LAKE TROUT POPULATION ASSESSMENT METHODS: A COMPARISON OF SPIN AND MARK-RECAPTURE

CARIBOU LAKE 2012

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Summary

Environment Yukon has been surveying important fish stocks since 1991. We use these surveys to detect population changes and monitor population health. Along with angler harvest surveys, these data are also used to assess the sustainability and impact of fisheries.

Environment Yukon works with first nations, RRCs, and user groups to determine priority lakes for surveys. Criteria for identification of priority lakes include accessibility for anglers, sensitivity of the fish population, and management concern. The surveys focus on lake trout and lake whitefish, indicators of the health of northern lake ecosystems.

In 2009 we began using the SPIN method (Summer Profundal Index Netting; Sandstrom and Lester 2009) to assess fish populations. This method provides more reliable data useful for management with the resources we have available. To implement this new method, we compared it to the previous method (Jessup and Millar 2011) and assessed the repeatability of the results (Barker et al. 2014). In this study we again examined the repeatability of results and we also compared population estimates from SPIN to a population estimate using a mark-recapture method. This comparison was needed to understand the relationship between relative density (number of lake trout caught per net) and absolute density (number of lake trout per hectare) for Yukon lakes.

We carried out SPIN surveys on Caribou Lake in 2011 and 2012 and found a high density of small-bodied lake trout. In 2012 we captured 83 lake trout, resulting in a lake-wide CPUE (catch per unit effort) of 3.81 lake trout per net, and a lake-wide biomass CPUE of 1.71 kg of lake trout per net. The estimated density of lake trout in Caribou Lake was 55.9 lake trout/ha for a total of 2,851 fish in the lake (68% confidence interval: 2360 – 3,389). These results were very similar to those for the 2011 Caribou Lake SPIN survey, demonstrating the method's repeatability.

We also carried out a mark-recapture study to estimate the total number of fish in Caribou Lake. Based on these results we estimated a lake trout population size of 1,820 fish (68% confidence interval: 1,267 – 2,624) or 35.68 fish/ha. Our point estimates using mark-recapture were 32% – 36% less than the estimates derived from SPIN in 2011 and 2012, but the confidence intervals of all estimates overlap, meaning they are not statistically different.

More comparisons like these are needed to confidently validate the CPUE – density relationship for Yukon lakes. Work is ongoing nationally to improve the SPIN CPUE-density relationship.

Key Findings

- Caribou Lake is a very small lake with a high density of small-bodied lake trout.
- SPIN surveys in 2011 and 2012 found very similar results confirming the method's repeatability (under comparable conditions).
- Data from the independently-derived population estimates from mark-recapture and the SPIN survey will be used to refine the relationship between SPIN CPUE and lake trout density for Yukon.

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Introduction

Each year, Environment Yukon conducts assessments of fish populations, with a focus on lake trout and lake whitefish. Between 1991 and 2009, over 100 Yukon lakes were surveyed using small-mesh netting, a method based on the index netting techniques described by Lester et al. (1991). Beginning in 2010, we began to assess fish populations using a new method, Summer Profundal Index Netting (SPIN; Sandstrom and Lester, 2009). SPIN provides more statistically robust data and improves confidence in survey results (Jessup and Millar 2011).

We choose lakes for assessment based on the size of the active recreational fishery, the aboriginal subsistence fishery, and the commercial and domestic fisheries, as well as other available information. Lakes with heavy harvest pressure are surveyed on a regular basis.

The SPIN assessment involves setting gillnets at various sites in the lake and recording the catch and biological information about each fish caught. The survey usually tells us:

- relative abundance of lake trout and lake whitefish as measured by an index (CPUE, or catch per unit effort);
- changes in relative abundance from previous surveys;
- for lake trout, the estimated density (number of lake trout per hectare) and abundance (number of lake trout) in the lake;
- length and weight of individual lake trout and lake whitefish, as well as other species captured; and
- age and diet of any fish killed.

We previously surveyed Caribou Lake using small-mesh netting methods in 1996, 2001, and 2006, and using SPIN in 2011. Differences between the 2 survey methods mean that results between them cannot be compared statistically. Here we report the 2012 SPIN results, make direct comparisons with the 2011 SPIN survey, and make only subjective comparisons with previous surveys.

Refinement and application of SPIN to Yukon lakes

We first tested the SPIN method for assessing lake trout populations in 2009. We were looking for a method that would provide data that could be used as a basis for robust and defensible fisheries management recommendations and actions (Jessup and Millar 2011). The first survey was successful and suggested a path forward. As part of our implementation of this method we have compared it to the previous method (Jessup and Millar 2011) and assessed the repeatability of the results through multiple assessments on Fish Lake (Barker et al. 2014) and Lewes Lake (Jessup et al. 2012).

Parks Canada has also carried out multiple consecutive-year assessments of Kathleen Lake (Wong 2013).

We carried out these repeat assessments at different times of year to understand how seasonality and differences in environmental conditions affect the results. Based on these studies we have modified the timing of SPIN surveys in Yukon and ensured that both temperature and dissolved oxygen are measured for every survey.

Like the previous small-mesh netting method we used, SPIN produces a measure of relative abundance (CPUE, i.e., the average number of fish caught per net). SPIN also produces an absolute estimate of population size (how many fish there are in the lake). It does this by converting CPUE to fish density (i.e., number of fish per hectare). Fish density can be easily converted to a lake-wide abundance (i.e., number of fish/ha • lake area (ha) = number of fish). The conversion of CPUE to fish density is based on a relationship between CPUE and density established in Ontario. While this relationship may also hold for Yukon lakes, it needs to be validated before strong conclusions can be drawn on the absolute measures of fish populations. Any differences in lake trout behaviour or catchability between Yukon and Ontario could alter the relationship, affecting the density estimates. To verify the relationship in Yukon, independent estimates of population size, such as those obtained through mark-recapture studies, are needed on several Yukon lakes to compare with results from SPIN-derived estimates.

