Saskatchewan
Environment
and Resource
Management

Lake Sturgeon in the Saskatchewan River:

Radio-tracking and index fishing

Fish and Wildlife Technical Report 99-4

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LAKE STURGEON IN THE LOWER SASKATCHEWAN RIVER:

RADIO-TRACKING AND INDEX FISHING,

1994 to 1997

by

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and

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A report to the

Interprovincial Sturgeon Steering Committee

Fish and Wildlife Technical Report 99 - 4

March 1999

Fish and Wildlife Branch
Saskatchewan Environment and Resource Management
Saskatoon, Saskatchewan

and

Northwestern Region - Fisheries
Manitoba Department of Natural Resources
The Pas, Manitoba

EXECUTIVE SUMMARY

Saskatchewan has resident populations of lake sturgeon in the Saskatchewan River system, and in the lower Churchill River. They are typically residents of large rivers or lakes.

The sturgeon population in the lower Saskatchewan River (Cumberland Lake area) was apparently healthy in the 1950s. Nonetheless, problems were observed in surveys between 1954 and 1990, particularly losses of habitat, higher mortality, and lower reproduction.

A proposal for protection and restoration of the population and habitat was sent to local users in Cumberland House, fisheries staff, and other agencies (Wallace 1991). A committee was established to discuss concerns and to review plans and progress.

This report covers radio-tracking and index fishing of these sturgeon. The area includes the Saskatchewan River (from EBCampbell dam in Saskatchewan, downstream to Cedar Lake in Manitoba) and several tributaries. A companion report covers spawning sites, general habitat, and tagging (Wallace 1999).

RADIO-TRACKING

Radio-tags allow workers to find sturgeon by boat or plane. Our objectives were to follow seasonal and longer migrations, assess patterns of movements, and begin to identify preferred habitat.

Radio-tags were applied through the dorsal scutes ("bony plates") to maximize their signal range. Deep water and high mineral levels in water both reduce radio signals.

In Saskatchewan, 15 sturgeon were tagged, ranging from 17 to 73 pounds. Periodic searches covered the Saskatchewan River, Cumberland Lake, and side-channels.

In Manitoba, 10 sturgeon were radio-tagged, ranging from 6 to 29 pounds. Regular searching by boat occurred along the mainstem river in summer.

Mature sturgeon tagged at the Torch River prior to spawning usually swam upstream (towards EBCampbell or into the river). Those released at other spawning sites like Bigstone Rapids and Tearing River moved downstream.

Sturgeon tagged at The Pas swam either upstream or downstream. Most of these were immature-size and were not likely affected by spawning behaviour.

This population uses the rivers and channels primarily. Radio-tagged sturgeon in Cumberland Lake were usually found around the margins, and no sturgeon were found in Cedar Lake.

After their initial movements, many sturgeon remained in local areas for long periods. In the first year of tracking, sturgeon covered almost all of the distance they moved in two years. This suggests that initial migrations had specific purposes.

INDEX FISHING

Index fishing was intended to continue the monitoring of fish sizes, to continue a historical index of abundance and provide a baseline for the future, and to provide data for tag-recapture estimates of abundance.

In Saskatchewan, about ten crews were paid for each sturgeon caught and released alive. Traditional sites were fished in June and July, using 10 and 12-inch gill-nets and baited hooklines. Project workers visited sites, measured and tagged fish, and assisted with crew-records.

In Manitoba, three crews were paid to fish in specific sites in June, using 5.5 to 12-inch gill-nets. Staff visited crews when required, measured and tagged fish, and retrieved records.

About 246 sturgeon were caught and released in 1996 and 1997. The largest was 60 inch long and weighed 73 pounds.

Sturgeon caught near spawning sites ranged from large at the Torch River, to intermediate at Bigstone Rapids, to smaller downstream in the Barrier and Elbow areas.

Commercial fishermen have provided specimens for fish-sizes and other uses since 1958 in Saskatchewan. Recent data on sizes suggest continuing changes in the population.

Average catch-rates in Saskatchewan were 2.5 to 3.9 market-size sturgeon per crew-week. Catch-rates were variable, due to differences in crew experience, fish behaviour, and habitat conditions.

The abundance of sturgeon is steady or declining, according to catch-rates from 1983 to 1997. Average catches are declining and the frequency of zero-catches is increasing, but neither indication is statistically significant.

MONITORING

Montioring to detect trends is difficult when populations fluctuate naturally and catches are variable. Longer series of data and more precise observations will improve this.

Simulations show that index fishing for 15 years has a good chance of detecting changes of 5% annually. This will detect the loss of half the population over that period, which is less than the age-of-maturity for lake sturgeon.

CONCLUSIONS

Radio-tracking showed movements by individual sturgeon between Saskatchewan and Manitoba. They also showed considerable overlap in the areas used by sturgeon tagged at different spawning sites.

Most mature-size fish tagged near spawning sites in Saskatchewan moved downstream after spawning season. Immatures tagged in Manitoba tended to swim some distance upstream and remain.

Radio-tagged sturgeon were found primarily in the mainstem river. The longest individual movements were 74 km upstream and 89 km (55 miles) downstream. This is much less than the range needed for reproduction and growth by the population.

Index fishing and historical data suggested there have been changes in sizes and abundance since 1983. This is consistent with a further decline in the population, but not yet conclusive.

Experienced index fishers have credibility within communities and their records and observations are useful.

RECOMMENDATIONS

Recovery of this sturgeon population depends on action on both habitat and harvests. Accordingly, actions selected from these recommendations must collectively address both of these issues.

Management on the population should continue to be a co-operative effort of provincial agencies, communities, and resource users.

Protection of the habitat and protection from local over-harvest is required, especially during spawning in former and present sites.

Continued harvesting of lake sturgeon from the lower Saskatchewan River will allow the present decline to continue, and may delay or prevent the recovery of this population.

Stakeholders should seriously consider restrictions on commercial and subsistence fishing. Information on subsistence fishing and cultural uses by First Nation and other aboriginal people is needed.

Agencies responsible for allocation and usage of water should analyse the effects of enhancing water flows in the former Tobin and Squaw Rapids for spawning.

Radio-tagging should be continued until late 1999. Index fishing should be continued for biological, economic, and action-plan reasons.

Further trials of egg collection for re-stocking should be undertaken.

These recommendations were based on work in both the present report and a companion report (Wallace 1999).

ACKNOWLEDGMENTS

We appreciate the efforts of the many people involved in this project.

Alfred Joe Goulet and Howard McKenzie (Cumberland House) and Ray Desjardins and Ian Kitch (The Pas) tracked radio-tags for long hours, tagged and released fish, and worked with index fishers on all aspects.

Earl Jessop and Robert Fudge (Canada Fisheries and Oceans), Don MacDonell (North/South Consultants), and Ken Kansas (Manitoba Natural Resources) aided greatly by providing advice and radio-tags for early trials. Pilots Dave Heidel and the late Brett Thomas (Northern Air Operations) flew tracking routes in winter.

Linda Brown, Lori Beatty, and Loretta McFadzean provided contract and payment support. Conservation Officers Donald McKay, Trent Catley, and Rob Stolz, and Caroline McKay, Ben Fiddler, and Nick Crane, assisted with logistics. Lennard Morin (Cumberland House) donated accomodation to us during field-work.

Index fishers in Manitoba (Simon Bignell, Simeon Sayese, and James Buck) and Saskatchewan (Marcel Fiddler, Nathan Settee, Joseph Budd, Philip Crane, William Chaboyer, Greg Crate, George Carriere, Peter Crane, John Carriere, Ralph Cook, Kevin Nabess, Joseph Fiddler, Glen McKenzie, Kennedy Dorion, and Kelvin McKay) provided experience and equipment, held fish carefully, kept fishing records, and contributed other observations.

Members of the steering committee reviewed the scientific aspects of this report during 1998 and 1999. Verbal and written comments were received from: Alfred Joe Goulet, Anne Acco, and John Carriere (Cumberland House), Chief Pierre Settee (Cumberland Cree Nation), Robert McGillivary (Opaskwayak Cree Nation), Scott Findlay (IREE University of Ottawa), Llewellyn Matthews (SaskPower), Maynard Chen and John Durbin (Saskatchewan Environment and Resource Management), and Dennis Windsor (Manitoba Hydro).

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INTRODUCTION

Concern for the status of the lake sturgeon (Acipenser fulvescens) population and habitat in the Saskatchewan River arose during monitoring in the 1980s. The situation was summarized in an earlier report (Wallace 1991), which called for protection of the population and restoration of suitable habitat conditions.

An Interprovincial Sturgeon Steering Committee was formed, including resource users (Saskatchewan and Manitoba commercial fishermen, First Nations users, and Metis users), staff from federal Fisheries & Oceans, Manitoba (Northwestern Region - Fisheries) and Saskatchewan (Fisheries Branch), and staff from SaskPower. This committee met periodically to discuss concerns and to review progress. Meetings were open to all interested people from the communities and other organizations.

Ongoing issues led to a four-year project from 1994 to 1997. Restoration of the sturgeon population in the Saskatchewan River from E.B.Campbell dam (formerly Squaw Rapids dam) in Saskatchewan downstream to Grand Rapids dam in Manitoba requires five components (M. Chen, pers. comm.):

- Habitat inventory and evaluation.
- Population assessment.
- Habitat protection, improvement, or creation.
- Population restoration and/or enhancement.
- Co-management with local stakeholders, and assessment of program effectiveness.

Some of these topics, such as spawning sites, water flow regimes, general habitat and forage conditions, and sizes and ages of sturgeon in commercial harvests were reported earlier in a companion report of this project(Wallace 1999).

The present report covers migrations of sturgeon through radio-tracking, and monitoring of abundance, sizes, and ages through index fishing.

The objectives of radio-tracking were to follow seasonal and longer movements in Saskatchewan and Manitoba, assess patterns of the single population (or several sub-populations), and begin identification of preferred habitat conditions.

The objectives of index fishing were to continue the monitoring of fish sizes, continue a historical catch-per-effort index of fish abundance, establish a baseline for future work on population declines or recoveries, and allow tagging of sturgeon for estimates of recent population abundance. Historically, commercial fishermen have provided specimens for fish-size monitoring since 1958 in Saskatchewan and during 1977 to 1980 in Manitoba. Index catch-rates should allow comparisons to previous commercial catch-per-effort, as well as future conditions.

In Manitoba, both sport and commercial fishing of sturgeon were closed by 1995. Sturgeon have been declared a "Heritage Species" and a vulnerable species under the Endangered Species Act (Manitoba).

Funding for radio-tracking and index fishing came from several sources: in Saskatchewan from SaskPower (1994 to 1997), Saskatchewan Environment and Resource Management (1994 to 1997), and Manitoba Hydro (1997); in Manitoba from Special Conservation and Endangered Species Fund (1995 to 1997) and Manitoba Department of Natural Resources (1994 to 1997).

PROJECT AREA

The project area extended from the EBCampbell dam to the upper end of Cedar Lake (Figure 1). At various times, radio- tracking and index fishing occurred in the Old Channel, the lower Torch River, the Mossy River and other channels, Cumberland Lake to Namew Lake, and downstream towards Cedar Lake in Manitoba.

About 1873, the Saskatchewan River overflowed its banks, joined existing rivers, and cut new channels to create a delta (Smith et al. 1989). Some former rivers retained their names after incorporation.

The present mainstem Saskatchewan River from upstream to downstream comprises:
EBCampbell spillway (6 km long),
Saskatchewan River (27 km long),
New Channel (22 km),
Centre Angling River (about 26 km),
Saskatchewan River (16 km),
Bigstone Cutoff (6 km),
Saskatchewan River (about 209 km), and
Cedar Lake (117 km).

The lengths of other channels which are not on the mainstem (such as North Angling River, or Summerberry River) are not shown.

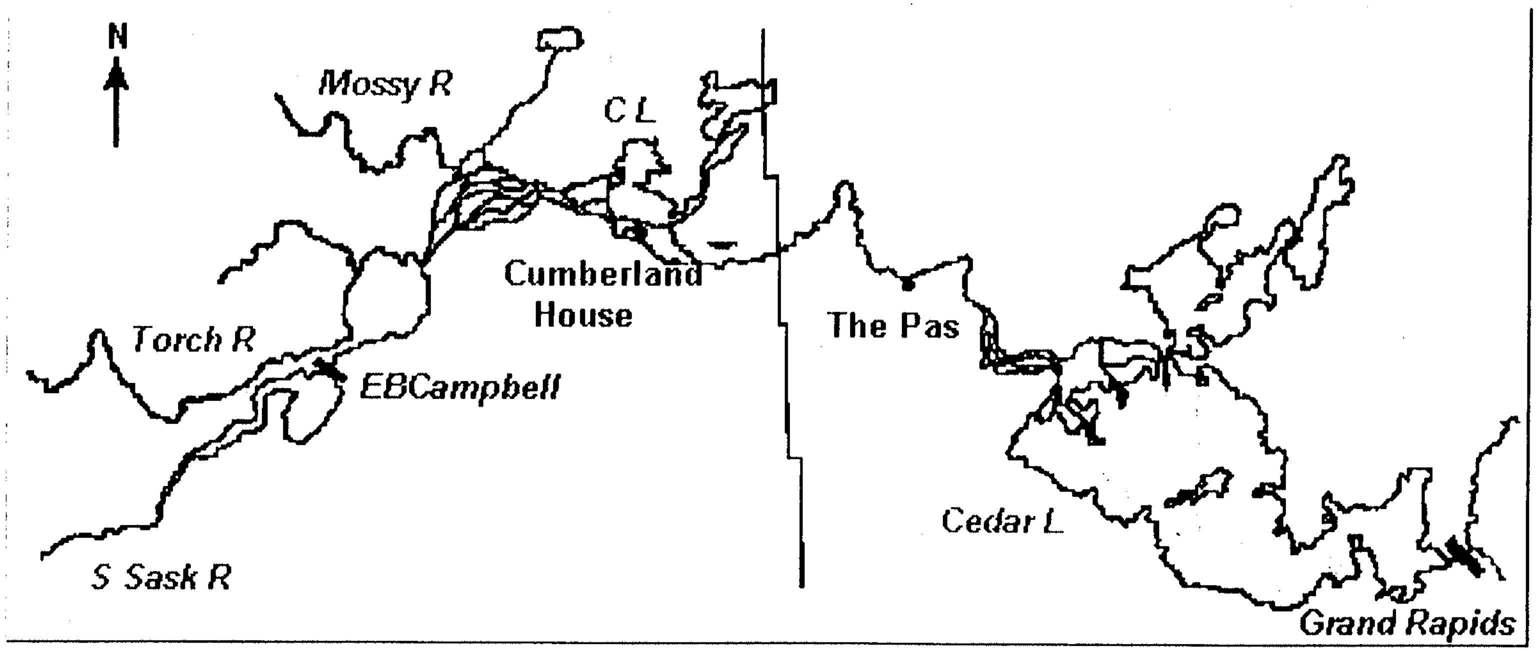


Figure 1. Map of Saskatchewan River and tributaries, from EBCampbell to Grand Rapids.

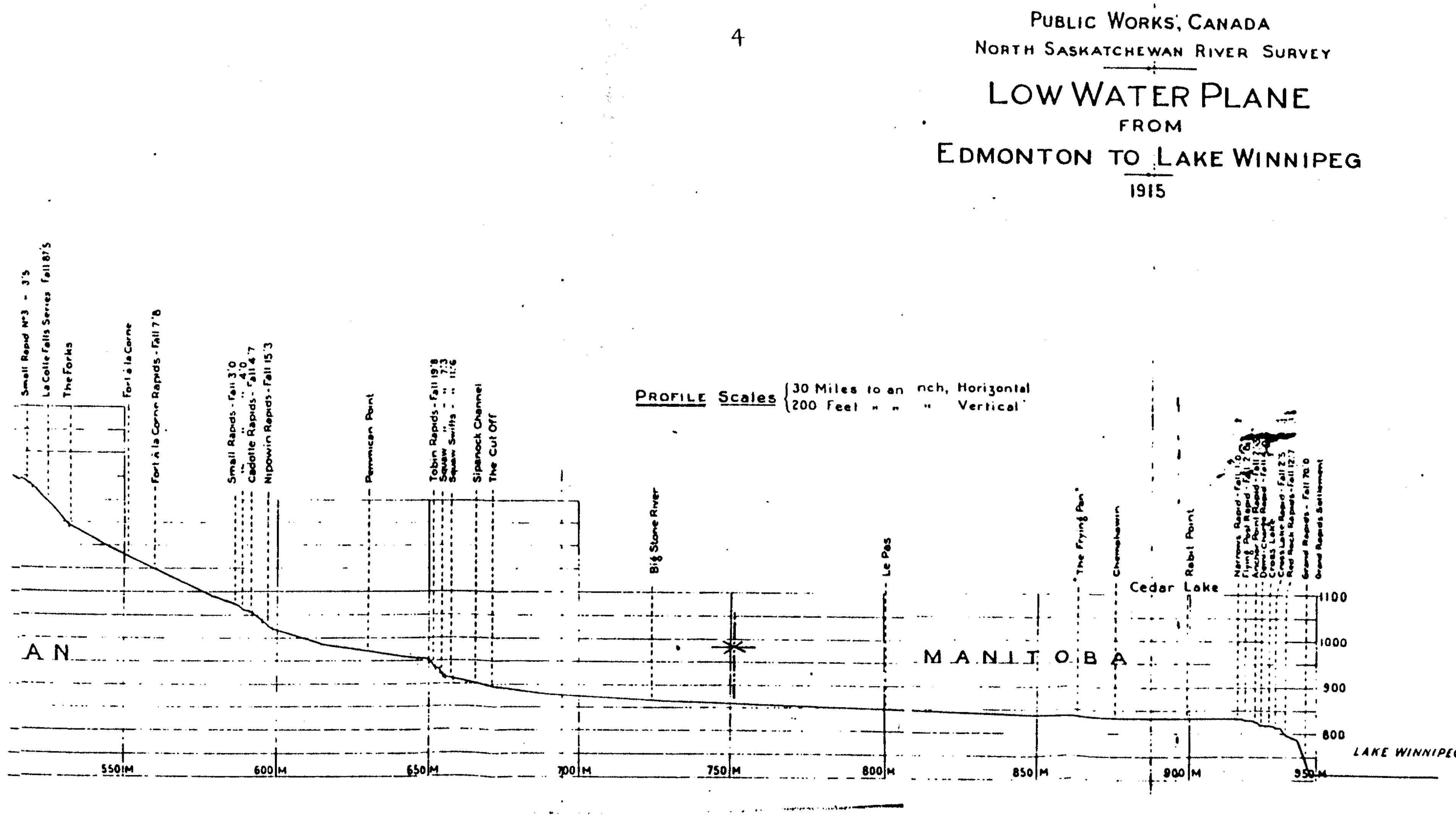


Figure 2. Profile of Saskatchewan River water surface from The Forks (Saskatchewan) to Grand Rapids (Manitoba). Portion of original map by Voligny (1917).

The upper portion of Saskatchewan River has a much steeper gradient than downstream (Figure 2), but is generally sandy due to sediment deposition in Tobin Lake. The New Channel and Centre Angling River are well defined, with some natural levees along the river-banks (Smith et al. 1989) and secondary channels (e.g. Steamboat Channel and North Angling Channel). The next area consists of the Saskatchewan River and interconnecting channels. The Bigstone Cutoff carries flow from the Saskatchewan River, and outflow from Cumberland Lake (both directly and via the Bigstone River). The Tearing River, which provides a second outlet for Cumberland and Namew Lakes, is flowing again after high water in March 1995 breached an earthen dam at its upper end.

The lower portion of the Saskatchewan River is again well-defined to and beyond The Pas. About 30 km below The Pas, the Saskatchewan River is surrounded by low-lying land, changes from hardpan bottom to silt and organic sediments (Cober 1968), and splits into various channels (such as Summerberry River and Head River).

In Saskatchewan, the maximum depth along the Saskatchewan River is 15 m (51 feet, Centre Angling River) and there are substantial areas over 8 m (25 feet) deep. Some channels are less than 1 m (3 feet) and not accessible to boats at typical river-flows (e.g. North Angling River and Steamboat Channel). Cumberland Lake is less than 2 m (6 feet) deep, with a maximum of 2.5 m (8 feet) under flood conditions (Willard et al. 1978).

In Manitoba, a number of areas in the river range from 10 to 18 m deep (30 to 60 feet), depending on waterlevels. These tend to be either scoured eddies or areas along the outside edge of bends in the river.

RADIO-TRACKING

BACKGROUND

Indirect evidence (such as growth rates, condition factors, and catch rates) was used previously to assess if sturgeon comprised a single population or several populations in the lower Saskatchewan River (Findlay et al. 1995). Direct information on migrations has traditionally depended on visual marking of sturgeon, their later recapture, and reliable reporting of information.

A newer approach uses radio-tags to track sturgeon, record their locations, and repeat this regularly for the same individuals. The migrations of sturgeon in the area between EBCampbell dam and Cedar Lake are unknown, so plans had to allow for long-range movements (250 km or more) and for individuals which stayed in smaller areas (Radford 1980, RLL 1991, Auer 1996).

Excellent outlines of the principles, problems, and practices of radio-tracking are found in Stasko and Pincock (1977) and Winter (1983). Basically, radio-signals radiate in all directions from the fish, and those which reach the surface within 6° of vertical emerge and can be detected. Antennas which receive the signal provide the location of the fish, using either triangulation or (less often) signal strength.

Radio signals are weaker in deep water or high-conductivity areas, reducing the detection range (Stasko and Pincock 1977). Lower radio frequencies of 50 MHZ are less affected by water than those used for wildlife (150 MHZ and up).

Depth-soundings in 1994 and 1995 showed deep spots of 15 m, and several areas over 8 m along the lower Saskatchewan River and other channels. Deeper pools usually provide mid-summer or over-winter habitat for sturgeon. Other agencies have noted that radio-signals were detectable for only a 30-m range when lake sturgeon were located in 10 m of water (Diana et al. 1990).

Signal strength from a fish 5 m deep in water with a conductivity of 300 uS/cm is only 5% of the same fish at the surface (Winter 1983). Problems with detection can begin at conductivity of 500 uS/cm (Tyus 1982, BIOTELEM 1996).

Historical data for the Saskatchewan River showed average conductivity for May to September was:

Specific conductivity	366.7 (uS/cm)
TDS	208.1 (mg/L)

below Carrot River in Manitoba. About 10% of samples were above

500 uS/cm, and only 3% over 700 uS/cm (data for Environment Canada Station #00MA05KH0001 for 1974 to 1993, from J.G. Zakreski, Environment Canada, Regina). Conductivity was 357 uS/cm in Cumberland Lake in September 1976 (Willard et al. 1978).

Therefore, our conductivity was moderately high for radio-tags, but typical of other Saskatchewan River areas (e.g. North Saskatchewan in Merkowsky 1987, and South Saskatchewan in Miles and Sawchyn 1988) and other sturgeon habitat.

Radio-tracking in winter was tentatively planned. Conductivity is lower during autumn to spring, with only 3% of readings over 500 uS/cm. However, ice-cover usually interferes with signals, though not seriously in most studies. A greater problem for tracking by snowmobile was the unsafe condition of ice in the river upstream of Cumberland House.

The alternative for tracking was an ultra-sonic tag, which operates at much lower frequency. Generally, these are used in very deep or very high-conductivity areas (e.g. sea water or coastal estuaries). However, they are unsuitable in areas with air-bubbles (e.g. below rapids), with algae or other vegetation (e.g. mid-summer in Saskatchewan River), or with poor line-of-sight (e.g. shallow and winding rivers). They also require the use of underwater phones for detection, so that tracking by boat or plane over long distances would not be possible (Stasko and Pincock 1977, Winter 1983, Diana et al. 1990).

METHODS

In 1994, we checked the feasibility of radio-tags in field trials. Radio-tags, a radio-scanner, and loop antennae were borrowed from Fisheries & Oceans and Manitoba Department of Natural Resources (K. Chu and E. Lodge, respectively).

Trials in the Bigstone River showed that the combination of depths and conductivities were a concern when using a boat for tracking. Radio signals were detectable from about 150 m away in this relatively narrow channel, although tags located over 8 m (25 feet) deep were not detected at all. However, these trial tags had been previously used and may not have been full-strength.

In 1995 and 1996, both ATS (Isanti MN) and Lotek (Newmarket ON) radio-tags were used; both cost about $ 300 Cdn each. They emit signals at 48 to 49.999 MHZ and have unique frequencies for each fish (spaced 0.010 MHZ apart). Both have C-size lithium batteries with a minimum 2-year life-span; later specifications indicated 3 years (ATS 1996). Tags were about 3 cm (1.5 inch) diameter by 9 cm (3.5 inch) long, with a 45-cm (18 inch) flexible, trailing antenna. The usual recommendation is that radio-tags should weigh less than 1.5 to 2 % of the fish body-weight (Winter 1983). These tags weighed 73 g (3 ounces), less than 1 % of any sturgeon over 7.8 kg (16 pounds).

In Saskatchewan, we radio-tagged sturgeon over 12 kg (25 pounds) when possible, to obtain information on mature-size fish and spawning migrations. Fish were usually examined for external signs of sex, maturity, and spawning stage. In Manitoba, radio-tags were applied to sturgeon of various sizes to initiate tracking earlier and because numbers of mature-size sturgeon were limited.

Sturgeon were tagged while restrained upright. Preferably, they were lying on a wetted board in shallow water, so that their head was underwater. Occasionally, they were in a sling on shore or in a boat when the shoreline was unsuitable.

We attached radio-tags externally through the dorsal row of scutes. Two 4-mm holes were made with a battery-powered drill, near mid-body of the fish. Attachment cables were run through the holes and plastic backing plates with foam padding (similar to Haynes et al. 1978, RLL 1991). ATS cables were multi-wire and took considerable effort to crimp. Lotek wires were more flexible single-wire and were simply tied. We usually applied a topical iodine solution to prevent or reduce infection. Larger sturgeon have flatter or embedded scutes, which are more difficult to pass wires through, but this was not a major problem.

External tags allow for maximum detection, although they may suffer from greater contact with rocks and debris, and allow for buildup of algae. Internal tags have a looped antenna, which reduces output substantially, or have an antenna protruding to the outside through the body wall, which requires more surgery.

Lotek-brand radio-tags cannot be identified visually once attached, as they have serial numbers only on the fish-side. We added numbered yellow, disc-type tags to enable identification without removal of the radio-tag and without the need for a radio-scanner. The ATS-brand tag frequency and serial number for each fish is visible after application.

Tagged fish were held for 5 to 30 minutes to assess condition of the fish and radio-tag. The site of release was scanned later the same day, and usually the next day, to check short-term movements.

