Experimental Removal of Lake Trout in Swan Lake, MT: 2016 Annual Report

Prepared for the Swan Valley Bull Trout Working Group

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**Background**

The Swan Valley has historically been one of Montana’s strongest Bull Trout populations. However, in 1998, anglers began to occasionally catch adult sized (20-30 inch) Lake Trout from Swan Lake and the Swan River. This caused alarm because Lake Trout are not native and are notorious for rapidly expanding and dominating fish communities in lakes with *Mysis* shrimp, particularly at the expense of Bull Trout and Kokanee Salmon (Martinez et al. 2009). In 2003, the level of concern was compounded when biologists gillnetted juvenile Lake Trout from Swan Lake during standard low-intensity sampling efforts, indicating that wild reproduction was occurring. Since 2003, Lake Trout catch by anglers as well as during Montana Fish, Wildlife & Parks (FWP) biological sampling has continued to increase, another indication that the population was expanding. Research efforts from 2006-2008 focused on Lake Trout population demographics and exploring potential techniques to reduce Lake Trout numbers while minimizing Bull Trout bycatch. Based on case histories from nearby waters, managers determined that developing long-term management actions to control this increasing Lake Trout population was necessary in order to maintain the popular Bull Trout and Kokanee fisheries.

In 2009, FWP released an environmental assessment (EA) for a three-year experimental removal of Lake Trout in Swan Lake. This removal experiment was a feasibility study to determine the effectiveness of using targeted gillnetting as a technique to reduce the number of Lake Trout and thus minimize threats to Kokanee and Bull Trout. From 2009-2011, over 20,000 Lake Trout were removed from Swan Lake. Modeled total annual mortality rates for Lake Trout year classes vulnerable to the nets (Predominantly age-3 and 4) were higher than literature suggests are sustainable (50%). FWP released another EA in May 2012 for a five-year extension of the project to further evaluate the long-term effectiveness of the current Lake Trout suppression effort relative to measurable goals and specific success criteria outlined in the original 2009 EA. The 2016 netting season represents the final year of this 8-year experiment. The results of this assessment will assist FWP and the Swan Valley Bull Trout Working Group (SVBTWG) with decisions regarding fisheries management of Swan Lake.

Previous annual reports can be found at: [http://montanatu.org/resources/swan-valley-bull-trout/](http://montanatu.org/resources/swan-valley-bull-trout/)

**Methods**

Attempts were made to keep netting methods from 2009-2016 as consistent as possible. This consistency has allowed researchers to continue to remove Lake Trout from Swan Lake at a level that we believe should lead to long-term decline, while providing repeatable data for year-to-year comparisons and analysis.
Throughout the 8 years of netting, the project was composed of two distinct events. The first event (Juvenile Netting) was aimed at removing juvenile and subadult Lake Trout throughout the two deep (>60 feet) basins of Swan Lake. This removal was carried out using small-mesh (1.5 – 2.75 inch stretch) gill nets, set by professional fisheries contractors over a three-week period in late August. This netting was conducted during a time in which most adult Bull Trout were upstream in the Swan River drainage in preparation for fall spawning and also occurred during the period in which Swan Lake is thermally stratified. Netting occurred only below the thermocline (>60 feet) to reduce incidental bycatch of Bull Trout and other fish species which occupy shallower depths.

Since 2009, netting for juvenile Lake Trout has been contracted to Hickey Brothers Fisheries of Baileys Harbor, Wisconsin. Each year the boat was cleaned and disinfected following a Hazard Analysis and Critical Control Point Plan (HACCP) to minimize the risk of spreading aquatic invasive species. The boat was inspected annually by FWP personnel prior to entering Swan Lake to ensure proper cleaning procedures had been followed.

