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A study of the River Redhorse, *Moxostoma carinatum* (Pisces; Catostomidae), in the tributaries of the Ottawa River, near Canada's National Capital and in a tributary of Lake Ontario, the Grand River, near Cayuga, Ontario.

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A study of the River Redhorse, *Moxostoma carinatum* (Pisces; Catostomidae), in the tributaries of the Ottawa River, near Canada's National Capital and in a tributary of Lake Ontario, the Grand River, near Cayuga, Ontario.

Étude du Chevalier des rivières, *Moxostoma carinatum* (Pisces; Catostomidae), dans les tributaires de la rivière des Outaouais, dans la région de la capitale nationale du Canada est une tributaire de lac Ontario, la rivière Grand, Cayuga, Ontario.

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Abstract

This study provides baseline data on the River Redhorse (*Moxostoma carinatum*; Moxostomatini: Catostomidae) in Canada. Sampling focussed on the Mississippi and Gatineau Rivers, in the National Capital Region, in 1998 and 1999. Spawning occurred in rocky, shallow (<2m) fast-water sections in May and June when the temperature reached 17 °C . In the Mississippi River, post-spawn specimens were captured on a variety of substrates in deeper waters. Both opercular bones and scales (n=19) recorded accurate age until age XII after which only the opercular bone provided clear annuli. Growth for both sexes was defined by the following equation: total length at age (mm) = $0.0905\ (\text{age})^3 - 5.1452\ (\text{age})^2 + 95.94\ (\text{age}) + 0.367$. Population sizes were assessed through capture-recapture methods. The population size in the Mississippi River was estimated at 622 (+- 6.3 s.d.). The spawning population of the Gatineau River was estimated at 1216 (+- 915 s.d.). It is suggested that the species remains a species of "special concern" in Canada.

L'objectif de cette étude vise à mieux connaître la biologie du chevalier des rivières (*Moxostoma carinatum*; Moxostomatini: Catostomidae) au Canada. L'échantillonnage a été fait dans la région la Capitale Nationale (rivières Mississippi et Gatineau) en 1998 et 1999. La fraye a eu lieu dans un secteur rocailleux en eau vive (< 2 m) en mai et juin lorsque la température de l'eau a atteint 17 °C. Dans le Rivière Mississippi, hors de la période de fraye, les individus ont été capturés sur divers types de substrat. L'os operculaire et les écailles ont permis d'établir l'âge d'individus de moins de 12 ans. Pour les individus plus vieux, seul l'opercule permettait d'observer des annuli distincts. La courbe de croissance peut être déterminée par l'équation suivante: longueur totale (mm) = $0.0905\ (\text{âge})^3 - 5.1452\ (\text{âge})^2 + 95.94\ (\text{âge}) + 0.367$. La taille des populations a été déterminée par la méthode des captures-recaptures. La population de la Rivière Mississippi a été estimée à 622 (+- 6.3 s.d.) alors que la population reproductrice de la Rivière Gatineau a été estimée à 1216 (+- 915 s.d.). Cette espèce doit demeurer une "espèce préoccupante" au Canada

Tables and Authorities

1.0 Introduction

Moxostoma carinatum (the River Redhorse) (Figure 1) is sparsely but widely distributed in eastern North America (Scott and Crossman, 1973). It has been captured in the United States throughout the Mississippi River drainage basin, from the tip of Lake Michigan to the Gulf Coast in Louisiana. In Canada, prior to 1997, only three breeding populations were known. Two were found in Quebec (Richelieu and Yamaska Rivers) and the third one was found in Ontario (Mississippi R.) (Scott and Crossman, 1973; Mongeau 1979 a and 1979 b; Fortin *et al.*, 1988; Parker, 1988; Dumont *et al.*, 1997). The latter population is located in an isolated 36-km stretch between Almonte and Galetta, Lanarck County, Ontario (Parker and McKee, 1984). More recently, a large breeding population was discovered (this study) in the Gatineau R. (Quebec) and a few individuals were captured in a some Ontario rivers. More specifically, isolated captures were made in the Ottawa River (McAllister and Coad, 1974; Haxton 1998b; present study), in the Madawaska River, near Arnprior (Erling Holm ROM pers comm; present study), in the Trent River (Beak Consultants, Sunoco EEM study phase 1, 1995; Erling Holm ROM pers comm; Dr. Robert E. Jenkins, Roanoke College, Virginia, pers. comm.) and in the Grand River, Cayuga, Ontario (present study)(Figure 2).

Parker and McKee (1984) surveyed the population of *M. carinatum* in the Mississippi River. Their research, mandated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), was aimed at providing a status report for this species in Canada. To do so, Parker and McKee (1984) captured some *M. carinatum* specimens but relied mainly on observations made on southern U.S. populations (mainly from Trautman, 1957; Hackney *et al.*, 1967; and Carlander, 1969) to predict the life history of this species in Canada. On the basis of

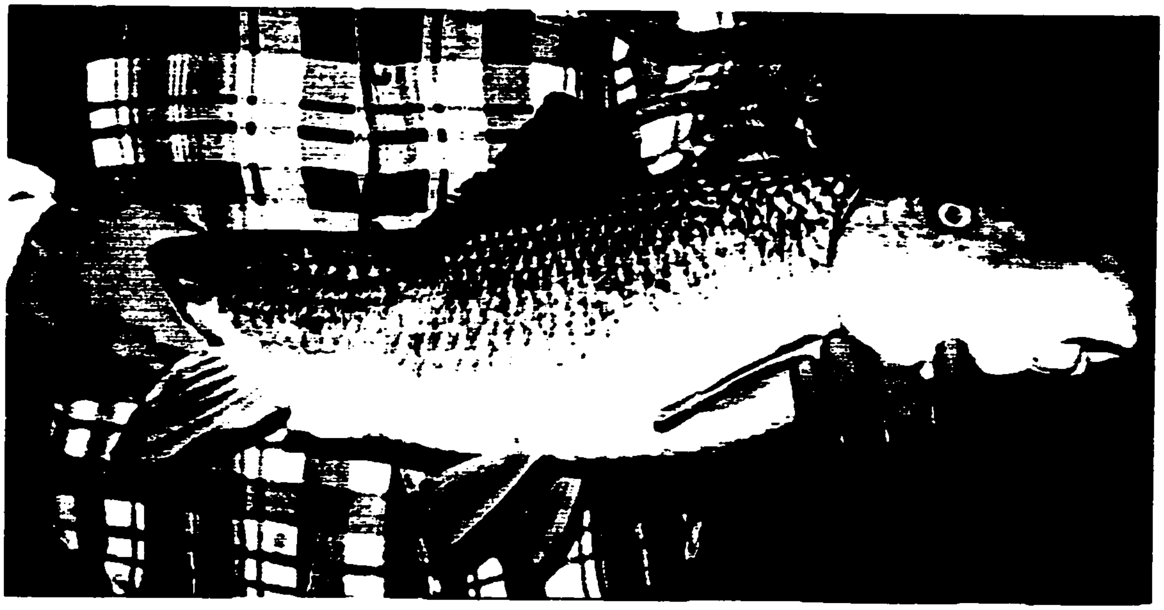


Figure 1. Large stage IV female *Moxostoma carinatum,* (710 mm, TL) captured by electrofishing in the Gatineau River just downstream of the Alonzo Wright Bridge, May 1999.

Figure 2. Known breeding Canadian populations of *Moxostoma carinatum* (▲) prior to 1997 and additional populations of *M. carinatum* (•) on record as of 2000. Map was altered from a free clipart of Corel Draw 8, Corel Corporation, Ottawa, Ontario, Canada.

Parker and McKee's status report, COSEWIC listed the River Redhorse as a "vulnerable" species (this category was later renamed "special concern" in 1999 by COSEWIC) (Parker 1987; Campbell 1998). A special concern species refers to "any indigenous species of fauna or flora, that, because of its biological characteristics, or because it occurs at the fringe of its range, or for some other reason, exists in low numbers, or in very restricted areas in Canada, but is not a threatened species". In the United States, this species is listed as endangered in Kansas and Ohio, threatened in Florida, and extirpated from several states including Arkansas, Iowa, Illinois, Indiana, Michigan and Pennsylvania (Trautman, 1957; Ohio Department of Natural Resources, 1976; Platt, 1974; Gilbert, 1978; Jenkins, 1980).

In 1997, the Ministry of Natural Resources of Ontario mandated a study of the biology of *M. carinatum* in the Mississippi R. It was felt that the population was under great anthropogenic stress from agricultural activities and urbanization and in need of a precise assessment of its current state.

In addition, the fortuitous discovery of a large breeding population at the foot of the rapids near the Alonzo Wright bridge in the Gatineau R. in 1998 offered an unique opportunity to collaborate with Faune et Parcs Québec on a sampling program aimed at increasing the knowledge of the biology of this species in the National Capital Region.

Finally, a participation into the sampling efforts of scientists from the Royal Ontario Museum and the Ontario Ministry of Natural Resources allowed for several investigatory samples to be taken across Ontario to provide additional information on the range and biology of this species.

During the survey of *M. carinatum* in the Gatineau and Mississippi R., additional information on the fish community of these rivers was also collected.

More specifically, this study has the following objectives:

1. To provide general information on the fish community and the habitat in which River Redhorse live and spawn in the Mississippi and Gatineau rivers.
2. To provide, when available, data on age, mass, length, fecundity and the general health of this species in the sampled rivers.
3. To provide an estimate of the abundance of *M. carinatum* in the Mississippi R. and of the size of the breeding population of *M. carinatum* in the Gatineau R.

2.0 Background studies and species identification

Moxostoma carinatum (*Moxostoma*- sucking mouth, *carinatum*- keeled) was originally described by Cope 1870, as *Placopharynx carinatus.* Scott (1954) and Jenkins (1970) placed this species in the genus *Moxostoma* and modified the species name to *carinatum* (Scott and Crossman, 1973). This genus belongs to the tribe Moxostomatini (Jenkins 1970).

Due to the low economic value of this species (Scott and Crossman, 1973), few studies have dealt with the biology of *M. carinatum* (Figure 1) in Canada. Several studies have dealt with its classification (Scott, 1954; Brown, 1984; Jenkins, 1970) and its geographic distribution (Hackney *et al.*, 1967; Jenkins, 1970,1980; McAllister and Coad, 1974; Mongeau, 1977a, 1977b; Parker and McKee, 1980, 1984; McAllister *et al.* 1985; Parker, 1988) but few have dealt with its ecology. In fact, only Mongeau *et al.*, (1992), studied a small population of *M. carinatum* in the Richelieu River, Quebec, and provided data on the species age (obtained from fin rays and scales), sexual maturity, length and mass. McAllister *et al.* (1985) and Carlander (1969) used scales to define the age of a few *M. carinatum* specimens.

Scott and Crossman (1973) offered a detailed morphological and morphometric description of the species. The body is olive and the fins, when coloured, range from bright orange (young specimens) to deep red (older breeding specimens). Males are differentiated by the presence of nuptial tubercles on the head, cheek, anal and caudal fins (Jenkins, 1970, Scott and Crossman 1973)(Figure 3). Females can have tuberculation on the anal fin but only in larger specimens (Scott and Crossman, 1973). We observed that tubercles are shed shortly after spawning in June (Parker and McKee, 1984) and began to re-appear in September - October. During the summer, tubercle scars can be seen on the males as black dots on the fins and head. Hackney *et al.*, (1967), Carlander (1969), Scott and Crossman (1973) and Parker and McKee (1980) suggested that breeding groups were found in the fast waters of large rivers and tributaries in the spring (May to June) when water temperatures reach 20-22°C. As an indication of spawning, Hackney *et al.*, (1967) and Parker and McKee (1988) suggested to look for the presence of shallow depression (or redds) on the river bed. These redds should be 1-2 m in diameter and should be a few cm deep, in fast moving, shallow water (<1 m), with clean rocky bottoms.

Despite its large size, *M. carinatum* can easily be misidentified. In fact, there are four known *Moxostoma spp.* found in the Ottawa River watershed: *M. anisurum* (Silver Redhorse), *M. carinatum* (River Redhorse), *M. macrolepidotum* (Shorthead Redhorse) and *M. valenciennesi* (Greater Redhorse)(Figure 4). These four species share several diagnostic features: large scales, subterminal mouth, complete lateral lines (38-48 scales), single dorsal fin (11- 17 rays), lack of buccal teeth, presence of modified pharyngeal teeth and red or grey tinted fins. An identification key is provided in Figure 5. They can be distinguished from each other by: fin colour, number of fin rays, caudal peduncle scale counts, relative eye position and lip morphology (Jenkins, 1970;

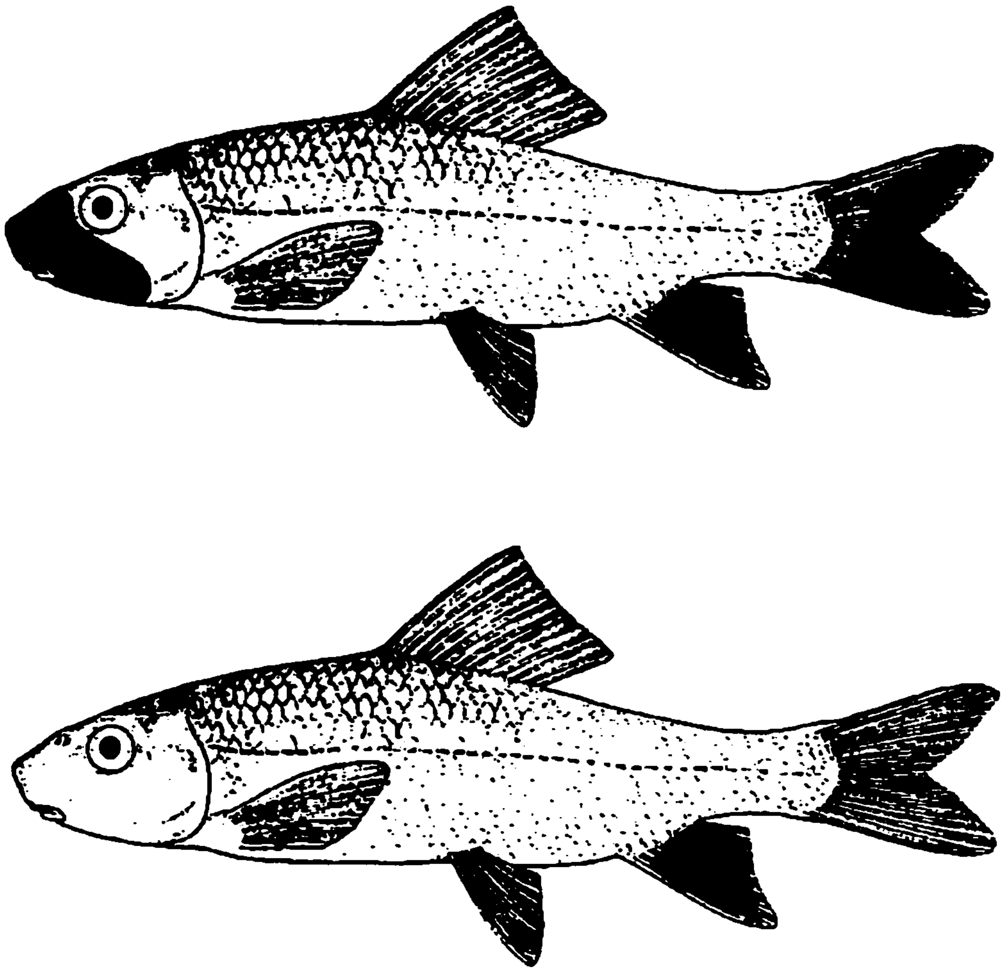


Figure 3. Line drawing of *M. carinatum*, adapted from Parker and McKee, (1984), to illustrate the position of tuberculation (shaded areas) of males (top) and females (bottom). Tuberculation was most noticeable between May and June. New tuberculation appeared in October.

M. carinatum **M. valenciennesi**

M. macrolepidotum **M. anisurum**

Figure 4. *Moxostoma* species found in the Ottawa River Watershed (clockwise from the top left): *M. carinatum*, *M. valenciennesi*, *M. anisurum*, and *M. macrolepidotum*. Pictures adapted from *Guide des poissons d'eau douce du Québec* (Bernatchez and Giroux, 1996).

Family Catostomidae: Fishes have a ventral subterminal mouth (not in *Ictiobus*). No teeth in mouth but a large single set of pharyngeal teeth are present. Fishes are small to large with cylindrical to laterally compressed bodies. Fishes lack a second dorsal and have no adipose fin. Fishes have a physotomous swim bladder with two or three chambers.

1. Lateral line scales small and more than 50................................ ***Catostomus commersoni***

   Lateral line scales large and less than 50 2

2. All fins without any red pigment, grey in colour.............................***Moxostoma anisurum***

   All fins with some red pigment...3

3. Caudal peduncle scales sixteen or greater, mouth located directly below snout, snout length greater than post orbital length................***Moxostoma valenciennesi***

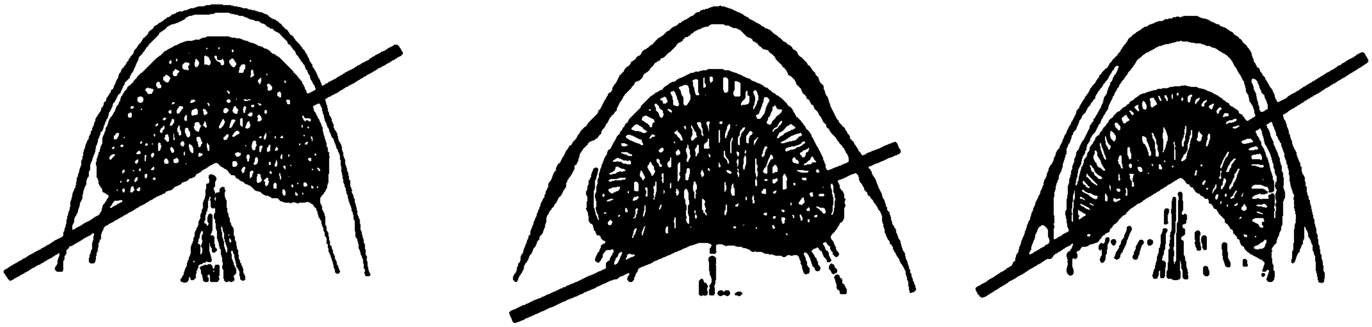
   Caudal peduncle scales less than 16, mouth located behind rostrum, snout length equal to post orbital length 4

4. Mouth large with a thick lower lip lacking transverse plicae, snout round and following curvature of the upper lip, extended dorsal fin flat, slightly curved in juveniles ....***Moxostoma carinatum***

   Mouth small not reaching width of head, lower lip thick with transverse plicae beginning on the posterior half of lower lip, snout pointy not following the curvature of the upper lip, dorsal fin with a strong "s" curve when extended...***Moxostoma macrolepidotum***

Figure 5. Identification key of the four species of *Moxostoma* and one *Catostomus* found in the Ottawa River watershed. Modified from Scott and Crossman (1973).

Scott and Crossman, 1973) (Figure 6).



Catostomus commersoni *Moxostoma macrolepidotum* *Moxostoma anisurum*

Moxostoma carinatum *Moxostoma valenciennesi*

Figure 6. Line drawings adapted from Scott and Crossman (1973) of four *Moxostoma spp.* and one *Catostomus spp.*. Solid lines indicate the slope of the lower lip. Other diagnostic features are the relative position of the mouth under the snout, the size of the upper and lower lips relative to each other and the striation, shape and orientation of lip plicae.

3.0 Methods

3.1 Study Sites

3.1.1 Mississippi River

All collections were made under the licence to collect fish for scientific purposes from the Ontario Ministry of Natural Resources (OMNR) numbers A 3041 (1998) and A 3089 (1999). These permits allowed for the capture of *M. carinatum* and the retention of 5 specimens.

The Mississippi River is a brown water river with a gradient of 1.5m/km of river in Eastern Ontario, that discharges into the Ottawa River (Ontario Ministry of the Environment, 1977). The flow ranges from 142 m^3/s in the spring to 14.2 m^3/s in the late summer (Ontario Ministry of the Environment, 1977). The river flows primarily on a limestone granite base, covered with a thin layer of detritus (1-2 cm) in the slower areas. Due to the high flow rates, the oxygen concentration rarely dropped below 3 mg/l and ranged from 7-11 mg/l (Ontario Ministry of the Environment, 1977; Parker and McKee 1984). Mean Secchi depth for the summer was 2.46 m (n=124, sd= 0.70 m). Sampling was done on a 36 km stretch of the Mississippi River delimited by two power dams, one at Almonte (Figure 7) and one at Galetta (Figure 8). Within the studied stretch, the presence of rapids and falls was used to define five sections: Almonte-Blakeney (4 km); Blakeney to Cedar Hill (5 km); Cedar Hill to Pakenham (10 km)(Figure 7); Pakenham to Highway 17 (10km) and Highway 17 to Galetta (7 km)(Figure 8).

3.1.1.1 Almonte to Blakeney (Figure 7)

This upstream section began at the foot of the hydroelectric facility in Almonte and extended northwards for 4 km (45°13'26N, 076°12"59 W to 45°15"40 N, 076°13'00 W) and was

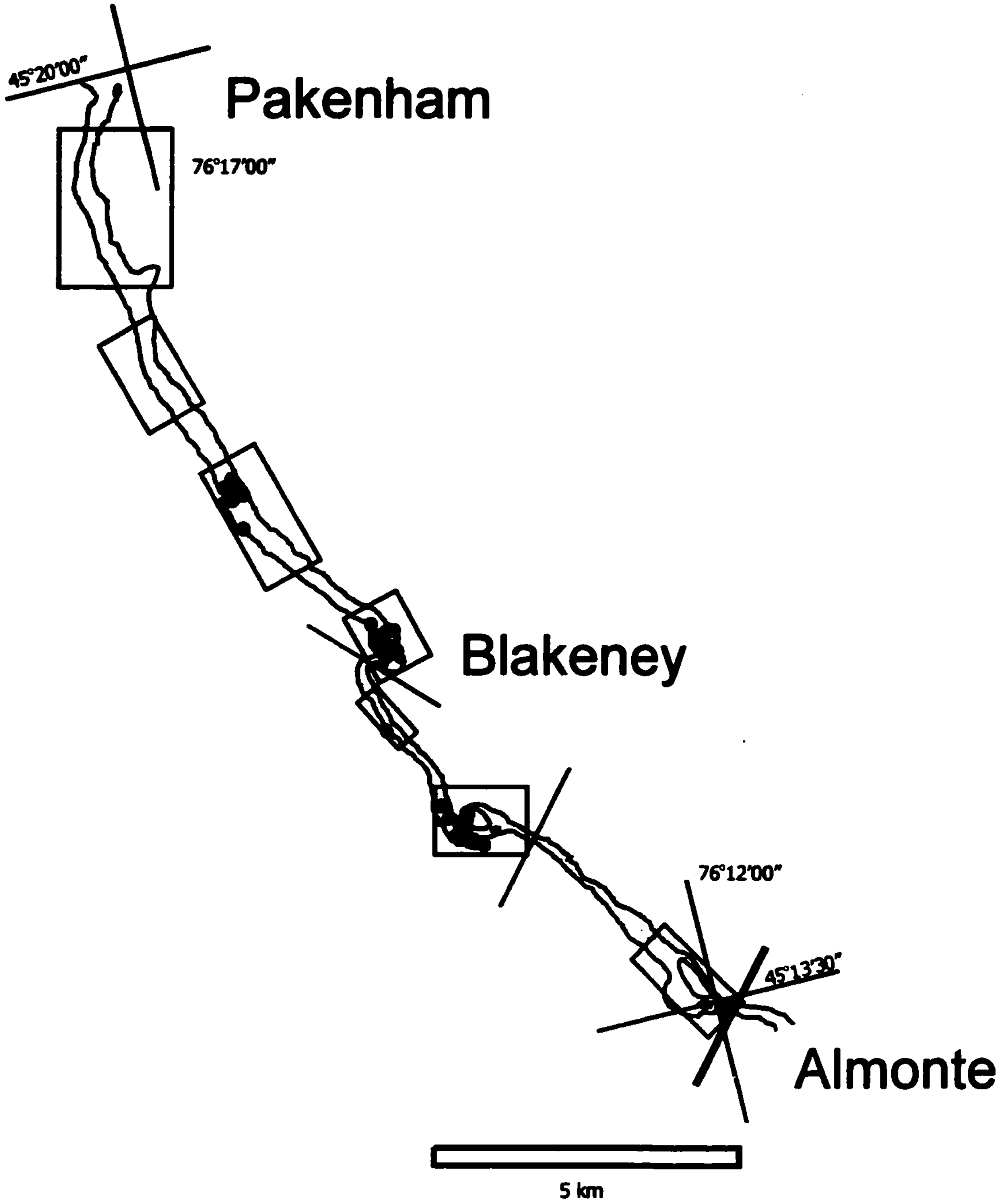


Figure 7. Map of the Mississippi River from Almonte to Pakenham. Solid lines indicate the limits of each section. Open boxes indicate net(s) location. Capture sites of *M. carinatum* are indicated by a closed circle (•).