Radio-tags emit about 55 signals/minute, which are turned into audible 'beeps' for average human hearing by the ATS radio-scanner (Model 2100). Usually, each frequency was scanned for 2 to 4 seconds to allow at least 2 beeps from each fish.

Planes were used for tracking occasionally, typically late fall/winter and early spring. Antenna were fitted to wing-struts of Cessna 185 according to methods and specifications in Gilmer et al. (1981). Flights speeds were about 120? knots (150 km/hour) and altitudes about 1500 feet (500 m) above ground. Radio-signals remain strong after emergence from water, so relatively high altitudes are suitable and allow reasonable scan-time for 10 or more frequencies.

Contractor's boats were used in Saskatchewan for irregular tracking trips, using a hand-held loop antenna. Most routes were along the Saskatchewan River, but tributary rivers, secondary channels, island areas, and both Cumberland and Namew Lakes were searched at times. Department boats were used in Manitoba for regular trips, using a tower-mounted loop antenna. Extending the antenna higher in a boat may achieve a slight gain, because refraction means that the signal is more diffuse near the surface.

In all years, commercial and other fishermen were asked to co-operate by reporting radio-tags numbers for a reward, or returning the tag itself for a reward if the sturgeon was not released. Fishers were advised and reminded verbally, and notices were posted at local department offices and access points at Cumberland House and campgrounds near EBCampbell power-station.

RESULTS

In 1995 and 1996, we applied 25 radio-tags (20 of ATS model 8, and 5 of Lotek model FRT-7) in Saskatchewan and Manitoba.

In Saskatchewan, workers applied 7 tags at three sites (Torch River, Bigstone Rapids, and Cumberland Lake) in 1995, and 8 tags at four sites (Torch River, Bigstone Cutoff, Bigstone Rapids, and Tearing River) in 1996. The first tags were applied in May 1995; one was still beeping in June 1997. The last tags were applied in July 1996; one has not been seen since October 1996. Radio-tagged sturgeon ranged from 8.2 to 33 kg (17 to 73 pounds).

In Manitoba, workers applied all 10 tags in June 1995. One was never relocated after release, while 8 were found in August 1997. Radio-tagged sturgeon ranged from 2.9 to 12.9 kg (6 to 29 pounds)(Table 1).

Table 1. Sizes of sturgeon radio-tagged in Saskatchewan and Manitoba, 1995 and 1996.

Release Site & Date	Radio freq	Fork length[a]	Round weight	Visual tags	Comments
	48.xxx	cm (inch)	kg (lbs)		
Torch outlet					
19-May-95	020	124 (49)	13.6 (30)	yes	...
19-May-95	042	130 (51)	13.6 (30)	no	...
31-May-96	030	119 (47)	17.5 (39)	no	Female, mature
31-May-96	050	127 (50)	21.5 (47)	no	Female, mature
Lake & Cutoff					
19-Jul-95	010	108 (42)	11.0 (24)	no	...
19-Jul-95	070	113 (44)	13.0 (28)	no	...
19-Jul-95	100	121 (48)	16.0 (35)	no	...
2-Jul-96	421	126 (50)	22.0 (48)	yes	...
3-Jul-96	361	125 (49)	20.0 (44)	yes	...
4-Jul-96	400	135 (53)	22.5 (50)	yes	...
Bigstone Rapids					
23-May-95	060	96 (38)	8.2 (18)	yes	Female, spent?
23-May-95	080	123 (48)	17.5 (39)	yes	...
6-Jun-96	090	131 (52)	14.8 (33)	no	Female, running
Tearing outlet					
11-Jun-96	321	140 (55)	28.0 (62)	yes	Female, ripe?
11-Jun-96	341	133 (52)	19.2 (42)	yes	Male, spent?
Barrier					
22-Jun-95	161	89 (35)	3.9 (9)	no	...
30-Jun-95	261	109 (43)	5.7 (13)	no	...
North outlet					
20-Jun-95	121	124 (49)	11.5 (25)	no	...
The Pas					
22-Jun-95	140	118 (46)	8.8 (19)	no	...
26-Jun-95	181	100 (39)	6.4 (14)	no	...
26-Jun-95	221	129 (51)	12.9 (28)	no	...
26-Jun-95	241	104 (41)	6.5 (14)	no	...
30-Jun-95	201	83 (33)	2.9 (6)	no	...
30-Jun-95	281	115 (45)	10.0 (22)	no	...
30-Jun-95	301	115 (45)	10.1 (22)	no	...

[a] Manitoba lengths are actually "total length" (about 108.1% of fork length, according to Royer et al. 1968).

Saskatchewan was committed to buying large sturgeon from commercial fishermen for tagging in 1995. On one occasion, a large sturgeon (about 58 pounds, from a spillway pool at EBCampbell) was released without a radio-tag to retain enough tags for commercial catches. Then, commercial fishing was 'washed-out' due to high river-flows in June and July 1995.

The radio-scanner was effective at automatically scanning for any frequencies stored in memory (typically, 10 tags). After each fish was located, its frequency was skipped during scans to reduce the chance of missing other frequencies. Aviation-grade headphones were necessary for tracking by boat and plane. Interference noises from outboard motors was a problem, especially during long sessions. The meter on the scanner was useful to 'flag' inaudible or low tones.

Several individual migrations or events are described here (Figures 3 and 4; others in Appendix 1). General movement patterns are shown later.

- Sturgeon #48.080 was reportedly caught at Bigstone Rapids within days of tagging in early June 1995, and the tag lost.

- Sturgeon #48.042 (tagged at Torch River in May 1995) swam upstream 17 km towards EBCampbell for two weeks, then turned and swam or drifted 70 km downstream by July 1995. It did not move more than 4 km by the fall of 1997.

- Sturgeon #48.121 (tagged near The Pas in June 1995) swam upstream 63 km in the first month, and has not moved more than 2 km since then.

- Sturgeon #48.181 (tagged near The Pas in late June 1995) also swam upstream 74 km in one month, then drifted back 13 km. It did not move more than 7 km by the end of 1997.

- Sturgeon #48.140 swam or drifted 21 km downstream after tagging at The Pas, and remains the furthest downstream.

The general direction for 4 sturgeon released at Torch River outlet was upstream: 2 reached EBCampbell power-station, 1 swam only partway to EBCampbell, and 1 moved into Torch River. Upstream water temperatures were still below (or near) suitable spawning temperatures at the time of release of these fish.

Most of 6 sturgeon tagged at Bigstone Cutoff and nearby in Cumberland Lake stayed locally: 4 remained in the cutoff or Bigstone Rapids, 1 swam upstream 28 km, 1 moved downstream into Manitoba. These fish were all released in July, when water temperatures were no longer suitable for spawning.

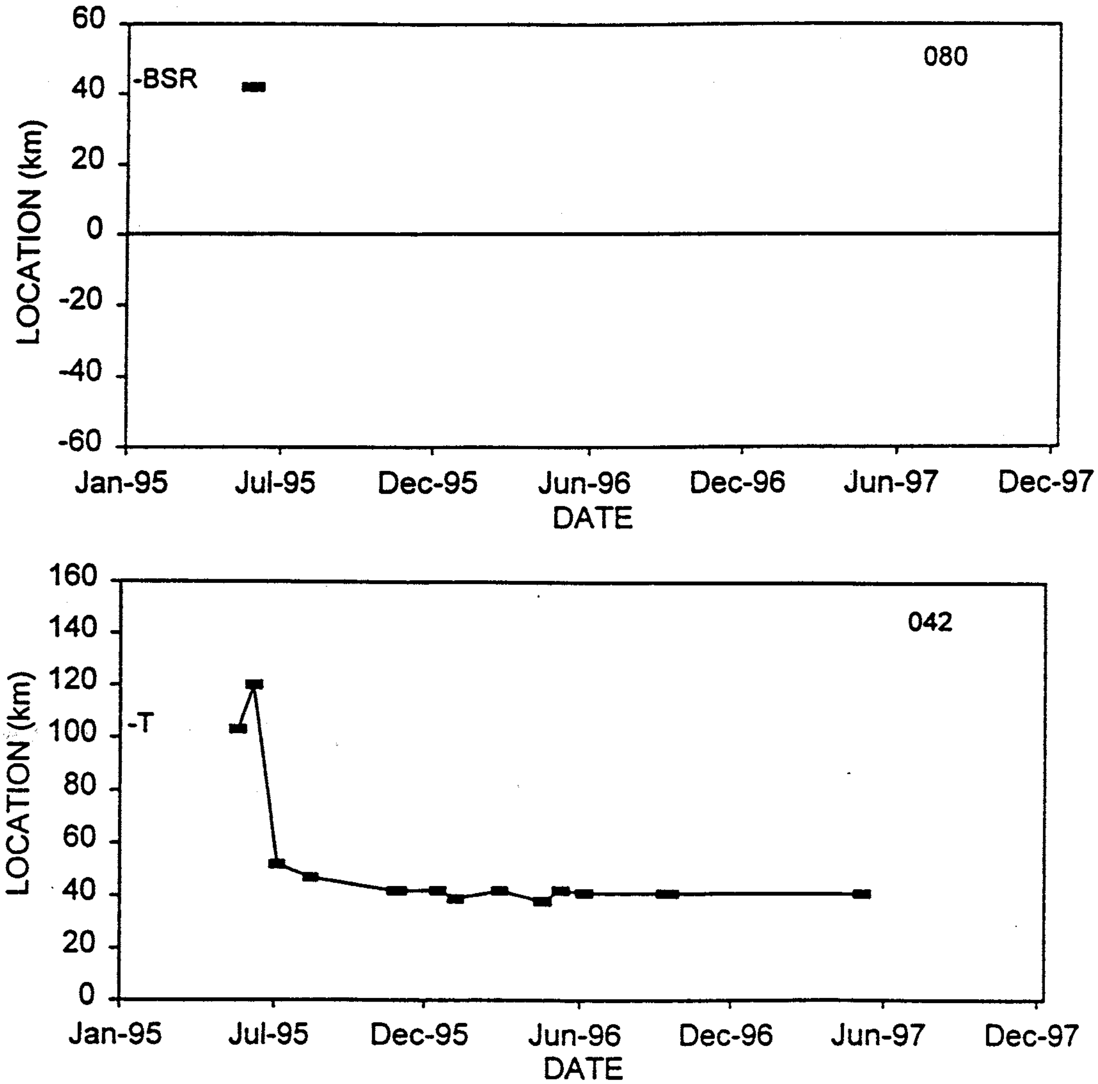
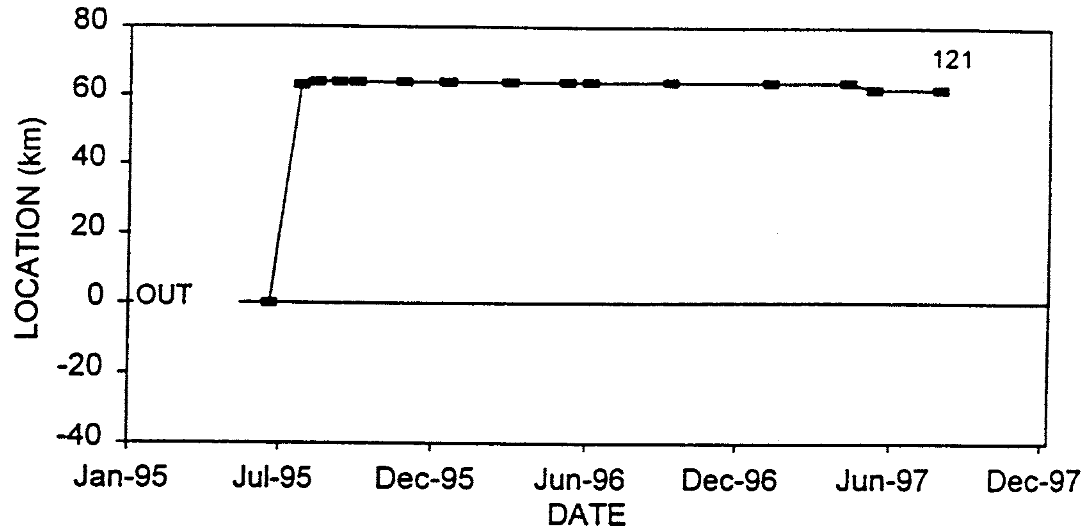


Figure 3a. Examples of upstream and downstream movements by individual radio-tagged sturgeon, 1995 to 1997. Zero (0) marks the provincial border; upstream is top of graph. BSR is Bigstone Rapids and T is Torch River in Saskatchewan.



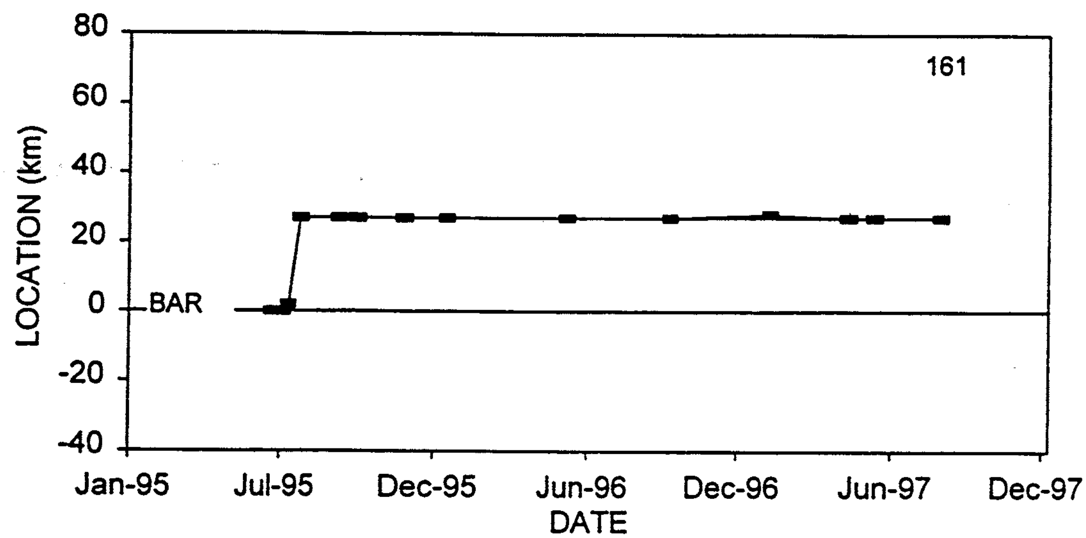
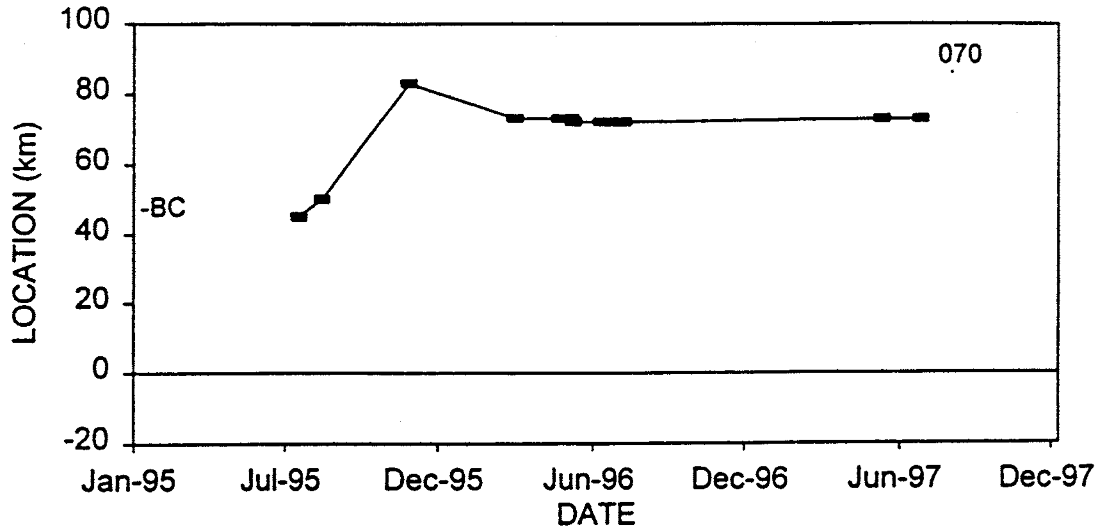


Figure 3b. Examples of upstream and downstream movements by individual radio-tagged sturgeon, 1995 to 1997. Zero (0) marks the release site; upstream is top of graph. OUT is North Outlet and BAR is Barrier area in Manitoba.



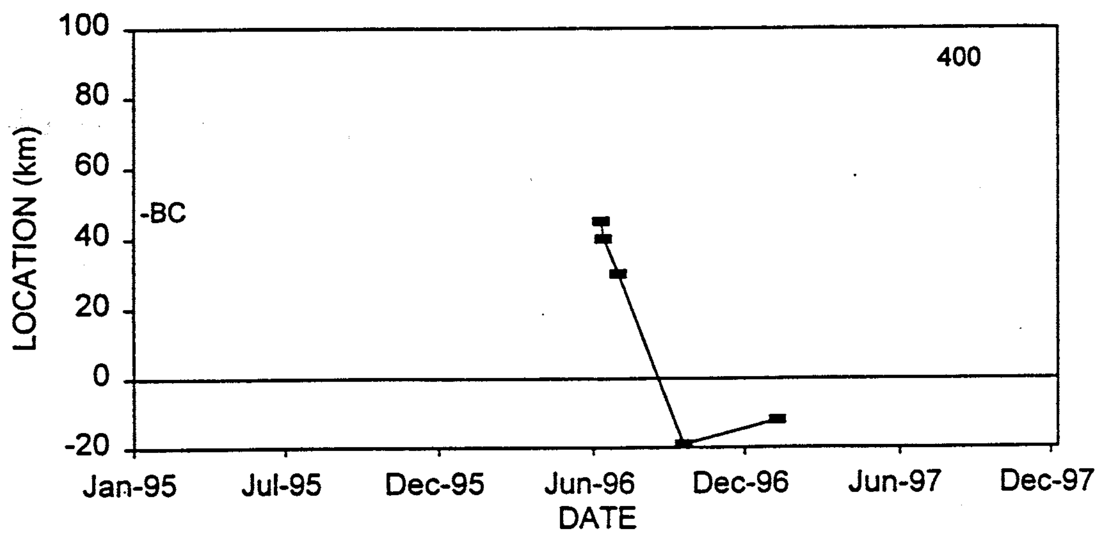


Figure 3c. Examples of upstream and downstream movements by individual radio-tagged sturgeon, 1995 to 1997. Zero (0) marks the provincial border; upstream is top of graph. BC is Bigstone Cutoff in Saskatchewan.

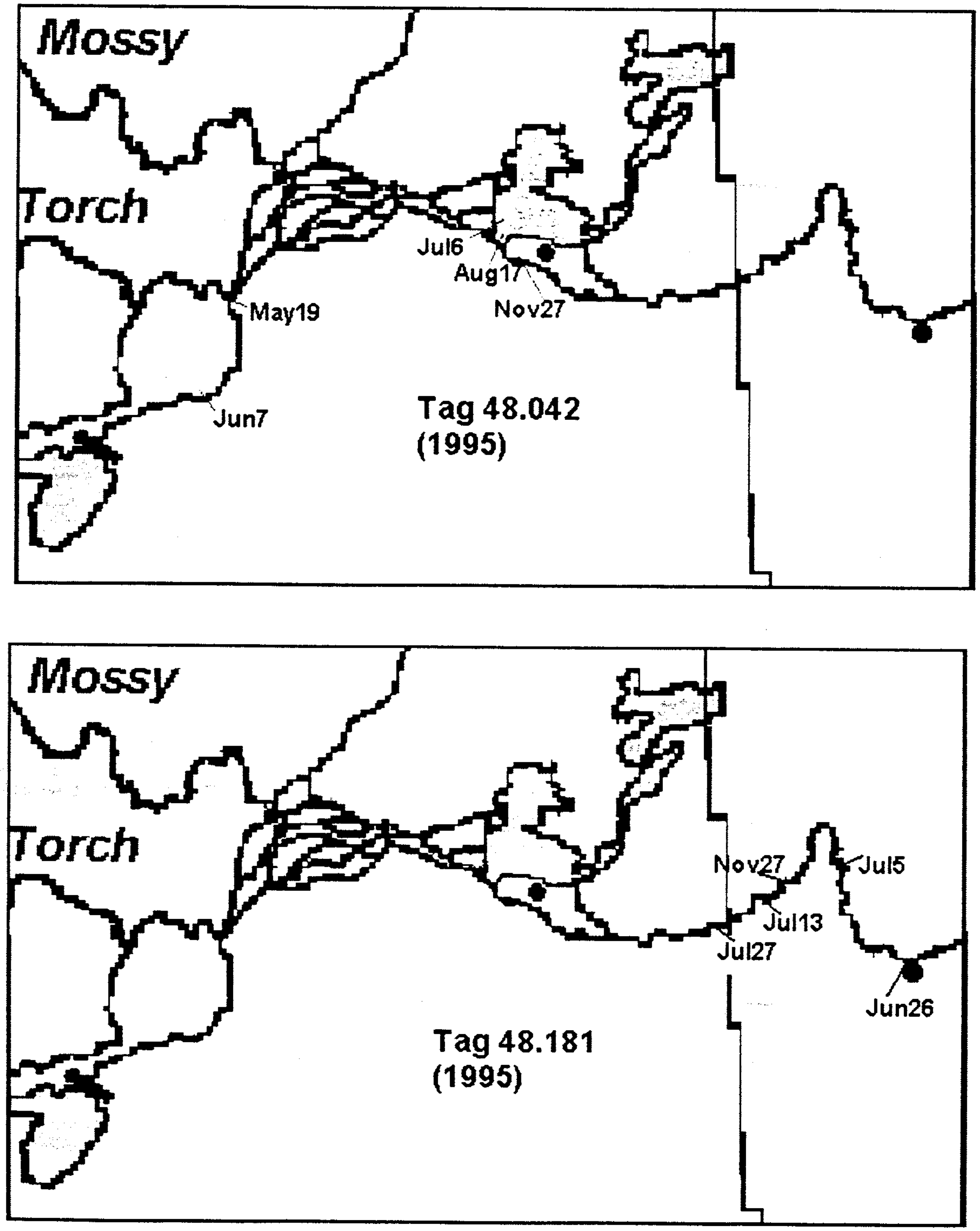


Figure 4. Examples of movements on maps by individual radio-tagged sturgeon, 1995 (see text).

Sturgeon released at Bigstone Rapids moved downstream: two moved downstream 65 to 100 km and remain inside Manitoba, one was lost within days. These fish were released prior to, or during, spawning temperatures. Sturgeon #48.090 was observed with free-running eggs, and probably spawned in these rapids before drifting.

Sturgeon radio-tagged at Tearing River moved downstream: 1 moved 88 km and remains in Manitoba, 1 was not seen after its release. Both of these fish were released near the end of spawning temperatures in the Tearing River. Sturgeon #48.341 left the area within three weeks, but was not located until mid-winter.

Most of the sturgeon tagged at The Pas swam upstream: 4 went upstream (34 to 74 km at farthest point), 2 moved downstream (2 to 21 km), and 1 was lost immediately. All but one were less than 12 kg (25 pounds) in size, and not likely influenced by spawning behaviour.

The maximum speeds observed were at least 3 to 5 km/day upstream (by two small sturgeon from The Pas) and 2 or 3 km/day upstream (by two large sturgeon migrating towards EBCampbell). The minimum speeds were near-zero, due to long periods of inactivity or local movements too small to detect by occasional tracking.

Movements (over 1 to 2 years) were assessed using the ranges of individual sturgeon, grouped by release site. We tested whether the extent of movements was limited by having only two years of tracking. Ranges at the end of 1 and 2 years were compared for 14 sturgeon (6 mature-size and 8 smaller). On average, they covered about 98% of their ranges within the first year after tagging, indicating that early migrations are relatively fast and presumably specific in intent.

Sturgeon released at Torch River outlet ranged from about km140 to km30. Sturgeon released in the Lake and Bigstone Cutoff area (the next site downstream) ranged from km80 to km-20 (Figure 5). These were simple counts of the number of fish using each 10-km stretch at some time, for either residence or passage.

There was a steady progression in ranges from uppermost to lowermost release sites. Most groups ranged over 80 to 100 km of the river, and all groups overlapped with 2 to 5 of the other 6 groups. This method of summing utilization includes both fish passage and residence periods. It does not weight long-term feeding and resting areas any differently than spawning sites, which are used only a few weeks.

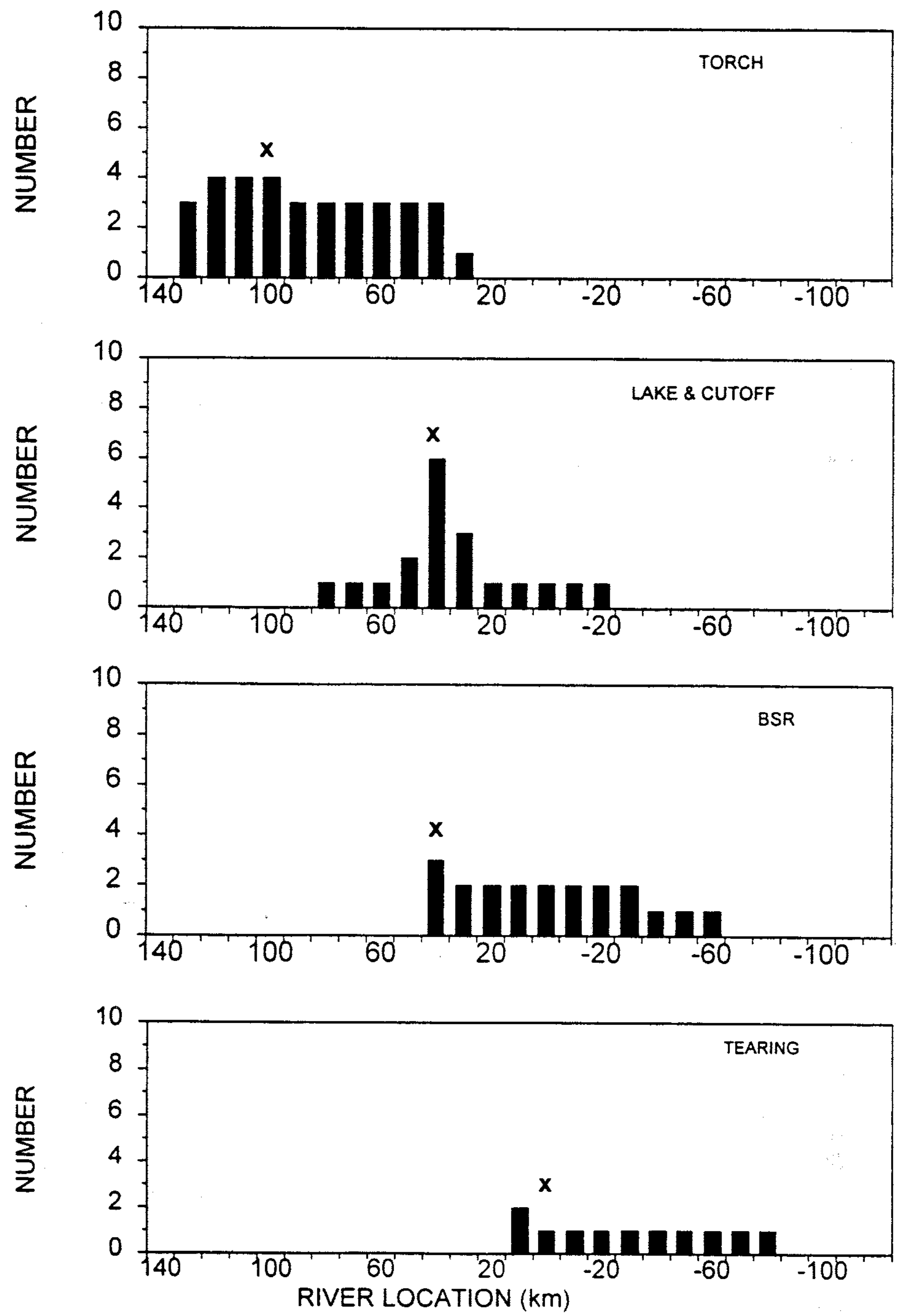


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Figure 5. Range of movement of radio-tagged sturgeon, grouped by release site, 1995 to 1997.
X marks the release site; river location is upstream (+) or downstream (-) from the provincial border.

