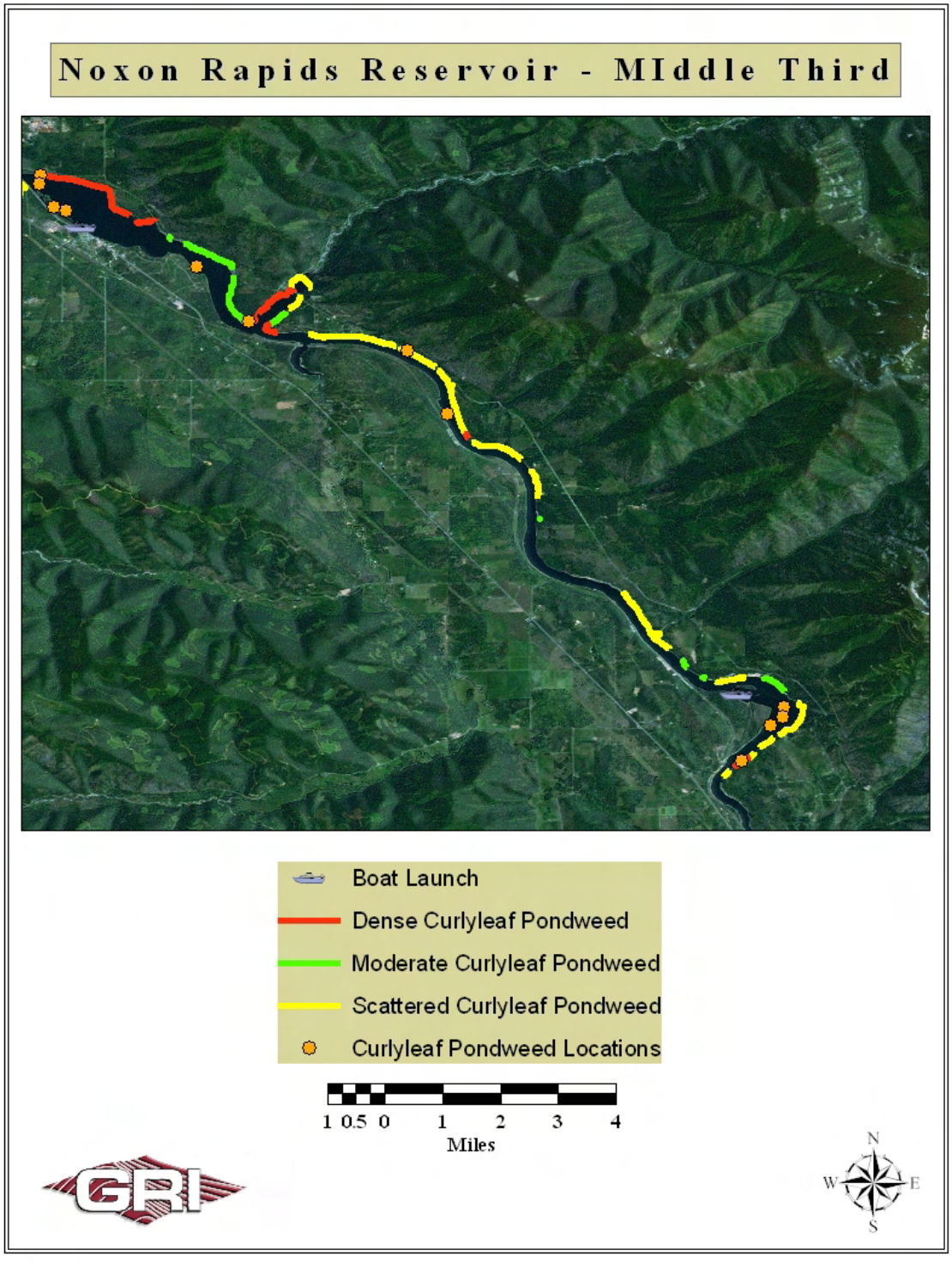

Figure 19b. Curlyleaf pondweed in the middle third of Noxon Rapids Reservoir. Red lines mark dense curlyleaf pondweed, green mark moderate curlyleaf pondweed, and yellow mark scattered curlyleaf pondweed. Points are curlyleaf pondweed locations from the point survey.

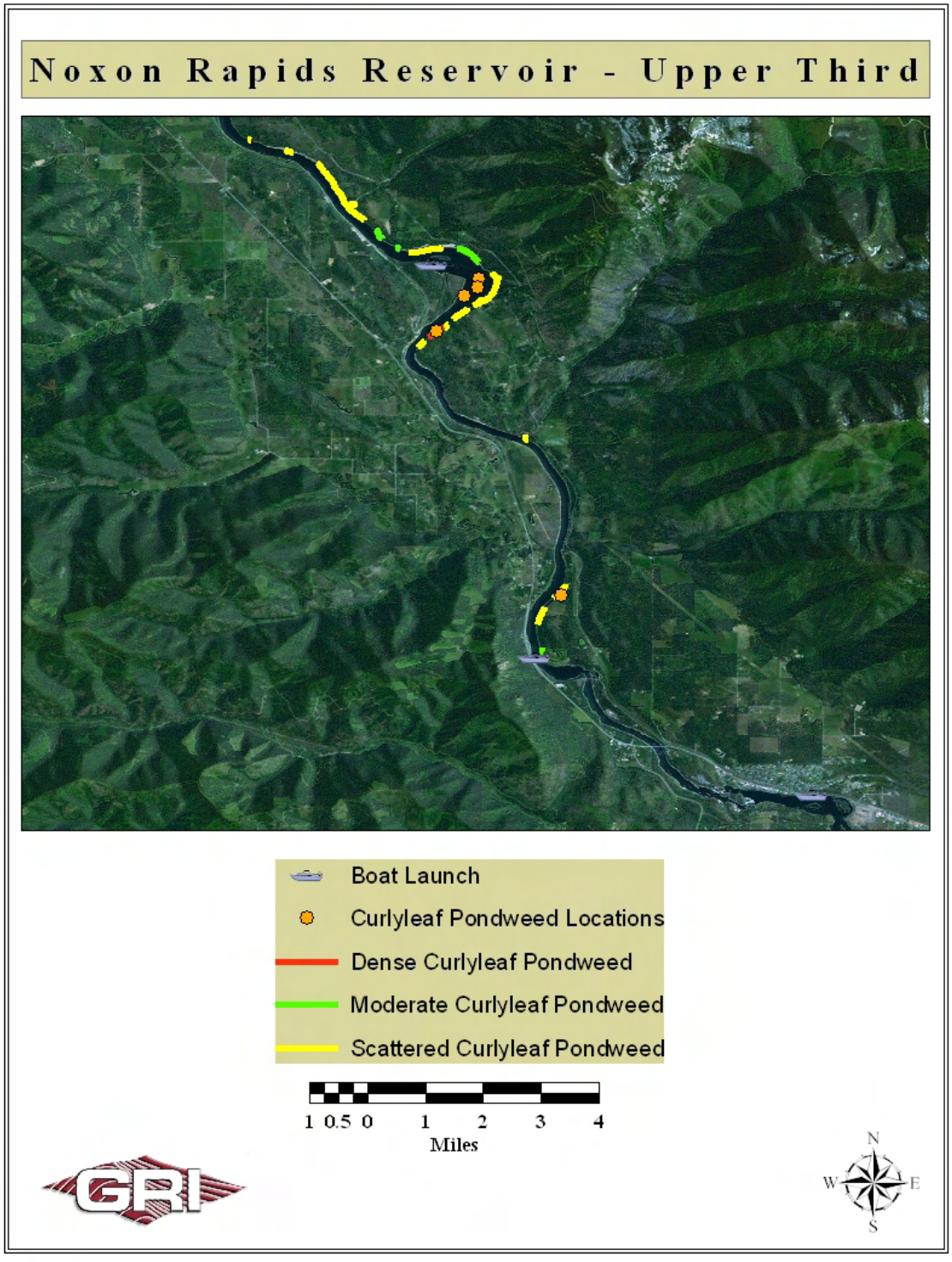

Figure 19c. Curlyleaf pondweed in the upper third of the Noxon Rapids Reservoir. Red lines mark dense curlyleaf pondweed, green mark moderate curlyleaf pondweed, and yellow mark scattered curlyleaf pondweed. Points are curlyleaf pondweed locations from the point survey.