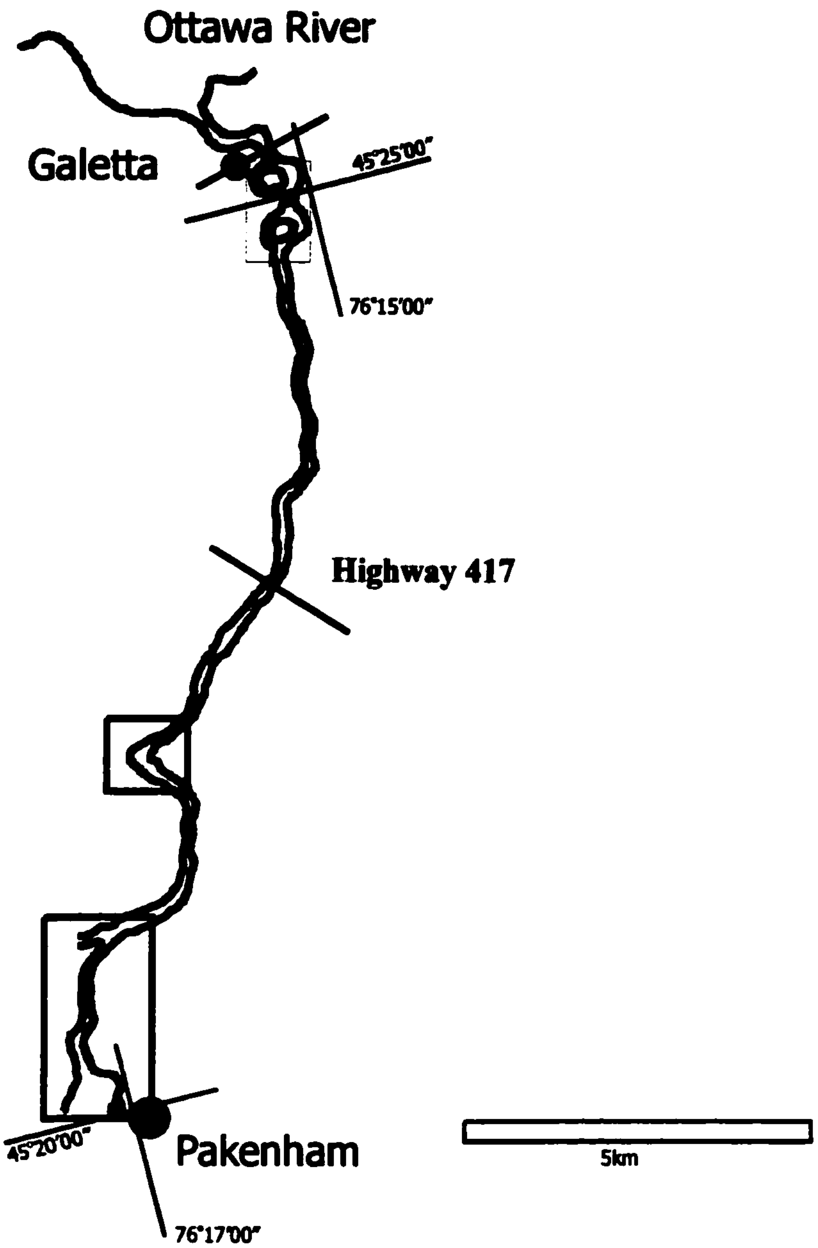


Figure 8. Map of the Mississippi River from Pakenham to Galetta. Solid lines indicate the end of a reach. Open boxes indicate net(s) location. Capture sites of *M. carinatum* are indicated by a closed circle (•).

sampled in May and June, 1998, when access to the river several sectors of fast flowing water were found immediately downstream from the dam. Shoreline sediments downstream from farms were often black and had a pungent smell. In the downstream sector, banks sloped at almost 90° from shore to the main channel to depths of 6 to 8 m (max. depth of 10 m). The shoreline vegetation was composed mainly of *Pinus spp.* and *Thuja spp.*. A set of four small rapids marks the end of the reach. Water depth over the rapids varied during sampling and was dependent on the outflow from the hydro dam in Almonte. The section with rapids was too shallow and water flowed too fast for the efficient use of our gear. During the last week in June and the first weeks of July, 1998, this section was not sampled because of repair work to the city's sewer system.

3.1.1.2 Blakeney to Cedar Hill (Figure 7)

This section (5 km, 45°15"40N, 076°13'00W to 45°16"08N, 076°14"57W) had an undisturbed shoreline except for three farms and five cottages. The maximum river width was 100 m. It was sampled from May until July and once in October, 1998. At the beginning of the reach, the river was 1-2 metres in depth and the bottom consisted of rocks (7 to 15 cm in diameter), sand, and wood debris; the remainder of the reach was usually deeper than 5 m. The bottom was made of silt and sand (often foul smelling) covered with submerging plants as of July. Sectors of fast water had bottoms made of flat shale and large rocks. The banks of the river were heavily vegetated with *Typha spp.*. The littoral zone had a width of 1 to 4 m with an average depth of less than 1 m in the spring. The shoreline was heavily forested, with *Pinus spp.* and *Thuja spp.* being the dominant species. Access to the river was not possible in July due to low waters at the boat launching facility.

3.1.1.3 Cedar Hill to Pakenham (Figure 7)

Except for the presence of a few cottages and a trailer park, most of this stretch (10 km, 45°16"08N, 076°14"57W to 45°17"22N, 076°19"47W) was bordered by *Pinus spp.* and *Thuja spp.* with a littoral zone vegetation consisting of *Typha spp.* extending 3 m from the shoreline. This section was sampled from May 1999 until July 1999 and once in October 1999. The last 1 km was heavily impacted by human activities (a trailer park and several houses near the shore of the river). Maximum water depth was greater than 6 m in the spring (May - June) throughout the reach. Detritus covered the riverbed in 90 % of the reach. The main channel meandered through this run and ranged from over 50 m at its widest to less than 3 m in its narrowest sections. Near Pakenham, the river was 10 m wide with a depth less than 1.5 m and its bottom was made of flat limestone and wood debris.

3.1.1.4 Pakenham to Highway 17 (Figure 8)

The section (10 km, 45°17"22N, 076°19"47W to 45°15"32N, 076°14"57W) from Pakenham to the Highway 17 flows through both urbanized and agriculturalized lands. It was sampled from May 1999 until July 1999. A small waterfall (1 m high) marked the beginning of this section. The riverbed was primarily composed of large boulders and wood debris at the beginning of the reach. Water clarity was much lower throughout the reach (Secchi < 1.0 m) than in all other reaches. The shoreline of this reach was heavily eroded and cattle were frequently observed wading in the river. The few-forested stretches along the eastern shore were primarily made of *Thuja spp.*, and there were numerous wetlands along the last 2 km of this section. Water velocity was slower than at all other upstream sites. The average depth was greater than 6 m in the middle of the channel. As of 1997, the Pakenham public boat launch was closed permanently. Access was only possible from April 1999 until the last week of June 1999 at the overpass of Highway 17. As the summer progressed water levels decreased markedly and prevented safe launching of the boat.

3.1.1.5 **Highway 17 to Galetta** (Figure 8)

Agricultural lands bordered this section (7 km, 45°15"32N, 076°14"57W - 45°25"35N, 076°15"20W) with very little forest remaining along either bank. It was sampled only in May, 1998. The water had low clarity (Secchi < 2.0 m) and the average depth was over 10 m. Only within the last 1 km did water clarity increase (Secchi < 3.0 m). The increase in Secchi depth was also met with a change in bottom composition, from silt and organic debris to mainly of rocks (7 to 15 cm in diameter) and boulders (> 15 cm in diameter). Due to the vandalization of the gear on two occasions early in the spring, this area was not sampled during the summer for safety concerns.

3.1.2 **Ottawa River** (45°27"30N, 076°21"00W)(Figure 9)

During the summer of 1997, a large section (33 km) of the Ottawa River between Fitzroy Harbour and Chenaux / Portage du Fort was sampled for fish as part of the OMNR Near Shore

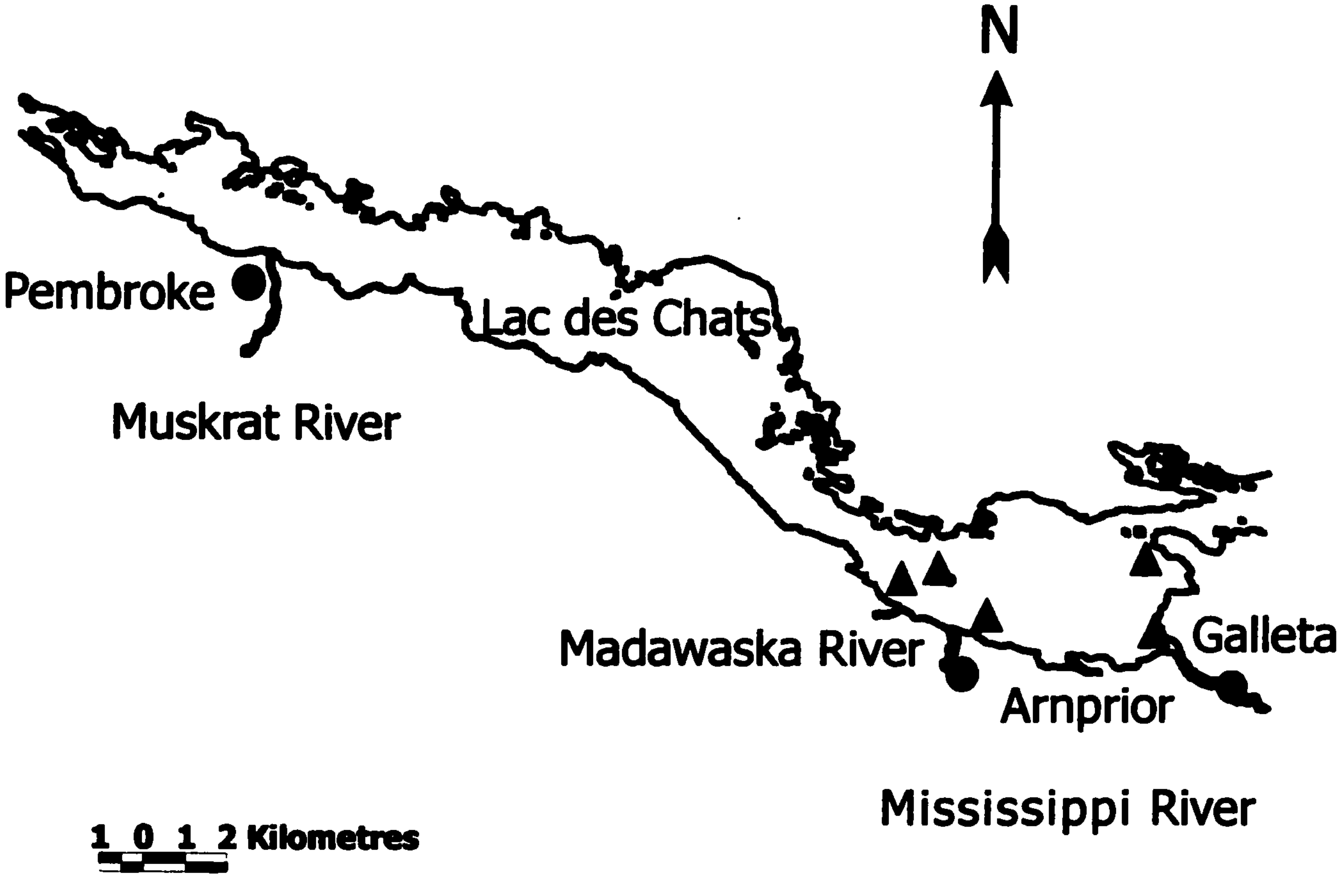


Figure 9. Ottawa River sampling sites. Capture sites of *M. carinatum* are indicated by (▲). Also indicated are the Madawaska, Muskrat and Mississippi Rivers and their confluence to the Ottawa River, adapted with permission from Haxton (1999).

Community Index Netting (NSCIN) (Haxton, 1998a). Participation in this project was aimed specifically at documenting and collecting additional information on *M. carinatum*. Water depth in this section of the river was controlled by Ontario Hydro and averaged approximately 10 metres during the spring (Haxton 1998a) with a maximum depth of 30 metres. Three rivers, the Mississippi, Madawaska and Muskrat are tributaries of this section of the Ottawa River. These three rivers have dams or impediments that prevent large scale movements of fish into and out of the Ottawa River.

Over a two-week period from August 24 to September 3, 1998, 40 nets were placed at one of 80 predetermined locations selected by a random number removal method (Haxton, 1998). All sites were 1 km apart and were never resampled. Nets were set perpendicular to shore, and were cleared of fish after 24 hrs and placed in a new location.

3.1.3 Madawaska River (Figure 9)

This section of river (45°26"00N, 076°23"30W - 45°25"35N, 076°23"W) was sampled once in April 1998 and once in April 1999 by the OMNR. Participation was aimed specifically at documenting and collecting information on *M. carinatum* in the Madawaska River. The sampling was done in the Madawaska River, 1 km from the confluence with the Ottawa River in the town of Arnprior in a pool at the base of a 3 m high weir. The water was brownish coloured and its depth was regulated by Ontario Hydro. During the spring, the water had a peak flow between 19:00 and 24:00 as an attempt to increase *Sander vitreum* (walleye) spawning success (Tim Haxton, Ontario Ministry of Natural Resources, Pembroke District, pers. comm.). Water depth throughout the pool varied between 0.5 m to >3m. The bottom was made of irregular jagged boulders with some visible epiphytic algae covering the rocks. There was a parking lot and nursing home adjacent to the sampling area. The channel from the Ottawa River has a private marina, a public marina, a sewage treatment facility, a small conservation area as well as the headquarters of the Arnprior Fish and Game Club. In both 1998 and 1999, sampling consisted of several random passes around the pool, using a Smith Root 16 R Electrofishing Boat, between 19:00 and 01:00. All captured specimens were removed from the boat and placed into a Nalgene® holding pen, weighed, measured, tagged and released.

3.1.4 **Muskrat River** (Figure 9)

This was the northernmost tributary of the Ottawa River sampled (April, 1998) during this study. Participation in this project was aimed specifically at documenting and collecting information on *M. carinatum* in the Muskrat River. Sampling was conducted in the city of Pembroke, at the outflow of the river near confluence with the Ottawa River. The sampled reach was approximately 20-30 m in width with an average depth of 3 m. The bottom was made of loose sediments (silt, sand and mud) with scattered large woody debris. The west bank was comprised of granite boulders and stone while the east bank was primarily forested. About 100 m from the confluence with the Ottawa River, both shores were lined with concrete walls, and a bridge overpassed the sampling area.

Sampling consisted of several random passes using a Smith Root 16 R Electrofishing Boat, between 19:00 and 01:00. All captured specimens were removed from the boat and placed into a Nalgene® holding pen, weighed, measured, tagged and released.

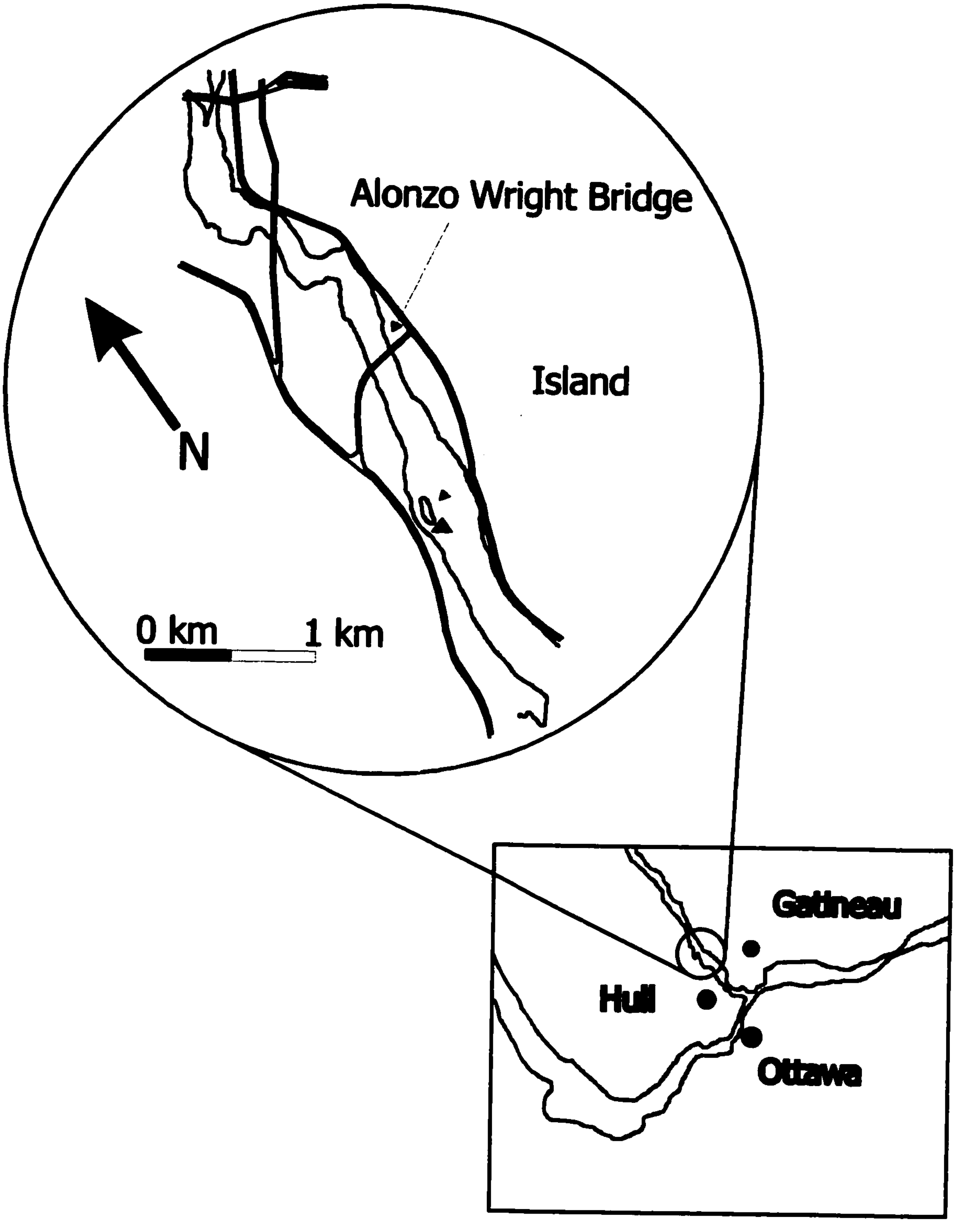


Figure 10. The Gatineau River near the Alonzo-Wright Bridge, 5 km from the confluence of the Ottawa and Gatineau rivers. (▴) indicates the capture site of the only juvenile of this study.

3.1.5 Gatineau River (45°28"N, 075°44"W) (Figure 10).

The sampled section of the Gatineau River (Quebec) is located immediately downstream from the Alonzo-Wright Bridge (Gatineau), 5.1 km upstream of its confluence with the Ottawa River. Water depth varied from 0.5 m to 5 m and was regulated via the hydro electric dam upstream from the rapids (Farmer's Point Facility). Maximum Secchi depth was 0-1.5 m during the investigation. In the fast water sections, depth < 3m, the primary substrates were rocks, large boulders and gravel. Just downstream from these sections were larger silt deposits, depth >3m). The bottom was marred by large woody debris, which was probably the results of wood floating activities that ended in the late 1980's.

Sampling occurred on April 29 and October 14, 1998, and biweekly from April 29 to June 23 1999 using a Smith Root 16 R Electrofishing Boat (voltage varied throughout the experiment from 250 V to 1000V and current ranged from 250 mAmp to 3 Amp), between 19h00 and 01h00.

Sampling in 1998 consisted of several random passes on and just downstream of the rapids. In 1999, five different areas were sampled regularly (Gatineau shore , Gatineau middle, Hull middle, Hull shore and around the island). Most sampling passes were made on the Gatineau, Hull middle and Hull shore reaches. Electrofishing runs started 20 m from the bridge's buttresses and continued 400 to 1000 m downstream of the Alonzo-Wright Bridge. All runs followed along the contour of the banks downstream until time had expired (1500 s) or when enough fishes were captured to fill the on-board live well. All electroshocked fish were captured, when possible.

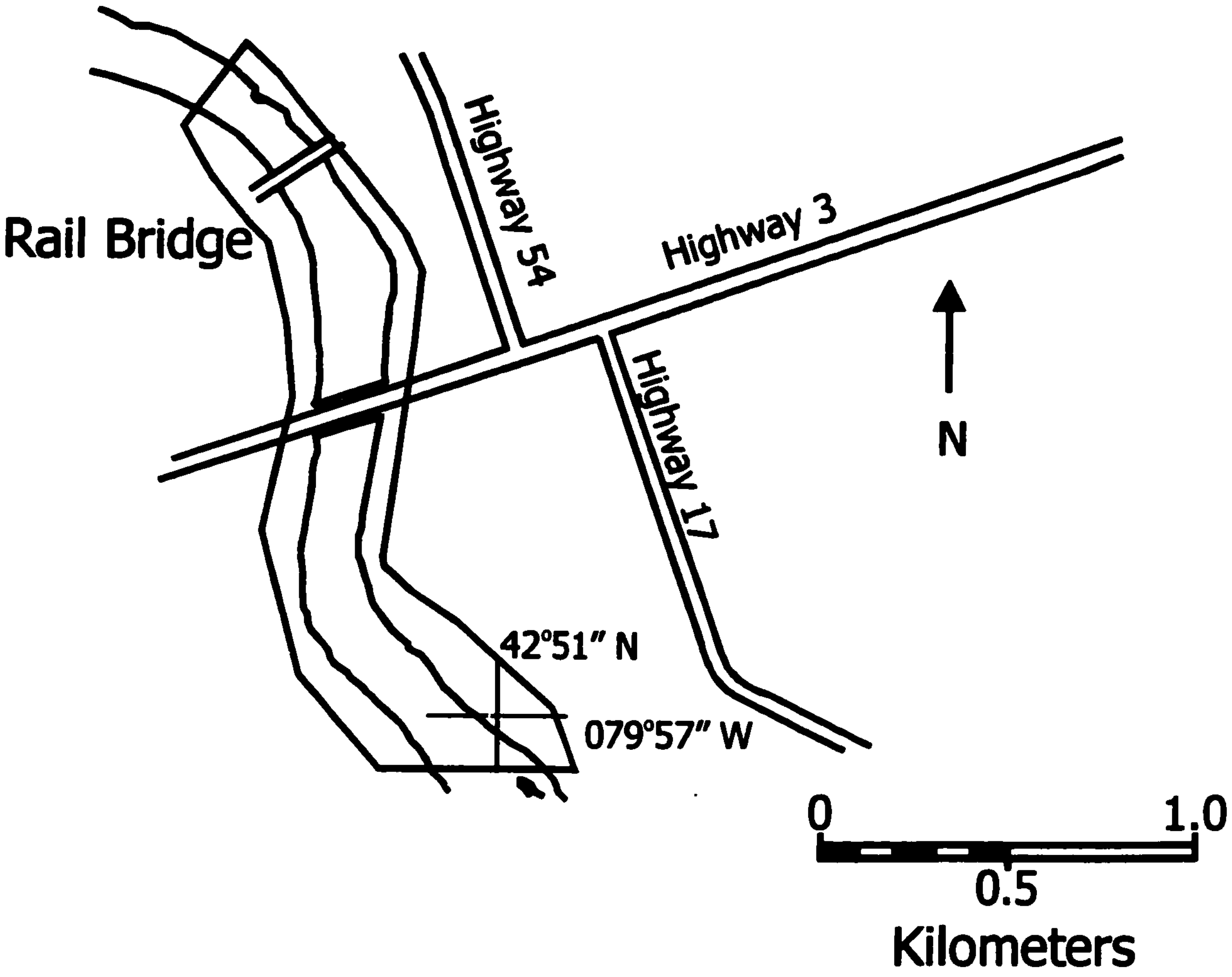


Figure 11. Map of the Grand River, Cayuga, Ontario. The sampled area is indicated by the boxed region. Map scale is 1:20000. The map is of the entire town of Cayuga.