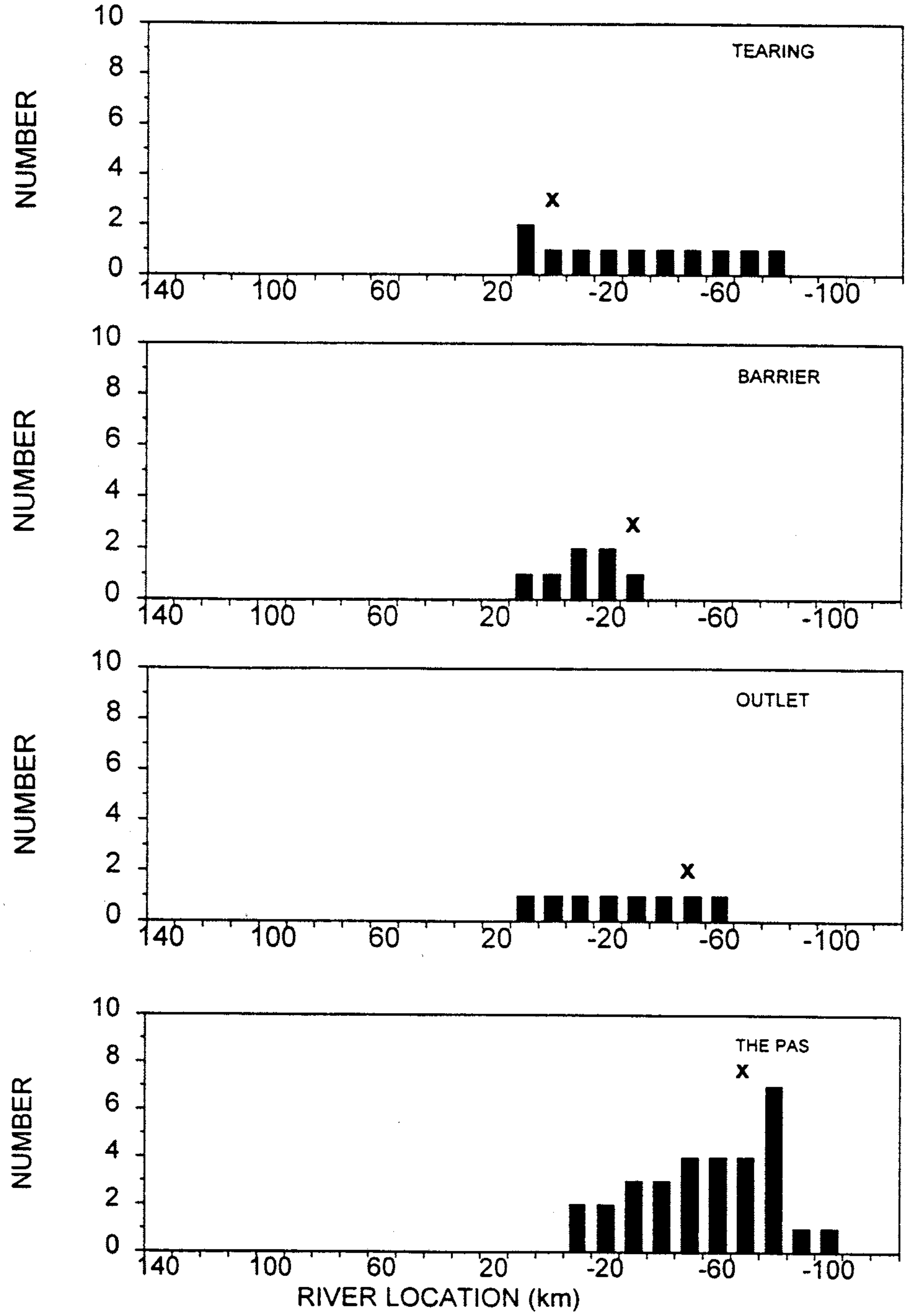


Figure 5 cont'd. Range of movement of radio-tagged sturgeon, grouped by release site, 1995 to 1997.
X marks the release site; river location is upstream (+) or downstream (-) from the provincial border.

DISCUSSION

RADIO-TAGS

Some issues of radio-tags will be addressed before further implications of tracking are outlined. The 1-in-100-year flood which occurred in early June 1995 was noteworthy: it prevented field-work at several sites and buried bottom-set gear in shifting river-bed sand. Nonetheless, it did not affect most sturgeon appreciably. High flow-rates did not appear to 'flush' fish downstream, as observed when radio-tagged sturgeon drifted 30 km in extreme flows during February (RLL 1991). The difference may be related to river habitat providing more refuges in the lower Saskatchewan River than in Alberta, or to stronger orientation to fixed sites during or just after the spawning period versus the sedentary mid-winter period.

Some of the downstream movements after release were probably due to the stress of capture and tagging. This was likely the reason for fish drifting 200 m to 3 km downstream for one to several days after tagging, before moving back upstream. General recommendations to minimize stress include:
- handling fish gently and releasing them quickly;
- avoiding attachment through major muscles (sturgeon scutes are good places);
- using a small radio-tag (perhaps more important for open-water species than bottom-dwellers);
- streamlining tags to prevent accumulation of weeds (a potential problem for sturgeon); and
- remaining reasonable distances from fish when tracking by boat (Stasko and Pincock 1977).

Guidelines were followed (where possible), but stress from gill-nets or hooks, handling, and attachment of radio-tags cannot be eliminated entirely. One improvement would be the use of tags which detach when their duty is done. For example, floating ultrasonic tags can be attached to fish by sutures which decompose over several weeks (Osborne and Bettoli 1995). Other trials have used bimetal wires which corrode and release, although the timing depends on water chemistry, fish activity, and other factors (BIOTELEM 1996). Or, tags could release after a fixed time or when battery-power indicates imminent failure. Work is underway on a tag that detaches by timer, then floats and signals for its retrieval (Weihs and Levin 1997).

Some radio-signals were lost, due to the death of sturgeon, shedding or destruction of radio-tags, or non-reporting of recaptures. Some remained stationary for long periods, with only small movements up or downstream or across the river, due to sedentary behaviour.

Handling and tagging techniques were designed to minimize any injury or shedding of tags, but shedding has been confirmed in other studies (RLL 1991). In at least one case in Saskatchewan, a large sturgeon was not radio-tagged due to poor condition after being tethered for 2 days and undergoing longer-than-usual handling. In two cases in Manitoba, fish which had been tethered for 1 day were radio-tagged which may have been "weakened" by tethering and handling. The difference between transporting and tethering a sturgeon to survive several days until marketing, and holding one for release and survival for several years is important. Still, three sturgeon were tethered a few days and tagged under similar conditions in 1984 and were successfully recaptured after 12 years in 1996.

Communication with resource users by poster and meetings, and the offer of rewards, should have improved co-operation. Only one radio-tagged sturgeon was reportedly caught, and the tag was not recovered. Other reasons for loss of radio-signals (such as premature battery failure or problems with signal-detection) are unlikely.

There are very few ways to detect shedding of radio-tags if the tag or fish is not recaptured. In Saskatchewan, one radio-tagged sturgeon was observed over several months at one spot in the power-station tail-race. During this time, flow patterns varied widely and this sturgeon was located in both an eddy and in high velocity water. This indicated probable entanglement of the fish or shedding of the tag, but was hardly conclusive. Only the complete loss of this signal from the tail-race (and everywhere else) was reasonable confirmation of physical destruction of the radio-tag.

Modifications are available for radio-tags (such as motion detection, temperature recording, and duty cycles)(ATS 1996). However, motion of a tag would likely be continuous in river situations, whether the fish was alive and the tag still attached or not.

MIGRATIONS

Radio-tracking confirms earlier indications of migrations between Saskatchewan and Manitoba. The longest movements were 74 km upstream and 89 km downstream from release sites.

Many of the mature-size sturgeon from Saskatchewan were tagged near known (or potential) spawning sites near spawning time. They then returned to downstream areas, as expected from other studies (Priegel and Wirth 1971, Sandilands 1987, RLL 1991). However, our lake sturgeon did not move further downstream as temperatures declined in autumn, as shown in these other studies. This may be because they are resident in the river, rather than both lakes and rivers.

Most of the sturgeon radio-tagged in Manitoba moved upstream; three sturgeon drifted or swam relatively short distances downstream. This may be related to the behaviour of smaller sturgeon, rather than habitat availability, because there are numerous deep areas below The Pas.

Sturgeon migrations are typically complex (relative to other fish), because they are influenced by geography, age, and state of maturity, as well as season. It is important to distinguish between movements due to post-spawning, seasonal, annual, mature-stage, and spawning behaviours, and (sometimes) origin of individuals. For example, lake sturgeon from Lake Winnebago (Wisconsin) migrate into both the Wolf and Fox Rivers to spawn, and sturgeon from Lake Poygan also spawn in Wolf River, but adults appear to return to their lake of origin (Lyons and Kempinger 1992). Some species migrate in separate groups according to size, sex, and reproductive stage (e.g. shortnose sturgeon in Dadswell 1979).

There were long periods of little or no movement during mid-summer and over-winter in the Saskatchewan River. Traditional views of sturgeon movements were of a 'home range' with more-or-less extensive spawning migrations. Wandering from the home area typically involved only a small group of fish (Scott and Crossman 1973, Priegel and Wirth 1971). 'Wandering' is perhaps an important element of populations in mainstem rivers. In Alberta, recaptures of visual tags over 10 years showed two stretches of river (70 and 100 km long) were used separately (Radford 1980). Later, radio-tracking of specimens released in the 100-km stretch showed that most remained in this area over the 15-month study, but a few ranged up to 140 km above and 40 km below this stretch (from table A9 in RLL 1991).

The question of a single population, or a number of sub-populations, from EBCampbell to Grand Rapids requires clarification. No single group of sturgeon ranged over the 240 km of river that was utilized, yet the several groups showed contiguous, overlapping usage. Migrations of individuals in a single population, or inter-mixing of those from separate sub-populations, is seldom all-or-nothing.

Using evidence from catch rates, ages, and growth rates at Cumberland House and The Pas, Findlay et al. (1995) suggested that there was "some support" for EBCampbell dam resulting in isolation of the population. They noted that the physical barrier would isolate a population in Tobin Lake from downstream populations. They also suggested that changes in distribution and quality of spawning, rearing, or over-wintering habitat would lead to isolation among sturgeon in downstream areas.

The progression in ranges from uppermost to lowermost release sites is primarily related to a maturity-stage (especially post-spawning). Behaviour probably encourages recovery, feeding, and growth in the next suitable downstream habitat.

There are management implications if these several groups (or sub-populations) have partially separate ranges. That is, protection/restoration of spawning habitat and fishing intensity becomes more important for each sub-population. Spawners in the Torch River area require suitable habitat at EBCampbell and Torch River; sturgeon in the Bigstone Rapids area require spawning habitat and protection from over-harvest; the Tearing River requires protection from blockages to maintain habitat for sturgeon from both Saskatchewan and Manitoba; juveniles near The Pas require protection from over-harvest and access to upstream spawning areas.

One sturgeon tagged with a visual tag in 1984 near the Saskatchewan/Manitoba border was recaptured in 1996 at the Torch River (Wallace 1999). This fish was a juvenile in 1984 and almost mature-size in 1996, suggesting that reaching maturity was more important than the 12 elapsed years.

Over the life-cycle of lake sturgeon, fish passage and residence are equally important. Critical habitats for spawning, feeding, and over-wintering are linked by equally critical migration routes. If each 10-km stretch was weighted by the length of time occupied, then small feeding and resting areas would predominate. Spawning sites used only several weeks every five years would appear to be marginally important, but this would be incorrect.

A recent review indicated that populations may require 250 km of habitat to complete their life-cycle, and sometimes longer (Auer 1996). The present range in the lower Saskatchewan River appears sufficient but further barriers would be a concern.

OVER-WINTERING

Aerial tracking during late fall and winter (late November 1995, mid-January 1996, and early February 1997) found sturgeon only in the main Saskatchewan River. Known over-wintering sites include areas of 15 m (51 feet) in Centre Angling, about 8 m (25 feet) below the Old Channel outlet, and over 8 m in numerous holes in Manitoba. Admittedly, a few sturgeon which disappeared for months and then re-appeared may have been in secondary channels, since locating signals may be more difficult in numerous channels and a large lake.

Over-wintering habitat is probably limited in secondary channels and Cumberland Lake. Winter flows probably do not provide sufficient depths in many channels, even though they are higher than summer flows. Winter oxygen conditions are likely poor in Cumberland Lake since it is shallow and eutrophic, with blue-green algae present, even though turbidity limits summer productivity (Willard et al. 1978).

Cumberland Lake has been affected by the natural evolution of the delta and changes in water-flow regimes (Smith et al. 1989). As early as 1915, reports predicted that flows would bypass the lake as the river-bed degraded (Voligny 1917). Maximum depth in June 1958 was 2.2 m (at 871 ft ASL), and only 1.4 m by mid-August 1958 (Reed 1959). Since natural spring floods were reduced in the 1960s, the lake is not recharged as regularly and summer inflows are restricted (Willard et al. 1978, Findlay et al. 1995). Recently, lake depths are about 1 m lower during summer than in the 1950s.

There does not appear to be a "lake population" of sturgeon in the Saskatchewan River, as found in Lake of the Woods (Rusak and Mosindy 1997). The latter sturgeon over-wintered in the lake in areas 7 to 11 m deep, while a "river population" over-wintered in river stretches 6 to 11 m deep.

FUTURE WORK

Since about half of the radio-tags are expected to last 4 or more years (R. Huempfner of ATS, pers. comm.), they could be tracked further. However, some of the females will not migrate for a second spawning before battery failure. Females in this population spawn only every 4 to 6 years, mature males every one or two years (Wallace 1991). If there is any doubt about the importance of spawning habitats, however, following mature sturgeon would provide the obvious confirmation.

Determining small-scale habitat preferences using radio-tags was not achieved, and may not be feasible. Using modified RG-58 co-axial cable underwater will detect radio-tags up to 10 or 15 m away, and obtain fairly precise locations (Winter 1983). Nonetheless, the fish must co-operate: in our experience, sturgeon move away from disturbances (such as boats and outboards) in water less than 3 m deep move away from. Furthermore, extensive surveys of utilized versus available habitat are required. General guidelines suggest at least 150 specimens are needed for preference curves (Bovee 1986).

INDEX FISHING

In Saskatchewan, commercial fishermen have provided fewer specimens for biological monitoring after effort and harvests declined in the early 1990s; sport fishing has always been sparse in this area. In Manitoba, both sport and commercial fishing were closed by provincial regulation by 1995.

The objectives of index fishing in 1996 and 1997 were to provide a catch-per-effort index of fish abundance, to continue monitoring of fish-size data (since 1958 in Saskatchewan and around 1980 in Manitoba), to establish a baseline for future evaluation of abundance and sizes, and to provide sturgeon for tagging and recapture for improved estimates of population abundance.

METHODS

In Saskatchewan, up to 10 crews of experienced fishers and helpers were contracted to index fish in 1996 and 1997. Special fishing permits were issued to allow the contractors and their helpers to fish and to retain sturgeon (Appendices 2 and 3). In Manitoba, 3 experienced fishers were signed on as contractors for three areas; they were paid a daily salary and approved fuel costs.

Crews fished at the traditional time and areas for sturgeon, using standardized gear. In Saskatchewan, this included both gill-nets (10-inch stretched mesh) and baited set-lines of Mustad 9/0 hooks on 3.5-mm sideline, which were provided to them, as well as some commercial gill-nets of their own (12-inch mesh by regulation). Local experience and other studies indicated that lake sturgeon up to 25 kg (55 pounds) would be caught in 10-inch and 12-inch mesh.

In Manitoba, crews fished out of their camps or residences in the areas of The Barrier (near the border), The Pas, and Pine Bluff (near Cedar Lake). Each fisher was provided with 8 gill-nets: two 46-m (50-yard) nets of 140, 203, 254, and 305 mm (5.5, 8, 10, and 12-inch) mesh. Nets were typically left in the water continuously (except for periodic cleaning), and checked at least once daily.

Crews were requested to record the amount and type of gear in use, and to note the gear in which individual sturgeon were caught. This was thought to be feasible since fewer than 10 sturgeon are usually caught in a week, and very seldom over 30 sturgeon (unlike catches of other fish species). Problems arose with these data in many cases, and results may be tentative.

Sturgeon were held by tethering them near the catch site, as previous experience with commercial fisheries showed low mortality from this practice. In Saskatchewan, the tagging crew visited each crew at least weekly. In Manitoba, department staff visited when required, typically within 2 days of capture.

Sturgeon were measured (fork length, cm or inches) and weighed (round, kg or pounds), usually in a sling. Sturgeon over 20 kg (44 pounds) required the use of a beam-scale, as they were over the capacity of our hanging-scale. In Manitoba, sturgeon were measured (total length to nearest 2 mm, and inter-orbital width to nearest 2 mm) and weighed (round or total weight to nearest 0.1 kg).

Sex and stage of maturity were observed visually on occasion. Observations have shown that external criteria are reasonably reliable close to spawning periods (e.g. personal observation at Wolf and Fox Rivers (Wisconsin), R. Bruch pers. comm.) and photos of spawning sturgeon (N. Auer pers. comm.).

Saskatchewan sturgeon were tagged at the base of the dorsal fin with two visual T-bar anchor tags. Most were Floy Model FD-67; some tags in 1997 were Hallprint-brand model #TBA-1. Use of double-tagging will reduce the number of fish which cannot be identified when recaptured, and will allow for estimates of tag loss. Manitoba sturgeon were not tagged with T-bar tags.

Sturgeon were also injected with a PIT tag. These are electronic tags (11 mm long x 2 mm diameter, sealed in glass, which sit passively until re-capture. Then a hand-held scanner is used to energize the PIT tag, and it responds with a unique 10-character code. PIT tags can only be detected at 5 to 10 cm so they are not useful for "tracking" fish, except in confined spaces.

PIT tags were Destron-brand #TX1400L (125 kHz). They were injected into the fleshy base of the left pectoral fin on the dorsal side, and topical iodine was applied. We used a Ralogun pistol designed for injection of cattle hormones; the standard 20-tag cartridge held PIT tags securely and made injection very easy (Bergersen et al. 1994). We did not retrofit a slightly smaller 12-gauge needle since they were not available, even from large-animal veterinary clinics. PIT tags were checked before release with a portable, 9V-battery scanner (Destron model HS5900L or similar). Its memory held identification codes for 100 tags and provided confirmation of records.

Index fishers in Saskatchewan were paid only for sturgeon released alive. In both years, payments for market-size sturgeon of $ 4/pound were based on their estimated dressed weight and recent market-prices paid by FFMC (by dressed weight FOB The Pas, according to T. Maher pers. comm.):

Year	$ / kg	Year	$ / kg
1985/86	$ 13.113	1990/91	$ 11.809
1986/87	$ 14.502	1991/92	$ 8.755
1987/88	$ 14.487	1992/93	$ 8.000
1988/89	$ 13.808	1993/94	$ ...
1989/90	$ 13.109	1994/95	$ 8.227

`Market-size' refers to sturgeon at least 8.2 kg (18 pounds) in round weight. Market-size sturgeon have been a minimum of 5.5 kg (12 pounds, dressed weight) since the 1960s. Dressed weights range from 58 to 66% of round weights for medium to large sturgeon (Wallace 1991).

In 1996, Saskatchewan fishers were paid a flat $10 fee for each small sturgeon (under 8.2 kg or 18 pounds, round weight) due to their lower priority in the study. In 1997, they were paid a half-price of $ 2/pound for small sturgeon, to encourage their capture and reporting and to increase the number of tagged fish.

RESULTS

In Saskatchewan, index fishing in 1996 started June 3, and finished on July 15. About 8 of the 10 crews (including one or two helpers) fished regularly (Appendix 4). They fished for 2 to 6 weeks each, typically 6 or 7 days each week. In 1997, funding was delayed and permits were not issued until June 18. Only 7 crews fished, for 2 to 4 weeks each, finishing on July 31.

In Manitoba, all fishermen worked from June 9 to 27 in 1996, and from June 1 to 15 in 1997.

Index fishers reported catching a total of 155 sturgeon in 1996 (129 in Saskatchewan and 26 in Manitoba) and 116 in 1997 (76 in Sask and 40 in Manitoba). In Saskatchewan, fishing was good in early June of 1996, but this period was not fished in 1997. More sturgeon were caught in Cumberland Lake than other areas, but fish were typically caught near the margins of the lake where effort was higher (Table 2). Catches were good at the Barrier and Elbow areas of Manitoba, but effort at these sites may also have been greater.

Table 2. Summary of sturgeon caught by index fishers in Saskatchewan and Manitoba, 1996 and 1997.

Area	1996	1997
Torch River	15	0
Mossy River	0	10
Cumberland Lake	65	46
Bigstone Cutoff	17	1
Bigstone Rapids	21	7
Tearing River	11	12
Barrier	9	20
Elbow Lake	14	7
Big Eddy	0	10
Hill Island	0	2
Pine Bluff	0	1

Period	1996	1997
June 1 - 15	72	40
June 16 - 30	37	22
July 1 - 15	46	36
July 15 - 31	0	18

Length[a] (cm)	1996	1997
0 - 19	0	0
20 - 39	0	0
40 - 59	1	0
60 - 79	8	14
80 - 99	49	28
100 - 119	63	48
120 - 139	30	19
140+	4	4
(maximum, cm)	(150)	(152)

Weight[b] (kg)	1996	1997
0 - 4.9	33	26
5 - 9.9	68	40
10 - 14.9	32	31
15 - 19.9	14	10
20 - 24.9	6	6
25 +	2	1
(maximum, kg)	(28)	(33)

[a] Length (cm) is fork-length, measured or converted from total-length using Royer et al. (1968).

[b] Weight (kg) is round or live weight; a few weights were estimated from lengths using Royer et al. (1968).

Maximum sizes of sturgeon caught during index fishing were 150 cm fork length (59 inch) and 33 kg (72 pounds) in Saskatchewan (Table 2). The largest in Manitoba were equivalent to 152 cm fork length (60 inch) and about 27 kg (59 pounds, estimated from Royer et al. (1968)). The smallest sturgeon caught on hooks and gill-nets was 58 cm (23 inch) and 1.5 kg (3.3 pounds).

In general, sturgeon caught at the Torch River were mostly mature-size, while those caught in Cumberland Lake / Bigstone Cutoff area were smaller (Figure 6). Sturgeon caught at Bigstone Rapids were intermediate in size, with very few large ones, presumably a result of long-term fishing at this site. Fish caught at Tearing river ranged from mature-size (similar to Torch River) to small. Sturgeon caught at the Barrier and Elbow areas of Manitoba were generally intermediate or small. About 1/3 of fish at the Barrier and 2/3 of those at Elbow were caught in 5.5 or 8-inch mesh, rather than in hooks and 10 or 12-inch nets (as used in upstream areas).

Fork lengths of sturgeon caught in Manitoba increased as the mesh-size increased, as expected:

Mesh (inch)	Number of fish	Average (cm)	Smallest (cm)	Largest (cm)	Percentiles 25%	50%	75%
5.5	10	79.2	62.9	127.7	66.6	76.1	82.3
8	12	92.7	77.7	107.3	87.9	93.4	96.7
10	25	103.6	71.2	151.7	90.7	104.5	115.6
12	1	112.9	...	...	...	...	...

The average size was 79.2 cm in 5.5-inch mesh and 103.6 cm in 10-inch mesh. Likewise, 25% were less than 66.6 cm and 75% less than 82.3 cm in the former.

The effect of mesh-size and hooks on fish sizes was not examined in Saskatchewan (see Discussion).

Comparisons of market-size sturgeon in commercial and index fishing show some trends in dressed weights since 1983. The median, which is the mid-point of the sample, varies from 7.4 to 8.0 kg (Table 3). Linear regression shows that average and maximum weights are increasing (at 0.07 and 0.44 kg/year), although the latter is quite variable.