In the final year of this experiment, juvenile netting took place from August 1-26, 2016, representing the earliest start to the netting season. Prior to 2015 the contract with the Hickey Brothers always provided 30 lifts, with a lift being described as an event in which nets are set and retrieved. Insight gained over previous years revealed that the schedule of netting twice daily was exhausting crews and creating potentially dangerous working conditions. Therefore, in 2015, the schedule was adjusted to provide 22 lifts total, where every other day the nets would be set in the evening and retrieved the next morning. This strategy continued in 2016. Because the evening nets were left out for a longer duration, total soak time (net-hours) was similar amongst all years despite the reduction in lifts in 2015 and 2016 (Table 1). Although the number of net panels has varied since inception of the project, the locations of the nets have remained constant. With 2016 being the last year of the project, another change to the schedule was introduced to examine potential reasons for the declining catch rates observed from 2009-2015. Therefore in 2016 a one-week rest period was allowed between weeks of netting. This strategy was employed in an effort to determine if declining catch rates were due to depletion of the Lake Trout or displacement associated with behavioral changes.
Table 1: Dates and numbers of nets set for juvenile netting 2009-2016.

<table>
<thead>
<tr>
<th>Year</th>
<th>Netting Dates</th>
<th># Lifts</th>
<th># 900' Nets</th>
<th>Net-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Aug 24-Sept 11</td>
<td>30</td>
<td>248</td>
<td>1,946</td>
</tr>
<tr>
<td>2010</td>
<td>Aug 23-Sept 10</td>
<td>30</td>
<td>311</td>
<td>2,436</td>
</tr>
<tr>
<td>2011</td>
<td>Aug 22-Sept 9</td>
<td>30</td>
<td>399</td>
<td>3,173</td>
</tr>
<tr>
<td>2012</td>
<td>Aug 13-Aug 31</td>
<td>30</td>
<td>382</td>
<td>2,130</td>
</tr>
<tr>
<td>2013</td>
<td>Aug 11-Aug 30</td>
<td>30</td>
<td>347</td>
<td>2,059</td>
</tr>
<tr>
<td>2014</td>
<td>Aug 10-Aug 29</td>
<td>30</td>
<td>354</td>
<td>2,007</td>
</tr>
<tr>
<td>2015</td>
<td>Aug 10-Aug 28</td>
<td>22</td>
<td>255</td>
<td>1,965</td>
</tr>
<tr>
<td>2016</td>
<td>Aug 1-Aug 26</td>
<td>22</td>
<td>252</td>
<td>2,198</td>
</tr>
</tbody>
</table>

The second netting event (Spawner Netting) removes adult Lake Trout during spawning and thus is targeted to directly affect further recruitment. This portion of the project is carried out largely by SVBTWG members (with contractor assistance) and takes place during the month of October. Large-mesh gill nets (4.5 – 5 inch stretch) are set at night and during early morning hours, along spawning areas identified through sonic telemetry 2006-2008 and 2014-2015. Netting for spawning Lake Trout in 2016 was conducted from October 11-28, with nets being set and lifted twice daily, Monday-Friday. While netting did not occur twice every day (Friday afternoons, Saturdays, Sundays, and Monday mornings were not fished), the schedule and subsequent effort was similar to previous years of the project.

Table 2: Dates and numbers of nets set for spawner netting 2009-2016.

<table>
<thead>
<tr>
<th>Year</th>
<th>Netting Dates</th>
<th># Lifts</th>
<th># 900' Nets</th>
<th>Net-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Oct 6-Nov 5</td>
<td>16</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>2010</td>
<td>Sept 28-Oct 29</td>
<td>25</td>
<td>101</td>
<td>542</td>
</tr>
<tr>
<td>2011</td>
<td>Oct 4-Oct 28</td>
<td>24</td>
<td>161</td>
<td>623</td>
</tr>
<tr>
<td>2012</td>
<td>Oct 8-Oct 25</td>
<td>24</td>
<td>154</td>
<td>450</td>
</tr>
<tr>
<td>2013</td>
<td>Oct 7-Oct 25</td>
<td>23</td>
<td>153</td>
<td>1,020</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 6-Oct 24</td>
<td>25</td>
<td>155</td>
<td>1,349</td>
</tr>
<tr>
<td>2015</td>
<td>Oct 5-Oct 23</td>
<td>24</td>
<td>157</td>
<td>1,375</td>
</tr>
<tr>
<td>2016</td>
<td>Oct 11-Oct 28</td>
<td>26</td>
<td>151</td>
<td>1,345</td>
</tr>
</tbody>
</table>

Results and Discussion

Juvenile Netting

A total of 6,443 Lake Trout ranging in total length from 6-33 inches were removed during the 2016 juvenile netting period (Figure 1). This represented a slight
increase from 2015. However, the total number of Lake Trout has been relatively stable since 2012. It appears 2010 and 2012 represented strong year classes of age-3 and age-4 Lake Trout, and that this year’s number is consistent with the eight-year average (7,122 fish). The length frequency distribution of Lake Trout caught during the juvenile netting period continues to be heavily skewed toward smaller fish, a result of targeting areas containing high density juvenile Lake Trout and fishing smaller mesh nets (Figure 2). The majority of the juvenile Lake Trout catch is composed of age-3 and age-4 Lake Trout (Cox 2010). Incidental catch of other fish species during juvenile netting continues to be relatively low (Table 3).

