RECLAMATION
Managing Water in the West

Beulah Reservoir Minimum Pool and Prey Base Studies 2010 – 2013: Part 1 Prey Base

Prepared for: **Bureau of Reclamation, Snake River Area Office, Boise Idaho**

U.S. Department of the Interior
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U.S. DEPARTMENT OF THE INTERIOR

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Front cover photograph – Beulah Reservoir

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Bureau of Reclamation
Technical Service Center
Fisheries and Wildlife Resources Group 86-68290

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PEER REVIEW DOCUMENTATION

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REVIEW REQUIREMENT

Part A: Document Does Not Require Peer Review

Explain

Part B: Document Requires Peer Review: SCOPE OF PEER REVIEW

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REVIEW CERTIFICATION

Peer Reviewer - I have reviewed the assigned Items/Section(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Dimitri Vidergar Review Date: 7/02/15 Signature: [signature]

I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Leader: Michael Horn Date: 6/22/15 Signature: [signature]

Acronyms and Abbreviations

BLM	Bureau of Land Mangement
cfs	cubic feet per second
CPUE	catch per unit effort
FL	fork length
FPH	fish per hour
km	kilometer
NFMR	North Fork of the Malheur River
NRCS	Natural Resources Conservation Service
ODFW	Oregon Department of Fish and Wildlife
Opinion	USFWS 2005 Biological Opinion
PIT	Passive integrated transponder
Reclamation	U.S. Bureau of Reclamation
T&C	Terms and Conditions
USDA	U. S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Table of Contents

List of Figures

Table of Contents (continued)

Table of Contents (continued)

List of Tables

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1. BACKGROUND AND OBJECTIVES

Agency Valley Dam on the North Fork of the Malheur River (NFMR), Oregon was constructed by the Bureau of Reclamation (Reclamation) during 1934 to 1935, resulting in the creation of the 59,512 acre-feet Beulah Reservoir. Agency Valley Dam is located at river kilometer (km) 29 upstream from the confluence of the NFMR and the mainstem of the Malheur. Vale Irrigation District currently operates Beulah Reservoir for the benefits of irrigation and flood control, and along with Bully Creek Dam and Reservoir, and water from Warm Springs Reservoir, provides water to nearly 35,000 acres of land downstream.

Beulah Reservoir can be reduced to run-of-the-river levels during years of low runoff from the watershed when water demands outpace supply. Reduction to a run-of-the-river level has been shown to significantly reduce forage fish populations, and potentially could affect listed Bull Trout (*Salvelinus confluentus*) that overwinter in the reservoir. The U.S. Geological Survey (USGS) (Rose and Mesa 2007; 2009) sampled fish, invertebrates, and water-quality variables seasonally during 2006 to 2008. In 2006, the summer drawdown was about 68 percent of full pool, which was less than the typical drawdown of 85 percent. Rose and Mesa detected few changes in pelagic invertebrate densities, and catch rates, abundance, and sizes of fish when comparing values from spring to fall. However, in 2007, the drawdown was 100 percent to run-of-the-river level and resulted in decreases in invertebrate abundance by as much as 96 percent, and the total biomass of forage fish were estimated to be one-quarter of the 2006 biomass amount. Other than population effects on forage fishes when the reservoir is empty, there is little data available to describe at what reservoir level the prey base could become limiting to Bull Trout.

When the U.S. Fish and Wildlife Service (USFWS) issued its Biological Opinion (Opinion) in 2004, there were four Terms and Conditions (T&C) for Beulah Reservoir. Because the effects of drawdowns had previously been valuated at only two levels – one moderate, one extreme – Reclamation did not have sufficient data available over a range of reservoir levels to make recommendations by March 31, 2010 and was granted an extension until April 30, 2015 (memo dated April 23, 2010).

Terms and Conditions pertaining to Beulah Reservoir from the 2005 Opinion (USFWS 2005).

4.a. Reduce the frequency and extent of drawdown of Beulah Reservoir to reduce harm and harassment associated with reduced or eliminated prey. Coordinate with the USFWS annually in implementing this Term and Condition until the parties reach agreement on a specific pool volume that would be a target level to minimize take effects from reservoir drawdown. Work to identify that target reservoir elevation should be completed by March 31, 2010. (March 31, 2010 deadline is extended to April 30, 2015; Memo dated April 23, 2010)

4.b. When conditions preclude maintaining water levels that will support a viable Bull Trout prey base, Reclamation shall work with the USFWS and other parties to explore opportunities to reduce take by supplementing the food base by stocking Beulah Reservoir with fish species suitable as prey for Bull Trout. Stocking of additional fish to supplement the Bull Trout prey base shall be done in every year that Beulah Reservoir is reduced below the level identified as part of Term and Condition 4.a.

4.c. Work with the USFWS and other willing participants to identify and implement any potential mechanism available to reduce the effects of anticipated take of Bull Trout from reservoir drawdown for the duration of the action. The mechanism shall be consistent with Reclamation authorities and capabilities, shall be carried out in cooperation with interested parties and willing participants, and should ensure that reservoir drawdown does not go below a level sufficient to maintain some habitat for Bull Trout prey. Efforts associated with this term and condition shall be completed by March 31, 2010. (March 31, 2010 deadline is extended to April 30, 2015; Memo dated April 23, 2010)

4.d. For the term of the proposed action, continue all existing efforts to trap and return Bull Trout that are entrained at Agency Valley Dam back to Beulah Reservoir or the North Fork Malheur River upstream from the dam. Maintain all protocols aimed at minimizing the likelihood of injury during this effort and maintain the existing scale and scope of the effort. Efforts to move Bull Trout shall take place in all years when the spillway is used at Agency Valley Dam.

Two of the four T&C (those regarding a conservation pool) expired on March 31, 2010. Reclamation did not have the data available to make recommendations by March 31, 2010 and were granted an extension by the USFWS until April 30, 2015. The final recommendation for a conservation pool level is not to provide year round habitat for Bull Trout, but to have a sufficient amount of water retained in the reservoir to allow for the maintenance of adequate habitat for Bull Trout prey. Bull trout migrate from the reservoir during the spring, but rely on food resources available in the reservoir during the winter. Past work by USGS has shown that while Bull Trout are in Beulah Reservoir they consume fish, insects, and zooplankton.

This 4-year study was initiated to extend fish, invertebrate, zooplankton, and water quality sampling to lower drawdown levels, and to complete bioenergetics modeling. The first 3 years consisted of prey base and Bull Trout studies, and the last year was spent applying the collected data from this effort, as well as previous sampling efforts, to the completion of bioenergetics modeling, and the development of a defensible conservation pool recommendation for Beulah Reservoir.

The Beulah Coordination Committee, which is a working group composed of interested parties including the Burns Paiute Tribe, the USFWS, Oregon Department of Fish and Wildlife (ODFW), Reclamation, USGS, Bureau of Land Management (BLM), and the U.S. Forest Service (USFS), identified four key areas that need to be addressed during this 4-year study:

- What is the benefit to fish, insects, and zooplankton by maintaining a conservation pool – and can a conservation pool maintain a prey base large enough to support a Bull Trout population of x number of fish?

- More data on Bull Trout is needed, including data on fish movement to determine what percent of the Bull Trout population uses the reservoir and at what time of year. Also, more data on diet and growth/age of Bull Trout are needed for bioenergetics modeling.

- Can entrained native fishes in the tailrace be salvaged and relocated back into the reservoir to bolster prey base in the reservoir? How can tens of thousands of entrained fish be handled?

- What reservoir water level is appropriate to maintain during the 3-year field portion of this study?

Question #1 was addressed by this study. Question #2 was addressed in the second part of this report concerning Bull Trout populations and bioenergetics modeling. Question #3 was addressed by the Burns Paiute Tribe in October 2010 during their collaborative fish salvage effort. Question #4, and our approach to it, is addressed in the following paragraph.

For this study, we recommended that the volume of water maintained in Beulah Reservoir during the course of the study be kept similar across years of the study given the relatively short time frame of this research. Prey base species populations in the reservoir vary widely based on results of previous studies, and may take more than one season to stabilize, if they do at all, following significant water level changes (Petersen, Kofoot, and Rose 2002; 2003; Rose and Mesa 2009). The agreed to proposal was to have Beulah Reservoir storage kept around 2,000 acre-feet during the study period. This ‘minimum’ pool level was selected because it could be a reasonable starting target level for future management. This level had previously been suggested as to potentially providing a benefit to prey species (Petersen, Kofoot, and Rose 2002; 2003; Reclamation 2013).

2. General Conditions in Beulah Reservoir

A. Water Levels

The highly variable inflows (Figure 1) and reservoir levels (Figure 2) experienced throughout the study provided us with a unique opportunity to obtain information from the reservoir under a range of conditions. For the period 1970 to 2012, maximum spring pool volumes exceeded 55,000 acre-feet 50 percent of the time. During the period of study from 2010 to 2013, the reservoir reached 52,509 acre-feet in 2010, full capacity of just over 59,000 acre-feet in 2011, 56,400 acre-feet in 2012, and 38,000 acre-feet in 2013 (Figure 1). Based on averaged historical data, for 2010 and 2012 the fill level was near the 50 percent exceedance level (average). It was at the 10 percent level (wet) in 2011, and just over the 90 percent level (dry) in 2013, making 2013 one of the drier years of record (Reclamation 2013). The 90 percent exceedance level means that based on the historical data used, in this case 1970 to 2012, it can be expected the reservoir pool elevation would be higher than this level 90 percent of the time.

End of season pool levels also varied significantly across years. For the period 1970 to 2012, Beulah Reservoir end of season water levels could be expected to drop below 10,000 acre-feet 50 percent of the time. The year prior to our study, 2009, the reservoir was essentially run-of-the-river from August 22 through the end of the irrigation season on October 22. In 2010, just prior to our first sampling event, the minimum pool was 4,500 acre-feet, or between the 90 percent and 50 percent exceedance levels. The year 2011 was a wetter year, and the reservoir was only drawn down to 16,900 acre-feet, or about 30 percent of capacity, between the 50 percent and 10 percent exceedance levels. The 10 percent exceedance for end of year storage is around 23,000 acre-feet. In 2012, the reservoir was drawn down to 2,270 acre-feet, which was reached at the same time irrigation releases were stopped for the fall. Releases were adjusted in late summer to allow the reservoir to hit as close as possible to 2,000 acre-feet (Figure 2). Had a study pool recommendation not been in place, the reservoir likely would have reached run-of-the-river for a short period of time. In 2013, since the reservoir never filled completely, the drawdown effect followed a different pattern. The reservoir reached 2,000 acre-feet by August 11, but evaporation resulted in a minimum study pool of 1,420 acre-feet at its lowest. Again, in 2013, Beulah Reservoir would have reached run-of-the-river if the minimum study pool had not been maintained. As with other years, as soon as irrigation releases were curtailed, the reservoir immediately started filling.

B. Inflows and Outflows

Generally, reservoir levels were a good indicator of what inflow patterns and precipitation levels were like that year. There were small short duration spikes in the hydrograph due to local climatic events. Typically, the river tended to be at or near a seasonal base flow level from approximately July through February during other than exceptionally wet water years (10 percent exceedance (Figure 1) (Reclamation 2013, Reclamation Hydromet site MABO). Late summer, fall, and early winter base flows have tended to vary between about 30 and 50 cubic feet per second (cfs) over the past 10 years (Reclamation Hydromet site BEUO). The NFMR watershed tends not to be high elevation, and most runoff occurs earlier in the season than would be expected for watersheds with higher average elevations. Runoff generally results in increased flows beginning in late February with peaks in snowmelt runoff occurring during April and May, after which time there was a rapid return to base flow. The start of irrigation releases from the reservoir begins in mid-April. Once the irrigation season is in full swing, releases tend to fluctuate between 350 to 400 cfs, until either reservoir storage is depleted or the irrigation seasons ends (Figure 3) (Reclamation Hydromet). Since 2002, Beulah Reservoir has only filled enough to spill on four occasions, 2005 to 2006, and 2011 to 2012, and only during 2006 and 2011 did the length of spill occur for any significant period of time. During each of those 2 years, precipitation was higher than normal (Figure 7).

2010. Precipitation accumulation was 92 percent of average in the Blue Mountain Range (United States Department of Agriculture, Natural Resources Conservation Service [USDA, NRCS] SNOTEL Water Year Data based on 1981 through 2010 averages). The hydrograph for the NFMR inflow into Beulah Reservoir was bimodal in the spring of 2010 with two peaks of over 600 cfs in April and June. The average discharge was 119 cfs, similar to the 10-year average of 116 cfs. The reservoir level peaked at 52,509 acre-feet and was drawn down 91 percent during the irrigation season to 4,559 acre-feet. Inflows during 2010 were probably near the 60 percent exceedance level.

2011. Precipitation accumulation was 129 percent of average (USDA, NRCS SNOTEL Water Year Data based on 1981 through 2010 averages). The hydrograph for the NFMR was again bimodal in the spring of 2011 with a peak of 1200 cfs in April and 1510 cfs in May. The average discharge for 2011 was 216; nearly twice the 10-year average. Inflows approached the 90 percent exceedance levels for discharge. High NFMR flow lead to the swift filling of Beulah Reservoir, and the reservoir spilled for a period of time during the late spring. Reservoir levels were compounded by numerous rain events that increased NFMR flows and decreased the need for irrigation releases downstream. In 2011, the reservoir peaked at a level of 59,403 acre-feet. The minimum reservoir level was experienced at the time of irrigation shutdown with a level of 16,934 acre-feet which represented a drawdown of 71 percent.

2012. Precipitation accumulation was 104 percent of average (USDA, NRCS SNOTEL Water Year Data based on 1981 through 2010 averages). Exceedance levels were lower than the previous two seasons but within the 50 percent level (Reclamation 2013). NFMR inflows averaged 112 cfs in 2012, and with the higher than average reservoir level remaining after the 2011 irrigation season, Beulah Reservoir was near full pool again in 2012 peaking at 57,562 acre-feet. The minimum reservoir level reached 2,269 acre-feet at the end of the irrigation season and represented a 96 percent drawdown.

2013. Precipitation accumulation was 93 percent of average (USDA, NRCS SNOTEL Water Year Data based on 1981 through 2010 averages). Our lowest water levels for the duration of our study were experienced in 2013. Data appeared to be near the 90 percent exceedance levels for inflow, making this a very dry water year based on long term trends. Inflows were below average at 90 cfs in 2013 with a peak flow of only 239 cfs in April. The reservoir level peaked at 38,014 acre-feet and dropped to 1,412 acre-feet when the outflows of Agency Valley Dam were shut off and represented a 96 percent drawdown in reservoir level.

C. Air Temperature, Water Temperatures, and Water Quality

Water quality in Beulah Reservoir was important primarily in relation to temperature as a limiting factor to Bull Trout. We did not measure water quality variables other than temperature on a year round basis. In the spring and fall, we occasionally took dissolved oxygen readings, but similar to results of Rose and Mesa, it would not appear to be a limiting factor during times Bull Trout were present in the reservoir. Water temperature in Beulah Reservoir and the NFMR inflow were the most important indicator of potential habitat suitability for Bull Trout (Figure 4 and Figure 5). 15^{o}C is used as a general guideline as an upper thermal limit for Bull Trout habitat suitability, although Bull Trout may be tolerant of somewhat higher temperatures (Rieman, Lee, and Thurow 1997; Selong et al. 2001). The last detection for Bull Trout leaving the reservoir each season coincided approximately with a period when surface temperatures in the reservoir surpassed 15^{o}C (Figure 5).

While the reservoir exhibits some stratification during the summer months, it did not strongly stratify as shown by the vertical temperature profiles, and the similarity between mean daily inflow and outflow temperatures (Figure 4, Figure 5, and Figure 6) (Reclamation 2002). Reclamation (2013) Appendix B indicated there may, under some conditions, be as much as a 10^{o}C difference between surface and bottom temperatures in late summer with bottom temperatures in the 12 to 14^{o}C range, which would be suitable for Bull Trout, although at this time dissolved oxygen could be an issue. Our data suggests this pattern of stratification might be rather uncommon, existing only for a short window of time and likely at higher reservoir pools. Beulah Reservoir is a bottom release reservoir, spilling only when absolutely necessary. The outlet structure releases from the deepest portion of the reservoir, and downstream temperatures (Figure 6) indicate any cool water pool in the reservoir is quickly depleted over the course of the summer. Our data from 2012 and 2013 indicates that, at most during those 2 years, there was only a 5 to 7^{o}C difference between surface and bottom temperatures at higher pool elevations, and that by July 1, even bottom temperatures would have been too warm to support Bull Trout (Figure 5). Since 2002, based on outfall temperatures, there never would have been a pool of water of suitable temperature within the reservoir by August (Figure 6, Reclamation Hydromet).

During the course of our studies, and during previous studies, there were no marked long-term historical trends in air temperatures that might have impacted the reservoir differently across studies (Figure 7). On a seasonal basis, however, year-to-year variation, combined with differing water levels, could impact the suitability of the reservoir and inflow areas for some aquatic species. Air temperature could also impact estimates of evaporation in the reservoir and potentially affect water level estimates. Average daily air temperature during the summer months increased each year of our study (Figure 7). This was also reflected in increases in inflow, reservoir, and outflow temperatures (Figure 4, Figure 5, and Figure 6). Conditions in Beulah Reservoir and its inflow waters would preclude its usage by Bull Trout for at least 4 months each year and may be having a deleterious impact on Rainbow Trout residing in the reservoir. Once temperatures exceed 20^{o}C for long periods of time, Rainbow Trout can begin to show stress related impacts (Coutant 1977; EPA 2001a; 2001b). Critical thermal maxima for Rainbow Trout is generally between 24 to 26^{o}C. In 2013, outflow temperatures during our study, which represent the coolest portion of the water column, exceeded 22^{o}C during the hottest part of the summer. Near surface temperatures in the middle of the reservoir were as high as 25^{o}C. Daily maxima for the inflow was over 30^{o}C for a short period in 2013.

3. PREY BASE

The study design for the prey base study was consistent with the work of the USGS (Rose and Mesa 2007; 2009). This allowed data collected from 2010 through 2013 to be used in the bioenergetics model currently under development and testing by the USGS. The use of similar methodologies also allowed for year-to-year comparisons with earlier work at Beulah Reservoir concerning the prey base (2006, 2007, and the spring of 2008, Rose and Mesa 2007; 2009); as well as work conducted in 2001 and 2002 (Petersen, Kofoot, and Rose 2002; 2003).

This study further expanded the previous prey base studies by increasing the sampling effort for prey fish and benthic invertebrates, and added sampling for zooplankton. Zooplankton can form a significant part of the diet of Bull Trout (Beauchamp and Shepard 2008). Basic data collection for Bull Trout was increased to determine the following: (1) relative abundance; (2) seasonal use of Beulah Reservoir; and (3) timing and extent of migration.

A. Benthic Invertebrates

1. Methods

Benthic invertebrates were sampled using the same techniques as those employed by Rose and Mesa, with the exception that we generally used just three quadrants to define reaches of the reservoir for purposes of sampling benthic invertebrates. These included the deep water Southern end or Dam area, the Northwestern side or North Fork Malheur section, and then the Northeastern side or Warm Springs Creek portion. We further tried to sample areas based on how long they could be expected to hold water that season. Rose and Mesa used a long-term average to determine which depths to sample in the spring; however, as they alluded to, this approach can have difficulties as Beulah Reservoir is very unpredictable in terms of how quickly it drops, or how long some areas remain dry. As an example of an extreme, areas that are wet 50 percent of the time could also be wet 100 percent of the time during wet years and never wet during dry years. Any long series of wet or dry years could impact where we should be sampling. Our sampling also occurred only twice yearly; once in the fall and again in the spring. As far as Bull Trout are concerned, summer sampling is largely irrelevant, as fish do not occupy the reservoir during the summer months. Sampling in the fall shows what potentially would be available to Bull Trout and other species going into the winter months.

Unlike the previous studies, we elected not to sample pelagic insects. Pelagic insects collected from previous studies, in large part, reflect either benthic species that may periodically move into the water column, or those species in the process of becoming terrestrial life stages. Both of these tend to be very timing specific in terms of when they appear, and given the window of time we had available for sampling each season, it was felt the data would have been of limited use.

Benthic invertebrates were collected using a 6-inch (0.0225 m2) ponar dredge at each site. In the spring, when the reservoir was at its fullest, we selected areas less than 3 m in depth to represent those areas frequently dewatered, areas from 6 to 8 m for a moderate degree of dewatering, and areas from 12 to 20 m for those areas infrequently dewatered. For the fall sample, our yearly collections were timed when the reservoir was at its lowest point, thus for fall samples, we collected from areas that never dewatered during the 3 years of this study, with the exception of some samples collected in the fall of 2011.

At each site, 2 to 3 pulls of the dredge were composited per sample. Samples were rinsed into a screened bucket (500 um wire screen base) to remove as much sediment as possible. Samples were then transferred to a 1L Nalgene bottle and preserved in ethanol. At the end of the season, all samples were sorted in the Reclamation laboratory in Denver, Colorado. Insects were separated from debris and placed in labeled scintillation vials of alcohol. Sample identification was then contracted out, and final results were provided back to Reclamation in the form of an Excel spreadsheet with counts of each species by sample.

2. Results, Comparison with Past Data

During the course of study, 21 different species of benthic organisms from 7 different orders were collected including Ephemerotptera, Odonata, Heteroptera, Coleoptera, Diptera, Oligochaeta, and Hirundinea (Table 1). Oligocheates and dipterans were the two predominate groups of organisms in the benthos of Beulah Reservoir, making up more than 99 percent of all organisms collected. Oligocheates were dominated by two groups of Tubificidae, those with hair chaetae, and those without hair chaetae. Dipterans were the most diverse group, with *Procladius* being present in every sample collected, closely followed by *Chironomus*. Only occasionally were odonates, plecoptera, heteroptera, bivalves, and gastropods sampled and overall, these groups made up an insignificant portion of the total sample. Diversity tended to be highest in the spring, and in those areas that were exposed to an intermittent amount of dewatering.

When comparing the magnitude of within season dewatering to benthic dipteran density, there was a trend toward greater densities in areas less frequently dewatered; however, this difference was not significant when averaging across years for our study. However, the data trends we observed were similar to those of Rose and Mesa (2007; 2009; 2013) where in 2006, they found a trend towards fewer benthic invertebrates in areas most frequently dewatered, but again it was not significant. In contrast, their 2009 and 2013 reports do show areas most frequently dewatered as having significantly lower populations of benthic invertebrates compared to areas never, or only infrequently, dewatered.

Sample-to-sample variation was extremely high within the reservoir for all studies for a given depth strata due to substrate differences, and such variation may have limited our ability to detect significant differences. Year-to-year variation was further a likely contributor to differences. During the period Rose and Mesa completed their studies, Beulah Reservoir filled to approximately the same volume each year. Thus, areas they determined as likely to dewater or not each year based on historical data, were relatively similar each year. During our period of study, reservoir levels covered a much broader span and may have produced the lack of significance we observed when attempting to sample those same depth contours, as although only intermittently being exposed, they were exposed more frequently in our study.

Areas of Beulah Reservoir that were never dewatered during our study showed differences between years in terms of benthic chironomid density ($F_{3,10}$= 5.782, p=0.015) (Figure 8). A multiple comparison of means indicated 2013, the driest year of the study, had lower fall benthic insect populations than either 2010 or 2011, the two wettest study years. Differences in tubificidae density were not significant between years. This data compares with the findings of Rose and Mesa (2013) where they noted that during the spring of 2008, which followed a drawdown in 2007, benthic invertebrate densities were lower than during the previous two springs. Taken together the results do indicate that there are at least short term impacts to benthic invertebrates during extreme drawdowns.

B. Plankton

1. Methods

Both zooplankton and phytoplankton were collected from Beulah Reservoir during our spring and fall sampling events. Similar to benthic collections, samples were collected near the dam and in the Northwest, and Northeast quadrants of the reservoir. Zooplankton samples were collected at each location using a composite of 3 to 5 surface to bottom tows using a 25 cm diameter 64 um mesh nitex plankton net. Samples were rinsed into amber Nalgene bottles and preserved with acid Lugol’s. Phytoplankton samples were collected using a surface grab in 1L amber Nalgene bottle which was then preserved with acid Lugol’s. Zooplankton and phytoplankton samples were then shipped to BSA Inc. in Beechwood, Ohio for analysis. Zooplankton samples were identified to the lowest practical taxonomic level. Several individuals of each species were measured to estimate biomass and total density of zooplankton for each species in the sample. Phytoplankton samples were analyzed in a similar manner with the exception that biovolume instead of biomass was the final product.

2. Results Plankton

Species makeup, size distributions, and biomass-varied across all years of the study (Appendix A and B). *Daphnia* sp. was the dominant species in terms of biomass for much of the study, followed by the copepod *Aglaodiaptomus* and then unidentified copoed nauplii. Numerous other species of copepods, rotifers, and cladocera were sampled, but collectively they made up lesser portions of the population biomass. Zooplankton biomass was highest during 2011, the wettest year of the study, when the reservoir was at its fullest, and lowest in 2013 during the period of lowest and longest average drawdown (Figure 9). *Daphnia* size also tended to track well with the trends in reservoir water levels. The smallest average body size was observed in both 2012 and 2013, following low water during the summer (Figure 10).

Phytoplankton biovolume was dominated by diatoms for most of the study and contained the greatest diversity of any group. Year-to-year variation in density and species makeup was significant, and reservoir level appeared to play a role in determining which species were dominant. In both 2010 and 2011 when the reservoir did not drop to minimum levels, Cyanobacteria species were more common. During the lower water years of 2012 and 2013, cyanobacteria were occasionally present but at lower levels, whereas the opposite trend was true for the Diatoms and Cryptophytes. During years when more of the reservoir shoreline was flooded, the added input of nutrients may have favored the development of blue-green algal blooms. Phytoplankton populations were highest during low water in 2013, when zooplankton populations were lowest and may have been indicative of reduced grazing by zooplankton allowing the development of higher plankton populations (Figure 9).

C. Fish

1. Methods

a. Netting Techniques, Location of Nets, Summary of Net Sets, Tagging Protocol, Population Estimating

Spring sampling began in March to April and continued to mid-May. Fall sampling began in late September and continued into mid-October. These time periods were selected to maximize the spring sampling effort when Bull Trout were expected to be present in the reservoir, and late enough in the fall to try to contact Bull Trout, but avoiding winter conditions. Reservoir sampling utilized fyke and experimental gill nets for fish collection. UV treated fyke nets # 44 (0.6 cm) square mesh consisting of a 91-cm-high, 122-cm-wide rectangular conduit frame opening; five 91-cm-diameter steel hoops held the throat open; and a 12 m long center lead would extend to shore (Figure 11). Fyke nets were usually set in the afternoon and allowed to fish overnight and retrieved the following day. Experimental gill nets were 36.5 m long by 3.0 m deep made of monofilament line and contained six 6 m panels consisting of square mesh sizes of 8.9, 7.6, 6.3, 5.1, 3.8, and 2.5 cm. Gill nets generally were fished on the bottom during daylight hours for 30 minutes or less. A typical sampling day generally entailed pulling fyke nets and processing fish, then resetting the fyke nets and fishing two gill nets at 30 minute intervals for the remainder of the day.