Here we conducted a first test of this relationship for Yukon by carrying out SPIN and a mark-recapture on the same population in the same year. We previously identified Caribou Lake as an ideal candidate for this test because of its high relative density but small total population size (Barker and Millar 2012). A mark-recapture study involves catching fish and applying an external visible tag (mark) to each one. Fish are then released back to the lake unharmed. After an appropriate period of time to allow mixing of the population, a second capture session (recapture) occurs. The total population can be estimated by comparing the number of marked fish relative to unmarked fish in the recapture while accounting for the number of fish that were initially marked.

We also used this study as another assessment of the repeatability of the SPIN method in consecutive years. We carried out the survey at similar times of year so that the environmental conditions would be as comparable as possible.

Study Area

Caribou Lake is located approximately 50 km southeast of Whitehorse, east of the northern end of Marsh Lake (Figure 1). The lake sits at an elevation of 820 m above sea level, is approximately 1.6 km long, and covers an area of 51 ha. It has a mean depth of 16.5 m and maximum depth of 21 m.

The lake is fed by a small unnamed creek at the north end, and drains westward into Marsh Lake via Caribou and Grayling creeks. Caribou Lake is highly productive compared to other Yukon lakes, with total dissolved solids (a measure of nutrients in the water) of 247 mg/l. Fish species known in Caribou Lake are lake trout, Arctic grayling, long nose suckers, burbot, lake chub, and slimy sculpins.

Access to Caribou Lake is by an unmaintained road from the Alaska Highway. There is no boat launch. There is one residence on the lake. Caribou Lake lies within an area of overlap between Carcross/Tagish First Nation and Kwanlin Dün First Nation Traditional Territories.

The recreational fishery at Caribou Lake has been managed under Special Management Water regulations since 2001. The catch and possession limits for lake trout are both one fish per day, and all lake trout over 65 cm must be released. The catch and possession limits for Arctic grayling are both 2 fish per day, and all grayling over 40 cm must be released. There are no northern pike in Caribou Lake. General catch and possession limits apply to all other fish species.

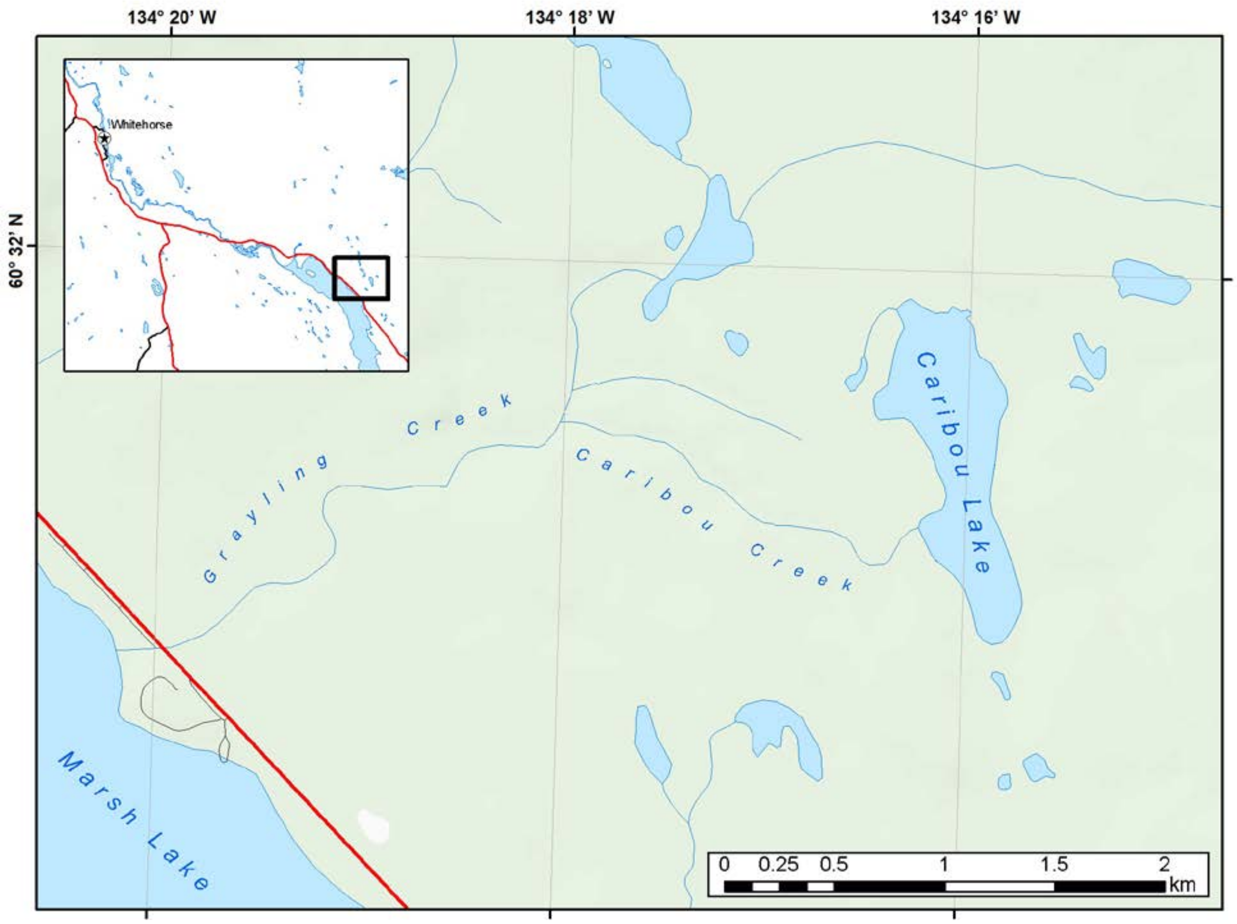

Figure 1. Location of Caribou Lake, Yukon.