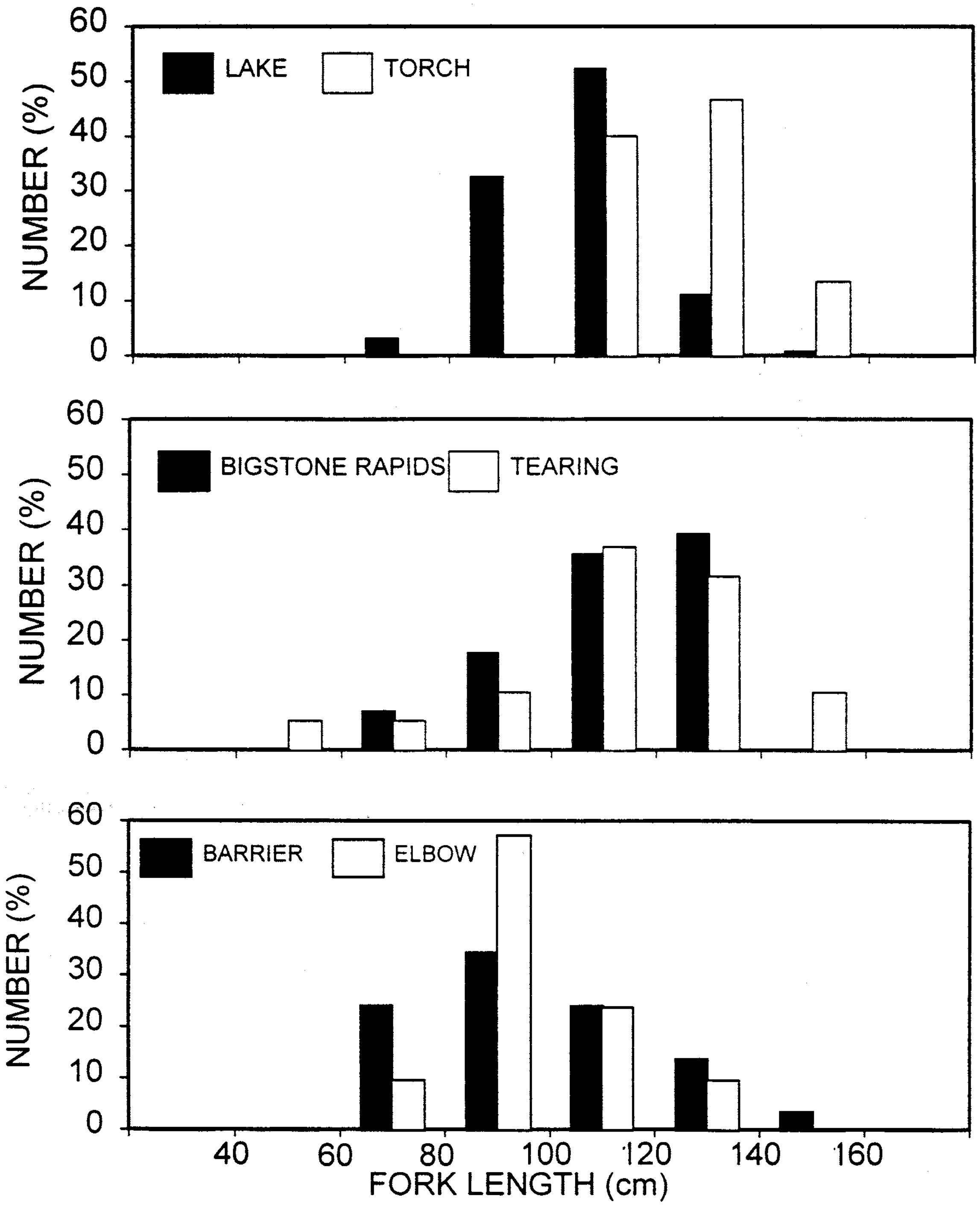


Figure 6. Sizes of sturgeon caught by index fishing, grouped by site of capture, 1996 and 1997.

Table 3. Summary of sizes of market-size sturgeon in commercial harvests (1983 to 1994) and index catches (1996 and 1997) in Saskatchewan.

Year	Number of sturgeon		Market-size (dressed weight, kg)		
	Total[a]	Market-size	Median	Average	Maximum
1983	254	238	7.4	7.72	14.1
1985	395	369	7.5	7.85	17.0
1986	244	222	7.5	8.15	15.8
1987	243	259	7.5	7.88	15.0
1988	247	230	8.0	8.17	17.0
1989	94	82[b]	8.0	7.88	13.8
1990	287	225	7.5	8.06	18.2
1991	212	163	7.0	7.87	18.0
1994	139	139	...[c]	...	...
1996	129	77[b]	7.5	8.6	18.7
1997	75	49[b]	8.0	8.9	22.0

[a] Some under-sized sturgeon are delivered before their dressed weights are known.

[b] Years with data for fewer than 100 fish are more variable in composition.

[c] Data were collected for only partial catches and differently from other years of commercial fishing.

More detailed data on weights were used to extend trends which began in 1958 (Figure 7). For this, data for 1996 and 1997 were combined to obtain at least 100 fish (Appendix 5). The declines about 1960 in all sizes represent a loss of larger sturgeon to fishing or stranding near spawning sites (Wallace 1991).

By 1996-97, the recent relative increase in sturgeon over 7.7 kg has apparently slowed, or even reversed. If this is confirmed by further monitoring, it indicates that the effects of reduced spawning after 1960 and/or reduced survival of young or juveniles continue to be a problem. The relative proportion of mature-female sizes (over 9.0 kg) continues to increase accordingly. Sturgeon over 13.0 kg have shown a proportional increase only since 1991.

The number of sturgeon caught ranged from 0 to 12 for a crew-week in Saskatchewan (Table 4). Sturgeon below market-size comprised about 1/4 of reported catches, ranging from 0 to 7 per week, in 1996-97.

In 1996, there were 1 to 3 sturgeon in almost half of catches, while a few had 10 to 12 (Figure 8). In 1997, more than 60% of catches were only 1 to 3 sturgeon, and none were over 9. Adjusting data to a weekly basis (for comparison with weekly commercial harvests, Appendix 6)increased the average catch rate in both years, but did not increase the maximum rate in 1997. Visits averaged about every 5 to 7 days, and more frequently to crews who reported catches, which kept the sturgeon in good condition but complicated the catch-per-effort analysis.

Average catches were 3.9 sturgeon/crew-week in 1996 and 2.5 sturgeon/crew-week in 1997, based on data for all index fishers, all sites, and all weeks in Saskatchewan. Variability of catches was relatively high (that is, standard deviations of 3.7 and 2.5, respectively). This indicates that Saskatchewan River sturgeon are concentrated at some sites at some times, and scarce at others. Any differences in the efforts of fishing crews between sites and weeks, or in their fishing ability, would add to this variability. This affects the effort needed for reliable long-term monitoring of abundance (see below).

Several adjustments were necessary prior to analysis for trends in catch rates of historical commercial fishing and recent index fishing. Index fishing data for 1996-1997 were adjusted to weekly rates to be comparable to commercial data, which were based on a single delivery day each week. Commercial data needed more complex adjustments because deliveries were only made if market-size sturgeon had been caught (Appendix 6).

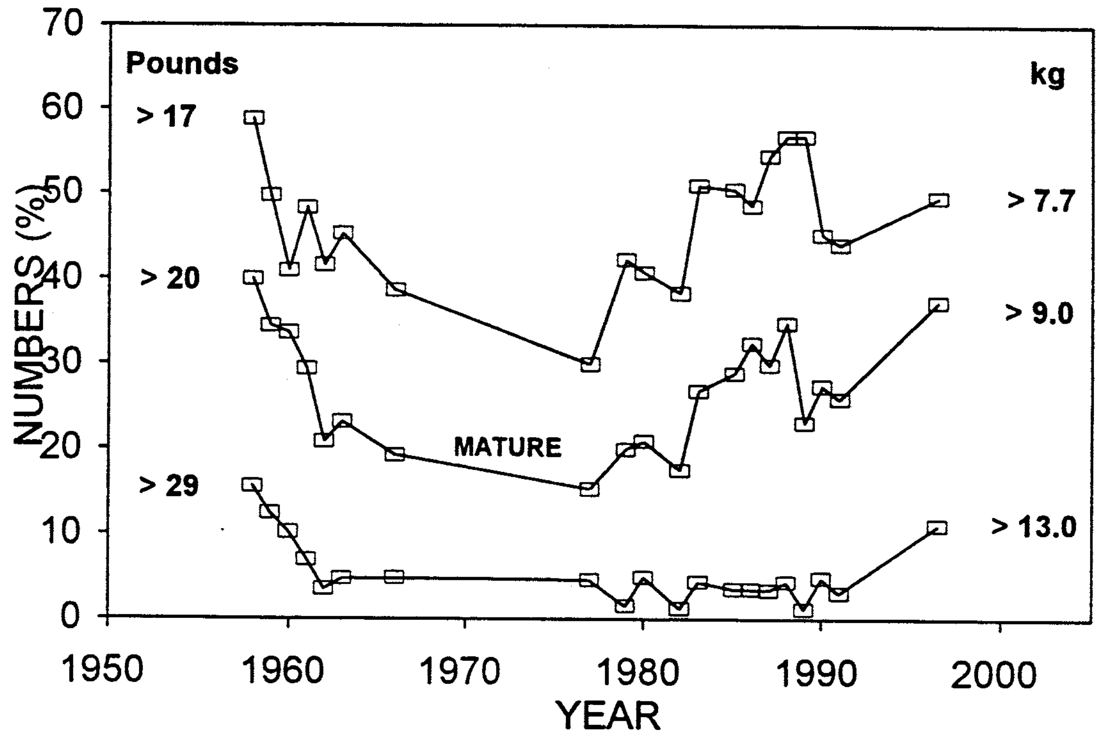


Figure 7. Proportions of larger sturgeon in commercial harvests (1958 to 1991) and index catches (1996-1997), Saskatchewan. Lines show proportion of fish over 17, 20, or 29 pounds among the market-size fish (over 12 pounds, dressed weight or equivalent). Missing years were not monitored, or methods were not comparable to other years.

Table 4. Number of sturgeon caught by index fishers in Saskatchewan (excluding weeks of zero catch), 1996 and 1997.

Date			Fisher	Number of sturgeon [a] Small	Market	Total
96	Jun	6	BUDD, Frank (Joseph)	0	12	12
96	Jun	6	CHABOYER, William	0	7	7
96	Jun	7	CRANE, Philip	3	1	4
96	Jun	7	FIDDLER, Marcel	0	1	1
96	Jun	10	BUDD, Frank (Joseph)	0	9	9
96	Jun	10	CRANE, Peter	2	5	7
96	Jun	11	CHABOYER, William	1	7	8
96	Jun	13	FIDDLER, Marcel	0	5	5
96	Jun	15	CARRIERE, John V.	1	8	9
96	Jun	15	CRATE, Greg	0	1	1
96	Jun	20	CARRIERE, John V.	2	2	4
96	Jun	24	FIDDLER, Marcel	1	4	5
96	Jun	28	CARRIERE, John V.	0	2	2
96	Jun	28	FIDDLER, Marcel	1	0	1
96	Jun	28	SETTEE, Nathan	6	0	6
96	Jul	3	FIDDLER, Marcel	0	3	3
96	Jul	5	BUDD, Frank (Joseph)	1	0	1
96	Jul	5	CARRIERE, John V.	0	3	3
96	Jul	5	SETTEE, Nathan	7	4	11
96	Jul	10	CARRIERE, John V.	1	6	7
96	Jul	10	SETTEE, Nathan	6	4	10
96	Jul	16	CARRIERE, John V.	2	3	5
96	Jul	16	SETTEE, Nathan	4	2	6
97	Jun	23	CRANE, Philip	0	1	1
97	Jun	24	FIDDLER, Joseph	1	6	7
97	Jun	26	DORION, Kennedy	1	2	3
97	Jun	27	CRANE, Philip	0	3	3
97	Jun	27	MCKENZIE, Glen	0	2	2
97	Jun	27	NABESS, Kevin	1	2	3
97	Jun	30	FIDDLER, Joseph	0	2	2
97	Jun	30	NABESS, Kevin	0	1	1
97	Jul	3	NABESS, Kevin	3	2	5
97	Jul	4	CRANE, Philip	0	2	2
97	Jul	4	FIDDLER, Joseph	0	5	5
97	Jul	4	MCKAY, Kelvin	1	6	7
97	Jul	7	BUDD, Frank (Joseph)	0	2	2
97	Jul	8	NABESS, Kevin	0	4	4
97	Jul	11	FIDDLER, Joseph	0	7	7
97	Jul	14	MCKAY, Kelvin	0	2	2
97	Jul	25	MCKENZIE, Glen	7	0	7
97	Jul	25	NABESS, Kevin	4	6	10

[a] These are numbers caught between visits by project workers, which typically occur more than once weekly and more often if catches are large.

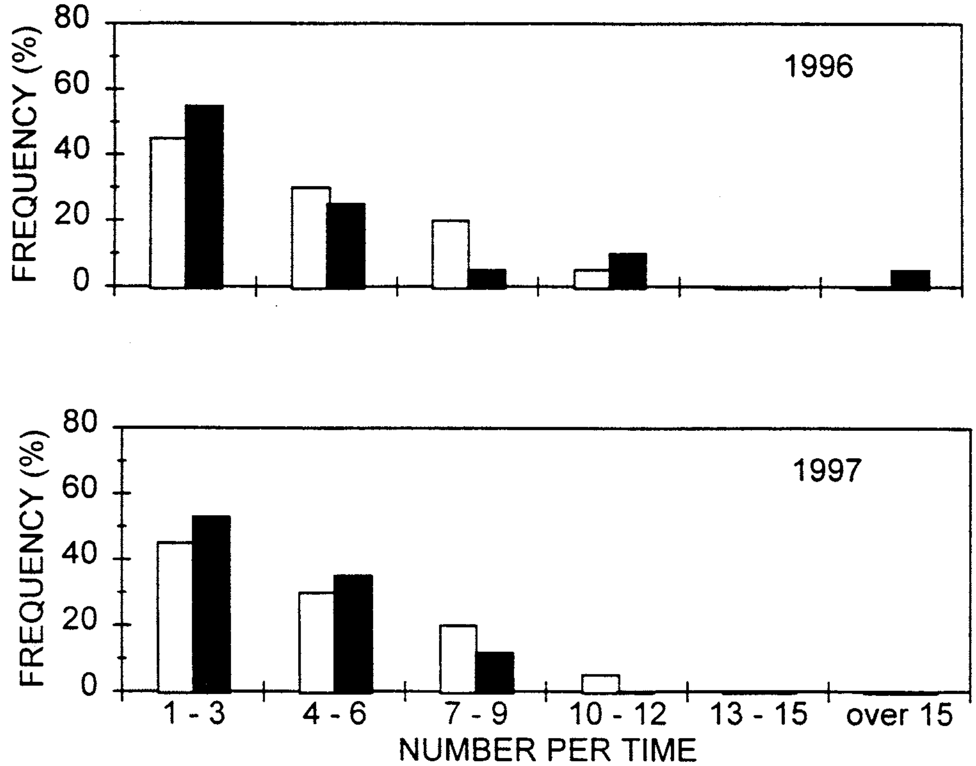


Figure 8. Number of sturgeon caught by index fishers, 1996 and 1997. Number caught between visits by staff (grey bars) were adjusted to number per week (black bars) for comparison with commercial fishing.

Two statistical distributions were fitted to the number of crew-weeks and number of sturgeon caught: lognormal curves fit poorly, but negative binomial curves fit 7 of 9 years. The "jackknife" approach was then used to estimate the number of missing zeros (Krebs 1989), and a final curve was fitted.

These adjustments caused minor changes to catch rates for some years, but substantial changes for others (Figure 9). In 1983, the original mode (meaning the "most common" catch rate) was 3 or 4 sturgeon/week and the maximum was 14 sturgeon. In 1996-97, the mode was 1 or 2 sturgeon and the maximum 19 sturgeon. In 1983, only 3 zero-catches probably occurred compared to 10 in 1996-97. Other years showed intermediate effects of adjustment.

A fuller analysis of recent abundance compared to previous decades will require data for historical periods, which may or may not become available. Harvests by individual commercial fisher are available in department records for only a few years, mostly since 1982.

Plots of catch rates showed relative population abundance was steady or declining from 1983 to 1996-97 (Figure 10). Linear regressions showed declining mean catches and increasing proportions of zero-catches, in both the actual data and after adjustments:

Mean catch (number / crew-week):
Actual = 4.82 - 0.0516 Years-since-1982, n = 6, r^2 = 0.096
Adjusted = 4.41 - 0.0724 Years-since-1982, n = 6, r^2 = 0.182

Expected number of zero-catches (as % of known catches):
Actual = 4.33 + 0.1858 Years-since-1982, n = 6, r^2 = 0.242
Adjusted = 7.86 + 0.7250 Years-since-1982, n = 6, r^2 = 0.366

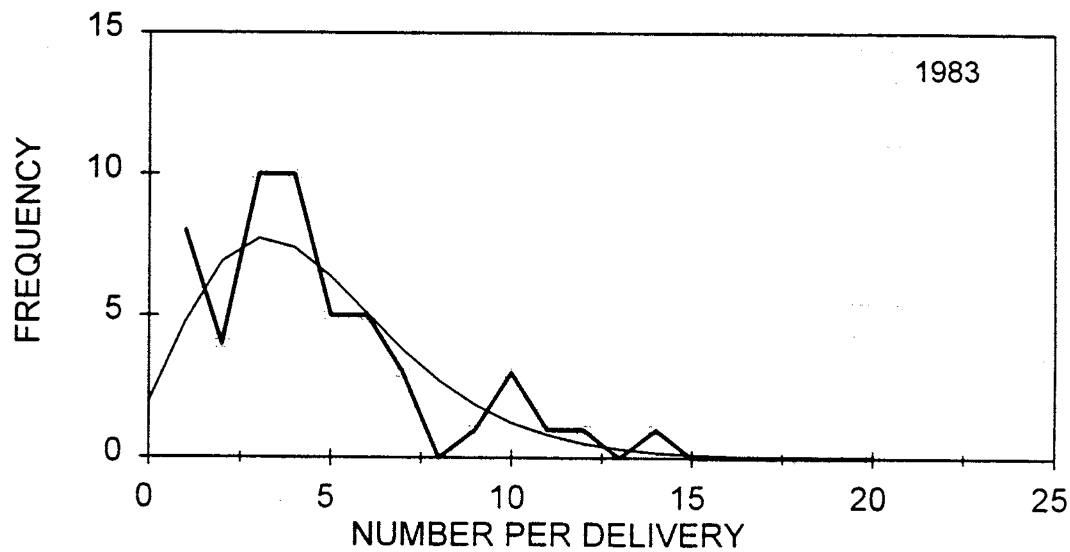
These regressions were statistically insignificant, so that there are no significant trends in abundance according to these catch rates.

Observed changes in the mean and expected zero-catches were relatively small:

Year	Mean	Expected zeros (%)
1983	...	...
1986	-1.7 %	7.8 %
1988	-1.8 %	6.5 %
1989-90	-1.8 %	5.9 %
1994	-1.9 %	5.0 %
1996-97	-2.1 %	4.2 %
Simple average	-1.87%	5.89%

The ability of this analysis to detect real trends (either decreasing or increasing) in the population is low, due to the limited number of years of data. This is a particular concern of ecologists as it implies that real changes may be ignored (Peterman 1990). More data and more precise data is often required, but sometimes cannot be collected due to natural variability of populations or limitations of field surveys.

In our case, the addition of historical commercial fishing data (if available), or future index fishing data would improve the power of this analysis. The estimates of changes (about 2% each year) are useful in planning for future index fishing, especially the length of time and effort needed (see Monitoring).



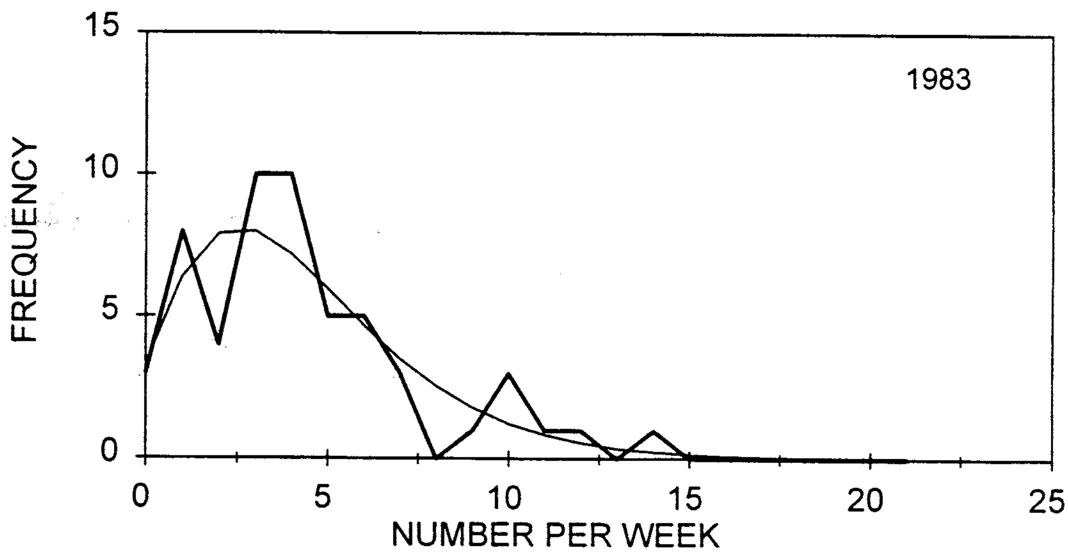
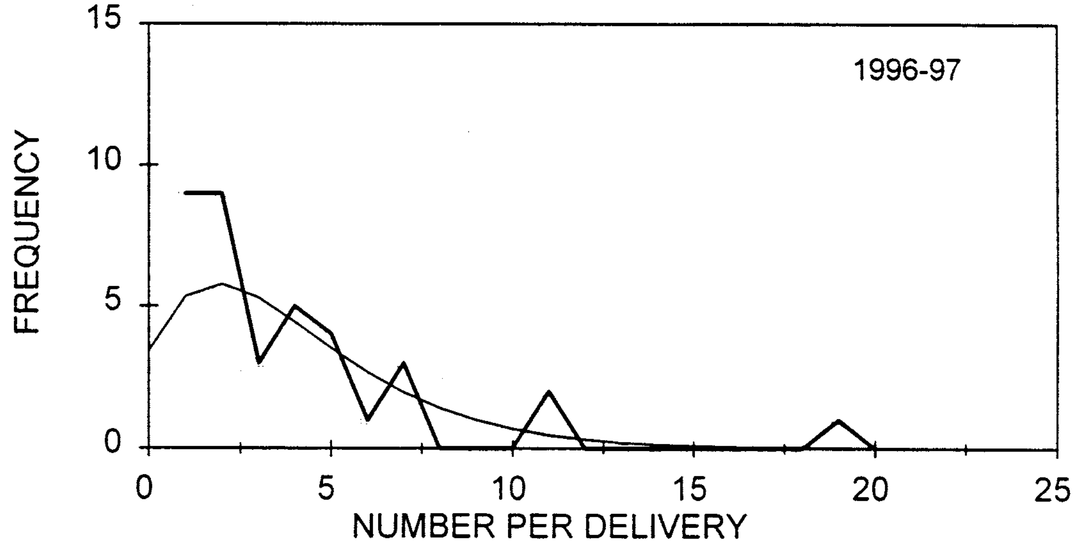


Figure 9A. Number of sturgeon caught by commercial fishers, Saskatchewan 1983. Points and bold lines show actual data; fine line shows curve fitted to data.
UPPER: Number caught, excluding weeks with zero-catches.
LOWER: Number caught, including an estimate of zero-catches.



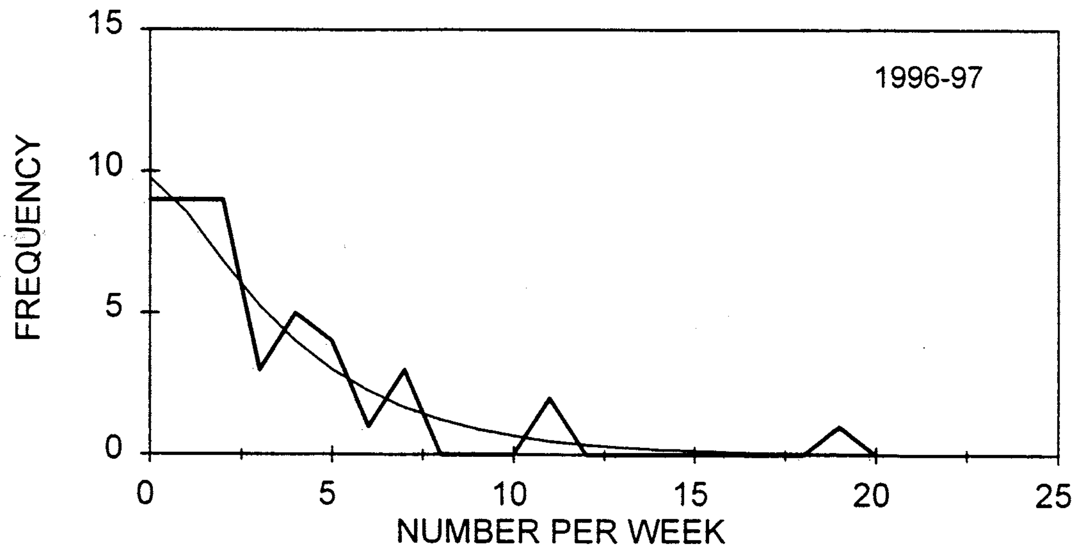
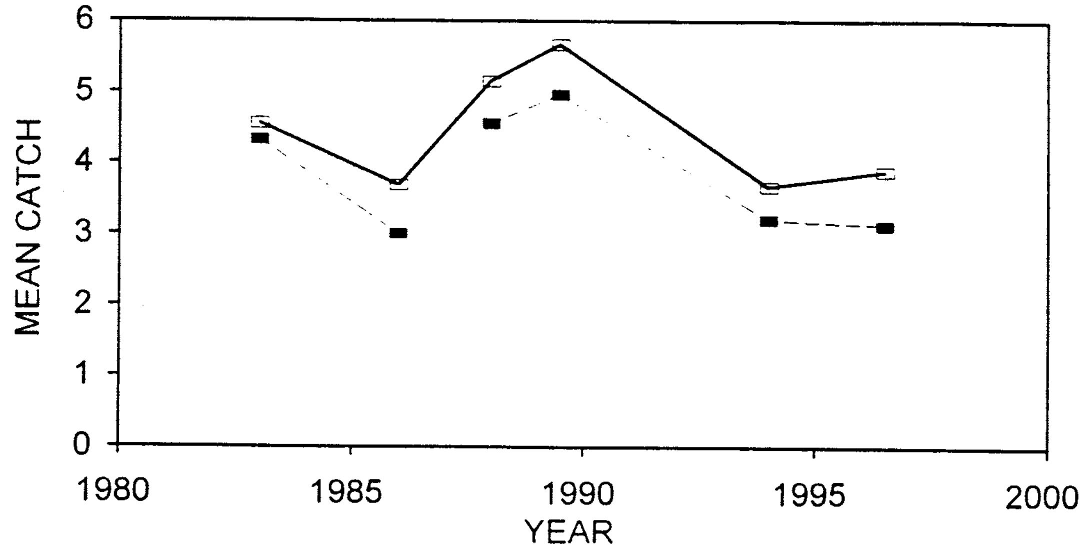


Figure 9B. Number of sturgeon caught by index fishers, Saskatchewan 1996-1997. Points and bold lines show actual data; fine line shows curve fitted to data.
UPPER: Number caught, excluding weeks with zero-catches.
LOWER: Number caught, including an estimate of zero-catches.