The reservoir was partitioned into four regions that were systematically sampled in turn, following the study design of Rose and Mesa. Attempts were made to sample all available habitats and select different sites within a region each time it was sampled. One notable difference between studies was how fyke nets were set each period. Rose and Mesa during their study tended to replace the nets where they were pulled, whereas we moved the nets around each day within the study quadrant. For a mark-recapture study both these techniques have their shortcomings. Resampling near the same spot can have the effect of a lower than expected population size, if the marked fish are not equally dispersed throughout the reservoir. If fish are not moving around as expected, resetting in the same spot could produce a higher than predicted number of recaptures, hence a lower population estimate. The same is true for spreading nets out too far during a sampling event. If we do not have enough samples within each quadrant, and they are spread out too far, this could have the effect of overestimating population size as the number of recaptures is lower than would otherwise be expected.

Following the success of our smaller meshed fyke nets the first year, we employed two larger fyke nets near the inlet of Beulah Reservoir in order to boost Bull Trout captures in the second year. Two fyke nets with larger 3.8 cm mesh with a 61-cm-high, 1-m-wide rectangular steel frame opening and three 1 m steel hoops were also fished (144 netting hours), but they proved to be ineffective and no fish were captured. We believed that the added depth of the net would allow us to fish deeper habitats and prevent cruising fish from simply swimming over the top of the trap net. These nets proved to be too difficult to maneuver and this effort was abandoned after 2 weeks.

Captured fish were anesthetized for processing as follows:

- Non game fish and Bull Trout use 50 mg/L buffered MS222
- Game fish use 1 tablet Alka Seltzer Gold in 2.5 L of water (generates CO2).

All fish captured were identified to species, with the exception of sculpins which were simply classified as cottidae. Fork length (FL) was measured in mm, and weights were taken to nearest 0.1g. Weights were not recorded when it was windy out due to inability to keep the scale stabilized on a rocking boat. In addition, water temperature and GPS location were recorded for each net set. When high fish numbers preclude processing fish in a timely manner, a subsample of 20 fish per species per net was measured, and the rest counted and marked. Fish less than 150 mm were marked by clipping a fin and releasing. Fin clips differed for each sampling period so population estimates could be calculated for spring and fall sampling. All fish greater than 150 mm in length received a Floy tag, with the exception of Bull Trout, which received a half-duplex passive integrated transponder (PIT) tag. Further, stomach samples were collected from all Bull Trout, and a subset of Rainbow Trout captured in the reservoir using nonlethal gastric lavage. Stomach samples were preserved in ethanol and returned to the laboratory for analysis. Recaptured Bull Trout were not subjected to repeat stomach pumping to minimize negative effects. Additionally, a scale sample was taken from each captured Bull Trout for age and growth analysis. Scale samples were processed by Reclamation's environmental staff from both the Technical Service Center in Denver and the Snake River Area Office.

Population abundance for most common species of fish was estimated in spring and fall using Schumacher-Eschmeyer estimator (Ricker 1975) and symmetrical 95 percent confidence limits derived from Schneider 1998 for multiple mark-recapture studies. Catch per unit effort (CPUE) was used as an alternative index when population estimates were not reliable. Bridgelip Sucker (*Catostomas columbianus*) and Largescale Sucker (*Catostomas macrocheilus*) were present in the reservoir, but for the purpose of our analysis the two species were pooled and split by size class (< or >156 mm FL). Bull trout are able to prey on fish half their body length (Beauchamp and Van Tassell 2001). Based on average size of Bull Trout collected in past studies on Beulah Reservoir (Petersen, Kofoot, and Rose 2003; Rose and Mesa 2009), suckers were partitioned into greater or less than 156 mm FL. Fish less than 156 mm were assumed acceptable Bull Trout prey for the purpose of our analysis.

b. Hydroacoustic Techniques and Analyses

Hydroacoustic estimation of fish populations was conducted during each spring and fall sampling period starting October 2010 and ending October 2013 and served as an additional reference point to determine the robustness of our net population estimates. For all sampling, we used a Biosonics DT6000 split-beam echosounder with a pair of 6.5 degree transducers operating at either 200 or 420 kilohertz, with one transducer aimed straight down and the other used in a side scan mode. Data was collected at 5 pulse per second and 0.4 miliseconds pulse width with a threshold set to -75 decibels. Maximum range was typically set to 20 m for both transducer orientations. Data was backed up to a portable USB drive for later analysis. All data was analyzed using Echoview, and once a template for the reservoir was developed, it was used for all subsequent analyses. Any variation in sampling techniques between trips was a result of equipment failure or weather conditions. We started each sampling period near the dam and collected data using a zig-zag transect back and forth from shore to shore up the length of the reservoir. We tried to sample the reservoir three times each study period (weather dependent), usually on consecutive days. Sampling was done at first light or at dusk each trip. It typically only took 2 to 3 hours to cover the reservoir each time.

During analysis, fish size was set at a threshold to exclude anything smaller than -55 decibels corresponding to approximately a 30 mm fish. We recognize numerous young fish less than 30 mm exist within Beulah Reservoir, but below that threshold environmental backscatter starts to overwhelm the acoustic data. Data was output as location and size of individual targets and density calculated as fish/m3 based on volume of water esonified during sampling. Density was scaled up to the total volume of the reservoir at the time of sampling to provide an estimated reservoir population, and the mean fish population determined as the average of the three sampling events.

2. *Results*

a. Species Makeup, Size Distributions and Biomass of Species, Condition Factors, Relation to Pool Level, Diet

Both gill and fyke nets were utilized in spring and fall sampling regimes for the duration of the study. Fyke nets proved to be the most effective technique for catching numbers of fish. Gill nets were effective at capturing more pelagic species and larger size classes of fish more associated with deeper habitats. A total of 711 fyke net sets were fished for a total of 14,075 hours and captured 110,501 fish. A total of 215 – 30 minute gill net sets produced 824 fish. Sampling captured 14 species that are all native to the region excluding Rainbow Trout (hatchery origin), White Crappie (*Pomoxis annularis*) and Largemouth Bass (*Micropterus salmoides*) (Table 2).

2011 Sampling

Spring—Spring sampling was conducted over two trips. The initial sampling period took place between April 19 and May 5, while the second sampling period encompassed May 24 through June 2. One hundred and forty-two fyke net sets were fished a total of 2,755 hours and 9,410 fish were collected. One hundred - 30 minute gill net sets captured 79 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 12. Predominant species included Redside Shiner (*Richardsonius balteatus*) (82 percent) and Northern Pikeminnow (*Ptychocheilus oregonensis*)(6 percent) (Figure 13).

Fall—Fall sampling was conducted in a single trip from September 22 to October 11. Seventy-eight fyke net sets were fished a total of 1,631 hours and 15,661 fish were collected. Eighteen - 30 minute gill net sets captured 91 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 14. Predominant species included Redside Shiner (74 percent), catostomidae less than 156 mm (16 percent), and cottidae (4 percent) (Figure 13).

2012 Sampling

Spring—Spring sampling was conducted from April 10 to May 11. One hundred and fifty-six fyke net sets were fished a total of 3,287 hours and 34,580 fish were collected. Thirty – 30 minute gill net sets captured 45 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 15. Predominant species included Redside Shiner (94 percent), catostomidae less than 156 mm made up 2 percent of the total catch (Figure 13).

Fall—Fall sampling was conducted from October 3 to October 19. Ninety-two fyke net sets were fished a total of 1,955 hours and 9,887 fish were collected. Fourteen – 30 minute gill net sets captured 366 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 16. Predominant species included Redside Shiner (69 percent), Rainbow Trout (9 percent), and catostomidae greater than 156 mm made up 7 percent of the total catch (Figure 13).

Past sampling of the reservoir documented an incidence of White Crappie (Petersen, Kofoot, and Rose 2003), but were absent in our collections in 2011 and spring of 2012. Our fall sampling once again documented the presence of crappie in the reservoir. In addition, Largemouth Bass were collected for the first time in the reservoir's history.

2013 Sampling

Spring—Spring sampling was conducted from April 10 to May 8. One hundred and fifty-three fyke net sets were fished a total of 2,590 hours and 36,851 fish were collected. Twenty-seven – 30 minute gill net sets captured 34 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 17. Predominant species included Redside Shiner (95 percent) and Rainbow Trout (2 percent) (Figure 13).

Fall—Fall sampling was conducted from October 1 to October 16. Ninety fyke net sets were fished a total of 1,857 hours with 4,112 fish being collected. Twenty six – 30 minute gill net sets captured 209 fish. Sampling locations of both fyke and gill nets can be viewed in Figure 18. Predominant species included Redside Shiner (47 percent) and smaller catostomids (less than 156 mm) comprised 15 percent of the total catch (Figure 13).

Relative Abundance

Overall, fyke net catch per unit effort (CPUE; number of fish/ hour [FPH]) values trended upward over years in the spring and downward in the fall during our study (Figure 19). Catch per unit effort for spring fyke net sampling ranged from 3.4 FPH in 2011 to 14.2 FPH in 2013. Catch per unit effort for fall fyke net sampling ranged from 2.3 FPH in 2013 to 9.3 FPH in 2011.

Catch rates were by far greatest for Redside Shiners during spring and fall sampling trips over all years (Figure 20). Catch per unit effort for Redside Shiners were presented separately from other species because of the extreme difference in scale. Catch per unit effort for other species contacted in the reservoir can be viewed in Figure 21 for spring and fall collections. During 2011 spring sampling, Redside Shiner CPUE averaged 2.75 FPH followed by Northern Pikeminnow at 0.2 FPH. Spring sampling during 2012 captured Redside Shiners at 9.92 FPH followed by catostomids <156mm at 0.17 FPH. Redside Shiners were captured at a rate of 13.53 FPH in the spring of 2013 followed by Rainbow

Trout at 0.2 FPH. Fall sampling in 2011 captured Redside Shiners at a rate of 6.8 FPH followed by catostomids <156mm at 1.57 FPH. Fall sampling in 2012 captured Redside Shiners at a rate of 3.47 FPH followed by Rainbow Trout at 0.47 FPH. Redside Shiner captures were at their lowest in the fall of 2013 at 1.04 FPH.

Length frequencies of Redside Shiners were bimodal in the spring of 2012 and 2013 and in all years during fall sampling (Figure 22). Average lengths for Redside Shiner were greatest in the fall of 2012 and least in spring of 2011. In the spring of 2012 and 2013 the evidence of two modes representing separate cohorts was not apparent during the 2011 sampling. This lack of a strong cohort may stem from the 2010 spring period when reservoir levels reached a lower than average level and did not inundate shoreline brush and provide adequate breeding habitat for adults and/or rearing cover for young. Prior to 2010, the reservoir had remained below full pool and had gone to run-of-the-river for a couple of years (Figure 2).

Length frequency for the more commonly captured prey species (catostomids <156 mm and Northern Pikeminnow) are shown in Figure 23 and Figure 24). Average lengths for catostomids <156 mm were least in spring of 2013 and greatest in the fall of 2011 (Figure 23). A strong age class is observed in the fall of 2012 which followed 2 years where the reservoir was either at or near full pool. In addition, a weak second mode alludes to poor survival of an older cohort in all years and is nearly absent in the spring of 2013. Northern Pikeminnow showed two strong age classes in the spring of 2011, but it is difficult to relate this to a reservoir condition, as water levels were not particularly low or high during the previous year. A remnant of this second, larger age class was still detected in the fall of 2011. By fall 2013, lengths of large Northern Pikeminnow indicated the presence of several year classes that were not previously present and indicated a maturing population of adult fish.

Acoustic size distributions provided similar results as field collected data (Figure 25 and Figure 26). Most of the smaller targets were presumed to be Redside Shiner based on net data. Larger targets tended to follow the same pattern as the net data with fall samples trending towards having more fish in the larger size classes. Spring data were difficult to compare against, because large numbers of fish move into the shallows in the spring as the reservoir warms and rises, both for feeding and spawning. At this time of the year, hydroacoustic data was not a good surrogate for net data because of the inability to sample shallow, highly vegetated habitat.

Population Estimates

Population estimates were generated for Redside Shiner (Figure 27), as they represented the most abundant prey species each sampling period over years. Populations varied greatly over years and between sampling events.

Redside Shiner abundance was at its highest in the spring of 2013 (1,014,064 ± 172,209) and lowest in the fall of 2013 (287,110 ± 493,113). The population of Redside Shiners was trending upward over years as the reservoir neared full pool each spring until the fall of 2013 when the population dropped by over 70 percent between the spring and fall sampling periods. This followed an abnormally low spring pool elevation experienced in 2013. Acoustic estimates of population size during the fall periods of sampling tracked well with net estimates, although lower. As explained earlier, it is not unexpected the two estimates would provide different numbers due to limitations with acoustic gear in shallow water (Figure 28). The trends being similar allow us to say with a greater degree of certainty that measured changes in the fish population for the reservoir are indeed correct.

Population biomass was calculated by taking the average weight of each prey species and multiplying it by population size (Figure 29). To do this for our data, since only population estimates of Redside Shiner were actually made, we had to use an approximation. Assuming all fish species had equal chances of capture in our fyke nets, then based on a calculated population of Redside Shiner and a relative difference in CPUE between species, we could come up with an estimate of each species.

4. Discussion

The primary reasons for maintaining a minimum study pool was the recognition that lowering the reservoir to run-of-the-river would essentially reset all potential prey species populations to very low numbers, as there would be no habitat refugea other than the flowing river channel itself. We hypothesized maintaining such a conservation pool would limit the magnitude of population changes in the reservoir, by providing some habitat for adult prey species, and fish newly entering the population following spring and early summer spawning. This provides a “seed” population for the next year. Since 2002, and if not for the minimum study pool during our study, eight of the twelve seasons would have resulted in a run-of-the-river condition, or close to it (Figure 1). Bull trout do not typically return to the reservoir until the end of irrigation season, but since 2002 in 2/3 of the years, fish would have been entering a reservoir that was almost devoid of a food base as a result of drawdowns to run-of-the-river. Over the past 42 years, Beulah Reservoir has been reduced to a volume of less than 2,000 acre-feet 20 times (Reclamation 2013).

Rose and Mesa (2009) demonstrated that surviving (prey) fish populations, following a drawdown to run-of-the-river, would not support any significant Bull Trout population, and suggested recovery from such a low number might not occur for several seasons. Petersen, Kofoot, and Rose 2002 came to a similar conclusion citing historical data indicating many of the species likely did not reach size classes making them susceptible to gill netting for 1 to 3 years following run-of-the-river drawdowns. Petersen et al. cite gill net data collected from 1955 through 1970 by ODFW which show gill net catches of Largescale Sucker and

Northern Pikeminnow increasing in population during the period between run-of-the-river drawdowns. Since there was little information available regarding gill net type, these increases in catch rates were likely a result of more mature adult fish entering the catchable population. Following a run-of-the-river drawdown event, and similar to all other studies, fish populations reset to a very low number. We assume there is recruitment to some degree from the NFMR following a drawdown, and this may compose a portion of the rebuilding populations as hypothesized by Petersen and Kofoot (2002). Anecdotal evidence from the weir we placed in the NFMR upstream of Beulah Reservoir indicated significant numbers of fish besides Bull Trout and Rainbow Trout moved downstream towards the reservoir during most fall sampling periods.

Our observations were similar to previous studies, in that over 3 years of study, we observed significant shifts in the size structure of fish populations. Prior to our study, the last time the reservoir was drawn down to run-of-the-river was in 2009. We first sampled in the spring of 2011, at which time the size, hence, age distribution of all fish populations differed greatly from that at the end of 2013. In the spring of 2011, Redside Shiner populations were distinctly unimodal, with smaller fish dominating. These spring fish likely represent the overwintering 2010 age class which would have been the first successful spawn following the 2009 drawdown. By the fall of 2011, a more bimodal population started to develop, with the spring fish having grown significantly, and a crop of new recruits now present in net surveys. By 2012, two distinct year classes were present each sampling period. There were probably two other year classes of shiner we did not capture effectively. Age 0 fish, of which large schools could be observed near the shoreline, were generally small enough to pass through the mesh of our fyke nets, thus we could not estimate how much of the total population may have been composed of these smaller fish. Gill netting also produced a few Redside Shiners well over 100 mm in length and these likely represented age 4 fish.

Beginning in 2011, almost no large Northern Pikeminnow were captured during fall sampling. In 2011 and 2012 a lot of fish were captured in the 150 to 170 mm range with very few larger fish. However, by fall 2013 a greater proportion of the population sampled was composed of older age class, larger fish some of which were upwards of 400 mm. Petersen, Kofoot, and Rose 2002 showed similar patterns for most species captured. The last year of their study was in 2002, and had followed a period of very wet years where minimum pool elevations in Beulah Reservoir remained above 20,000 acre-feet for several years. Size distributions of fish they sampled showed what appeared to be a mature population of fishes.

Four factors potentially impact how fish populations in Beulah Reservoir respond any given year, but with the amount of data available, it is difficult to apportion specific percentages to each. These factors include:

1. How low (storage) did the reservoir get?
2. How long did the reservoir remain low?
3. How fast was it drawn down?
4. How much was the reservoir filled that spring?

Fluctuating reservoir levels themselves can be a good thing for a fishery, as areas that are seasonally inundated can provide significant amounts of spawning and rearing habitat, as well as an influx of nutrients which can lead to a boost in productivity. At some point though, extremes in fluctuation will limit a reservoir's capacity to maintain a viable fish population. Similarly, stable reservoirs often exhibit declines in the fishery as population structures and species dominance change (Cooke et al. 2005; Heman, Campbell, and Redmond 1969). Understanding what potentially limits fish populations under different water level scenarios are key to developing a recommended operational scenario.

If the reservoir is drawn down too far (e.g., run-of-the-river), this has obvious negative consequences for the fishery, as the majority of the fishery is simply entrained and removed from the system. On the other hand, significant drawdowns, but not to run-of-the-river, and where a portion of the population remains, may show minimal long-term effects where highly fecund annual species are concerned, particularly if the timing of drawdown does not coincide with reservoir spawning species. Petersen et al. sampled following a very wet period, and during the early portion of their study saw only a moderate drawdown to just over 10,000 acre-feet in 2001. During this time, they noted no significant changes in the fishery. Rose and Mesas' first year of sampling had occurred following three consecutive years of dewatering, yet indications were that a robust fish population had already redeveloped (Rose and Mesa 2013). Our first full year of study (2011) had followed dewatering in 2007 to 2009, and similar to Rose and Mesa, our sampling showed a fairly significant population of fish in Beulah Reservoir, although size structure indicated much of this was a result of young fish hatching during the periods of post drawdown spawning. While we did not have net data for 2010, acoustic data indicate similar population sizes for both 2010 and 2011 during fall sampling events, following moderate drawdowns both years. During 2012, the reservoir was reduced to 2000 acre-feet, yet fall sampling indicated significant populations of fish still remained in the reservoir following this period. In fact, in spring of 2013, we estimated some of our highest populations ever, indicating that the previous year's drawdown had had little impact on the overall health of the reservoir population.

The pool elevation dropping below 2,000 acre-feet in 2013 as a result of evaporation (1,400 acre-feet), possibly had deleterious effects on the fish populations, with much lower fish populations being recorded in the fall of 2013 than during the previous years of our study.

This large population decrease from spring to fall measured in 2013 did not occur in 2012 when the reservoir was dropped to 2,000 acre-feet, so why was such a difference observed in 2013? This is where other population limiting factors may start to come into play. Apportioning importance of each to a reduction in population is difficult, as a variety of conditions occurred in 2013 that all potentially interact with each other. The first is the reservoir did drop significantly below the suggested study pool, decreasing to just over 1400 acre-feet instead of the desired 2,000 acre-feet. This is a significant difference and could have resulted in greater entrainment of fish out of the reservoir. Unfortunately, this was something we were not able to measure. In terms of factor two, 2013 was a year the reservoir would have gone run-of-the-river had we not requested a study pool. The reservoir reached this low level in early August, and remained near that level until after the irrigation season. This is different from the 2012 water year where the reservoir, while being drawn down all summer, only reached 2,000 acre-feet at the end of the irrigation season. Thus, in 2013, not only did the fish population experience a lower water level, but it existed for a longer duration as well. Another confounding factor was that by the third year of our study, pikeminnow populations had far greater numbers of adults, and the Rainbow Trout (hatchery origin) population was quite large, both of which could have exerted a significant predation influence on a concentrated group of prey.

The other issue arising in 2013 was the reservoir did not reach full pool (factor three). In the spring of 2010, 2011, and 2012, Beulah Reservoir filled to well over 50,000 acre-feet, which inundated large areas of shallow, brushy (mostly willows; *Salix* spp.) shoreline that potentially provided suitable spawning and rearing habitat for prey species. During this time, an upward trend in population was observed with Redside Shiners and young fish of other species. In 2013, we observed the lowest seasonal maximum pool volume of our study (38,014 acre-feet), leading us to believe that habitat during spawning may have been limiting. As these conditions may have been absent in the spring of 2013, shoreline vegetation would no longer provide as significant an element of cover for spawning and rearing of young fishes. This lack of habitat type could strongly influence the composition and age class structure of the local fish community through changes in survivorship of different age cohorts. There was still a fair amount of brushy habitat flooded at this level, but it was primarily low cocklebur plants (*Xanthium* spp.) which dominate the mudflats of Beulah Reservoir during drawdown. Willow vegetation and thick grassy habitat are only inundated at higher pool levels.

Associated with not filling to full pool, is the speed of drawdown during the spring. The actual rate of water release generally varies little from year to year. Once irrigation season starts, releases from the dam are quite stable, averaging around 350 cfs. What does change is the amount of water entering the reservoir, and this can greatly impact the rate of drawdown. In 2010, while not completely filling, the reservoir remained fairly full for a length of time. In 2011, with high runoff, the reservoir remained near full pool almost into July. In 2012, while filling the reservoir started dropping almost immediately, but followed the same time frame as it had for 2010. However, in 2013, as soon as irrigation season started in April, reservoir levels began dropping as inflows did not exceed outflows by this time. For fish in Beulah Reservoir, this variation in water years could have a strong impact on spawning success. Largescale Sucker, Northern Pikeminnow, and Redside Shiner are all spring spawners. In years that the reservoir remains relatively stable in the spring, we would expect high spawning success, as eggs have time to hatch, and larval fish are allowed some time to mature before receding water levels displace young from rearing habitat. In 2013, the reservoir was likely already dropping prior to most species spawning. The rate of elevation decline is quite rapid and there was a good chance any eggs spawned in shallow waters were desiccated due to dropping water levels. Even if eggs did hatch, larvae would be stranded, or moved to less amenable habitats. While this was hard to determine with our study as most age 0 fish were still too small to be effectively captured during fall sampling, the proportions of large to small sizes for several species indicated there was a reduction in recruitment.

While neither zooplankton or phytoplankton would be considered food for adult Bull Trout, they do provide much of the food base for the rest of the reservoir fishery, and as such can be an indicator of overall reservoir health. Zooplankton populations indicated, that at very low reservoir levels, there is likely a predation effect, where the concentrated fish populations crop off larger bodied forms of dominate species. During low water years, such as 2012, we observed low zooplankton populations, but relatively high densities of algal species that would be edible to zooplankton species. We suspect during low water periods, concentrated fish populations may be acting to reduce zooplankton populations to the point they cannot take advantage of this abundant food source. This pattern fits the predictions of cascading trophic interactions (Carpenter, Kitchell, and Hodgson 1985). Higher observance of blue-green algae during years the reservoir was not drawn down as much could be linked to short term increases in eutrophication as a result of longer term flooding of vegetated shorelines.

In summary, during the course of monitoring the prey base, it became apparent there are some potential issues associated with maintaining a minimum pool during which otherwise would have been run-of-the-river years. These observations could be made with previous studies to some extent as well. First, is that populations of species like Northern Pikeminnow start developing a large cohort of older age classes, which during times of limited food will be direct competitors with Bull Trout for food. Secondly, Rainbow Trout populations (hatchery origin) may also increase to the point where they potentially impact both the plankton and fish prey base. The potential for Rainbow Trout to impact the prey base is addressed in detail in Part 2 of this report series. We did not address the potential impacts of Northern Pikeminnow, but could draw conclusions about the potential population effects based on abundance data. The third issue with a minimum pool involves the presence of crappie and Largemouth Bass, both of which are non-native species and active fish predators, the latter possibly becoming big enough to forage on Bull Trout. Petersen and Kofoot, and

Petersen et al. captured large numbers of crappie during their netting surveys, close to 40 percent of the fyke net catch. Rose and Mesa also captured several crappie early on during their study, but like our study, no non-native predators were found the year following a drawdown. Fish were either flushed out of the system during the run-of-the-river operations, and either repopulated from a few undetected remaining fish, from an upstream site, or via illegal angler reintroduction. By the third year of our study, crappie were becoming more commonplace again. Our study did document the first report ever of Largemouth Bass in Beulah Reservoir which if a sizeable population were to develop could impact prey species.

While the maintenance of some level of water in Beulah Reservoir seems like a good idea from the standpoint of a prey base, ours and previous studies indicate there is the potential for a minimum pool to have negative consequences, and the only way to determine if this would occur in the long term, is to take an adaptive management approach whereby some sampling does occur periodically to allow us to monitor the health of the reservoir. We suggest the current 2,000 acre-feet pool is a good starting point for the maintenance of an adequate prey base. There is evidence fish may be concentrated enough at this low level to impact their prey base (plankton), but again we looked at low water levels following several very high water years which would have placed a large population of fish into a small area during drawdown. Even so, the population of fish remaining during fall of 2013 following the most extreme drawdown of our study was still large enough to support a significant Bull Trout population. It should also be remembered that how full the reservoir fills, and in particular the timing of when it drops, also impact the prey base. Years when a minimum pool is needed to maintain a reservoir pool are also likely the same years the reservoir does not fill, and may drop quick enough to limit spawning success. Thus it is likely a combination of factors that are coming into play during those years.