Methods

SPIN Methods

We followed the Summer Profundal Index Netting (SPIN) method for lake trout assessment (Sandstrom and Lester 2009, Jessup and Millar 2011). Gillnets were set at different depths throughout the lake to capture lake trout and determine CPUE. Each 64 m gillnet was made up of 8 panels of monofilament mesh ranging in size from 57 mm to 127 mm (stretch mesh). We set each net for 2 hours.

Survey effort

We surveyed Caribou Lake 25 -27 June 2012. We set a total of 30 nets, divided among 4 depth strata (Table 1). We initially weighted the number of sets in each stratum by the surface area of the stratum. After the first day, distribution of effort was adjusted by concentrating on those strata with the highest catch rates. We chose the locations for setting the nets within each stratum randomly by using random point generation in ArcGIS 9.3. Any clumped distributions of points were manually dispersed to ensure coverage of the entire lake.

SPIN - Lake trout

We calculated the lake-wide catch per unit effort (CPUE) as the number of lake trout of "harvestable" size (300 mm and up) caught per net. Following SPIN protocols, we calculated CPUE using catch numbers adjusted to account for net selectivity bias based on lengths of lake trout captured (Sandstrom and Lester 2009).

CPUE is considered an index of abundance, and changes in the CPUE are thought to reflect actual changes in the lake trout population. CPUE can therefore be compared between surveys and used to detect population growth or decline. The method excludes fish below 300 mm because they are not usually captured by anglers.

We converted CPUE to density (fish/ha) based on the empirical relationship between CPUE and fish density that has been established for Ontario lakes. From this, we estimated a total population size by multiplying density by lake size (number of fish/ha • lake area (ha) = number of fish in lake).

Table 1. Effort breakdown by stratum.

Stratum	Depth range	Area (ha)	Area (%)	Nets Set	Nets Set (%)
1	**0 - 3 m**	13	25%	6	20%
2	**3 - 9 m**	17	33%	11	37%
3	**9 - 15m**	12	24%	8	27%
4	**> 15 m**	9	18%	5	17%
Total		51	100%	30	100%

We measured, weighed, and released all fish captured alive. Any fish that died was sampled for length, mass, sex, maturity, age (using otoliths or ear “bones”) and diet (stomach contents).

We used SPIN Support Systems Ver. 9.04 for calculations of CPUE, density, and population size, as well predictions of sample size and power for future surveys. Temperature and dissolved oxygen profiles were taken using a multi-parameter water quality probe (YSI 600QS; YSI Inc., Yellow Springs, OH).

Mark-recapture

We also used a mark-recapture to estimate lake trout abundance in Caribou Lake in 2012.

For the first capture, we angled for trout 6 – 9 June, 2012. We angled approximately 6 hours per day for a total of 11 angler days. Effort and catch was evenly distributed around the lake, with no more than 15 tags applied in any one location. A trap net was also set in the early evening on 6 June, emptied on 7 June, and emptied and pulled on the morning of 9 June 2012 (Appendix 4). Individually numbered Floy® t-bar anchor tags were applied to the right base of the dorsal fin, and the adipose fin was removed as a secondary mark to evaluate tag loss. Marks were not applied to lake trout smaller than 300 mm in fork length.

For the second capture session, we used the SPIN survey (25 – 27 June). All lake trout captured in the nets were inspected for the presence of a t-bar anchor tag and/or adipose clip.

All major assumptions of the Petersen mark-recapture method were met (Appendix 2), and we proceeded with the Bailey (1951, 1952) modification of the Petersen mark-recapture method (Krebs 1999), to estimate lake trout population size in Caribou Lake. Population size at time of marking ($\hat{N}$) was estimated using:

$$\hat{N} = \frac{(M)(C+1)}{(R+1)}$$

Where, M = number of individuals marked in the first sample
C = Total number of individuals captured in the second sample
R = number of individuals in the second sample that are marked

Variance was estimated using:

$$Var\ \hat{N} = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)}$$

Confidence intervals were estimated using a Poisson distribution following Krebs (1999), where R/C < 0.10 and R < 50.

Results and Discussion - SPIN

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen are water quality variables critical to lake trout, and they determine suitable and optimal habitats within a lake. Lake trout habitat has been defined as *suitable* where temperatures are below 15° C and dissolved oxygen is above 4 mg/L (Clark et al. 2004). Outside these levels (i.e., temperature above 15° C and dissolved oxygen below 4 mg/L) the habitat is *unsuitable* for lake trout. The *optimal* temperature range for Yukon lake trout is between 2° C and 12° C (Mackenzie-Grieve and Post 2006). The *optimal* dissolved oxygen level for lake trout is ≥7 mg/L (Evans 2005).

We took a temperature and dissolved oxygen profile in the north basin of Caribou Lake on 25 June 2012 (Appendix 4). The lake was strongly stratified, with the thermocline (zone of steep temperature gradient) between 3 m and 10 m (Figure 2). Temperatures were unsuitable (>15 °C) from the surface to 3 m, suitable (12 °C – 15 °C) between 3 m and 4 m, and optimal (≤12 °C) 4 m and below. Dissolved oxygen levels were optimal (≥7 mg/L) down to 15 m, suitable (4 – 7 mg/L) between 16 m and 19 m, and unsuitable below 19 m (Figure 3).