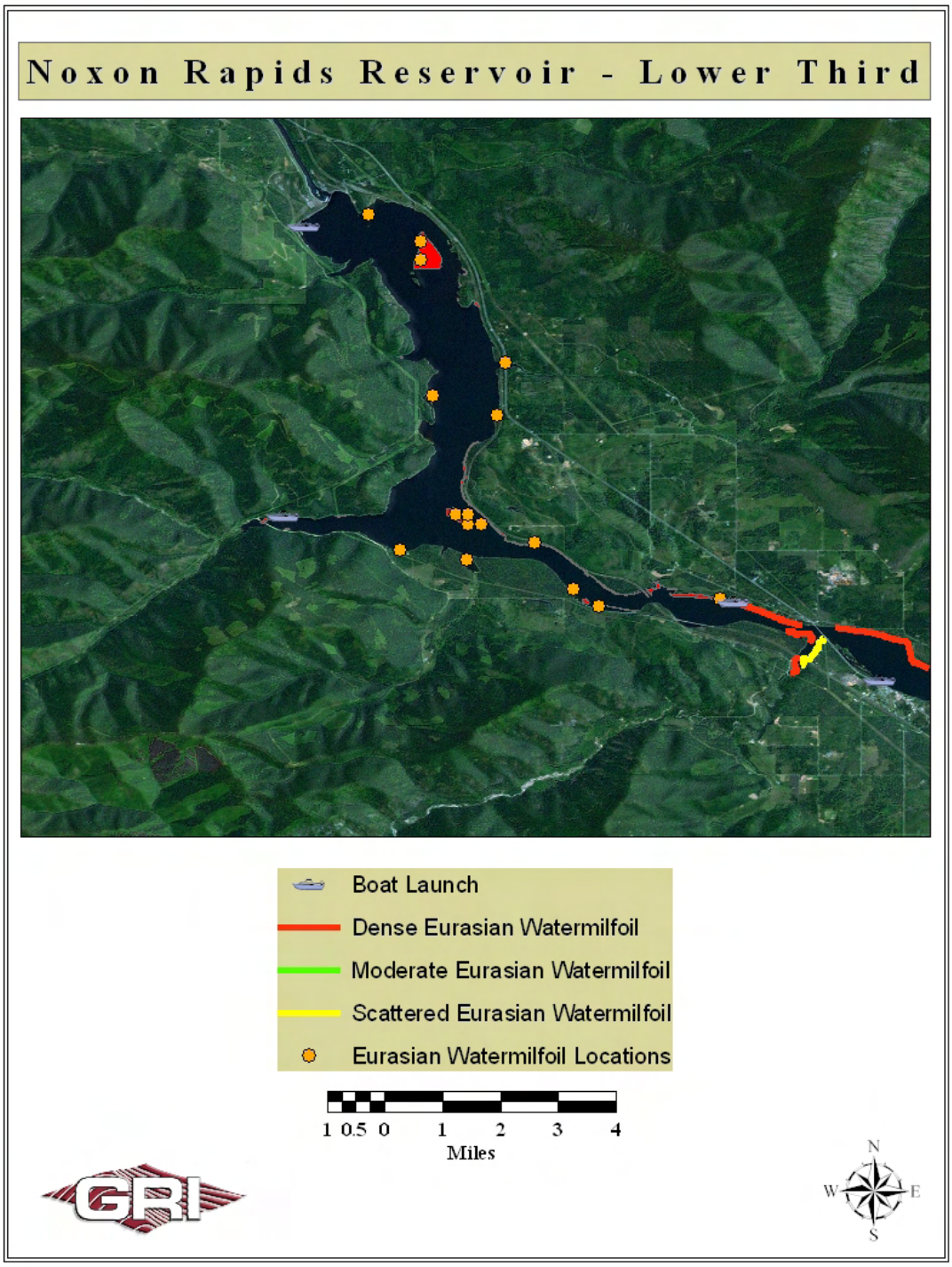

Figure 20a. Eurasian watermilfoil in the lower third of Noxon Rapids Reservoir. Red lines mark dense Eurasian watermilfoil, green mark moderate density of Eurasian watermilfoil, yellow marks scattered Eurasian watermilfoil, and orange points indicate locations of Eurasian watermilfoil from the point survey.

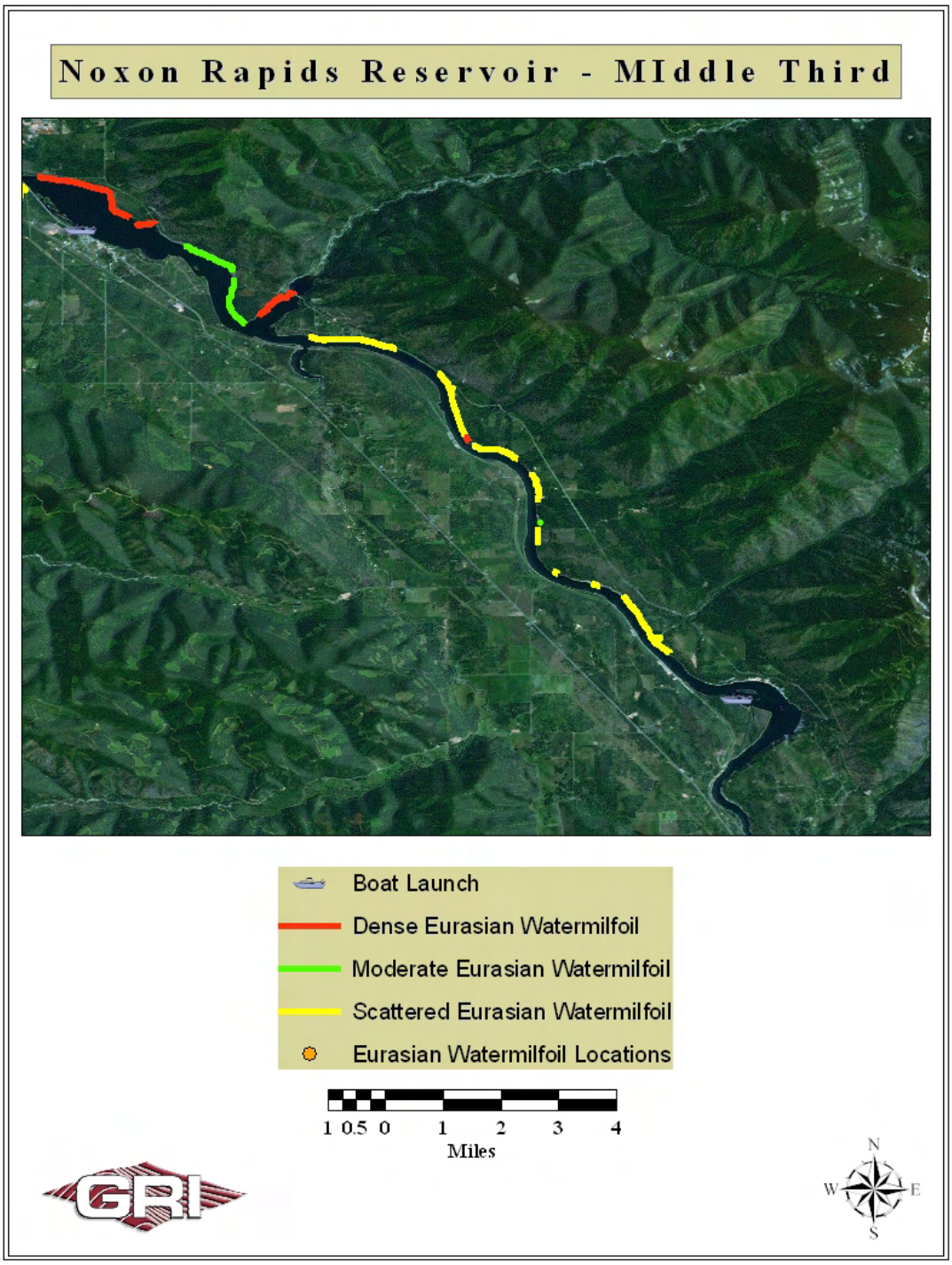

Figure 20b. Eurasian watermilfoil in the middle third of Noxon Rapids Reservoir. Red lines mark dense Eurasian watermilfoil, green mark moderate density of Eurasian watermilfoil, yellow marks scattered Eurasian watermilfoil, and orange points indicate locations of Eurasian watermilfoil from the point survey.