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FIGURES AND TABLES

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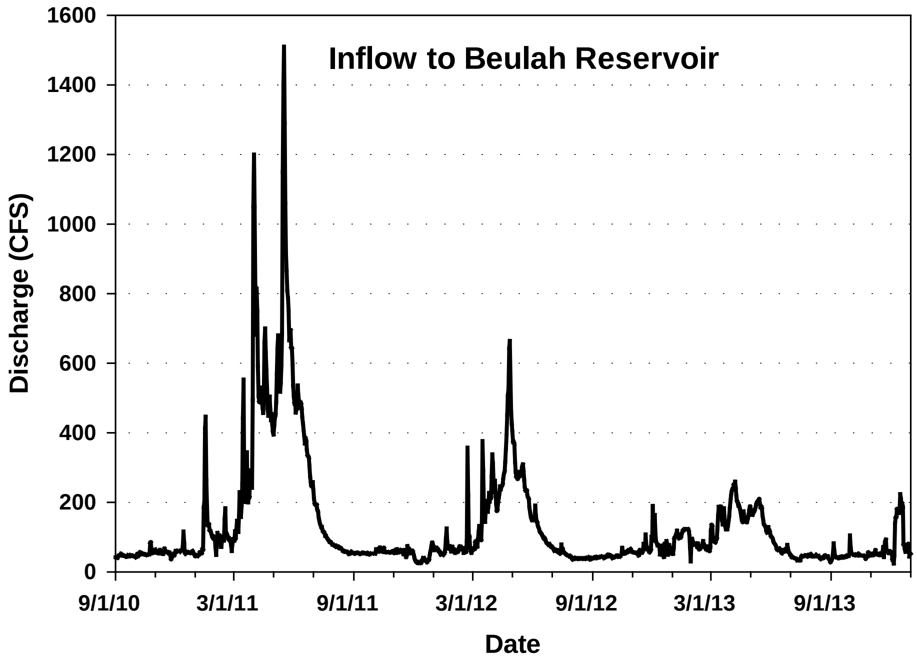


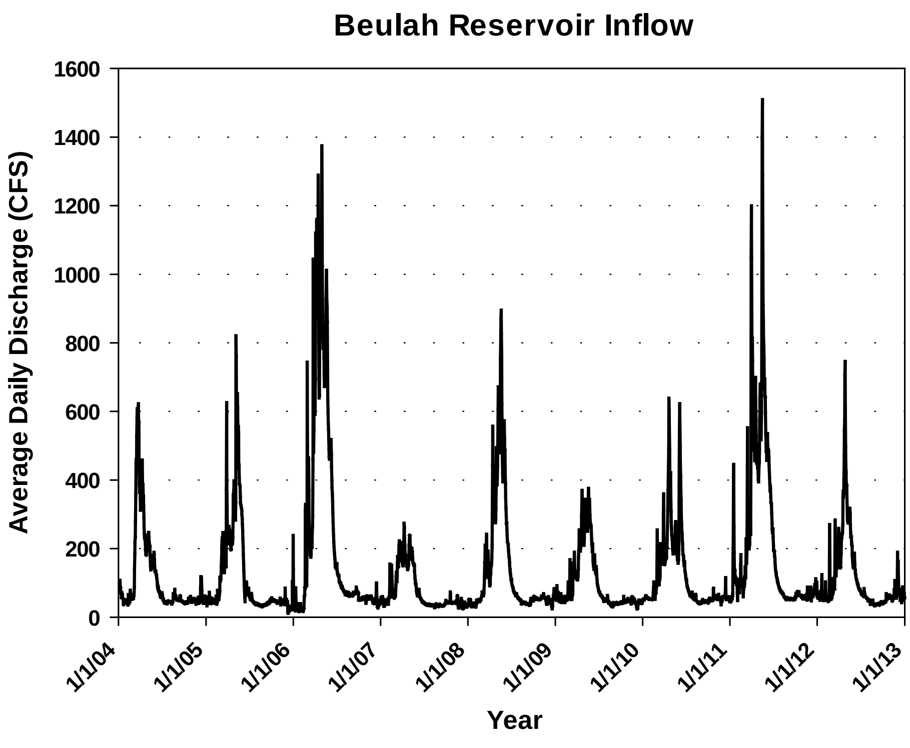


Figure 1. Inflows to Beulah Reservoir during the 4 years of study, and for the period 2004 on for comparison.

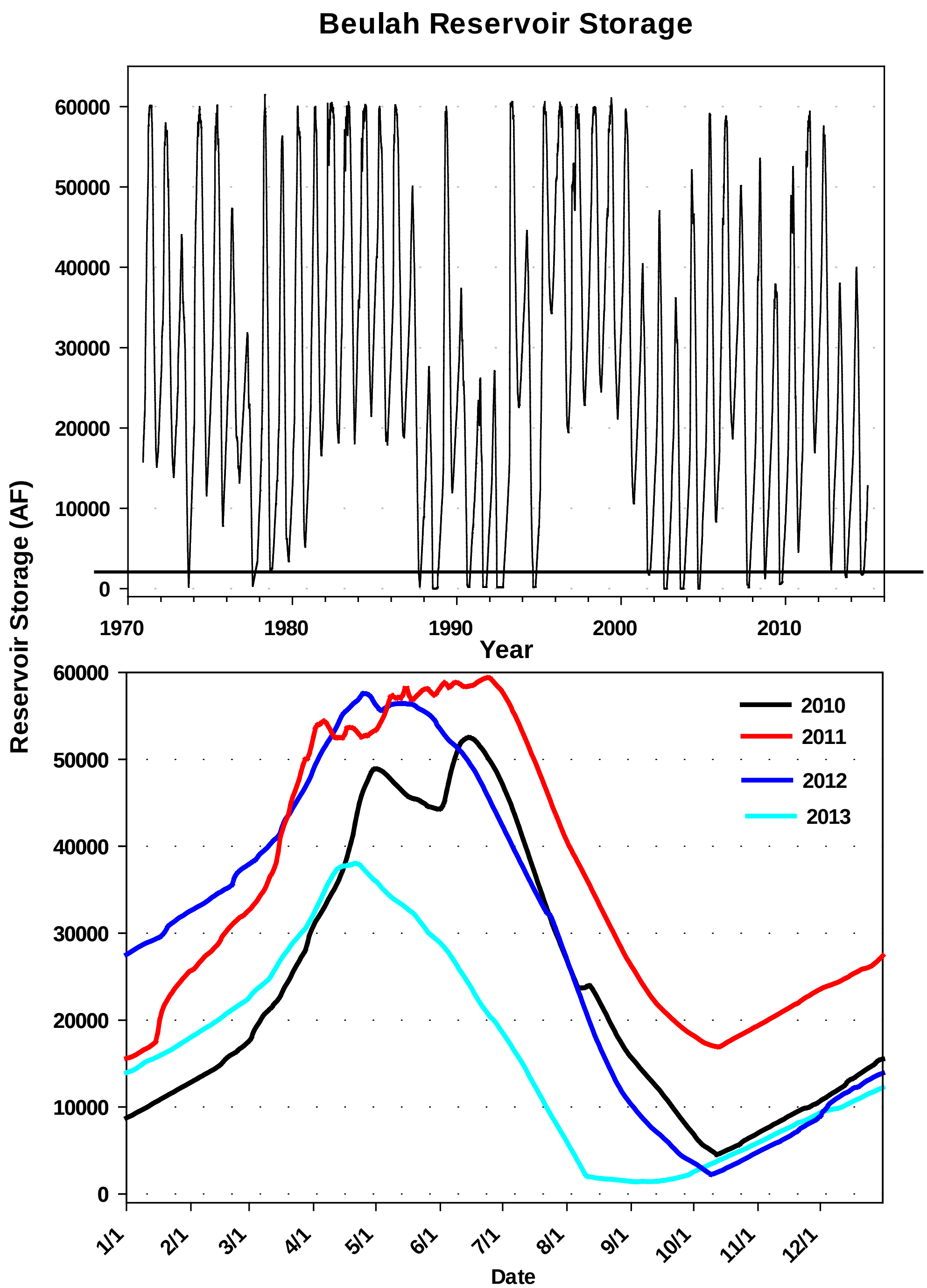


Figure 2. Historical water levels at Beulah Reservoir from 1970-2014, and water levels experienced during the course of this study. Black line in upper panel represents the 2000 acre-feet minimum pool agreed to for this study.

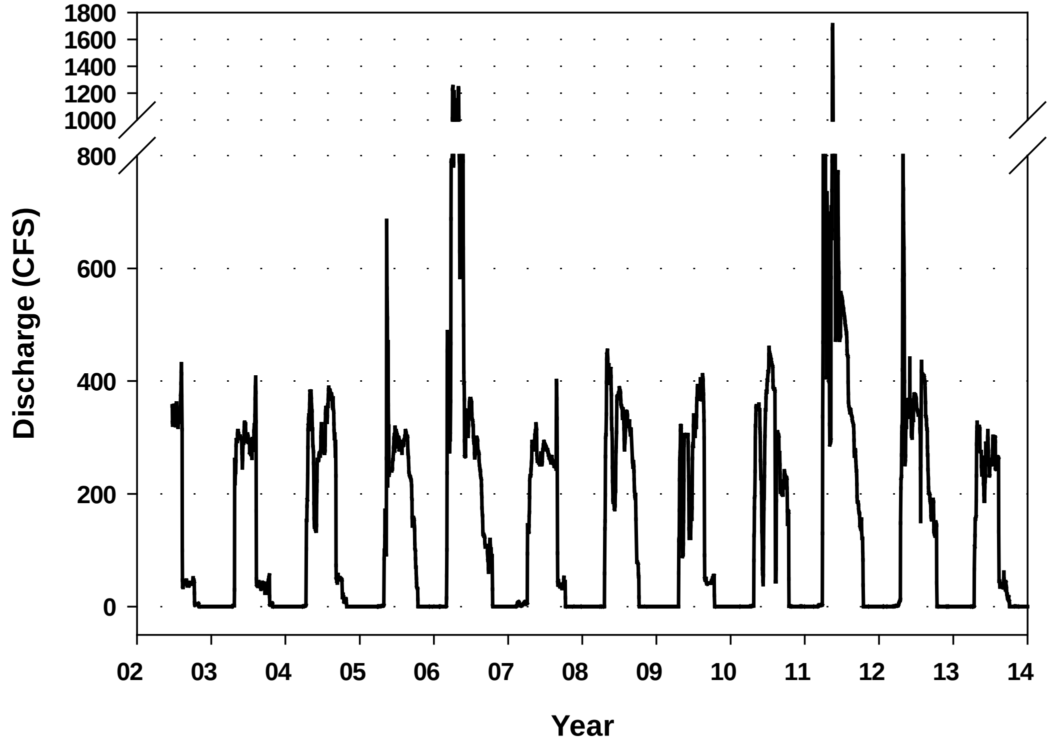


Figure 3. Average daily discharge from Beulah Reservoir for the period 2002-2013. Flows significantly higher than 400 CFS indicate spill periods.

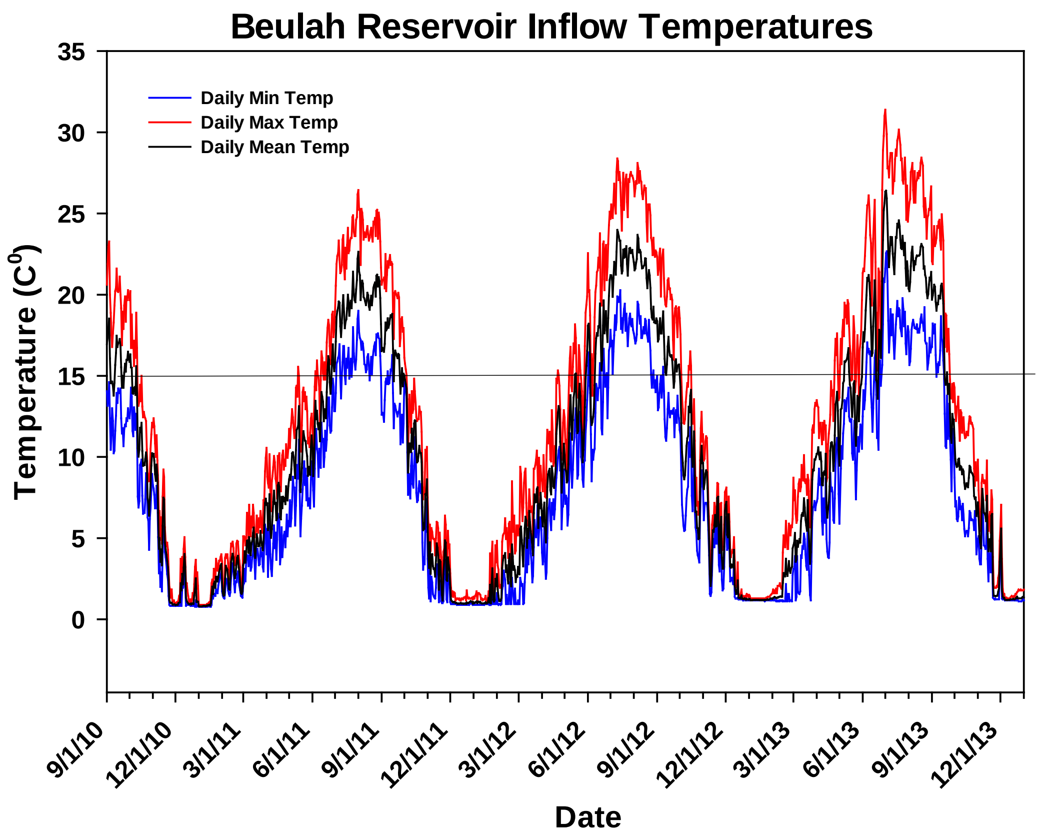


Figure 4. Seasonal pattern of inflow temperatures to Beulah Reservoir as measured at the USGS gage MABO upstream of Beulah Reservoir. Vertical black lines in 2012 and 2013 represent last upstream detection in the spring and first downstream detection in the fall of Bull Trout.

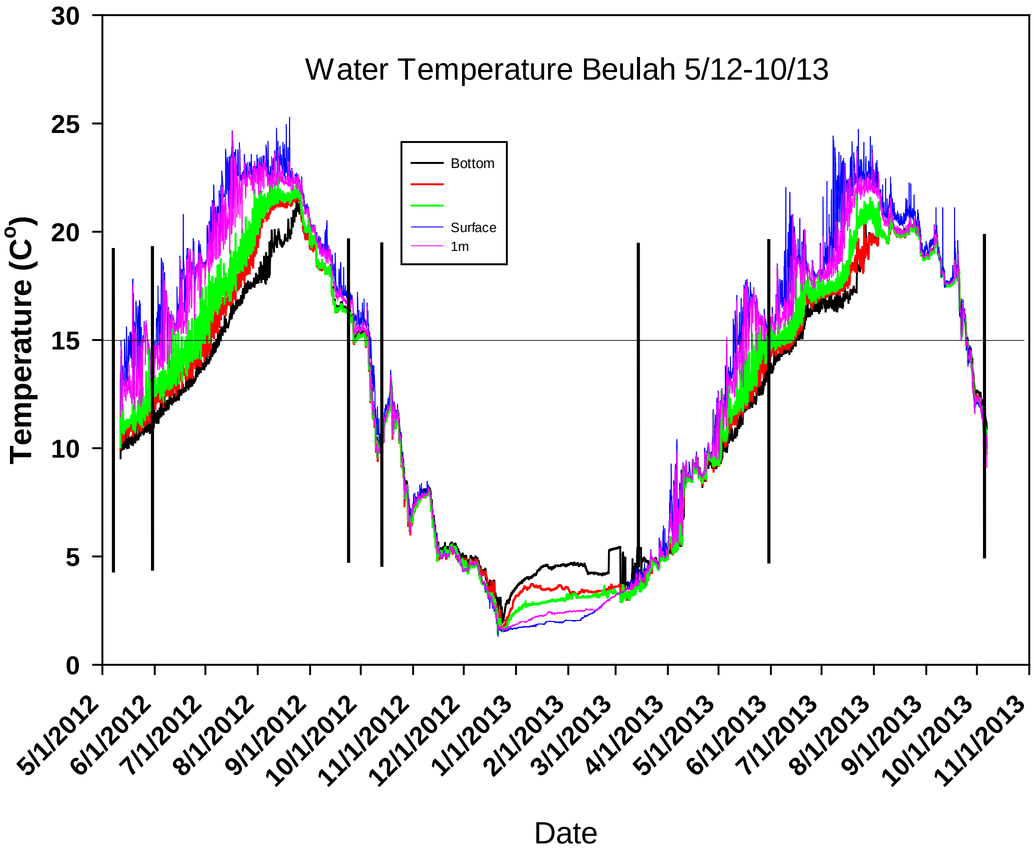


Figure 5. Seasonal water temperature in Beulah Reservoir as measured by a series of Tidbit temperature recorders strung at intervals beneath about anchored in the thalweg near the deepest portion of the reservoir.

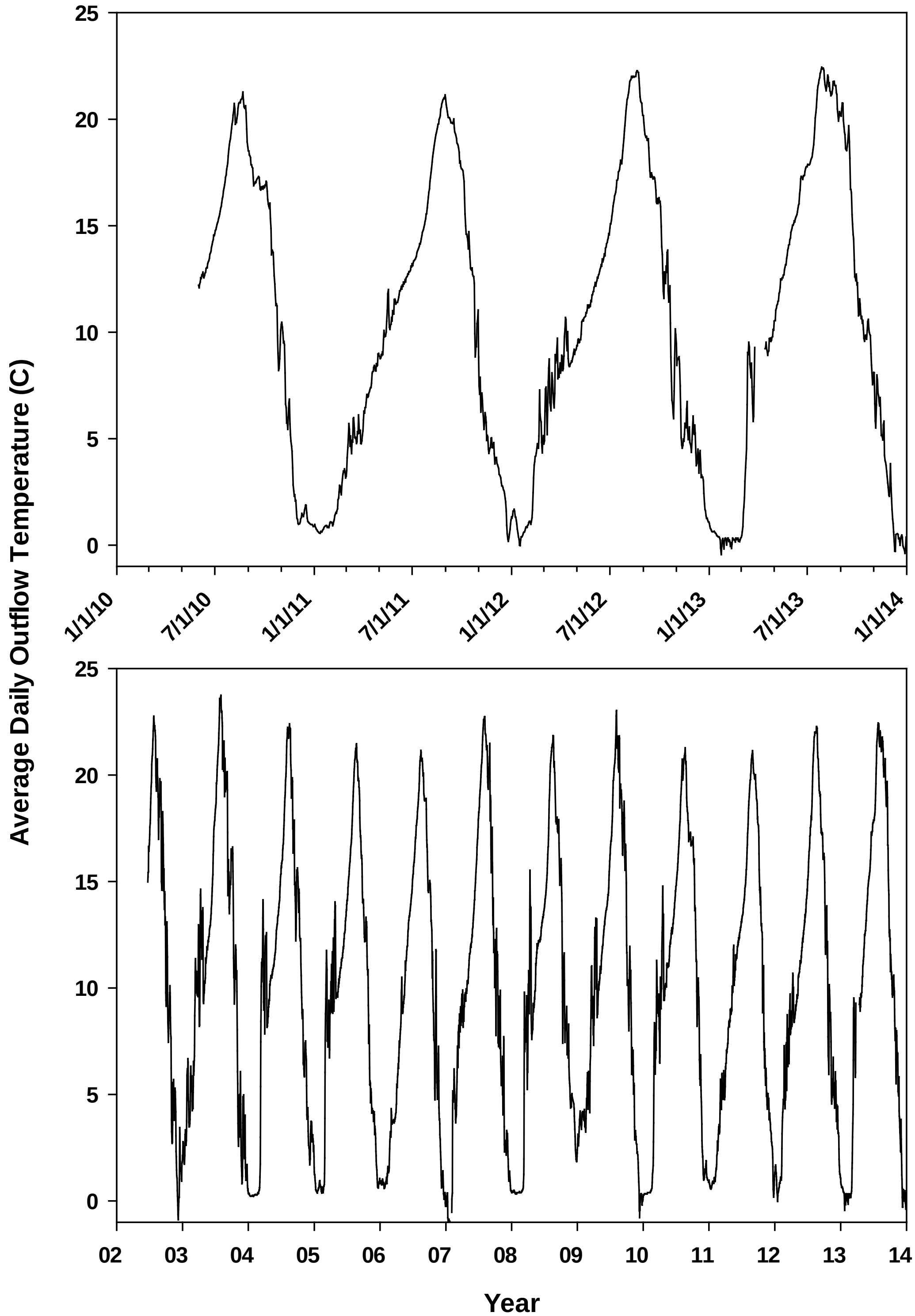


Figure 6. Average daily outflow temperatures for waters released from Beulah Reservoir.

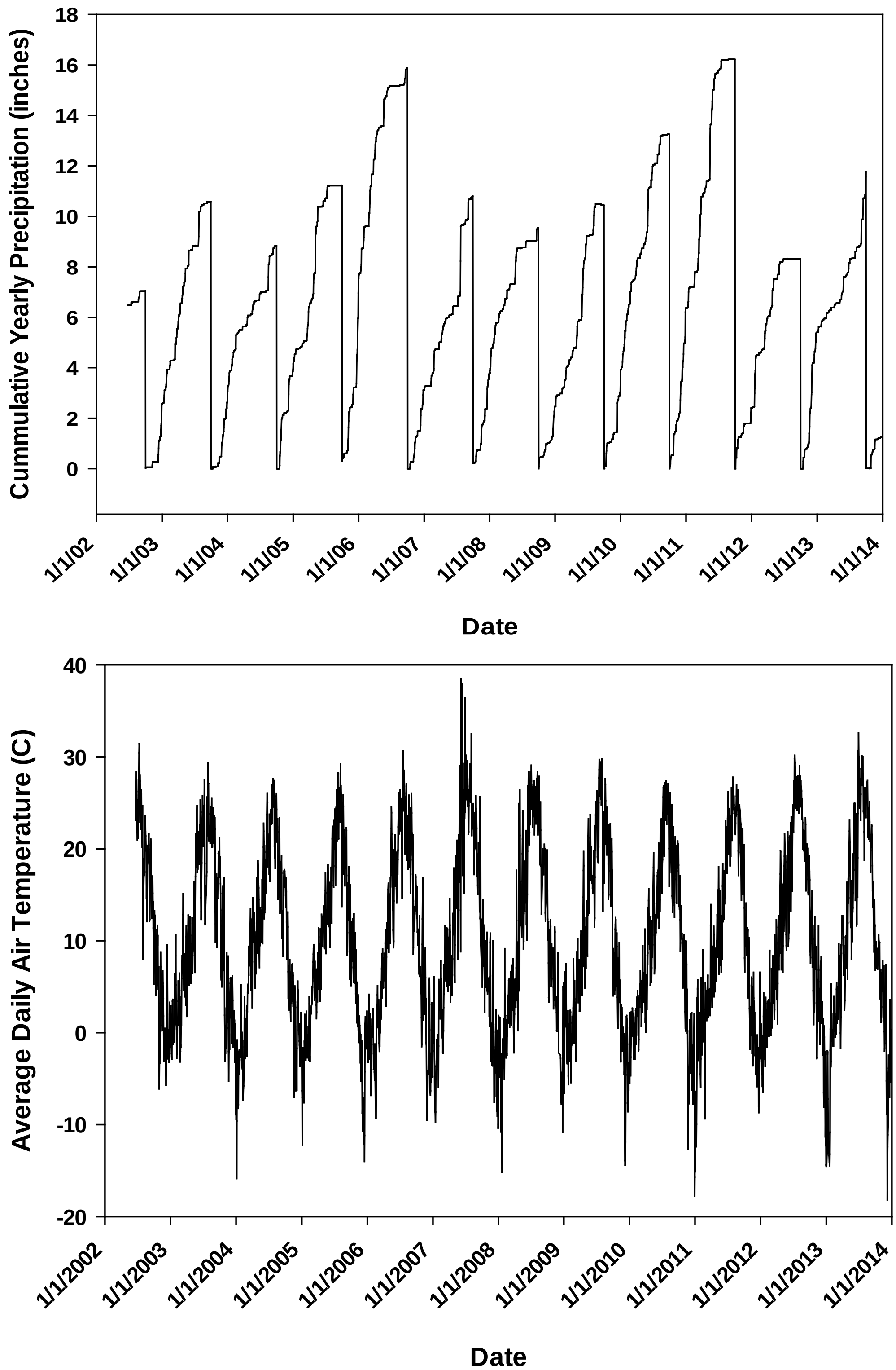


Figure 7. Cumulative seasonal precipitation at Beulah Reservoir and, and average daily air temperature as recorded at Beulah Reservoir hydromet site BEUO.

Table 1. List of Benthic Organisms Collected from Dredge Samples in Beulah Reservoir.

EPHEMEROPTERA
- Baetidae
  - *Siphlonurus sp.*

ODONATA
- Coenagrionidae

HETEROPTERA
- Corixidae
  - *Cenocorixa wileyae*

PLECOPTERA
- Chloroperlidae
  - *Triznaka signata*

DIPTERA pupae
- Chironomidae
- Orthocladiinae
  - *Parametriocnemus sp.*
- Chironominae
  - *Chironomus sp.*
  - *Cryptotendipes sp.*
  - *Cryptochironomus sp.*
  - *Micropsectra sp.*
  - *Parachironomus sp.*
  - *Parakiefferiella sp.*
  - *Paratendipes sp.*
  - *Phaenopsectra sp.*
  - *Polypedilum sp.*
  - *Tanytarsus sp.*
- Tanypodinae
  - *Procladius sp.*
  - Thienemannimyia group

OLIGOCHAETA
- *Enchytraeidae*
- *Naididae*
  - *Dero sp.*
  - *Ophidonais serpentina*
- *Tubificidae with hair chaetae*
- *Tubificidae without hair chaetae*

HIRUDINEA
- *Glossiphoniidae*
  - *Helobdella stagnalis*

CLADOCERA
- *Daphniidae*
  - *Daphnia sp.*

ACARI
- *Pionidae*
  - *Piona sp.*

GASTROPODA
- *Physidae*
- *Planorbidae*

BIVALVIA
- *Sphaeriidae*

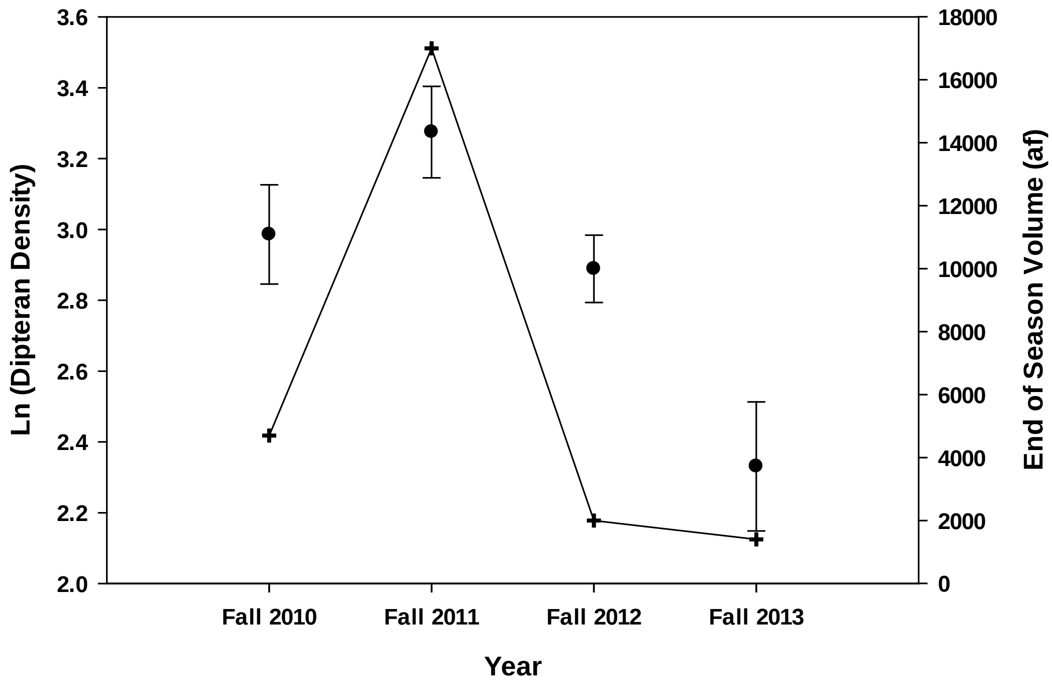


Figure 8. Relationship between dipteran densities and end of season water level in Beulah Reservoir during the 4 years of study.