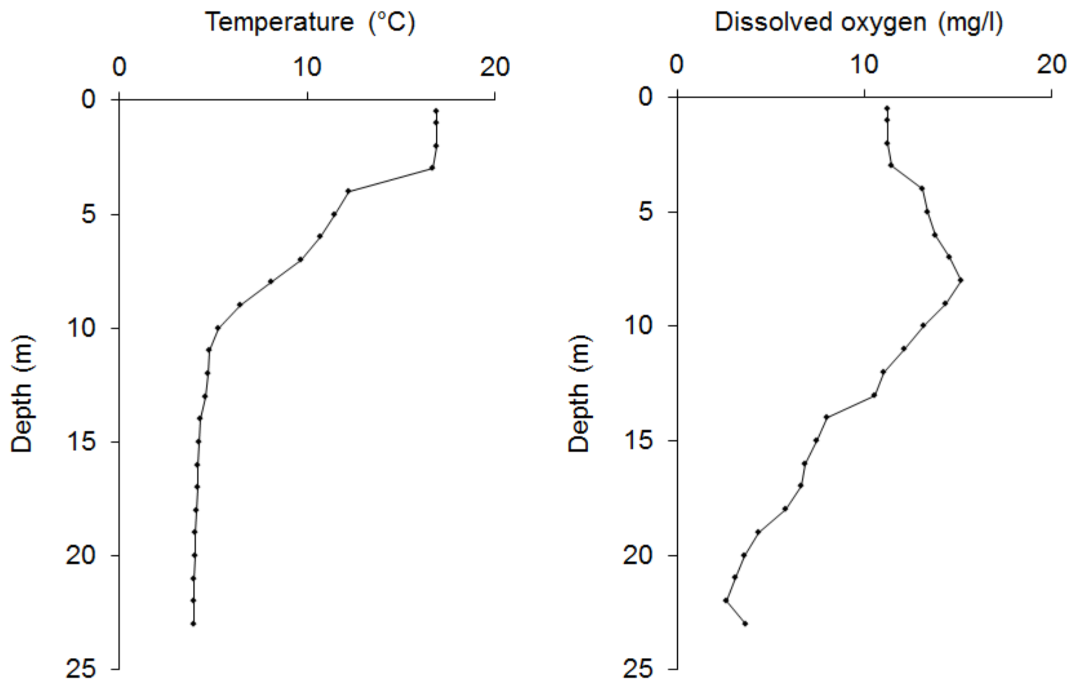

Figure 2. Temperature and dissolved oxygen profiles of Caribou Lake on 25 June 2012.

Overall, water conditions were suitable between 3 m and 19 m, and optimal between 4 m and 15 m. Suitable habitat was constrained by high temperature (>15 °C) in shallower water (<3 m) and low dissolved oxygen (<4 mg/L) in deeper water (>19 m). The usable and optimal habitat corresponded to a volume within the 2nd, 3rd, and upper half of the 4th depth strata.

CPUE, Density, and Population Size

We captured a total of 83 lake trout (not including 1 fish <300 mm) in 2012 (see Appendix 4 for set locations). The mortality rate for lake trout was 26% (22 fish).

We adjusted the catch to account for net selectivity bias based on the lengths of lake trout captured. The selectivity-adjusted total catch was 119 lake trout (Table 2). After weighting the data by catch in each strata, we found a lake-wide CPUE of 3.81 lake trout/net (SE = 0.55).

Table 2. Selectivity-adjusted catch by depth stratum.

Stratum	Depth Range	Nets Set (%)	Lake Trout Caught	Lake Trout Caught (%)
1	**0 - 3 m**	20	13	11
2	**3 - 9 m**	37	70	59
3	**9 - 15 m**	27	25	21
4	**>15 m**	17	11	10
Total		100	119	100

Using the Ontario empirical relationship, we estimated lake trout density at 55.9 lake trout/ha, giving a lake-wide abundance estimate of 2,851 lake trout (68% confidence interval: 2,360 – 3,389).

Size, Age and Diet

Both stomach contents and size can reveal whether a lake contains small-body lake trout that feed mostly on invertebrates or large-body lake trout that feed mostly on fish. Maximum size and size at maturity is smaller and growth is slower in the small-body, invertebrate-eating life history form than the large-body, fish-eating form.

Lake trout in Caribou Lake are of the small-bodied type and feed on a mix of fish and invertebrates. Lake trout ranged between 260 mm and 490 mm in length (Figure 3) with an average length of 390 mm. The average weight of lake trout was 630 g. Average condition factor, a relationship between length and weight, was 1.07, indicating healthy fish. Lake trout ages ranged from 7 – 24 years, with an average age of 16.1 (Figure 4).

Twenty-two lake trout stomachs were examined for diet; one was empty and the remaining 21 averaged 45% full. Unidentified fish were the most common diet item and fish made up 54% of the stomach contents (Table 3).