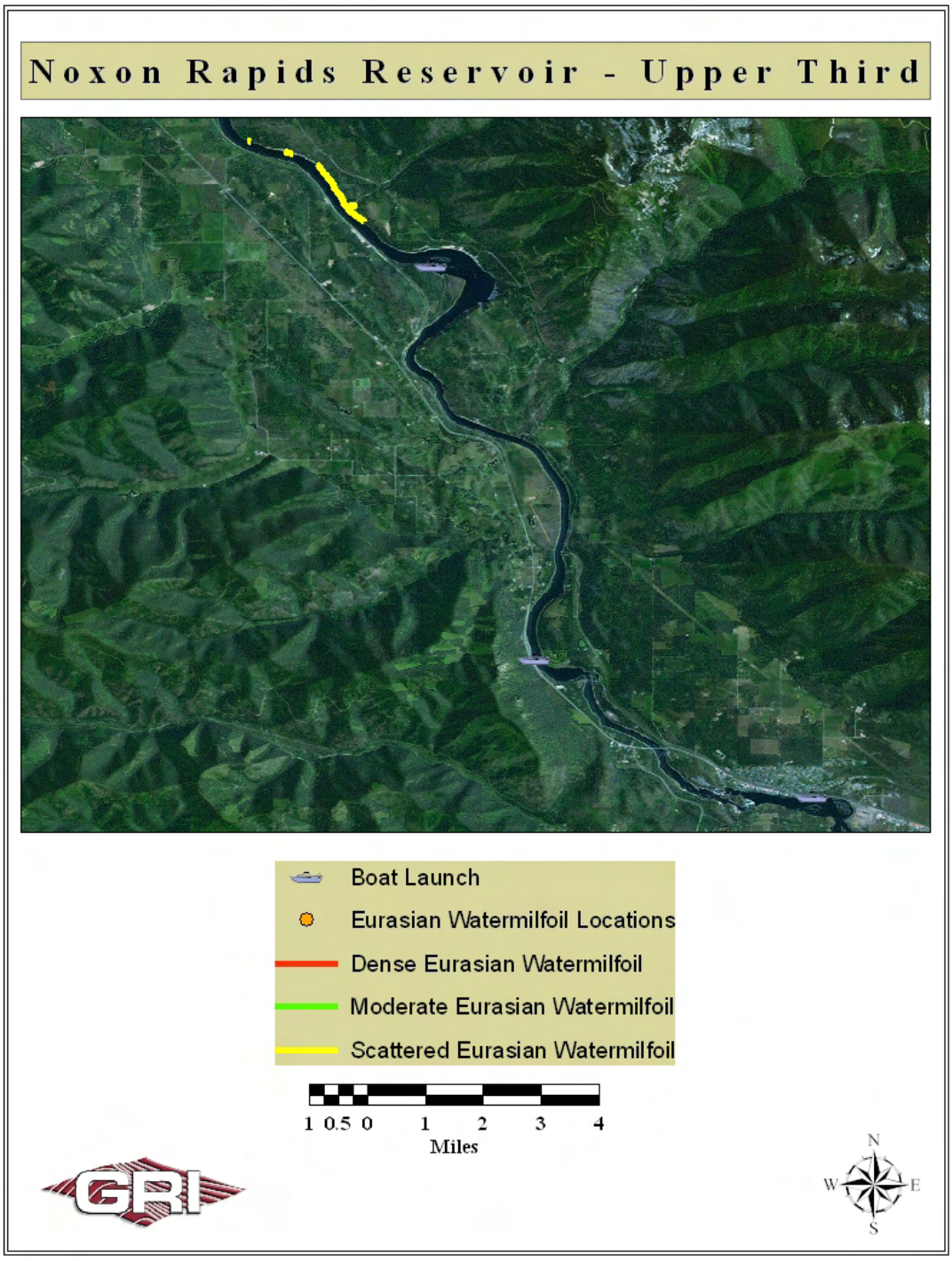

Figure 20c. Eurasian watermilfoil in the upper third of Noxon Rapids Reservoir. Red lines mark dense Eurasian watermilfoil, green mark moderate density of Eurasian watermilfoil, yellow marks scattered Eurasian watermilfoil, and orange points indicate locations of Eurasian watermilfoil from the point survey.

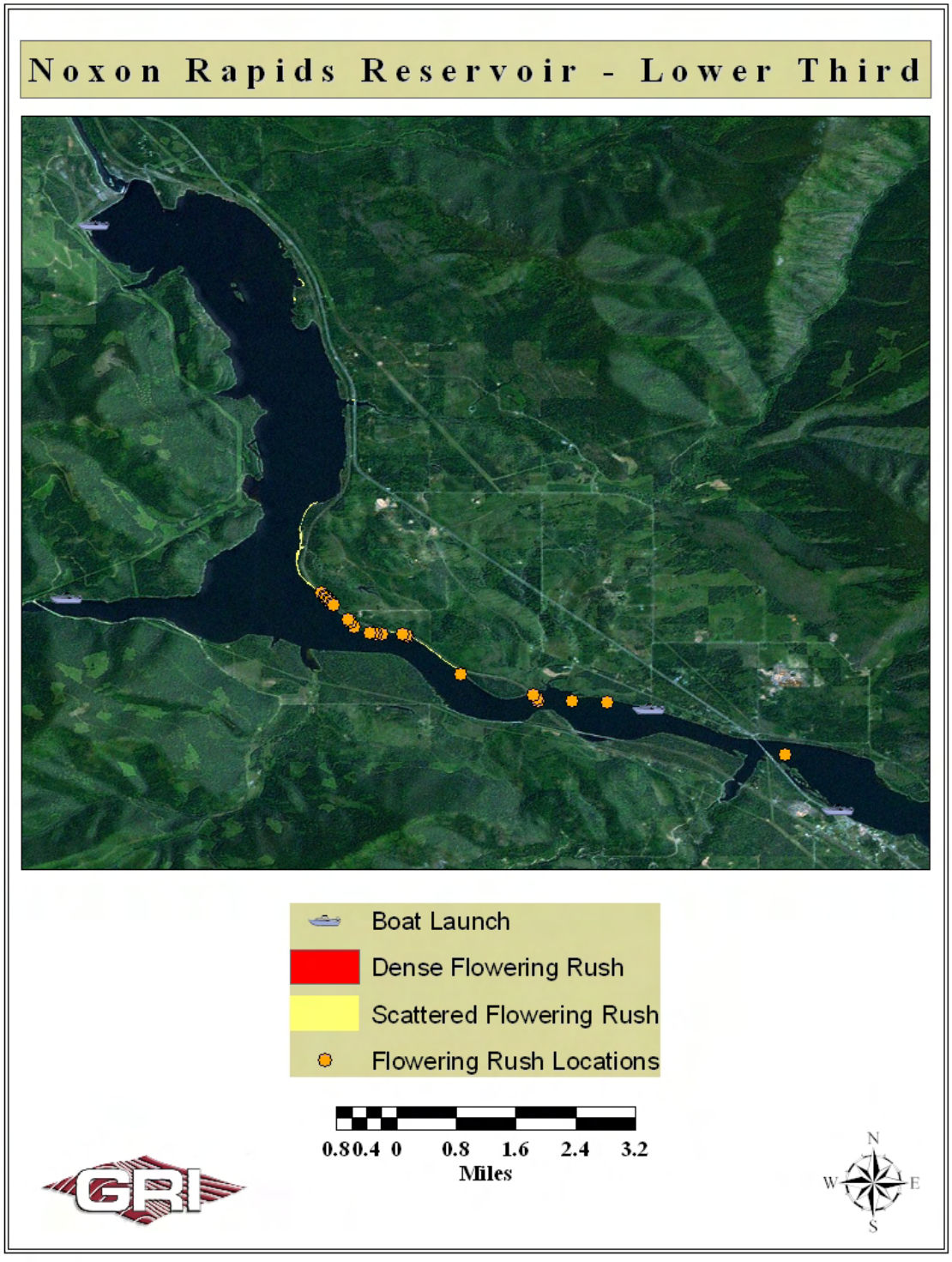

Figure 21c. Flowering rush in the lower third of Noxon Rapids Reservoir. Red marks areas of dense flowering rush, yellow marks areas of scattered flowering rush, and orange points are locations of flowering rush from the point survey.