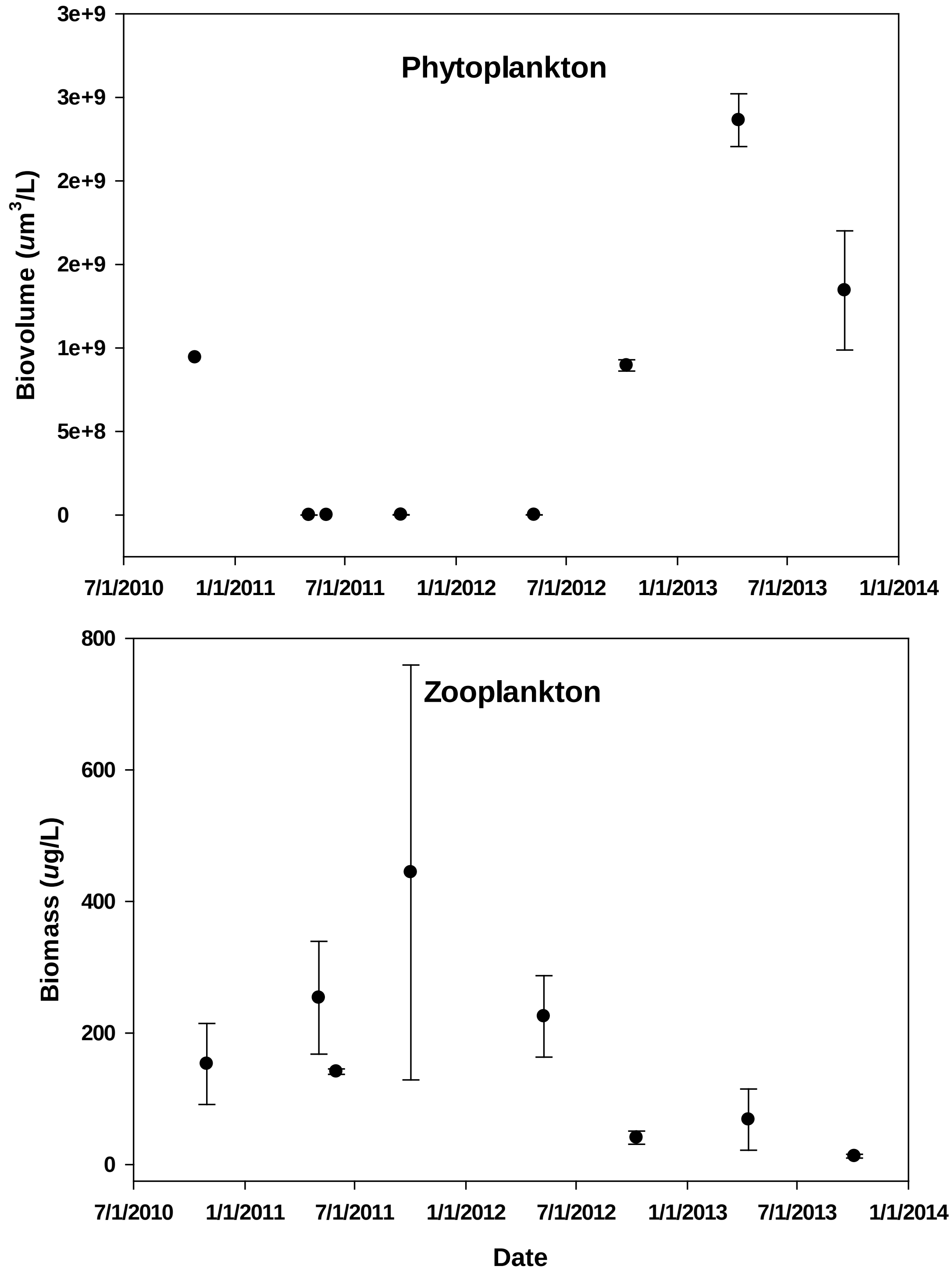


Figure 9. Relationship between phytoplankton biovolume and zooplankton biomass in Beulah Reservoir during the four seasons of study.

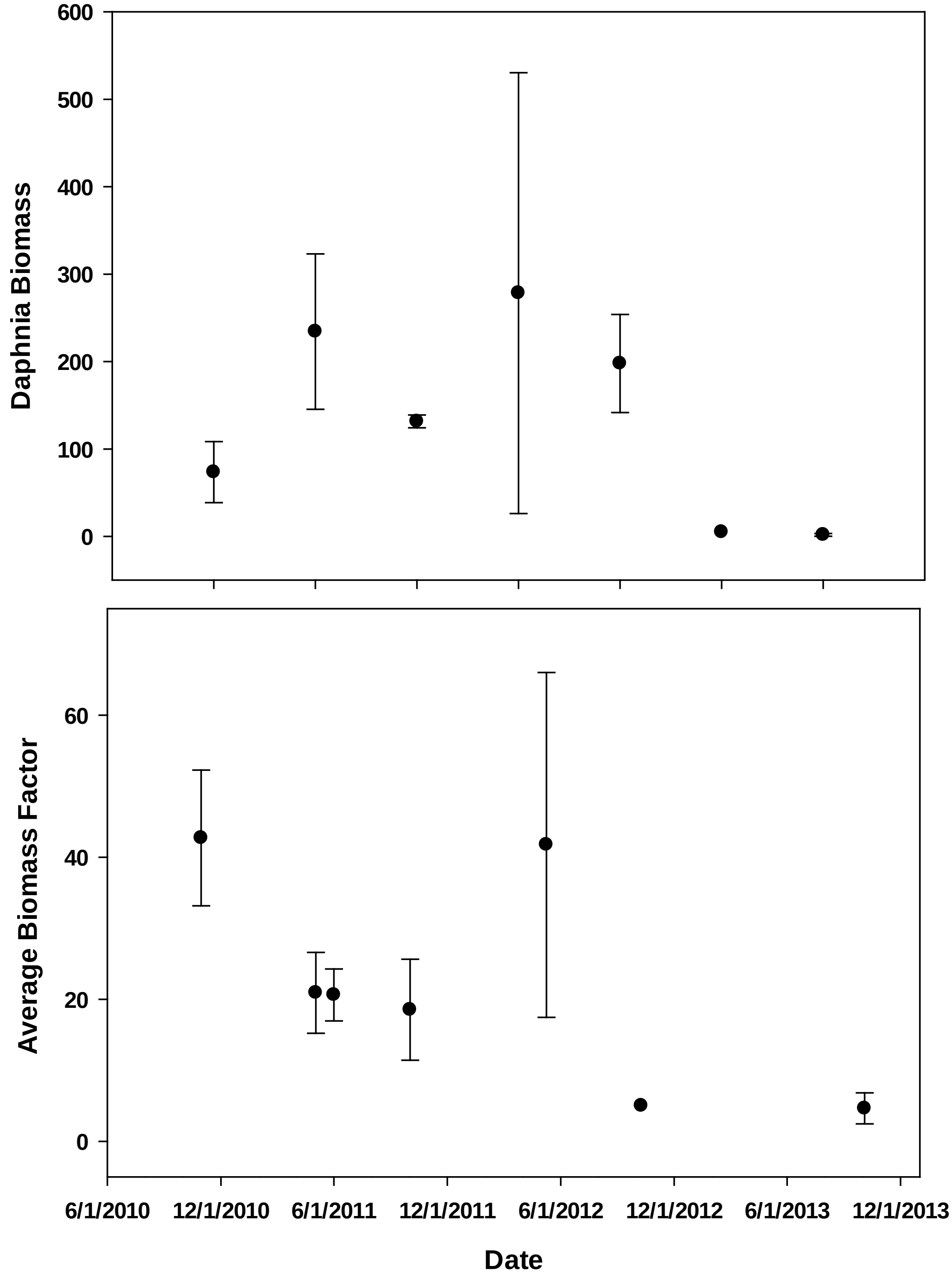


Figure 10. Average biomass factor for Daphnia in Beulah Reservoir. No cladocera were collected during the April, 2013 sampling trip.

Figure 11. Typical fyke net set in Beulah Reservoir with lead line running to shore.

Table 2. List of Fishes Collected at Beulah Reservoir, Oregon, during 3 years of study.

Common Name	Scientific Name	Native
Bridgelip Sucker	*Catostomus columbianus*	X
Largescale Sucker	*Catostomus macrocheilus*	X
Northern Pikeminnow	*Ptychocheilus oregonensis*	X
Redside Shiner	*Richardsonius balteatus*	X
Longnose dace	*Rhinichthys cataractae*	X
Speckled dace	*Rhinichthys osculus*	X
Redband trout	*Oncorhynchus mykiss gairdnerii*	X
Rainbow Trout	*Oncorhynchus mykiss*	
White crappie	*Pomoxis annularis*	
Sculpin spp.	*Cottus* spp.	X
Mountain whitefish	*Prosopium williamsoni*	X
Bull Trout	*Salvelinus confluentus*	X
Largemouth bass	*Micropterus salmoides*	
Chiselmouth	*Acrocheilus alutaceus*	X

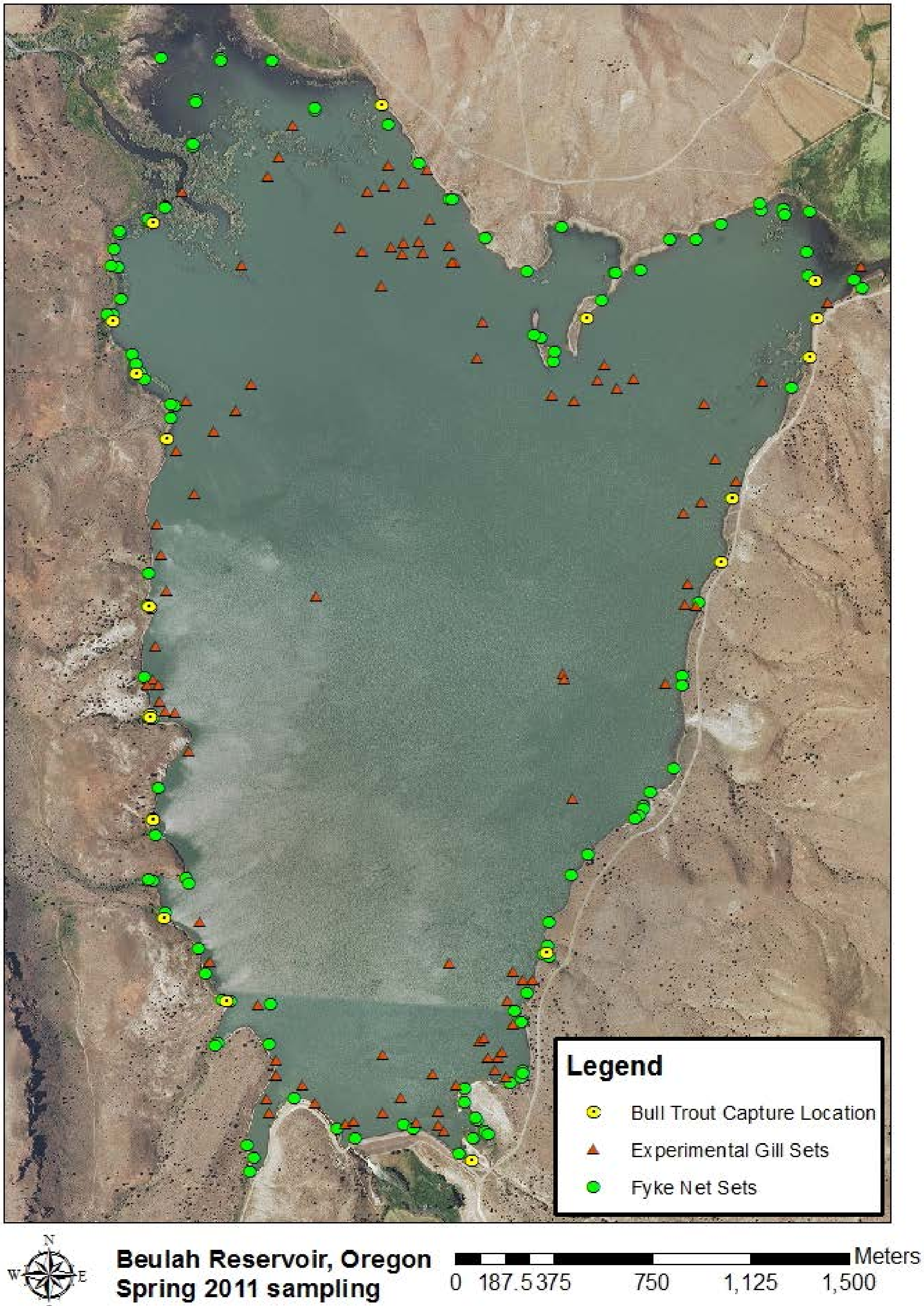


Figure 12. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during spring 2011 sampling in Beulah Reservoir.

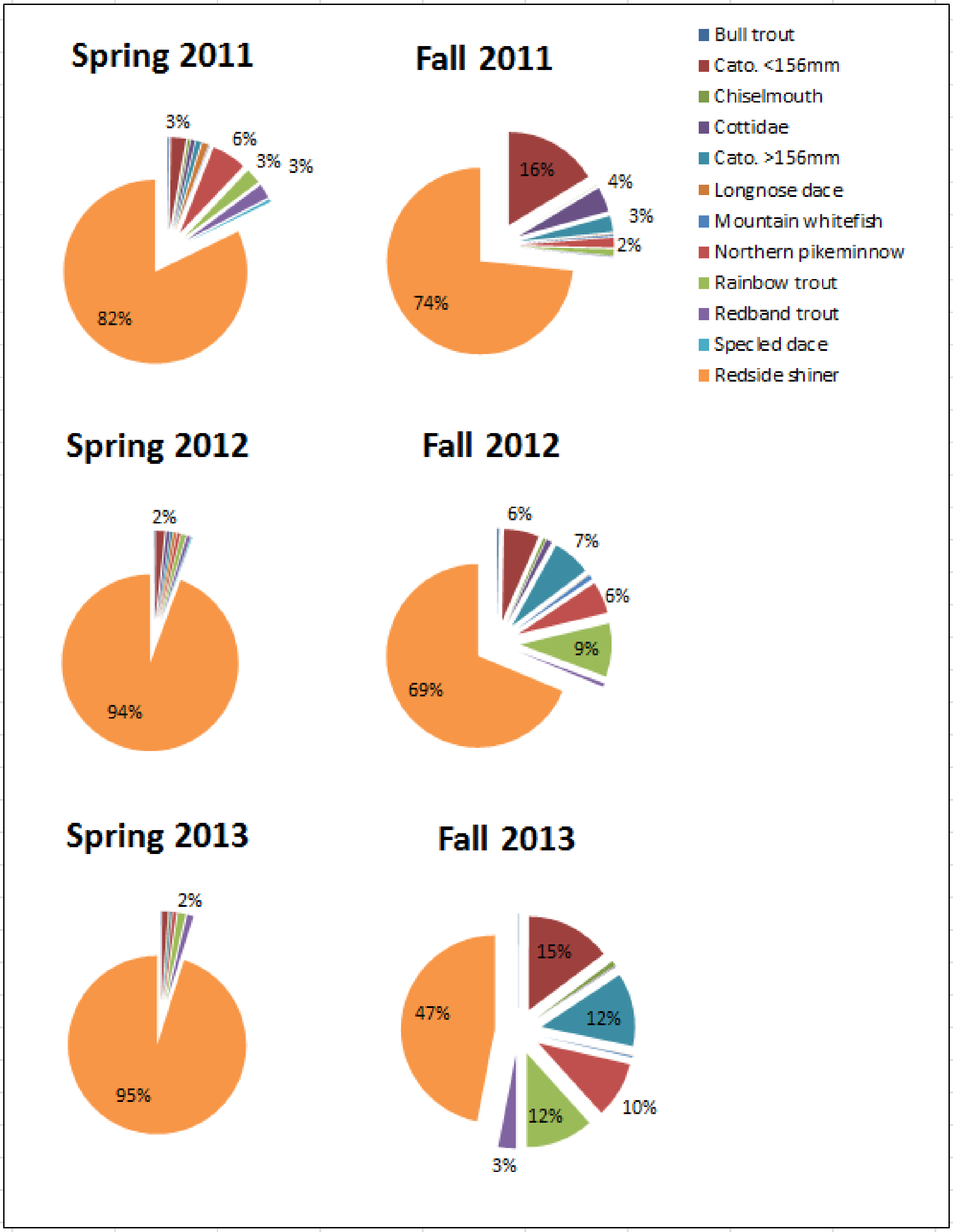


Figure 13. Percent composition of fish collected with fyke and gill nets at Beulah Reservoir, 2011-2013.

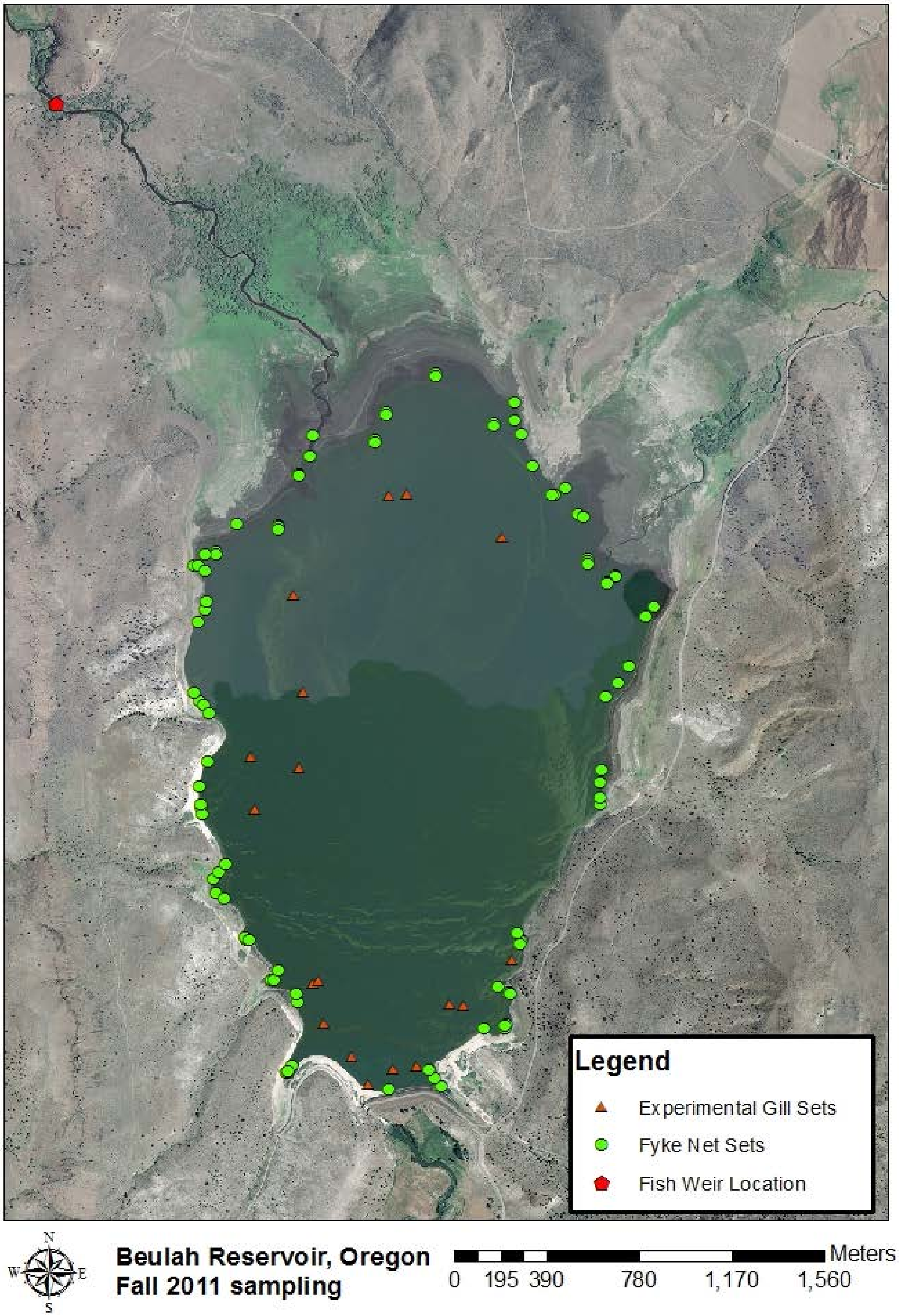


Figure 14. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during fall 2011 sampling in Beulah Reservoir.

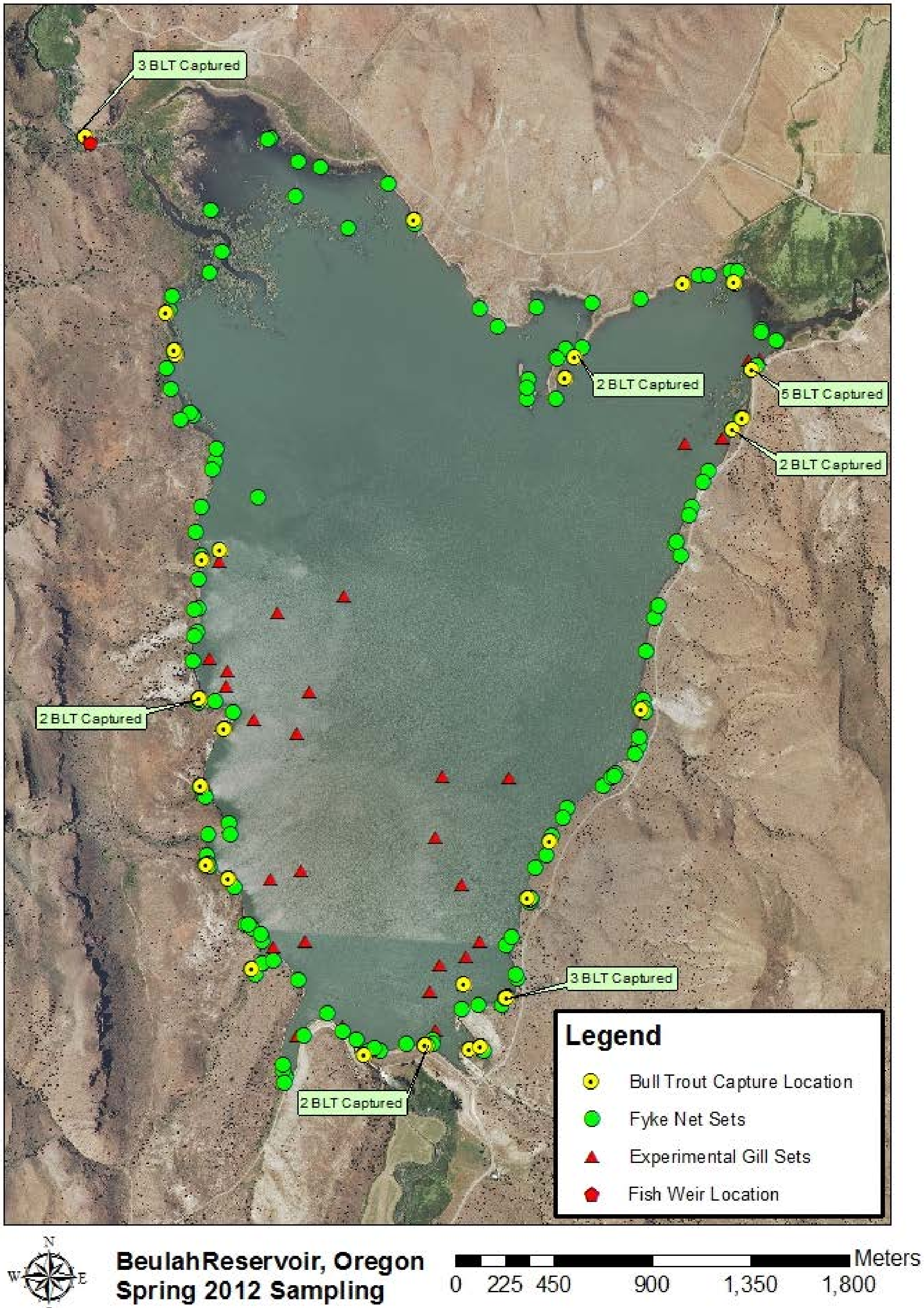


Figure 15. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during spring 2012 sampling in Beulah Reservoir.

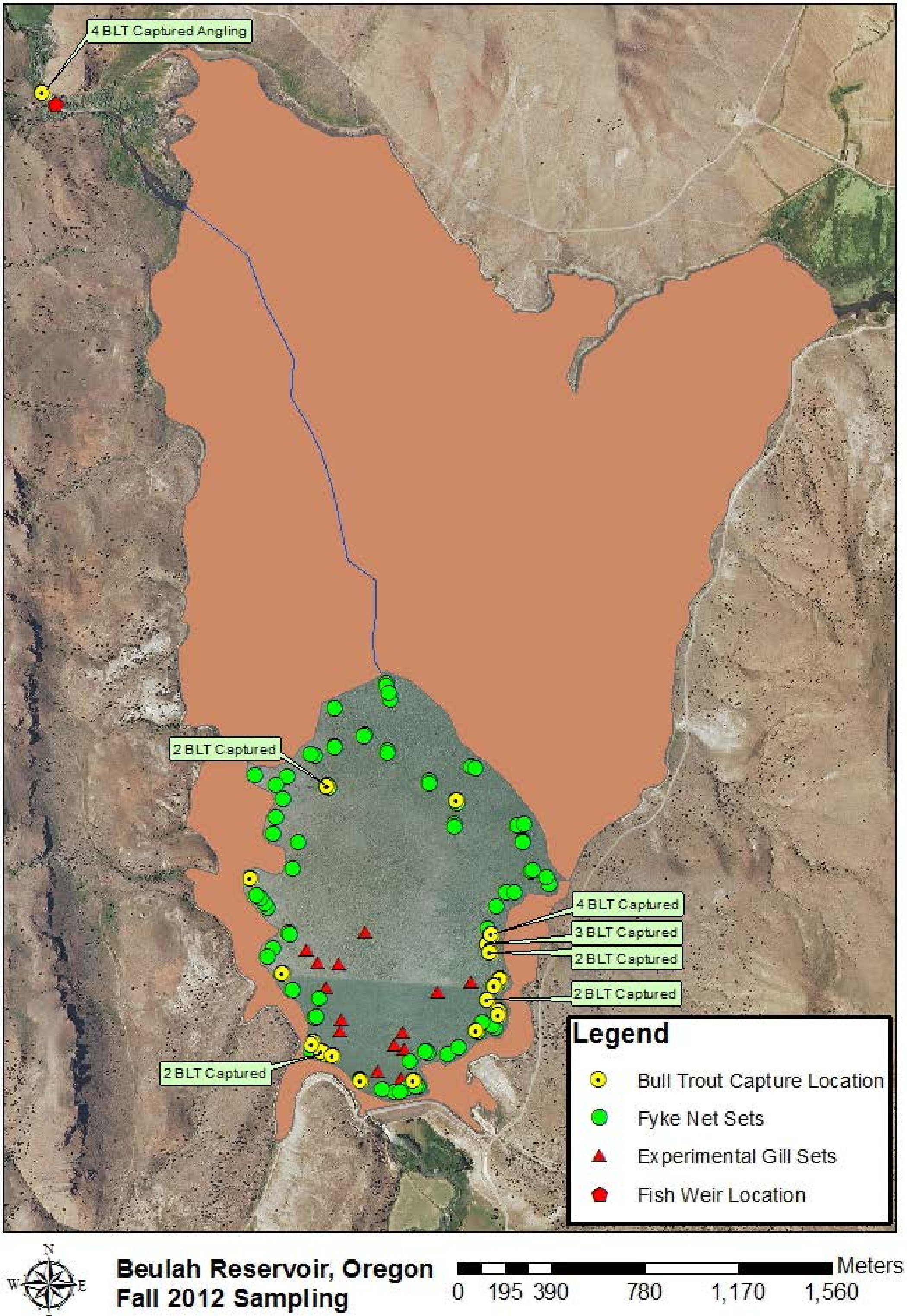


Figure 16. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during fall 2012 sampling in Beulah Reservoir.

