

## Note

# Development of an assessment approach for remnant lake salmonin populations: The Crean Lake example

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Received 13 May 2005; Accepted 18 July 2005

**Abstract** – This research investigates a status assessment approach for remnant lake salmonin populations, using the lake charr (*Salvelinus namaycush* Walbaum) of Crean Lake (105 km<sup>2</sup>) as an example. A mark-recapture program was implemented employing small-mesh gill nets to ensnare charr by the teeth at spawning. Prior to sampling, potential spawning sites were designated primary or secondary based on habitat. Most charr were caught on three primary reefs, with some spawners moving between reefs. The spawning period peaked at day 2, enhancing spawning synchrony, and lasted up to 10 days. Results produced very low sampling mortality (5.7%), consistent estimates of the number of spawning charr (~60 y<sup>-1</sup>) and a very low (<2000) estimate of the total number of mature charr in Crean Lake. The approach offers an effective means of assessing remnant salmonins with minimal impact on their populations.

**Key words:** Status assessments / Lake charr / *Salvelinus namaycush* / Spawning aggregations / Live-capture / Tagging

## 1 Introduction

Many fish populations in North America are viewed as declining, often based largely on expert opinion (Pearse 1988). Post et al. (2002) conclude that we require efforts to increase the visibility of population declines, as well as independent assessments of the status of fish populations, to improve the management of recreational fisheries. We also need to develop different approaches to assessing status in lakes, especially where fish population numbers are thought to be low. In the Boreal Plain ecozone (Acton et al. 1998) for example, many lake charr (*Salvelinus namaycush* Walbaum) populations are considered extirpated because of over-fishing. It is inappropriate to use traditional lethal methods such as standard gill-netting of dispersed fish to assess such populations.

This research investigates the main scientific aspects of live-capture salmonin assessments (where, when, how many) in lakes, targeting populations at spawning. The scientific community has expressed concerns about the future of salmonins for decades (Maitland et al. 1981). To illustrate the approach, the study analyzes fall spawning in the lake charr of Crean Lake (Fig. 1), in Prince Albert National Park of Canada, over six years. The lake is a large (105 km<sup>2</sup>) open ecosystem with limited accessibility, challenging study conditions and many

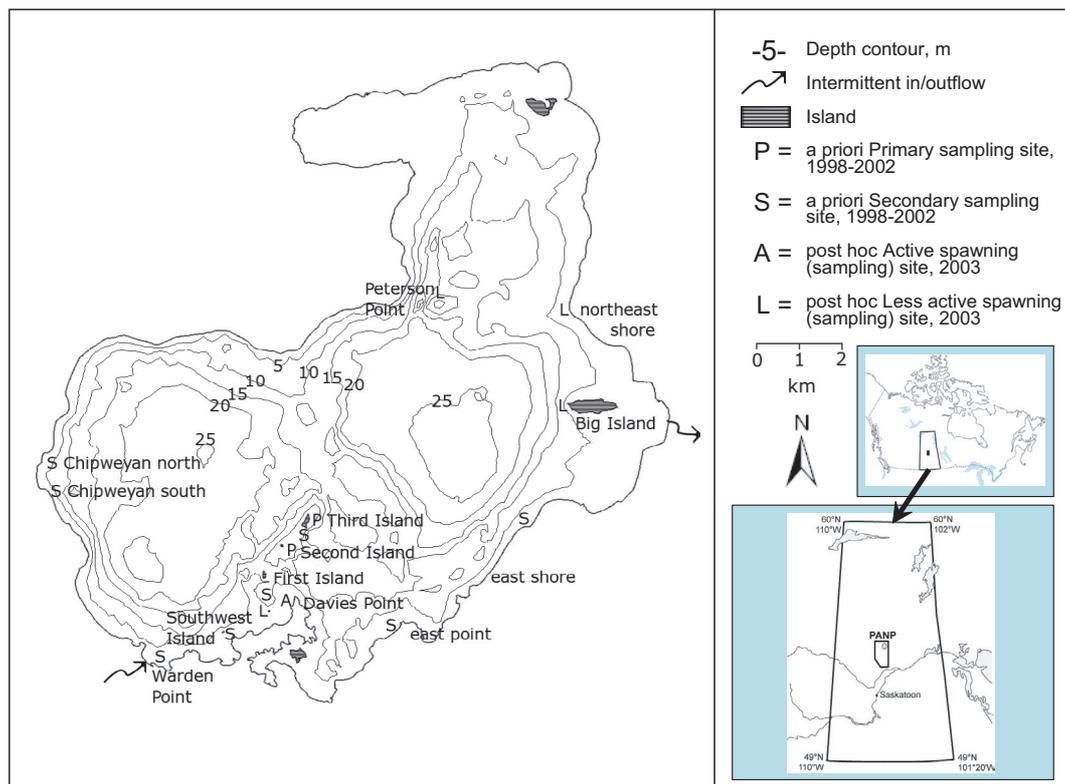
knowledge gaps with respect to its fisheries ecology. First, the investigation addresses whether we can readily determine the most active spawning locations, at a scale of 10 m (sensu Gunn et al. 1996). Hypothetically the most active sites can be located in an initial phase of a multi-year study. In a similar vein, spawning sites that are relatively close could constitute a spawning habitat complex. Second, can we readily characterize, in numerical terms, the period when spawning actually occurs? A number of papers (Martin 1957; DeRoche 1969) document lake charr behaviour during the spawning season, but provide largely verbal synopses. A priori spawning in Crean should peak rapidly then decline in a skewed manner over a short period. Third, with reasonable effort, can field crews capture and recapture enough charr to obtain accurate values of the number spawning? One can calculate spawning numbers with relatively low capture and recapture rates and, over a period of years, the approach should also provide estimates of the mature charr population.