![Bar chart showing total number of Lake Trout removed during juvenile netting 2009-2016.](chart.png)

**Figure 1:** Total number of Lake Trout removed during juvenile netting 2009-2016.
Figure 2: Relative length frequency of Lake Trout less than 500 mm (20 inches) total length caught during juvenile netting in Swan Lake 2009-2016.

Table 3: Bycatch of non-target fish species captured during juvenile and (spawner) netting events 2009-2016. Abbreviations are: BULL (Bull Trout), KOK (Kokanee), MWF (Mountain Whitefish), PWF (Pygmy Whitefish), LNSU (Longnose Sucker), NPM (Northern Pikeminnow), CSU (Largescale Sucker), RBT (Rainbow Trout), PIKE (Northern Pike). Most fish were released alive.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>BULL</td>
<td>238 (26)</td>
<td>212 (87)</td>
<td>237 (104)</td>
<td>334 (103)</td>
<td>168 (135)</td>
<td>146 (161)</td>
<td>74 (174)</td>
<td>52 (80)</td>
</tr>
<tr>
<td>KOK</td>
<td>205 (23)</td>
<td>414 (110)</td>
<td>159 (46)</td>
<td>521 (114)</td>
<td>388 (300)</td>
<td>138 (431)</td>
<td>166 (76)</td>
<td>499 (84)</td>
</tr>
<tr>
<td>MWF</td>
<td>107 (0)</td>
<td>28 (5)</td>
<td>31 (2)</td>
<td>67 (0)</td>
<td>104 (2)</td>
<td>93 (4)</td>
<td>15 (1)</td>
<td>70 (1)</td>
</tr>
<tr>
<td>PWF</td>
<td>139 (0)</td>
<td>63 (0)</td>
<td>9 (0)</td>
<td>79 (0)</td>
<td>27 (0)</td>
<td>11 (0)</td>
<td>28 (0)</td>
<td>2 (0)</td>
</tr>
<tr>
<td>LNSU</td>
<td>86 (50)</td>
<td>49 (306)</td>
<td>65 (145)</td>
<td>17 (207)</td>
<td>7 (157)</td>
<td>31 (213)</td>
<td>3 (234)</td>
<td>16 (118)</td>
</tr>
<tr>
<td>NPM</td>
<td>27 (36)</td>
<td>14 (136)</td>
<td>31 (131)</td>
<td>2 (68)</td>
<td>1 (132)</td>
<td>4 (147)</td>
<td>0 (141)</td>
<td>6 (71)</td>
</tr>
<tr>
<td>CSU</td>
<td>0 (58)</td>
<td>0 (109)</td>
<td>0 (111)</td>
<td>0 (54)</td>
<td>0 (96)</td>
<td>0 (147)</td>
<td>0 (134)</td>
<td>1 (244)</td>
</tr>
<tr>
<td>RBT</td>
<td>6 (3)</td>
<td>5 (10)</td>
<td>7 (11)</td>
<td>0 (11)</td>
<td>1 (11)</td>
<td>6 (16)</td>
<td>4 (19)</td>
<td>10 (30)</td>
</tr>
<tr>
<td>PIKE</td>
<td>0 (2)</td>
<td>0 (0)</td>
<td>0 (7)</td>
<td>0 (2)</td>
<td>1 (7)</td>
<td>0 (3)</td>
<td>0 (8)</td>
<td>0 (3)</td>
</tr>
</tbody>
</table>
The one-week rest period between weeks of netting did not appear to influence the number of Lake Trout caught during juvenile netting in 2016. Each year the juvenile netting period is examined by week and the rate of decline is used for population estimation (Figure 3). The rate of decline in 2016 was similar to most years of the project. This suggests that the observed decline in catch may be a result of depletion rather than displacement associated with behavioral changes. However, more research is warranted regarding these behavioral changes and potential avoidance.