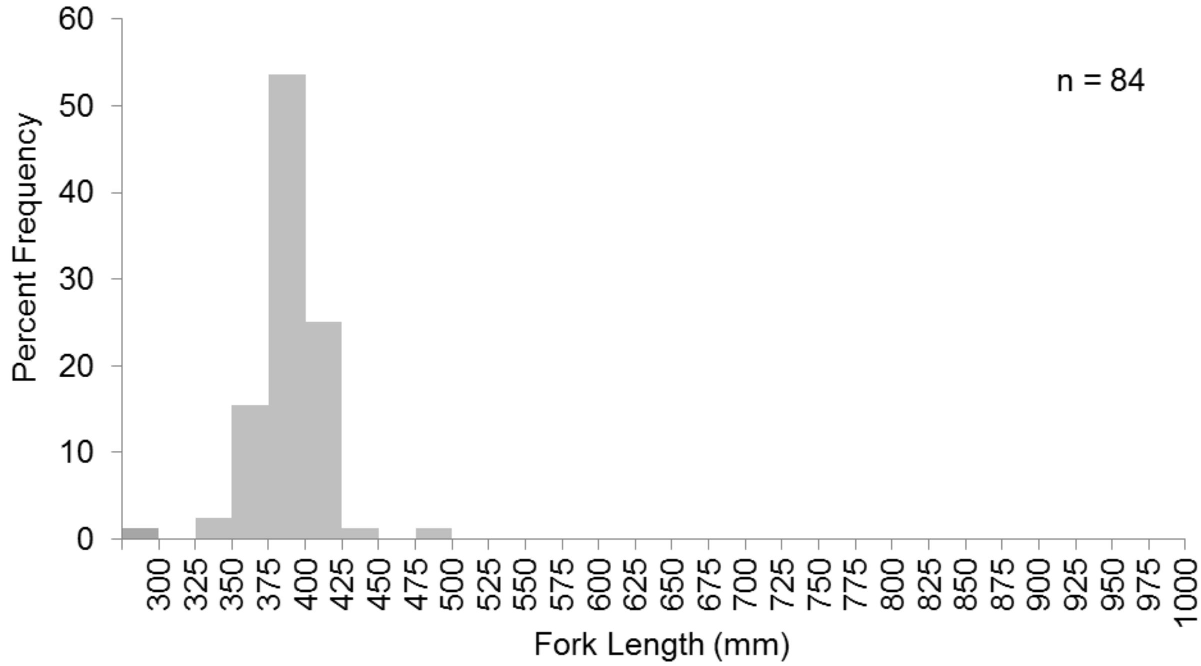

Figure 3. Length distribution of sampled lake trout, Caribou Lake SPIN 2012.

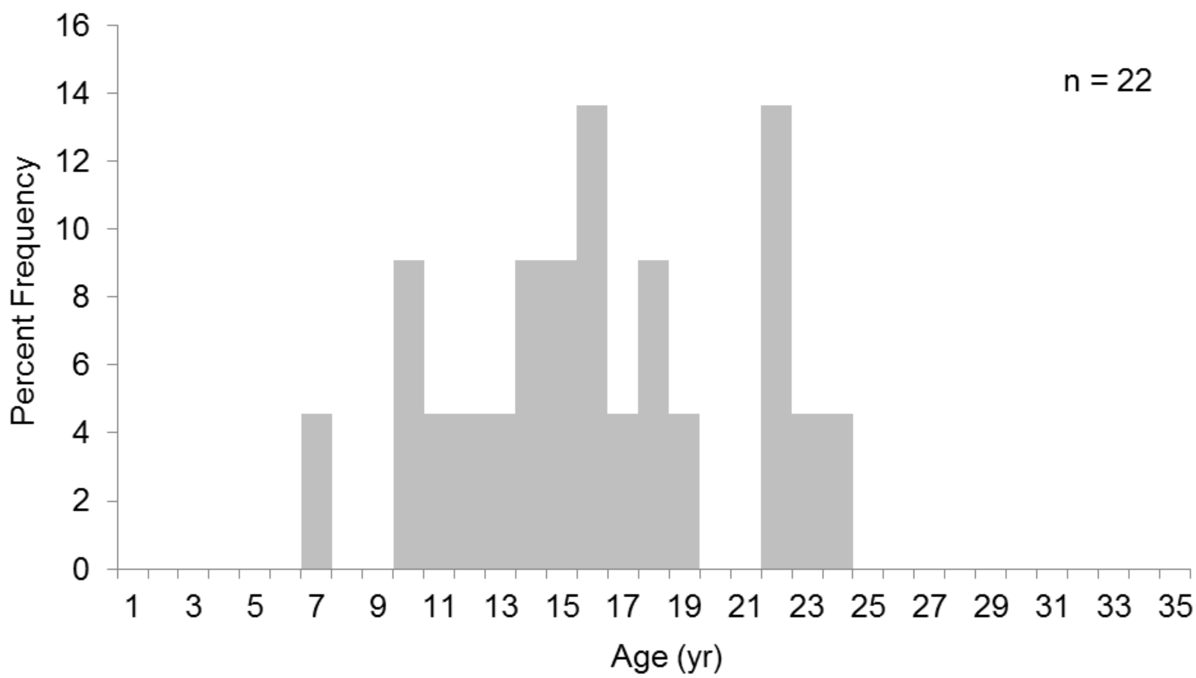

Figure 4. Age distribution of sampled lake trout, Caribou Lake SPIN 2012.

Table 3. Stomach contents of lake trout sampled from Caribou Lake, 2012.

	Percent volume
Unidentified fish	36
Non-biting midges	27
Slimy sculpin	16
Pond snails	8
Orb snails	5
Unidentified vegetation	4
Clams	2
Caddisflies	1
Beetles	Traces
Dragonflies, Damselflies	Traces
Scuds, Sideswimmers	Traces

Results from Previous Surveys

The results of the 2012 survey were very similar to the 2011 results (Barker and Millar 2012). The 2012 selectivity-adjusted CPUE of 3.81 (SE = 0.55) was nearly identical to the 2011 CPUE of 3.63 (SE = 0.56; Table 4) with no significance to the difference (two-tailed Welch's $t_{df=60}$ = -0.22, P = 0.82). These results suggest a high level of repeatability can be obtained using the SPIN method under similar seasonal and environmental conditions.