3.1.6 Grand River (Figure 11)

This section of the Grand River (42°57"N, 079°51"W), Haldimand Township, Ontario, was sampled once on July 23, 1998 by the OMNR. Participation in the sampling effort was aimed at documenting and collecting information specifically on *M. carinatum* in this tributary of Lake Ontario. Water depth ranged from 0.3 m to 2.0 m with a bottom composition of 50% pebbles and 50% soft substrates (sand, silt and clay). There was little cover along its banks, little shoreline vegetation and sparse underwater vegetation (*Potamogeton spp.*, *Myriophyllum spp.*). Water clarity was minimal (Secchi <0.3m) and the current was slow. The midday air and water temperatures reached a maximum of 29 °C and 25.7 °C respectively.

Sampling consisted of 6 passes using a Smith Root 21H Electrofishing Boat, between 10h00 and 18h00. All captured specimens were removed from the boat and placed into Roughneck® laundry bins, anaesthetized with clove oil, identified, weighed, measured, tagged and released.

3.2 Netting Protocol for the Mississippi River

During the spawning period from May to June, all net types were set immediately downstream of the mouth of streams and downstream of rapids found along the Mississippi River. However, due their size, large trap nets were set in deeper waters than the hoop and minnow nets (see section 3.2.1). Nets were placed perpendicular to the shore, in areas having the characteristics of spawning areas described by Hackney et al. (1967) and Parker and McKee (1988). From mid-May to July and once in October, nets were placed randomly at least 2 km apart from each other from week to week. All nets were lifted after 24 hours and the fish were removed. Nets were then either placed back in the water at the same location (up to and including 4 days) or were moved to a different location. All net locations were recorded with a Magellan® GPS Pioneer Global Positioning System handheld receiver.

3.2.1 Nets

Trap nets used for the Mississippi River were purchased from Halltech® Environmental, Guelph, Ontario. The 2 m trap nets were custom made to match those used by the Ontario Ministry of Resources Fisheries Assessment Unit (OMNR FAU). These nets had a 50 m lead, 2.0 m box height and were made of 6 cm stretch mesh of knotless black poly (Appendix A).

Trap nets used in the Ottawa River ranged in box height from 2.0 m to 3.3 m. All three nets were similar in design to those used in the Mississippi River experiments. Except for the box size, the major difference between the nets, was the size of the leads, the 2.3 m trap-nets had 50 m leads while the 3.3 m nets had 66 m leads with all other measurements being increased proportionally.

Hoop nets used for in Mississippi River sampling were purchased from Halltech® Environmental, Guelph, Ontario. Nets had a 3 m lead, 1 m box height and were made of 3.3 cm stretch mesh of knotless black poly. (Appendix B).

Minnow nets used for the Mississippi River sampling were purchased from Nichol's Net and Twine Co., Illinois. Nets had a 2.5 m lead, 1 m box height and were made 1.5 cm stretch mesh of knotless white poly. (Appendix C).

Nets were set in water ranging in depth from 0 to 8 m on a variety of habitats, where the channel width was greater than 3 m. Nets were lifted every 24 hours emptied of fish and replaced in the same location for another 1 to 3 days.

3.3 Morphological Measurements and Observations

3.3.1 Weight Determination

All fishes were weighed *in situ,* in a 1m long 15 cm deep Nalgene® tray on either an Acculab ® 6000 (6000 g, +/-1g) or an Acculab ® 10K (10000 g, +/-1g) portable battery operated digital scales. The Nalgene® tray facilitated fast measurement of large un-anaesthetized fish while maintaining accurate results.

3.3.2 Length Determination

All *in situ* measurements were made using a 1m fish board graduated in 1 mm increments. Three length measurements were taken *in situ* standard length (from snout to the distal end of the hypural plates), fork length (from snout to the middle of the fork in the caudal fin) and total length (snout to the longest lobe of the caudal fin). Retained specimens were frozen within four hours and all *in situ* measurements were repeated in the lab.

3.4 Sexual Differentiation and Sexual Maturity

Gender was determined externally using the presence or absence of nuptial tubercles.

Males were differentiated by the presence of nuptial tubercles on the head, cheek, anal fin and caudal fin (Jenkins, 1970). In general, the male's tubercles were located on the nose, the ventral margins of the face and on the fin rays of the anal and caudal fins. Only large females had tubercles, localized on the anal fin. Field assessment of gonadal maturity were done using Nikolsky's (1963) index of gonadal maturity. This scale starts at 0 when fish have no gonadal tissue; stages I, II and III describe histological differences in the gonads which are not detectable externally; stage IV, indicates firm gonads which are not at spawning stage; stage V, identifies ripe gonads which are easily stripped by abdominal pressure; stage VI, identifies a spent gonad.

3.4.1 Egg and Testes Measurements

To determine fecundity 10 stage V individuals (5 males and 5 females) were sacrificed from those fish captured on June 2, 1998. Specimens were dissected and the gonads were removed. Excess tissue and fat were removed from the gonads and the latter was weighed on a tarred Toledo® lab scale (+/- 0.001 g).

To determine egg counts, 10 samples of 2 to 5 grams of fresh untreated ovarian tissue were removed from each female. Eggs in each sample were floated in water and counted using a bottom lit dissecting microscope at 50 X magnification on a 0.1 mm graduated micrometer slide. The mass of the sample was divided by the number of eggs in the group to determine the average mass of an egg. The gonadal weight was divided by the mass per egg to determine the number of eggs in each gonad.

3.5 Age Determination

On the left side of each specimen, three scales were removed from the third row of scales ventral to the dorsal fin immediately posterior to the first dorsal fin ray. Dissections were performed on retained specimens to remove pharyngeal teeth, pectoral girdle, cleithra, opercula, subopercula bones and three additional scales. Only scales and the opercula provided legible annulii for each fish.

Bones were defleshed using boiling water and allowed to dry prior to examination. All structures were observed using a dissecting microscope at 50 X magnification and read independently by a minimum of two individuals on separate occasions. Due to the low number of specimens, no samples were discarded. Disagreements between readers were re-evaluated until an agreement could be reached. Annuli were determined using the methods described by Lagler as outlined in Francis (1990).

3.5.1 Back Calculation of Length at Age

Measurements were made of the distance between annular marks on the opercula bone using digital calipers under 50 X magnification. Length at age calculations were performed using the Fraser Lee Back calculation method (*in* Francis, 1990)(Appendix D).

$$\mathbf{LT}_t = \mathbf{L}_{oss} + (\mathbf{TL} - \mathbf{L}_{oss})[(\mathbf{DF}_t - \mathbf{DF}_{t-1}) / (\mathbf{TLB})]$$

Where:
$\mathbf{LT}_t$ = Length at time "t" in mm; **TL** = Total length of fish in mm; $\mathbf{L}_{oss}$ = Total length of fish at ossification in mm; **LB** = Total length of bone or scale in mm; $\mathbf{DF}_t$ = Distance from focus at time "*t*" in mm; $\mathbf{DF}_{t-1}$ =- Distance from focus at time "*t-1*") in mm; **TLB** = Total length of bone or scale in mm.

This equation assumes proportional somatic growth of the fish through life. The length at age is calculated using the length of the organism at capture and the age, as indicated by annular growth marks as the end point of the calculation. There is also a correction factor added to allow for the length of the fish at the time of initial bone calcification (L_{oss}). This is important to accurately predict the growth of younger specimens. The growth between annular marks is measured along the same axis radiating from the focus. The distance between annular marks is then assumed to be proportionally reflected in the somatic growth of the fish. The length at initial ossification for *M. carinatum* was determined from literature (Auer, 1982) and was fixed at 25.0 mm.

3.6 Habitat and Temperature

The onshore and underwater substrates were visually classified into percent relative abundance. To standardize the measurement, a 1 m^2 quadrat of the bottom was sampled at half of the length of the lead for underwater substrates. Substrates were classified into 7 categories: organic material; silt; sand; coarse substrate >2mm but less than 5 cm; coarse substrates > 5cm; submerged plants (*Elodea spp.*, *Vallisneria americana, Potamogeton spp., Myriophyllum spp.* and *Chara spp.*); emergent plants (sedges, arrow leaf, lilies); and wood (large woody debris, sticks, twigs and stumps). Habitat maps of each netting location were drawn and the latitude, longitude, water depth, net depth and water and air temperature were all measured.

3.7 Mark Recapture Methods

Tags were purchased from Northwest Marine Technologies (NMT) International Ltd.. Two tag sizes, small (0.9 mm X 2.5 mm) and large (2.5 mm X 4.5 mm), were tested in the lab and the field. Both size tags were inserted with a modified syringe, the single shot injector (SSI) (Blakenship and Tipping, 1993), on preserved specimens of redhorse (*M. anisurum, M. carinatum,* and *M. macrolepidotum*) from 7 to 25 cm to determine the best location for tagging. The anal fin was found to be the best site for tagging using the modified methodology of Wenburg and George (1995).

Prior to the injection of the tag fish were initially placed on their left side and measured for standard, fork and total length. The injection site was 1 cm plus the distance of the SSI away from the fins' insertion on the body. The SSI was placed on a 10-25^0 angle to the fin and inserted (Wenburg and George, 1995). The SSI was inserted 2-3 cm along the ray and the tag injected. After the removal of the SSI, the injection site was rubbed gently with a finger to flattened the tag, close the wound and remove any trapped air (Wenburg and George, 1995). The tag was then quickly inspected for legibility using either a hand held Mini-Maglight® or hand held 365 nm fluorescent black-light (VWR-Canlab). When this was completed, the specimen was weighed and returned to the water.

Population size determination was conducted using single capture recapture models from Ricker (1975) of Schnable (1938)(eq. 1)(Appendix E), Schnable (1938) modified by Gerking (1953)(eq. 2)(Appendix F) and Schumacher and Eschmeyer (1943)(eq. 3)(Appendix G) and multiple recapture models from Ricker (1975) of Seber (1962) (the Jolly Seber model, eq. 4, modifications in eq.4*)(AppendixH).

eq. 1 $$N_t = \frac{\sum (C_t M_t)}{R}$$ **eq. 2** $$N_t = \frac{\sum (C_t M_t)}{R+1}$$ **eq. 3** $$N_t = \frac{\sum (C_t M_t^2)}{\sum (M_t R_t)}$$

For equations 1,2,3:

N_t = Total number of fish in sample area at time "*t*", C_t = Total captures at time "*t*", M_t = Total marked fish in population, R = Total recaptures, R_t = Total recaptures at time "*t*"

eq. 4 $$N_i = \frac{\left(\left(\frac{(M_i)\cdot K_i}{R_i}\right) + m_i\right)\cdot(C_i)}{M_i}$$ **eq. 4*** $$N_i = \frac{\left(\left(\frac{(M_i+1)\cdot K_i}{R_i+1}\right) + m_i + 1\right)\cdot(C_i+1)}{M_i+1}$$

For eq 4 and 4*:

N_i = Population size at time "i"; M_i = New marks in the population at time "i"; C_i = Non recaptures examined at time "i"; R_i = First time recaptures at time "*i*"; m_i = Total recapture events at time "i"; K_i = the sum of all recaptures after time "i"marked before time "i"

The single capture-recapture models assume that the proportion of recaptured fish in a sample is equivalent to the proportion in the population. Confidence intervals are approximated using the Students *t* (*df* = sample runs-1) distribution for equations 1 and 3, Poisson's distribution for equation 2 (*df* = sample runs-1).

For the multiple recapture model , the correction allows for low rates of capture and recapture. In addition this model can be used to calculate the recruitment into the population and the survival rate. The model assumes that the proportion of marked fish in the population is equal to the sample but the model is corrected for the multiple recapture of any individual. To utilize this equation, samples were pooled for the entire night. This violated one assumption that all fish have an equal chance of capture and recapture, since those fish captured earlier in the evening and released could be recaptured on a subsequent sampling run that night. Also this model does assume equal time frames between sampling days. Sampling was carried out on the Tuesday and Thursday of any one week; only once was an additional investigation run. Confidence intervals are approximated using the normal distribution (*df* = sample runs-1).

3.8 Statistical analysis

The average length and weight was calculated for each sex to determine differences in growth between water bodies. Weight and length data were $\log_{10}$ transformed. Both ANOVA and non parametric Mann-Whitney *U* tests were performed on the mean weight and lengths between sexes and sites. Transformed length and weight data were used in a linear regression.

ANCOVA analysis was performed on the length weight relationships to determine differences in the length weight relationships between sex and that between different sites. *Post hoc* Bonferroni tests were used to determine groupings of data. To determine the effect that spawning has on specimens of *M. carinatum,* changes in length weight regression lines were grouped by sexual stage (stages according to Nikolsky (1963)).

A third order polynomial regression (Chen *et al.*, 1992) was performed on the length at age data for these specimens. All sites and sexes were pooled due to the small number of samples. Data were then compared to the lengths noted by Carlander (1969), McAllister *et al.* (1985) and Mongeau *et al.*, (1992).

Mean egg counts were calculated and confidence intervals were determined for females. Egg counts were calculated from the total mass of the gonads divided by the average mass of one egg. Differences between gonadal mass from the left and right sides of the fish were tested for normality using Lilliefors analysis and parametric pair-wise *t* tests were conducted as well as nonparametric Wilcoxon Ranked Signs tests.

Contingency table analysis was performed to determine if the frequency of different staged fish was dependent on day, temperature, sex or a combination of these factors in the Gatineau River during the spring of 1999. It was also performed to examine the role substrate and other species have on the presence or absence of *M. carinatum* in the Mississippi River, two-way contingency analysis was performed on frequency of sites where *M. carinatum* was either present or absent.

A crude estimate of population size was conducted in the Mississippi and Gatineau Rivers utilizing the methods outlined in section 3.7. Due to the low number of recaptures in both rivers, it was decided to use the equations provided by Schnable (1938) with modifications by Gerking (1953), the model of Schumacher and Eschmeyer (1953) as well as the Jolly-Seber multiple recapture method (Jolly, 1965; Seber 1965).

All single capture recapture models assume equal probability of recapture as first capture, no emigration or immigration, no mortality and complete mixture of the tagged and untagged fish. Multiple capture recapture models assume equal probability of recapture as first capture, accounts for emigration or immigration, mortality and complete mixture of the tagged and untagged fish.

4.0 Results

4.1 Capture data for each sampling localities

Sampling effort in the Mississippi River totalled 3,022 hours (1,170 hours of the large trap-nets; 1,331 hours of minnow nets and 521 hours of hoop-nets)(Table 1). A total of 1,549 fish belonging to 20 species were captured (Table 2). The five most abundant species (including recaptures) accounted for more than 70 % of all fish captured. They were *Ambloplites rupestris* (23.1%), *Moxostoma anisurum* (22.8%), *Micropterus dolomieu* (15.8%), *Moxostoma macrolepidotum* (5.9%), and *Ameiurus nebulosus* (5.6 %).

In the Mississippi River, a total of 72 *M. carinatum* were captured and three fish were recaptured. Sixty-nine fish (and three recaptures) were caught in the Blakeney to Cedar Hill and Cedar Hill to Pakenham reaches. Only three *M. carinatum* were captured in the Pakenham to Highway 17 reach while no fish were captured in the other two river sections. Sixty-nine of the 72 *M. carinatum* were captured in the large trap nets, with two captures with one recapture occurring in the minnow nets (Table 1). No captures of *M. carinatum* occurred in the hoop-nets. In terms of catch-per-unit-effort, one *M. carinatum* was captured every 17 hours in trap nets and one *M. carinatum* was captured for every 266 hours for the minnow nets. Females outnumbered the males by a ratio of 53:19 (2.8:1). *M. carinatum* accounted for 4.7% of the total sample of fishes and 12.1% of the total Catostomidae catch (n = 597 specimens)(Table 3) (Appendix I).

To determine fish associations with *M. carinatum*, contingency table analysis was conducted to compare the frequency of fish captured in nets with and without *M. carinatum*. There were significant differences in the relative abundance of *Micropterus dolomieu* (Pearson $\chi^2 = 22.98$, $df = 12$, $p = 0.03$), *Ambloplites rupestris* (Pearson $\chi^2 = 29.56$, $df = 16$, $p = 0.02$) and

River	Sample interval	Method	Time (H)	Catch	CPUE	Recapture
Mississippi River	May -October 1998	Trap Nets	1170	69	0.059	2
		Hoop nets	521	0	-	-
		Minnow Nets	1331	3	0.002	1
	Total	All nets	3022	72	0.024	3
Madawaska	May 1998	Electrofish	3	15	5.000	-
Ottawa	July 1998	Trap Nets	1680	31	0.018	-
Gatineau	June 2 1998	Electrofish	2	95	47.500	-
	October 14 1998	Electrofish	2	4	2.000	-
	May-June 1999	Electrofish	12.65	271	21.423	34
	Combined	Electrofish	16.65	370	22.222	34

Table 1. Catch per unit effort (CPUE) ((total # of fish captured) / (duration of fishing in hours)) of *M. carinatum* in the Ottawa River and some of its tributaries. Sample intervals indicate sampling dates. Method indicates mode of capture. Time is given in hours of active fishing, catch refers to total *M. carinatum* captured, recapture refers to the total number of *M. carinatum* recaptured.

Family	Scientific Name	Common Name	Mississippi		Ottawa		Gatineau	
			Abun	RA	Abun	RA	Abun	RA
Petromyzontidae	*Ichthyomyzon unicuspis*	Silver Lamprey					11	0.46
	Lampetra appendix	American Brook Lamprey					28	1.17
Lepisosteidae	*Lepisosteus osseus*	Longnose Gar			84	4.67		
Acipenseridae	*Acipenser fulvescens*	Lake Sturgeon			11	0.61	19	0.80
Salmonidae	*Salmo trutta*	Brown Trout					1	0.04
	Salvelinus namaycush	Lake Trout					1	0.04
Hiodontidae	*Hiodon tergisus*	Mooneye	1	0.06			276	11.56
Esocidae	*Esox lucius*	Northern Pike	32	2.07	31	1.72	1	0.04
	E. masquinongy	Muskellunge			9	0.50	4	0.17
Cyprinidae	*Phoxinus eos*	Northern Redbelly Dace					4	0.17
	Notemigonus crysoleucas	Golden Shiner					2	0.08
	Notropis atherinoides	Emerald Shiner					309	12.95
	N. heterodon	Blackchin Shiner	2	0.13				
	N. hudsonius	Spottail Shiner					2	0.08
	Pimephales notatus	Bluntnose Minnow	2	0.13				
	Rhinichthys cataractae	Longnose Dace					1	0.04
	Semotilus corporalis	Fallfish					52	2.18
Catostomidae	*Carpiodes cyprinus*	Quillback					67	2.81
	Catostomus commersoni	White Sucker	67	4.33	15	0.83	33	1.38
	Moxostoma anisurum	Silver Redhorse	353	22.79	254	14.13	223	9.34
	M. carinatum	River Redhorse	72	4.65	31	1.72	271	11.35
	M. macrolepidotum	Shorthead Redhorse	92	5.94	13	0.72	254	10.64
	M. valenciennesi	Greater Redhorse	13	0.84	2	0.11		
Ictaluridae	*Ameiurus nebulosus*	Brown Bullhead	86	5.55	24	1.33	9	0.38
	Ictalurus punctatus	Channel Catfish	1	0.06	1179	65.57	57	2.39
	Noturus insignis	Marginated Madtom					3	0.13
Anguillidae	*Anguilla rostrata*	American Eel	6	0.39	1	0.06	1	0.04
Gadidae	*Lota lota*	Burbot	1	0.06				
Percopsidae	*Percopsis omiscomaycus*	Trout-Perch					5	0.21
Centrarchidae	*Ambloplites rupestris*	Rock Bass	357	23.05	17	0.95	116	4.86
	Lepomis gibbosus	Pumpkinseed	77	4.97	20	1.11	9	0.38
	L. macrochirus	Bluegill					4	0.17
	Micropterus dolomieu	Smallmouth Bass	244	15.75	77	4.28	17	0.71
	M. salmoides	Largemouth Bass	5	0.32	8	0.44	1	0.04
	Pomoxis nigromaculatus	Black Crappie	43	2.78	2	0.11	22	0.92
Percidae	*Perca flavescens*	Yellow Perch	39	2.52			79	3.31
	Sander canadense	Sauger					16	0.67
	S. vitreum	Walleye	56	3.62	20	1.11	80	3.35
	Etheostoma nigrum	Johnny Darter					1	0.04
	E. olmstedi	Tesselated darter					12	0.50
	Percina caprodes	Logperch					315	13.20
	Percina copelandi	Channel Darter					76	3.18
Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum					5	0.21
Totals			1549		1798		2387	

Table 2. Abundance (Abun) and percent relative abundance (RA) of species captured by water body. Data from the Ottawa River were obtained from Haxton (1999). Data from the Gatineau River include the 1999 sampling period only.

Species	River System						
	Mississippi	Ottawa	Gatineau '98	Gatineau '99	Madawaska	Muskrat	Grand River
	Percent Relative Abundance						
Carpiodes cyprinus				7.90			
Catostomus commersoni	11.22	4.76		3.89			
Moxostoma anisurum	59.13	80.63	21.43	26.30	75.58	89.80	25.76
M. carinatum	12.06	9.84	64.29	31.96	10.47		3.03
M. erythrurum							63.64
M. macrolepidotum	15.41	4.13	14.29	29.95	1.16	9.18	7.58
M. valenciennessi	2.18	0.63			12.79	1.02	
	Total Abundance						
Carpiodes cyprinus				67			
Catostomus commersoni	67	15		33			
Moxostoma anisurum	353	254	33	223	65	88	17
M. carinatum	72	31	99	271	9		2
M. erythrurum							42
M. macrolepidotum	92	13	22	254	1	9	5
M. valenciennessi	13	2			11	1	
Total Captured	597	315	154	848	86	98	66

Table 3. Percent relative abundance and total abundance of all catostomid species captured (and including recaptures) in the Ottawa River, its tributaries and the Grand River, Cayuga, Ontario. Data from the Ottawa River were obtained from Haxton (1999).

Sander vitreum (Pearson χ^2= 15.268, *df*=5 , p=0.009) in nets with and without *Moxostoma carinatum*. Both *Micropterus dolomieu* and *S. vitreum* were more abundant in nets with *Moxostoma carinatum*, and *A. rupestris* was more abundant in the nets without *M. carinatum.*

The Lac des Chats section of the Ottawa River was sampled by the Ontario Ministry of Natural Resources from August 24 until September 3, 1998. There were a total of 40, 24 h net sets, capturing 1,798 fish from 18 species including 31 *M. carinatum*. In the Ottawa River, the ratio was approximately 6:1 in favour of females. The five most abundant species in this section were *Ictalurus punctatus* (65.57 %), *M. anisurum* (14.13 %), *Lepisosteus osseus* (4.67 %), *Micropterus dolomieu* (4.28 %), and equal abundance of *Moxostoma carinatum* and *Esox lucius* (1.72 %) (Table 2). *Moxostoma carinatum* accounted for 9.8% of the total catostomid catch in the Ottawa River (Table 3).

Catch-per-unit-effort in the Ottawa River was one *M. carinatum* per 30.7 hours of netting. Broken down by net size, a *M. carinatum* was captured every 45.3 hours in the 2 m trap nets (22 nets, 11 specimens, 498.12 hrs) and every 22.64 hours for the 2.3 m trap nets (20 nets, 20 specimens, 452.74 hrs) (Haxton, 1999).