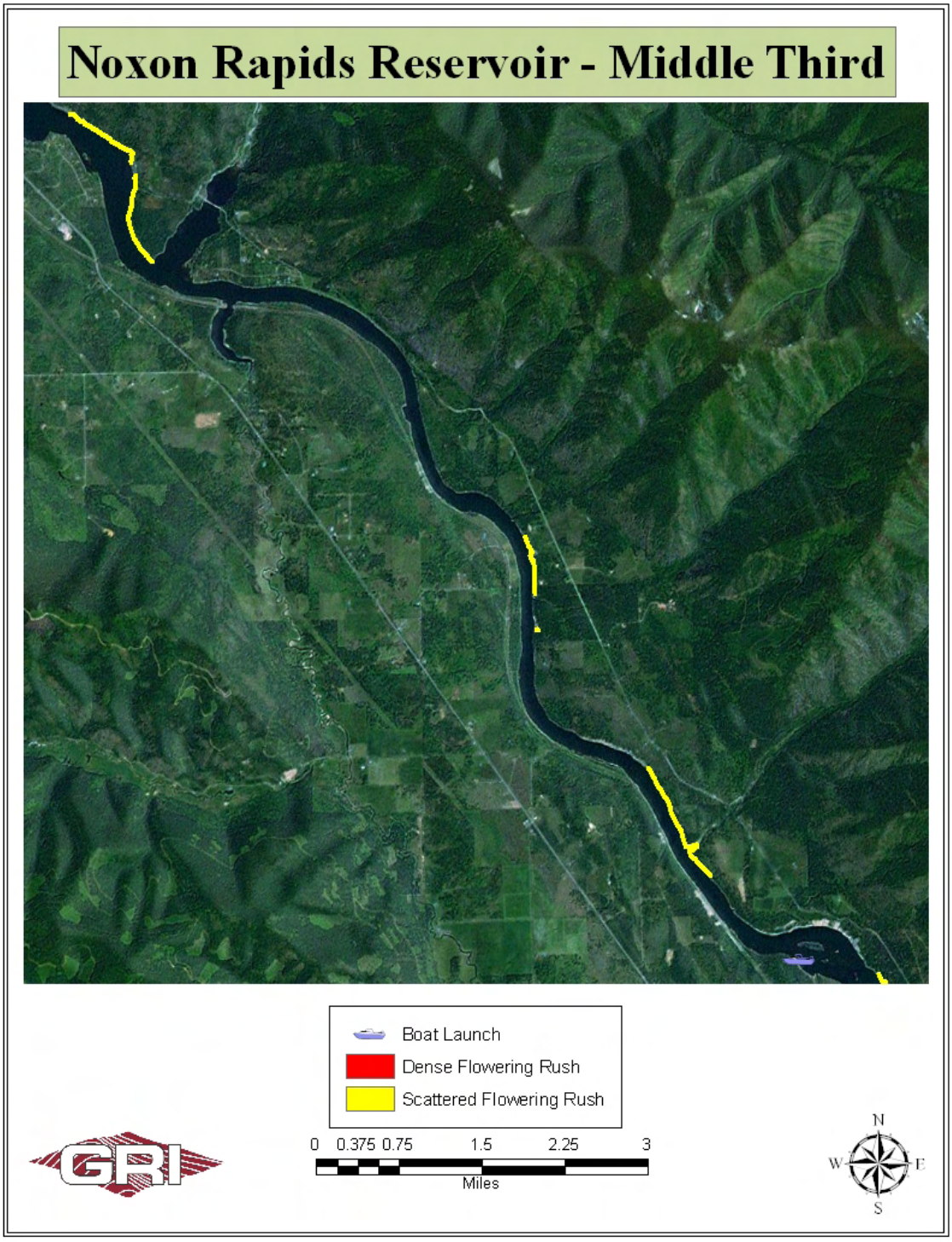

Figure 21b. Flowering rush in the middle third of Noxon Rapids Reservoir. Red marks areas of dense flowering rush, yellow marks areas of scattered flowering rush, and orange points are locations of flowering rush from the point survey.

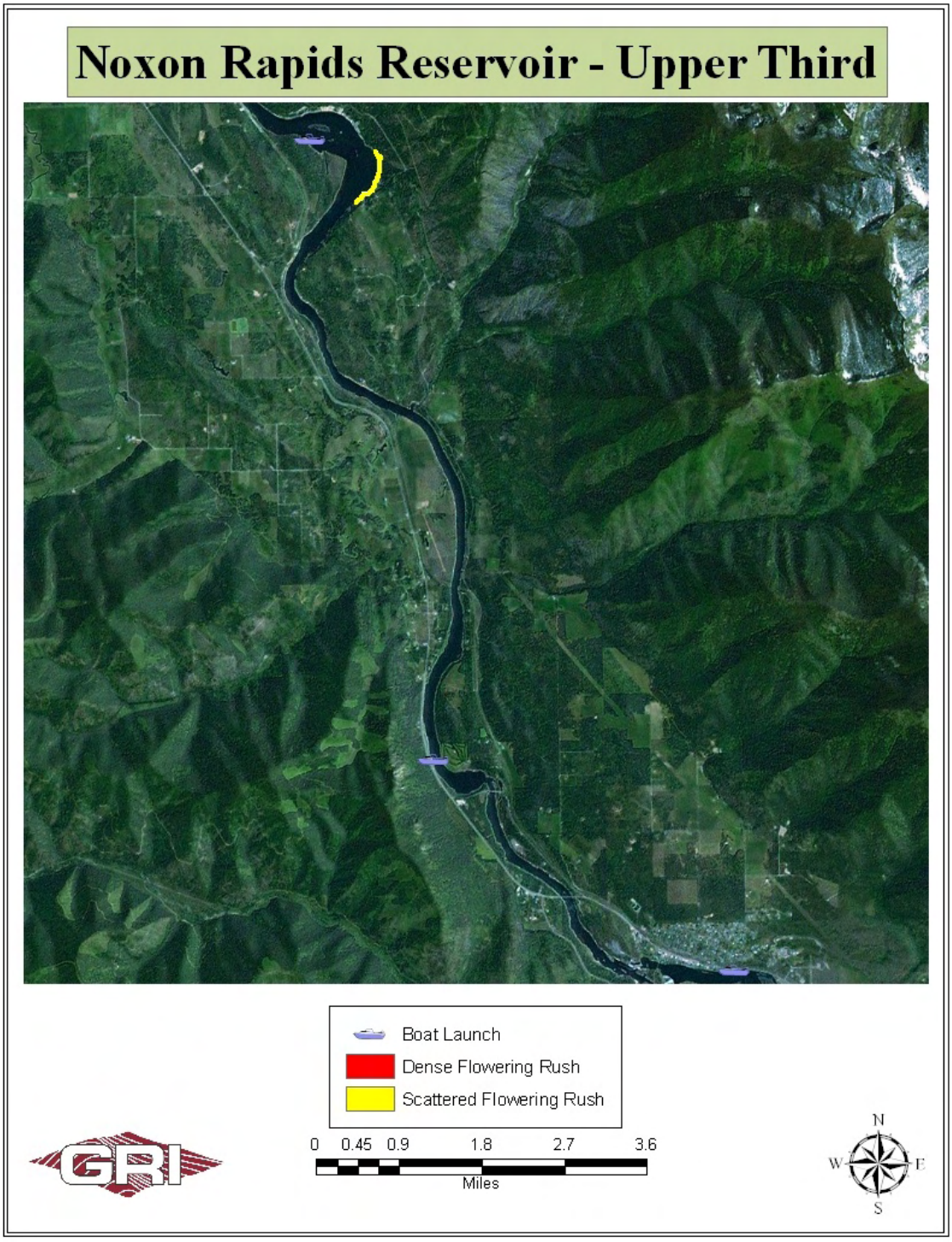

Figure 21c. Flowering rush in the upper third of the Noxon Rapids Reservoir. Red marks areas of dense flowering rush, yellow marks areas of scattered flowering rush, and orange points are locations of flowering rush from the point survey.

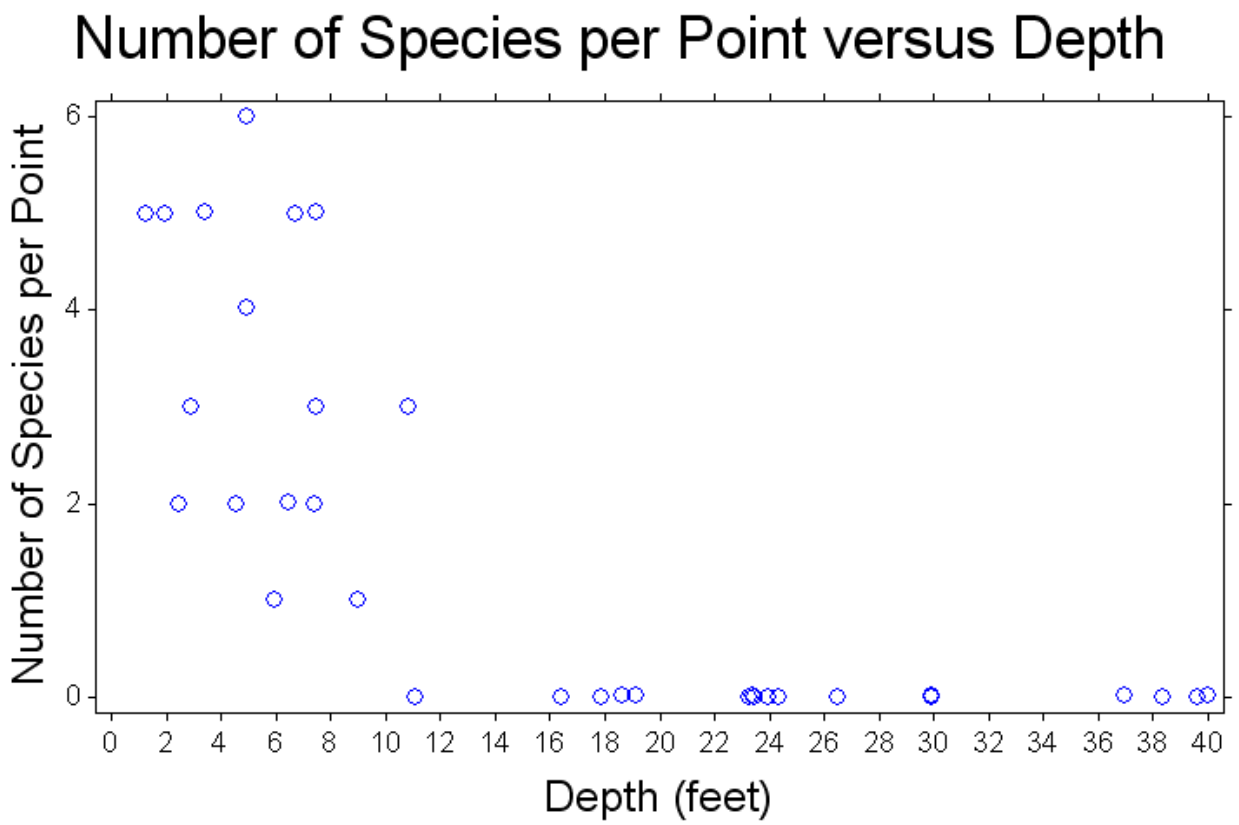

Figure 22. Number of species per point versus depth for Thompson Falls Reservoir. Although the deepest plant observed was 11 feet, water clarity would allow deeper colonization so we maintained the 25' littoral convention.