Table 4. Results of SPIN netting surveys of Caribou Lake.

	2012	2011
Survey Dates	25 – 27 June	5-7, 12 July
Nets Set	30	32
Lake trout captured	83	89
Selectivity adjusted catch	119	129
CPUE (lake trout/net)	3.81	3.63
Density (lake trout/ha)	55.9	53.2
Population (68% CI)	2,851 (2,360 - 3,389)	2,716 (2,238 - 3,237)
Power (to detect 25% change)	66%	62%

Biological characteristics of the lake trout we caught and sampled were similar in the 2011 and 2012 SPIN surveys (Table 5). Parameters tested were non-normally distributed, and no significant differences were detected in fork length ($D_{df=173}$ = 0.139, P = 0.376), weight ($D_{df=170}$ = 0.147, P = 0.327), or condition factor ($D_{df=170}$ = 0.133, P = 0.197).

Table 5. Biological data of lake trout from Caribou Lake captured in SPIN surveys.

	2012	2011
Fork length (mm)	389 (265 - 485)	390 (280 - 460)
Weight (g)	630 (175 - 1,550)	654 (325 - 1,325)
Condition factor	1.07	1.10
Age (Mean)	16.1	*

** lake trout age data for 2011 are not available*

Lake trout diet differed between years. Although the same diet items were identified in both years, fish comprised 52% of the diet in 2012, compared with 16% in 2011 (see Barker and Millar 2012 for data).

Previous small-mesh netting surveys showed an increase in CPUE between 1996 and 2001, and then remained stable between 2001 and 2006 (reviewed by Barker and Millar 2012). Small-mesh CPUE was higher than the Yukon average for small-body, productive lake trout lakes (1.19 lake trout per net) in 2001 and 2006, but only equal to the average in 1996. These surveys used a method that is quite different from the SPIN method. Nets were set from shore out into the lake only sampling the littoral (nearshore) zone, mesh material and mesh sizes were different, set duration was only one hour compared with 2 hours, and effort was lower. Though only subjective comparisons can be made, the results from both the SPIN surveys and the 2 most recent small-mesh surveys agree: Caribou Lake has a high density of lake trout.

Future Surveys

At the 2012 sample size (n = 30 sets) and variability of data, our predicted power to detect changes of 25% in the lake trout relative abundance in Caribou Lake is 0.66 (i.e., if there is a change of 25% or more in the lake trout population, we will detect it 66% of the time). In order to detect change with a power of 80% (a common management goal), sample size would need to be increased to an estimated 46 sets. Increasing sample size to this level would represent a large increase in effort, and is not recommended. Rather, future surveys should monitor and attempt to minimize within-strata variation as the survey progresses in order to improve power to detect change.

Results and Discussion - Mark-Recapture

In the first capture session in early June we applied marks to 196 lake trout, with one lake trout too small for marking (277 mm) released without a mark. All fish were captured by angling with the exception of 2 captured by trapnet.

The mixing period was 15 – 22 days, an appropriate time period given the small size of the lake and the distribution of mark deployment throughout the lake. One tagged lake trout was removed by recreational anglers over the mixing period (Stu Withers, local resident, *pers. comm.*), which left 195 marked lake trout available for recapture during the second session, given our assumptions of no tag loss and no mortality.

In the recapture session in late June (i.e., the SPIN survey), we captured 83 lake trout (not including one lake trout that was too small (265 mm)), of which 8 were marked. There were no tag losses on the 8 recaptures, with all fish retaining both marks. This supports our assumption of no tag loss.

There was no difference in size selectivity between the capture sessions (Appendix 2), a scenario which falls under Case I (Appendix 3), and indicates that we are able to use an unstratified Petersen abundance estimate.

We estimate the lake trout population in Caribou Lake to be 1,820 (68% confidence interval: 1,267 – 2,624). Confidence intervals around the estimate are larger than ideal, as we only recaptured 4% of deployed marks rather than a preferable 10% – 12%. For management purposes, Krebs (1999) recommends an accuracy of ±25% of the estimate at α = 0.05. Our 95% confidence interval is 977 – 3,678, or -46% to +102%. This result limits the utility of our mark-recapture estimate.

Results and Discussion – SPIN vs. Mark-Recapture

The population estimates derived from mark-recapture is 32% – 36% lower than the estimate from SPIN (both 2011 and 2012), but the confidence intervals overlap such that our estimates are not statistically different (Table 6).

Table 6. Caribou Lake lake trout population size estimates.

Survey	Estimate (68% CI)
2011 SPIN	2,716 (2,238 – 3,237)
2012 SPIN	2,851 (2,360 – 3,389)
2012 Mark-recapture	1,820 (1,267 – 2,624)

After initial testing in 2009, Yukon government adopted the SPIN method of lake trout population assessment in 2010, as an improvement over traditional small-mesh netting surveys (Jessup and Millar 2011). Since then, we have carried out surveys to understand repeatability, constraints of seasons and environmental conditions, and feasibility of using the method on Yukon's large lakes. The outcomes of these surveys have helped us refine and understand the applicability of using SPIN to monitor lake trout, and other species, in Yukon lakes.

A remaining uncertainty with the method has been the use of the relationship between CPUE and density that was initially established using data from Ontario lakes. With this empirical relationship we can discuss lake trout in terms of absolute numbers of fish, rather than using relative measures like the number of trout caught per net. Expert opinion and testing in neighbouring jurisdictions has shown the relationship is likely valid in lakes in both western and northern Canada (Environment Yukon files) and this provided a good foundation to expand this work to Yukon waters. In 2010, we began a mark-recapture on Fish Lake, but found that the population size was too large for us to obtain an accurate estimate. We turned our attention to Caribou Lake, a much smaller lake with fewer lake trout, as a likely candidate for a successful mark-recapture study.