## 2 Study system

Crean Lake is located at 54°N 106°W in the Lower Saskatchewan freshwater ecoregion of North America. One larger intermittent stream flows into the lake but no permanent streams or rivers, while the lake outlet is small and intermittent. Mean and maximum depths are 12 and 27 m

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**Fig. 1.** Sampling sites in Crean Lake during charr spawning seasons. P, S: a priori hypothesized Primary and Secondary spawning sites respectively, 1998–2002; A, L: Active and much Less active sites respectively, investigated post hoc, 2003; lines are 5 m contours. Inset shows Crean Lake in Prince Albert National Park of Canada (PANP).

respectively. Shoreline variation is relatively infrequent, occurring mostly along 5 km of the southwest shore (Fig. 1), and little littoral zone development exists. Crean Lake freezes in late November, becoming ice-free in mid May. The lake stratifies in summer, with a median temperature of 20 °C at 5 m in the epilimnion and 10 °C at 20 m in the hypolimnion. The hypolimnetic oxygen concentration, at 20 m, is 6.0 mg L<sup>-1</sup>. Three other large piscivorous fish species, burbot (*Lota lota* L.), pike (*Esox lucius* L.) and walleye (*Sander vitreus* Mitchill), and two large benthic feeders, whitefish (*Coregonus clupeaformis* M.) and sucker (*Catostomus commersoni* Lacepède), inhabit Crean.

Commercial fishing records indicate that charr were the dominant piscivorous species of Crean Lake from 1921 to 1927 (Golumbia 1988). Approximately 13 t of largely-mature charr were harvested annually over this period. Commercial fishing was discontinued following the establishment of Prince Albert National Park of Canada in 1928.

Sport fishing was promoted in the park and the angler catch of charr at Crean Lake peaked at 1003 fish in 1933. Subsequently the catch decreased and, between 1945 and 1951, the reported total harvest from Crean Lake was less than ten charr per year despite substantial effort by experienced anglers (Golumbia 1988). The overall catch of lake charr was very low in test netting between 1948 and 1950. Reportedly, over 2000 charr still spawned in Crean Lake in 1938.

Management interventions began in the early 1950s, including episodes of charr stocking – which many of the

stocked fish did not survive, artificial enhancement of a potential spawning reef, and the reduction of angler possession limits. No sustained increase in the reported catches of charr occurred and in 1989, Parks Canada closed Crean Lake to charr angling.