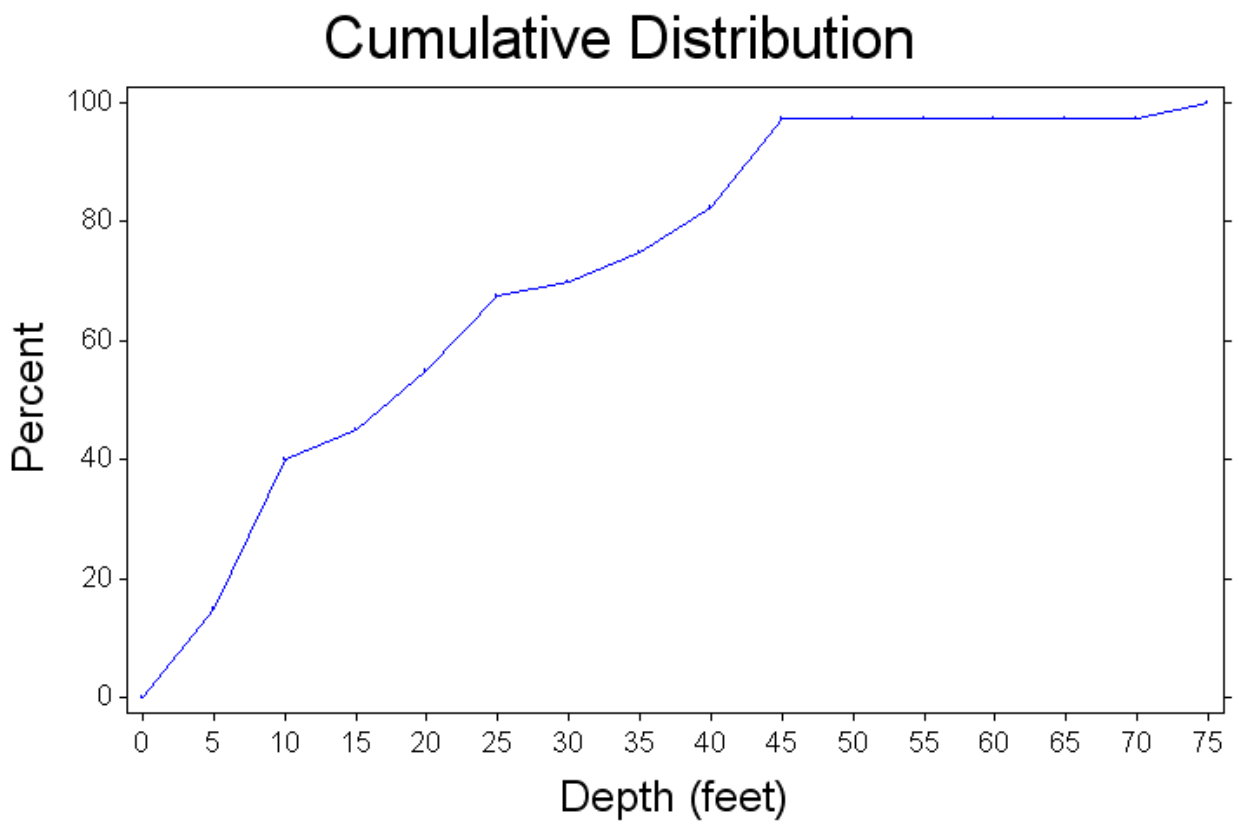

Figure 23. Cumulative distribution of depths in Thompson Falls Reservoir. The littoral zone depth of 25' indicates that more than 65% of the reservoir is littoral zone; plants were found to 11 feet or in 45% of the reservoir.

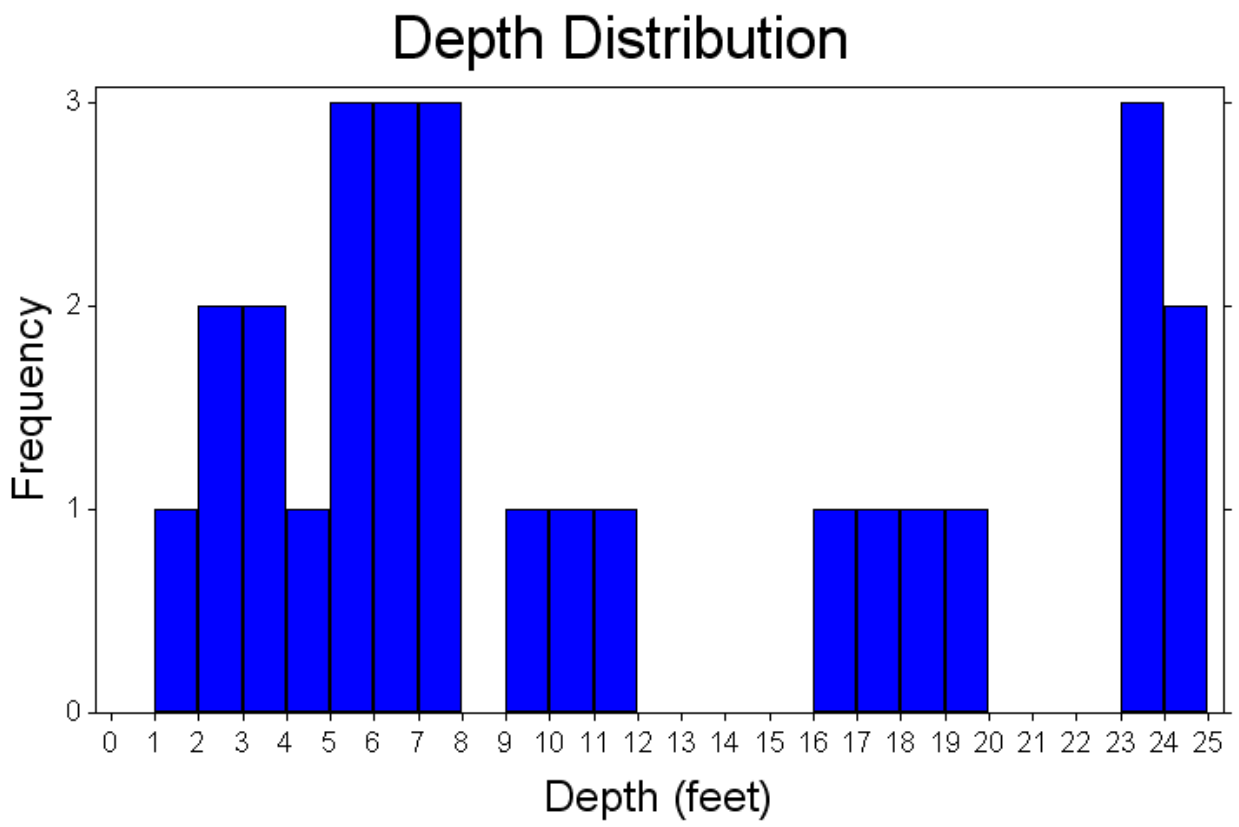

Figure 24. Histogram of the number of points in each 1-foot depth class from Thompson Falls Reservoir.