![Figure 3: Lake Trout removed during each week of juvenile netting 2008-2016.](image)

**Spawner Netting**

The removal of adult Lake Trout to directly reduce recruitment was an important aspect of the project. Adult Lake Trout catch in 2016 was 601 fish, which represents the third consecutive year of increased catch (Figure 4). In order to maintain netting effort on the traditional spawning area and produce consistent data, the majority of nets (99) set for adult Lake Trout were placed along the same area fished from 2009-2013 (Highway 83 road cut). The remainder of the netting effort (52 nets) was placed in areas informed by acoustic telemetry. No additional sonic tags were implanted in adult Lake Trout in 2016. Because all previously implanted tags were either recovered in previous netting events or had batteries expire, no additional telemetry was conducted in 2016. Spawning locations identified in 2014-2015 were fished as “exploratory” sites in 2016. Differing from 2014-2015, gillnetting on the traditional locations in 2016 produced higher catch rates than the exploratory sites, with 428 fish caught along the road cut and 173 fish caught along the newly identified areas.
Relative length frequency of Lake Trout captured along the Highway 83 road cut (Traditional) during spawner netting continues to be skewed to smaller individuals, suggesting that previous efforts effectively exploited larger, older fish from that area (Figure 5). Similarly, after netting over newly identified areas (Exploratory) in 2014-2016 relative length frequency in those areas also shifted toward smaller individuals. This further reinforces the notion that targeted netting can affect the age distribution of adult fish in known spawning areas (Figure 6). Bycatch of fish species other than Lake Trout during spawner netting was similar to past years, with the exception of Bull Trout which will be described later in this document (Table 3).

![Figure 4: Total number of Lake Trout removed during spawner netting in Swan Lake 2009-2016. The red bars represent adult Lake Trout removed along the “traditional” spawning area and the blue bars represent adult Lake Trout removed over “exploratory” areas identified during 2014-2015 telemetry efforts.](image-url)
Figure 5: Relative length frequency of Lake Trout captured during spawner netting 2009-2016.

Figure 6: Relative length frequency of adult Lake Trout removed over “traditional” spawning areas in 2009 (blue) and 2016 (black), and “exploratory” spawning areas in 2014 (green) and 2016 (red).
**Bycatch of Bull Trout**

Throughout this program, Bull Trout bycatch has been closely monitored. A total of 132 Bull Trout were inadvertently captured as bycatch during combined project netting activities in 2016 (Figure 7). This is almost half of the previous lowest number (248 in 2015). The juvenile netting period resulted in only 41 Bull Trout being captured, with 11 more in the supplemental nets and 80 in the spawner netting.

![Bull Trout Bycatch by Year](image)

**Figure 7:** Bull Trout bycatch captured in juvenile and spawner netting programs on Swan Lake 2009-2016.

While it’s important to note that the juvenile Lake Trout suppression netting is not designed to capture Bull Trout (mostly set in water deeper than 60 feet), there is still a high degree of randomness and high likelihood the Bull Trout bycatch indices reflect real population change. Changes in net configurations to improve standardization, beginning in 2012, included incorporating a higher density of smaller (1.5”-2.25” stretch) mesh sizes and dropping larger (2.5” plus) mesh sizes during the juvenile netting. These changes may have enhanced Bull Trout capture rates. However, neither those changes nor other minor adjustments to locations and strategies in 2012-2016 can explain the over 50% decline in Bull Trout bycatch that has occurred since 2012.

**Declining Bull Trout Age Cohorts**

Because of this apparent declining trend in Bull Trout bycatch over the past five years, some additional analysis was performed. In order to examine age class cohorts, we assigned Bull Trout from the capture sample, by length, to age classes. Those age classes were pre-selected based on previously collected age/growth data for Swan Lake (Leathe et al. 1985). That analysis (Figure 8) shows that strong Bull Trout cohorts were produced in 2006, 2007, and 2008.
when redd counts were highest (Basin-wide totals of 656, 762, and 598 redds, respectively), and increasingly diminishing returns of Bull Trout occurred to the gillnet bycatch from cohorts spawned in 2009, 2010, 2011, and 2012 (Basin-wide totals of 481, 378, 297, and 383 redds, respectively).