Two CPUE-density relationships have been developed according to the life history type of lake trout: one for where lake herring are not present in the lake (small-bodied lake trout) and one for where lake herring are present (large-bodied lake trout; Figure 5, Sandstom and Lester 2009). Lake trout in Caribou Lake are of the small bodied life history type and we used this relationship to convert the CPUE into a density (55.9 lake trout/ha) and population size 2,851 (68% confidence interval: 2,360 – 3,389).

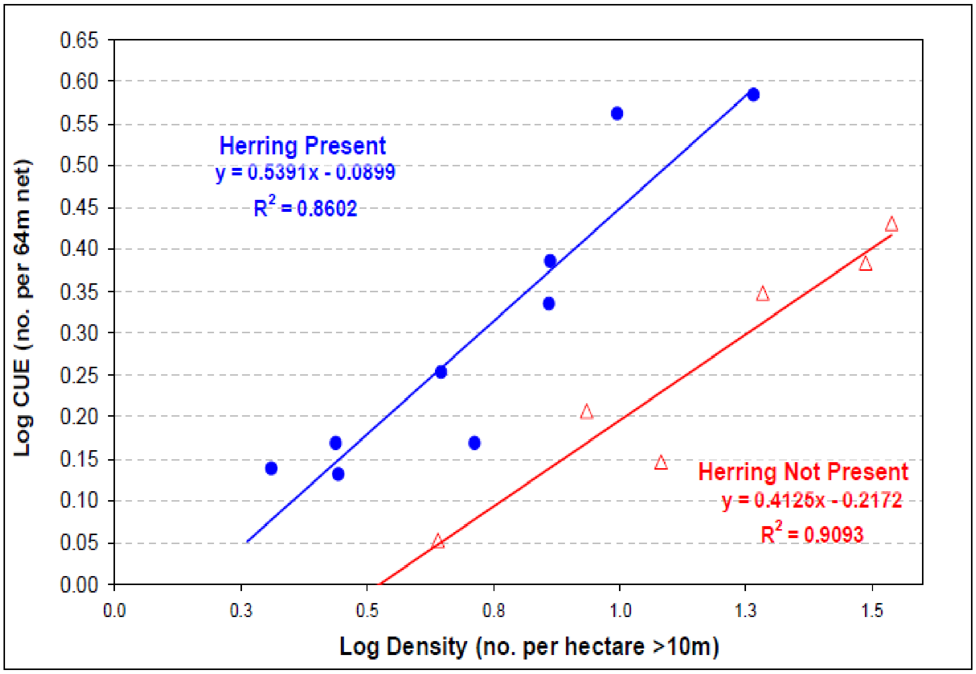

Figure 5. Lake trout SPIN CPUE- density relationship (Sandstrom and Lester 2009) with the lower (red) line representing the relationship for lakes like Caribou Lake with the small bodied life history type of lake trout.

In the mark-recapture study we found a density of 35.6 lake trout/ha (or 1.55 lake trout/ha on the x-axis logarithmic scale used in Figure 5. This density is higher than any of the data points from lakes used in this version of CPUE–density relationship. In the SPIN survey we found a CPUE of 3.81 (or 0.58 on the y-axis logarithmic scale) which is also higher than the CPUE values used in this version of the relationship.

Work to refine this relationship with newly acquired data from across Canada is ongoing, including additional points from other lakes with high densities of lake trout (Steve Sandstrom, *pers. comm.*). Revisions will be made to both the large- and small-bodied lake trout CPUE-density relationships for SPIN but preliminary information suggests that the overall relationship will not change dramatically.

Population Status and Conclusions

Smaller, more productive lakes (like Caribou) usually have high fish densities when compared to larger, less productive lakes (Burr 1997). Lakes like Caribou, that have few competing piscivorous fish like northern pike and burbot, are also expected to have higher densities than lakes with these species present (Carl et al. 1990).

In both 2011 (Barker and Millar 2012) and 2012 we found that Caribou Lake had a high CPUE and therefore a high density of small-bodied lake trout. When compared to other Yukon lakes with small-bodied lake trout Caribou Lake had a higher than average CPUE and density (Appendix 1). Previous small-mesh netting surveys also found that Caribou Lake had a high lake trout density relative to other lakes.

Despite the high density of lake trout in Caribou Lake, this population is vulnerable to overharvest by virtue of its small size. While current angler effort and harvest is low (Environment Yukon files), it has been very high in the past, and even modest increases in angling activity could reduce lake trout density in Caribou Lake. We recommend continued monitoring of angler effort at Caribou Lake.

This was the first Yukon examination of the relationship between SPIN CPUE and lake trout density. The independent estimate of lake trout population size (and density) obtained using mark-recapture was 32% - 36% lower than estimate obtained from SPIN. However, the confidence intervals were broad for both estimates such that we cannot conclude that there is a different CPUE-density relationship for Yukon lakes, nor can we confidently conclude that Caribou Lake fits the existing relationship well. Further work must be done to refine the SPIN CPUE – density relationship to fully understand how it applies to Yukon lakes.

One challenge of this study that led to the inconclusive result was the small number of marked lake trout recaptured in the mark-recapture. This led to very wide confidence intervals (even at 68%). Future mark-recapture studies must increase the number of marked fish and/or the recapture effort. It is important to consider an estimate of the population size when planning these studies.