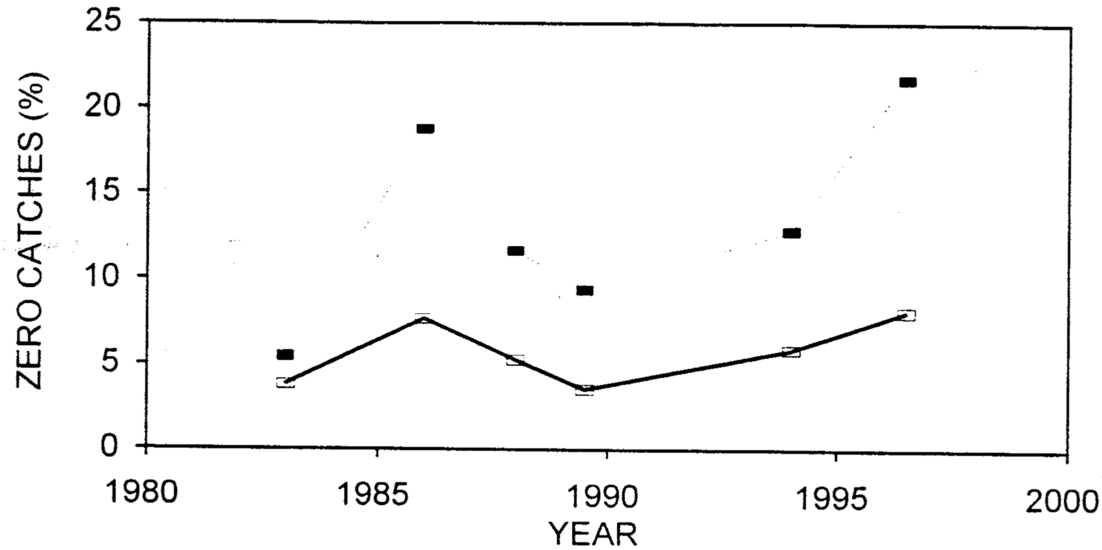


Figure 10. Catches (number/week) of sturgeon by commercial and index fishers, Saskatchewan 1983 to 1996-1997. Bold lines show actual data; fine lines show data after adjustments.
UPPER: Average number caught per crew-week.
LOWER: Estimated proportion of zero catches (as % of known catches) (see text).

DISCUSSION

SIZES

The sizes of sturgeon caught have been variable for decades, partly due to their longevity and multi-year spawning, and partly because annual commercial harvests comprised only 200 to 400 fish.

Recent changes in long-term trends might indicate a 'recovery' of the population if the overall abundance of sturgeon was constant or improving. Otherwise, these proportional changes reflect lower recruitment of young sturgeon into the 7.7 kg class, and imply that recruitment is declining faster than mortality removes sturgeon over 9 (or 13) kg. Findlay et al. (1995) came to a similar conclusion using similar data for 1958 to 1990.

Although size selection by gear (e.g. hooks and several gill-net meshes) was expected, further analyses of data were not done for two reasons. Firstly, different gears are used at different sites to be effective, particularly hooks in fast currents and warmer temperatures when filamentous algae become abundant. Since sturgeon sizes may vary between sites, the effect of gear selection was unknown. Secondly, such analyses would be most useful after decisions are made regarding the importance of small versus spawning sturgeon. Management of sturgeon populations in North America typically protects small and intermediate sizes, which implicitly encourages harvesting of mature-size fish (see Wallace 1991, Scarnecchia et al. 1989).

YOUNG AND JUVENILES

Young and juvenile sturgeon are not efficiently captured in most studies, and presumed to inhabit different areas and types of habitat than adults. Index netting did not catch any small juveniles in Saskatchewan or Manitoba. However, commercial and aboriginal fishers report they are present in the lowest reaches of the river. In 1995, three sturgeon (about 25 cm long) were caught near Pine Bluff (Manitoba) and in the forebay of Cedar Lake (Charlie Lavallee pers. comm.). For years, there have also been reports of similar sturgeon in the lower areas of Mossy River and around Oldman's Island in Cumberland Lake (Franklin Carriere and others, pers. comm.).

In several studies of river-and-lake situations, the lake provides habitat for young and juveniles. Cumberland Lake has several inflows from known or potential spawning areas upstream in the Mossy and Saskatchewan Rivers.

Bottom-dwelling food organisms for sturgeon (such as insect larvae and fingernail clams) are unusually low in Cumberland Lake. In the 1950s, Reed (1959) found only 5.3 kg/ha of food (dry weight), which was only 1/3 of that in Namew Lake and much lower than other lakes in southern Saskatchewan. In the 1970s, Willard et al. (1978) noted that abundant broken clam shells indicated that the lake bottom was unstable and unsuitable for food organisms, due to constant erosion by wave action.

Food conditions are much better in Cedar Lake, according to surveys done in the 1960s prior to impoundment (Webb 1965). Insects, clams, and others averaged 26.2 kg/ha (dry weight). The major factor in abundance was bottom type, with mud or sandy-mud containing greater numbers and species (Webb 1965). Mud was only found at depths over 6 m, which do not occur in Cumberland Lake.

There seems to be a tendency for young and juvenile sturgeon to prefer the lower reaches of rivers (Priegel and Wirth 1971, Y. Mailhot, Quebec, pers. comm.).

CATCH RATES

There are only a few known reports which contain details of catch rates for lake sturgeon in rivers (see Table 5).

Considerably higher catch rates were reported for a few sites on the South Saskatchewan River in Alberta (RLL 1991). Comparisons cannot be precise, but catch rates were 24 to 53 times higher in set-lines and 9 times higher in gill-nets in Alberta. Gear was similar between these two studies: Alberta set-lines were 15 to 100 m long and baited; gill-nets were 15.3 m long, 3 m deep, and 8-inch or 10-inch mesh. Our index fishing set-lines were typically 50 or 100 m long and baited; gill-nets were 10 to 50 m long, and 10-inch or 12-inch mesh.

In Alberta, gear was set at only 6 specific sites, which were known congregating areas for sturgeon and catches were highly variable (RLL 1991). Catches at one exceptional site (about 600 m long) provided 90% of the sturgeon caught in 300 km of river (RLL 1991). In Saskatchewan, fishing effort may have been dispersed into less suitable areas and mesh-sizes may have been less effective. Nonetheless, Alberta's population may be more abundant because a CFB Base lies across or beside the river and reduces access for fishing (RLL 1991).

Table 5. Comparisons of catch rates in gill-nets and set-lines with three other studies.

South Saskatchewan River (Alberta, RLL 1991)

Gear	Alberta Effort	Alberta number/effort Reported	Equivalent	Saskatchewan index fishing
Set-lines	15,322 hook-hours	0.0029 /hook-hour	0.0689 /hook-day	0.0029 (1996) 0.0013 (1997) /hook-day
Gill-nets	394 net-hours	0.0203 /net-hour	0.0291 /yard-day	0.0032 (1996) /yard-day

Groundhog River and others (Ontario, Seyler 1997)

River	Mesh	Ontario number/effort Report	Equivalent	Saskatchewan index fishing
	(inch)	/15m-hours	/yard-day	number/yard-day
Groundhog	2 to 12	0.030	0.0029	0.0032 (1996)
Carmichael	1.5 to 9	0.034	0.0034	
Carmichael	1 to 9	0.096	0.0094	
Carmichael	2 to 10	0.109	0.0107	
Faquier	1 to 8	0.098	0.0095	

Columbia River (Oregon, North et al. 1993)

Reservoir	Month	Oregon number/effort Reported	Equivalent	Saskatchewan index fishing
		/set-day	/hook-day	/hook-day
Bonneville	Apr-May	2.4	0.06	0.0029 (1996)
	June	6.0	0.15	0.0013 (1997)
The Dalles	Apr-May	1.8	0.04	
	June	2.1	0.05	
John Day	Apr-May	0.2	0.005	
	June	0.1	0.002	

Oregon sites exclude the problematic "boat-restricted zone" below each dam.

A summary of surveys in north-eastern Ontario (Seyler 1997) showed catch rates which are similar to 3-fold higher than ours. Their gill-nets were set in May or June, so water temperatures and seasonal behaviour were similar. Set-lines cannot be compared because only gill-nets were used in Ontario. Their gill-nets included much smaller meshes than ours, yet 86% of sturgeon caught on the Groundhog River were over 100 cm long. Large sturgeon are not often caught in small meshes, so these comparisons should be reasonable.

Years of surveying showed that the Columbia River had catch rates which are mostly higher than ours (up to 100-fold higher, see North et al. 1993). These surveys used only set-lines of 40 hooks (sizes 12/0 to 16/0)(North et al. 1993):

Catch/effort data on lake sturgeon have been complicated by the tendency of sturgeon to congregate in distinct areas (Haugen 1969, RLL 1991).

TRENDS IN CATCH RATES

Findlay et al (1995) used time-series regressions of seasonal commercial harvests per licensed fisher. They concluded that catch rates declined after 1981, and were significantly below historical levels after 1989. Unless less intensive fishing was a response by fishers to concerns of biologists in the 1980s, this decline may explain the lack of detectable trends since 1983 in our analysis. Much of the decline in population status occurred about 1960 and became observable in the 1980s, and any present changes are smaller.

Future monitoring of abundance using catch rates of index fishing is discussed below.

POPULATION ABUNDANCE

Realistic targets of abundance are useful if restoration of habitat and protection of this population are undertaken. There were three estimates available from earlier work (Wallace 1991):

1) About 5,000 sturgeon would live in the river and lake habitat available in the Saskatchewan River and Cumberland Lake before 1958, according to densities observed in other lake sturgeon populations.

2) From 10,000 to 16,000 medium and large sturgeon were present

in 1958, according to observed mortality rates and estimated fishing rates for this population at that time.

For planning purposes, we assumed there were only 5,000 sturgeon present in 1994, and the population did not change over a short period (a "closed" population). This allows the simplest approach, a one-time marking and one-time recapture. In our case, we needed to tag a minimum of 500 sturgeon and re-examine about 600 sturgeon the next year to get an estimated abundance within $\pm$ 25% of the true abundance.

Field work from 1994 to 1997 actually tagged about 400 different sturgeon (about 334 with T-bar and 255 with PIT tags, most with both tags). There have been too few recaptures of tagged fish by 1997 to estimate tag loss or population abundance in the Saskatchewan River (Appendix 7).

There are other major problems with estimating abundance, particularly concentrations of sturgeon in some areas, growth of smaller fish to catchable size, natural or fishing mortality, and migrations which overlap (but do not provide complete inter-mixing of individuals).

Such a situation is called an "open" population, and will require a Jolly-Seber analysis (Arnason et al. 1995). This type of analysis should provide biological realism, but is complex and may provide only a relatively imprecise estimate, due to tag losses, mortality of fish, unknown harvests, non-reporting of recaptures, and the small population.

Preliminary indications are that marking and recapturing sturgeon for another 1 to 2 years (1998 and 1999) should allow for Jolly-Seber estimates of population abundance.

T-bar and PIT tags should be suitable for this period. T-bar tags show early losses from fish, followed by good retention, in several species. They are quick to apply, provide reasonable long-term retention, should not entangle in gill-nets or other gear, allow visual identification by anyone, are inexpensive (less than $1 Cdn each), and require no specialized detectors.

Double-tagging lake sturgeon in the Saskatchewan River should provide at least one remaining tag on 85% of sturgeon at 180 days and 81% after 5 years, if 60% of T-bars remain at 180 days and 80% of those remain at 5 years. After tagging more than 7,000 fish with various tags in 4 years, Rien et al. (1994) concluded that "Double-tagging white sturgeon remains the most satisfactory method of ensuring high-tag retention rates over a period of several years".

MONITORING

The practical aspects of index fishing have been established, although there is room for refinement in reporting forms, payment schedules, and other details. The basis for future work, however, deserves some consideration.

Long-term monitoring should be able to detect notable changes in populations. In our case, this includes either a decline or (hopefully) an improved status of sturgeon in this area. If managers know that only large changes in abundance can be detected, then alternatives can be evaluated (Peterman 1990). These can include improvements to the precision of methods, length of trends, frequency of surveys, or the kinds of changes examined.

The "statistical power" of a monitoring program is its probability of detecting real trends. Simulations of the power of index fishing towards sturgeon abundance were based on 1996-1997 index catches.

The software program MONITOR (Gibbs 1998) estimates power, using preliminary data on the variability of the species, survey methods, size of expected change, and others.

For simplicity, simulations were run assuming a 15-year annual survey, 10 or 15 sites, each fished for 3 or 4 weeks in June. Presumably, 10 sites can be fished by 10 different fishers, or by 5 fishers each fishing 2 sites. Annual changes in abundance up to 10% were evaluated. Declines of only 3% and 5% produce large losses of 37% and 54% in abundance over 15 years (Gibbs 1998).

Lake sturgeon abundances should change only slowly (given their age-at-maturity) and have low natural variability over time. Lake trout are a similar long-lived species, and have a low coefficient of variation (CV of 0.2 for 5 of 11 studies in Gibbs (1998)). Therefore, only moderate "plot variations" of 0.05 to 0.10 were used in simulations.

Results show that index fishing at 10 sites for 4 weeks has a reasonable chance (over 80%) of detecting changes in abundance of 5% or 10% annually over 15 years (see Table 6). Improving the precision of catch-per-effort data would improve the detection of declines slightly (e.g. see average=3 and sd=2). Fishing at 15 sites for 3 or 4 weeks will likely detect increases in abundance of 3% annually, but not declines of 3%.

Table 6. The ability of monitoring to detect annual changes in abundance of lake sturgeon.

		Sturgeon caught per week				Probability of detecting annual changes up to 10%					
Sites	Weeks	Average	(sd)	Alpha	Plot var	10%	5%	3%	-3%	-5%	-10%
						%	%	%	%	%	%
10	4	3	3	0.2	0.05	100	98	74	55	89	100
10	4	3	2	0.2	0.05	100	96	78	60	92	100
15	3	3	3	0.2	0.05	100	99	86	70	96	100
15	4	3	3	0.2	0.05	100	99	83	69	96	100
10	4	3	3	0.2	0.10	98	80	51	24	32	84
15	3	3	3	0.2	0.10	100	91	70	28	37	92
15	4	3	3	0.2	0.10	100	87	71	22	44	87

While plot variation in our situation is unknown at present, we have assumed that it is moderate for sturgeon. If it is relatively large (0.10), only increases or large declines in abundance (-10%) will likely be detected.

Future monitoring should review and improve on the present methods of analysis (if possible), and should include factors other than abundance. A suite of indicators (such as size composition, condition, and local distribution) may be required to assess population status.

Monitoring should continue be concerned with detecting changes in zero-catches, so that lack of fish can be distinguished from non-fishing. Recording of zero-catches during index fishing should be improved. Even so, the indirect effects of reduced effort by some fishers in response to poor catches by other fishers complicates records and analysis, since it may be a reasonable indicator of sturgeon behaviour and location. ???

The use of simple catch/effort data may under-estimate declines or over-estimate increases, depending on the direction of population change. Modifications to catch-per-effort data may be available to minimize this problem (Bannerot and Austin 1983).

CONCLUSIONS

1. Radio-tags showed movements by individual sturgeon between Saskatchewan and Manitoba. They also showed considerable overlap in the stretches of river used by sturgeon tagged at different spawning sites.

2. Tracking showed the longest observed movements were 74 km upstream and 89 km downstream over 2 years. It did not show the complete migration range for the population, either for a second spawning or throughout a life-cycle.

3. Radio-tags (and visual tags) confirmed some specific migrations and habitat usage:

- More sturgeon tagged at the outlet of the Torch River swam upstream to the EBCampbell tailrace than into the Torch.
- Mature-size sturgeon swam to the EBCampbell dam when waterflows occurred in the former Tobin and Squaw Rapids.
- Most mature-size fish tagged near spawning sites in Saskatchewan moved downstream after spawning season.
- Immature-size sturgeon tagged in Manitoba tended to swim some distance upstream and remain.
- There were long periods (up to 2 years) of little or no movement during mid-summer and over-winter.
- Radio-tagged sturgeon were found primarily in the mainstem river or near the margin of Cumberland Lake. Some may have used secondary channels during periods of undetected signals.

4. Several large and medium-size rapids remain available for spawning. Actual spawning in Torch River rapids and Bigstone Rapids was confirmed. Potential spawning in the EBCampbell tailrace, the former Tobin and Squaw Rapids (historically), and the Tearing River was confirmed by migrations or sturgeon in spawning condition.

5. Radio-tagged sturgeon which moved downstream after release may have been drifting passively (after the stress of handling) or swimming actively (after spawning).

6. Radio-tags were lost more often than expected, due to death of sturgeon, shedding of radio-tags, non-detection of signals, or non-reporting of recaptures. Better attachment techniques, and better co-operation with resource users would be helpful.

7. Determining micro-habitat preferences using radio-tags requires considerably more effort than is available. Extensive surveys of utilized and available habitat are required but are not feasible.

8. Commercial fishermen have been unable to provide enough specimens for monitoring since effort and catches have been reduced; other fisheries have not provided any specimens.

9. Index fishing allows experienced fishers to monitor traditional sites, and provides data on sturgeon sizes and abundance for comparison to both historical and future situations.

10. Index fishing showed some changes in size composition and in abundance since 1983. Both are consistent with further decline in population status, but were not conclusive of either decline or stability in this long-lived species.

11. An advantage of index fishing is that local fishers are monitoring their traditional season and sites. Their credibility is better and their observations more relevant to local concerns, than those of outside experts. Resource-management staff are required to manage data collection, record-keeping, and analysis and evaluation.

A second set of conclusions comes from a companion report (Wallace 1999):

12. The suitability of most rapids, relative to other rapids and to historical conditions cannot be assessed based on field-work alone. Ranking of spawning habitats using physical-habitat simulation models and species-preference curves from literature and other sources appears to be necessary.

13. General habitat conditions for lake sturgeon in this area are similar to those of other populations. Deeper areas in rivers provide suitable over-wintering habitat, and many areas provide suitable food conditions.

14. Water temperatures are notably cooler during spawning season (for 20 km below EBCampbell) than downstream in Manitoba. Food supplies of bottom-dwelling insects and other invertebrates are also lower in this area than downstream.

15. Tributary waters (such as the Torch River) reach spawning temperatures about one week earlier than Saskatchewan River sites (such as Bigstone Rapids). In turn, Bigstone Rapids is suitable at least one week earlier than EBCampbell area.

16. Proposals to restore spawning habitat at EBCampbell area to historical conditions will be complicated by cooler water at spawning time and poor food conditions nearby, as well as by the changes in flow regime. These potential limitations exist in the power-station tailrace area at present.

RECOMMENDATIONS

These recommendations are based on work in both the present report and a companion report (Wallace 1999).

Recovery of this sturgeon population depends on action on both habitat and harvests. Accordingly, actions selected from these recommendations must collectively meet the test of addressing both of these issues.

1. Management on the population should continue to be a co-operative effort of provincial agencies, communities, and resource users. This may include reviews of biological status and management options, and co-ordinated discussions with all parties. Regulatory agencies should work towards concordance in the effect of actions, even if specifics differ.

2. Protection of the habitat and protection from local over-harvest is required, especially during spawning. The objective is to have a reliable flow of water in habitat which meets the spawning needs of sturgeon. The critical period begins at water temperatures of 10°C and ends two weeks after they reach 15°C, typically from mid-May to end of June.

Specific sites of importance include:
- Tobin and Squaw Rapids were former spawning sites and are potentially suitable;
- EBCampbell tailrace is a potential spawning site;
- Torch River is a known spawning area;
- Bigstone Rapids is a large spawning and fishing site;
- Tearing River was a historical spawning site, and is again suitable for spawning;
- Summerberry River and downstream areas are potential juvenile habitat; other juvenile areas have not been found.

3. Continued harvesting of lake sturgeon from the lower Saskatchewan River (EBCampbell to Grand Rapids) will allow the present decline to continue, will probably delay the recovery of this population, and may reduce the chance of recovery over the long-term.

4. Stakeholders should seriously consider restrictions on commercial and subsistence fishing. Potential restrictions include lower (or nil) harvest quotas, the protection of spawners and spawning sites, and fewer licences or permits. Alternatively, fishers could be assured of their right-of-access to future fishing through an agreement that included the non-exercise of fishing rights for a defined period.

5. Information on subsistence fishing and cultural uses by First Nation and other aboriginal people is needed. Periodic

discussions between a Steering Committee, First Nations, consultants, and funding sources have occurred, and should be encouraged.

6. Agencies responsible for allocation and usage of water (such as SaskWater) should analyse the effects of enhancing water flows in the former Tobin and Squaw Rapids for spawning.
Specific items for analysis include:
(i) the effects of suitable, minimum, instantaneous flow for downstream sturgeon habitat *versus* Tobin Lake pike habitat;
(ii) the effects of higher flows during June and July (for spawning, incubation, and fry movement) on upstream and downstream users.
Assessment may require either the release of water through the spillway, or agreement among agencies that other methods provide reliable modelling of flow conditions.

7. Radio-tagging should be continued until most tags have quit, estimated as late 1999. Tracking during spring (spawning) and late-summer would be the most useful times. This can be a special program or an incidental item, as feasible.

8. Index fishing should be continued for biological, economic, and action-plan reasons. It allows for tagging and live-release of sturgeon at relatively low cost, continues the monitoring of catch rate index of abundance, and provides an alternative to continued commercial fishing.

9. Further trials of egg collection for re-stocking should be undertaken. This includes using morphological and physiological assays to identify potential spawners and determine timing, and hormone-induction of egg release. The latter requires federal regulatory approval for wild stocks, since the sacrifice of spawning females should be avoided. Recovery may be aided by re-stocking, but the potential is unproven in this population.

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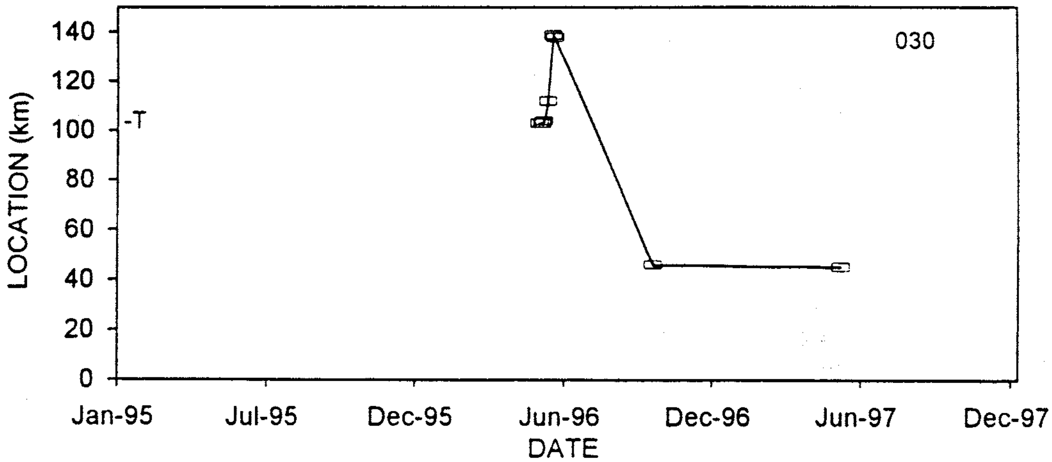
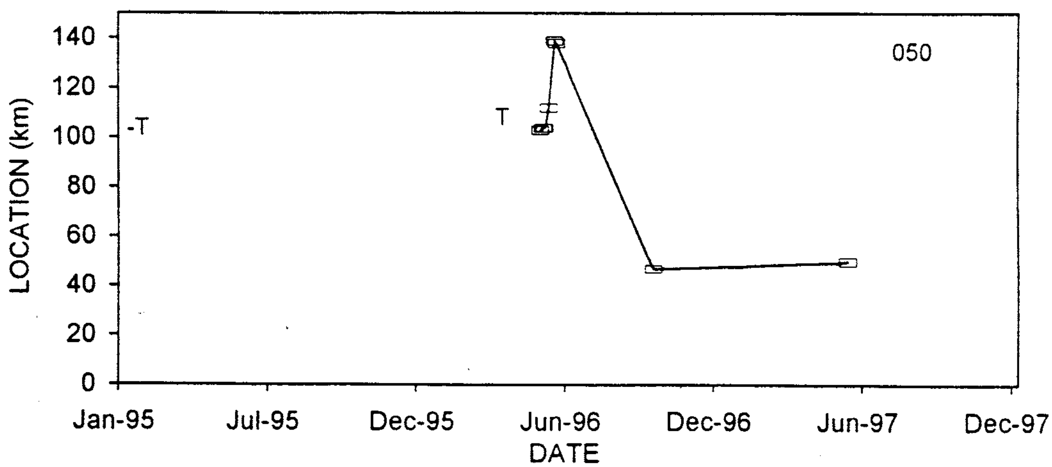
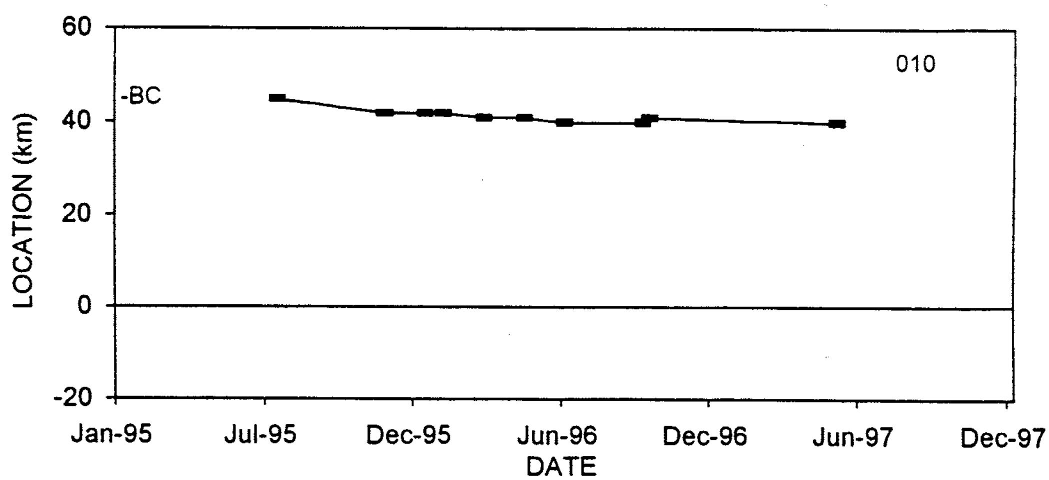
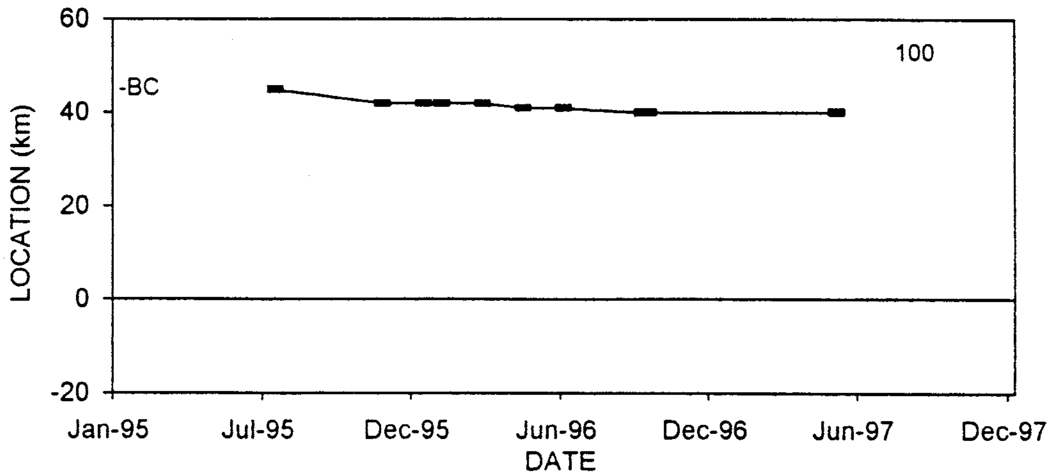
Appendix A. Examples of upstream and downstream movements by individual radio-tagged sturgeon, 1995 to 1997. T is Torch River; BC is Bigstone Cutoff / Lake area.