**Figure 8:** Bull Trout bycatch from August juvenile Lake Trout suppression netting in Swan Lake for years 2008-2016, apportioned by assigned Age Class cohort.

As an aid in interpreting Figure 8, we present the following example. The 2007 spawning cohort produced 762 redds (legend), which resulted in the strongest year class to date of Bull Trout (black bars). Bull Trout from the 2007 spawning cohort were subsequently caught in gillnet bycatch in years 2011 (Age-3) through 2015 (Age-7). Contrast that with the 2009 spawning cohort (bright green) where the redd count of 481 translated to a relatively weak year class in the bycatch at Ages 3-6 (with Age-7 yet to be determined in bycatch in 2017).

Age-4 Bull Trout bycatch (the first year class that typically is fully recruited to the gillnets), seems to be a relatively strong predictor of year class strength. Age-4 bycatch, representing spawning cohorts 2007-2011, declined nearly 97% in the nets from 2012 (n = 188) to 2016 (n = 6). A decline this steep is not explainable by reduction in redd counts, even though there was a roughly 60% decline in redd numbers from the 2007 recent high to the 2011 observed low. Additionally, as previously discussed in depth in our 2015 report (Rosenthal et al. 2016), the stream juvenile abundance indices, which were designed to predict potential
recruitment to the lake, do not exhibit a declining trend despite the redd count reductions.

The declining gillnet bycatch indicators cause concern that juvenile and subadult Bull Trout populations in Swan Lake appear to be declining, and perhaps doing so at a much steeper rate than would be indicated by changes in the redd counts and juvenile abundance indices for those same cohorts in the stream system. Based on this observation, it is likely that disproportionately low survival of juvenile Bull Trout in Swan Lake is occurring, at least for fish emigrating to the lake from the 2009 and later spawning cohorts.

Alternatively, observed declines in Bull Trout bycatch could be due to behavioral (net avoidance) or spatiotemporal changes in the lake (e.g., water temperatures). It’s also possible that other external influences have caused the Bull Trout population to change in other ways (e.g., becoming more fluvial in behavior). However, these are unsupported hypotheses. It is our belief, based on the evidence, that a direct decline in numbers of juvenile and subadult Bull Trout in Swan Lake is most likely related to competition and/or predation from Lake Trout and other predators in Swan Lake.

The decline in Bull Trout numbers in Swan Lake bycatch begins to manifest itself at the earliest ages at which these fish recruit to our gillnet methods (i.e., Ages 3-4). This factor alone all but rules out gillnet bycatch as the primary cause of the recent decline, since weak year classes are present from the very beginning (e.g., in the first year(s) they can be netted) and these weak cohorts extend across the age spectrum. In addition, our previous analysis (Rosenthal and Fredenberg 2014) found that even under worst case scenarios existing levels of gillnet bycatch could reduce Bull Trout redd counts by 130-150 annually. An impact of that magnitude would not be sufficient to result in Bull Trout recruitment failure at the level we are witnessing.

Alternative Hypotheses and Corroborating Lines of Evidence
As a cautionary note, bycatch of Bull Trout in the juvenile Lake Trout suppression netting is only one line of evidence. That evidence indicates there is declining abundance of Age-3 and older Bull Trout in Swan Lake, with the declining trend first observed in 2013 and continuing through at least 2016.

However, if the indicators we are presently seeing in the lake are real, it could translate into Bull Trout redd counts declining in 2017 or beyond, and we are concerned a cascading decline in the Swan Lake Bull Trout population could ensue. Redd counts continue to be at an acceptable level and there is evidence of continuing strong recruitment from the tributaries, but if redd counts decline further the cascading effects might be severe.

As discussed in detail in the 2015 report (Rosenthal et al. 2016), we empirically derived an estimated mortality rate of 53.6% for Bull Trout caught in the bycatch and have applied that value to gillnetted Bull Trout throughout this
project. Applying this formula, the estimated bycatch mortality of Bull Trout in 2016 was calculated at 71 fish (i.e., 41 juvenile + 80 spawner + 11 supplemental = 132 X .536 = 71). Because of the declining bycatch, the calculated mortality in 2016 was correspondingly much lower than in any of the past years.