### 3 Methods

#### 3.1 Netting and fish handling

Two hundred net sets were carried out between 1998 and 2002 using 25.4 mm (1 inch) stretched mesh. All nets were 22.5 m long and 1.5 or 1.8 m high. The nets covered 40 to 60% of each potential spawning site per sampling, and provided similar coverage of the approaches to sites during pre-spawning periods. Fifteen nets were set post hoc by park staff in 2003, using nets approximately twice the length of the nets used in previous years, and made of 38 mm (1.5 inches) stretched mesh.

Net sets were initiated between September 26 and 28 in all years, and final net sets were terminated October 11 in 1998 and 1999, October 6 or 7 from 2000 to 2003. Netting was carried out between 1930 and 2330 hours when most spawning behaviour was observed. No spawning charr were captured in preliminary netting prior to 1900 hours, and no activity was observed after about midnight. Crews checked the nets in the evening and once in the morning, with the frequency of evening checks varying with the weather. Personnel made

fewer checks during moderately high winds ( $>20 \text{ km h}^{-1}$ ) since little or no spawning was observed under these conditions. Nets were removed in windy weather ( $>25 \text{ km h}^{-1}$ ) or if high winds were forecast.

Net checks and handling procedures minimized the overall risk of injury or death to the charr via capture and measurements, following The Association for the Study of Animal Behaviour (1998). Charr were not anaesthetized and were usually observed in large tanks containing fresh lake water after removal from the nets, and again after data collection.

### 3.2 Spawning sites, period and abundances

Fifteen potential spawning sites were identified based on reconnaissance by boat and floatplane, examination of aerial photographs and historical (Golumbia 1988) and anecdotal accounts of potential spawning habitat. Ten of these (Fig. 1) were selected for sampling from 1998 to 2002.

At a scale of 10 m, the ten sites were categorized as either primary (active) or secondary (much less active) (Fig. 1). Two of the ten sampling sites, both situated on the northern edge of the main reef complex (in the southwest quadrat, at Second and Third Islands), were designated as primary. These coarse-scaled sites (Gunn et al. 1996) offer a variety of cobble-boulder microhabitats as well as some pebble and gravel, over a range of depths from the surface to approximately 3 m, and exposure to wave action, characteristics typical of lake charr spawning habitat (Martin 1957; Gunn 1995; Sly and Evans 1996). About half the charr reportedly observed spawning in 1938 were associated with the two primary reefs. The eight secondary sites selected for sampling had some of the primary features but they were less pronounced. One of the secondary sites, at Wardens Point, was considered among the most active spawning locations in 1938.

Primary sites were sampled with a total of 164 net sets over the five seasons while secondary sites were sampled a total of 36 times. At primary sites personnel sampled a core subset of point locations every year, and always concurrently with sampling at secondary sites. Catch differences between the primary and secondary sites were compared by analysis of frequencies.

The five remaining sites (Fig. 1) were sampled in 2003. One of these sites, off Davies Point, was reportedly very active in 1938.

Spawning was defined as the period when one could easily express eggs from females, with a minimum of posterior abdominal massaging. Many males could express some sperm prior to spawning. Sampling core reef-top locations throughout study periods also helped to identify spawning. The mean number of charr caught per day during spawning was calculated using the numbers caught each day in each year of sampling. The resulting distribution was then tested for skewness.

Charr were marked using pastic t-bar anchor tags numbered serially (Floy® Tag and Manufacturing, Seattle). Marking and recapturing were carried out concurrently. The modified Schnabel method (Ricker 1975) is used to calculate abundance estimates and confidence intervals of spawning charr:

$$\hat{N} = \frac{\sum C \times M}{\sum R + 1}$$

where  $\hat{N}$  is the estimate of the number of spawning charr,  $C$  is the number of charr caught during a particular sampling interval,  $M$  is the total number of charr marked during previous sampling intervals, and  $R$  is the number of charr marked and recaptured during an interval.

## 4 Results

A total of 106 charr including recaptures were sampled from 1998 to 2002. Six (5.7%) charr died, one of which was female. The estimated female mortality is 2.5% from 1998 to 2002.

From 1998 to 2002, all charr were caught on the primary reefs during spawning, except for one which was captured in-between. Thus the capture of charr was highly dependent on location ( $p < 0.001$ , two-way G-test of independence). Seven charr were recaptured at primary sites within years, four at the same reef and three at the opposite reef. Of the five sites sampled in 2003, group spawning behaviour occurred only at one, offshore of Davies Point in the middle of the main reef complex. Two charr taken at Davies Point were recaptures, tagged at Second Island in 2000.