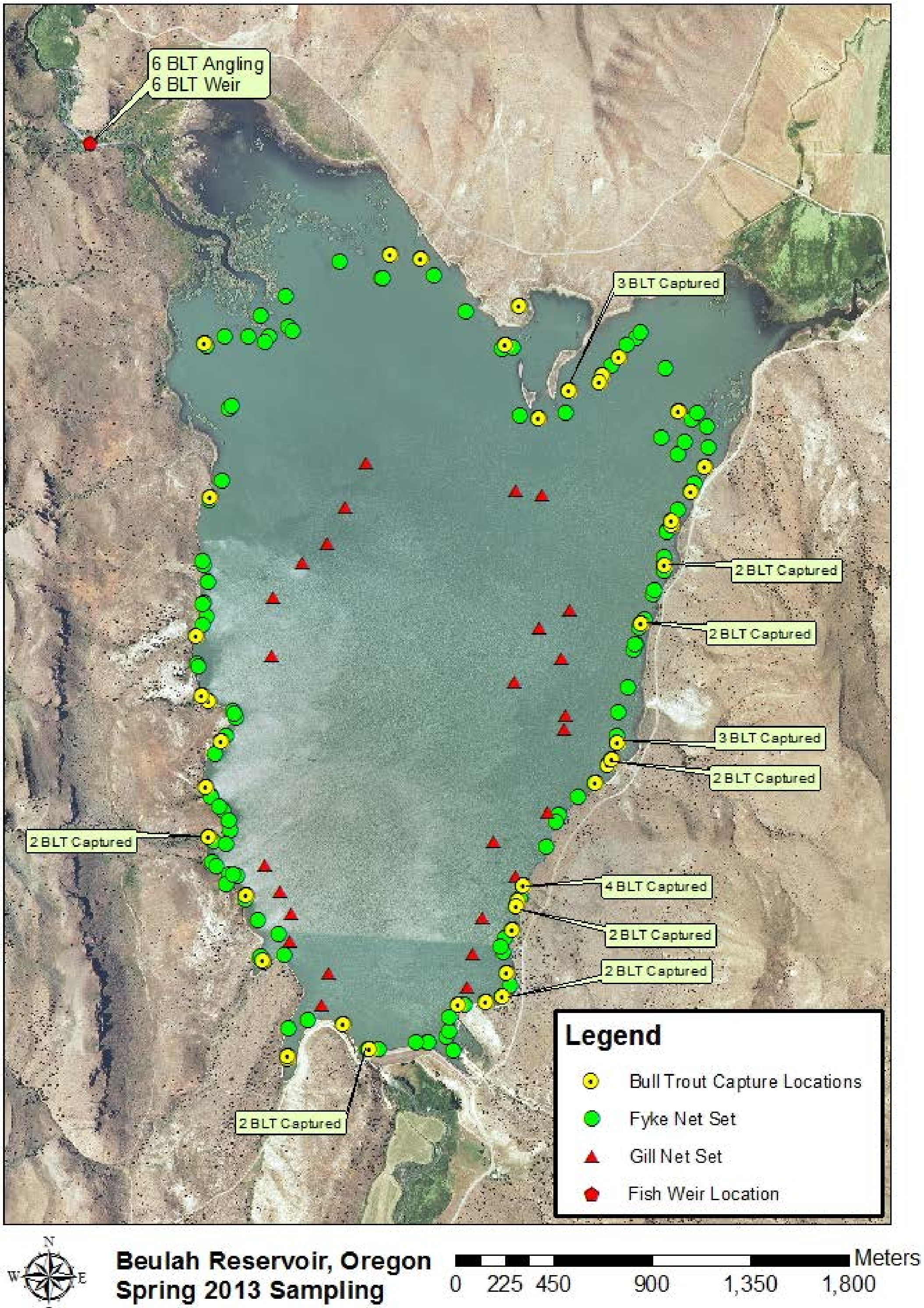


Figure 17. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during spring 2013 sampling in Beulah Reservoir.

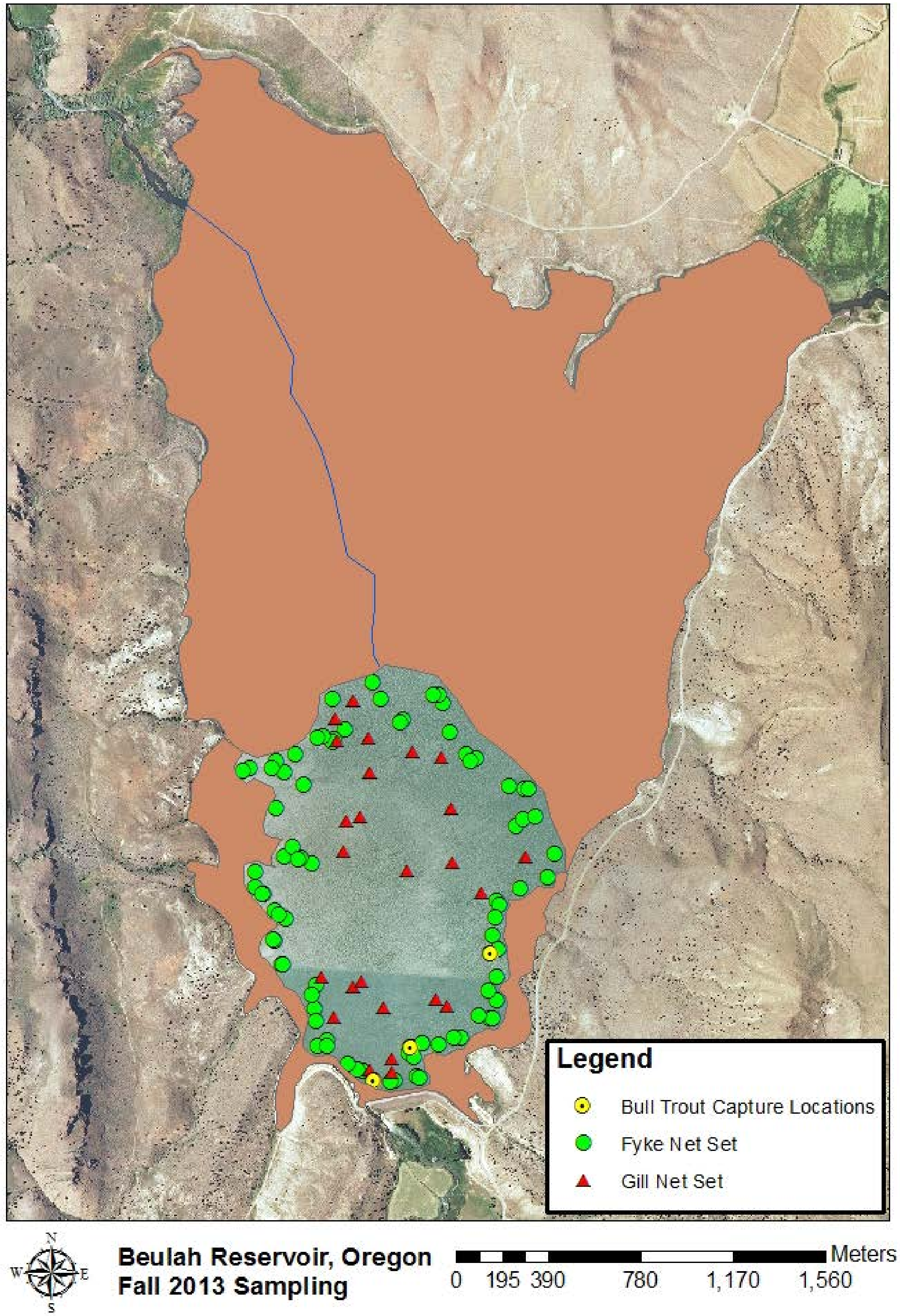


Figure 18. Locations of experimental gill net and fyke net sets and Bull Trout capture locations during fall 2013 sampling in Beulah Reservoir.

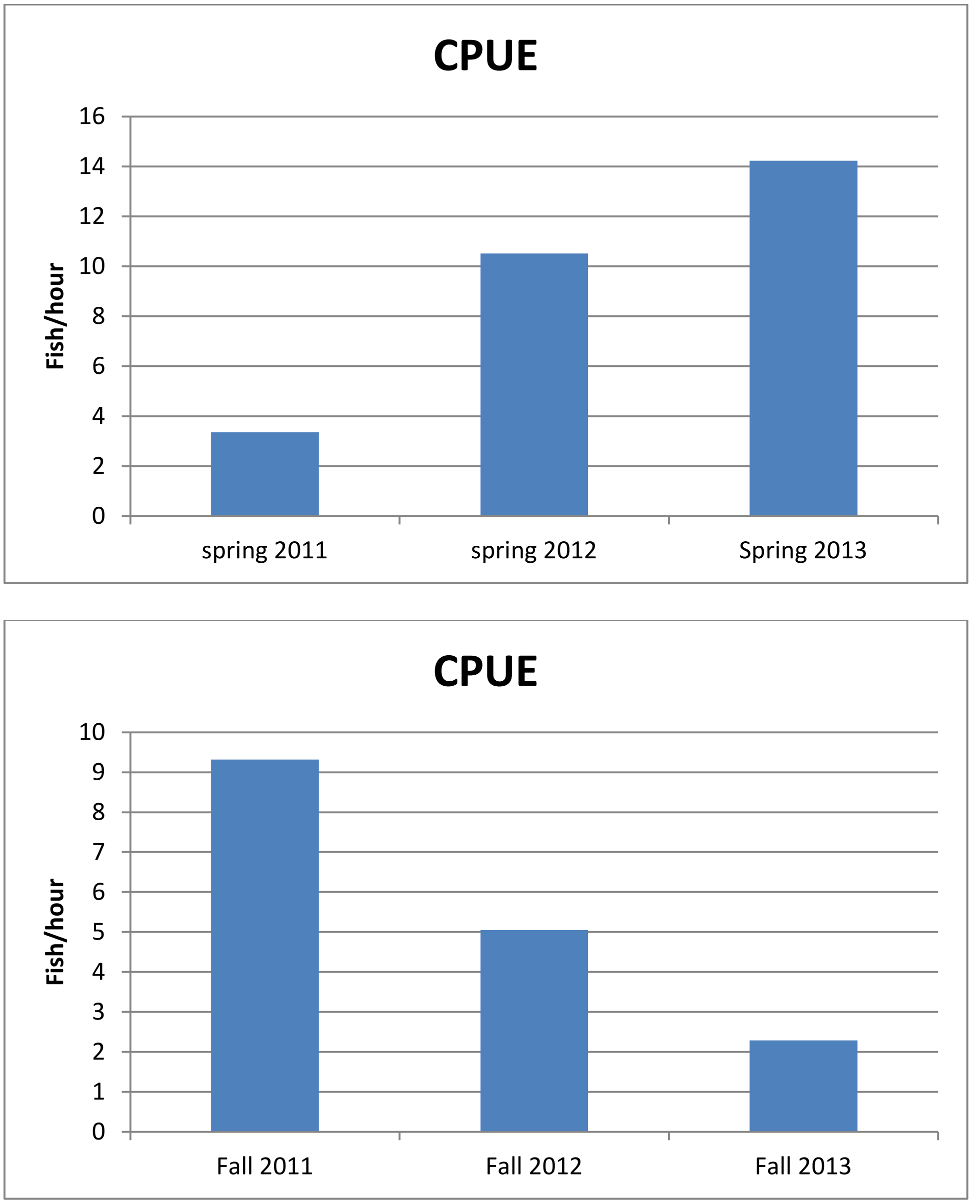
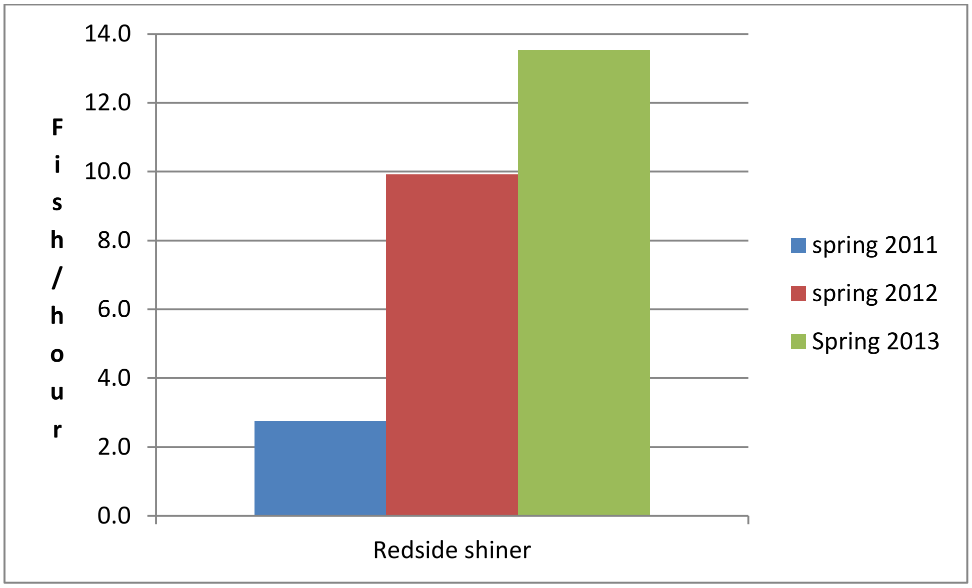


Figure 19. Catch per unit effort of all species in fyke nets for spring and fall sampling at Beulah Reservoir, 2011-2013.



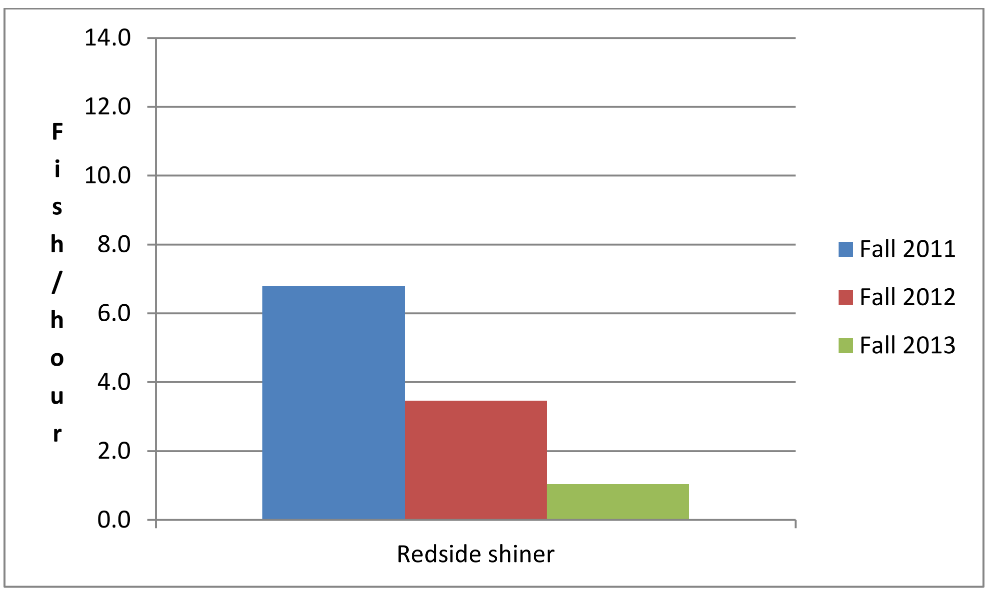
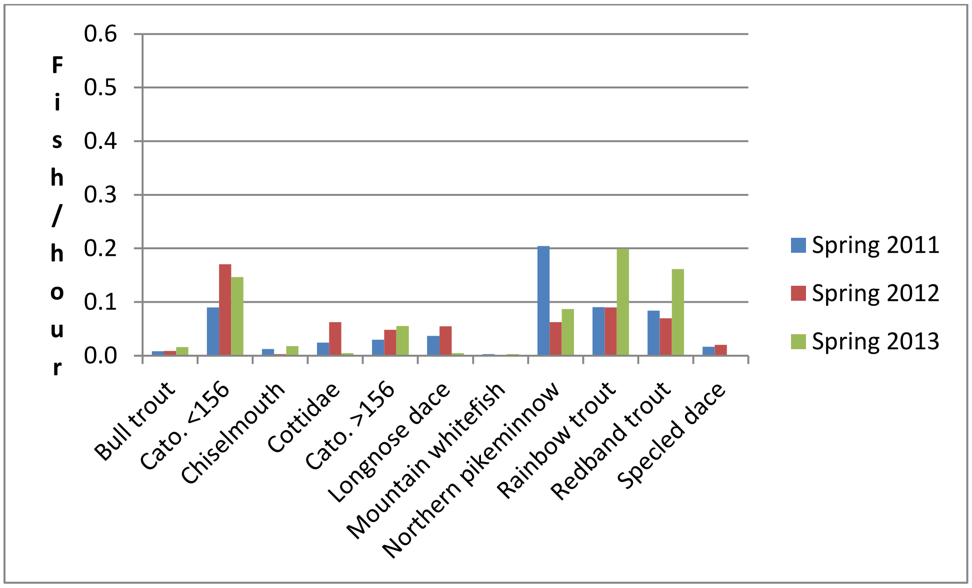


Figure 20. Spring and fall catch per unit effort for Redside Shiner in fyke nets, Beulah Reservoir, 2011-2013.



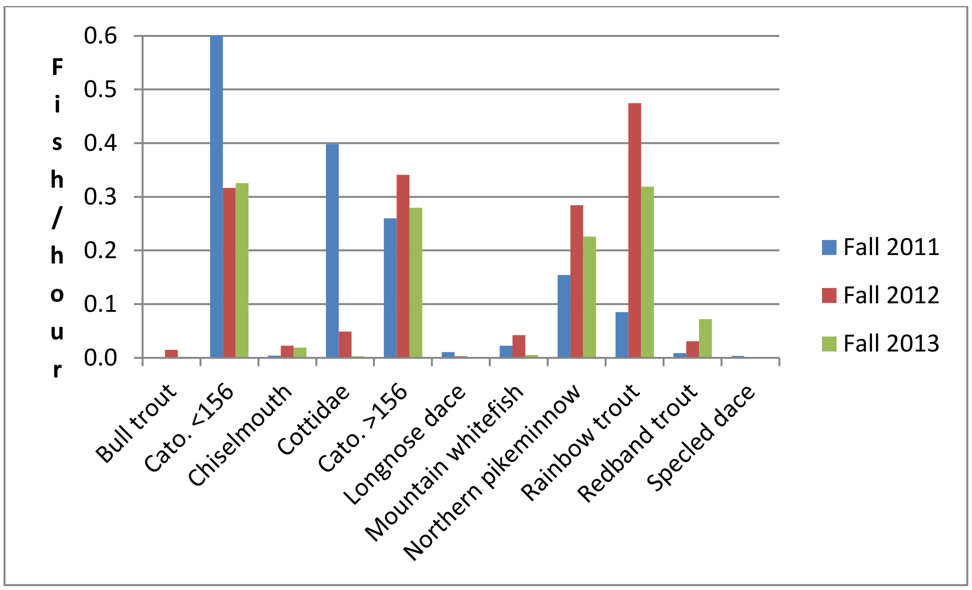
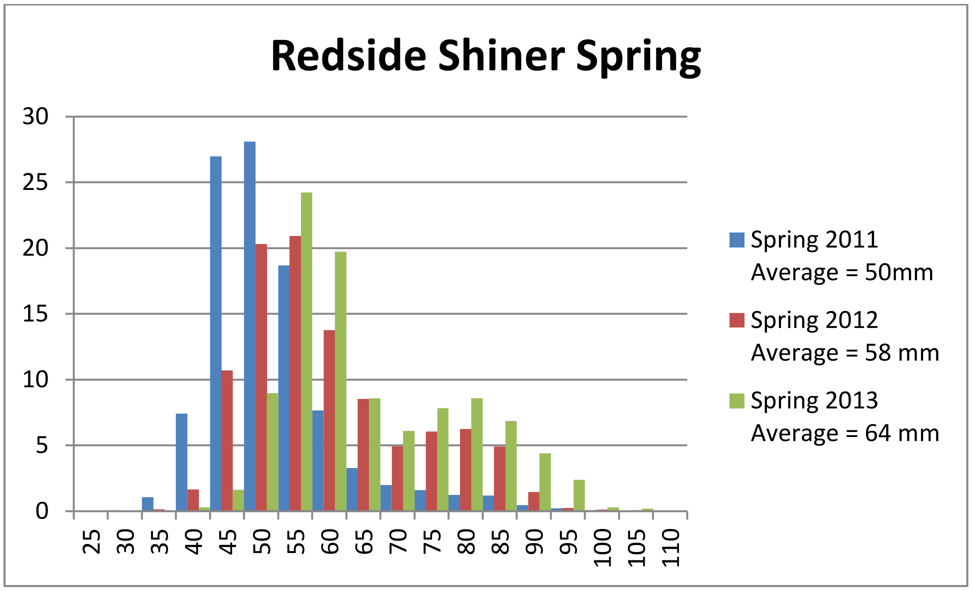


Figure 21. Spring and fall catch per unit effort for common fish in fyke nets, Beulah Reservoir, 2011-2013.



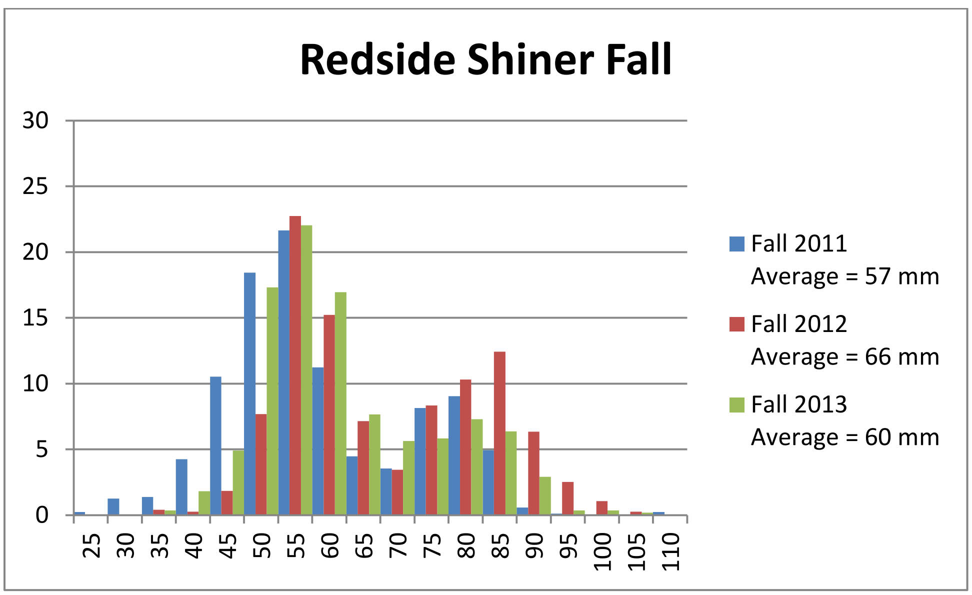
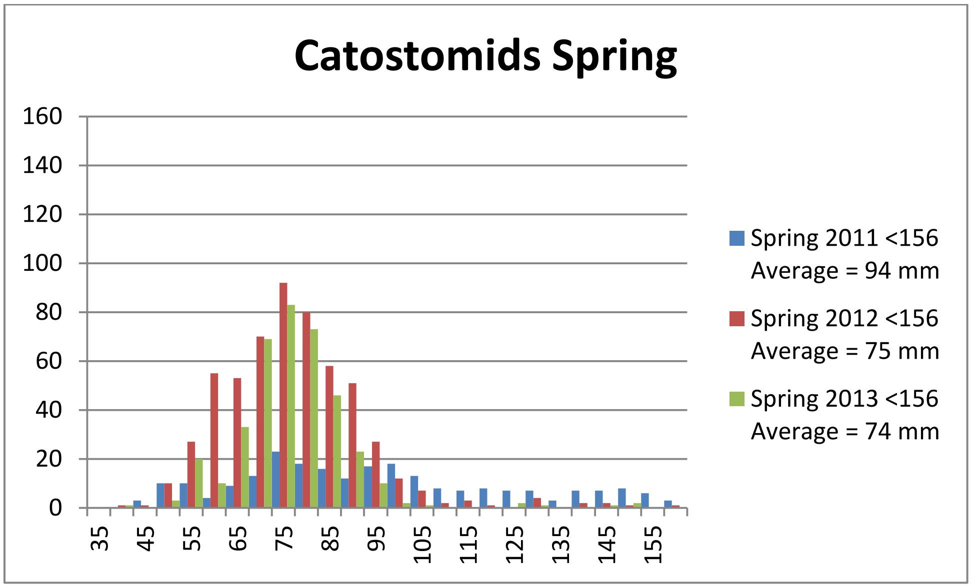


Figure 22. Spring and fall length frequency for Redside Shiner, Beulah Reservoir, 2011-2013.