There was a significant difference (p<0.001) in the distribution of some fish species in nets with and without *M. carinatum*. In nets with *M. carinatum,* there were higher number of *M. anisurum* and *Micropterus dolomieu* than in nets without them. There were higher occurrences of *Lepisosteus osseus, Moxostoma macrolepidotum* and *Lepomis gibbosus* in nets without *M. carinatum.*

The sampling of the Madawaska River took place from 21h00 to 24h30 on May 4, 1998. Only *Moxostoma spp*. and *Sander vitreum* were selectively captured. The active electrofishing period was 2.0 hours. Eighty-six *Moxostoma spp.* were captured: 65 *M. anisurum*, 11 *M.*

valenciennesi, 9 *M. carinatum* and 1 *M. macrolepidotum*. In the Madawaska, the sex ratio was 8:1in favour of females.

The Muskrat River was sampled from 20h00 to 24h00 on May 5, 1998, in which only *Moxostoma spp.* were selectively captured. The active electrofishing period was 7200 seconds (two hours). Ninety-eight *Moxostoma spp.* were captured: 88 *M. anisurum*, 9 *M. macrolepidotum* and 1 *M. valenciennesi*.

In the Gatineau River, on June 2, 1998 a total of 7,200 seconds were spent electrofishing specifically for *Moxostoma spp.* from 20h00 to 24h00. There were 154 fish captured including 99 *M. carinatum*, 22 *M. macrolepidotum* and, 33 *M. anisurum*. A subsequent 7,200 seconds (two hours) electrofishing period was done on October 14, 1998, again targeting *Moxostoma spp.* Twenty *Moxostoma spp.* were captured: 4 *M. carinatum*, 5 *M. macrolepidotum*, 11 *M. anisurum*.

From April 29 until June 23, 1999, biweekly electrofishing sampling was done in the Gatineau River. Fifty-four separate runs were performed totalling 47,705 seconds (13.25 hours) of active electrofishing sampling. A total of 2,387 specimens were captured belonging to 38 species (13 families including Petromyzontidae). A total of 226 individual *M. carinatum* were captured and 45 fish were recaptured (including 6 multiple recaptures) (Appendix J). *M. carinatum* accounted for 11.4 % of the total fish captured and for 32 % of all Catostomidae captured. The five most abundant species in the sample were: *Percina caprodes* (315), *Notropis atherinoides* (309), *Hiodon tergisus* (276), *M. carinatum* (271), *M. macrolepidotum* (254).

Nearly 22 *M. carinatum* were captured per hour of sampling (either recapture or new fish), 18.34 first-time captures were noted per hour of sampling while there was 3.6 recaptures per hour of sampling. Overall, the sex ratio was 109:145 in favour of males (or 1:1.3 females to males).

In the Grand River, sampling occurred on July 7, 1998, from 09:00 until 15:00. Only *Moxostoma spp.* were counted from the five sample runs (1000 seconds per run). Capture data were pooled due to the low rate of capture of *Moxostoma spp.*. A total of 66 *Moxostoma spp.* were captured from 4 species: 17 *M. anisurum*, 2 *M. carinatum*, 42, *M. erythrurum* and 5 *M. macrolepidotum*.

4.2 Allometric Comparisons

4.2.1 Variation in the size of *M. carinatum*

The 72 captures of *M. carinatum* in the Mississippi River, was comprised of 53 females (including two recaptures) and 19 males (including one recapture). There was no significant difference from the normal distribution for length or mass (Lilleifors, $p = 0.059$ and $p = 0.727$ respectively). However, when sample sizes were small and or unequal the nonparametric Mann-Whitney U test was conducted in addition to t test (Table 4).

In the Mississippi R. captured males were shorter ($U_{(0.05,68)} = 704.000$; $p < 0.001$; $t_{(0.05,68)} = 4.247$; $p < 0.001$)(Table 4) and weighed less ($U_{(0.05,71)} = 778.000$; $p < 0.001$; $t_{(0.05,71)} = 4.470$; $p < 0.001$) (Table 5) than females. Males had a narrower range in size than females and accounted for the smallest captured specimen (533 mm) (Table 4). The lightest specimen taken was a 1530 g male and the heaviest was a 4994 g female (Table 5).

In the Ottawa River (Lac des Chats), 31 *M. carinatum* were captured: 11 females and 2 males, 18 unsexed specimens). The smallest specimen of *M. carinatum* was 543 mm (TL). The smallest male *M. carinatum* caught was 685.0 mm in total length. There was not a significant

Water Body	Sex	*n*	Mean	Max	Min	Std
Mississippi	Male	17	624.4	694.0	533.0	34.4
	Female	51	668.2	741.0	554.0	43.2
Ottawa	Male	2	715.0	745.0	685.0	42.4
	Female	11	699.5	780.0	543.0	63.5
Madawaska	Male	1	687.0	-	-	-
	Female	8	710.8	761.0	653.0	39.0
Gatineau[1]	Male	211	605.2	715.0	508.0	44.7
	Female	144	633.2	798.0	500.0	49.9

[1]= Pooled data from 1998 and 1999

Table 4. Number of specimens measured, mean total length (mm), minimum (Min) and maximum (Max) values, and standard deviation (STD +/-) of *Moxostoma carinatum* captured in the Ottawa River and its tributaries.

Water Body	Sex	*n*	Mean	Max	Min	Std
Mississippi	Male	19	2417.2	3558.0	1530.0	467.7
	Female	52	3068.1	4994.0	1676.0	709.8
Ottawa	Male	2	4565.0	5100.0	4030.0	756.6
	Female	11	4045.5	5100.0	1500.0	1039.6
Madawaska	Male	1	3435.0	-	-	-
	Female	8	4242.9	5822.0	3316.0	843.1
Gatineau[1]	Male	209	2714.5	5465.0	1129.0	682.8
	Female	143	3435.7	7938.0	1466.0	1009.5

[1]= Pooled data from 1998 and 1999

Table 5. Number of specimens measured, mean wet weight (g), minimum (Min) and maximum (Max) values and standard deviation (STD +/-) of *Moxostoma carinatum* captured in the Ottawa River and its tributaries.

difference from the normal distribution for length or mass (Lilliefors, $p = 0.228$ and $p = 0.438$, respectively). The shortest male was 26% longer than the shortest female *M. carinatum* and the longest male *M. carinatum* was only 2.2 % shorter than the largest female *M. carinatum.*

Length and weight data were tested for normality using Lilliefors analysis and because sample sizes were small and unequal, nonparametric Mann-Whitney *U* tests were conducted in addition to the Students *t* test to evaluate the differences between the length and weight means between sexes. There were no significant differences between the lengths of captured male and female *M. carinatum* in the Ottawa River ($U_{(0.05,(1,10))} = 9.50$; $p = 0.767$; $t_{(0.05,11)} = 2.201$; $p = 0.751$) but there was insufficient power to ensure that no significant difference in length existed ($(1\text{-}\beta) = 0.665$; $d = 2.00$; $\delta = 2.6050$; $n = 13$). The lightest male and female specimens captured weighed 5100 g wet weight. The largest specimen, a male, was 565 g larger than the next largest specimen, a female. This was the only river system where the mean weight of males captured was higher than the mean weight of females (Table 5). However, the difference was not significant ($U_{(0.05,(1,10))}=7.50$; $p=0.488$; $t_{(0.05,11)}=2.201$; $p=0.520$) and despite the small sample size (n=13) there was sufficient power to support the conclusion that there is no significant difference between males and females ($(1\text{-}\beta) = 1.00$; $d = 16.31$; $\delta = 41.6$; $n = 13$). There were 363 *M. carinatum* specimens captured in the Gatineau River ($n_{male}=211$, $n_{females}=144$, $n_{not\ sexed}=8$). The longest and heaviest ever recorded specimen of *M. carinatum* was captured in this river. A female specimen measured 798 mm (TL) another weighed 7938 g (wet weight). The length and weight data for all specimens of *M. carinatum* were tested for normality using Lilliefors analysis. There was a significant difference from the normal distribution for weight ($p < 0.001$) but not for total length ($p = 0.627$). Weight values were log transformed to normalize the distribution of the data (Lilliefors test $p = 0.387$). The mean weight of captured females is higher than the mean weight of males ($U_{(0.05,(350))} = 21940.5$; $p < 0.001$; $t_{(0.05,350)} = 7.475$; $p < 0.001$; $(1-\beta) = 0.6947$; $d = 0.2687$; $\delta = 2.4759$; n = 352). Females were also longer than males ($U_{(0.05,(353))} = 20093.5$; $p < 0.001$; $t_{(0.05,353)} = 5.407$; $p < 0.001$; $(1-\beta) = 1.000$; $d = 3.9687$; $\delta = 36.716$; n = 355).

Nine *M. carinatum* (8 females; 1 male) were captured in the Madawaska River. Sample size was too low to test for differences in the mean length or mean mass between the gender groups.

4.2.2 Variability in the Length Weight Relationship

There was a significant positive ($p<0.001$) linear relationship between the $\log_{10}$ weight and $\log_{10}$ total length for males and females *M. carinatum* captured in the Mississippi River (Table 6). An ANCOVA analysis between males and females determined that there was no significant difference between the slopes ($p = 0.833$; $F_{(1,64)} = 0.045$; $n_{males}=17$, $n_{females}=51$, $f^2 = 0.004$; $(1-\beta)_{(v1 = 3,\ v2 = 64)} = 0.061$) (Figure 12) and intercepts ($p = 0.734$; $F_{(1,65)} = 0.116$; $n_{males}=17$, $n_{females}=51$; $f^2 = 0.004$; $(1-\beta)_{(v1 = 2,\ v2 = 65)} = 0.072$) of the two regression lines. However, there was insufficient power, with this effect size, to ascertain if there was a true statistical difference between slopes or intercepts. When the data were pooled, there was a significant positive linear relationship of the $\log_{10}$ total length versus $\log_{10}$ weight ($p<0.001$; $F_{(1,66)}=219.705$; $r^2=0.769$; n = 68). The regression coefficients for males and females were 3.243 and 3.113 respectively (Table 6) indicating that both sexes are were heavier than predicted by their length. The regression coefficient for the pooled sample was 3.243.

Water Body	Sex	n	a	constant	p	r^2	F ratio
Mississippi	Male	17	3.243	-5.685	<0.001	0.716	123.640
	Female	51	3.113	-5.315	<0.001	0.792	56.943
	Combined[1]	68	3.243	-5.479	<0.001	0.769	219.705
Ottawa	Male	2	2.804	-4.347	-	-	-
	Female	11	3.296	-5.783	<0.001	0.853	52.080
	Combined[1]	13	3.113	-5.317	<0.001	0.852	63.520
Madawaska	Male	1	-	-	-	-	-
	Female	8	2.382	-3.171	0.059	0.473	5.390
	Combined[1]	9	2.496	-3.500	0.034	0.495	6.872
Gatineau[2]	Male	207	2.752	-4.228	<0.001	0.664	370.270
	Male[3]	206	2.913	-4.677	<0.001	0.780	722.909
	Female	142	2.870	-4.515	<0.001	0.656	266.930
	Combined[1]	354	2.837	-4.447	<0.001	0.644	638.070
All Rivers Combined	Male	227	2.706	-4.106	<0.001	0.628	380.317
	Male[3]	226	2.854	-4.521	<0.001	0.749	670.087
	Female	212	2.512	-3.542	<0.001	0.558	264.891
	Combined[1]	444	2.700	-4.080	<0.001	0.640	784.258
	Combined[1,4]	443	2.769	-4.275	<0.001	0.685	960.172

[1]=All captured fish including unsexed individuals

[2]=Data combined for 1998 and 1999

[3]=Data with one significant outlier removed (Studentized residual = -11.707)

[4]=Data with one significant outlier removed (Studentized residual = 8.800)

Table 6. Regressions of $\log_{10}$ total length in mm (tl) versus $\log_{10}$ wet mass in g (m) of males, females and both sexes combined for *M. carinatum* captured in the Ottawa River and tributaries.

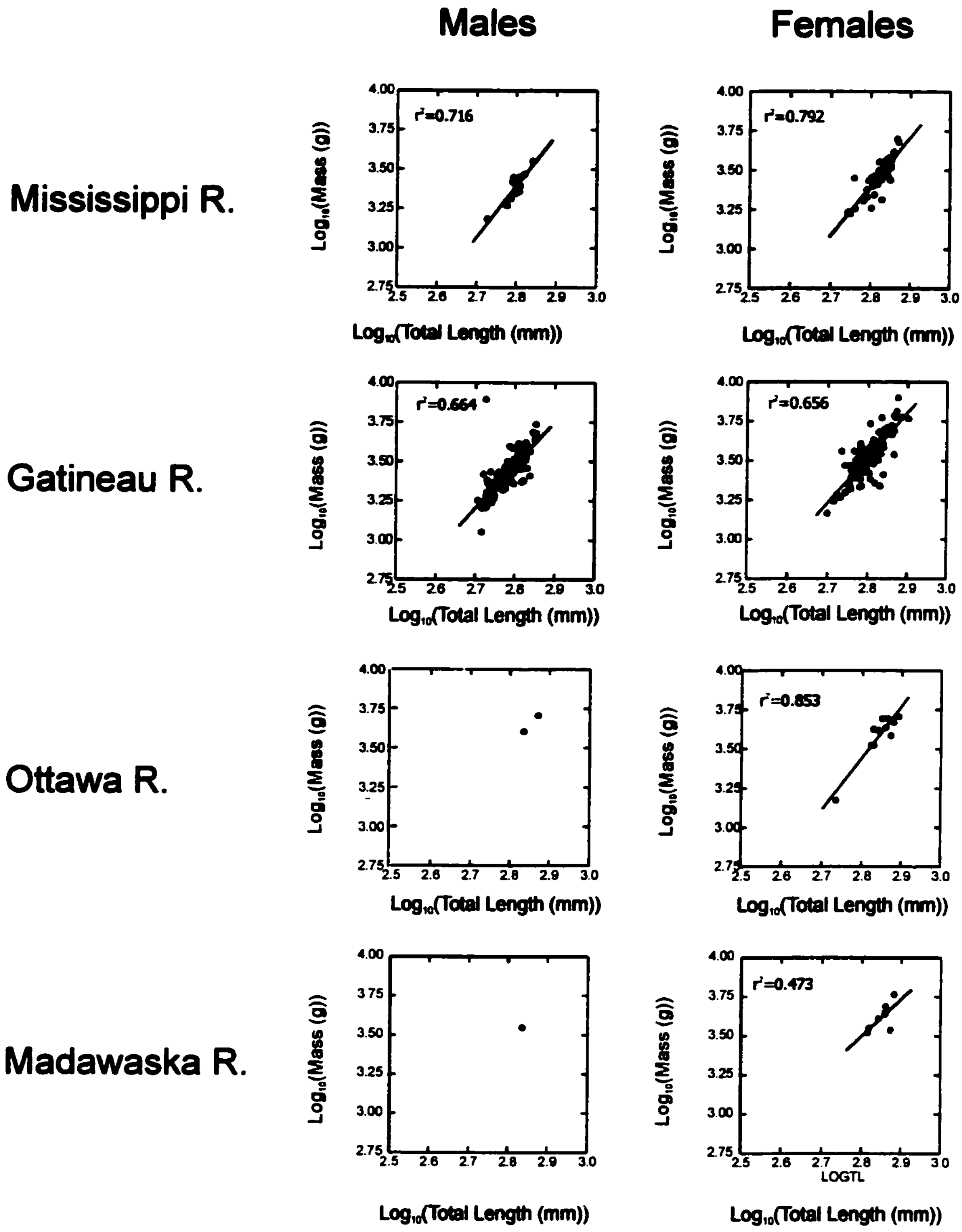


Figure 12. Plots of the $\log_{10}$ total length in mm (tl) versus $\log_{10}$ wet mass in g (m) of males and females *M. carinatum* captured in the Ottawa River and tributaries. Solid line represents the linear approximation of the regression. For regression line equations and sample sizes refer to Table 6.

For the Gatineau River, specimens from 1998 and 1999 were pooled for the analysis. There was a significant linear relationship of the $\log_{10}$ weight and $\log_{10}$ total length of both male ($p<0.001$; $F_{(1,205)} = 370.270$; $r^2 = 0.664$) and female ($p<0.001$; $F_{(1,138)} = 266.930$; $r^2 = 0.656$) *M. carinatum* in the Gatineau River (Table 6). ANCOVA analyses found no significant difference in the slopes of the regression lines of males and females ($p = 0.600$; $F_{(3,345)} = 0.275$; $8 < 0.001$; $f^2 < 0.001$; $(1-\beta)_{(v1=3,\ v2=365)} = 0.050$). However, there was a significant difference in the intercepts of the regression lines of male and female *M. carinatum* ($p < 0.001$; $F_{(2,346)} = 27.063$; $\lambda = 26.768$; $f^2 = 0.077$; $(1-\beta)_{(v1=2,\ v2=346)} = 0.999$).

In the Gatineau River, both male and female specimens had regression coefficients smaller than 3 (2.752 and 2.870 respectively; Table 6) indicating a lower weight than predicted by their length. Some fish in this sample included some individuals that had spawned and could have lost up to 14% of their total wet mass after the release of gametes (Table 7). One male had significant pull (Studentized residual =-11.707) on the regression line. With the removal of this datum point (Figure 13) the coefficient of determination of the length-weight regression model went from $r^2 = 0.664$ to $r^2 = 0.780$ for just males.

Due to the mixture of individuals that had and had not spawned, the regressions were redone taking into account individuals reproductive stage (Figure 14). The regression coefficient decreased as females were going through the different stages (stage IV= 3.133, Stage V = 2.532, Stage VI = 2.181 (Figure 14)) regression equations follow the general equation $\log_{10}(m) = a \log_{10}(tl) + c$; ($a$)= regression equation coefficient, p= probability, r^2 = the coefficient of determination, n= number of observations used to produce the regression equation. For males, there was an opposite trend. Males of stage IV (coefficient=2.445) had a lower regression coefficient than stage V (coefficient=2.503) or stage VI (coefficient=3.092).

Fish I.D.	River	Date of Capture	Sex	Mass (g)	Total Length (mm)	Left Gonad (g)	Right Gonad (g)	Total gonad (g)	% of mass	# of eggs
EL0206GAT1	Gatineau	June 2 1998	F	2631	609	181	206	387	14.71	21799
EL0206GAT4	Gatineau	June 2 1998	F	4465	612	131	140	271	6.07	15265
EL0206GAT5	Gatineau	June 2 1998	F	2843	598	116.45	160.14	276.59	9.73	15580
EL3105GAT3	Gatineau	May 31 1998	F	1752	523	77.39	84.9	162.29	9.26	9141
T20907CED4	Mississippi	July 9 1998	F	3175	661	21.06	18.14	39.2	1.23	2208
T20907CED5	Mississippi	July 9 1998	F	3466	695	24.14	28.71	52.85	1.52	2977
T13010BLA6	Mississippi	October 10 1998	F	2907	645	42.35	43.85	86.2	2.97	4855
T0904OTT3	Ottawa	September 4 1998	F	4532	745	80.03	86.75	166.78	3.68	9394
T0904OTT4	Ottawa	September 4 1998	F	4232	691	62.37	68.2	130.57	3.09	7355
ELCAY10	Grand	July 7 1998	J	508	357	1.53	1.93	3.46	0.68	-
EL0206GAT10	Gatineau	June 2 1998	M	2101	546	53	59	112	5.33	-
EL0206GAT11	Gatineau	June 2 1998	M	2631	556	85	76	161	6.12	-
EL0206GAT6	Gatineau	June 2 1998	M	2489	557	118	232	350	14.06	-
EL0206GAT8	Gatineau	June 2 1998	M	2180	547	76	69	145	6.65	-
EL0206GAT9	Gatineau	June 2 1998	M	2367	544	-	76	76	3.21	-
EL3105GAT2	Gatineau	May 31 1998	M	2666	593	53.88	69.52	123.4	4.63	-

Table 7. Captured date, sex, gonad size, estimates of percent wet weight of the total body weight attributed to gonads of sacrificed fish and number of eggs for females. Egg estimations were based on an average of 56.32 (+/- 8.91 std.) eggs per gram of ovary. Fish I.D. refers to the net (M=Minnow trap, T= Trap net), date (dd/mm), location of capture (CAY= Grand River, OTT= Ottawa River, BLA/CED= Mississippi River, GAT= Gatineau River); sex (m= male, f= female, j= juvenile).

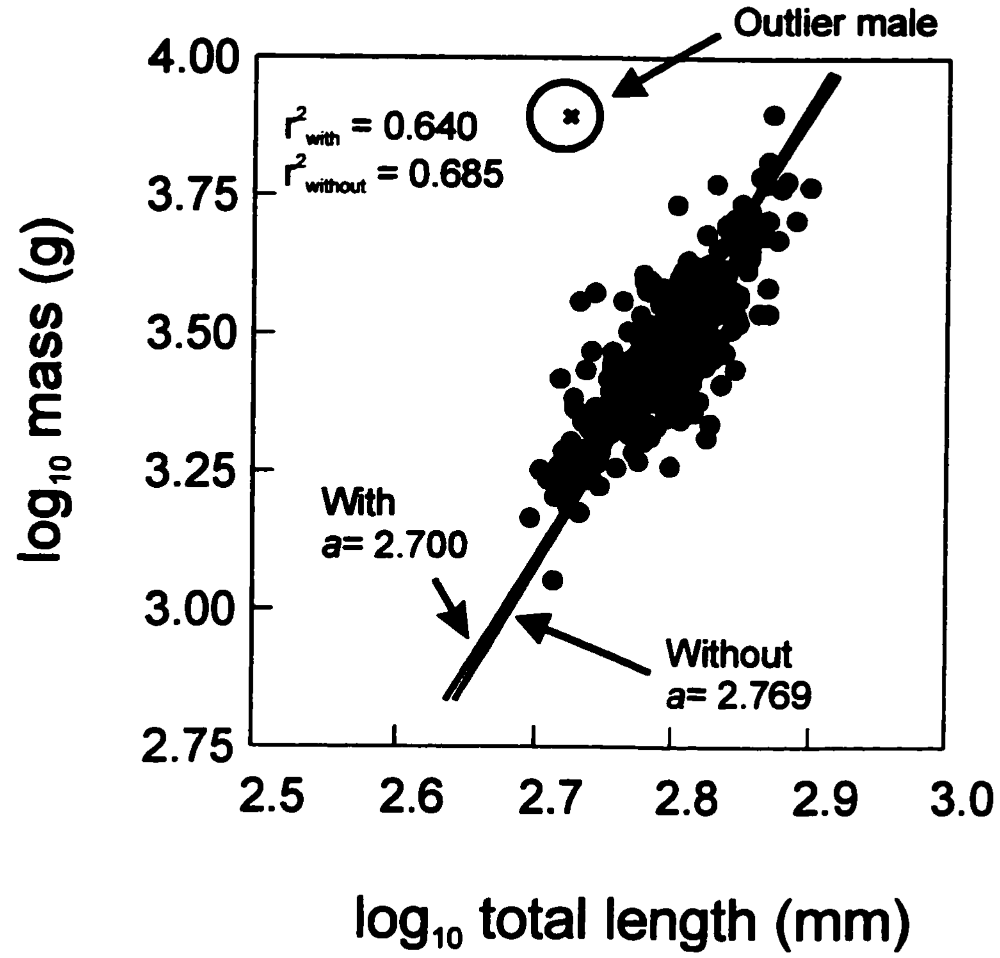


Figure 13. Plot of the $\log_{10}$ transformed length versus weight of male *M. carinatum* captured in the Gatineau River for 1998 and 1999. The designation "With" represents regression line of the pooled data with all data points, the designation "Without" represents the regression line after the removal of the outlier.