Most charr were sampled on day two of spawning, after which the number generally decreased (Fig. 2). The distribution of spawners caught over time is heavily skewed to the right (skewness statistic  $g_1 = 0.414$ ). Estimates incorporating 100% sampling coverage of the primary spawning reefs, which are for the most part curvilinear in shape, result in a similar daily capture pattern (Fig. 2). From 1998 to 2002, wind and wave conditions were very rough 40% of the time. The first day of spawning occurred between 2 and 5 October in four years and slightly earlier in the fifth year from 1998 to 2002.

Modified Schnabel estimates indicate a narrow range of 52 to 68 (about 60) charr spawning per year (Table 1). Estimates cannot be made for 2000 and 2001 since there were no recaptures. Use of the Schnabel model results in 610 mature charr in the Crean population between 1998 and 2002. The upper confidence limit varies from 1230 to 1760 mature individuals, depending on the confidence level (90 to 99% respectively).

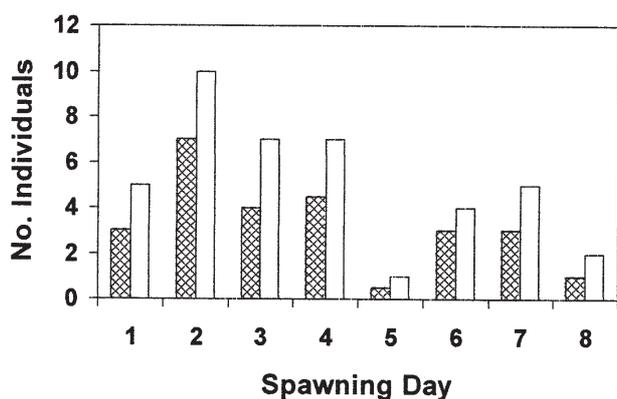
## 5 Discussion

Implementation of the assessment approach achieved a high degree of preservation of the charr sampled. This result is paramount given the status of charr in Crean Lake and high-profile societal concerns for the welfare of wildlife under scientific study (Clugstun 2001). The mortality of females – one individual – by way of entanglement was slightly less than the overall mortality rate of Mills et al. (2002). They used larger 38 mm (1.5 in) stretched mesh, but on tiny lakes much more conducive to study than Crean Lake. The 5.7% total mortality estimated in our study was similar to the rates from the use of gill nets in other types of studies ( $<5.6\%$ , Chen 1979;  $<5.0\%$ , McAughy and Gunn 1995). Mesh sizes were larger in these studies, 51 mm as well as 38 mm. Chen (1979) reported discontinuing the use of 64 mm mesh after finding mortality of about 10%. Mortality increases with increasing mesh size of

**Table 1.** Capture and recapture data with population estimates for spawning charr (*Salvelinus namaycush*) in Crean Lake, 1998 to 2002.

Year	Days <sup>1</sup>	Number of captures	Number of same-year recaptures	Modified Schnabel population estimate	Lower to upper 90% confidence intervals
1998	7	23	2	68	29 to 150
1999	9	21	2	52	22 to 116
2000	5	12	0	-	-
2001	9	26	0	-	-
2002	5	24	3	52	24 to 114

<sup>1</sup> excludes windy days.



**Fig. 2.** Number of spawning charr caught per day in Crean Lake, autumn 1998-2002. Hatched bars: average number, open bars: estimate of number with 100% sampling coverage of primary spawning reefs.

gill nets due because of interference with gill function. With respect to preservation, a mesh size of 25 mm is probably preferred in live-trapping nets under variable conditions on large lakes, while very short lengths of 38 mm mesh are acceptable in small lakes (McAughey and Gunn 1995; Mills et al. 2002).