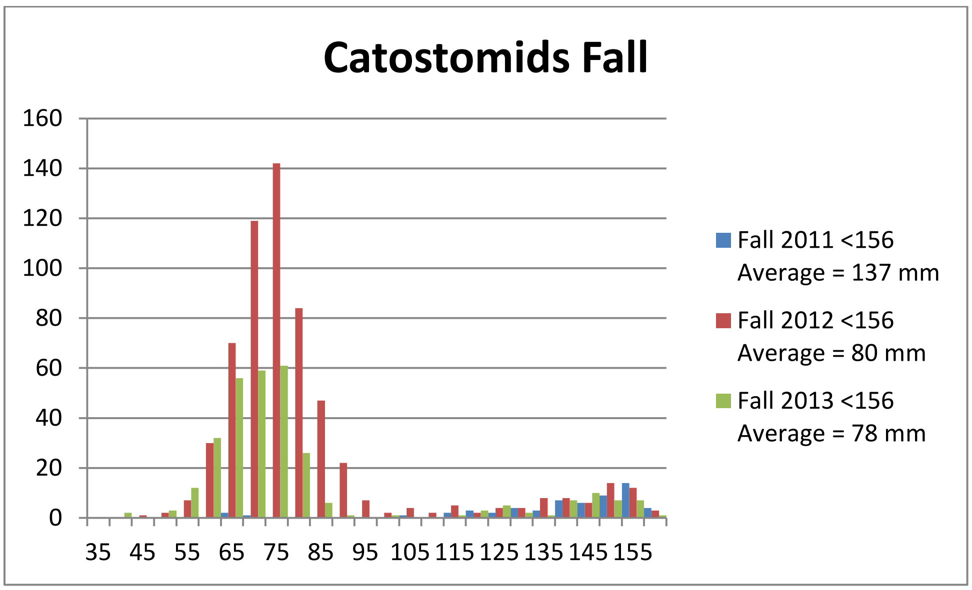
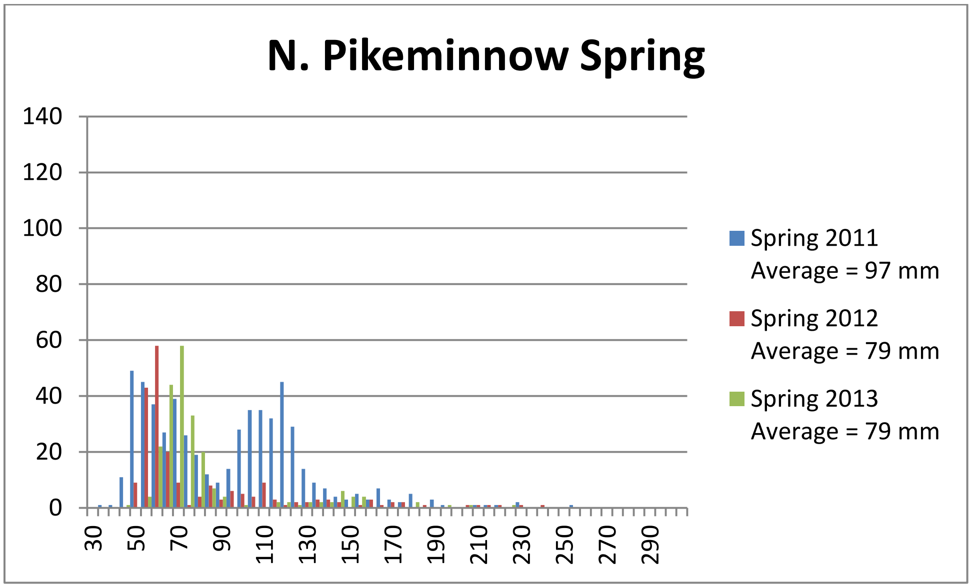


Figure 23. Spring, and fall length frequency for catostomids <156 mm, Beulah Reservoir, 2011-2013.



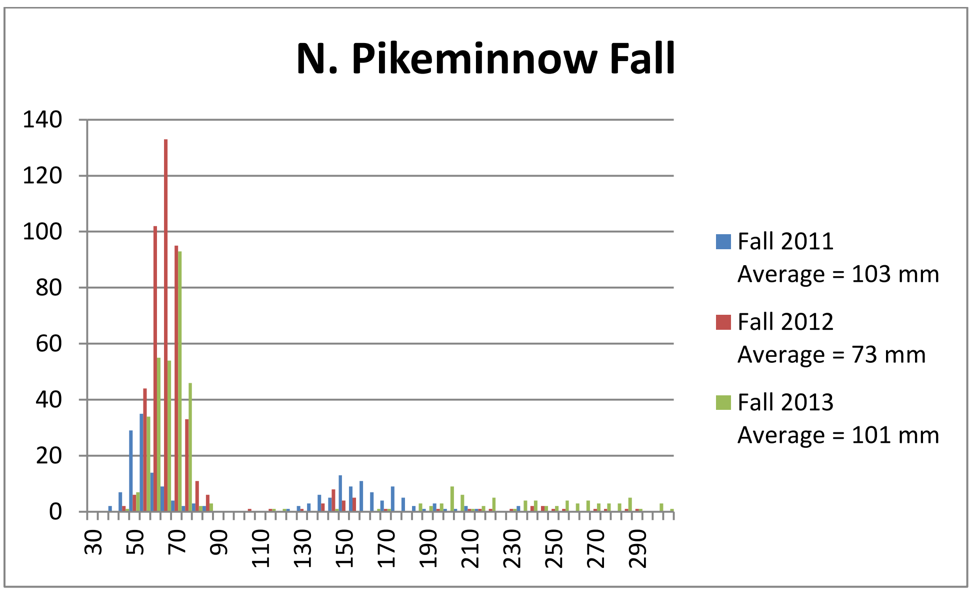


Figure 24. Spring, and fall length frequencies for Northern Pikeminnow (N. Pikeminnow), Beulah Reservoir, 2011-2013.

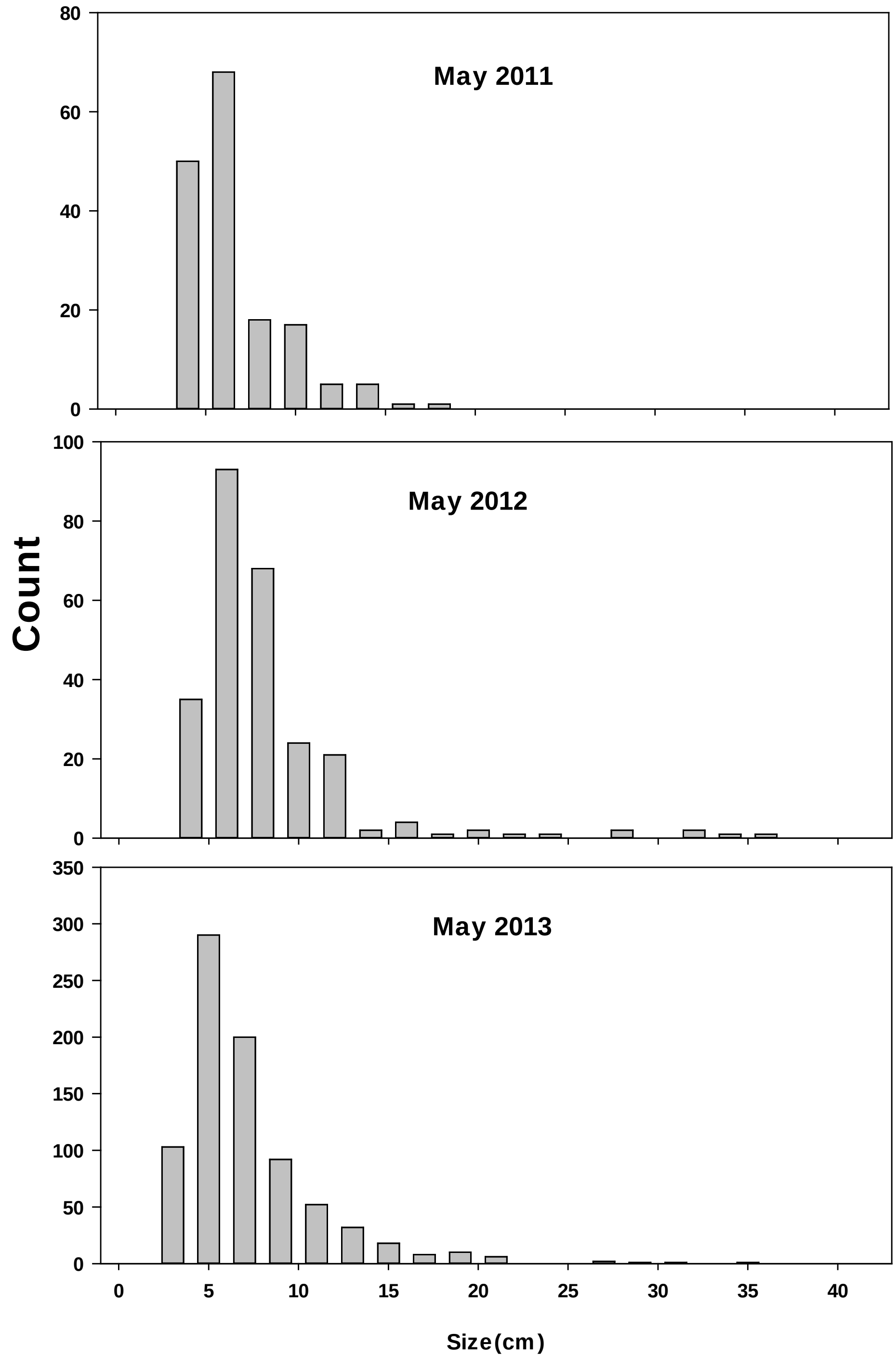


Figure 25. Size distribution of acoustically detected fish during spring sampling events for Beulah Reservoir.

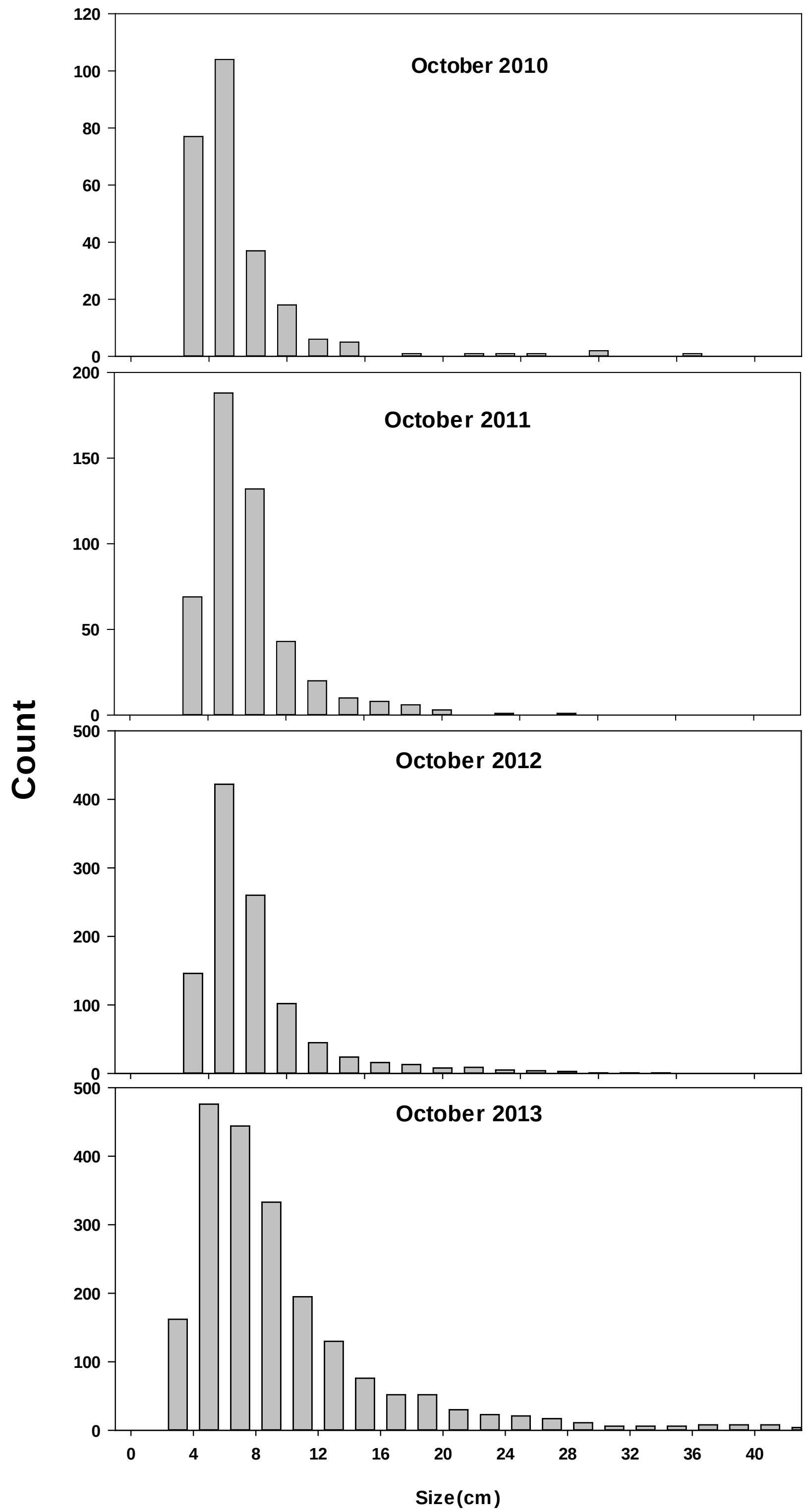


Figure 26. Size distribution of acoustically detected fish during fall sampling events for Beulah Reservoir.

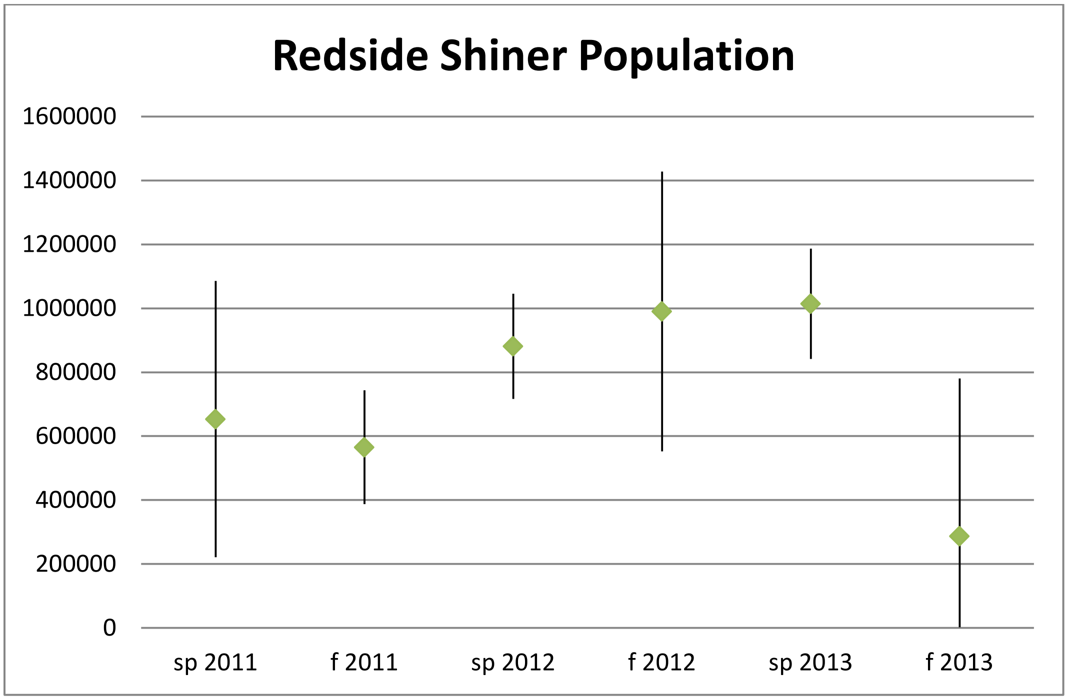


Figure 27. Population estimate of Redside Shiner in spring and fall, Beulah Reservoir, 2011-2013.

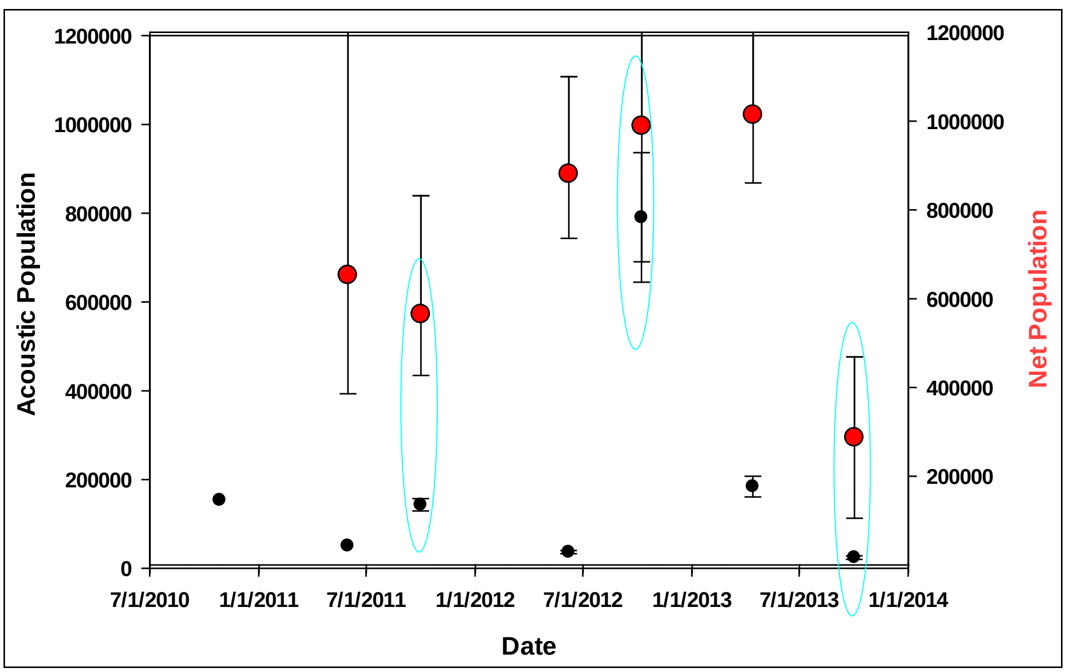


Figure 28. Hydroacoustic estimation fish populations in Beulah Reservoir (black circles) vs net estimates (red circles).

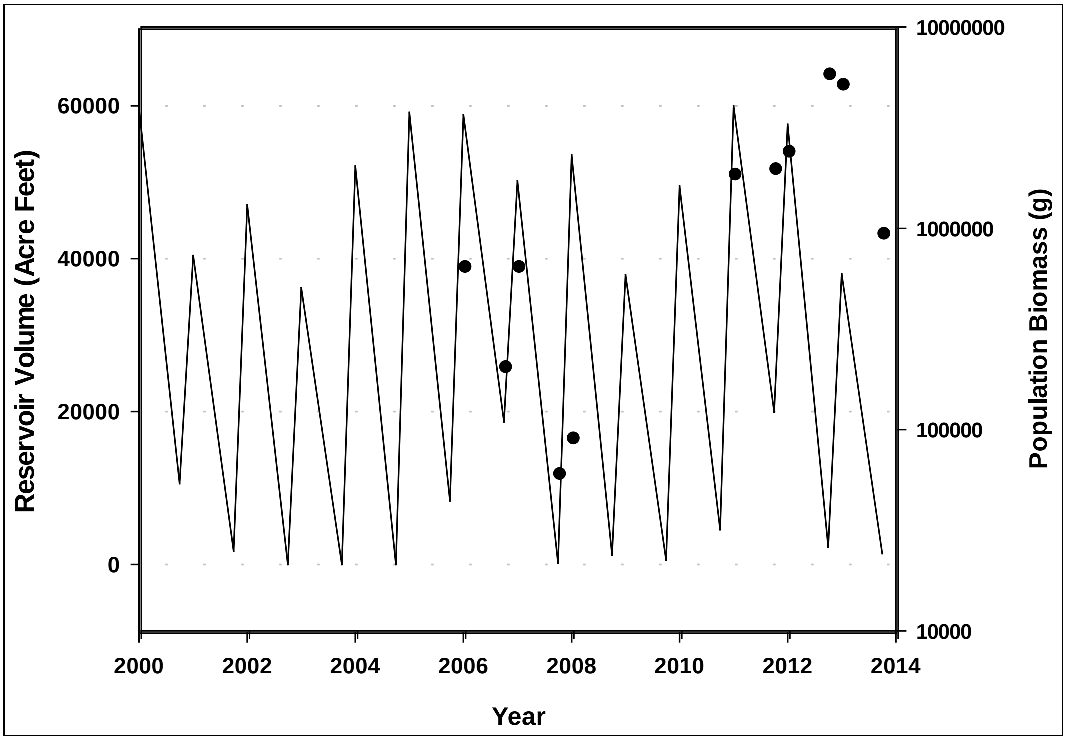


Figure 29. Estimated population biomass of prey sized fish in Beulah Reservoir, including data from 2006-2008 from Rose and Mesa USGS study.

Appendix A

Zooplankton Data Summary

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Sample	Date	Genus	Species	Division	# / L	Biomass Factor	Species Biomass
B1	10/30/2010	*Ceriodaphnia*	*spp.*	Cladocera	0.186	9.702	1.803
B1	10/30/2010	*Dap hnia*	*pulicaria*	Cladocera	1.859	50.359	93.613
B1	10/30/2010	*Daphnia*	*spp.*	Cladocera	0.372	33.525	12.464
B1	10/30/2010	*Diaphanosoma*	*spp.*	Cladocera	0.558	0.753	0.420
B1	10/30/2010	*Aglaodiaptomus*	*forbesi*	Copepoda	3.532	15.579	55.024
B1	10/30/2010	*calanoid*	*copepodid*	Copepoda	0.744	1.305	0.970
B1	10/30/2010	*cyclopoid*	*copepodid*	Copepoda	14.314	1.314	18.806
B1	10/30/2010	*Diacyclops*	*thomasi*	Copepoda	2.231	1.041	2.322
B1	10/30/2010	*nauplii*		Copepoda	12.641	0.052	0.662
B1	10/30/2010	*Conochilus*	*spp.*	Rotifera	1.115	0.011	0.012
B1	10/30/2010	*Keratella*	*quadrata*	Rotifera	0.186	0.046	0.009
B2	10/30/2010	*Daphnia*	*pulicaria*	Cladocera	5.125	23.710	121.506
B2	10/30/2010	*Diaphanosoma*	*spp.*	Cladocera	1.098	6.962	7.645
B2	10/30/2010	*immature*	*cladoceran*	Cladocera	0.366	1.151	0.421
B2	10/30/2010	*Aglaodiaptomus*	*forbesi*	Copepoda	4.637	11.984	55.565
B2	10/30/2010	*calanoid*	*copepodid*	Copepoda	7.077	4.581	32.419
B2	10/30/2010	*cyclopoid*	*copepodid*	Copepoda	7.199	2.760	19.872
B2	10/30/2010	*Diacyclops*	*thomasi*	Copepoda	0.122	1.187	0.145
B2	10/30/2010	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.488	3.358	1.639
B2	10/30/2010	*nauplii*		Copepoda	1.464	0.044	0.064
B2	10/30/2010	*Conochilus*	*unicornis*	Rotifera	0.732	0.008	0.006
B2	10/30/2010	*Hexarthra*	*spp.*	Rotifera	0.122	0.137	0.017
B3	10/30/2010	*Ceriodaphnia*	*spp.*	Cladocera	0.052	4.858	0.254
B3	10/30/2010	*Daphnia*	*pulicaria*	Cladocera	0.104	54.056	5.648
B3	10/30/2010	*Daphnia*	*spp.*	Cladocera	0.070	21.504	1.498
B3	10/30/2010	*Diaphanosoma*	*spp.*	Cladocera	0.244	5.565	1.357
B3	10/30/2010	*Aglaodiaptomus*	*forbesi*	Copepoda	2.020	10.180	20.562
B3	10/30/2010	*calanoid*	*copepodid*	Copepoda	0.766	4.064	3.114
B3	10/30/2010	*cyclopoid*	*copepodid*	Copepoda	0.766	0.873	0.669
B3	10/30/2010	*Diacyclops*	*thomasi*	Copepoda	0.087	1.049	0.091
B3	10/30/2010	*harpacticoid*		Copepoda	0.052	3.163	0.165
B3	10/30/2010	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.139	3.005	0.419
B3	10/30/2010	*nauplii*		Copepoda	0.348	0.051	0.018
B3	10/30/2010	*Conochilus*	*spp.*	Rotifera	0.174	0.008	0.001
B3	10/30/2010	*Keratella*	*quadrata*	Rotifera	0.017	0.029	0.001
B2	5/3/2011	*Daphnia*	*pulicaria*	Cladocera	13.104	28.628	375.130
B2	5/3/2011	*cyclopoid*	*copepodid*	Copepoda	13.104	0.432	5.658
B2	5/3/2011	*Diacyclops*	*thomasi*	Copepoda	3.780	1.101	4.160
B2	5/3/2011	*nauplii*		Copepoda	26.963	0.088	2.364
B2	5/3/2011	*Asplanchnopus*	*spp.*	Rotifera	5.292	0.265	1.403
B1	5/3/2011	*Daphnia*	*pulicaria*	Cladocera	10.610	24.292	257.743
B1	5/3/2011	*immature*	*cladoceran*	Cladocera	1.061	0.960	1.019
B1	5/3/2011	*cyclopoid*	*copepodid*	Copepoda	28.648	0.409	11.727
B1	5/3/2011	*Diacyclops*	*thomasi*	Copepoda	4.244	0.984	4.178