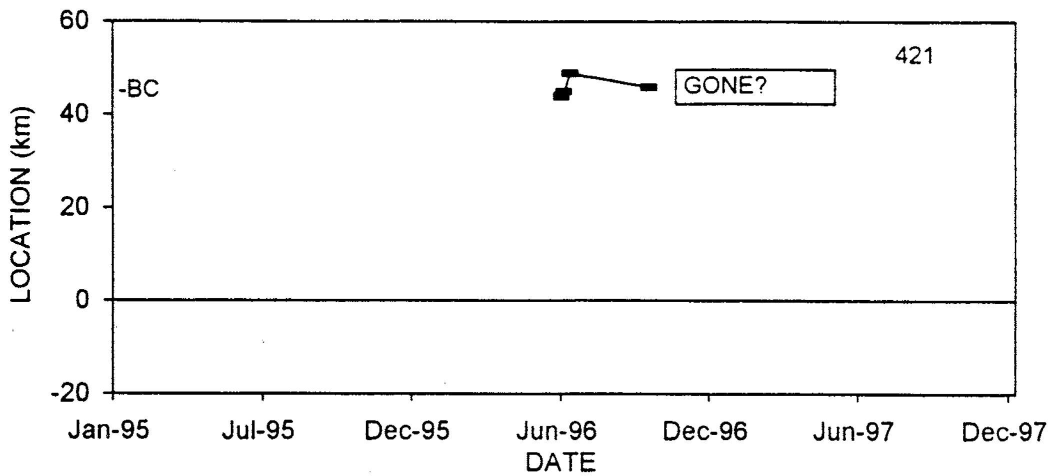


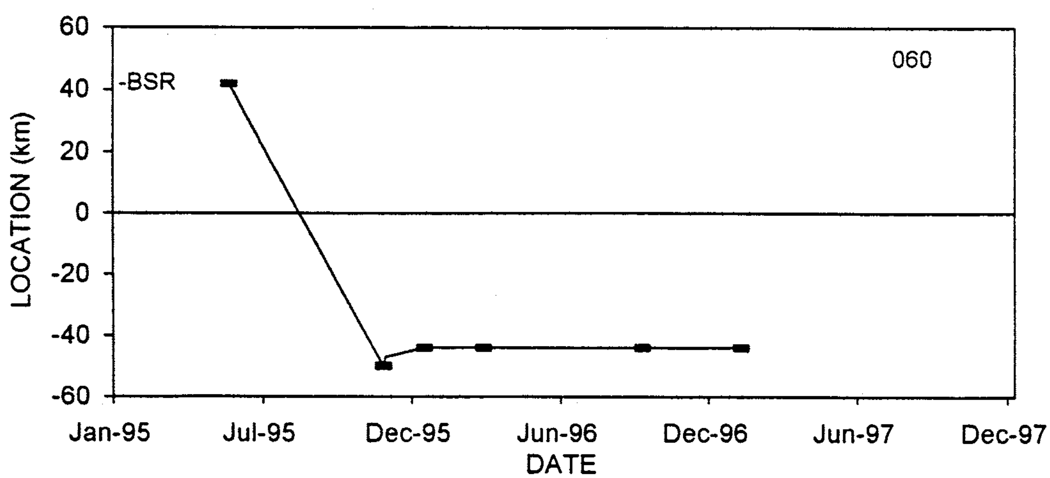




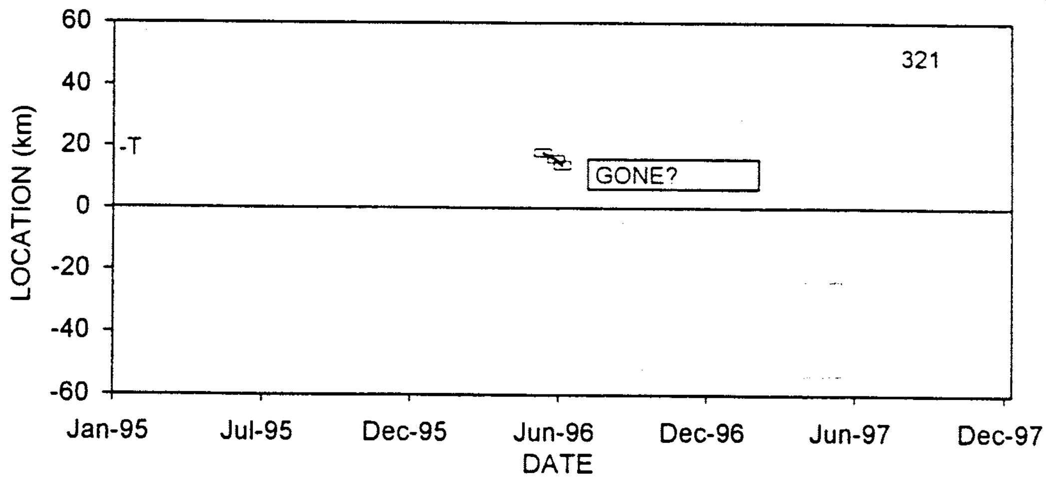
Appendix A cont'd. BSR is Bigstone Rapids.

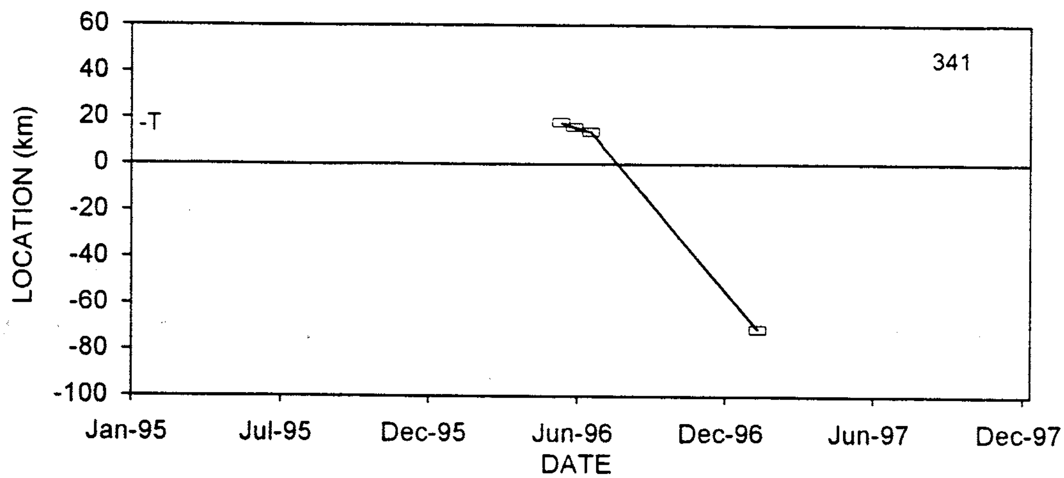


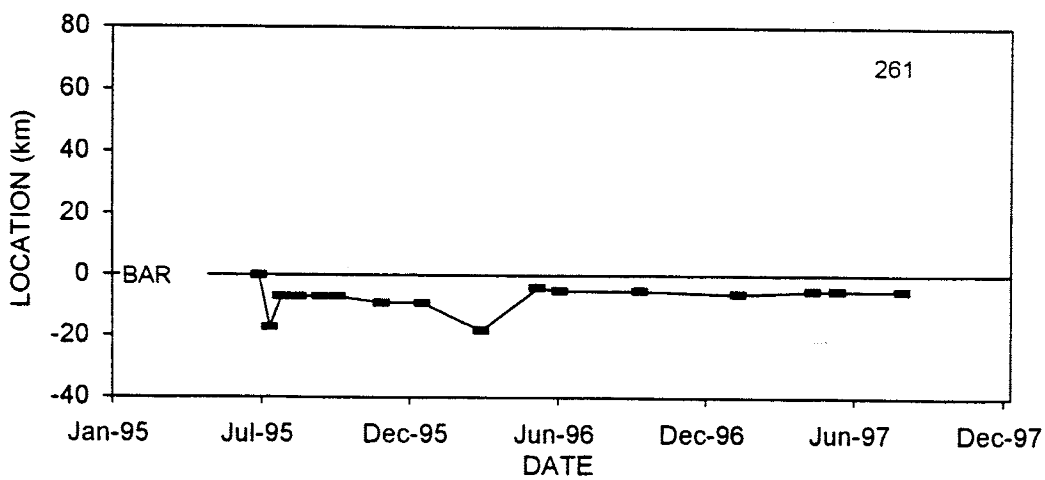




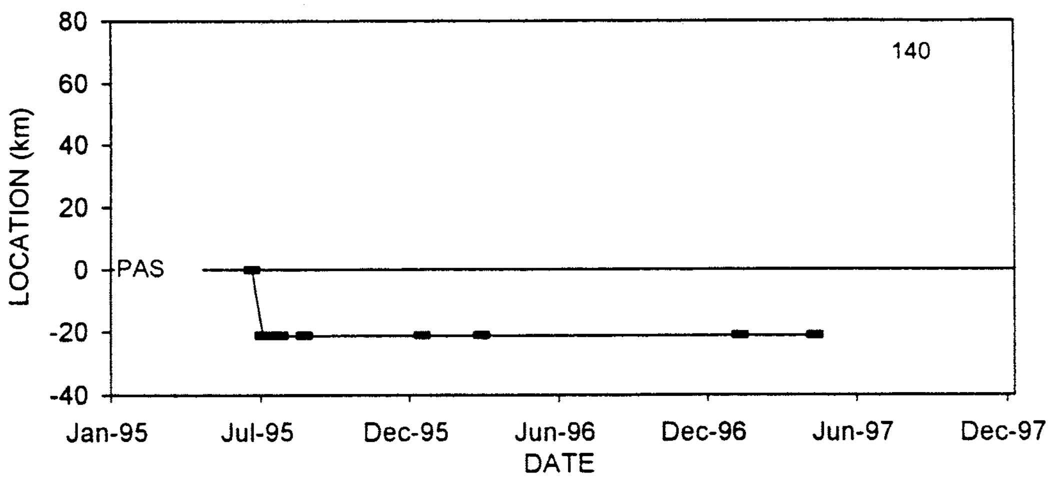
Appendix A cont'd. T is Tearing River; BAR is Barrier area.

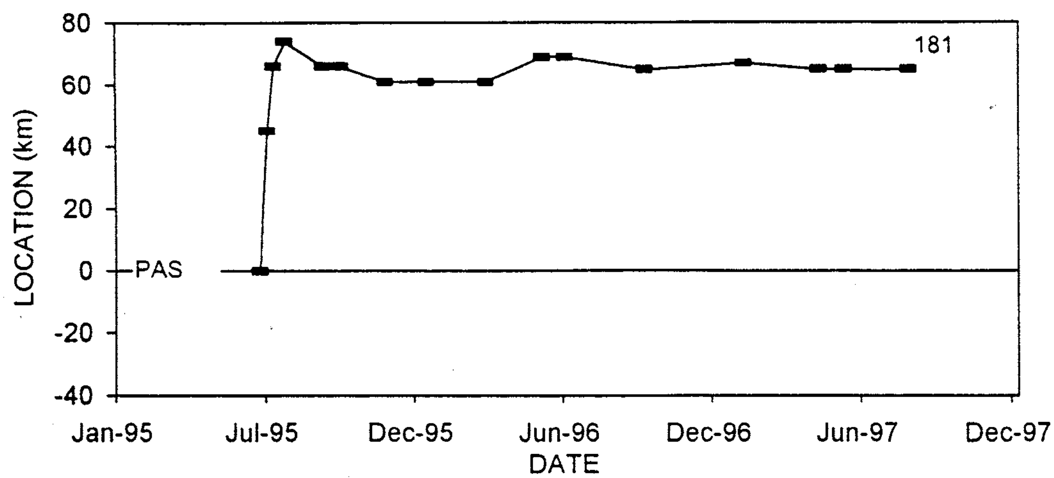


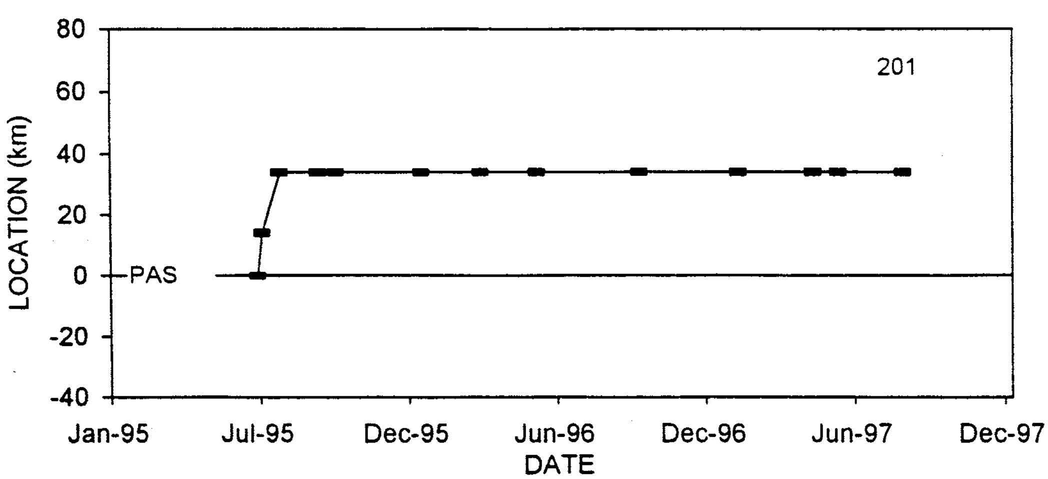




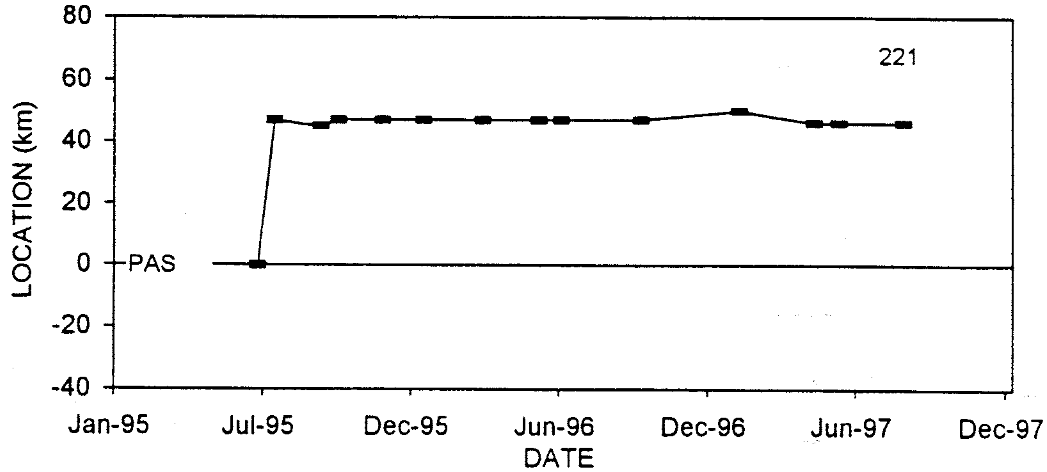
Appendix A cont'd. PAS is The Pas area.

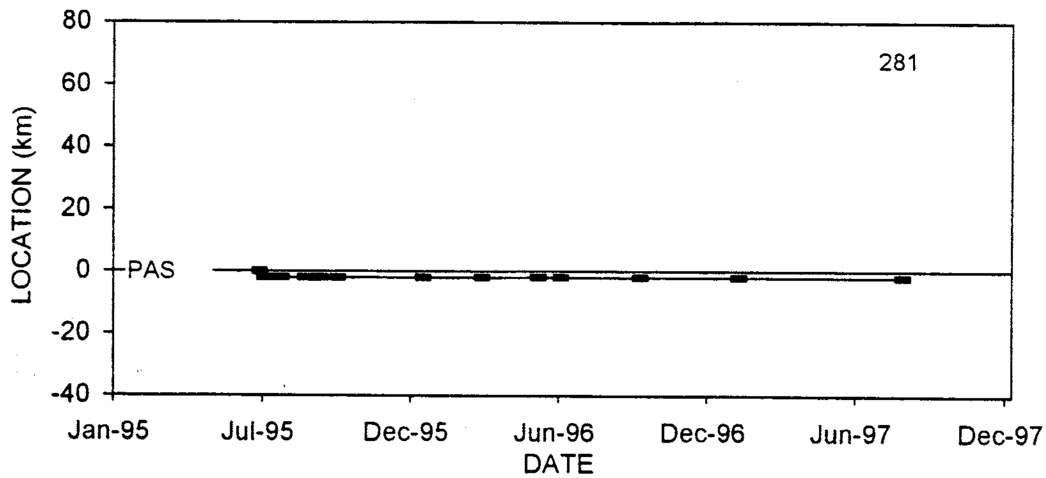


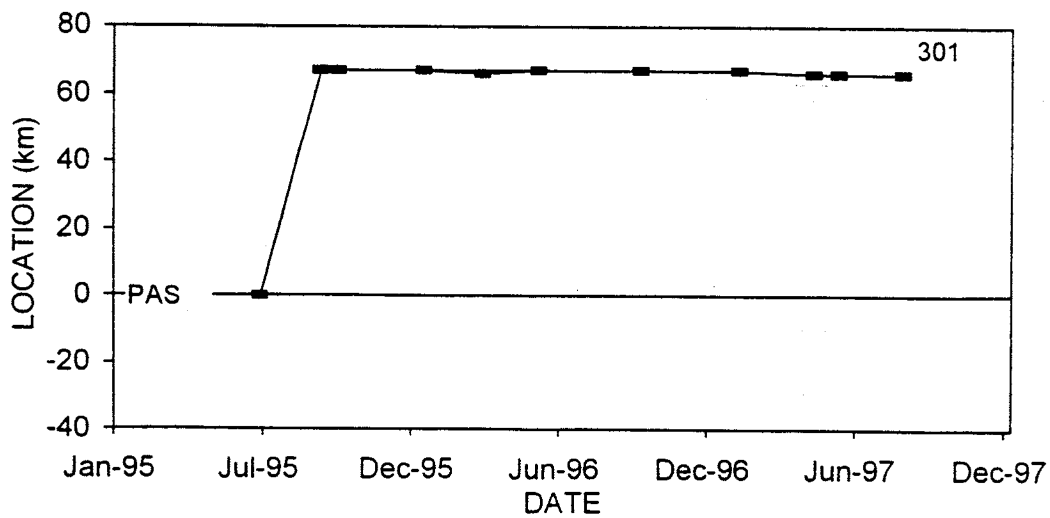




Appendix A cont'd.







Appendix B. Conditions of special fishing permits issued for index fishing in Saskatchewan, 1996 and 1997.

SPECIAL FISHING PERMIT #

The following Special Fishing Permit is issued to:

xxx

of Cumberland House, Saskatchewan
under the following conditions.

1. This permit is valid for use by the permittee and other persons authorized to act on his behalf, including the following:

xxx

2. This permit is valid only in the Saskatchewan River and connecting channels and lakes in the Cumberland House area, lying east of 103°20' west longitude.

3. The purpose of this permit is to allow fishing for sturgeon for examination, tagging, and live release, in order to determine their location, abundance, and sizes. All terms and conditions of the contract governing this work by the permittee apply.

4. This permit is valid from June 1, 1996 to July 15, 1996 unless extended or cancelled earlier by an officer.

5. Fishing gear may include gillnets of 10 to 12-inch stretched mesh and lines of hooks. Gillnets of 4.5-inch mesh may be used only to provide fish to bait hooks in active use.

6. Any fishing gear must be marked with this permit number. If fishing gear is lost or cannot be retrieved, this must be reported to a Conservation Officer, Fisheries Branch, or their designate.

7. Sturgeon may be retained only for biological examination, tagging, and release. Any sturgeon which die must have this permit number affixed securely and be reported to a Conservation Officer or to Fisheries Branch.

Date

Ed Dean, A/Director
Fisheries Branch

cc: B. Hathaway, La Ronge
D. McKay, Cumberland House
J. Durbin, Prince Albert
R. Coleman, Nipawin
M. Chen, Regina

Appendix C. Conditions of contracts for index fishing in Saskatchewan, 1996 and 1997.

CONTRACT #

The parties agree as follows:

1. THE WORK: ... the Contractor will provide the following services (called "index fishing") as part of a study of lake sturgeon:

- Use gillnets and hooks to catch sturgeon, according the terms and conditions of a Special Collection Permit ...

- Provide information on the locations and daily number of fishing gear in use, at least once per week.

- Provide information on the type of gear which caught each sturgeon, at least once per week.

- Retain all captured sturgeon alive for examination, tagging, and live release, unless advised otherwise ...

The Contractor will make reasonable efforts to ensure that any information provided on fishing and catches is complete and reliable ...

The Contractor will perform this work at his own expense and will provide and maintain a suitable boat and motor, associated gear, fuel and oil, and other equipment as needed.

The Province agrees to provide fishing gear and forms for recording information ... The Contractor agrees to use due care in operating and maintaining any gear and to return any gear ...

The Contractor will advise a Conservation Officer at Cumberland House of any activities which are planned or in progress if requested ...

2. LOCATION OF WORK: The work will be carried out on the Saskatchewan River and connecting channels and lakes in the Cumberland House area.

3. TERM: ... period commencing June 15, 1997 and terminating July 15, 1997, unless terminated earlier.

cont'd

Appendix C cont'd

4. PRICE: ... for each sturgeon which is made available for examination and tagging, and which is released alive.

Payments for market-size sturgeon (a minimum round or live weight of 18 pounds or 8.16 kg), will be based on 2/3 of the round weight, multiplied by a rate of $ 4.00 per pound.

Payments for smaller sturgeon will be based on 2/3 of the round weight, multiplied by a rate of $ 2.00 per pound.

Payments will only be made if information on fishing gear and catches is provided ...

...

6. TERMINATION: This agreement may be terminated without cause by either party upon 3 (three) days written notice ...

Contractor

Witness

Date of execution

Saskatchewan Environment and Resource Management

Witness

Date of execution

Appendix D. List of index fishers and helpers in Saskatchewan, 1996 and 1997.

1996:
134 - Marcel Fiddler (helper Joe Fiddler)
135 - Nathan Settee (helper Clinton Carriere)
136 - Frank (Joseph) Budd (helper John Budd)
137 - Philip Crane (helper Harvey Fiddler)
138 - William Chaboyer (helpers Cyril Goulet,
Gary Carriere, Floyd McKenzie)
139 - Greg Crate (helper Victor Crane)
140 - George Carriere (helpers Ovide Goulet,
James Carriere, Donald Carriere)
141 - Peter Crane (helper Kennedy Dorion)
142 - John Carriere (helper Kevin Nabess)
143 - Ralph Cook (helpers Bill Cook, Frank McLeod)

1997:
144 - Philip Crane (helpers Peter Crane, Harvey Fiddler)
145 - Kevin Nabess (helper John Carriere)
146 - Joseph Fiddler (helper Donovan Fiddler)
147 - Frank (Joseph) Budd (helpers Robert Budd, Harry Budd)
148 - William Chaboyer (helper ?)
149 - Glen McKenzie (helper Kelvin Fiddler)
150 - Kennedy Dorion (helper Sean McKenzie)
151 - Kelvin McKay (helper Donald McKay)

Permit numbers are marked on all fishing gear for identification. These numbers are part of the contract numbers assigned, and are also used as prefixes for invoices.

Appendix E. Sizes of sturgeon in commercial harvests (1958 to 1991) and index catches (1996 and 1997) in Saskatchewan, by number in each size-category.