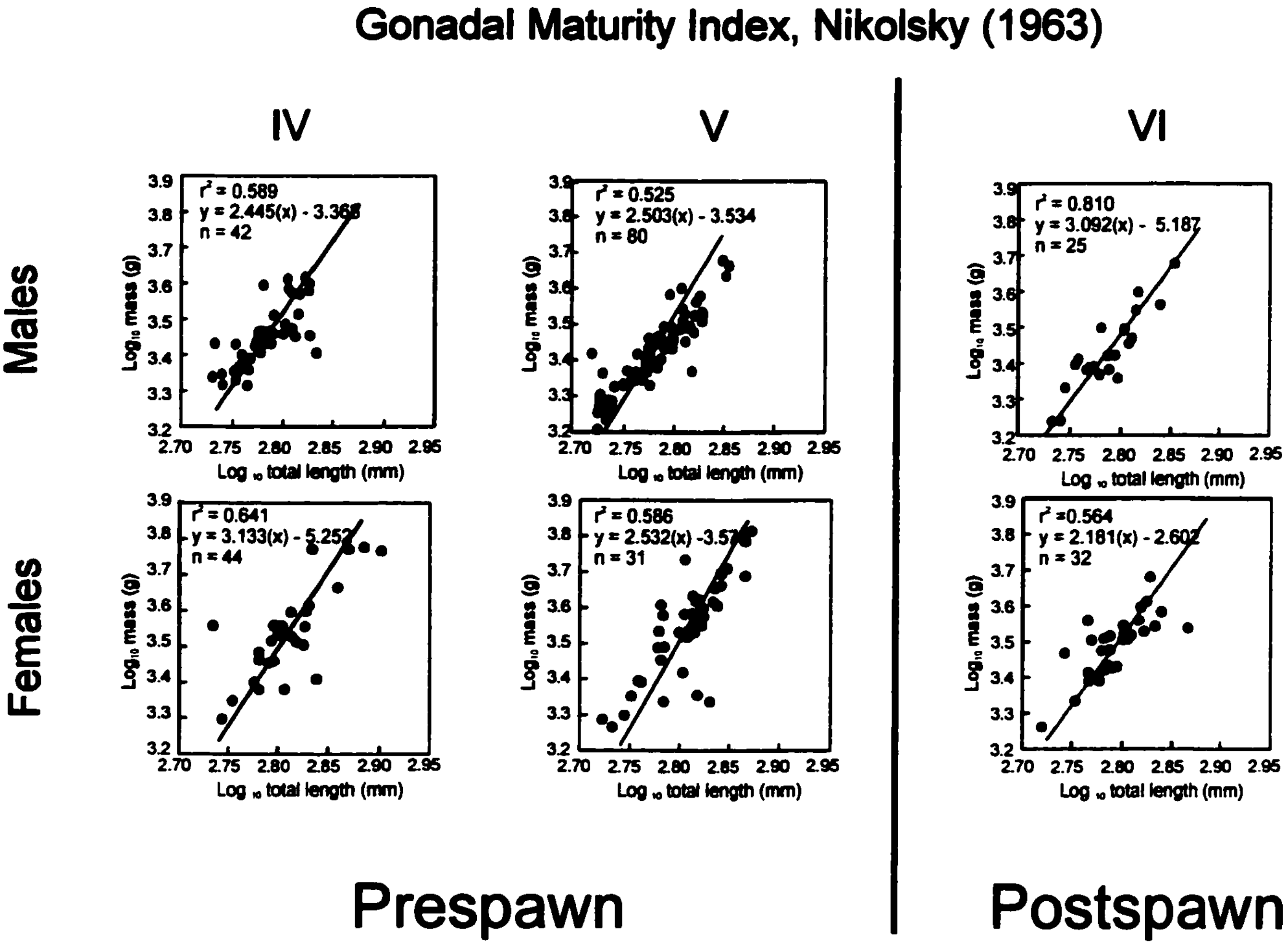


Figure 14. Linear regressions of $\log_{10}$ total length in mm (tl) versus $\log_{10}$ wet mass in g (m) of *M. carinatum* captured in the Gatineau River, spring of 1999, separated by sex and reproductive stage as defined by Nikolsky (1963). "Prespawn" refers to stages where significant amounts of gonadal material are still present within the fish, "Postspawn" individuals are defined when the gonads can no longer produce sperm or ova when abdominal pressure is applied.

There was no significant difference in the length of males ($p = 0.240$; $F_{(2,148)} = 1.442$; $f = 0.8980$; $\lambda = 121.767$; $(1-\beta) = 1.000$) or females ($p = 0.069$; $F_{(3,106)} = 2.437$; $f = 1.863$; $\lambda = 381.949$; $(1-\beta) = 1.000$) of different stages (Figure 14). Indicating that the weight was the variable factor among the reproductive stages. An ANCOVA analysis found no significant difference in the slopes of the regression lines between stages in the females ($p = 0.207$; $F_{(6,101)} = 1.602$; $\lambda = 3.586$ $f^2 = 0.0332$; $(1-\beta)_{(v1=6,\ v2=101)} = 0.3394$), there was insufficient data to test the for a difference in the males.

When comparing the various stages within one sex, there was not a significant difference in the intercepts for females ($p = 0.569$; $F_{(6,101)} = 0.675$; $\lambda = 5.368$ $f^2 = 0.0497$; $(1-\beta)_{(v1=6,\ v2=101)} = 0.3394$) or males ($p = 0.207$; $F_{(3,143)} = 1.602$; $\lambda = 20.286$; $f^2 = 0.1380$; $(1-\beta)_{(v1=3,\ v2=143)} = 0.9734$) in the length-weight regression. However, there was insufficient power to ascertain if the lack of a significant linear relationship reflected a low sample size.

In the Ottawa River, there was a significant ($p<0.001$; $F_{(1,9)} = 52.018$; $r^2 = 0.853$) linear relationship between the $\log_{10}$ weight and $\log_{10}$ total length of females (n=10) *M. carinatum* (Table 6). A regression analysis could not be done for males due to low sample size (n=2). Combining both sexes produced a significant ($p<0.001$; $F_{(1,11)} = 63.520$; $r^2 = 0.852$; $df = 11$) length-weight regression equation (Table 6). All fish were caught in September when no external evidence of breeding preparedness was present.

In the Madawaska River, there was no significant linear relationship for females ($p=0.059$; $F_{(1,6)} = 5.390$; $r^2 = 0.473$) $\log_{10}$ weight versus $\log_{10}$ length relationship for *M. carinatum* (Table 6). The sample size (n=11) was too small to proceed with a regression analysis . When the sexes were pooled, there was a significant linear regression of length and weight ($p=0.034$,

$F_{(1,7)}$=6.872, r^2=0.495, n = 9).

The female $\log_{10}$ weight versus $\log_{10}$ length regression coefficient was a = 2.382 indicating a lower mass than predicted, a = 3.0, for their respective length. All female specimens that were captured were fish that had already spawned or that produced very few eggs when abdominal pressure was applied.

After pooling the data from the four samples (n_{male}=227, $n_{females}$=212), it was tested for differences in length versus weight relationships between the sexes. Significant difference were recorded between the intercepts of the regression lines between males and females ($p = 0.006$; $F_{(2,436)} = 7.595$;$\lambda = 9.060$;$f^2 = 0.020$; $(1-\beta)_{(v1=2,\ v2=436)} = 0.555$) but not for the slope of the lines ($p = 0.352$; $F_{(3,435)} = 0.867$;$\lambda = 1.229$;f^2=0.003; $(1-\beta)_{(v1=3,\ v2=435)} = 0.136$). This indicates that, in general, females were heavier than males but had a similar allometric pattern, at least for the size spectrum of fish captured (Figure 15).

A residual analysis of the data from the pooled, for all sites, regression analysis indicates that the male sample should have one case removed due to the large pull on the data set (males only: Studentized residual = -11.707, pooled sample: Studentized residual = 8.800)(Table 6). When the male regression was conducted without this data point there was a 12.1 % increase in the coefficient of determination for the male regression model ($r^2_{n=227}$=0.628 increases to $r^2_{n=226}$ = 0.749)(Table 6) with no change in the “p” value of the relationship. When applied to the pooled sample there was an overall increase of 4.5 % in the regression coefficient ($r^2_{n=443}$=0.640 increases to $r^2_{n=226}$ = 0.685)with no change in the “p” value of the relationship.

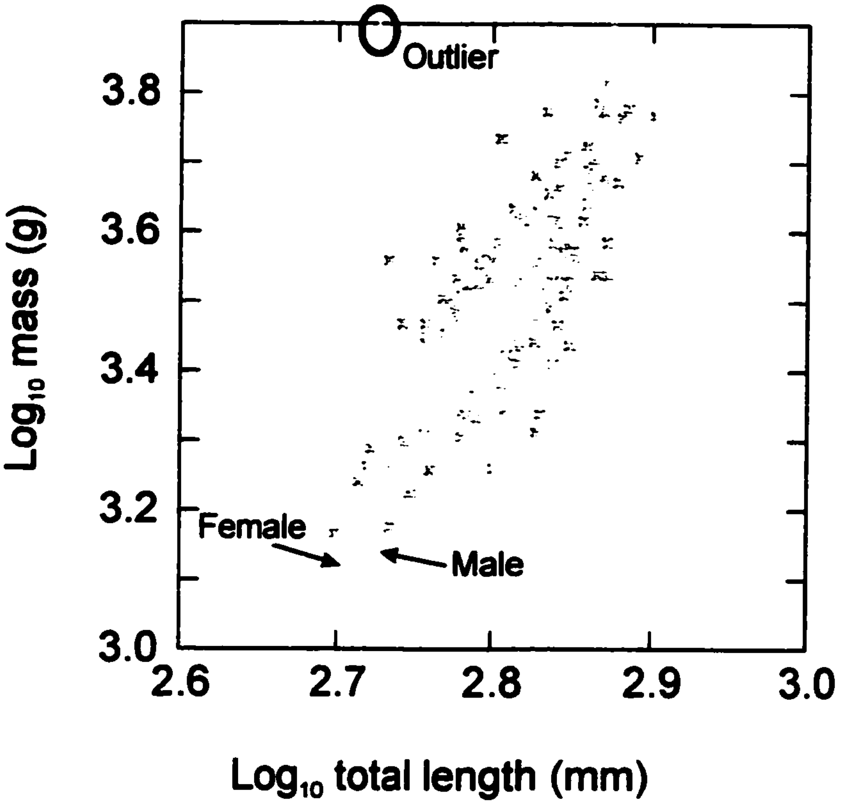


Figure 15. Combined linear regressions of $\log_{10}$ total length in mm (tl) versus $\log_{10}$ wet mass in grams (m) of *M. carinatum* for all sexed fish from all systems. Males (✚)and females(✖) had a significant linear length-weight relationship (males ,$p<0.001$, $F=264.89$, $r^2=0.55$, $y = 2.706(x)-4.106$, $n = 227$ and females $p<0.001$, $F=264.89$, $r^2=0.628$, $y = 2.512(x)- 4.080$, $n = 212$).

4.2.3 Length and Mass Differences Between River Systems

A comparison of length-weight regression lines, pooled for each river, for all fishes was conducted to determine if a common regression equation could be developed. No significant differences were found between the slopes of the regression lines ($p = 0.745$; $F_{(7,436)} = 0.350; \lambda = 0.444$; $f^2 = 0.001$; $(1-\beta)_{(v1=7,\, v2=436)} = 0.066$). However, there were significant differences between the intercepts ($p < 0.001$; $F_{(4,439)} = 60.064; \lambda = 46.620; f^2 = 0.241$; $(1-\beta)_{(v1=4,\, v2=439)} = 1.000$) of the four different study sites (Figure 16). *Post hoc* Bonferroni analysis found that there was a significant difference in the intercepts of the regression lines between the Mississippi and Ottawa Rivers ($p = 0.015$) and the Gatineau River and Mississippi River ($p<0.001$).

This sample was then divided by sex to determine wether the capture of gravid females and males could be affecting the relationship. There was no significant differences between the slopes of sites in either males ($p = 0.769$; $F_{(6,220)} = 0.263$; $\lambda = 0.227$; $f^2 = 0.001$; $(1-\beta)_{(v1=6,\, v2=220)} = 0.0587$) or females ($p = 0.748$; $F_{(7,204)} = 0.407$; $\lambda =; f^2 = 0.241$; $(1-\beta)_{(v1=7,\, v2=204)} = 0.574$). There was a significant difference between the intercepts of sites of males either males ($p < 0.001$; $F_{(4,222)} = 9.442$) and females ($p < 0.001$; $F_{(4,207)} = 33.230$). *Post hoc* Bonferroni analysis found that there was only significant differences in the intercepts of the regression lines between the Mississippi and Gatineau Rivers for both males ($p < 0.001$; $n = 17$, $n = 207$ respectively) and females ($p < 0.001$; $n = 51$, $n = 142$ respectively).

4.3 Fecundity

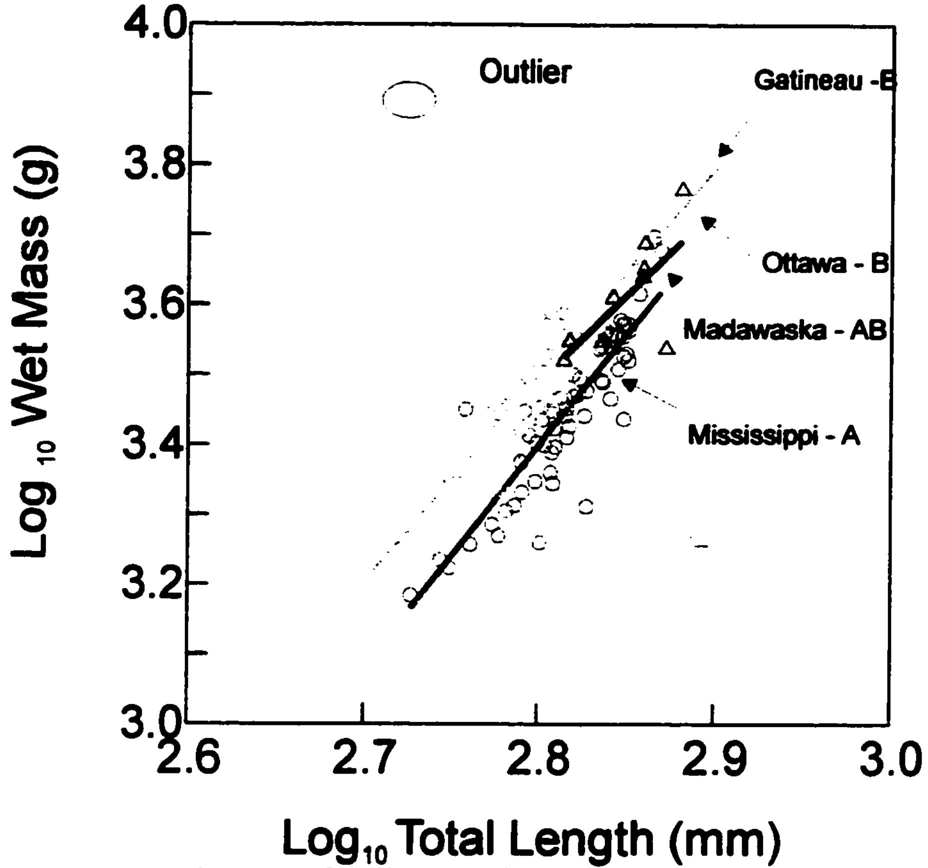


Figure 16. Linear regression plot of the $\log_{10}$ total length in mm (tl) versus $\log_{10}$ wet mass in g (m) of *M. carinatum* grouped by study sites; Mississippi River (O)(Mis), Madawaska (▵)(Mad), Ottawa (+)(Ott) and Gatineau (x)(Gat). Regression line equations are; $y_{Mis} = 3.243(x) - 5.479$, $y_{Mad} = 2.496(x) - 3.500$, $y_{Ott} = 3.113(x) - 5.317$, $y_{Gat} = 2.837(x) - 4.447$ respectively. Letters indicate significant difference between the intercepts of the regression line ($p<0.001$) using *post hoc* Bonferroni tests.

The gonads of 16 specimens (9 females, 6 males and 1 juvenile)(Table 7) from four sites were examined. Both left and right gonads were weighed separately and inspected for any sign of disease or trauma. No visual abnormalities were noticed. The ovaries were bright pink in life and ran the length of the abdomen. Testes were similar in colour and were easily distinguished from the ovaries by their non-granular appearance (no eggs). All gonads were firm and well defined in mature individuals. The juvenile specimen captured in the Grand River was not sexed due to the immature gonads and the lack of exterior sexual markings.

Pre-spawning males and female specimens were always taken in fast, shallow (1.5-2.5 m deep water) water, on hard coarse substrates such as pebbles and rocks, at a water temperature between 18-20 °C. Due to the small number of captures and threatened state of this species in the Mississippi River, no gravid or spawning females were sacrificed for comparison with the Gatineau River.

Eggs were counted and measured as described in section 3.4.1. Egg diameters ranged from 2.3mm to 3.0mm, with a mean diameter of 2.8mm. During the spawn stripped eggs were yellow in colour and adhesive (see also Hackney *et al.*, 1965) however, in the lab the eggs of retained specimens were orange rather than the bright yellow noticed when they were released in life.

Paired t-tests and Wilcoxon Ranks tests were conducted to determine if there was a significant difference in mass of either the left or right gonad of both males and females. Data were tested for normality using Lilliefors test and it was determined that for the pooled samples only the distribution of the left gonad for the pooled sample differed from the normal distribution ($n = 15$, $p_{left} = 0.533$, $p_{right} = 0.004$). Since sexes were to be assessed individually the test for normality was also performed on the individual sexes. Females, were not significantly different from the normal approximation ($n = 9$, $p_{left} = 0.651$, $p_{right} = 0.372$), however, males ($n=5$) did significantly differ from the normal approximation at the right gonad but not the left ($p_{left} = 1.000$, $p_{right} < 0.001$).

Females had an average mass of 5.81 % (± 4.55 % std) of their body mass as gonads while males had an average mass of 6.67 % (± 3.41 % std) of their body mass. It was discovered that the right gonad of females was significantly larger ($p = 0.047$, $t_{(df=9)} = -2.341$; $p = 0.015$, Wilcoxon $_{(df=9)} = 2.429$). For males, no differences between the two sides ($p = 0.356$, $t_{(df=5)} = -1.042$; $p = 0.500$, Wilcoxon $_{(df=5)} = 0.674$) were observed. To account for the paired samples the degrees of freedom were divided in half. There was sufficient power for the tests dealing with males ($d = 7.165$; $\delta = 4.0900$; $(1-\beta)_{(2.5\,,\,2.5)} = 0.8578$), however, the power was below 50 % for females ($d = 2.9582$; $\delta = 3.3395$; $(1-\beta)_{(2.5\,,\,2.5)} = 0.4484$). The power for the non-parametric test was calculated at 95% of the parametric value. Due to the small sample size during any one time frame, it was not possible to determine the relationship of either age or overall size to the volume of gonadal material (# of eggs or mass of testes). What is distinguishable from the present data is that for females from the time of spawning (late May - early June) until the fall (September -October) is that this species regains approximately half of their gonadal weight. It was estimated that, of the fish during the breeding season carried between 9000 and 22000 (mean egg mass = 0.0178 g).

4.4 Ageing

The subopercle, cleithra and scapular bones were rejected as valid indicators of age because, in older specimens, the focal point and the first four or five annuli were illegible due to the thickness of the bone matrix. The opercle provided a better estimation of the age but the annulus detection was sometimes problematical on the distal edge of the bone and near the focus. The age obtained when opercular bones indicated an age of XII or younger was congruent for scales and opercula bones ($p<0.001$, $r^2 = 0.946$; $F_{(1,8)} = 11.801$)(Figure 17). For fish older than XII years, there was little congruence between these two ageing structures ($p = 0.463$, $r^2 = 0.093$, $F_{(1,6)} = 0.615$). For fish older than 12, scales consistently underestimated the age (loss of precision due to annulus crowding) when compared to the opercle (Table 8). The opercle was found to be the best structure to determine the age of fish.

4.4.1 Fraser Lee Back Calculations

Figure 18 shows the expected length of fish at various age calculated from the Fraser-Lee equation. Growth becomes asymptotic after age 13 (using opercle bones) (Figures 18-20), with the most growth coming within the first 5 years (avg. 70.5 mm/y; +/-1.4 cm/y) (Figures 18-20; Table 9). The largest increase in length was in the transition from age II to age III, rate = 80.6 mm/yr. After age III, there is a large degree of variability in the growth rate, as indicated by the standard deviations around the mean length at age (Figure 18).

According to this graph the shortest spawning fish captured the (500mm) should be nearly 8 years old (± 2 years, scales indicate 7+). However, because only one fish longer than 70 cm, 74.5 cm, was sacrificed it made it difficult to determine the approximate age of 43 specimens captured that were larger than 70 cm in our sample. However, it is likely that the longest specimen captured during this investigation was over 30 years old, at the time of capture.

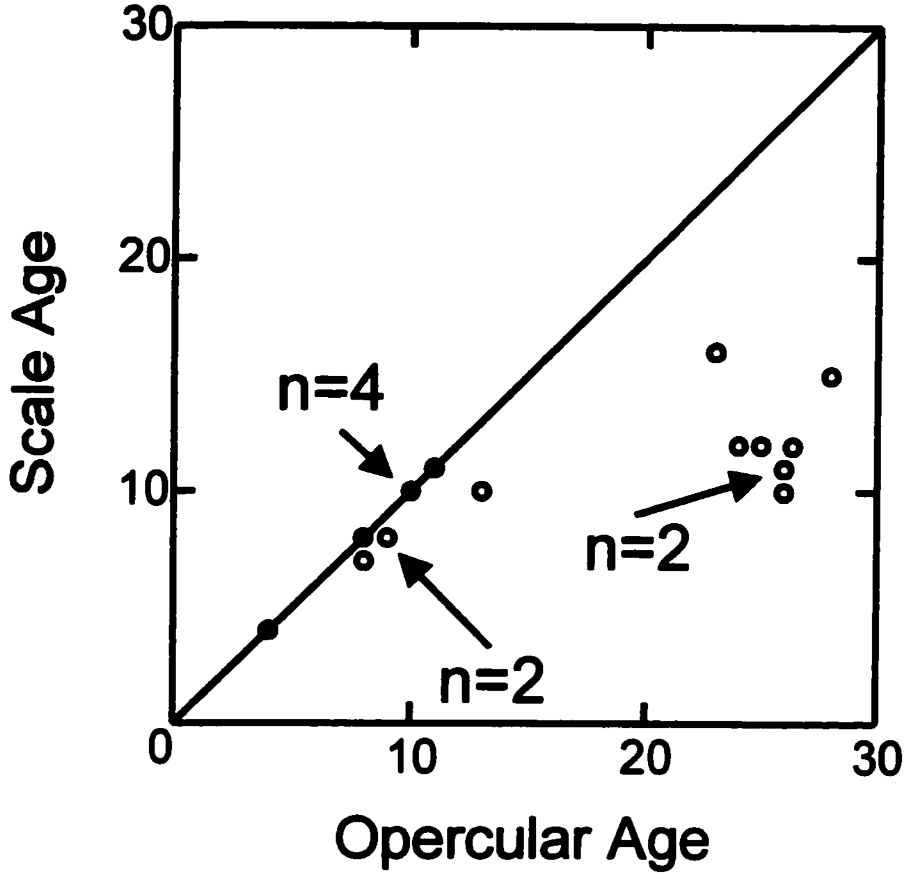


Figure 17. Plot of the age predicted by scales and by the opercular bone. Line represents a 1:1 relationship of scale annuli to opercular annuli. All sexes and water bodies were mixed for this analysis. There is a significant linear relationship between scale age and opercle age ($p < 0.001$, $r^2 = 0.563$, $F_{(1,16)} = 20.566$) when all fish are included.

Fish I.D.	Sex	Mass (g)	Total Length (mm)	Opercle age (y)	Scale age (y)
EL0407CAY10	Juvenille	508	357	4+	4
EL0206GAT6	Male	2489	557	10	10
EL0206GAT1	Female	2631	609	13	10
EL0206GAT10	Male	2101	546	8	8
EL0206GAT11	Male	2631	556	10	10
EL0206GAT4	Female	4465	612	10	10
EL0206GAT5	Female	2843	598	11	11
EL0206GAT8	Male	2180	547	9	8
EL0206GAT9	Male	2367	544	9	8
EL3105GAT3	Female	1752	523	8	7
EL3105GAT2	Male	2666	593	10	10
T13010BLA8	Male	2060	612	26+	11
T20907CED4	Female	3175	661	24+	12
T20907CED5	Female	3466	695	28+	15
T13010BLA5	Male	2106	612	26+	11
T13010BLA6	Female	2907	645	26+	10
T0409OTT3	Female	4532	745	25+	12
T0409OTT4	Female	4232	691	23+	16

Table 8. Comparison of age obtained using scales and opercle for 18 *M. carinatum* specimens. Fish ID indicates the method of capture (e=electrofishing; t=trap-net), date (dd/mm/yy), reach where taken (BLA= Blakeney to Cedar Hill Mississippi River; CAY= Grand River in Cayuga, Ont; CED= Cedar Hill to Pakenham Mississippi River; GAT=Gatineau River, OTT=Ottawa River,); mass is in grams; total length is in mm.