Sample	Date	Genus	Species	Division	# / L	Biomass Factor	Species Biomass
B1	5/3/2011	*nauplii*		Copepoda	33.157	0.059	1.948
B1	5/3/2011	*Keratella*	*valga f. tropica*	Rotifera	1.061	0.028	0.029
B1	5/3/2011	*Synchaeta*	*spp.*	Rotifera	8.223	0.109	0.894
B3	5/3/2011	*Daphnia*	*pulicaria*	Cladocera	7.162	9.792	70.128
B3	5/3/2011	*immature*	*cladoceran*	Cladocera	7.520	0.743	5.589
B3	5/3/2011	*immature*	*daphnid*	Cladocera	2.865	2.238	6.412
B3	5/3/2011	*cyclopoid*	*copepodid*	Copepoda	27.932	0.242	6.752
B3	5/3/2011	*Diacyclops*	*thomasi*	Copepoda	2.507	0.758	1.900
B3	5/3/2011	*nauplii*		Copepoda	46.911	0.055	2.572
B3	5/3/2011	*Asplanchnopus*	*spp.*	Rotifera	7.878	0.163	1.280
B1	6/1/2011	*Daphnia*	*pulicaria*	Cladocera	5.724	24.262	138.883
B1	6/1/2011	*cyclopoid*	*copepodid*	Copepoda	8.718	0.554	4.833
B1	6/1/2011	*Diacyclops*	*thomasi*	Copepoda	0.881	1.196	1.053
B1	6/1/2011	*nauplii*		Copepoda	11.272	0.065	0.728
B3	6/1/2011	*Daphnia*	*pulicaria*	Cladocera	7.334	16.945	124.274
B3	6/1/2011	*Aglaodiaptomus*	*forbesi*	Copepoda	0.204	15.327	3.122
B3	6/1/2011	*calanoid*	*copepodid*	Copepoda	0.204	1.832	0.373
B3	6/1/2011	*cyclopoid*	*copepodid*	Copepoda	10.593	0.561	5.942
B3	6/1/2011	*Diacyclops*	*thomasi*	Copepoda	2.241	0.996	2.232
B3	6/1/2011	*nauplii*		Copepoda	23.428	0.060	1.413
B2	10/2/2011	*Ceriodaphnia*	*spp.*	Cladocera	15.391	4.778	73.537
B2	10/2/2011	*Daphnia*	*pulicaria*	Cladocera	7.516	6.522	49.025
B2	10/2/2011	*Diaphanosoma*	*birgei*	Cladocera	3.221	2.933	9.447
B2	10/2/2011	*Aglaodiaptomus*	*forbesi*	Copepoda	4.653	6.740	31.360
B2	10/2/2011	*calanoid*	*copepodid*	Copepoda	18.970	1.977	37.512
B2	10/2/2011	*cyclopoid*	*copepodid*	Copepoda	1.790	0.399	0.714
B2	10/2/2011	*Diacyclops*	*thomasi*	Copepoda	3.221	0.856	2.756
B2	10/2/2011	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.716	1.633	1.169
B2	10/2/2011	*nauplii*		Copepoda	12.885	0.028	0.366
B2	10/2/2011	*Conochilus*	*unicornis*	Rotifera	7.516	0.003	0.025
B2	10/2/2011	*Hexarthra*	*mira*	Rotifera	3.579	0.096	0.343
B1	10/2/2011	*Ceriodaphnia*	*spp.*	Cladocera	7.292	5.702	41.578
B1	10/2/2011	*Daphnia*	*pulicaria*	Cladocera	0.135	31.122	4.203
B1	10/2/2011	*Diaphanosoma*	*birgei*	Cladocera	0.405	2.933	1.188
B1	10/2/2011	*Aglaodiaptomus*	*forbesi*	Copepoda	0.405	11.557	4.682
B1	10/2/2011	*calanoid*	*copepodid*	Copepoda	1.350	3.224	4.353
B1	10/2/2011	*cyclopoid*	*copepodid*	Copepoda	0.810	0.462	0.375
B1	10/2/2011	*Diacyclops*	*thomasi*	Copepoda	0.270	0.983	0.266
B1	10/2/2011	*nauplii*		Copepoda	12.154	0.034	0.412
B1	10/2/2011	*Conochilus*	*unicornis*	Rotifera	1.080	0.004	0.004
B1	10/2/2011	*Hexarthra*	*mira*	Rotifera	3.781	0.056	0.211
B3	10/2/2011	*Ceriodaphnia*	*spp.*	Cladocera	9.037	4.859	43.908
B3	10/2/2011	*Chydorus*	*sphaericus*	Cladocera	0.532	5.086	2.704
B3	10/2/2011	*Daphnia*	*pulicaria*	Cladocera	43.589	17.939	781.944
B3	10/2/2011	*Diaphanosoma*	*birgei*	Cladocera	2.126	2.454	5.218

Sample	Date	Genus	Species	Division	# / L	Biomass Factor	Species Biomass
B3	10/2/2011	*immature*	*cladoceran*	Cladocera	1.595	0.960	1.532
B3	10/2/2011	*immature*	*daphnid*	Cladocera	0.532	1.733	0.921
B3	10/2/2011	*Aglaodiaptomus*	*forbesi*	Copepoda	21.795	7.424	161.803
B3	10/2/2011	*calanoid*	*copepodid*	Copepoda	25.516	2.015	51.420
B3	10/2/2011	*cyclopoid*	*copepodid*	Copepoda	1.595	1.157	1.845
B3	10/2/2011	*Diacyclops*	*thomasi*	Copepoda	10.632	1.453	15.449
B3	10/2/2011	*Leptodiaptomus*	*novamexicanus*	Copepoda	1.063	1.881	2.000
B3	10/2/2011	*nauplii*		Copepoda	7.974	0.018	0.143
B3	10/2/2011	*Conochilus*	*unicornis*	Rotifera	2.126	0.005	0.011
B3	10/2/2011	*Hexarthra*	*mira*	Rotifera	1.595	0.018	0.029
B1	5/9/2012	*Daphnia*	*pulicaria*	Cladocera	2.345	89.888	210.776
B1	5/9/2012	*Daphnia*	*spp.*	Cladocera	0.828	8.358	6.917
B1	5/9/2012	*Aglaodiaptomus*	*forbesi*	Copepoda	0.138	15.945	2.199
B1	5/9/2012	*calanoid*	*copepodid*	Copepoda	1.931	2.291	4.424
B1	5/9/2012	*cyclopoid*	*copepodid*	Copepoda	2.897	0.290	0.839
B1	5/9/2012	*Diacyclops*	*thomasi*	Copepoda	2.069	3.251	6.726
B1	5/9/2012	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.138	1.914	0.264
B1	5/9/2012	*nauplii*		Copepoda	24.138	0.079	1.906
B2	5/9/2012	*Daphnia*	*pulicaria*	Cladocera	7.834	12.111	94.881
B2	5/9/2012	*Daphnia*	*spp.*	Cladocera	0.253	2.005	0.507
B2	5/9/2012	*Aglaodiaptomus*	*forbesi*	Copepoda	0.253	10.724	2.710
B2	5/9/2012	*calanoid*	*copepodid*	Copepoda	2.274	1.332	3.030
B2	5/9/2012	*cyclopoid*	*copepodid*	Copepoda	13.394	0.359	4.815
B2	5/9/2012	*Diacyclops*	*thomasi*	Copepoda	1.516	2.150	3.260
B2	5/9/2012	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.253	1.980	0.500
B2	5/9/2012	*nauplii*		Copepoda	109.427	0.041	4.496
B3	5/9/2012	*Daphnia*	*pulicaria*	Cladocera	12.386	23.233	287.760
B3	5/9/2012	*calanoid*	*copepodid*	Copepoda	8.014	1.446	11.586
B3	5/9/2012	*cyclopoid*	*copepodid*	Copepoda	21.129	0.821	17.346
B3	5/9/2012	*Diacyclops*	*thomasi*	Copepoda	1.457	1.668	2.431
B3	5/9/2012	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.729	2.962	2.158
B3	5/9/2012	*nauplii*		Copepoda	117.300	0.056	6.520
B3	5/9/2012	*Synchaeta*	*spp.*	Rotifera	0.729	0.145	0.105
B1	10/9/2012	*Ceriodaphnia*	*spp.*	Cladocera	9.677	1.803	17.448
B1	10/9/2012	*Daphnia*	*pulicaria*	Cladocera	1.019	5.029	5.122
B1	10/9/2012	*Diaphanosoma*	*spp.*	Cladocera	2.037	1.177	2.398
B1	10/9/2012	*Aglaodiaptomus*	*forbesi*	Copepoda	1.528	5.200	7.945
B1	10/9/2012	*calanoid*	*copepodid*	Copepoda	4.074	1.928	7.854
B1	10/9/2012	*cyclopoid*	*copepodid*	Copepoda	13.242	0.613	8.113
B1	10/9/2012	*Diacyclops*	*thomasi*	Copepoda	0.509	0.454	0.231
B1	10/9/2012	*Skistodiaptomus*	*pallidus*	Copepoda	1.528	1.017	1.555
B1	10/9/2012	*nauplii*		Copepoda	10.186	0.012	0.126
B1	10/9/2012	*Conochilus*	*unicornis*	Rotifera	60.606	0.002	0.146
B2	10/9/12	*Ceriodaphnia*	*spp.*	Cladocera	9.793	0.686	6.722
B2	10/9/12	*Daphnia*	*sp.*	Cladocera	0.377	1.658	0.624

Sample	Date	Genus	Species	Division	# / L	Biomass Factor	Species Biomass
B2	10/9/12	*Diaphanosoma*	*birgei*	Cladocera	8.663	0.900	7.799
B2	10/9/12	*calanoid*	*copepodid*	Copepoda	2.260	1.146	2.590
B2	10/9/12	*cyclopoid*	*copepodid*	Copepoda	12.053	0.885	10.667
B2	10/9/12	*Diacyclops*	*thomasi*	Copepoda	3.013	0.713	2.150
B2	10/9/12	*nauplii*		Copepoda	17.327	0.022	0.379
B2	10/9/12	*Conochilus*	*unicornis*	Rotifera	24.107	0.002	0.042
B1	4/12/13	*cyclopoid*	*copepodid*	Copepoda	34.059	0.345	11.762
B1	4/12/13	*Diacyclops*	*thomasi*	Copepoda	2.271	0.921	2.092
B1	4/12/13	*nauplii*		Copepoda	445.039	0.018	7.790
B1	4/12/13	*Keratella*	*quadrata*	Rotifera	4.541	0.011	0.050
B1	4/12/13	*Polyarthra*	*dolichoptera*	Rotifera	29.518	0.006	0.187
B1	4/12/13	*Synchaeta*	*sp.*	Rotifera	2.271	0.005	0.011
B2	4/12/13	*cyclopoid*	*copepodid*	Copepoda	120.703	0.459	55.422
B2	4/12/13	*Diacyclops*	*thomasi*	Copepoda	33.529	0.697	23.369
B2	4/12/13	*nauplii*		Copepoda	511.311	0.014	7.323
B2	4/12/13	*Keratella*	*quadrata*	Rotifera	3.353	0.007	0.022
B2	4/12/13	*Polyarthra*	*vulgaris*	Rotifera	18.441	0.010	0.178
B2	4/12/13	*Synchaeta*	*spp.*	Rotifera	8.382	0.002	0.019
B2	4/12/13	*cyclopoid*	*copepodid*	Copepoda	42.441	0.405	17.172
B2	4/12/13	*Diacyclops*	*thomasi*	Copepoda	16.976	0.404	6.862
B2	4/12/13	*nauplii*		Copepoda	327.646	0.014	4.464
B2	4/12/13	*Conochiloides*	*sp.*	Rotifera	1.698	0.008	0.014
B2	4/12/13	*Polyarthra*	*vulgaris*	Rotifera	13.581	0.006	0.086
B2	4/12/13	*Synchaeta*	*spp.*	Rotifera	8.488	0.002	0.019
B1	10/4/13	*Ceriodaphnia*	*spp.*	Cladocera	0.369	0.678	0.250
B1	10/4/13	*Daphnia*	*pulicaria*	Cladocera	0.492	6.821	3.358
B1	10/4/13	*Diaphanosoma*	*spp.*	Cladocera	1.108	1.370	1.518
B1	10/4/13	*Aglaodiaptomus*	*sp.*	Copepoda	0.492	4.132	2.034
B1	10/4/13	*calanoid*	*copepodid*	Copepoda	5.539	0.865	4.788
B1	10/4/13	*cyclopoid*	*copepodid*	Copepoda	6.277	0.400	2.509
B1	10/4/13	*Diacyclops*	*thomasi*	Copepoda	2.831	0.402	1.139
B1	10/4/13	*nauplii*		Copepoda	9.477	0.016	0.148
B1	10/4/13	*Collotheca*	*sp.*	Rotifera	0.246	0.003	0.001
B1	10/4/13	*Conochilus*	*unicornis*	Rotifera	0.985	0.000	0.000
B1	10/4/13	*Keratella*	*quadrata*	Rotifera	0.369	0.005	0.002
B1	10/4/13	*Synchaeta*	*spp.*	Rotifera	0.862	0.003	0.003
B2	10/4/13	*Ceriodaphnia*	*spp.*	Cladocera	0.333	0.713	0.238
B2	10/4/13	*Daphnia*	*pulicaria*	Cladocera	0.111	2.463	0.274
B2	10/4/13	*Daphnia*	*spp.*	Cladocera	0.444	1.350	0.600
B2	10/4/13	*Diaphanosoma*	*birgei*	Cladocera	0.555	0.872	0.484
B2	10/4/13	*Aglaodiaptomus*	*forbesi*	Copepoda	0.555	4.008	2.225
B2	10/4/13	*calanoid*	*copepodid*	Copepoda	2.554	1.408	3.596
B2	10/4/13	*cyclopoid*	*copepodid*	Copepoda	4.220	0.421	1.775
B2	10/4/13	*Diacyclops*	*thomasi*	Copepoda	0.666	0.313	0.209
B2	10/4/13	*Leptodiaptomus*	*novamexicanus*	Copepoda	0.555	0.451	0.250

Sample	Date	Genus	Species	Division	# / L	Biomass Factor	Species Biomass
B2	10/4/13	*nauplii*		Copepoda	11.883	0.023	0.277
B2	10/4/13	*Conochilus*	*spp.*	Rotifera	1.111	0.001	0.002
B2	10/4/13	*Keratella*	*quadrata*	Rotifera	0.111	0.011	0.001
B2	10/4/13	*Synchaeta*	*spp.*	Rotifera	0.222	0.003	0.001

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Appendix B

Phytoplankton Data

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Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B1	10/27/2010	*Achnanthidium minutissimum*	Bacillariophyta	1.04E+05	8.07E+06
B1	10/27/2010	*Amphora pediculus*	Bacillariophyta	2.83E+04	1.42E+06
B1	10/27/2010	*Amphora sp.*	Bacillariophyta	6.29E+03	6.92E+05
B1	10/27/2010	*Asterionella formosa*	Bacillariophyta	1.89E+04	1.75E+07
B1	10/27/2010	*Aulacoseira spp.*	Bacillariophyta	9.44E+04	8.00E+06
B1	10/27/2010	*Caloneis sp.*	Bacillariophyta	3.15E+03	1.41E+06
B1	10/27/2010	*Cocconeis placentula*	Bacillariophyta	5.66E+04	2.35E+07
B1	10/27/2010	*Craticula sp.*	Bacillariophyta	3.15E+03	5.19E+05
B1	10/27/2010	*Cyclostephanos invisitatus*	Bacillariophyta	3.15E+04	2.67E+06
B1	10/27/2010	*Cyclotella ocellata*	Bacillariophyta	3.15E+03	2.67E+05
B1	10/27/2010	*Diatoma moniliformis*	Bacillariophyta	2.20E+04	6.54E+06
B1	10/27/2010	*cf. Discostella pseudostelligera*	Bacillariophyta	2.83E+04	1.88E+07
B1	10/27/2010	*Encyonema minutum*	Bacillariophyta	1.26E+04	4.19E+06
B1	10/27/2010	*Epithemia sorex*	Bacillariophyta	1.26E+04	5.37E+06
B1	10/27/2010	*Fragilaria vaucheriae*	Bacillariophyta	3.77E+04	1.11E+07
B1	10/27/2010	*Gomphoneis olivacea*	Bacillariophyta	1.26E+04	1.41E+06
B1	10/27/2010	*Gomphoneis ventricosum*	Bacillariophyta	1.82E+03	1.71E+06
B1	10/27/2010	*Hannaea arcus*	Bacillariophyta	1.26E+04	7.29E+06
B1	10/27/2010	*Hantzschia amphioxys*	Bacillariophyta	2.52E+04	1.21E+07
B1	10/27/2010	*Navicula capitatoradiata*	Bacillariophyta	6.29E+03	7.91E+06
B1	10/27/2010	*Navicula margalithii*	Bacillariophyta	1.82E+03	3.19E+06
B1	10/27/2010	*Navicula spp.*	Bacillariophyta	2.83E+04	4.67E+06
B1	10/27/2010	*Nitzschia amphibia*	Bacillariophyta	9.44E+03	7.79E+05
B1	10/27/2010	*Nitzschia dissipata*	Bacillariophyta	3.15E+04	4.95E+06
B1	10/27/2010	*Nitzschia palea*	Bacillariophyta	7.55E+04	1.25E+07
B1	10/27/2010	*Nitzschia spp.*	Bacillariophyta	6.92E+04	2.70E+06
B1	10/27/2010	*Pinnularia sp.*	Bacillariophyta	1.82E+03	2.17E+06
B1	10/27/2010	*Planothidium lanceolatum*	Bacillariophyta	2.52E+04	2.96E+06
B1	10/27/2010	*Pseudostaurosira brevistriata*	Bacillariophyta	5.03E+04	6.52E+06
B1	10/27/2010	*Rhopalodia brebissonii*	Bacillariophyta	4.40E+04	4.62E+06
B1	10/27/2010	*Staurosirella leptostauron*	Bacillariophyta	1.82E+03	2.22E+06
B1	10/27/2010	*Stephanocyclus meneghiniana*	Bacillariophyta	5.03E+04	1.98E+07
B1	10/27/2010	*Stephanodiscus hantzschii*	Bacillariophyta	6.29E+03	4.18E+06
B1	10/27/2010	*Stephanodiscus niagarae*	Bacillariophyta	1.26E+04	1.86E+08
B1	10/27/2010	*cf. Synedra mazamaensis*	Bacillariophyta	6.29E+03	4.45E+06
B1	10/27/2010	*Synedra ulna*	Bacillariophyta	4.09E+04	1.00E+08
B1	10/27/2010	*Characium ambiguum*	Chlorophyta	3.15E+03	5.93E+05
B1	10/27/2010	*Sphaerocystis schroeteri*	Chlorophyta	6.29E+03	1.69E+06
B1	10/27/2010	*Chroomonas sp.*	Cryptophyta	6.29E+03	2.11E+07
B1	10/27/2010	*Cryptomonas ovata*	Cryptophyta	2.83E+04	3.41E+07
B1	10/27/2010	*Rhodomonas sp.*	Cryptophyta	2.26E+05	2.35E+07

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B1	10/27/2010	*Anabaena sp.*	Cyanobacteria	5.47E+06	3.58E+08
B1	10/27/2010	*Trachelomonas sp.*	Euglenophyta	4.40E+04	2.88E+06
B1	10/27/2010	*TOTAL*		6.76E+06	9.43E+08
B1	5/3/2011	*Achnanthidium spp.*	Bacillariophyta	0	5.33E+00
B1	5/3/2011	*Aulacoseira granulata*	Bacillariophyta	15	1.71E+04
B1	5/3/2011	*Cocconeis placentula*	Bacillariophyta	4	3.19E+03
B1	5/3/2011	*Cyclotella sp.*	Bacillariophyta	12	2.03E+03
B1	5/3/2011	*Cymbella sp.*	Bacillariophyta	4	9.25E+02
B1	5/3/2011	*Eunotia sp.*	Bacillariophyta	4	1.83E+02
B1	5/3/2011	*Fragilaria capucina*	Bacillariophyta	1	6.40E+01
B1	5/3/2011	*Fragilaria sp.*	Bacillariophyta	30	2.04E+03
B1	5/3/2011	*Gomphonema sp.*	Bacillariophyta	0	9.73E+01
B1	5/3/2011	*Rhoicosphenia curvata*	Bacillariophyta	8	1.47E+03
B1	5/3/2011	*Synedra delicatissima*	Bacillariophyta	0	4.84E+02
B1	5/3/2011	*Synedra spp.*	Bacillariophyta	4	1.74E+03
B1	5/3/2011	*Chlamydomonas spp.*	Chlorophyta	353	4.69E+04
B1	5/3/2011	*Mallomonas sp.*	Chrysophyta	18	4.64E+03
B1	5/3/2011	*Cryptomonas spp.*	Cryptophyta	88	6.96E+03
B1	5/3/2011	*Ceratium hirundinella*	Pyrrophyta	6	1.25E+04
B1	5/3/2011	*TOTAL*		546	1.00E+05
B3	5/3/2011	*Achnanthidium spp.*	Bacillariophyta	44	1.28E+03
B3	5/3/2011	*Cocconeis placentula*	Bacillariophyta	3	2.41E+03
B3	5/3/2011	*Cyclotella sp.*	Bacillariophyta	13	3.12E+03
B3	5/3/2011	*Diatoma vulgare*	Bacillariophyta	9	1.33E+03
B3	5/3/2011	*Encyonema sp.*	Bacillariophyta	0	5.58E+01
B3	5/3/2011	*Eunotia sp.*	Bacillariophyta	4	2.25E+02
B3	5/3/2011	*Fragilaria sp.*	Bacillariophyta	26	1.77E+03
B3	5/3/2011	*Navicula sp.*	Bacillariophyta	31	7.62E+03
B3	5/3/2011	*Neidium sp.*	Bacillariophyta	3	8.71E+02
B3	5/3/2011	*Rhoicosphenia curvata*	Bacillariophyta	4	8.46E+02
B3	5/3/2011	*Synedra spp.*	Bacillariophyta	13	6.39E+03
B3	5/3/2011	*Chlamydomonas spp.*	Chlorophyta	379	6.82E+04
B3	5/3/2011	*Mallomonas sp.*	Chrysophyta	9	2.35E+03
B3	5/3/2011	*Cryptomonas spp.*	Cryptophyta	57	4.35E+03
B3	5/3/2011	*TOTAL*		597	1.01E+05
B2	5/3/2011	*Achnanthidium spp.*	Bacillariophyta	26	6.08E+02
B2	5/3/2011	*Cocconeis placentula*	Bacillariophyta	22	1.43E+04
B2	5/3/2011	*Cyclotella sp.*	Bacillariophyta	13	2.02E+03

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B2	5/3/2011	*Diatoma vulgare*	Bacillariophyta	9	1.64E+03
B2	5/3/2011	*Epithemia sp.*	Bacillariophyta	4	1.52E+03
B2	5/3/2011	*Eunotia sp.*	Bacillariophyta	9	4.94E+02
B2	5/3/2011	*Fragilaria sp.*	Bacillariophyta	62	2.65E+03
B2	5/3/2011	*Melosira varians*	Bacillariophyta	35	2.31E+04
B2	5/3/2011	*Navicula sp.*	Bacillariophyta	3	4.71E+02
B2	5/3/2011	*Nitzschia sp.*	Bacillariophyta	0	3.96E+01
B2	5/3/2011	*Rhoicosphenia curvata*	Bacillariophyta	53	1.34E+04
B2	5/3/2011	*Stephanodiscus sp.*	Bacillariophyta	4	2.65E+03
B2	5/3/2011	*Synedra spp.*	Bacillariophyta	13	6.66E+03
B2	5/3/2011	*Chlamydomonas spp.*	Chlorophyta	185	2.18E+04
B2	5/3/2011	*Closterium spp.*	Chlorophyta	4	6.35E+02
B2	5/3/2011	*Stigeoclonium sp.*	Chlorophyta	126	1.55E+04
B2	5/3/2011	*Mallomonas sp.*	Chrysophyta	13	3.81E+03
B2	5/3/2011	*Cryptomonas spp.*	Cryptophyta	44	3.53E+03
B2	5/3/2011	*TOTAL*		627	1.15E+05
B1	5/3/2011	*Aulacoseira sp.*	Bacillariophyta	1	1.21E+02
B1	5/3/2011	*Eunotia sp.*	Bacillariophyta	6	2.63E+02
B1	5/3/2011	*Nitzschia sp.*	Bacillariophyta	0	1.12E+02
B1	5/3/2011	*Chlamydomonas spp.*	Chlorophyta	194	3.78E+04
B1	5/3/2011	*Monoraphidium sp.*	Chlorophyta	106	1.27E+03
B1	5/3/2011	*Mallomonas sp.*	Chrysophyta	6	1.64E+03
B1	5/3/2011	*Cryptomonas spp.*	Cryptophyta	26	2.01E+03
B1	5/3/2011	*Cylindrospermopsis raciborskii*	Cyanobacteria	1613	9.68E+03
B1	5/3/2011	*TOTAL*		1952	5.29E+04
B2	6/1/2011	*Achnanthidium spp.*	Bacillariophyta	84	2.09E+03
B2	6/1/2011	*Aulacoseira sp.*	Bacillariophyta	0	6.56E+01
B2	6/1/2011	*Cocconeis placentula*	Bacillariophyta	4	3.03E+03
B2	6/1/2011	*Cyclotella sp.*	Bacillariophyta	0	4.34E+01
B2	6/1/2011	*Cymbella sp.*	Bacillariophyta	3	7.60E+02
B2	6/1/2011	*Encyonema sp.*	Bacillariophyta	4	1.71E+03
B2	6/1/2011	*Fragilaria capucina*	Bacillariophyta	1	4.00E+01
B2	6/1/2011	*Melosira varians*	Bacillariophyta	18	1.10E+04
B2	6/1/2011	*Neidium sp.*	Bacillariophyta	0	7.46E+01
B2	6/1/2011	*Nitzschia sp.*	Bacillariophyta	6	5.94E+02
B2	6/1/2011	*Rhoicosphenia curvata*	Bacillariophyta	0	4.92E+01
B2	6/1/2011	*Stephanodiscus sp.*	Bacillariophyta	6	2.47E+03
B2	6/1/2011	*Synedra spp.*	Bacillariophyta	6	2.86E+03
B2	6/1/2011	*Chlamydomonas spp.*	Chlorophyta	450	6.38E+04

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B2	6/1/2011	*Monoraphidium sp.*	Chlorophyta	9	1.04E+02
B2	6/1/2011	*Mallomonas sp.*	Chrysophyta	4	1.09E+03
B2	6/1/2011	*Cryptomonas spp.*	Cryptophyta	137	1.07E+04
B2	6/1/2011	*TOTAL*		731	1.00E+05
B1	10/2/2011	*Achnanthidium spp.*	Bacillariophyta	17	4.63E+02
B1	10/2/2011	*Aulacoseira granulata*	Bacillariophyta	0	2.11E+02
B1	10/2/2011	*Cocconeis placentula*	Bacillariophyta	3	2.49E+03
B1	10/2/2011	*Cyclotella sp.*	Bacillariophyta	8	1.89E+03
B1	10/2/2011	*Fragilaria capucina*	Bacillariophyta	6	2.57E+02
B1	10/2/2011	*Fragilaria sp.*	Bacillariophyta	1	2.88E+01
B1	10/2/2011	*Gomphonema sp.*	Bacillariophyta	0	5.81E+01
B1	10/2/2011	*Melosira varians*	Bacillariophyta	0	1.38E+02
B1	10/2/2011	*Rhoicosphenia curvata*	Bacillariophyta	1	2.94E+02
B1	10/2/2011	*Synedra spp.*	Bacillariophyta	0	4.95E+01
B1	10/2/2011	*Chlamydomonas spp.*	Chlorophyta	17	2.63E+03
B1	10/2/2011	*Cryptomonas spp.*	Cryptophyta	25	1.76E+03
B1	10/2/2011	*Anabaena spp.*	Cyanobacteria	5	4.14E+01
B1	10/2/2011	*Aphanizomenon flos-aquae*	Cyanobacteria	5240	4.19E+04
B1	10/2/2011	*TOTAL*		5322	5.22E+04
B2	10/2/2011	*Achnanthidium spp.*	Bacillariophyta	4	9.00E+01
B2	10/2/2011	*Aulacoseira granulata*	Bacillariophyta	11	1.13E+04
B2	10/2/2011	*Cyclotella sp.*	Bacillariophyta	4	1.16E+03
B2	10/2/2011	*Encyonema sp.*	Bacillariophyta	1	5.33E+02
B2	10/2/2011	*Epithemia sp.*	Bacillariophyta	0	8.40E+01
B2	10/2/2011	*Fragilaria capucina*	Bacillariophyta	0	9.80E+00
B2	10/2/2011	*Fragilaria sp.*	Bacillariophyta	6	2.28E+02
B2	10/2/2011	*Chlamydomonas spp.*	Chlorophyta	4	6.47E+02
B2	10/2/2011	*Cryptomonas spp.*	Cryptophyta	3	2.23E+02
B2	10/2/2011	*Anabaena flos-aquae*	Cyanobacteria	206	2.36E+04
B2	10/2/2011	*Anabaena spp.*	Cyanobacteria	94	2.54E+03
B2	10/2/2011	*Aphanizomenon flos-aquae*	Cyanobacteria	18566	1.30E+05
B2	10/2/2011	*Woronichinia sp.*	Cyanobacteria	17	1.49E+02
B2	10/2/2011	*TOTAL*		18917	1.71E+05
B3	10/2/2011	*Aulacoseira granulata*	Bacillariophyta	57	5.80E+04
B3	10/2/2011	*Diatoma vulgare*	Bacillariophyta	19	2.91E+03
B3	10/2/2011	*Eunotia sp.*	Bacillariophyta	1	3.13E+01
B3	10/2/2011	*Stephanodiscus sp.*	Bacillariophyta	10	6.09E+03
B3	10/2/2011	*Anabaena flos-aquae*	Cyanobacteria	9521	1.13E+06