For the first time since 2011, there was also a fairly large decline in the Bull Trout bycatch during the October, 2016 Lake Trout spawner netting season. As this netting is less standardized and less randomized than the juvenile netting and focuses on only a small portion of the lake where Lake Trout concentrations during spawning are known to occur, we place less confidence in the spawner netting bycatch as a trend indicator. However, it is at least noteworthy that the 2016 bycatch during spawner netting (Figure 7) of 80 Bull Trout was less than half that observed in 2014 and 2015.

At least 26 Bull Trout of the total 132 captured in 2016 (a minimum of 19.7%) had been previously caught during this project and implanted with PIT Tags. This was the highest proportion of marked fish handled in the bycatch to date and another possible indicator that the Bull Trout numbers in the lake have declined. The 2016 result represented a roughly 40% increase in proportion of tagged fish over 2014 and 2015 results. We are continuing to investigate ways to use this recapture information to potentially generate Bull Trout population estimates or trend indicators.

In the 8 years since Lake Trout suppression efforts began (2009), there have been over 3,100 Bull Trout redds (i.e., spawning beds) counted in the 11 identified Swan spawning tributaries (described later in this report). Bull trout redd counts in the Swan drainage in 2016 were down slightly from 2014-2015, but largely consistent with 2010-2013 results. The 2016 spawning conditions were unusual, with a record high volume of October rainfall. It’s not known how these conditions may have affected redd distribution, but the unusually high flows did have some effect on ability of observers to locate and recognize redds.

**SUMMARY**

In conclusion, the lag time inherent in the metrics we use to monitor Bull Trout abundance, from spawning (redd counts), to stream recruitment (stream juvenile abundance) to subadult (Age-4, 5) and adult (Age-6+) abundance reflected as bycatch in the lake, may provide conflicting and even opposing signals. Each can only be judged on their own merits. The current evidence is that our indices measuring abundance of Bull Trout during early life history in the upstream spawning and rearing habitat of the Swan Lake core area remain relatively strong. However, there is also solid evidence that subadult populations in the lake have declined. The bottleneck appears to be developing at early (Age-3, 4) lake survival.
It seems inevitable that this observed subadult bottleneck will feed back into decreasing Bull Trout redd counts and contribute to some measure of declining recruitment of the Bull Trout population in the Swan Lake core area in the next few years. To what extent cascading events can be forestalled by controlling the factors causing the decline (ostensibly, Lake Trout competition and/or predation) or mitigated by shifts in the Bull Trout life history parameters (i.e., toward more fluvial or resident life history forms) is, at present, largely unknown.

In order to more adequately predict Bull Trout trends we recommend that the existing basin-wide redd count strategy be maintained, that juvenile recruitment indices in the spawning and rearing streams be modified and improved (as is currently in process), and that a better lake-wide population index be developed, either from a revised monitoring method or by re-interpreting existing tag and recapture information.

**Kokanee**

Nonnative Kokanee Salmon are another important fish species in Swan Lake. Kokanee provide a popular angling opportunity in Swan Lake for both ice and open-water fishermen and represent an important food resource for adult Bull Trout and Lake Trout. Case histories from surrounding area lakes have demonstrated that the combination of Mysis, Kokanee, Bull Trout, and Lake Trout typically results in decreased abundance of Bull Trout and elimination of Kokanee. Therefore, Kokanee represent a potentially sensitive indicator of Lake Trout abundance, as increases in Kokanee abundance may suggest a reduction in predatory Lake Trout density.

Kokanee abundance in Swan Lake is monitored annually through redd counts along an index reach of Swan Lake shoreline. Kokanee spawner abundance had declined from 2005-2011 and then incrementally increased reaching 739 redds in 2014 (Figure 9). Kokanee were last stocked in Swan Lake in 2005, and at least some of the decline from 2005-2011 could partially be a result of the cessation of planting. The 2016 survey revealed a total of 691 redds. This represented a considerable increase from the low count in 2015 and is similar to the recent counts since 2012. The low count in 2015 should be viewed with caution, as weather conditions during the 2015 survey made counting difficult and some redds may not have been seen. Kokanee bycatch during both netting periods can also be used to track their relative abundance and the 2016 results show an increase in the number of small Kokanee (Table 3).
Length frequency analysis of Kokanee inadvertently captured during the 2016 netting reveals no missing age classes in Swan Lake (Figure 10). Kokanee in the bycatch ranged from 5-20 inches (125-500 mm) with a strong peak of 200 mm (~8 in) probably representing age-2+ kokanee. Kokanee smaller than 7 inches were likely not captured as a result of the mesh sizes used for the netting. While no missing age classes were observed, there continue to be a noticeable reduction in the age-3+ Kokanee when compared to the 2014 data (Figure 10).
Evaluation Criteria