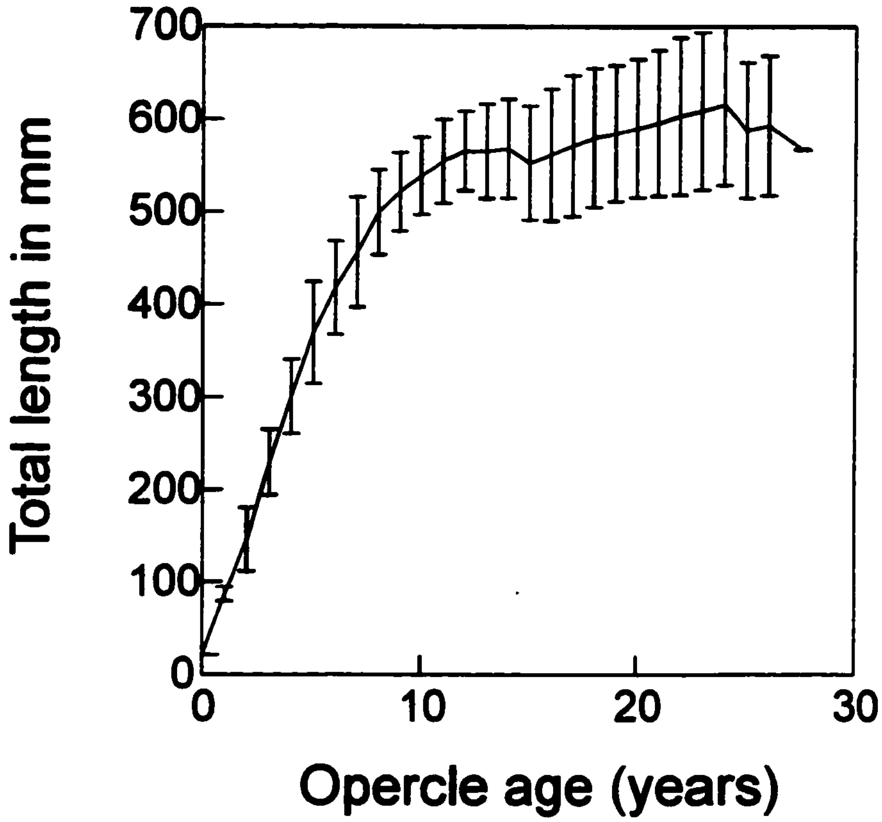


Figure 18. Length at age of sacrificed fish from the Ottawa River Watershed and one juvenile form the Grand River, as predicted by the Fraser-Lee length at age back calculation (*in* Francis, 1990). Error bars indicate one standard deviation around the mean length at age.

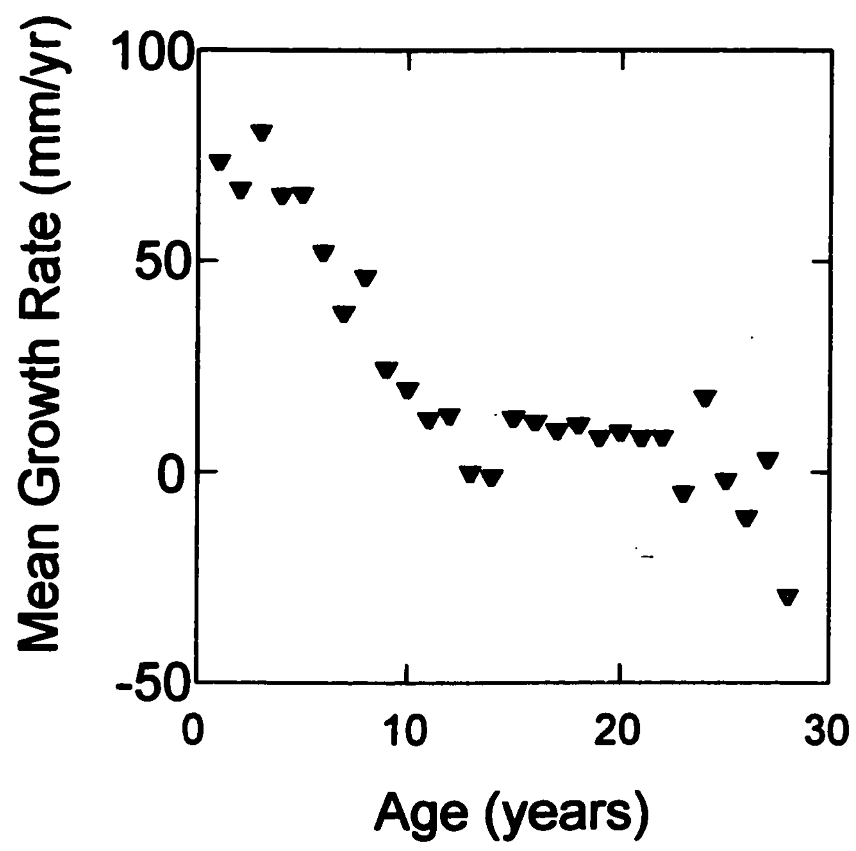


Figure 19. Mean growth (mm/yr) per year for *M. carinatum* of the Ottawa River and one juvenile form the Grand River, its tributaries using the Fraser Lee equation for length at age back calculation. Data are found in Table 9.

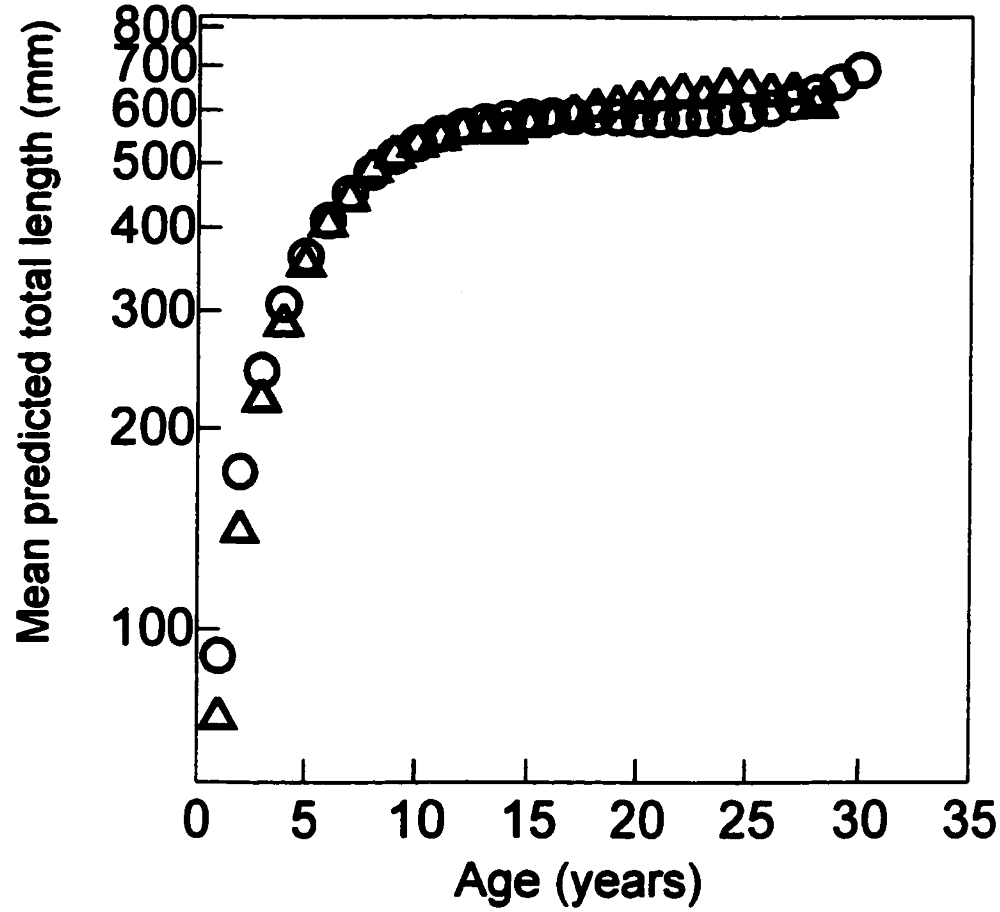


Figure 20. Mean total length (mm/yr) at various age for *M. carinatum* of the Ottawa River Watershed and one juvenile form the Grand River, predicted by the Fraser Lee length at age equation(△) and the third order polynomial (○) of Chen *et al.* (1992). Data are found Table 9.

Age	Carlander (1969)[1]		McAllister *et al.* (1985)[1]		Mongeau *et al*., (1992)[2]		Present Study[2]		Present Study[3]	
	Scales		Scales		Fin Rays		Opercle		Opercle	
	Total length	Rate mm/yr	Total length	Rate mm/yr	Total length	Rate mm/yr	Total length	Rate mm/yr	Total lengtl	Rate mm/yr
Squamation point m	0		0		27		25			
1	61	61	60.0	60.0	72.4	72.4	73.6	73.6	91.3	91.3
2	135	74	103.0	43.0	141.7	69.3	140.5	67.0	172.4	81.1
3	206	71	152.0	49.0	228.6	86.9	221.1	80.6	244.3	71.9
4	264	58	189.0	37.0	303.6	75.0	286.8	65.6	307.6	63.3
5	297	33	246.0	57.0	369.5	65.9	352.7	66.0	362.8	55.2
6	351	54	311.0	65.0	409.5	40.0	404.9	52.2	410.3	47.6
7	414	63	345.0	34.0	466.9	57.4	442.7	37.8	450.9	40.5
8	452	38	373.0	28.0	502.6	35.7	489.0	46.3	484.9	34.1
9	503	51	402.0	29.0	533.3	30.7	513.5	24.5	513.0	28.1
10	531	28	379.0	-23.0	554.8	21.5	533.2	19.7	535.7	22.7
11	559	28	390.0	11.0	572.4	17.6	545.8	12.6	553.6	17.8
12	597	38	410.0	20.0	585.9	13.5	559.3	13.5	567.1	13.5
13			438.0	28.0	598.4	12.5	559.2	-0.1	576.9	9.8
14			461.0	23.0	621.1	22.7	558.2	-1.0	583.4	6.5
15					659.3	38.2	571.1	12.9	587.2	3.8
16					677.0	17.7	583.0	11.9	588.9	1.7
17					684.2	7.2	592.9	9.9	589.0	0.1
18					680.3	-3.9	604.0	11.2	588.0	-1.0
19					687.9	7.6	612.2	8.2	586.5	-1.5
20					669.0	-18.9	621.8	9.5	585.1	-1.5
21							629.9	8.2	584.2	-0.9
22							638.2	8.3	584.4	0.2
23							633.3	-5.0	586.3	1.9
24							651.0	17.8	590.4	4.1
25							649.1	-1.9	597.2	6.8
26							638.3	-10.7	607.3	10.1
27							641.4	3.1	621.2	13.9
28							612.0	-29.4	639.5	18.3

[1]=Using direct proportion length at age back calculation

[2]=Using Fraser-Lee length at age back calculation

[3]=Using third order polyomial function of Chen *et al*. (1992)

Table 9. Mean growth rate (mm/yr) and mean total length (mm) predicted by this study and those of Carlander (1969); McAllister *et al.* (1985); Mongeau *et al.*, (1992). The bony structure used to determine the age is indicated for each study.

(Figure 20). Length at age calculations vary between authors for *M. carinatum*, however, all calculations are based on first order direct proportional increment calculation except for our study where a third order polynomial equation (Chen *et al.*, 1992) was used. This equation, which describe the allometric growth of *M. carinatum*, is: Total Length(mm) = $0.0905 (\text{Age})^3 - 5.1452 (\text{Age})^2 + 95.94 (\text{Age}) + 0.367$ (Figure 20).

4.5 Habitat features in relation to fish capture

Various habitat characteristics were noted at each netting sites. A summary of these data is presented in Table 10 and compares sites in which *M. carinatum* were captured with sites in which *M. carinatum* were not captured. It is assumed that if the fishing gear did not capture *M. carinatum*, it is because they were absent from that site during the sampling period. We could not verify this assumption.

The only habitat characteristics that differed between the two sets of nets is Secchi depth. There was a significant increase of 0.5 m in mean Secchi depth at sites were *M. carinatum* was captured ($U = 699.5$, $p= 0.05$). However, in several cases, Secchi depth was equal to the bottom depth preventing accurate Secchi readings. There were no captures of *M. carinatum* in sites where the Secchi depth was less than 1 m. In 81.9 % of all sites where *M. carinatum* was captured, Secchi depth was equal to or greater than 2.4 m. There was no difference in the mean depth sampled by nets with and without *M. carinatum* captures (U=920.0, $p = 0.106$, n =124). Since most sites were sampled during the breeding season, data were insufficient to accurately determine the depth preference of this species with any degree of reliability. In general, fish

	With *M. carinatum*				Without *M. carinatum*			
	Max	Min	mean	std.	Max	Min	mean	std.
Water temperature °C	26	16	21.24	3.17	28	16	21.43	3.21
Air temperature °C	33	8	22.13	5.82	34	8	23.77	5.30
Secchi depth (m)	3.9	1	2.82	0.71	4	0.5	2.38	0.68
Initial net depth (cm)	210	0	53.48	59.82	210	0	44.56	52.54
End net depth (cm)	800	100	310.87	132.14	800	50	275.54	132.27
Organic (%)	50.0	0.0	6.5	12.0	50.0	0.0	8.4	14.1
Silt (%)	30.0	0.0	5.4	8.9	100.0	0.0	8.3	14.7
Sand (%)	20.0	0.0	4.3	5.5	100.0	0.0	14.5	23.1
Stones (%)	80.0	0.0	9.3	19.4	95.0	0.0	8.8	21.1
Rock (%)	100.0	0.0	12.6	27.3	100.0	0.0	17.5	32.3
Emergent (%)	50.0	0.0	7.6	13.8	50.0	0.0	6.3	12.0
Submergent (%)	100.0	0.0	36.5	40.4	90.0	0.0	17.5	25.6
Wood (%)	80.0	0.0	11.3	21.3	80.0	0.0	8.1	15.8

Table 10. Comparison of habitat data, Mississippi River, for netting sites with or without captures of *M. carinatum*. Organic = detritus and leaf litter; silt = fine sediments <1 mm; sand = sediment > 1mm but < 2 mm; stone = sediments >3mm but <5cm; rock = sediments >than 5cm; emergent = plants such as rushes, sedges, lilies and arrow leaf that have leaves above or at the surface of water; submergent = plants including *Elodea spp.*, *Potamogeton spp.*, *Vallisneria americana* and *Myriophyllum spp.* which are submerged in water; wood =debris such as sticks, twigs, logs and fallen trees.

were captured in water less than 2 m in depth during breeding events in the Mississippi and Madawaska and Gatineau Rivers. In the Ottawa River, depths were often greater than 3 m for many of the nets that captured *M. carinatum*, but exact water depth was not measured.

Fish captured during the breeding season were consistently captured in areas that were within 100 m of rapids (Table 11). In the Mississippi River, 28 of 69 specimens were taken within 200 m of rapids. Forty five of 69 fish were taken within 1 km of the rapids, while only 1 specimen was taken at a distance greater than 3 km away from the nearest set of large rapids (Table 11).

In the Ottawa River, fish were consistently taken at distances greater than 10 km from medium to large size rapids. One specimen was taken in the middle of Lac des Chats, 3 km from the Madawaska River, 6 km from the mouth of the Mississippi River, 18 km from the mouth of the Muskrat River and more than 8 km from the rapids connecting Lac du Rocher Fendu. In the Gatineau River, 1 specimen (October, 14, 1998) was taken 4 km downstream from the rapids below the Alonzo-Wright Bridge. In the Grand River, the two juvenile specimens were taken in a small pool off the main channel 4 km from the closest set of large rapids.

4.6 Spawning preparedness, temperature and dates

M. carinatum specimens were captured in waters ranging from 7 °C up to 27 °C. Data from the Gatineau River in the spring of 1998, indicates that at a temperature of 17.5 °C, 34.4 % of the fish were females at stage V (eggs flowing out of abdomen with manual pressure) females and 52.2 % of all the fish were at stage V. In the Madawaska River, stage V fish were captured at water temperatures of 12.5 °C. In the Mississippi River, fish caught before the water reached

Distance of capture from rapids	Number of *M. carinatum* captured	% of total sample of *M. carinatum*
<100	23	31.94
100-200	5	6.94
200-500	0	0.00
500-1000	17	23.61
1000-1500	15	20.83
1500-2000	0	0.00
2000-3000	11	15.28
>3000	1	1.39

Table 11. Distance of *M. carinatum* captures from closest set of rapids in the Mississippi River. Distances are given in m. Data include both captured and recaptured specimens, n = number of fish, % = percent of total *M. carinatum* sampled.

18 °C were in stage IV. In all rivers sampled, males and females *M. carinatum* had reached the post-spawning stage VI when water temperature was 20 °C.

The extensive data set of 1999 in the Gatineau River allowed us to investigate the relationship of spawning readiness and water temperature. There was no significant difference ($p=0.945$; $df=14$; Pearson $\chi^2=6.713$;$w = 0.248$;$\lambda = 15.598$; $(1-\beta) = 0.7136$) between the frequency of males and females based on temperature or date. In can be inferred that males and females seem to have similar prespawning preference in terms of temperature. However, since both temperature and date are correlated factors it is not possible determine which factor controls the spawning behaviour fully.

Male and female *M. carinatum* may have similar temperature preference in their prespawning habitat but their level of prespawning reproductive preparedness differs. Males entered stage V at a temperature of 13 °C while female attained this stage at 18 °C or 14 days later (Tables 12-13, Fig 21). No males remained in stage IV after June 10th (18 °C) while no females were observed in stage IV after June 17th. (Fig. 21). The spawning period began when the water reached 18°C on June 10th as we started to capture females in stage VI (no or very few flowing eggs when applying pressure on the abdomen). The first males in stage VI were captured on June 17th (Fig 21). A summary of this data is available in Figure 22.

4.7 Tagging and Estimation of Population Size

As indicated in the Methods, tagging was done on all *M. carinatum* captured in the Mississippi River and during the 1999 sampling period in the Gatineau River. Fish were double-

Breeding Status	Prespawning				Spawned	
Gonadal Maturity (Nicolsky 1963)	IV		V		VI	
Water Temperature °C	Female	Male	Female	Male	Female	Male
7	1					
7.5						
8.5						
9						
9.5						
10	1	2				
1.5						
11						
11.5						
12						
12.5	5	3		1		
13						
13.5	2	3		2		
14	1	3				
14.5						
15						
15.5						
16						
16.5						
17	6	5		5		
17.5						
18	6	5	2	9		
18.5	28	11	2	33	1	
19	3		12	47	37	17
Grand Total	53	32	16	97	38	17

Table 12. Frequency of male and female *M. carinatum* in the Gatineau River in relation to temperature. Gender was determined by the presence/absence of tubercles and the gonadal condition (Nikolsky, 1963). There was no significant difference in frequency of males and females in relation to temperature ($p=0.945$; $df=14$; Pearson $\chi^2=6.713$).

Breeding Status	Unspent				Spent	
Gonadal Maturity (Nicolsky 1963)	IV		V		VI	
Calendar date	Female	Male	Female	Male	Female	Male
04/29/1999	1					
05/03/1999						
05/06/1999	1	2				
05/10/1999	2	1		1		
05/13/1999	3	2				
05/17/1999						
05/20/1999						
05/25/1999	1	3				
05/27/1999	2	3		2		
05/31/1999	6	5		5		
06/03/1999	6	5	2	9		
06/07/1999	14	11	1	9		
06/10/1999	14		1	24	1	
06/14/1999	1		1	11	7	
06/16/1999	1		4	8	5	
06/17/1999	1		4	14	9	2
06/21/1999				7	8	10
06/23/1999			3	7	8	5
Grand Total	53	32	16	97	38	17

Table 13. Frequency of appearance of fish classified as male, female and juvenile in the Gatineau River in relation to the calendar date. Gender was determined by the presence/absence of tubercles and the gonadal condition (Nikolsky, 1963). There was no significant difference in frequency of males and females based on calendar date ($p=0.945$, *df* =16, Pearson $\chi^2= 8.00$).

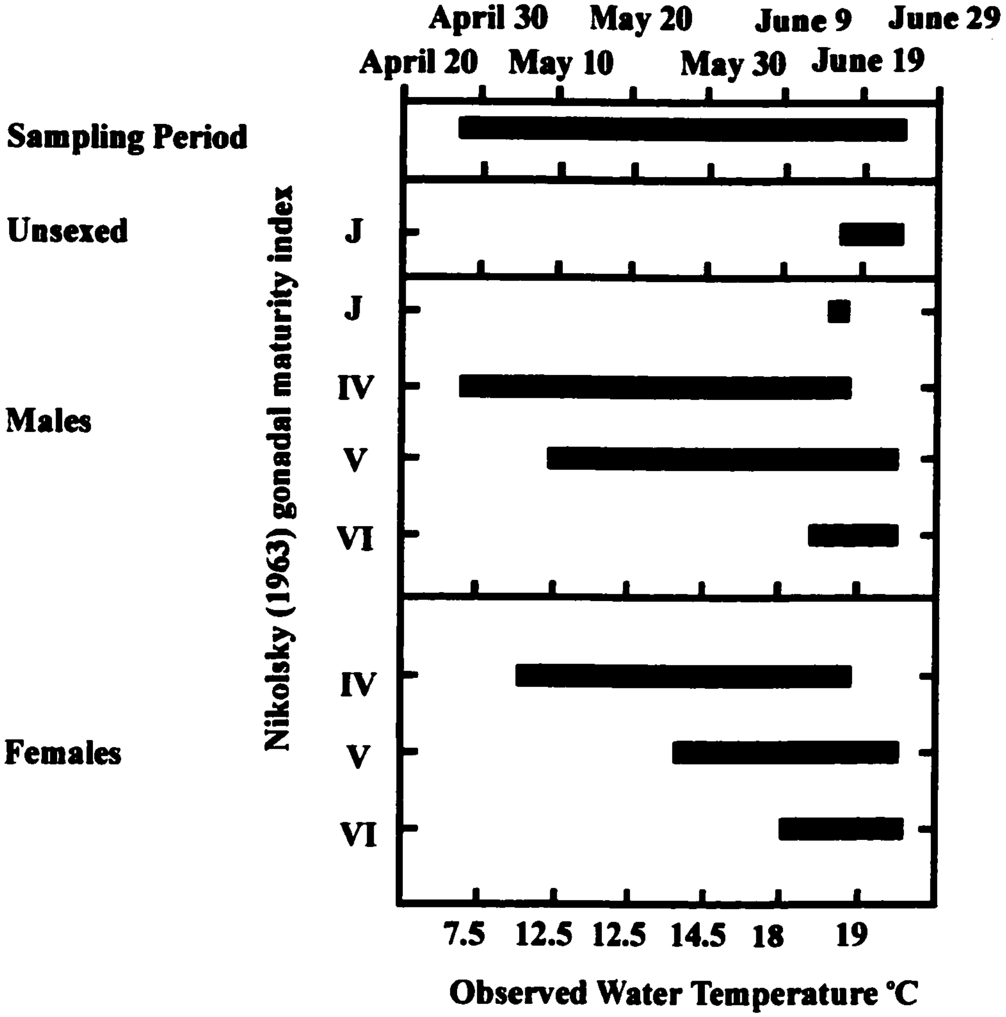


Figure 21. Graph showing the general timing of spawning preparedness and actual spawning of *M. carinatum* in the Gatineau River in 1999 in relation to temperature and calendar dates. Reproductive stages follow Nikolsky (1963). Black bars indicate the range of date when fish were captured.