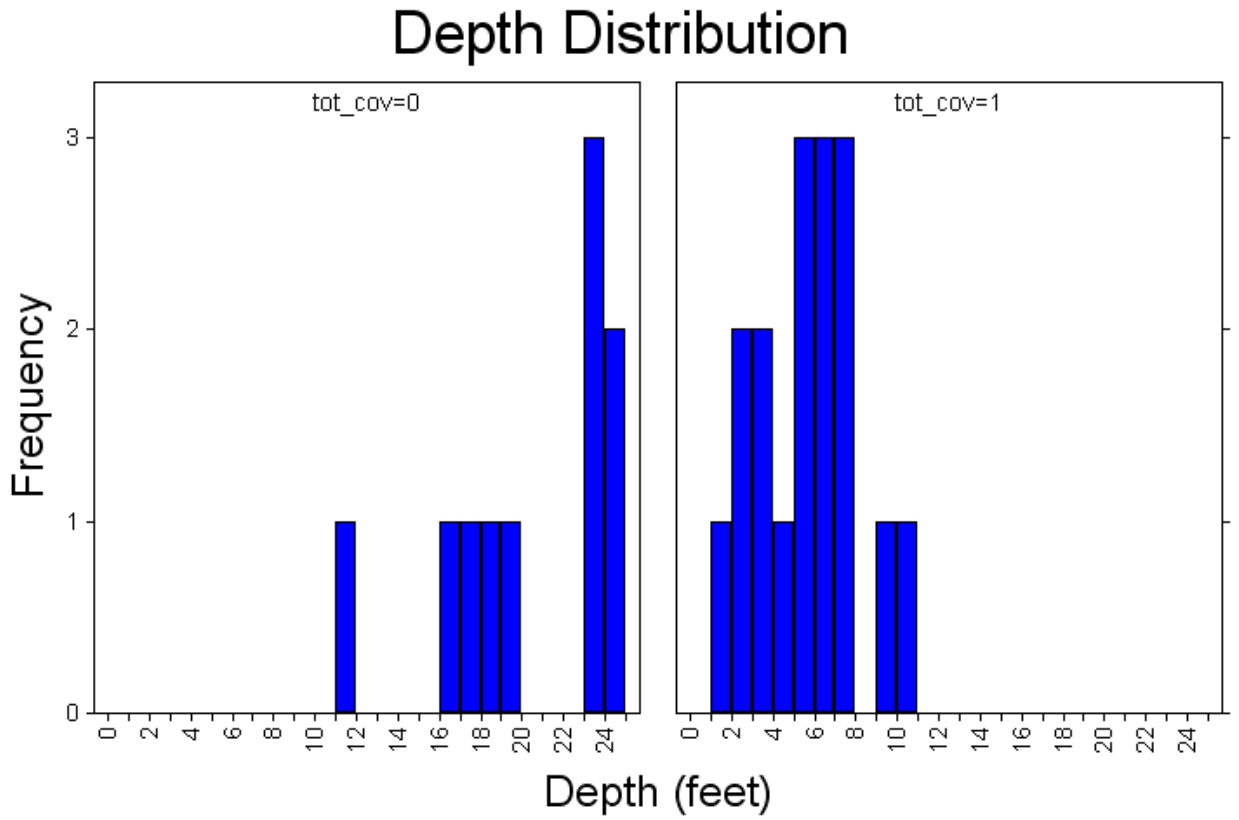

Figure 25. Depth distribution of sites without (tot_cov=0, left) and with plant cover (tot_cov=1, right) in Thompson Falls Reservoir.

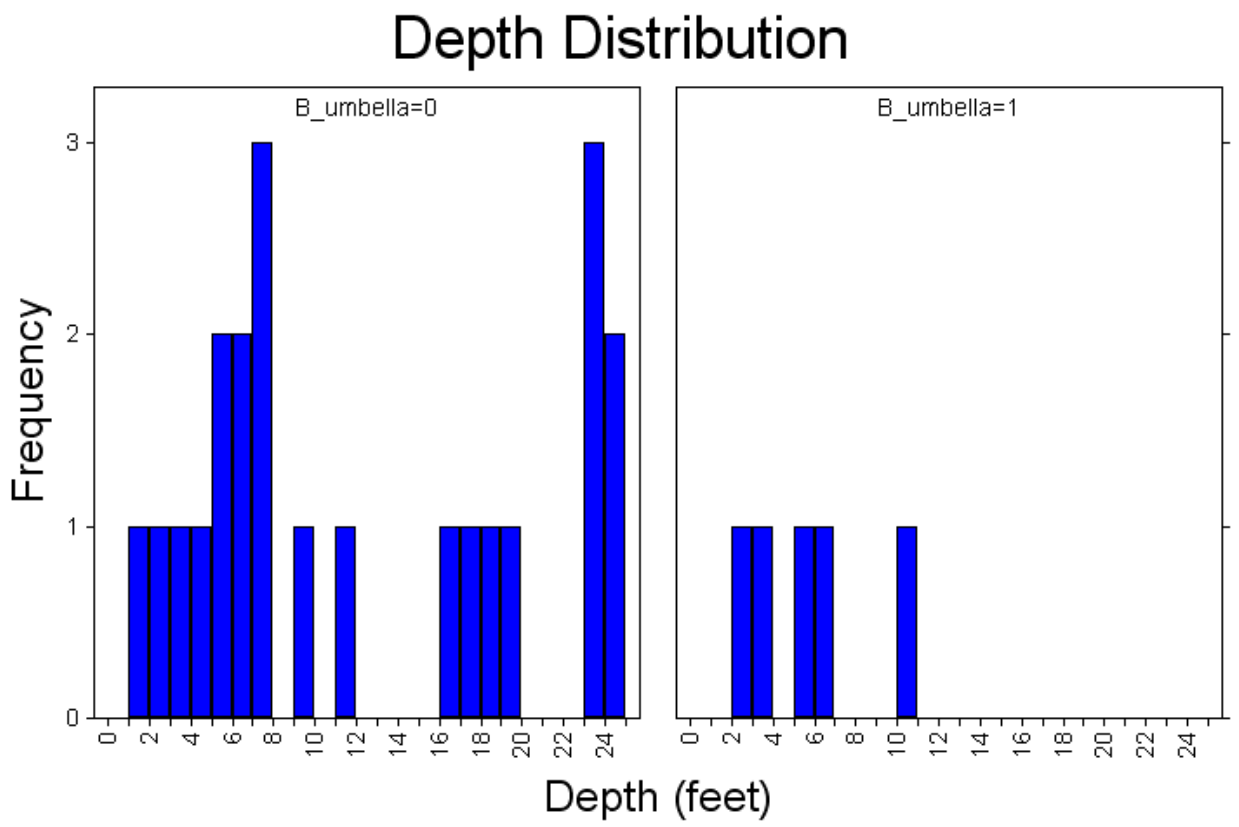

Figure 26. Depth distribution of flowering rush (B_umbella=1, right) versus sites without flowering rush (B_umbella=0, left) in Thompson Falls Reservoir.

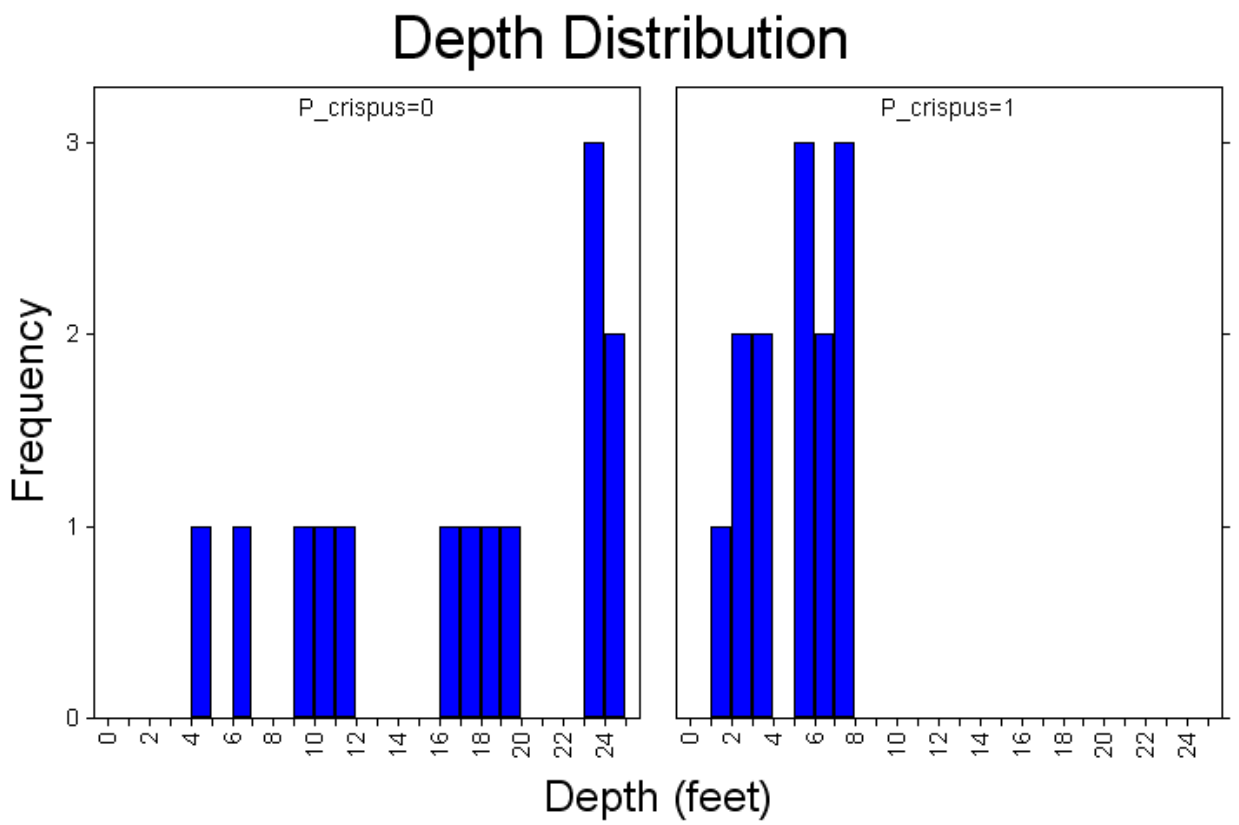

Figure 27. Depth distribution of sites colonized by curlyleaf pondweed (P_crispus=1, right) versus not colonized by curlyleaf pondweed (P_crispus=0, left) in Thompson Falls Reservoir.