Year	1958	1959	1960	1961	1962	1963	1966	1977	1979	1980
Weight (lb.)										
5-7	28	89	1	1	0	0	0	0	0	0
8-10	172	111	21	60	10	6	0	34	0	0
11-13	123	97	29	84	113	50	15	86	77	16
14-16	106	83	21	31	123	45	23	34	105	32
17-19	80	43	5	27	82	37	12	19	70	16
20-22	51	34	9	18	36	19	4	7	30	4
23-25	34	18	3	6	18	8	4	5	26	6
26-28	18	10	4	8	15	4	1	2	2	3
29-31	20	8	2	0	7	2	1	4	4	1
32-34	8	4	1	2	3	2	0	1	1	3
35-37	7	4	0	0	2	0	1	0	0	0
38-40	10	6	0	0	0	2	0	0	0	0
41-43	5	1	3	2	0	1	0	0	0	0
44-46	3	3	0	2	0	0	0	0	0	0
47-49	2	1	0	0	0	1	0	1	0	0
50-59	6	3	0	3	2	0	1	0	0	0
60-69	3	1	0	1	0	0	0	0	0	0
70+	2	4	1	0	0	0	0	0	0	0
n=	678	520	100	245	411	177	62	193	315	81

Year	1982	1983	1985	1986	1987	1988	1989	1990	1991	1996	1997
Weight (kg)											
4.0-4.4	1	3	0	0	3	1	1	14	4	33	15
4.5-4.9	4	0	0	3	11	6	4	13	18	9	3
5.0-5.4	20	2	29	13	25	13	7	34	28	10	8
5.5-5.9	22	8	20	15	28	18	9	31	27	16	10
6.0-6.4	31	46	79	32	28	29	11	35	18	9	1
6.5-6.9	27	26	19	22	14	22	9	21	25	6	6
7.0-7.4	14	30	55	38	18	23	5	26	17	7	4
7.5-7.9	12	27	20	18	15	17	6	21	9	7	2
8.0-8.4	18	25	54	19	26	28	11	16	16	1	6
8.5-8.9	7	20	13	10	14	11	12	14	8	3	1
9.0-9.4	10	13	40	16	11	17	6	15	5	2	4
9.5-9.9	5	12	9	7	9	11	4	10	9	4	2
10-10.9	4	19	21	20	12	27	2	11	12	4	4
11-11.9	2	6	18	14	15	8	4	12	7	5	2
12-12.9	5	6	5	9	7	6	2	3	4	5	1
13-13.9	2	2	9	4	5	3	1	2	1	2	1
14-14.9	0	2	1	3	1	3	0	2	2	3	2
15-15.9	0	6	1	0	1	3	0	4	1	1	1
16-16.9	0	1	1	1	0	0	0	1	0	0	1
17+	0	0	1	0	0	1	0	2	1	2	1
n=	184	254	395	244	243	247	94	287	212	129	75

Commercial harvests are dressed weights; index catches are equivalent to dressed weights (see text). Prior to 1982, numbers of fish were reported in 3-pound intervals. Since 1982, weights (rounded to 0.1 or 0.5 kg) have been recorded for individual sturgeon.

Appendix F. Fitting and adjustments to catch rates by commercial and index fishers, 1983 to 1997.

Data:

Raw data for 1996 and 1997 consists of actual effort and catches for each fishing crew (Table F1). Raw data for historical commercial fishing was retrieved from files used for either marketing or quota-management purposes (similar to Wallace 1991).

A more useful form of data required adjustments, as described below.

Methods and results:

(1) Commercial fishing occurred regularly in June-July, and usually again in August after 1984; index fishing occurred only in June-July. Only catches for June-July were used in comparisons.

Commercial harvest rates were based on a single delivery day each week. Catches for the more frequent visits in 1996 and 1997 were adjusted to weekly.

Each actual catch was adjusted by 7 days/number-of-days-between-visits, while constraining the overall yearly number caught to remain constant. Results show that some catch rates were lower and some higher in 1996; catch rates were lower after adjustment in 1997.

(2) Commercial harvest rates for 1983 to 1994 were known only for crew-weeks in which at least one market-size sturgeon was caught. (Only a few deliveries were made for fish which were then found to be small). We needed to avoid the problem of crew-weeks with zero catches increasing if the abundance of market-size fish was declining, without having data on all fishing effort (Table F2).

Table F1. Effort and catches for index fishing, 1996 and 1997.

1996 and 1997 Index Fishing cue				Number of sturgeon			Fishing	Hooks			Nets				Nets				
								Hook-	Sturgeon			Yard-	Sturgeon			Yard-	Sturgeon		
Year	Month	Day	Fisher	Small	Market	Total	days	days	Small	Market	Mesh	days	Small	Market	Mesh	days	Small	Market	Area
96	6	6	BUDD, Frank (Joseph	0	12	12	3	0			10	150	0	1	own	450	0	11	SR Bigstone Rapids
96	6	10	BUDD, Frank (Joseph	0	9	9	6	0			10	300	1	3	own	1500	0	5	SR Bigstone Rapids
96	6	18	BUDD, Frank (Joseph	0	0	0	8	0			10	400	0	0	own	1600	0	0	SR Bigstone Rapids
96	7	5	BUDD, Frank (Joseph	1	0	1	5	500	1	0	10	200	0	0	own	1000	0	0	CL Lake
96	6	7	CARRIERE, John V.	0	0	0	2	0			10	100	0	0	own	100	0	0	MOR Mossy River
96	6	15	CARRIERE, John V.	1	8	9	7	0			10	350	3	2	own	1000	4	2	CL Lake (2 fish stolen)
96	6	17	CARRIERE, John V.	1	1	2	2	0			10	100	0	1	own	300	1	0	CL Lake
96	6	20	CARRIERE, John V.	2	2	4	3	0			10	150	2	2	own	650	0	0	CL Lake
96	6	28	CARRIERE, John V.	0	2	2	7	0			10	400	1	1	own	2000	1	1	CL Lake (2 fish stolen)
96	7	5	CARRIERE, John V.	0	3	3	7	700	3	1	10	700	0	0	own	1800	1	1	SR Bigstone Cutoff (1 fish died)
96	7	10	CARRIERE, John V.	1	6	7	5	500	1	4	10	500	0	2	own	1000	0	0	CL (Spruce)
96	7	16	CARRIERE, John V.	2	3	5	6	600	2	3	10	300	0	0	own	300	0	0	CL (Spruce)
96	6	4	CHABOYER, Wm.	0	0	0	1	0			10	50	0	0	own	100	0	0	CL Lake
96	6	6	CHABOYER, Wm.	0	7	7	2	0			10	100	0	4	own	150	0	3	TOR Torch outflow
96	6	11	CHABOYER, Wm.	1	7	8	5	0			10	350	0	5	own	500	1	2	TOR Torch outflow
96	6	7	CRANE, Peter	1	1	2	2	600	1	0	10	100	0	1	own	50	0	0	TER Tearing outflow
96	6	10	CRANE, Peter	2	5	7	3	600	1	2	10	150	0	2	own	300	1	2	TER Tearing outflow (3 fish stolen)
96	6	14	CRANE, Peter	0	0	0	4	600	0	0	10	150	0	0	own	300	0	0	TER Tearing outflow
96	6	22	CRANE, Peter	0	0	0	8	1800	0	0	10	450	0	0	own	700	0	0	TER Tearing outflow
96	6	7	CRANE, Philip	3	1	4	3	300	3	1	10	0			own	0			SR below Tearing River
96	6	13	CRANE, Philip	0	0	0	6	600	0	0	10	300	0	0	own	300	0	0	SR Barrier
96	6	22	CRANE, Philip	0	0	0	8	800	0	0	10	400	0	0	own	400	0	0	SR Barrier
96	6	15	CRATE, Greg	0	1	1	8	600	0	0	10	0			own	900	0	1	CL Lake
96	6	22	CRATE, Greg	0	0	0	7	...			10	0			own	1050	0	0	CL Lake
96	6	7	FIDDLER, Marcel	0	1	1	3	600	0	0	10	100	0	1	own	100	0	0	CL Lake
96	6	13	FIDDLER, Marcel	0	5	5	6	1200	0	0	10	250	0	5	own	250	0	0	CL Oldman's
96	6	24	FIDDLER, Marcel	1	4	5	10	2000	0	0	10	450	1	4	own	450	0	0	CL Oldman's
96	6	28	FIDDLER, Marcel	1	0	1	4	800	1	0	10	200	0	0	own	200	0	0	CL Oldman's
96	7	3	FIDDLER, Marcel	0	3	3	5	1000	0	0	10	200	0	2	own	200	0	1	CL Oldman's
96	7	15	FIDDLER, Marcel	0	0	0	10	2000	0	0	10	400	0	0	own	400	0	0	CL Lake
96	6	28	SETTEE, Nathan	6	0	6	2	400	6	0	10	0			own	0			CL Oldman's
96	7	5	SETTEE, Nathan	7	4	11	7	1400	7	4	10	0			own	0			CL Oldman's
96	7	10	SETTEE, Nathan	6	4	10	5	1250	6	4	10	0			own	0			CL Oldman's
96	7	16	SETTEE, Nathan	4	2	6	2	600	4	2	10	0			own	0			CL Nathan's Reef
			Totals	40	91	131	172	19450	36	21		7300	8	36		18050	9	29	
			Average	0.2	0.5	0.8	5.1	113	0.2	0.1		42	0.0	0.2		105	0.1	0 2	Averages / day (unless noted).
				/day	/day	/day	/visit	/day				/day				/day			

continued...

Table F1 cont'd.

1996 and 1997 Index Fishing cue

Year	Month	Day	Fisher	Number of sturgeon Small	Number of sturgeon Market	Number of sturgeon Total	Fishing days	Hooks Hook-days	Hooks Sturgeon Small	Hooks Sturgeon Market	Nets Mesh	Nets Yard-days	Nets Sturgeon Small	Nets Sturgeon Market	Nets Mesh	Nets Yard-days	Nets Sturgeon Small	Nets Sturgeon Market	Area
97	6	26	BUDD, Frank (Joseph	0	0	0	7	3500	0	0	10	0			own	0			SR Bigstone Rapids
97	7	3	BUDD, Frank (Joseph	0	0	0	8	4000	0	0	10	0			own	0			SR Bigstone Rapids
97	7	14	BUDD, Frank (Joseph	0	3	3	11	4500	0	3	10	0			own	0			CL Lake (1 fish stolen)
97	7	18	BUDD, Frank (Joseph	0	0	0	4	2000	0	0	10	0			own	0			SR Bigstone Rapids
97	6	23	CRANE, Philip	0	1	1	8	2000	0	1	10	0			own	0			SR below Tearing
97	6	27	CRANE, Philip	0	3	3	4	1200	0	3	10	0			own	0			SR below Tearing
97	7	4	CRANE, Philip	0	2	2	7	2100	0	2	10	0			own	0			SR below Tearing
97	7	18	CRANE, Philip	0	0	0	14	4200	0	0	10	0			own	0			SR below Tearing
97	6	26	DORION, Kennedy	1	2	3	7	1400	1	2	10	0			own	0			SR above Tearing
97	6	24	FIDDLER, Joseph	1	6	7	6	1800	1	6	10	0			own	0			CL Lake
97	6	30	FIDDLER, Joseph	0	2	2	6	1800	0	2	10	0			own	0			CL Lake
97	7	4	FIDDLER, Joseph	0	5	5	4	1200	0	5	10	0			own	0			CL Lake?
97	7	11	FIDDLER, Joseph	0	7	7	7	2100	0	7	10	0			own	0			CL Lake
97	7	18	FIDDLER, Joseph	0	0	0	7	2100	0	0	10	0			own	0			CL Lake
97	6	29	MCKAY, Kelvin	0	0	0	9	2700	0	0	10	0			own	0			MOR Mossy River?
97	7	4	MCKAY, Kelvin	1	6	7	5	1500	1	6	10	0			own	0			CL Lake
97	7	14	MCKAY, Kelvin	0	2	2	10	3000	0	2	10	0			own	0			CL Lake
97	7	18	MCKAY, Kelvin	0	0	0	4	1200	0	0	10	0			own	0			CL Lake
97	6	27	MCKENZIE, Glen	0	2	2	8	1000	0	2	10	0			own	0			SR near Tearing River
97	7	25	MCKENZIE, Glen	7	0	7	8	1600	7	0	10	0			own	0			SR Bigstone Rapids
97	6	27	NABESS, Kevin	1	2	3	9	2700	0	4	10	0			own	0			CL Lake (1 fish died)
97	6	30	NABESS, Kevin	0	1	1	3	900	0	1	10	0			own	0			CL Lake
97	7	3	NABESS, Kevin	3	2	5	3	900	3	2	10	0			own	0			CL Lake
97	7	8	NABESS, Kevin	0	4	4	5	1500	0	4	10	0			own	0			CL Lake
97	7	18	NABESS, Kevin	0	0	0	10	3000	0	0	10	0			own	0			CL Lake
97	7	25	NABESS, Kevin	4	6	10	7	2100	4	6	10	0			own	0			MOR Mossy River
			Totals	18	56	74	181	56000	17	58		0	0	0		0	0	0	
			Average	0.1	0.3	0.4	7.0	309	0.1	0.3		0	0.0	0.0		0	0.0	0.0	Averages / day (unless noted).
				/day	/day	/day	/visit	/day				/day				/day			

Table F2. Number of market-size sturgeon per delivery or per crew-week in June-July catches of commercial fishers (1983 to 1994) and index fishers (1996 and 1997).

Number of sturgeon	Years 1983	1985	1986	1987	1988	1989	1990	1991	1994	1996	1997
1	8	21	6	11	6	2	0	3	7	5	4
2	4	11	5	7	5	2	1	3	7	4	5
3	10	8	4	7	6	1	3	7	4	3	0
4	10	7	6	8	3	4	3	3	7	2	3
5	5	7	1	3	4	2	0	0	2	1	3
6	5	4	0	0	6	0	4	2	1	1	0
7	3	2	2	3	1	0	1	2	3	1	2
8	0	2	0	0	1	0	1	3	2	0	0
9	1	1	0	4	1	0	0	0	0	0	0
10	3	1	1	0	1	1	1	0	0	0	0
11	1	1	0	0	0	0	0	0	1	2	0
12	1	0	0	1	0	0	0	0	0	0	0
13	0	0	0	0	1	0	0	0	0	0	0
14	1	0	0	0	1	0	0	0	0	0	0
15	0	0	1	1	0	0	0	0	0	0	0
16	0	0	0	0	1	0	0	0	0	0	0
17	0	0	0	0	1	0	1	0	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0
19	0	0	0	0	0	0	0	0	0	1	0
20	0	0	0	0	0	0	0	0	0	0	0
21+	0	0	0	1	0	1	0	1	0	0	0
Number of crew-weeks	52	65	26	46	38	13	15	25	34	20	17

This complication is known as "truncation" since information on the number of "zero" catches is cut-off (Cohen 1991). Assuming that all weeks during open-season were fished by all licensed fishers seemed unrealistic. Assuming that each crew fished between two deliveries of market-size fish seemed better, but still uncertain. Other methods were used.

(3) Commercial catch rates were adjusted by test-fitting mathematical curves to the non-zero catch data. Lognormal and negative binomial curves were likely candidates since the variability (as "variance") of the catches was always greater, and sometimes much greater, than the mean.

The lognormal curve fit only 3 of 9 years available. Further, using corrections based on lognormal situations (Krebs 1989 p. 352) provided estimates of the number of missing zeros which seemed too variable. The estimated number of zero catches ranged from very low to over 50% of the non-zero catches, which seemed high.

(4) Negative binomial curves fit 7 of 9 years of commercial and index catches. This provided initial estimates of the mean and variability according to this curve, and the mean and confidence limits of abundance (Table F3).

Then the "jackknife" method was used to estimate the number of zeros (Krebs 1989). For this, curves for each year were fitted to all data (except one delivery, repeated sequentially for n deliveries), parameters u and k were calculated for each of the n curves, and pseudo-values were used to estimate the confidence limits for the number of missing zeros for each year. The 90% upper limit of predicted zeros were added to the original non-zero data. The "bootstrap" method was not used, but usually gives more precise estimates (S. Findlay pers. comm.).

By this approach, estimated numbers of zero catches ranged from 3.6 to 8.7% of non-zero catches. A final negative binomial curve was fitted to each year, and years with acceptable fit were used in trends. Catch rates for some years were shown in the text (Figures 9A and 9B). Two other examples are shown here (Figure F1).

Discussion:

The intent of these adjustments was to make historical commercial data and recent index fishing data comparable. With more data from long-term index fishing, the particular adjustments used may be confirmed or changed.

Table F3. Fitting of commercial deliveries of market-size sturgeon with lognormal and negative binomial curves, to estimate the number of weeks with "zero" catch, Saskatchewan, available years from 1983 to 1996-97.

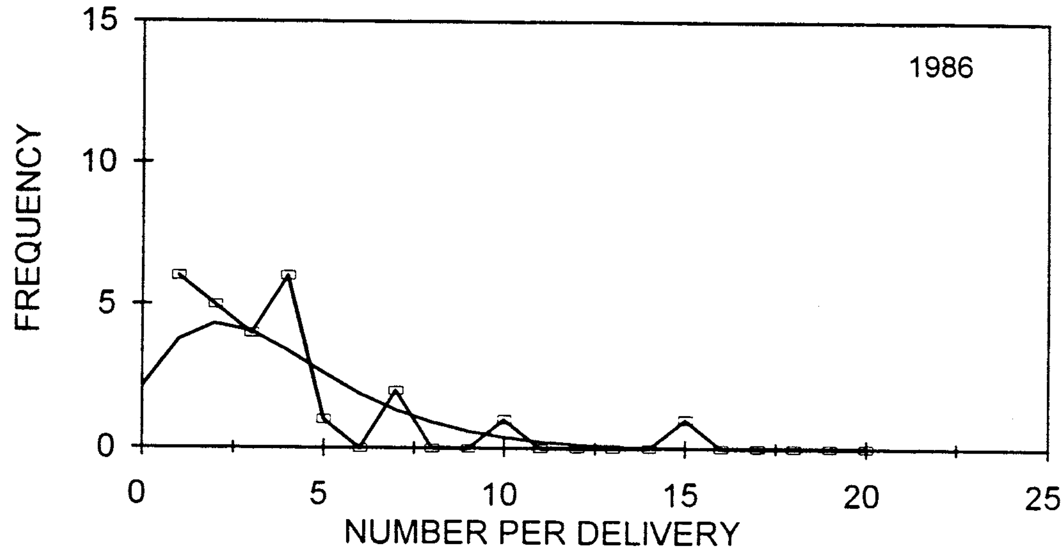
Year	Dels[a]	Lognormal[b] Fit	Negative Binomial[c] Fit	Prob<	Parameters u	k	Expected zeros	Retransformed Mean (95% CI)
1983	52	no	yes	0.127	4.577	5.097	2 (3.8%)	3.85 (1.32 - 9.14)
1985	65	no	no	0.006	3.292	4.500	5 (7.7%)	2.70 (0.76 - 6.81)
1986	26	yes	yes	0.132	3.692	3.420	2 (7.7%)	2.99 (1.92 - 4.45)
1987	46	no	no	0.017	3.870	3.111	4 (8.7%)	3.09 (1.20 - 6.59)
1988	38	yes	yes	0.477	5.158	2.742	2 (5.3%)	4.07 (1.81 - 8.16)
1989[d]	28	no	yes	0.283	5.679	2.895	1 (3.6%)	4.57 (3.46 - 5.96)
1991	25	yes	yes	0.227	4.440	3.395	1 (4.2%)	3.61 (2.39 - 5.26)
1994	34	no	yes	0.168	3.676	6.294	2 (5.9%)	3.10 (1.61 - 5.44)
1996[d]	37	no	yes	0.104	3.892	2.594	3 (8.1%)	3.04 (1.43 - 5.72)

[a] Number of deliveries with at least one market-size sturgeon.

[B] Data was fitted using LOGNORM2 Windows-95 program (InTech Software 1998). "Fit" was assessed at Prob=0.05 level using Shapiro-Wilks W-test.

[C] Data was fitted using Krebs/WIN NEGBINOM Windows-95 program (Version 0.9 (28-Oct-1997) by C. Krebs and J. Brzustowski [ftp://gause.biology.ualberta.ca/pub/jbrzusto/ krebs]. "Fit" was assessed using chi-square and Prob< level is shown (Krebs 1989).

[d] This year and the following year were combined, to have at least 25 deliveries.



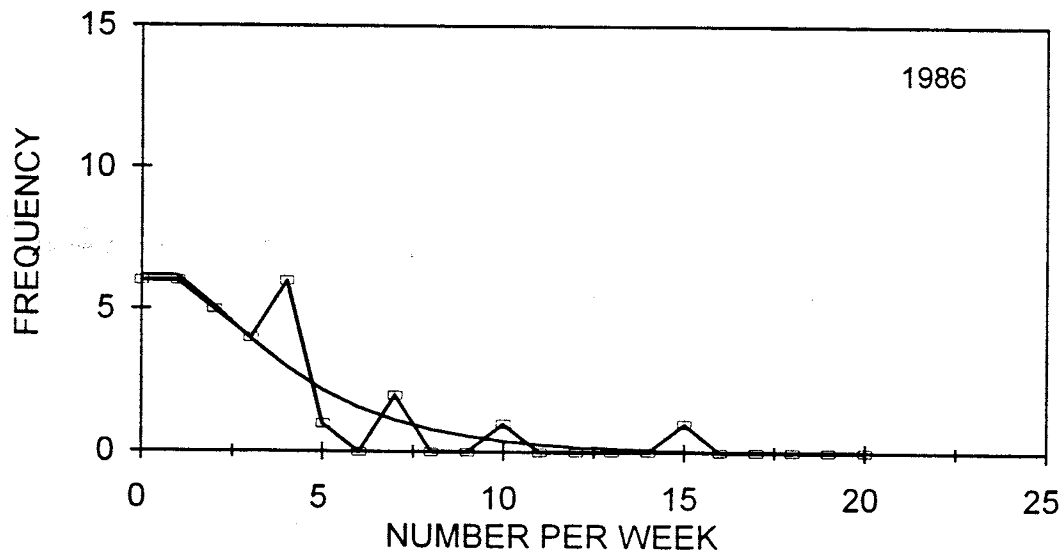
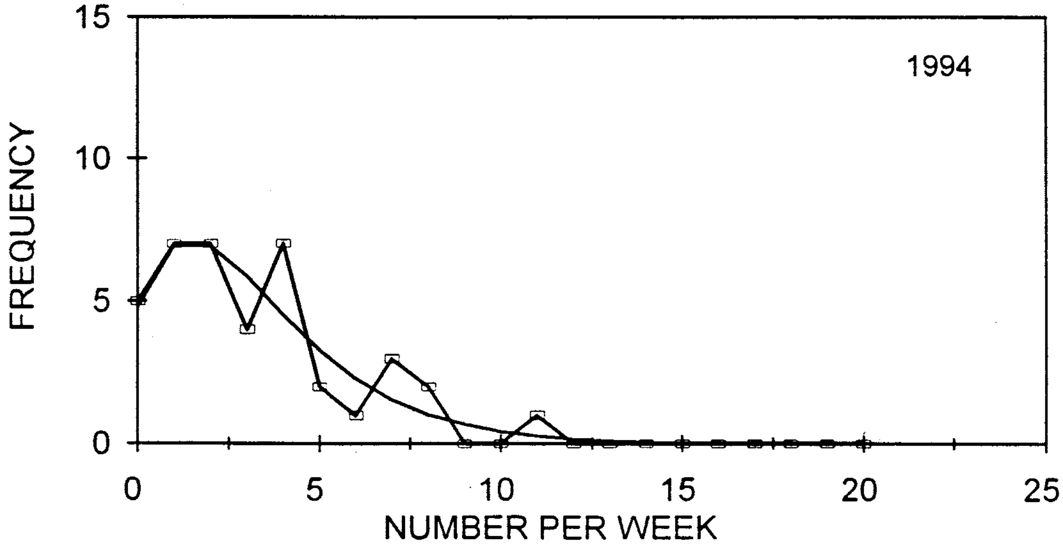


Figure F1. Number of sturgeon caught by index fishers, Saskatchewan, 1986. Points and bold lines show actual data; fine line shows curve fitted to data.
UPPER: Number caught, excluding weeks with zero-catches.
LOWER: Number caught, including an estimate of zero-catches.



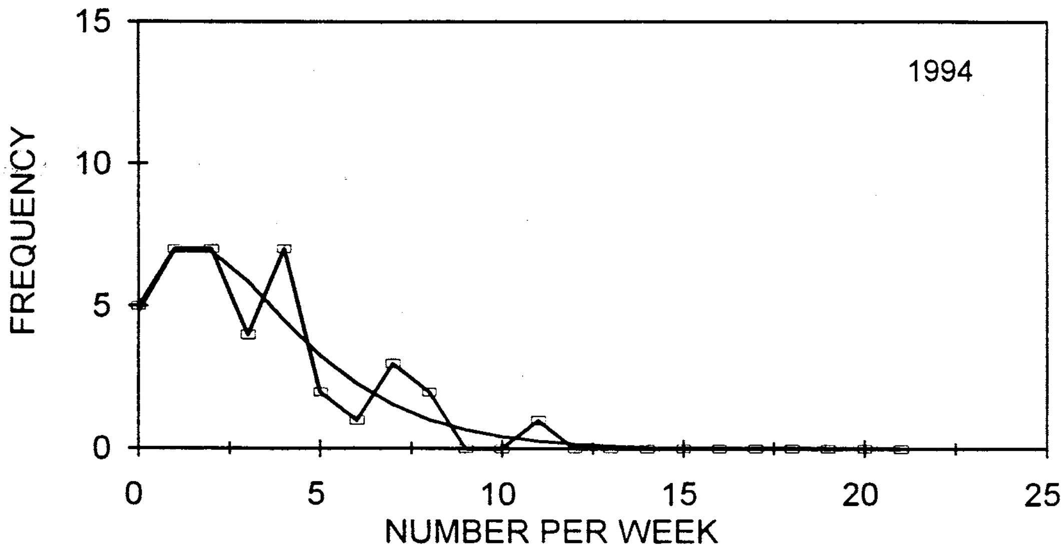


Figure F1 cont'd. Number of sturgeon caught by index fishers, Saskatchewan, 1994.

Appendix G. Records of T-bar and PIT tags on sturgeon in the Saskatchewan River.

T-BAR TAGS

In some studies on sturgeon, T-bar retention rates have been 25 to 84% over 6 to 24 months: 25% of tags (base of dorsal fin) after 127 days in juvenile shortnose sturgeon, but "excess trauma" of wound was noted (Smith et al. 1990); 40% of tags (hole in scute, and base of dorsal fin) after 180 days in juvenile Atlantic sturgeon, then 75 to 100% for 454 days (Smith et al. 1990); 75% of tags (base of dorsal fin) after 191 days in juvenile shortnose sturgeon, and then 80% for 306 days (Collins et al. 1994); 79 to 84% of tags (pectoral fin) after 2 years, and 41 to 72% after 3 years, in Gulf sturgeon (Clugston 1996).

PIT TAGS

Experience shows that PIT tags are well retained by fish, once a suitable site of injection is found. Since they have no battery or moving parts, life-span is very long if the PIT tag is not physically broken.

Retention rates of PIT tags in sturgeon are: 100% of PIT tags (under dorsal scutes) over 60 days in adult shortnose sturgeon (Smith et al. 1990); 72 to 75% of tags (base of dorsal fin) after 2 years, and 65 to 68% after 3 years, in Gulf sturgeon (Clugston 1996).

PIT tags offer excellent identification, should not entangle, and remain invisible (for unbiased searches for recaptures), but are expensive ($ 8 Cdn each) and require a hand-scanner to read. PIT tags were placed in pectoral fins (rather than in muscle or at base of dorsal fin) to avoid problems if caught and eaten, and to allow for recovery if pectoral fins were collected in future for ageing.