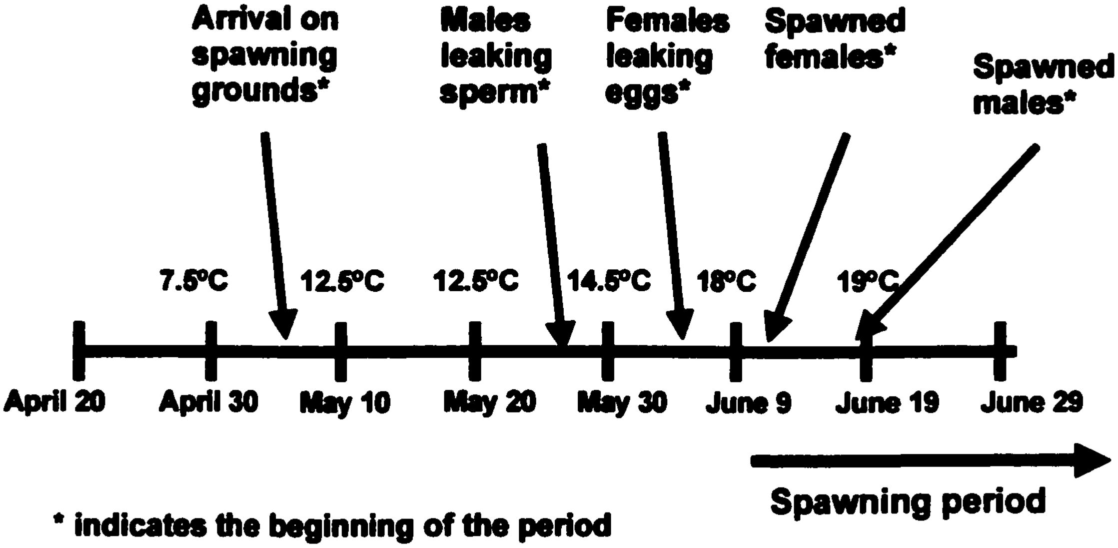


Figure 22. Summary of reproductive events of *Moxostoma carinatum* in relation with the temperature profile of the Gatineau River from April 29, 1999 until June 23, 1999.

-tagged: alphanumeric tag and fin clip. Except for one case, the recaptured fish showed no visible reaction or infection related to the presence of a tag in its anal fin. In one instance a tag on a recaptured fish could not be read and had to be removed. The fish had developed a large cyst around the insertion point. The cyst was drained. The fish was tagged with a new number after the infection site was treated with iodine. In general, tag sites showed no scarring tissue and tags were easy to read even after being inserted for 133 days. In total (including the Mississippi and Gatineau rivers), 78 recaptures were obtained. Tag retention rates were 98.7 % and legibility was 93.5 %. Factors influencing tag legibility were: tag inversions, tag movements and slightly thicker tissue covering the incision and tag.

Sixty-nine fish in the Mississippi River were double-tagged and three fish were recaptured. Most tagged specimens were captured in two sections Blakeney to Cedar Hill (n=32, 2 recaptures) and Cedar Hill to Pakenham (n=33, one recapture). Specimens recaptured were: Z82, captured 22 days and 8 m from its original capture; Y57, captured in the same location 45 days from its original capture; Z00, captured 133 days from original capture and 1500 m downstream from its original location of capture (Table 14). Z82 lost 3 mm in total length and lost 165g in 22 days. Z00 did not change in total length, but gained 377 grams. Y57 lost 138 grams and lost 10 mm in total length (Table 14). Recaptured specimens were on average 124.6 g heavier and lost an average of 2.3 mm. Variation in length and part of the variation in weight may be due to measurement error.

In the Gatineau River, during the spring of 1999, a total of 232 individual fish were tagged. Thirty-eight of these fish were recaptured including 6 double recapture events (Appendix J). All but 5 tags were legible in the field and these erroneous data points were removed from

Fish I.D.	Y57		Z00		Z82	
Sex	Female		Female		Male	
Latitude	45"16'13	45"16'17	45"16'08	45"16'08	45"16'08	45"15'05
Longitude	76"14'53	76"15'01	76"14'54	76"14'54	76"14'54	76"14'19
Date	June 2, 1998	July 15, 1998	June 4, 1998	October 15, 1998	June 4, 1998	June 26, 1998
Days from first capture		45		133		22
Water Temperature °C	19.5	25	19.5	22	19.5	26
Total Length (mm)	666	656	706	706	620	617
Mass (g)	2980	2842	3364	3741	2810	2645
Distance (m) from first capture		1500		0		8

Table 14. Net change in total length (mm) and mass (g) of recaptured specimens from the Mississippi River, Lanark, Ontario. Fish I.D. refers to the identifications alphanumeric implant tag; time from first capture is in days, as well sex is indicated as; Male or Female. The Latitude and Longitude of each capture and recapture is ± 30 m and distance from first capture is given in metres.

analysis. The first capture of a *M. carinatum*, occurred on the first day (Table 14) of sampling but the first recapture took 18 720 seconds (5.2 hours) of active sampling (18 sampling runs, 3 weeks elapsed time). On average each specimen was caught 14.1 days (+/-9.8 days) after its original capture.

From the recaptured specimens, it was possible to determine that post-spawn fish had decreased in mass versus their own pre-spawn mass. In this analysis, only fish captured in Stage IV and V and recaptured at Stage VI were included. Fish were grouped into pre-spawn (Stages IV and V) and post-spawn (Stage VI). Both pair-wise *t* tests and Wilcoxon Signed Rank tests were conducted on the paired data to prevent a type 2 error. For both males (p = 0.034, $t_{(df=6)} = 0.408$, d = 15.142, (1-) = 0.999; p = 0.028, Wilcoxon $_{(df=6)}$ = 2.197) and females (p = 0.046, $t_{(df=5)} = -2.646$, d = 17.652, (1-) = 0.999; p = 0.046, Wilcoxon $_{(df=2)}$ = 1.992) there was a significant decrease in mass from pre-spawn to post-spawn fish. Females lost an average of 288.5 g.(267.1 g s.d.) and males lost an average of 222.3 g.(214.3 g s.d.) as they went from pre-spawn (Stage IV and V) to post-spawn (Stage V) gonadal maturity.

In 1999, seven fish had noticeable markings from the fin clips from the prior year were recaptured. They were identified from the three missing scales on the fourth row immediately ventral to the insertion of the dorsal fin on the left side. In particular the largest specimen measured that was captured for the first time in 1998 was again recaptured in 1999 (see section 4.2.1). The female (1998: TL=781 mm, mass =5800g) was recaptured during the 1999 field season and showed an increase of 17 mm in length and of 58 g in mass. In general, most fish (23 of 34 recaptured specimens) were caught less than 100 m from the original capture indicating little movement while the fish are near the spawning site.

		Mass (g)			Length (mm)		
		Prespawning		Spawned	Prespawning		Spawned
Fish ID	Sex	IV	V	VI	IV	V	VI
L00	Male	2995	2900	2860	653	645	644
L06	Male		4776	4624		714	715
L07	Female	2850		2462	618		599
N20	Female	3350		3366	645		634
N25	Male	2080	2620		590	581	
N31	Male	2534	2576		583	595	
N38	Female	2873	2220		612	588	
N65	Female	2853	2822		657	618	
O64	Male		2846	2645		630	614
O76	Male	3101		2512	609		640
O80	Female	2890		2166	572		567
O86	Female		3009	2640		613	606
L27	Female	4042		3840	689		690
L32	Female	1996	2328		555	593	
L85	Male		3640	3436		655	635
L35	Male		2112	2150		551	558
L36	Female	2257		2193	564		564
L49	Male		3630	3222		635	638
L56	Male	2724	2510		548	593	

Table 15. Net change in mass (g) and total length (mm) of recaptured specimens from the Gatineau River, Gatineau, Québec, 1999. Fish I.D. refers to the Visible Implant Tag, Mass in given in grams and Stage refers to the gonadal maturity index of Nikolsky (1963).

For the Mississippi River, population size estimates were made for the Almonte to Galetta section and for the two reaches where recapture events occurred. Using the equations of Schnable (and its modifications) (Table 16), the population of *M. carinatum* was estimated to range from 623 to 830 fish with 95 % confidence intervals ranging as low as 575 to 897 specimens for the 36 km stretch of the river examined (Table 16).

However, since only three fish were recaptured in two sections of the Mississippi River, this population estimate should be confined to this small section of the river. For the Blakeney section, estimates ranged from 174 to 427 specimens (± 8 s.d.) with 95 % confidence intervals ranging from 150 to 568 individual *M. carinatum*. In the Cedar Hill section, estimates ranged from 174 to 262 specimens (± 31 s.d.) with 95 % confidence intervals ranging from 150 to 267 individual *M. carinatum*.

For the population in the Gatineau River, single mark recapture estimations of the spawning population near the Alonzo-Wright bridge ranged from 671 to 694 individuals. The 95% confidence intervals had a range of 622 to 724 specimens. Using the Jolly Seber multiple recapture model, an estimate of the population and the recruitment size required to maintain the population could be made for each day. At the high point of the spawn, between 2 (± 1 s.d.) and 933 (± 568 s.d.) (Table 17) were predicted to be within the study area. Recruitment into the population peaked on between June 7 to June 10, 1999, when an estimated 636 (± 210 s.d.) entered the spawning area. The largest movement of fish out of the spawning area came between June 14 and 16, 1999, when an estimated 1216 (± 915 s.d) fish left the area (Figure 23)(Appendix H).

River System	Mississippi River			Gatineau River 1999
	All sites	Blakeny	Cedar Hill	
Schnable	830.3	348.0	261.5	686.3
95% confidence interval (Student's "*t*")				
Upper	897.2	436.7	266.9	693.0
Lower	772.8	289.3	256.3	679.7
Standard deviation	6.3	8.3	30.8	9.6
Schnable with the Gerking modification	622.8	174.0	174.3	671.4
95% confidence interval (Poisson's)				
Upper	673.6	199.9	202.2	724.1
Lower	574.7	150.0	150.3	622.5
Standard deviation	6.3	8.3	30.8	9.6
Schumacher and Eschmeyer	722.3	426.9	208.1	694.3
95% confidence interval (Student's "*t*")				
Upper	772.3	568.5	211.5	701.2
Lower	678.3	341.7	204.8	687.6
Standard deviation	6.3	8.3	30.8	9.6

Table 16. Mark recapture estimations for the Mississippi and Gatineau Rivers based on the equations of Schnable (1938), Schnable (1938, modified by Gerking (1953)), Schumacher and Eschmeyer (1952). Confidence intervals are given to the 95th percentile for the appropriate distribution.

Date	Recature estimations	Std.	Recruitment into population	Std.
29-Apr-99	2.000	1.118		
			17.000	5.000
03-May-99	20.000	10.000		
			2.000	0.616
06-May-99	2.000	1.000		
			26.000	8.152
10-May-99	30.000	15.000		
			20.000	12.247
13-May-99	30.000	24.495		
			2.000	0.850
17-May-99	2.000	1.700		
			4.000	1.246
20-May-99	4.000	1.732		
			36.500	18.958
25-May-99	42.500	35.239		
			48.200	30.005
27-May-99	72.000	52.663		
			396.750	207.412
31-May-99	522.750	363.819		
			494.667	298.114
03-Jun-99	904.667	543.118		
			-272.535	90.706
07-Jun-99	289.440	147.966		
			90.783	209.540
10-Jun-99	447.583	261.687		
			636.018	914.582
14-Jun-99	933.800	568.135		
			-1216.152	141.347
16-Jun-99	507.500	123.202		
			171.573	161.810
17-Jun-99	361.667	267.061		
			42.795	60.368
21-Jun-99	150.750	109.000		
			39.889	5.831
23-Jun-99	140.000	71.708		

Table 17. Mark recapture estimations for the Gatineau River based on the multiple capture-recapture equation of Jolly (1965) and Seber (1965). Recaptures and recruitment estimations and the standard deviations associated with them are based of the modified Jolly Seber equation (Appendix H).

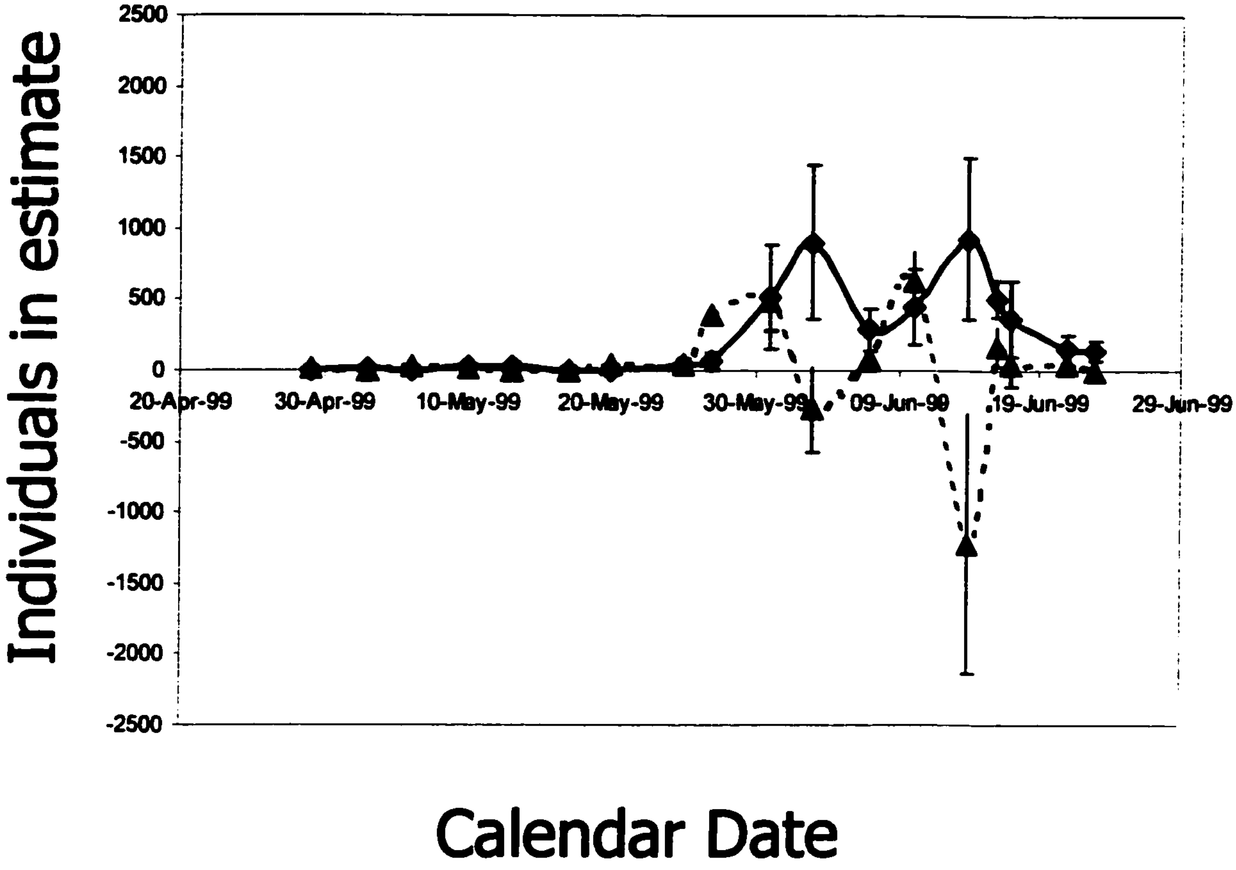


Figure 23. Mark recapture estimations for the Gatineau River based on the multiple capture-recapture equation of Jolly (1965) and Seber (1965). Population estimates (solid line) and recruitment estimates (dashed line) are plotted by calendar date. Error bars are one standard deviation from the mean as determined by the equations of the Jolly Seber model.

For the single capture models estimations from the modifications of Gerking (1953) always produced the lowest estimations and the smallest confidence intervals. Estimations from the Jolly-Seber multiple recapture model suggested that at the peak of the breeding event there was 34 % higher abundance of fish than in other models.

4.8 General External Appearance

In the Mississippi R, nearly 70% of the fish captured showed some apparent external trauma (including lacerations, infections, leeches, fungus, tumours, blindness and unidentified invertebrates parasites) (Table 18). In the Gatineau River, only 6% of the fish showed some kind of trauma (same trauma as the Mississippi minus the invertebrates parasites but with lamprey scars) (Table 18). In the Mississippi River (n=6) and the Gatineau river (n=10), several individuals were blind in one or both eyes. There were three captures (plus one recapture) of individuals with both eyes damaged (2 in the Mississippi River and 1 in the Gatineau River). There were higher occurrences (nearly 78% of captures) of traumas in the Cedar Hill section than in any other section of any river sampled. Parasitism by an unidentified worm at the base of the ventral fins was particularly prevalent on fish of this section.

Several males of the Mississippi and Gatineau rivers showed a papilloma-type growth on the anal fin (Figure 24). These growths were large enough to alter the appearance of the fin to a clubby mottled ball of flesh.

		Water Body	Mississippi River (%)				Gatineau River (%)	Ottawa River (%)	Grand River (%)	All systems (%)
		Reach	Blakeney	Cedar Hill	Pakenham	Total				
		# of Captures	31	37	4	72	272	18	2	364
No trauma			35.5	22.6	97.7	29.2	94.1	100.0	100.0	83.4
Body	Opercle	Trauma		3.2		1.4				0.2
	Lateral	Trauma		3.2		1.4	0.3			0.5
	Dorsal	Trauma		3.2		1.4	0.9			0.9
		Parasites		3.2		1.4	0.6			0.7
		Fungus		3.2		1.4				0.2
	Ventral	Tumor			3.2	1.4				0.2
Fins	Dorsal	Trauma		3.2		1.4				0.2
		Parasites	12.9			5.6				0.9
	Pectoral	Tumor		3.2		1.4				0.2
		Trauma		3.2		1.4				0.2
		Parasites		25.8		13.9				2.3
	Pelvic	Trauma		9.7		4.2				0.7
		Parasites	16.1	19.4		15.3				2.5
	Anal	Trauma		12.9		5.6				0.9
		Parasites	6.5	12.9		8.3				1.4
		Tumor		3.2		1.4				0.2
	Caudal	Trauma		9.7		4.2	0.3			0.9
		Parasites	12.9	25.8		16.7	0.6			3.2
		Tumor		3.2		1.4				0.2
Eyes		Left	6.5	9.7		6.9	2.6			3.2
		Right	9.7	9.7		8.3	0.9			2.1
Lips		Trauma	3.2	9.7		5.6				0.9
		Parasites	16.1	35.5		22.2				3.6
		Tumor		6.5		2.8	0.3			0.7

Table 18. Percent occurrence and location of various external trauma observed on Moxostoma carinatum captured in the Mississippi, Gatineau, Ottawa and Grand rivers. A single specimen can have more than one trauma, and be included in more than one area.

Figure 24. Photograph of "tubercle overgrowth" on the anal fin of a male *M. carinatum* captured in the Gatineau River on June 3, 1999.

5.0 Discussion

5.1 Methods of capture, distribution and CPUE

As indicated in the introduction, the knowledge associated with this species in Canada is confined into the studies of Parker and McKee (1980,1984), Parker (1988) and Mongeau *et al.* (1992). All of these investigations provided some basic information on *M. carinatum* but were based on a single river system and few specimens. In this study, 484 specimens of *M. carinatum* were examined. Fish were captured in the Mississippi River, the Ottawa River (Lac des Chats section), the Gatineau River, the Madawaska River and the Grand River. All these rivers are tributaries of the Ottawa River except the Grand River, Cayuga, Ontario, which is a tributary of Lake Ontario. Present data indicate that this species might not perfectly conform to the small range of environmental parameters (i.e. fast, deep and clear water) and life history characteristics that have been indicated by other authors (Hackney *et al.* 1965; Scott and Crossman, 1973; Parker and McKee, 1980,1984; Parker, 1988).

Prior to the present study, only small populations of *M. carinatum* had been recorded in the Mississippi (Parker and McKee, 1980,1984; Parker, 1988) and Yamaska and Richelieu rivers (Mongeau *et al.*, 1992) and only a few confirmed captures of specimens in the Ottawa River (McAllister and Coad, 1974) had been made. *M. carinatum* is probably misidentified with other *Moxostoma spp.* (Scott and Crossman, 1973). The present study provides the first mention of a large breeding population in the Gatineau River.

In the present study, *M. carinatum* accounted for 12.7 % of all Catostomidae, more than twice the percentage reported in the literature (5%) by Parker and McKee (1984) for the

Mississippi River. However, sampling methodology is an important factor in explaining the differences between the two studies. Parker and McKee (1984) used minnow and hoop nets in their study. Our data for these two gear indicate that approximately 5.2 % of the Catostomidae captured were *M. carinatum*. Thus, the observed increase in relative abundance of this species is more likely the product of the sampling methodology rather than an actual increase in relative abundance.

Previous work in Canada and the United States on *M. carinatum* and other large benthic fishes (Hackney *et al.*, 1967; Parker and McKee 1980; Laarman and Rykman, 1982; von Rossen, 1983; Mongeau *et al.*, 1992; Kreuger *et al.*, 1998) suggested that this species could be captured using a variety of gear: minnow nets, hoop-nets, trap-nets, seine nets and gill nets. In this study larger nets (2 m trap-nets) were the most effective (section 3.2.1) at capturing *M. carinatum*. In fact, 96 % of all *M. carinatum* captures occurred in this type of net in the Mississippi River (Table 1). Although net mesh sizes could catch fish from Age 1 (Laarman and Rykman, 1982), no juvenile were captured using nets. Several factors might explain this occurrence; the habitat of juveniles was not sampled, that juveniles do not enter nets or recruitment is very low for this species of special concern. Juveniles are reported to be very elusive in other studies of this species (Hackney *et al.*, 1967; Laarman and Rykman, 1982; von Rossen, 1983; Mongeau *et al.*, 1992; Kreuger *et al.*, 1998).

This result is supported by other studies showing trap-nets to be both species and size selective based on size and shape of the net (Hubert and Schmitt, 1982; Laarman and Rykman 1982; Hubert and Patton 1994; Hubert, 1996; Kreuger *et al.*, 1998). The steep slope of the littoral zone may have limited the smaller nets from capturing specimens because of the decreased height and length of the leads in comparison to those of the large trap nets (Kreuger *et* *al.* 1998). To illustrate this, on one occasion on July 7, 1998, a school of *M. anisurum* swam over the top of a lead (height = 1 m) placed in a heavily vegetated zone in less than 2 m of water. Consequently water depth and bottom profile may affect the success rate of fish capture in the river (Kreuger *et al.* 1998).

In addition to netting, boat electroshocking was also found to be an effective and safe, method for sampling the spawning populations of the Gatineau 1998 and 1999, Madawaska and Grand rivers (see also; Bauman and Kitchell, 1974; Sonski, 1982; Gilland, 1985; Graham, 1986; Sanders, 1992; Schill *et al.* , 1995; Pushey *et al.*, 1998). Although there is some debate on the use of electrofishing for the sampling of rare and threatened populations (Nielson, 1995), most authors indicate that this method has minimal effects at the population level (Loeb, 1957; Witt and Campbell, 1959; Sanderson, 1960; Bauman and Kitchell, 1974; Sonski, 1982; Gilland, 1985; Graham, 1986; Sanders, 1992; Schill *et al.*, 1995; Pushey *et al.*, 1998). To verify the impact of this method on individual *M. carinatum*, all fish captured by electrofishing in 1998 were kept in large net enclosures for a period of 24 hours before being released in the river. All fish were released and none had visible injuries.

During the pre-spawning and spawning period, CPUE reached 24.1 *M. carinatum*/hour. In the Fall (1998), CPUE was 1 *M. carinatum* / hour. This seasonal pattern was also noted for other fish communities (Sanders, 1992; Schill *et al.*, 1998; Pugh and Schramm, 1998 and Pushey *et al.*, 1998). These results confirm the suggestion that this species, like several other freshwater species, spawns in fast water and does a post-spawn migration off the breeding sites, moving farther downstream in the Gatineau River and most probably into the Ottawa River.