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B3	10/2/2011	*Anabaena spp.*	Cyanobacteria	63	1.75E+03
B3	10/2/2011	*Aphanizomenon flos-aquae*	Cyanobacteria	163970	1.31E+06
B3	10/2/2011	*Aphanocapsa sp.*	Cyanobacteria	17808	2.49E+05
B3	10/2/2011	*Chroococcus minutus*	Cyanobacteria	1587	1.54E+05
B3	10/2/2011	*Chroococcus sp.*	Cyanobacteria	4055	2.35E+05
B3	10/2/2011	*Coelosphaerium kuetzingianum*	Cyanobacteria	27	3.47E+02
B3	10/2/2011	*Merismopedia spp.*	Cyanobacteria	171	1.88E+03
B3	10/2/2011	*Microcystis flos-aquae*	Cyanobacteria	1752	2.63E+04
B3	10/2/2011	*TOTAL*		199039	3.18E+06
B1	5/9/2012	*Asterionella formosa*	Bacillariophyta	1.26E+01	8.02E+03
B1	5/9/2012	*Fragilaria crotonensis*	Bacillariophyta	1.26E+01	2.65E+03
B1	5/9/2012	*Nitzschia sp.*	Bacillariophyta	6.29E+00	1.25E+03
B1	5/9/2012	*Planothidium lanceolatum*	Bacillariophyta	1.82E+00	3.00E+02
B1	5/9/2012	*Synedra tenera*	Bacillariophyta	6.29E+00	1.38E+03
B1	5/9/2012	*Ankyra judayi*	Chlorophyta	9.44E+00	1.07E+03
B1	5/9/2012	*Botryococcus braunii*	Chlorophyta	3.07E+02	1.44E+05
B1	5/9/2012	*Chlamydomonas sp.*	Chlorophyta	2.20E+01	2.77E+03
B1	5/9/2012	*Coelastrum microporum*	Chlorophyta	1.01E+02	1.42E+03
B1	5/9/2012	*Monoraphidium sp.*	Chlorophyta	2.52E+01	1.16E+03
B1	5/9/2012	*Dinobryon sp.*	Chrysophyta	1.26E+01	6.40E+03
B1	5/9/2012	*Mallomonas akrokomos*	Chrysophyta	1.26E+01	1.48E+03
B1	5/9/2012	*Chroomonas sp.*	Cryptophyta	8.18E+01	4.28E+03
B1	5/9/2012	*Cryptomonas marssonii*	Cryptophyta	3.65E+02	5.78E+05
B1	5/9/2012	*Cryptomonas ovata*	Cryptophyta	2.61E+02	1.92E+05
B1	5/9/2012	*Rhodomonas sp.*	Cryptophyta	5.66E+02	2.96E+04
B1	5/9/2012	*Aphanocapsa sp.*	Cyanobacteria	7.23E+02	3.03E+03
B1	5/9/2012	*TOTAL*		2.53E+03	9.79E+05
B2	5/9/2012	*Aulacoseira sp.*	Bacillariophyta	9.08E+00	5.35E+02
B2	5/9/2012	*Cocconeis placentula*	Bacillariophyta	5.35E+00	3.44E+03
B2	5/9/2012	*Eunotia sp.*	Bacillariophyta	5.35E+00	7.18E+02
B2	5/9/2012	*Fragilaria capucina*	Bacillariophyta	2.14E+01	8.82E+03
B2	5/9/2012	*Fragilaria crotonensis*	Bacillariophyta	4.00E-01	3.36E+02
B2	5/9/2012	*Planothidium lanceolatum*	Bacillariophyta	5.35E+00	1.01E+03
B2	5/9/2012	*Puncticulata bodanica*	Bacillariophyta	1.60E+01	3.64E+04
B2	5/9/2012	*Stephanocyclus meneghiniana*	Bacillariophyta	1.82E+00	1.21E+03
B2	5/9/2012	*Characium sp.*	Chlorophyta	5.35E+00	9.24E+02
B2	5/9/2012	*Chlamydomonas sp.*	Chlorophyta	1.07E+01	1.01E+03
B2	5/9/2012	*cf. Chlorella sp.*	Chlorophyta	6.95E+01	2.33E+03
B2	5/9/2012	*Coelastrum sphaericum*	Chlorophyta	6.10E+02	3.99E+04

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B2	5/9/2012	*Monoraphidium tortile*	Chlorophyta	5.35E+00	4.79E+02
B2	5/9/2012	*Mallomonas akrokomos*	Chrysophyta	1.07E+01	8.06E+02
B2	5/9/2012	*Mallomonas sp.*	Chrysophyta	5.35E+00	1.68E+03
B2	5/9/2012	*Pseudokephyrion ellipsoideum*	Chrysophyta	5.35E+00	1.26E+02
B2	5/9/2012	*Chroomonas sp.*	Cryptophyta	1.60E+01	8.40E+02
B2	5/9/2012	*Cryptomonas marssonii*	Cryptophyta	3.21E+02	2.37E+05
B2	5/9/2012	*Cryptomonas ovata*	Cryptophyta	2.46E+02	2.06E+05
B2	5/9/2012	*Rhodomonas sp.*	Cryptophyta	3.42E+02	1.79E+04
B2	5/9/2012	*Anabaena sp.*	Cyanobacteria	2.98E+02	1.95E+04
B2	5/9/2012	*Trachelomonas sp.*	Euglenophyta	1.82E+00	3.04E+02
B2	5/9/2012	*TOTAL*		2.01E+03	5.81E+05
B3	5/9/2012	*Cocconeis placentula*	Bacillariophyta	4.46E+00	5.08E+03
B3	5/9/2012	*Encyonema silesiacum*	Bacillariophyta	2.23E+00	1.47E+03
B3	5/9/2012	*Gomphonema sp.*	Bacillariophyta	1.82E+00	6.72E+02
B3	5/9/2012	*Navicula sp.*	Bacillariophyta	2.23E+00	2.18E+03
B3	5/9/2012	*Synedra sp.*	Bacillariophyta	1.82E+00	3.59E+02
B3	5/9/2012	*Chlamydomonas sp.*	Chlorophyta	4.68E+01	5.29E+03
B3	5/9/2012	*Coelastrum microporum*	Chlorophyta	1.76E+01	7.37E+01
B3	5/9/2012	*Monoraphidium tortile*	Chlorophyta	8.69E+01	3.46E+03
B3	5/9/2012	*Mallomonas akrokomos*	Chrysophyta	1.78E+01	4.43E+03
B3	5/9/2012	*Cryptomonas marssonii*	Cryptophyta	1.29E+02	1.72E+05
B3	5/9/2012	*Cryptomonas ovata*	Cryptophyta	3.32E+02	3.30E+05
B3	5/9/2012	*Rhodomonas sp.*	Cryptophyta	3.05E+02	8.95E+03
B3	5/9/2012	*TOTAL*		9.48E+02	5.34E+05
B1	10/9/2012	*Achnanthidium minutissimum*	Bacillariophyta	7.35E+04	4.50E+06
B1	10/9/2012	*Asterionella formosa*	Bacillariophyta	5.45E+03	3.59E+06
B1	10/9/2012	*Cocconeis placentula*	Bacillariophyta	3.63E+03	4.99E+06
B1	10/9/2012	*Cyclotella ocellata*	Bacillariophyta	1.07E+05	2.04E+07
B1	10/9/2012	*Encyonema minutum*	Bacillariophyta	1.34E+04	3.74E+06
B1	10/9/2012	*Epithemia sorex*	Bacillariophyta	1.00E+02	2.03E+05
B1	10/9/2012	*Navicula cryptotenella*	Bacillariophyta	6.68E+03	2.28E+06
B1	10/9/2012	*Nitzschia amphibia*	Bacillariophyta	1.34E+04	2.09E+06
B1	10/9/2012	*Nitzschia inconspicua*	Bacillariophyta	5.35E+04	2.73E+06
B1	10/9/2012	*Rhoicosphenia curvata*	Bacillariophyta	1.82E+03	1.41E+06
B1	10/9/2012	*Staurosirella pinnata*	Bacillariophyta	1.34E+04	3.46E+06
B1	10/9/2012	*Stephanocyclus meneghiniana*	Bacillariophyta	1.82E+03	1.83E+06
B1	10/9/2012	*Stephanodiscus parvus*	Bacillariophyta	5.55E+05	6.41E+07
B1	10/9/2012	*Synedra tenera*	Bacillariophyta	6.68E+03	9.13E+05
B1	10/9/2012	*Synedra ulna*	Bacillariophyta	6.68E+03	1.97E+07

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B1	10/9/2012	*Botryococcus braunii*	Chlorophyta	5.25E+04	2.31E+06
B1	10/9/2012	*Chlamydomonas sp.*	Chlorophyta	6.02E+04	4.57E+07
B1	10/9/2012	*Pyramimonas tetrarhynchus*	Chlorophyta	3.07E+05	4.10E+08
B1	10/9/2012	*Mallomonas sp.*	Chrysophyta	2.01E+04	4.96E+07
B1	10/9/2012	*Cryptomonas sp.*	Cryptophyta	7.35E+04	2.26E+07
B1	10/9/2012	*Rhodomonas spp.*	Cryptophyta	1.38E+06	1.95E+08
B1	10/9/2012	*TOTAL*		2.76E+06	8.62E+08
B2	10/9/2012	*Achnanthidium minutissimum*	Bacillariophyta	5.35E+04	3.53E+06
B2	10/9/2012	*Asterionella formosa*	Bacillariophyta	3.63E+03	2.43E+06
B2	10/9/2012	*Aulacoseira granulata*	Bacillariophyta	1.78E+04	1.08E+07
B2	10/9/2012	*Cocconeis placentula*	Bacillariophyta	1.82E+03	1.88E+06
B2	10/9/2012	*Cyclotella ocellata*	Bacillariophyta	5.35E+04	8.06E+06
B2	10/9/2012	*Encyonema minutum*	Bacillariophyta	8.91E+03	3.83E+06
B2	10/9/2012	*Fragilaria capucina*	Bacillariophyta	3.63E+03	2.43E+06
B2	10/9/2012	*Navicula trivialis*	Bacillariophyta	1.82E+03	4.26E+06
B2	10/9/2012	*Nitzschia inconspicua*	Bacillariophyta	3.56E+04	1.82E+06
B2	10/9/2012	*Nitzschia palea*	Bacillariophyta	4.46E+04	1.68E+07
B2	10/9/2012	*Planothidium lanceolatum*	Bacillariophyta	8.91E+03	7.84E+06
B2	10/9/2012	*Staurosirella pinnata*	Bacillariophyta	2.67E+04	6.30E+06
B2	10/9/2012	*Stephanodiscus niagarae*	Bacillariophyta	1.00E+02	1.61E+06
B2	10/9/2012	*Stephanodiscus parvus*	Bacillariophyta	8.11E+05	9.36E+07
B2	10/9/2012	*Botryococcus braunii*	Chlorophyta	3.56E+05	1.57E+07
B2	10/9/2012	*Characium ambiguum*	Chlorophyta	8.91E+03	3.64E+05
B2	10/9/2012	*Pyramimonas tetrarhynchus*	Chlorophyta	3.56E+04	2.60E+07
B2	10/9/2012	*Mallomonas sp.*	Chrysophyta	1.25E+05	3.51E+08
B2	10/9/2012	*Rhodomonas spp.*	Cryptophyta	2.41E+06	3.40E+08
B2	10/9/2012	*Trachelomonas sp.*	Euglenophyta	6.24E+04	3.14E+07
B2	10/9/2012	*TOTAL*		4.07E+06	9.29E+08
B1	4/12/2013	*Achnanthidium minutissimum*	Bacillariophyta	4.28E+04	2.82E+06
B1	4/12/2013	*Cocconeis placentula*	Bacillariophyta	3.63E+03	4.64E+06
B1	4/12/2013	*Diatoma mesodon*	Bacillariophyta	2.14E+04	1.21E+07
B1	4/12/2013	*Diatoma moniliformis*	Bacillariophyta	7.26E+03	4.22E+06
B1	4/12/2013	*Encyonema minutum*	Bacillariophyta	4.00E+02	1.87E+05
B1	4/12/2013	*Fragilaria capucina*	Bacillariophyta	7.26E+03	3.97E+06
B1	4/12/2013	*Navicula veneta*	Bacillariophyta	3.63E+03	1.28E+06
B1	4/12/2013	*Nitzschia amphibia*	Bacillariophyta	2.14E+04	3.21E+06
B1	4/12/2013	*Nitzschia perminuta*	Bacillariophyta	2.14E+04	2.05E+06
B1	4/12/2013	*Pseudostaurosira brevistriata*	Bacillariophyta	1.80E+03	1.50E+06
B1	4/12/2013	*Rhoicosphenia curvata*	Bacillariophyta	4.28E+04	3.94E+07

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B1	4/12/2013	*Staurosirella pinnata*	Bacillariophyta	8.56E+04	2.82E+07
B1	4/12/2013	*Stephanodiscus niagarae*	Bacillariophyta	2.14E+04	3.88E+08
B1	4/12/2013	*Stephanodiscus parvus*	Bacillariophyta	3.98E+06	4.59E+08
B1	4/12/2013	*Synedra ulna*	Bacillariophyta	3.63E+03	1.87E+07
B1	4/12/2013	*Pyramimonas tetrarhynchus*	Chlorophyta	8.56E+04	6.23E+07
B1	4/12/2013	*Mallomonas pseudocoronata*	Chrysophyta	1.71E+05	3.83E+08
B1	4/12/2013	*Mallomonas sp.*	Chrysophyta	4.28E+04	1.81E+08
B1	4/12/2013	*Rhodomonas spp.*	Cryptophyta	2.87E+06	2.43E+08
B1	4/12/2013	*Raphidiopsis curvata*	Cyanobacteria	9.41E+05	2.96E+06
B1	4/12/2013	*Trachelomonas sp.*	Euglenophyta	8.77E+05	8.36E+08
B1	4/12/2013	*TOTAL*		9.25E+06	2.68E+09
B3	4/12/2013	*Achnanthidium minutissimum*	Bacillariophyta	3.21E+05	2.12E+07
B3	4/12/2013	*Asterionella formosa*	Bacillariophyta	7.26E+03	4.87E+06
B3	4/12/2013	*Aulacoseira granulata*	Bacillariophyta	8.56E+04	3.29E+07
B3	4/12/2013	*Cocconeis placentula*	Bacillariophyta	4.00E+02	4.90E+05
B3	4/12/2013	*Cymbella cistula*	Bacillariophyta	3.63E+03	1.02E+07
B3	4/12/2013	*Diatoma moniliformis*	Bacillariophyta	4.28E+04	1.17E+07
B3	4/12/2013	*Epithemia sorex*	Bacillariophyta	3.63E+03	1.17E+07
B3	4/12/2013	*Fragilaria capucina*	Bacillariophyta	3.63E+03	8.90E+05
B3	4/12/2013	*Hannaea arcus*	Bacillariophyta	4.00E+02	5.94E+05
B3	4/12/2013	*Melosira varians*	Bacillariophyta	3.63E+03	2.37E+07
B3	4/12/2013	*Navicula cryptotenella*	Bacillariophyta	3.63E+03	1.16E+06
B3	4/12/2013	*Nitzschia amphibia*	Bacillariophyta	7.26E+03	9.59E+05
B3	4/12/2013	*Nitzschia dissipata*	Bacillariophyta	2.14E+04	1.16E+06
B3	4/12/2013	*Nitzschia inconspicua*	Bacillariophyta	6.42E+04	3.47E+06
B3	4/12/2013	*Nitzschia palea*	Bacillariophyta	3.63E+03	2.40E+06
B3	4/12/2013	*Rhoicosphenia curvata*	Bacillariophyta	2.14E+04	1.68E+07
B3	4/12/2013	*Stephanodiscus parvus*	Bacillariophyta	3.12E+06	3.61E+08
B3	4/12/2013	*Synedra tenera*	Bacillariophyta	3.63E+03	4.62E+05
B3	4/12/2013	*Synedra ulna*	Bacillariophyta	2.00E+02	7.48E+05
B3	4/12/2013	*Pyramimonas tetrarhynchus*	Chlorophyta	1.50E+05	1.09E+08
B3	4/12/2013	*Selenastrum gracile*	Chlorophyta	2.14E+04	1.81E+06
B3	4/12/2013	*Mallomonas sp.*	Chrysophyta	8.56E+04	9.76E+07
B3	4/12/2013	*Rhodomonas spp.*	Cryptophyta	3.70E+06	5.22E+08
B3	4/12/2013	*Raphidiopsis curvata*	Cyanobacteria	7.06E+05	2.22E+06
B3	4/12/2013	*Trachelomonas sp.*	Euglenophyta	8.98E+05	9.88E+08
B3	4/12/2013	*TOTAL*		9.28E+06	2.23E+09
B2	4/12/2013	*Achnanthidium minutissimum*	Bacillariophyta	1.60E+05	9.83E+06
B2	4/12/2013	*Cocconeis placentula*	Bacillariophyta	3.63E+03	4.08E+06

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B2	4/12/2013	*Cymbella cistula*	Bacillariophyta	3.63E+03	1.08E+07
B2	4/12/2013	*Diatoma moniliformis*	Bacillariophyta	2.67E+04	4.79E+06
B2	4/12/2013	*Diatoma vulgaris*	Bacillariophyta	3.63E+03	1.60E+07
B2	4/12/2013	*Nitzschia inconspicua*	Bacillariophyta	2.41E+05	1.23E+07
B2	4/12/2013	*Nitzschia perminuta*	Bacillariophyta	2.67E+04	2.33E+06
B2	4/12/2013	*Planothidium lanceolatum*	Bacillariophyta	2.00E+02	1.08E+05
B2	4/12/2013	*Pseudostaurosira brevistriata*	Bacillariophyta	4.72E+04	2.80E+07
B2	4/12/2013	*Rhoicosphenia curvata*	Bacillariophyta	1.34E+05	1.29E+08
B2	4/12/2013	*Staurosirella pinnata*	Bacillariophyta	2.67E+04	1.18E+07
B2	4/12/2013	*Stephanodiscus parvus*	Bacillariophyta	5.32E+06	6.14E+08
B2	4/12/2013	*Synedra ulna*	Bacillariophyta	4.00E+02	1.12E+06
B2	4/12/2013	*Pyramimonas tetrarhynchus*	Chlorophyta	1.07E+05	8.13E+07
B2	4/12/2013	*Scenedesmus quadricauda*	Chlorophyta	1.45E+04	1.22E+06
B2	4/12/2013	*Mallomonas sp.*	Chrysophyta	1.34E+05	1.19E+08
B2	4/12/2013	*Rhodomonas spp.*	Cryptophyta	4.30E+06	6.07E+08
B2	4/12/2013	*Raphidiopsis curvata*	Cyanobacteria	9.89E+05	3.11E+06
B2	4/12/2013	*Trachelomonas sp.*	Euglenophyta	4.81E+05	5.29E+08
B2	4/12/2013	*TOTAL*		1.20E+07	2.19E+09
B1	10/4/2013	*Asterionella formosa*	Bacillariophyta	3.21E+04	1.94E+07
B1	10/4/2013	*Aulacoseira granulata*	Bacillariophyta	8.56E+04	4.73E+07
B1	10/4/2013	*Cocconeis placentula*	Bacillariophyta	1.07E+04	1.16E+07
B1	10/4/2013	*Cymbella cistula*	Bacillariophyta	1.07E+04	1.94E+07
B1	10/4/2013	*Diatoma moniliformis*	Bacillariophyta	3.21E+04	1.11E+07
B1	10/4/2013	*Encyonema minutum*	Bacillariophyta	2.14E+04	5.99E+06
B1	10/4/2013	*Epithemia sorex*	Bacillariophyta	2.00E+02	7.62E+05
B1	10/4/2013	*Fragilaria capucina*	Bacillariophyta	6.42E+04	2.06E+07
B1	10/4/2013	*Gomphonema parvulum*	Bacillariophyta	3.63E+03	3.02E+06
B1	10/4/2013	*Gomphonema truncatum*	Bacillariophyta	7.26E+03	1.39E+07
B1	10/4/2013	*Gyrosigma sp.*	Bacillariophyta	2.00E+02	8.06E+05
B1	10/4/2013	*Meridion circulare*	Bacillariophyta	3.63E+03	2.42E+06
B1	10/4/2013	*Navicula cryptotenella*	Bacillariophyta	1.07E+05	4.87E+07
B1	10/4/2013	*Navicula trivialis*	Bacillariophyta	1.07E+04	3.41E+07
B1	10/4/2013	*Nitzschia amphibia*	Bacillariophyta	4.28E+04	5.39E+06
B1	10/4/2013	*Nitzschia inconspicua*	Bacillariophyta	3.96E+05	1.90E+07
B1	10/4/2013	*Nitzschia palea*	Bacillariophyta	2.14E+04	1.64E+07
B1	10/4/2013	*Nitzschia perminuta*	Bacillariophyta	4.28E+04	4.11E+06
B1	10/4/2013	*Planothidium lanceolatum*	Bacillariophyta	1.07E+04	8.23E+06
B1	10/4/2013	*Rhoicosphenia curvata*	Bacillariophyta	3.21E+04	3.22E+07
B1	10/4/2013	*Staurosirella pinnata*	Bacillariophyta	1.82E+05	4.28E+07
B1	10/4/2013	*Stephanocyclus meneghiniana*	Bacillariophyta	2.14E+04	6.77E+07

Station	Sample	*Genus*	Division	Density (cells/L)	Total Bv
B1	10/4/2013	*Stephanodiscus hantzschii*	Bacillariophyta	2.14E+04	2.15E+07
B1	10/4/2013	*Stephanodiscus parvus*	Bacillariophyta	1.88E+06	2.17E+08
B1	10/4/2013	*Synedra ulna*	Bacillariophyta	3.63E+03	7.46E+06
B1	10/4/2013	*Chlamydomonas sp.*	Chlorophyta	3.21E+04	3.14E+07
B1	10/4/2013	*Pyramimonas tetrarhynchus*	Chlorophyta	4.28E+04	3.12E+07
B1	10/4/2013	*Mallomonas sp.*	Chrysophyta	2.14E+04	7.12E+07
B1	10/4/2013	*Rhodomonas spp.*	Cryptophyta	1.21E+06	1.03E+08
B1	10/4/2013	*Trachelomonas sp.*	Euglenophyta	5.35E+04	7.06E+07
B1	10/4/2013	*TOTAL*		4.40E+06	9.88E+08
B2	10/4/2013	*Achnanthidium minutissimum*	Bacillariophyta	4.28E+04	2.62E+06
B2	10/4/2013	*Aulacoseira granulata*	Bacillariophyta	2.14E+04	9.05E+06
B2	10/4/2013	*Cymbella cistula*	Bacillariophyta	2.14E+04	5.59E+07
B2	10/4/2013	*Diatoma vulgaris*	Bacillariophyta	3.63E+03	1.45E+07
B2	10/4/2013	*Encyonema minutum*	Bacillariophyta	4.28E+04	1.92E+07
B2	10/4/2013	*Fragilaria capucina*	Bacillariophyta	4.28E+04	2.26E+07
B2	10/4/2013	*Gomphonema truncatum*	Bacillariophyta	2.00E+02	3.62E+05
B2	10/4/2013	*Gyrosigma sp.*	Bacillariophyta	2.00E+02	8.68E+05
B2	10/4/2013	*Mastogloia smithii*	Bacillariophyta	4.00E+02	1.60E+06
B2	10/4/2013	*Navicula cryptotenella*	Bacillariophyta	4.28E+04	1.41E+07
B2	10/4/2013	*Navicula lanceolata*	Bacillariophyta	2.00E+02	1.85E+06
B2	10/4/2013	*Navicula veneta*	Bacillariophyta	4.28E+04	1.63E+07
B2	10/4/2013	*Nitzschia amphibia*	Bacillariophyta	2.14E+04	4.11E+06
B2	10/4/2013	*Nitzschia inconspicua*	Bacillariophyta	1.07E+05	5.78E+06
B2	10/4/2013	*Nitzschia palea*	Bacillariophyta	1.71E+05	1.36E+08
B2	10/4/2013	*Planothidium lanceolatum*	Bacillariophyta	8.56E+04	4.52E+07
B2	10/4/2013	*Rhoicosphenia curvata*	Bacillariophyta	2.14E+04	2.14E+07
B2	10/4/2013	*Staurosirella pinnata*	Bacillariophyta	1.07E+05	2.52E+07
B2	10/4/2013	*Stephanocyclus meneghiniana*	Bacillariophyta	2.14E+04	8.13E+07
B2	10/4/2013	*Stephanodiscus parvus*	Bacillariophyta	4.02E+06	4.64E+08
B2	10/4/2013	*Synedra ulna*	Bacillariophyta	3.63E+03	1.25E+07
B2	10/4/2013	*Chlamydomonas sp.*	Chlorophyta	6.42E+04	9.88E+07
B2	10/4/2013	*Pyramimonas tetrarhynchus*	Chlorophyta	2.14E+04	2.02E+07
B2	10/4/2013	*Cryptomonas sp.*	Cryptophyta	1.28E+05	2.66E+07
B2	10/4/2013	*Rhodomonas spp.*	Cryptophyta	3.66E+06	5.16E+08
B2	10/4/2013	*Aphanizomenon flos-aquae*	Cyanobacteria	1.49E+05	2.34E+07
B2	10/4/2013	*Trachelomonas sp.*	Euglenophyta	6.42E+04	6.11E+07
B2	10/4/2013	*TOTAL*		8.91E+06	1.70E+09