This Lake Trout removal project in Swan Lake was initiated to evaluate the efficacy of using gill nets to control the expansion of the Lake Trout population and simultaneously benefit Bull Trout and Kokanee. Criteria to evaluate this project were outlined in the original 2009 EA, and were monitored throughout the study. A previous review of these criteria with regard to the 2009-2011 efforts can be found in the 3-year Summary Report (Rosenthal et al. 2012). A comprehensive review of the criteria can be found below.

**TOTAL ANNUAL LAKE TROUT MORTALITY OF AT LEAST 50%**

Netting mortality of Lake Trout during juvenile netting has been evaluated annually. Total annual Lake Trout mortality rates more than 50% have been shown to cause population declines in traditional Lake Trout fisheries (Healey 1978). In Swan Lake, conservative estimates of exploitation (mortality) of age-3 and age-4 Lake Trout have been near 50% in most years since 2009 (Figure 11). These modeled estimates are most accurate for age-3 and age-4 fish, as they are the most vulnerable to the nets being deployed and the locations being sampled. We consider these estimates as “conservative”, as they use the upper confidence interval (95%) of the Lake Trout population estimate. These estimates should therefore be viewed with caution, as the true exploitation rate may be higher or lower. Estimates of exploitation on the spawning Lake Trout population are more difficult to acquire. Based on tag recaptures from the 2014 and 2015 sonic telemetry project, we can estimate exploitation on known spawning areas. Exploitation on known spawning areas was 54% in 2014 and 42% in 2015. When examining the Lake Trout population as a whole, it is unlikely that we are inflicting a total annual mortality in excess of 50%, as estimates show that at best we are inflicting 50% mortality on age-3 and age-4 Lake Trout and on age-7+ Lake Trout on known spawning areas. These exploitation rates do not apply to Lake Trout younger than age-3, Lake Trout age-5 to age-7, and adult Lake Trout spawning at unknown locations. It is likely that survival among the aforementioned groups of fish is high and that total annual mortality is likely less than would be expected if all age classes were vulnerable to netting.
TRENDS IN LAKE TROUT DENSITY, CONDITION, AND LENGTH OF SPAWNING FISH
Lake Trout density in Swan Lake is evaluated by examining the catch per unit effort during juvenile and spawner netting events. Lake Trout catch per unit effort during juvenile netting activities has been relatively consistent since the beginning of the project (Figure 12). This lack of trend in catch per unit effort suggests that spawner netting efforts have been insufficient to affect recruitment to a point in which the Lake Trout population is declining. Similarly, Lake Trout catch per unit effort in 4.5” and 5.0” mesh (stretch) nets set along the traditional spawning area show no significant decline (Figure 13). In fact, Lake Trout catch per unit effort appears to be increasing in recent years. The lack of a significant declining trend suggests that mortality rates from juvenile netting have not been sufficient to reduce recruitment of adult Lake Trout to the spawning grounds.

Figure 11: Modeled exploitation rates for Juvenile Netting 2010-2016.
Lake Trout condition in Swan Lake has been evaluated by examining the relative weight of Lake Trout captured in both netting events. Consistent with the work done by Cox (2010), we examined three different size classes of Lake Trout.
Immature Planktivorous Lake Trout (280-499 mm) are defined as juvenile fish that use Mysis as their primary food source. Immature Piscivorous Lake Trout (500-699 mm) are fish that have yet to reach spawning age but have made a diet shift to eating fish more than Mysis. Finally, Mature Piscivorous Lake Trout (>700 mm) are sexually mature individuals that eat other fish almost exclusively.

Relative weight data in all three life history stages shows no significant trend (Figure 14). This lack of trend suggests that there is no density-dependent relationship with regard to condition and that netting has not affected relative weight of the Lake Trout population.