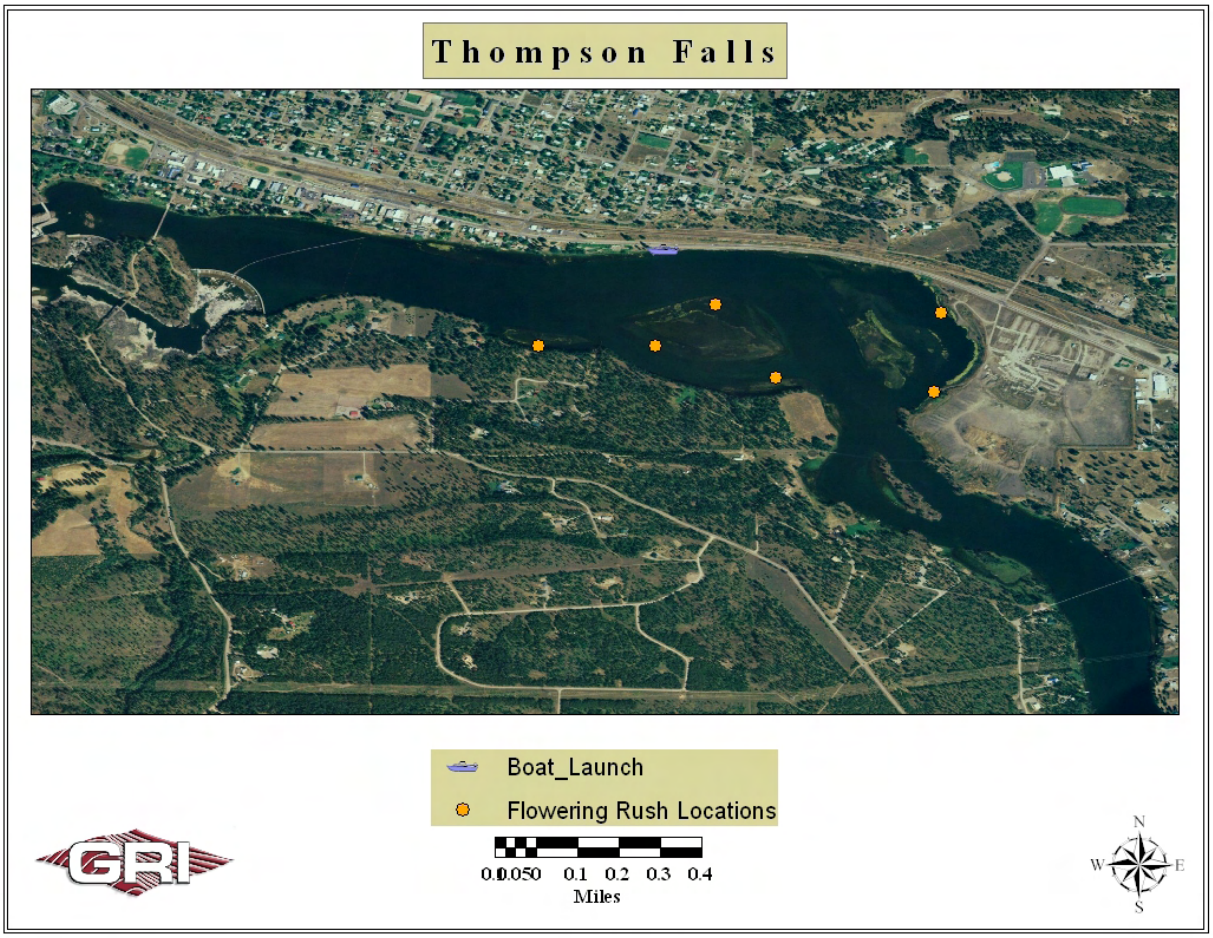

Figure 28. Distribution of flowering rush in Thompson Falls Reservoir.

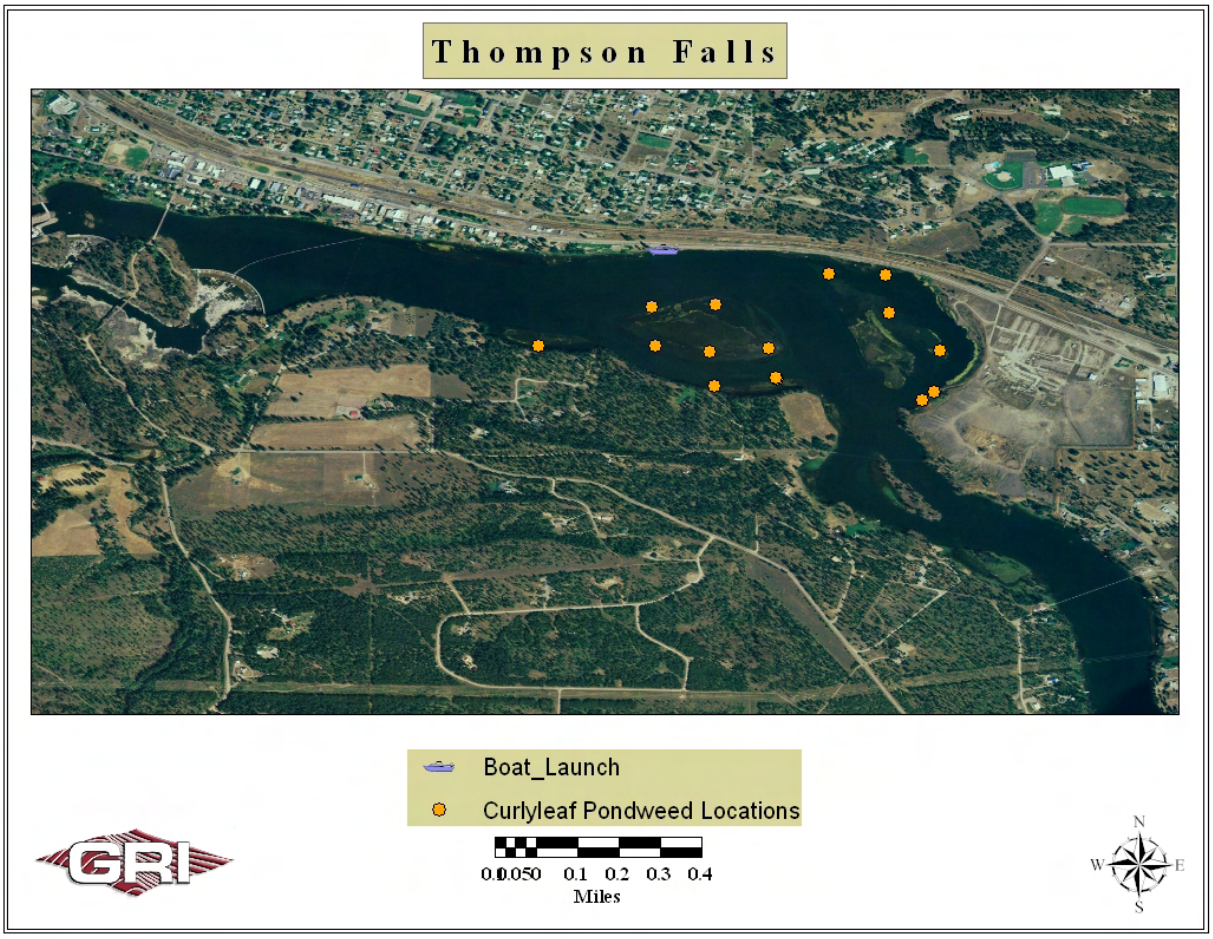

Figure 29. Distribution of curlyleaf pondweed in Thompson Falls Reservoir.

Table 1. Species summary for all points in Cabinet Gorge Reservoir.
Multiply mean frequency by 100 for percent frequency.

Species Name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering rush	334	0.000	0.0
Ceratophyllum demersum L.	Coontail	334	0.147	14.7
Chara sp.	Chara	334	0.006	0.6
Elodea canadensis Michx.	Elodea	334	0.159	15.9
Juncus pelocarpus E. Mey.	Brownfruit rush	334	0.003	0.3
Myriophyllum sibiricum Komarov	Northern watermilfoil	334	0.051	5.1
Myriophyllum spicatum L.	Eurasian watermilfoil	334	0.063	6.3
Nitella sp.	Nitella	334	0.003	0.3
Potamogeton crispus L.	Curlyleaf pondweed	334	0.105	10.5
Potamogeton foliosus Raf.	Leafy pondweed	334	0.024	2.4
Potamogeton gramineus L.	Variableleaf pondweed	334	0.009	0.9
Potamogeton illinoensis Morong	Illinois pondweed	334	0.027	2.7
Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed	334	0.060	6.0
Potamogeton zosteriformis Fernald	Flatstem pondweed	334	0.030	3.0
Ranunculus aquatilis L.	White watercrowfoot	334	0.009	0.9
Stuckenia pectinata (L.) Boerner	Sago pondweed	334	0.018	1.8
Depth (ft)		334	35.0	
Average number of exotic species per point		334	0.168	
Average number of native species per point		334	0.551	
Average number of species per point		334	0.719	
Plant cover (any species)		334	0.213	21.3

Table 2. Species summary for littoral points (< 25' deep) in Cabinet Gorge Reservoir. Multiply mean frequency by 100 for percent frequency.