Population size and density estimates provided by SPIN are based on the relationship between CPUE and independent measures of lake trout density established for Ontario lakes prior to 2009. This relationship will continue to be improved across Canada and verified for Yukon lakes. Further development must be completed before full weight is given to Yukon population size and density estimates.

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Appendix 1 – Estimated lake trout CPUE (SPIN) and density from Yukon lakes to date.

Lake	Lake Trout Morphology	Year	CPUE (SPIN)	Density (fish/ha)
Caribou	**Small body**	**2012**	**3.81**	**55.9**
Lewes	Small body	2010	3.31	48.6
Kathleen	Small body	2012	2.18	
Louise (Jackson)	Small body	2011	2.06	30.3
Fish	Small body	2010	2.01	29.7
Mush	Small body	2012	1.18	
Tetl’ámā̱n	Large body	2011	1.08	4.4
Sekulmun	Large body	2010	0.88	3.7
Quiet	Large body	2012	0.73	3.3
Frenchman	Large body	2012	0.31	2.0
Ethel	Large body	2011	0.27	1.9
Tarfu	Large body	2010	0.2	1.7
Pine	Large body	2010	0.08	1.5
Snafu	Large body	2010	0	0

Appendix 2 – Adherence to mark-recapture assumptions.

Petersen mark-recapture assumptions

The Petersen method of mark-recapture abundance estimation requires that several criteria be met (Seber 1982, Krebs 1999):

1. Immigration and/or recruitment to gear are negligible, or if immigration and/or recruitment are present, the population estimate applies to the time of the second capture session only; if absent, the population estimate applies to the time of the first capture.
2. Emigration and/or mortality are negligible, or if emigration and/or mortality occur, it is at equal rates for marked and unmarked fish.
3. All fish have equal catchability in both capture sessions, and marked fish mix completely with unmarked fish between the first and second session.
4. Tag loss is negligible, and all marked fish are identified in the second capture session.

Adherence to assumptions

1. We consider the Caribou Lake lake trout population to be closed. The lake has negligible inflow with no upstream connections to other lake trout lakes, and only a small outflow creek with a distant connection to Marsh Lake; we assume lake trout immigration to be nil, particularly for lake trout of sizes recruited to sampling gear. For the purposes of mark-recapture population estimation, recruitment refers to growth of lake trout between capture sessions such that lake trout too small to be vulnerable to capture in the first session become vulnerable to capture by the second session. Yukon lake trout growth is very slow in comparison to the interval between our capture sessions (Yukon Environment files) and can be considered negligible. In this case, the population estimate will apply to the population at the time of the initial capture session.
2. Emigration of lake trout from Caribou Lake is also assumed to be nil, given the same rationale as immigration. Over the interval between capture episodes, we monitored and quantified angler harvest, and assumed that natural mortality of lake trout was very low and equally distributed among marked and unmarked fish.
3. a. We examined for size selectivity in non-normally distributed catches using non-parametric two sample Kolmogorov-Smirnov comparisons of lake trout size distributions between sessions (Seber 1982, Schwanke 2009). Evidence of size-selectivity in the first capture session is provided by a significant difference between lake trout size distribution in the first and second capture sessions.

Evidence of size-selectivity in the second capture session is provided by a significant difference between lake trout size distributions from the first capture event and marked lake trout recaptured in the second sampling event. Appendix 3 provides methodologies for abundance estimation under the four resulting possible scenarios. We found that there was no difference in size selectivity between the first and second capture session ($D_{196,83}$ = 0.142, P = 0.195), or between the first capture session and the marked fish captured in the second session ($D_{196,8}$ = 0.413, P = 0.135).

b. We were unable to statistically examine for geographical selectivity in catches as specific tagging locations were not recorded. However, given the small size of Caribou Lake, the consistent and complete distribution of sample locations around the lake in the first capture session, the time period between capture sessions, and the complete coverage and random distribution of samples in the second capture session, we assumed complete mixing and equal probability of capture in both sessions.

4. We considered tag loss to be nil in this study, given that we applied 2 marks to each fish, a primary t-bar anchor tag, and a secondary permanent mark (removal of adipose fin). This assumption is further supported by very high tag retention rates observed with the Floy© t-bar anchor tags in other YG fish tagging projects (Yukon Environment files). With 2 obvious marks, and 2 observers on the capture crew handling low numbers of fish in the second capture session, we assumed that no marked fish were overlooked.

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Appendix 3 – Lake trout population abundance estimation methodologies under differing scenarios of size selectivity bias (after Schwanke 2009).

	Significant difference between size distribution in first session and recaptures in second session	Significant difference between size distributions in first and second sessions
Case I	No	No
Case II	No	Yes
Case III	Yes	No
Case IV	Yes	Yes

Case I: No evidence for size selectivity in either capture session. Use unstratified abundance estimate. Pool burbot lengths from first and second capture sessions for population composition estimates.

Case II: Evidence for size selectivity in the first capture session, but not the second. Use unstratified abundance estimate, applicable to population estimate at time of second capture session only. Consider only lengths from the second capture session for population composition estimates.

Case III: Evidence for size selectivity in both first and second capture sessions. Stratify abundance estimates within length strata, and sum estimates for total population estimate. Use length distributions from both first and second capture sessions, weighted by stratum capture probabilities, for population composition estimates.

Case IV: Evidence for size selectivity in the second capture session, and unknown status of size selectivity in the first capture session. Stratify abundance estimates within length strata, and sum estimates for total population estimate. Use length distributions from second capture session only, weighted by stratum capture probabilities, for population composition estimates.

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Appendix 4 - Caribou Lake 2012 SPIN set locations, trapnet location and profile location.