**Figure 14: Lake Trout relative weight data from Swan Lake 2007-2016.**

The average length of spawning Lake Trout has also been monitored throughout the project. We would expect to see the average length decline if our efforts have been effective at removing the older portion of the Lake Trout population. As described previously, the relative length frequency distribution of Lake Trout captured during suppression efforts has shifted toward smaller individuals on known spawning areas (Figures 5 and 6). This finding suggests that gillnetting can be effective at exploiting the larger, older Lake Trout on previously identified spawning areas. This stresses the importance of periodic sonic telemetry, as it takes only a few successful spawners to create future cohorts of Lake Trout.

**TRENDS IN OTHER FISH POPULATIONS (BULL TROUT, KOKANEE, MYSIS)**

Trends associated with the Bull Trout population continue to be monitored as part of the success criteria. Maintaining or increasing the population of Bull Trout is something the SVBTWG has been working toward since their creation in 2005. Adult Bull Trout numbers are monitored annually through redd counts. Bull Trout redd counts have been counted in four index tributaries (Elk, Lion, Goat, and Squeezer) since 1982 (Figure 15) and have been counted in the other eight tributaries (North and South Lost, Main and South Woodward, Soup, Cold, Piper, and Jim) for a basin-wide survey since 1995 (Figure 16). The 2016 index count of 177 redds is 49% below the long-term average of 364 redds. Similarly, the 2016 basin-wide count of 348 redds is 40% below the 21-year average. Record precipitation in October of 2016 affected biologists’ ability to accurately conduct the surveys and the 2016 data should be viewed with caution. However, this year’s results were mostly consistent with those of the last seven years (range 312-428 basin-wide). While it appears as though this lower level of abundance is
stable, there remains concern about the trajectory of the redd count data in upcoming years. As mentioned previously, we have observed a substantial decline in the number of sub-adult Bull Trout captured as bycatch. This trend will likely translate into reduced redd numbers in subsequent surveys irrespective of any future Lake Trout harvest scenarios.

Figure 15: Bull trout redd counts in index streams of the Swan River drainage 1982-2016.

Figure 16: Basin-wide bull trout redd counts for the Swan River drainage 1995-2016.

Kokanee Salmon and *Mysis* shrimp also continue to be monitored. As described previously in the report, Kokanee numbers have remained relatively stable during
the past five years, after rebounding from the lowest spawning counts on record. The number of Kokanee captured as bycatch in the project has also been relatively stable with all age classes represented. This finding is of interest, as Kokanee Salmon are many times extirpated at the expense of Lake Trout. *Mysis* shrimp densities have been monitored since 1983 by vertical plankton tows at two locations (Figure 17). While *Mysis* densities appear to be variable, the 2016 survey revealed one of the lowest densities on record. However, the 2015 sample was consistent with the long term average.

![Graph showing Mysis shrimp densities in Swan Lake 1983-2016.](image)

**Figure 17: Mysis shrimp densities in Swan Lake 1983-2016.**

### 2017 Plans

The 2016 field season represented the final year of this eight-year experiment. The project was initiated to determine if a limited amount of gillnetting effort (3 weeks juvenile netting and 3 weeks spawner netting) could be an effective tool to reduce Lake Trout numbers and increase the Bull Trout and Kokanee populations. This project was given a discrete timeline and the information gained will provide biologists options for the future management of Lake Trout in Swan Lake. Alternatives regarding future Lake Trout harvest scenarios are currently being discussed through the SVBTWG, but currently there are no plans for Lake Trout suppression netting in 2017.

In the meantime, monitoring of the aquatic organisms will continue in the Swan Lake system. The routine spring gill net survey, which examines the entire fish community of Swan Lake, will occur in late May. Annual *Mysis* sampling occurs in early June. Bull Trout will continue to monitored through juvenile estimates in select spawning tributaries and basin-wide Bull Trout redd counts will be
conducted in October. Kokanee will continue to be monitored through redd counts completed in early December. In addition to these surveys, plans are currently underway to create a new survey to track Lake Trout abundance and mortality rates in Swan Lake. This survey is necessary to track trends in the Lake Trout population independent of any type of harvest scenario. This will allow biologists to better evaluate any proposed suppression alternatives.
References