Records of sturgeon tagged during index fishing in 1996 and 1997 are shown below (Tables G1 to G3).

Table G1. Record of sturgeon with visual T-bar tags and PIT tags applied during index fishing, Saskatchewan, 1996 and 1997.

Area	Caught Site	Date	Released Site (if different)	Fisherman	Fork lengt (cm)	Round weig (kg)	Tag numbers 1st	2nd	PIT tag	Comments
CL	Lake	96Jun07		IF Marcel Fiddler	116	12.5	2685	2686	410A627925	
CL	Oldman's Island	96Jun13		IF Marcel Fiddler	109	11.3	2746	2747	410A74132A	
CL	Oldman's Island	96Jun13		IF Marcel Fiddler	106	10.7	2732	2733	410A602020	
CL	Oldman's Island	96Jun13		IF Marcel Fiddler	122	15.5	2742	2745	410A53210B	
CL	Oldman's Island	96Jun13		IF Marcel Fiddler	112	9.5	2738	2739	410A18163E	
CL	Oldman's Island	96Jun13		IF Marcel Fiddler	120	11.7	2735	2736	410A4B0E78	
CL	Lake	96Jun15		IF Greg Crate	98	9.0	2748	2749	410F4A3162	
CL	Lake	96Jun15	Cutoff	IF John Carriere	94	7.5	2891	2892	410F3C173E	
CL	Lake	96Jun15	Cutoff	IF John Carriere	70	2.1	2881	2882	410F4B6448	
CL	Lake	96Jun15	Cutoff	IF John Carriere	96	5.7	2889	2890	410F427C33	
CL	Lake	96Jun15	Cutoff	IF John Carriere	102	8.5	2895	2897	410F446F31	
CL	Lake	96Jun15	Cutoff	IF John Carriere	96	8.0	2898	2899	410F3D6100	
CL	Lake	96Jun15	Cutoff	IF John Carriere	116	11.0	2883	2884	410F3D4103	
CL	Lake	96Jun15	Cutoff	IF John Carriere	107	7.6	2893	2894	410FA0426 ?	
CL	Lake	96Jun15	Cutoff	IF John Carriere	105	7.4	2887	2888	410F347F55	
CL	Lake	96Jun15	Cutoff	IF John Carriere	108	10.0	2885	2886	410F5B2F06	
CL	Lake	96Jun20		IF John Carriere	104	10.2	2860	2862	410F3F0204	
CL	Lake	96Jun20		IF John Carriere	100	7.6	2863	2865	41046A7429	
CL	Lake	96Jun20		IF John Carriere	121	16.0	2869	2870	410F520D78	
CL	Lake	96Jun20		IF John Carriere	89	5.5	2866	2868	410F40584D	
CL	Oldman's Island	96Jun24		IF Marcel Fiddler	102	12.0	2876	2875	410A684846	
CL	Oldman's Island	96Jun24		IF Marcel Fiddler	97	6.8	2856	2859	410F50622E	
CL	Oldman's Island	96Jun24		IF Marcel Fiddler	99	8.5	2874	2873	410A74187B	
CL	Oldman's Island	96Jun24		IF Marcel Fiddler	106	9.6	2853	2852	410F3A4671	
CL	Oldman's Island	96Jun24		IF Marcel Fiddler	101	8.3	2871	2872	410F6B2959	
CL	Oldman's Island	96Jun28		IF Marcel Fiddler	107	7.7	2802	2803	410F4C3604	
CL	Lake	96Jun28		IF Nathan Settee	89	4.5	...	...	...	Died before release.
CL	Lake	96Jun28		IF Nathan Settee	84	3.2	2814	2815	410F477831	
CL	Lake	96Jun28		IF Nathan Settee	89	5.2	2812	2813	410F544B44	
CL	Lake	96Jun28		IF Nathan Settee	90	5.5	2807	2808	410F456D11	
CL	Lake	96Jun28		IF Nathan Settee	87	4.5	2809	2811	410F307C4E	
CL	Lake	96Jun28		IF Nathan Settee	92	5.2	2804	2805	410F445E6F	
CL	Lake	96Jul03	Oldman's Island	IF Marcel Fiddler	104	8.5	2824	2826	4142753E11 ?	
CL	Lake	96Jul03	Oldman's Island	IF Marcel Fiddler	112	9.5	2822	2823	410F394864A	

Table G1 cont'd.

CL	nr Bigstone Cutoff	96Jul05	IF Joseph Budd	83	3.8	2427	2428	...	Recapture.
CL	Oldman's Island	96Jul05	IF Nathan Settee	95	5.0	2839	2840	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	104	9.1	2762	2763	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	97	5.2	2751	2752	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	102	7.6	2843	2844	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	81	3.7	2764	2765	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	105	9.0	2753	2754	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	105	9.0	2757	2759	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	114	11.8	2845	2847	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	78	3.0	2841	2842	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	86	3.8	2837	2838	...	
CL	Oldman's Island	96Jul05	IF Nathan Settee	82	3.4	2760	2761	...	
CL	Lake	96Jul10	IF John Carriere	106	9.2	2799	none	...	
CL	Lake	96Jul10	IF John Carriere	111	11.0	2794	2796	...	
CL	Lake	96Jul10	IF John Carriere	104	10.3	2797	none	...	
CL	Lake	96Jul10	IF John Carriere	135	22.5	2790	none	...	Radio 48.400 (c/w yellow #3193 & #3177) applie
CL	Lake	96Jul10	IF John Carriere	108	9.3	2792	2793	...	
CL	Lake	96Jul10	IF John Carriere	105	9.4	2795	none	...	
CL	Lake	96Jul10	IF John Carriere	104	8.0	2748	2749	...	Recapture.
CL	Lake	96Jul10	IF Nathan Settee	110	11.0	2784	2785	...	3rd tag 2786 applied
CL	Lake	96Jul10	IF Nathan Settee	105	8.2	2768	2769	...	
CL	Lake	96Jul10	IF Nathan Settee	84	3.2	2777	2778	...	
CL	Lake	96Jul10	IF Nathan Settee	97	6.3	2773	2774	...	
CL	Lake	96Jul10	IF Nathan Settee	107	8.5	2782	2783	...	
CL	Lake	96Jul10	IF Nathan Settee	96	7.3	2787	2788	...	
CL	Lake	96Jul10	IF Nathan Settee	100	7.2	2766	2767	...	
CL	Lake	96Jul10	IF Nathan Settee	90	4.2	2770	2771	...	
CL	Lake	96Jul10	IF Nathan Settee	87	4.1	2779	2781	...	
CL	Lake	96Jul10	IF Nathan Settee	108	8.2	2789	2791	...	
CL	Spruce Island	96Jul16	IF John Carriere	108	8.2	2921	2922	410F3D7B0C	
CL	Spruce Island	96Jul16	IF John Carriere	110	8.6	2915	2916	...	
CL	Spruce Island	96Jul16	IF John Carriere	103	7.2	2917	2918	410F390342	
CL	Spruce Island	96Jul16	IF John Carriere	102	8.5	2913	2914	...	
CL	Spruce Island	96Jul16	IF John Carriere	83	4.1	2923	2924	...	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	88	4.5	2909	2910	...	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	66	1.6	2911	2912	...	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	107	9.5	2904	2905	...	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	119	15.4	2902	2903	410F630F23	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	83	4.7	2906	2907	...	
CL	Nathan's Reef	96Jul16	IF Nathan Settee	87	4.5	2900	2901	...	

Table G1 cont'd.

SR	Bigstone Rapids	96Jun06		IF Joseph Budd	128	17.7	2657	2659	410A4A6773	Female?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	133	18.8	2654	2656	410 A545267	Female?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	138	19.5	2666	2667	410A63044A	Female?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	102	9.0	2669	2668	410A5C7007	
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	102	8.5	2664	2665	410A536F1A	Male?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	119	11.5	2640	2641	410A4A336E	Male?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	121	13.0	2652	2653	410A4A0313	
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	111	9.3	2643	2644	410A691C42	Ripe male.
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	128	17.3	2646	2648	410A5D5133	Spent? female.
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	106	9.1	2660	2662	410A704B67	Male?
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	131	14.8	none	none	410A699101E ?	Radio 48.090 applied. Ripe female!
SR	Bigstone Rapids	96Jun06		IF Joseph Budd	122	14.0	2698	2651	410A724265	3rd tag #2650?
SR	Simpson Road	96Jun07	Tearing River	IF Philip Crane	62	1.8	2682	2684	410A636A58	
SR	Simpson Road	96Jun07	Tearing River	IF Philip Crane	99	6.6	2675	2676	410A6A5014	Male.
SR	Simpson Road	96Jun07	Tearing River	IF Philip Crane	130	14.7	2677	2678	410A612F7F	Male.
SR	Simpson Road	96Jun07	Tearing River	IF Philip Crane	87	4.6	2680	2681	410A716021	
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	108	8.4	2706	2707	410A4B425D	Male.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	122	11.5	2716	2717	410A595F57	Immature?
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	105	7.8	2708	2709	410A574D21	Unknown.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	121	14.8	2714	2715	410A514E5D	Spent female.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	110	9.8	2710	2711	410A5C3C22	Immature?
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	134	16.8	2712	2713	410A5F1537	Ripe female.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	118	11.4	2702	2703	410A7AA60B	Spent female.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	106	8.2	2704	2705	410A4E465F	Spent male.
SR	Bigstone Rapids	96Jun10	300 m below	IF Joseph Budd	139	19.0	2700	2701	410A5F4A7B	Spent male?
SR	Bigstone Cutoff	96Jun17		IF John Carriere	102	9.0	2877	2878	410A603E36	
SR	Bigstone Cutoff	96Jun17		IF John Carriere	96	6.4	2879	2880	410A4F4372	
SR	Bigstone Cutoff	96Jun28		IF John Carriere	105	8.8	2800	2801	410F343144	
SR	Bigstone Cutoff	96Jun28		IF John Carriere	126	13.5	2850	2851	410F423E7E	
SR	Bigstone Cutoff	96Jul03	Elm Portage	IF Marcel Fiddler	125	20.0	2827	2830	...	Radio 48.361 applied. Female.
SR	Bigstone Cutoff	96Jul05		IF John Carriere	126	22.0	2820	2821	...	Radio 48.420 applied.
SR	Bigstone Cutoff	96Jul05		IF John Carriere	111	11.9	2833	2836	...	
SR	Bigstone Cutoff	96Jul05		IF John Carriere	98	6.7	2831	2832	...	

Table G1 cont'd.

TER	Outflow	96Jun07		IF	Peter Crane	109	8.9	2670	2671	410A60626D	
TER	Outflow	96Jun07		IF	Peter Crane	58	1.5	2672	none	410A59147F	
TER	Outflow	96Jun10		IF	Peter Crane	133	19.2	2691	2692	410A560C6F	Radio 48.341 (c/w yellow #3166 & #3178) applie
TER	Outflow	96Jun10		IF	Peter Crane	140	28.0	2689	2690	410A521924	Radio 48.321 (c/w yellow #3164) applied.
TER	Outflow	96Jun10		IF	Peter Crane	146	26.0	2695	2696	410A580D70	Spent female.
TER	Outflow	96Jun10		IF	Peter Crane	130	13.3	2687	2688	410A70650C	
TER	Outflow	96Jun10		IF	Peter Crane	61	1.5	2693	2694	...	
TOR	Outflow	96Jun06		IF	William Chaboyer	149	23.0	2638	2639	410A6E6F2E	
TOR	Outflow	96Jun06		IF	William Chaboyer	133	14.4	2610	2611	410A586156	Recapture from 1984 for 2nd time!
TOR	Outflow	96Jun06		IF	William Chaboyer	131	17.4	2629	2631	410A640D50	
TOR	Outflow	96Jun06		IF	William Chaboyer	120	11.6	2636	2637	410A67005C	
TOR	Outflow	96Jun06		IF	William Chaboyer	138	18.2	2614	2618	410A671101	Recapture.
TOR	Outflow	96Jun06		IF	William Chaboyer	135	14.8	2633	2634	410A565200	3rd tag # 2635.
TOR	Outflow	96Jun06		IF	William Chaboyer	113	10.0	2506	2507	410A515572	
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	115	10.1	2406	2407	410A5F1E66	Recapture. Immature.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	130	20.5	2724	2725	410A4E5C53	Ripe female.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	125	16.9	2728	2729	410A732B65	Male.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	119	10.6	2726	2727	...	
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	101	7.0	03694	none	410A484414	Recapture # N03694 from 1984. Immature.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	150	22.6	2718	2719	410A757D2C	Ripe? female.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	123	15.2	2720	2721	410A6D5552	Spent male.
TOR	Outflow	96Jun11	SR 400 m below	IF	William Chaboyer	119	11.3	2722	2723	410A4A0004	Male.

Table G1 cont'd.

Area	Caught Site	Date	Released Site (if different)	Fisherman	Fork lengt (cm)	Round weig (kg)	Tag numbers 1st	2nd	PIT tag	Comments
CL	Lake	97Jun23	Oldman's Island	IF Joe Fiddler	99	8.6	3205	3204	4062562A02	
CL	Lake	97Jun23	Oldman's Island	IF Joe Fiddler	103	8.2	3208	3209	4062682A45	
CL	Lake	97Jun23	Oldman's Island	IF Joe Fiddler	104	9.1	3206	3207	4062754C32	
CL	Lake	97Jun23	Oldman's Island	IF Joe Fiddler	111	11.3	3211	3212	4062705008	
CL	Lake	97Jun23	Oldman's Island	IF Joe Fiddler	96	7.3	3213	3214	40626E3C7E	
CL	Lake	97Jun24	Oldman's Island	IF Joe Fiddler	102	8.6	3218	3217	40626F004B	
CL	Lake	97Jun24	Oldman's Island	IF Joe Fiddler	124	16.3	3219	3220	4062715'406	
CL	Lake	97Jun27	Oldman's Island	IF Kevin Nabess	93	6.8	3235	3236	4062784867	
CL	Lake	97Jun27	Oldman's Island	IF Kevin Nabess	105	8.2	3237	3238	40626D2E47	
CL	Lake	97Jun27	Oldman's Island	IF Kevin Nabess	...	21.8	none		...	Died before tagging.
CL	Lake	97Jun30	Nathan's Reef	IF Joe Fiddler	104	8.2	3240	3239	406270572B	
CL	Lake	97Jun30	Nathan's Reef	IF Joe Fiddler	110	10.0	3241	3242	40627B1E3D	
CL	Lake	97Jun30	Bigstone Cutoff	IF Kevin Nabess	106	10.0	3243	3244	4062612779	
CL	Lake	97Jul03	near Oldman's	IF Joe Fiddler	106	10.0	4002	4003	40626D0436	
CL	Lake	97Jul03	near Oldman's	IF Joe Fiddler	108	9.1	4000	4001	406277312E	
CL	Lake	97Jul03	near Oldman's	IF Joe Fiddler	110	13.6	3247	3248	4062527542	
CL	Lake	97Jul03	near Oldman's	IF Joe Fiddler	101	8.6	3246	3245	4062796A44	
CL	Lake	97Jul03	Oldman's Island	IF Kelvin McKay	114	10.4	4014	4016	4062704155	
CL	Lake	97Jul03	Oldman's Island	IF Kelvin McKay	115	11.3	4012	4013	40626E5755	
CL	Lake	97Jul03	Oldman's Island	IF Kelvin McKay	100	9.1	4017	4018	406271455B	
CL	Lake	97Jul03	west shoreline	IF Kevin Nabess	111	9.5	4008	4009	40626C4F0A	
CL	Lake	97Jul03	west shoreline	IF Kevin Nabess	105	7.7	4010	4011	4062542639	
CL	Lake	97Jul03	west shoreline	IF Kevin Nabess	84	4.5	2932	2934	4062757C4F	Recapture.
CL	Lake	97Jul03	west shoreline	IF Kevin Nabess	72	2.7	4006	4007	4062601633	
CL	Lake	97Jul03	west shoreline	IF Kevin Nabess	105	8.2	4004	4005	40627A5422	
CL	Lake	97Jul04	near Oldman's	IF Joe Fiddler	...	...	404?	402?	...	
CL	Lake	97Jul04	near Oldman's	IF Joe Fiddler	121	14.5	4019	4020	40625D0057	
CL	Lake	97Jul04	Oldman's Island	IF Kelvin McKay	111	11.8	4024	4025	406301101B	
CL	Lake	97Jul04	Oldman's Island	IF Kelvin McKay	110	11.3	4021	4022	40626E4331	
CL	Lake	97Jul04	Oldman's Island	IF Kelvin McKay	86	3.9	2837	2838	...	Recapture. Died before release.
CL	Lake	97Jul04	Oldman's Island	IF Kelvin McKay	101	12.7	4049	4023	406276055D	

Table G1 cont'd.

CL	Oldman's Island	97Jul08	IF	Joe Fiddler	100	8.6	4034	4035	40627B3E3E	
CL	Oldman's Island	97Jul08	IF	Joe Fiddler	121	11.8	4036	4037	406261054E	
CL	Oldman's Island	97Jul08	IF	Joe Fiddler	99	8.2	4040	4041	406302540B	
CL	Oldman's Island	97Jul08	IF	Joe Fiddler	...	14.1	?	?	4062607D18	Recapture.
CL	Oldman's Island	97Jul08	IF	Kevin Nabess	109	10.0	4038	4039	4062604717	
CL	Oldman's Island	97Jul08	IF	Kevin Nabess	129	14.5	4045	4046	4062604523	
CL	Oldman's Island	97Jul08	IF	Kevin Nabess	121	12.2	2432	2431	406303107C	Recapture.
CL	Oldman's Island	97Jul08	IF	Kevin Nabess	127	17.2	2673	2699	40626E1E49	
CL	Oldman's Island	97Jul11	IF	Joe Fiddler	102	10.0	2661	2647	40625C6423	
CL	Oldman's Island	97Jul11	IF	Joe Fiddler	123	19.0	2663	2643	40627E6C15	
CL	Oldman's Island	97Jul11	IF	Joe Fiddler	116	12.2	2645	2679	40625C2B11	
CL	Oldman's Island	97Jul14	IF	Joseph Budd	98	6.3	4101	4102	4062703E1A	
CL	Oldman's Island	97Jul14	IF	Joseph Budd	114	12.7	2746	2747	410A74132A	Recapture.
CL	Oldman's Island	97Jul14	IF	Joseph Budd	143	33.1	4047	4100	40627E6049	
CL	Oldman's Island	97Jul14	IF	Kelvin McKay	118	12.2	2632	2683	40625D7267	
CL	Oldman's Island	97Jul14	IF	Kelvin McKay	133	20.0	4043	4042	406278443B	
MOR	below Windy	97Jul25	IF	Kevin Nabess	144	24.9	4138	4139	40627B1B04	
MOR	below Windy	97Jul25	IF	Kevin Nabess	105	8.2	4140	4141	4062787B0D	
MOR	below Windy	97Jul25	IF	Kevin Nabess	104	7.3	2491	4133	4062661F3D	Recapture.
MOR	below Windy	97Jul25	IF	Kevin Nabess	116	16.8	4145	4146	...	
MOR	below Windy	97Jul25	IF	Kevin Nabess	84	3.6	4136	4137	406267655F	
MOR	below Windy	97Jul25	IF	Kevin Nabess	123	15.9	4125	none	406263571A	
MOR	below Windy	97Jul25	IF	Kevin Nabess	101	7.5	2787	2788	40627F0C7B	Recapture.
MOR	below Windy	97Jul25	IF	Kevin Nabess	77	3.4	4122	4123	40625A202B	
MOR	below Windy	97Jul25	IF	Kevin Nabess	107	8.6	2782	4120	4062553249	Recapture. 3rd tag 4121.
MOR	below Windy	97Jul25	IF	Kevin Nabess	124	15.9	4143	4144	40625A4346	

Table G1 cont'd.

SR	near Tearing	97Jun23	Tearing outflow	IF	Philip Crane	116	14.1	3215	3216	4062711A17	
SR	near Tearing	97Jun27	Tearing outflow	IF	Glen McKenzie	100	14.1	3225	3226	4063005466	
SR	near Tearing	97Jun27	Tearing outflow	IF	Glen McKenzie	112	11.3	3233	3234	4062681a38	
SR	near Tearing	97Jun27	Dorion's Island	IF	Kennedy Dorion	138	21.3	3223	3224	406300484E	
SR	near Tearing	97Jun27	Dorion's Island	IF	Kennedy Dorion	144	24.0	3221	3222	40626C357C	
SR	near Tearing	97Jun27	Dorion's Island	IF	Kennedy Dorion	110	7.7	2904	2905	40625D1C75	Recapture.
SR	near Tearing	97Jun27	Tearing outflow	IF	Philip Crane	104	9.1	3231	3232	40626C4807	
SR	below Tearing	97Jun27	Tearing outflow	IF	Philip Crane	130	16.3	3227	3228	4062672B4E	
SR	below Tearing	97Jun27	Tearing outflow	IF	Philip Crane	121	14.1	3229	3230	40627D4D46	
SR	near Tearing	97Jul04	Tearing outflow	IF	Philip Crane	120	12.2	4026	4027	4062647E03	
SR	near Tearing	97Jul04	Tearing outflow	IF	Philip Crane	105	9.1	4033	4031	4062625D7C	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	63	2.7	4104	4105	406263552E	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	96	6.8	4114	4115	4062640475	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	91	5.9	4108	4109	4062646853	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	87	5.0	4110	4111	4062732000	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	85	4.5	4106	4107	4062676648	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	80	4.1	4112	4113	406269543D	
SR	Bigstone Rapids	97Jul22	Ferry Crossing	IF	Glen McKenzie	90	5.0	4131	4132	4062646F5E	
TER	near Tearing	97Jul25	Tearing outflow	IF	Philip Crane	94	6.3	4129	4130	4062715E74	

Table G2. Record of sturgeon with PIT tags applied during index fishing, Manitoba, June 9 - 27, 1996.

Tag #	Total Length (cm)	Total Weight (kg)	Mesh (inches)	Capture Location
1F4A3D4416	87	3.4[a]	10	n/a
1F47604377	115.5	8.5[a]	10	n/a
1F4F7F7F14	125.7	11.2[a]	10	n/a
1F48413028	87	3.3	8	Barrier Lake
1F4A370C54	90	4.5	5.5	Barrier Lake
1F4A315511	86	2.85	5.5	Barrier Lake
1F4A082867	70	1.83	5.5	Barrier Lake
1F5006107B	122	9.4	12	Barrier Lake
1F4A0D5E2C	94	4.65	10	Barrier Lake
1F483F4812	96	4.8	10	Barrier Lake
1F4A37637D	99	6.1	10	Barrier Lake
1F477B405F	99	6.0	10	Barrier Lake
1F4A335212	98	5.3	10	Elbow Lake
1F4A5A6855	84	3.2	8	Elbow Lake
1F5002040B	106	6.7	8	Elbow lake
1F5003335B	92	4.5	8	Elbow Lake
1F4A295519	94	5.4	n/a	Elbow Lake
1F4A135F25	102	6.1	n/a	Elbow Lake
1F4A06070A	90	4.5	n/a	Elbow Lake
1F4765486D	84	3.36	n/a	Elbow Lake
1f50027D12	102	5.75	8	Elbow Lake
1F4A2D7A70	112	8.3	8	Elbow Lake
1F482B3935	116	9.3	8	Elbow Lake
1F47620038	134	12.2	10	Elbow Lake
1F477A217F	96	4.1	8	Elbow Lake
1F50071773	99	5.1	8	Elbow Lake

[a] Estimated from length (see Royer et al. 1968).

Table G3. Record of sturgeon with PIT tags applied during index fishing, Manitoba, June 1 - 15, 1997.

PIT tag #	Total Length (mm)	Total Weight (kg)	Inter Orbit (mm)	Mesh (inch)	Capture Location
1F4A12067F	1224	9.8	...	10	Hill Island
1F4A501433	1040	6.9	79	8	Hill Island
1F4A191266	1040	5.9	68	8	Pine Bluff
1F5001632D	910	3.4	55	10	Big Eddy
1F4A162160	1150	6.8	70	10	Barrier Lake
1F47594F72	1380	16.5	90	10	Barrier Lake
1F4A374F11	900	3.7	54	10	Barrier Lake
1F4A026F26	1250	5.8	65	10	Barrier Lake
1F4A2F0464	1320	14.8	85	10	Barrier Lake
1F4A20581F	1040	6.5	66	10	Barrier Lake
1F4A5A3211	890	3.8	55	5.5	Barrier Lake
1F4A030014	1640	26.7[a]	110	10	Barrier Lake
1F4A55251D	1300	14.3	87	10	Barrier Lake
1F4A142E5S	1140	10	80	10	Barrier Lake
1F4A47557B	1120	6.2	70	10	Barrier Lake
1F4A567849	890	3.6	...	5.5	Big Eddy
1F477B554A	1000	4.5	...	8	Big Eddy
1F4A2F2345	785	2.4	...	5.5	Big Eddy
1F47640B2B	680	2.3	...	5.5	Big Eddy
1F4A213541	1380	15.2[a]	...	5.5	Barrier Lake
1F4B22165E	1260	11.8	...	n/a	Barrier Lake
1F4A107A0D	770	2.3	...	10	Barrier Lake
1F4A104443	820	2.7	...	n/a	Barrier Lake
1F4842B29?	800	2.3	...	n/a	Barrier Lake
1F476F1516	1200	7.3	...	n/a	Elbow Lake

cont'd

Table G3 cont'd

1F50084049	1235	14.5	93	10	Elbow Lake
1F4B206C0A	1030	4.5	87	n/a	Elbow Lake
1F4A1F0474	1075	15.9	83	n/a	Elbow Lake
1F475A5070	1415	20	103	n/a	Elbow Lake
1F4A38005F	755	1.9	48	n/a	Big Eddy
1F4C262E41	765	1.9	45	n/a	Big Eddy
1F4843292D	855	3.6	59	n/a	Big Eddy
1F476D7A33	800	2.8	58	n/a	Big Eddy
1F4A0C216A	1210	11.9	75	n/a	Elbow Lake
1F48500445	1070	6.5	69	n/a	Elbow Lake
1F475C4E70	970	4.6	64	n/a	Big Eddy
1F48511A2E	780	2.3	47	5.5	Barrier Lake
1F497F3FSA	695	2.1	49	5.5	Barrier Lake
1F48411B3D	1010	5.5	69	10	Barrier Lake
1F4A4F1A2E	1130	8.3	75	10	Barrier Lake

[a] Estimated from length (see Royer et al. 1968).