The most active spawning locations at a scale of 10 m (*sensu* Gunn et al. 1996) were accurately identified following the approach used in this study. This interpretation is supported by the difference in the catch results between the two primary and eight secondary sites sampled from 1998 to 2002. The same proportion was confirmed or “validated” as relatively active in 2003. A total of three active sites is within the range observed for other lakes, although the number probably increases with lake size in unexploited or lightly exploited lake charr systems. Gunn et al. (1996) found that lake charr spawned at three natural sites covering a total of 41 m<sup>2</sup> in a lake 67 ha in area. At the other end of the spectrum, Fitzsimons (1995) documents a total of five actively-used natural sites (of 14 potential sites) covering 7800 m<sup>2</sup> in Lake Ontario, although the number was probably higher before exploitation eliminated lake charr from much of the lake.

The recapture data confirm the concept of a spawning reef complex, since fish were recaptured at other tagging sites. The three active spawning sites form a triangle, with each site about 1 km from the others.

Spawning charr were absent around Warden Point even though the 1930s observations indicated several hundred charr spawning just off the point. Large quantities of substrate

were added to the reef circa 1973 which altered its structure and probably reef processes. Lake charr will spawn at artificial reefs if they have been carefully designed (Martin 1955; Eshenroder et al. 1995), although it can be many years before usage starts to occur.

The average charr spawning period of eight days in Crean Lake falls within the duration of 7 to 10 days, inferred for all (Martin 1957; Chen 1979; Sly and Evans 1996) but the largest lake charr lakes elsewhere. Where studies suggest longer periods of lake charr spawning (DeRoche 1969; Fitzsimons 1995; Sly and Evans 1996), they do not clearly differentiate between spawning, for example the number of ovulated females, and prespawning. The skewed pattern is consistent with verbal accounts of spawning for other lakes (Martin 1957; DeRoche 1969), with the initial peak adding to the synchrony of the process.

The assessment approach developed in this study results in consistent estimates of the number of charr spawning within years in Crean Lake. This “precision” was achieved, in part, via systematic sampling of approximately one-third of the total core habitat at the most active spawning sites identified by field crews (half of each of two primary sites). One could probably narrow the confidence intervals substantially by sampling Davies Point as well, i.e. sampling at least fifty percent of the total core spawning habitat. This increase would probably not have a significant incremental impact on charr spawning, leaving substantial habitat for spawning to continue (Cuthill 1991). The abundance of charr spawning in Crean Lake within years is very low, numbering in the tens to perhaps a few hundred individuals per year given the confidence intervals. These numbers are much smaller than the high hundreds or thousands of charr reported spawning in Crean in 1938, prior to the final decline through the 1940s (Golumbia 1988).

The new assessment approach indicates that a relatively small number of fish make up the population of mature charr in Crean Lake. A total of 1760 fish (the uppermost confidence interval), for example, translates into a mature charr population of 0.17 ha<sup>-1</sup>, between 15 and 60% of the number (Healey 1978) remaining in other highly exploited populations. From a biomass perspective, the total weight of mature charr in Crean is a small fraction of that once removed annually by either commercial fishing or angling at its peak.

Overall, the approach developed in this study offers a highly effective conservative means of assessing remnant salmonin populations, the constraints of small sample sizes (Chittendon 2002) and population models (Pine et al. 2003)

notwithstanding. The confidence intervals, while large, are proportionately similar to those obtained for estimates of unexploited (Gunn and Sein 2000) and recovering (Reid et al. 2001) charr populations. Extending yearly sampling, as well as increasing the sampling effort within years, could contribute greatly to narrowing the confidence intervals of the population estimates. The approach could be used to determine the size and characteristics of a vulnerable population for comparison with angling data (van Poorten and Post 2005), for example, whether the population was a remnant or more numerous. It would allow researchers and fisheries managers to sacrifice subsamples of fish rather than samples (Magnan et al. 2005) when collecting biological materials such as otoliths. More broadly, developments in management science such as this approach may be more effective than status assessments per se in increasing the visibility of fish population declines.

*Acknowledgements.* Many people assisted in the field, particularly M. Fitzsimmons, M. Batycki, R. Cargan, I. English, and J. and C. Melville. D. Wieder, G. Bond and C. Beaulieu generated the Crean map, and L. Crone and C. Hudym prepared the final manuscript. Comments by two anonymous reviewers improved the manuscript. I am grateful to M. Fitzsimmons and N. Stolle for their support of this research throughout the project. Major funding for this research was provided by Prince Albert National Park of Canada and the SRC.

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