Species Name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering rush	139	0.000	0.0
Ceratophyllum demersum L.	Coontail	139	0.353	35.3
Chara sp.	Chara	139	0.014	1.4
Elodea canadensis Michx.	Elodea	139	0.381	38.1
Juncus pelocarpus E. Mey.	Brownfruit rush	139	0.007	0.7
Myriophyllum sibiricum Komarov	Northern watermilfoil	139	0.122	12.2
Myriophyllum spicatum L.	Eurasian watermilfoil	139	0.151	15.1
Nitella sp.	Nitella	139	0.007	0.7
Potamogeton crispus L.	Curlyleaf pondweed	139	0.252	25.2
Potamogeton foliosus Raf.	Leafy pondweed	139	0.058	5.8
Potamogeton gramineus L.	Variableleaf pondweed	139	0.022	2.2
Potamogeton illinoensis Morong	Illinois pondweed	139	0.065	6.5
Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed	139	0.144	14.4
Potamogeton zosteriformis Fernald	Flatstem pondweed	139	0.072	7.2
Ranunculus aquatilis L.	White watercrowfoot	139	0.022	2.2
Stuckenia pectinata (L.) Boerner	Sago pondweed	139	0.043	4.3
Depth (ft)		139	14.1	
Average number of exotic species per point		139	0.403 (0.057)	
Average number of native species per point		139	1.324 (0.142)	
Average number of species per point		139	1.727 (0.179)	
Plant cover (any species)		139	0.511	51.1

Table 3. Noxon Rapids Reservoir point intercept summary for all points.
Multiply mean frequency by 100 for percent frequency.

Scientific Name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering Rush	487	0.006	0.6
Ceratophyllum demersum L.	Coontail	487	0.064	6.4
Chara sp.	Chara	487	0.058	5.8
Elodea canadensis Michx.	Elodea	487	0.101	10.1
Heteranthera dubia (Jacq.) MacMill.	Yellow stargrass	487	0.019	1.9
Myriophyllum sibiricum Komarov	Northern watermilfoil	487	0.058	5.8
Myriophyllum spicatum L.	Eurasian watermilfoil	487	0.033	3.3
Nitella sp.	Nitella	487	0.006	0.6
Potamogeton crispus L.	Curlyleaf pondweed	487	0.053	5.3
Potamogeton foliosus Raf.	Leafy pondweed	487	0.068	6.8
Potamogeton illinoensis Morong	Illinois pondweed	487	0.004	0.4
Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed	487	0.035	3.5
Potamogeton zosteriformis Fernald	Flatstem pondweed	487	0.006	0.6
Ranunculus aquatilis L.	White watercrowfoot	487	0.008	0.8
Stuckenia pectinata (L.) Boerner	Sago pondweed	487	0.082	8.2
Vallisneria americana Michx.	Water celery	487	0.002	0.2
Depth (feet)		487	58.7	
Average Number of Exotic Species per Point		487	0.092	
Average Number of Native Species per Point		487	0.509	
Average Number of Species per Point		487	0.602	
Total plant cover (all species)		487	0.184	18.4

Table 4. Noxon Rapids Reservoir point intercept summary for littoral (<25') points. Multiply mean frequency by 100 for percent frequency.

Scientific Name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering Rush	130	0.023	2.3
Ceratophyllum demersum L.	Coontail	130	0.239	23.9
Chara sp.	Chara	130	0.215	21.5
Elodea canadensis Michx.	Elodea	130	0.377	37.7
Heteranthera dubia (Jacq.) MacMill.	Yellow stargrass	130	0.069	6.9
Myriophyllum sibiricum Komarov	Northern watermilfoil	130	0.215	21.5
Myriophyllum spicatum L.	Eurasian watermilfoil	130	0.123	12.3
Nitella sp.	Nitella	130	0.023	2.3
Potamogeton crispus L.	Curlyleaf pondweed	130	0.200	20.0
Potamogeton foliosus Raf.	Leafy pondweed	130	0.254	25.4
Potamogeton illinoensis Morong	Illinois pondweed	130	0.015	1.5
Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed	130	0.131	13.1
Potamogeton zosteriformis Fernald	Flatstem pondweed	130	0.023	2.3
Ranunculus aquatilis L.	White watercrowfoot	130	0.031	3.1
Stuckenia pectinata (L.) Boerner	Sago pondweed	130	0.308	30.8
Vallisneria americana Michx.	Water celery	130	0.008	0.8
Depth (feet)		132	12.9	
Average Number of Exotic Species per Point		130	0.346	
Average Number of Native Species per Point		130	1.908	
Average Number of Species per Point		130	2.254	
Total plant cover (all species)		130	0.682	68.2

Table 5. Thompson Falls Reservoir point intercept summary for all points. Multiply mean frequency by 100 for percent frequency.

Scientific name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering rush	40	0.125	12.5
Ceratophyllum demersum L.	Coontail	40	0.200	20.0
Elodea canadensis Michx.	Elodea	40	0.325	32.5
Heteranthera dubia (Jacq.) MacMill	Yellow stargrass	40	0.025	2.5
Myriophyllum sibiricum Komorov	Northern watermilfoil	40	0.200	20.0
Myriophyllum spicatum L.	Eurasian watermilfoil	40	0.000	0.0
Potamogeton crispus L.	Curlyleaf pondweed	40	0.325	32.5
Potamogeton foliosus Raf.	Leafy pondweed	40	0.025	2.5
Ranunculus aquatilis L.	White watercrowfoot	40	0.125	12.5
Stuckenia pectinata (L.) Boerner	Sago pondweed	40	0.150	15.0
Depth		40	20.450	
Average number of exotic species per point		40	0.450	
Average number of native species per point		40	1.050	
Average number of species per point		40	1.500	
Total plant cover (any species)		40	0.425	42.5

Table 6. Thompson Falls Reservoir point intercept summary for Littoral Zone Points (Depth < 25 ft). Multiply mean frequency by 100 for percent frequency.

Scientific name	Common Name	N	Mean	Percent
Butomus umbellatus L.	Flowering rush	27	0.185	18.5
Ceratophyllum demersum L.	Coontail	27	0.296	29.6
Elodea canadensis Michx.	Elodea	27	0.482	48.2
Heteranthera dubia (Jacq.) MacMill	Yellow stargrass	27	0.037	3.7
Myriophyllum sibiricum Komorov	Northern watermilfoil	27	0.296	29.6
Myriophyllum spicatum L.	Eurasian watermilfoil	27	0.000	0.0
Potamogeton crispus L.	Curlyleaf pondweed	27	0.482	48.2
Potamogeton foliosus Raf.	Leafy pondweed	27	0.037	3.7
Ranunculus aquatilis L.	White watercrowfoot	27	0.185	18.5
Stuckenia pectinata (L.) Boerner	Sago pondweed	27	0.222	22.2
Depth		27	10.944	
Avg. number of invasive species per point		27	0.667	
Avg. number of native species per point		27	1.556	
Avg. number of species per point		27	2.222	
Total plant cover (any species)		27	0.630	63.0

Table 7. Estimated acreage based on the number of points where invasive plant species occur in the Lower Clark For River Reservoirs.

Reservoir	Cabinet Gorge	Noxon Rapids	Thompson Falls
Grid Interval (m)	150	250	150
Number of Points:			
Curlyleaf pondweed	35	26	13
Eurasian watermilfoil	21	16	0
Flowering Rush	0*	3	5
Acres:			
Curlyleaf pondweed	195	401	72
Eurasian watermilfoil	117	247	0
Flowering Rush	0	46	28

*Flowering rush was observed in Cabinet Gorge Reservoir, but not at a grid point.

Appendix 1. Daily Secchi Disk readings from Lower Clark Fork Reservoir surveys.

		UTM 11T		Secchi Disk Depth* (m)		
Date	Reservoir	Northing	Easting	Down	Up	Average
8/9/2008	Cabinet Gorge	5324068.94	579950.41	4.70	4.48	4.59
8/10/2008	Cabinet Gorge	-	-	-	-	-
8/11/2008	Noxon Rapids	5304347.58	596535.02	3.55	3.04	3.30
8/12/2008	Cabinet Gorge	-	-	-	-	-
8/13/2008	Thompson Falls	5272283.00	624451.00	2.78	2.65	2.72
8/14/2008	Noxon Rapids	5275672.77	620759.43	5.00	4.80	4.90
8/15/2008	Cabinet Gorge	5326108.00	574245.00	5.17	5.08	5.13
8/16/2008	Noxon Rapids	5302493.00	599418.00	5.20	5.17	5.19
8/17/2008	Noxon Rapids	5289728.00	615174.00	3.59	3.55	3.57
8/18/2008	Noxon Rapids	-	-	-	-	-
8/19/2008	Noxon Rapids	-	-	-	-	-

*The Secchi Disk depth is measured using a standard 8”disk painted in an alternate white and black pattern. Secchi Disk is the universal (and inexpensive) method of determining lake transparency. An approximation of the littoral zone would be twice the observed Secchi Disk depth, and of the phytoplankton photic zone would be three times the Secchi Disk depth.