5.2 Length and weight relationships of *M. carinatum* in the Ottawa River Watershed

During the course of this study, the heaviest and longest specimens of *M. carinatum* were captured in the Gatineau River in 1998 and 1999 respectively. The heaviest specimen was a gravid female weighing 7.938 kg, (TL = 750 mm) and the longest was a post-spawn female measuring 798 mm TL (5.858 kg). Both were captured in the Gatineau River. Both specimens are, heavier and longer than any previously captured *M. carinatum* or *Moxostoma spp.* reported in Trautman (1957), Scott and Crossman (1973), Jenkins (1970, 1980, *pers. comm.* 2001) or Mongeau *et al.* (1992) for the Southern United States and Canada. In all river systems examined, except for the Ottawa River (n=13), the average male was significantly shorter and lighter than the average female yet, both males and females attained sizes in excess of 700 mm.

The length-weight regression coefficients (condition factor) from the Mississippi River (a = 3.2) and the Ottawa River (a = 3.1) suggest that these specimens are heavier for their length than the Aideal@ fish (a = 3.0) (Wootton, 1998). This is in contrast to the fish in the Gatineau and Madawaska which all had regression coefficients of less than three indicating these fish were lighter for their length than the Aideal@ fish (Table 6). This is similar to the findings of Mongeau *et al.* (1992) where a low condition factor for *M. carinatum* was recorded for the Yamaska and Richelieu River systems. The time of capture suggests that the reduction could be due to the release of large amounts of gametes (Wootton, 1990). Gonad measurements of fish taken in June of 1998 in the Gatineau River indicated that gonads made up in excess of 14 % of the wet mass of both male and female specimens of *M. carinatum*. Accordingly females showed a decrease in the regression coefficient from 3.13 to 2.81 before and after spawning. In males, the regression constant increased as the spawn progressed.

One possible explanation for this increase in regression coefficient, at least from Stage IV to Stage V in males could be the increased water content in the testes. During Stage IV, testes are firm and compacted. During Stage V, when the sperm are easily striped from the males the sperm must have an increased water content in order to be ejected.

Most fish captured in the Mississippi were caught during the summer and fall when gonads are maturing and when the fish had a chance to feed during the summer, thus resulting in a higher condition factor as the summer progressed (Wootton, 1990).

A constant in all the length-weight regressions done in this study is the fact that there were no significant differences in the slope of the regression lines between populations. This suggests a common growth pattern between populations. This common pattern could therefore serve as a measure of the fishes health or breeding state (Wooton, 1990). However, males and females should be evaluated separately. It is evident from the captured specimens that males and females were significantly different in both mean mass and mean length for all river systems. Although the slopes of the regression lines were not significantly different within river systems, the intercepts of these lines were different, indicating that for adults, the sexes have different masses for similar lengths. Due to the relatively few captures outside of the breeding season it is not possible to determine wether the difference was related to directly to the gonadal or somatic tissue.

5.3 Redhorse Species Associations

No study has examined species associations within the tribe Moxostomatini. In the Mississippi River, many *M. carinatum* were captured in nets that contained other *Moxostoma* *spp.*. This trend was also observed in the Ottawa River, with one slight difference, there were more *M. macrolepidotum* than *M. anisurum* in samples without *M. carinatum* in the nets. In both river systems, a high number of *Moxostoma spp.* in nets was associated with an increased probability that *M. carinatum* would be captured. Data on the Ottawa and Mississippi Rivers indicate a strong tendency of *M. carinatum* to be more abundant in nets where there was an increased abundance of both *Moxostoma spp.* and *Micropterus dolomieu*. This was possibly related to the propensity of nets to capture fishes from different depths, due to the lead length, 50 m, or it might indicate that the two species prefer similar habitat. The later would be contrary to previous accounts of preferred distinct habitats for these *Moxostoma* species (Scott and Crossman, 1973).

In the Gatineau River, several *Moxostoma spp.* were caught during the electrofishing sampling. However, there seems to be a temporal instead of a spatial partitioning on the spawning grounds since species seems to prefer different spawning temperatures (and dates), *M. carinatum* being the last redhorse species to spawn.

5.4 Habitat Associations

Previous research by Hackney *et al.* (1967); Jenkins (1970); Parker and McKee (1980,1984); McAllister *et al.* (1995) and Parker (1988) indicated that this species lived in fast flowing, clear, deep water. According to the results these habitat characteristics are typical of the spawning habitat of this species. In the Gatineau , individuals in spawning state were taken in areas downstream of rapids with an abundance of hard, coarse substrate, as described by Hackney (1967). In the Mississippi River, fish were also captured on hard substrate in areas near rapids located in Blakeney and Pakenham townships.

During the summer, however, the Mississippi River *M. carinatum* were caught on a variety of habitats. For example, many fish were caught in areas with high abundances of vegetation, fairly slow current and soft substrates (Appendix K). This apparent non-conformity in habitat characteristics for several of the fish captured in the Mississippi River could be an indication that this species is not as selective for habitat as once thought or that several fish were caught while moving from one area to another (transient in an non ideal habitat) or that because the Mississippi River population is a closed system, fish must survive in sub-optimal habitats. It is possible that a combination of these three reasons explains the range of habitat characteristics for this species in the Mississippi River system. For example, a few captures (n=3) did occur in areas where the sediments were primarily made of silt and organic debris. All captures on soft substrates, including one recapture, were large females that appeared to be actively feeding, as evident from their swollen abdomen and the production of feces when pressure was applied to the abdomen.

In the Pakenham to Galleta reaches, where only a few *M. carinatum* were caught during the spawning season, it was not possible to determine if this species moved into the downstream areas of the Mississippi River below Pakenham where the water becomes increasingly turbid, deep and slow. Despite the few captures of *M. carinatum* around Pakenham, it appears that this species can survive in this area despite the less than "ideal" or typical habitat.

In the Mississippi R., areas with the greatest abundance of *M. carinatum*, had Secchi depths greater than 2 m. It was not uncommon for Secchi depth to be equal to the depth of the water column. Our Secchi depth average value (2.25 m) in the Mississippi R. is higher from that observed by Parker and McKee (1984) 1 m. However, the size of the Secchi disk used by

Parker and McKee (1984) is unknown and could account for this difference.

Specimens captured in the Cedar Hill to Pakenham were 2 km away from any rapids. *M. carinatum* were only caught this far downstream of rapids only after the breeding season. From the type of gear used, it was impossible to determine the swimming direction of the fish. However, the capture of one specimen in the spawning area and its recapture in a vegetated area downstream of the breeding site suggests a downstream migration from the rapids after spawning.

The best estimate of this species' summer habitat could come from the examinations made in the Lac des Chats area of the Ottawa River. In nets, where *M. carinatum* was captured the net depth was always greater than 3 m and was as deep as 10 to 12 m, in areas with few plants and probably coarse hard substrates. The capture of specimens in deep waters reinforces the idea that they can be captured in areas not previously considered typical for this species (see Hackney *et al.*, 1967; Jenkins ,1970; Scott and Crossman, 1973; Parker and McKee, 1980; 1984, Jenkins and Burkhead, 1993).

This wider definition of the preferred habitat used by the *M. carinatum* must be applied by managers when assessing an area to be targeted for the protection of this species. This is important since most present action plans, such as the OMNR's *M. carinatum* breeding sanctuary in the Mississippi River, are focused on the breeding areas, but it appears that this species is not restricted to this habitat during the entire year.

5.5 Age and growth

Only the opercular bones and dorsal scales provided accurate determination of the age of the *M. carinatum*. These two structures provided similar reading of the fish age for specimen younger than 12 years old. Carlander (1969) and McAllister *et al.* (1985) indicated that annular formations in scales should be clearly visible for young *M. carinatum*. For specimens older than 12 years, the detection of valid annuli on scales proved to be very difficult. Fortunately, opercular bones were found to be legible to, at least, age XXVII, an age that doubles the age previously recorded using scales (Carlander, 1969) and seven years older than that observed by Mongeau *et al.*, (1992) using fin rays. Twelve years old fish measured 565.8 mm, using the Fraser Lee proportional back calculations method. This value is lower than that published by Carlander (1969: 597 mm TL) for the same age. Carlander (1969) also indicated that the maximum size of this species at 737 mm. During our sampling program, 2.9 % of the fish were greater than 737 mm.

Beamish and Harvey (1969), Casselman (1969, 1974, 1979, 1990), Quinn and Ross (1982), Campana (1984, 1990) and Laine *et al.* (1991) addressed the issue of lack of reliability of scales for long-lived fish. They indicated that the relationship between the age predicted by external calcified structures decreases at some time "t" when the somatic growth of the species decreases in order to begin gonadal growth. This difference is the result of physiological changes such as scale reabsorption, i.e. in winter, to protect the axial bones from being reabsorbed, thereby decreasing the accuracy that scales provide as an indicator of fish age (Bigler, 1989). These physiological reasons might explain the lack of accuracy of scales for *M. carinatum* older than 12 years old.

Using the Fraser-Lee equation, the youngest *M. carinatum* captured during the spawning period was at least age VI with a maximum of age VIII. An examination of the scale of this fish confirmed that this fish was 7+ (this fish was not used to obtain the Fraser-Lee equation). It was impossible to accurately age the largest specimens (>700 mm, n=43) since no specimen of that size were sacrificed (no opercular bone). However, using the growth rates published by Mongeau *et al.* (1992)(max. age = XXII+) and those calculated from the present study, it is reasonable to suggest that the largest specimens would be older than 30 years.

One important piece of information that can be gathered from annular marks is growth increments, and rate using annular ring information (Fry, 1943). Traditionally, the von Bertalanffy calculation was used to determine size at age as well as growth rate. However, in long-lived species, this equation can overestimate the growth rate of the older individuals (Chen *et al.*, 1992). In our case, the growth curve can be best represented by a third order polynomial function using the Fraser-Lee equation estimates. This method of curve fitting, although non-traditional, can provide a better fit for the present data than the traditional von Bertalanffy equation, by decreasing the error of the model beyond the range of the data. Although this model accurately predicts the length at age within the size classes investigated during this experiment, there were serious problems at predicting the age of extremely large specimens. At age 30, the regression predicts a fish would achieve a total length of 691.4 mm, by age 35 the model predicts a length of 935.6 mm. This large increase in length is highly speculative because as Chen *et al.*(1992), indicates most models used in natural systems describe the growth of fish accurately within the measured values, beyond measured values, the estimates are likely to be inaccurate. The observed growth data has some serious gaps (age 0-8 and age 12-22). Consequently, the present third order polynomial model's predictive power outside of the data range is low.

5.6 Reproduction

There was a temporal sequence of spawning activities among *Moxostoma spp.* in the Gatineau river. *M. macrolepidotum* was first to spawn, followed by *M. anisurum* and *M. carinatum* being last in this system. Hackney *et al.* (1967) and Jenkins (1970) also noted such a temporal sequence. Both authors indicate that each species of *Moxostoma* requires a specific temperature range to initiate spawning activities. For *M. carinatum,* data from the Gatineau River suggest that spawning occurs when the temperature is between 17.5°C and 19°C.

The timing of spawning appears to coincide with specific temperature profiles. As summarized in Figure 22, males became ready to spawn at a temperature 4.5 °C colder than females (see also Table 13). The presence of sexually ripe males on the breeding ground prior to females corroborates the observations of Hackney *et al.* (1967). The ability of the males to produce sperm prior, during and after females have released their eggs would no doubt provide a distinct advantage since it would ensure the availability of sperm during the fairly short period in which they are actively spawning (Wootton, 1990). A similar reproductive pattern was observed by Cooke and Bunt (1999) for *M. valenciennesi*. In the Mississippi River, spawning individuals were all taken prior to 20 °C, in the Madawaska sexually ripe specimens were taken in only one of the two years when water temperatures were in excess of 16 °C and no individuals were taken in the Muskrat river when sampling occurred prior to 14 °C.

Contrary to the observations of Parker and McKee (1980, 1984), no redds were observed from the present study in any of the locations where breeding individuals were captured in the Mississippi River. According to Jenkins (pers. comm., and videotape, Roanoke College), spawning rituals of *M. carinatum* might differ from what was previously indicated by Hackney *et al.* (1967). Videotape evidence from Virginia shows *M. carinatum* defending spawning areas during the day. It shows the redd being mainly an artifact of the aggressive mating, not a depression dug before spawning. In the Gatineau River, no redds were noticed but spawning behavior was never observed. Some habitat differences mainly in the nature of the sediments could explain the lack of large visible redds in the Mississippi and Gatineau rivers. Large rocks and stones (>7 cm in the Gatineau and Mississippi Rivers) were prevalent in the Ottawa River and the tributaries where spawning *M. carinatum* were observed. In Virginia, the spawning substrate is composed mainly of small rocks (2-3 cm in diameter) with a moderate current (Jenkins, pers. comm.). Clearly, the construction of redds in the Gatineau or Mississippi Rivers would be a difficult endeavor for a fish. This would indirectly support the hypothesis that redds in these rivers might be the result of spawning activity, not a prelude to spawning activity.

It was noted by Hackney *et al.*, (1967) that this species might have a tendency for important migration from the fast flowing shallow water in the spring to other areas of the river during the summer. This would suggest that few if any specimens should be captured on the breeding grounds once spawning has occurred. Usually nets contained one or two individuals of the *M. carinatum* during the summer in the Ottawa and Mississippi rivers and during spawning it was not uncommon to catch 5 or more fish in a net. The recapture of one *M. carinatum* several kilometers from its site of capture near spawning grounds suggests a capacity for long-distance migration. But, the capture of two individuals within 50 m of a known spawning site in the Mississippi R. refutes the notion that this species migrates great distances. However, in the Mississippi River, the ability for large scale movements is constrained by the landlocked nature (because of dams) of each sections. Consequently, in the Mississippi River, the species must be able to complete its entire life cycle within the confine of the sections.

In the Gatineau River, fish recaptures were always made near the spawning grounds since sampling was limited to the area near the spawning ground. Nonetheless, the lack of recaptures of *M. carinatum* in early May 1998, in October 1998 and in May 1999, suggests that fish remain near the spawning grounds only for a short period of time. Because, electrofishing is not very efficient in water deeper than 3 m (Gilland, 1985; Graham, 1986; Sanders, 1992; Schill and Beland , 1995; Pushey *et al.*, 1998), it was not possible to ascertain that fish spawning near the Alonzo Wright bridge are part of a resident population of the deeper waters of the Gatineau River or if they reside in the Ottawa River. Sampling between the mouth of the Gatineau River and the Alonzo Wright bridge on October 14, 1998, produced only a few isolated captures suggesting that the spring spawning population near the Alonzo Wright bridge resides mainly in the Ottawa River the rest of the year.

5.7 Determination of population sizes

The use of the subcutaneous implant tags to identify recaptured specimens appeared to have little detrimental effect on the recaptured specimens (Butler, 1957; Roberts *et al.*, 1973 a,b,c; Morgan and Roberts 1976; Crook and White, 1995). In only one case was there any signs of infection. There was only one case where a tag was lost and five cases where a tag was misread. These results are similar to those obtained in studies using tags for other riverine species (Isaakson and Bergman , 1978; Haw *et al.*,1990); McMahon *et al.*, 1996; Treasurer, 1996; Halls and Azim, 1998). This method inflicts a quick and relatively benign mark to a threatened species when compared to the traditional method of external tagging (Wydoski and Emery, 1983).

M. carinatum appears to comprise a larger proportion of the Catostomidae population in the Mississippi River than observed by Parker and McKee (1980, 1984), and is more widely distributed in the Ottawa River watershed than previously reported (Scott and Crossman, 1973; McAllister and Coad, 1974; Jenkins, 1980; Parker and McKee 1980, 1984). In three of the four areas where *M. carinatum* was sampled it was among the top six most abundant species of fish (Table 2). This could be the result of one or more of the following factors: increased sampling effort, gear diversity and our ability to distinguish this species from other *Moxostoma spp.*

Parker and McKee (1980) did not indicate the population size estimate or the number of individuals they examined but indicated that the *M. carinatum* sample totaled 5% of the Catostomidae in the Mississippi River. In the present study, the *M. carinatum* comprised 12.1 % of the total Catostomidae population of the Mississippi River, a value more likely the result of a different sampling regime than an actual increase in population size. Consequently, we do not have a definite reason to think that the population of *M. carinatum* as increased or decreased in the Mississippi River during the last 20 years.

An estimate of the population of *M. carinatum* for the Mississippi River and of the spawning population near the Alonzo-Wright Bridge was made using capture-recapture data. Population estimate based on single capture-recapture must comply with some conditions to be reliable. Most of these conditions could not be verified in the present study casting some serious reservations on the actual estimates. Some of these conditions are equal time periods between the capture and recapture sampling and no immigration/emigration in the studied population (Ricker, 1971, 1980; Pollock and Mann, 1983; Pollock *et al.*, 1990)

In the Mississippi River, the low capture and recapture rate preempted the use of multiple recapture models and any model that required estimates of survival and recruitment rates.

Therefore, three standard models were chosen to get a rough estimate of population size. We used the Schnable (1938), Schnable (1938, with Gerking ,1954 modifications) and the Schumacher and Eschmeyer (1954) models. These models are often used by the OMNR (Wilcox *et al.*, 1997; Haxton 1998a and 1998b, 1999) and, more importantly, these models are flexible enough to deal with the relatively few captures returned during this experiment.

Estimates of the size of the population of *M. carinatum* for the section investigated of the Mississippi River indicates a population of 623-830 fish. But, when the individual sections of the river were analyzed separately rather than compiled, the results were somewhat different. The total population was estimated between 348 and 687 fish. The main reason for this difference is that only two sections of the Mississippi River produced recaptures, even when all habitats of the river were sampled. Therefore, only the sections where recaptures occurred should be viewed as producing valid estimates.

In the Gatineau River, the situation was slightly different. Due to a possible high immigration/emigration rate into the test site, one of the major assumptions of the single mark recapture models were violated. Over the course of the sampling period there was a general increase in abundance of this species in the samples suggesting an important immigration rate. Moreover, the lack of large scale captures in the 1998 October sampling, indicates that emigration also occurred from the breeding grounds. Despite these violations the mean population number predicted by the estimation of the single capture recapture equations were approximately 670-695 fish.

The estimation based on multiple recapture reduces the error of the model by accounting for any second or third recapture of an individual from being counted as a new recaptured specimen. By doing so this reduces the inherent error by reducing the total number of recaptures proportionally and taking into account when each recapture was originally marked and when each subsequent recapture occurs (Ricker, 1971). For the Gatineau population estimates ranged from 2 fish to as high as 1012 fish at the peak of spawning (Figure 23). The peak number in population estimates occurred one week June 3rd (one sampling event) prior to the first post spawn fish being captured.

As mentioned previously this model also predicts the size of population required to maintain the observed fluctuations in the population. The largest removal of fish from the breeding grounds occurred between the 14th and 16th of June. This also coincided with the lowest capture during the ideal temperature range and a major storm. The ability of this model to estimate the population and the recruitment pool is a valuable tool when tracking a large transient population.

There are no other tributaries as large as the Gatineau River along the Lower Ottawa River until its confluence with the St. Lawrence River. Therefore, the Alonzo bridge spawning grounds is possibly the only large spawning site for this species along the lower Ottawa River basin. As such, this area of the Gatineau River is a unique habitat for this species and the habitat should be protected by all legal means possible. Moreover, the same habitat is the spawning ground of many of the fish species (Table 2) captured in conjunction with *M. carinatum*.

5.8 Trauma and General Characteristics of Fish Health

As mentioned previously several fish captured in trap nets in the Mississippi River had noticeable torn fins or abrasion (Table 18). Although it could not unequivocally be related to the fishing gear, it was noted that the incidence of scarring and torn fins was much higher for fish captured in trap nets than those captured using electrofishing methods (Table 18).

Most fish captured in nets showed evidence of torn fins, bite marks from snapping turtles (also captured in the nets; no mortality) on the fins, as well as minor abrasions from the nets on their snout. Most of these injuries though appeared to be a direct result of the large trap-nets when they were set in areas of high current. They also seemed to crowd into one area of the net during collection and thrash before being remove from the nets. This could have caused some of the external trauma. In addition, many fish also had large areas with scales showing signs of rejuvenation either from being bitten by a predator when younger or from abrasions with rocks or trees. The abrasions caused by the net appeared to be the only detrimental effect of the netting process in the Mississippi River, since no mortality was observed for this species in the net as well as the lack of any dead fish along the river that were either tagged or had fin clips.

Of special concern was the presence of a small worm parasite found in the soft tissue immediately posterior to the fins, most commonly, the ventral fins. The parasites, although not noticeably causing any major detrimental effects ranged in number from 1-7 parasites per fin. These worms were found mainly on the fish captured in the Blakeney to Pakenham area, in the area below the rapids of the Blakeney falls where many breeding individuals were captured. The worm was only present in those fish captured from May until the end of June, and was not seen on fish captured from July to October. Further investigation is needed to identify this parasitic worm and to determine its effect on this threatened species.

Another area of concern are the possible negative impacts on this species due to the developments near their spawning grounds, especially along the Mississippi and Gatineau Rivers. In the Mississippi R. where agricultural activities are intense, the introduction of fertilizers, herbicides and pesticides could prove detrimental if they come into contact with the developing eggs and juveniles of this species. In areas of agricultural activities along the Mississippi River, from Pakenham to Galetta, only 4 *M. carinatum* were captured. Consequently, special care should be taken to preserve the habitat of what looks to be an aging population of *M. carinatum* in the Mississippi River. There is also a desperate need to determine the level of recruitment and renewal of the population. This is particularly troubling because we were unable to capture any young fish during our sampling.

In the Gatineau, anthropogenic pressures take the shape of fluctuating water level, housing and industrial development and road construction. For example, a project dealing with the enlargement of the Alonzo Wright from two to four lanes is being discussed. It is quite clear that the spawning ground of all the species that spawn in this area could be greatly affected by the actual construction of the bridge. Special care should be taken to minimize the impact of heavy machinery on the nature of the sediment near the bridge. It should be noted that while this study concentrated on *M. carinatum*, several species were found to reproduce in the same area, this included two other COSEWIC listed species, the Channel Darter (*Percina copelandi*) and the Marginated Madtom (*Noturus insignis)*. Consequently, this sector of the Gatineau River should be protected from anthropogenic stresses.

6.0 Conclusions

In conclusion, it appears that *M. carinatum* in the National Capital Area and the Grand River is more widely distributed locally than previously thought, and was captured on a variety of substrates throughout the year. However, this species was never caught in areas where Secchi depth was less than 1 m. For breeding purposes these populations do show an increased abundance on hard coarse substrates in fast water sections of the Gatineau, Madawaska and Mississippi Rivers during the breeding season from late May to early June, when water temperatures are greater than 14.0 °C. During the spawning event some recaptured specimens were observed to lose up to 14 % of their wet mass. Males and females are easily distinguished during the breeding season by the presence of nuptial tubercles on the snout, anal and caudal fins. Tubercles were lost shortly after breeding and were noticeable again by October. Both sexes had two gonads with the right gonad being larger in females but no difference in males. Females were estimated to release between 9000 and 22000 eggs during the spawning event. There can be large scale changes in the fishes length and weight regression coefficient as a result of changes in the fishes' mass when breeding. Breeding individuals were captured up to a size of 798 mm and a mass of 7980 g. Ageing of this species has yet to be validated however, using the opercular bone appears to be a better measure than scales. Opercular bones appeared to estimate the age of the fish after age XI at which point scales became illegible. Using the opercular bone the maximum observed age was estimated at XXVII+ years. Growth in this species appeared to slow at approximately age VIII, at a length noticed to be approximately the minimum size recorded on the breeding grounds. *M. carinatum* occurred sympatrically in the National Capital Region with three other *Moxostoma spp.*, and was generally caught in increased abundance when one or more *Moxostoma spp.* were also present. Single recapture models predicted the population of *M. carinatum* to range from 576 to 898 fish in the Mississippi River and 671 to 694 for the Gatineau River. Using a multiple recapture model for the Gatineau River the population peaked at 933 individuals with a recruitment population in excess of 1400 individuals using this location as a spawning site. This fish is susceptible to capture by a variety of sampling gears, but large trap-nets over 2 m and boat electrofishing produced the highest number of capture for the unit effort, of all the gear used for this experiment. Despite the discoveries of large breeding populations of this species in this watershed its cryptic nature, increased anthropogenic stresses and the disjunct distribution, indicate that these new captures do not preclude this species from being at risk. Several key elements of this species' life history remain unknown: diet composition; reproductive success; development of yearling and juvenile fish; and movement patterns prevent this species from being removed from the COSEWIC list as a a species of special concern until more is known.

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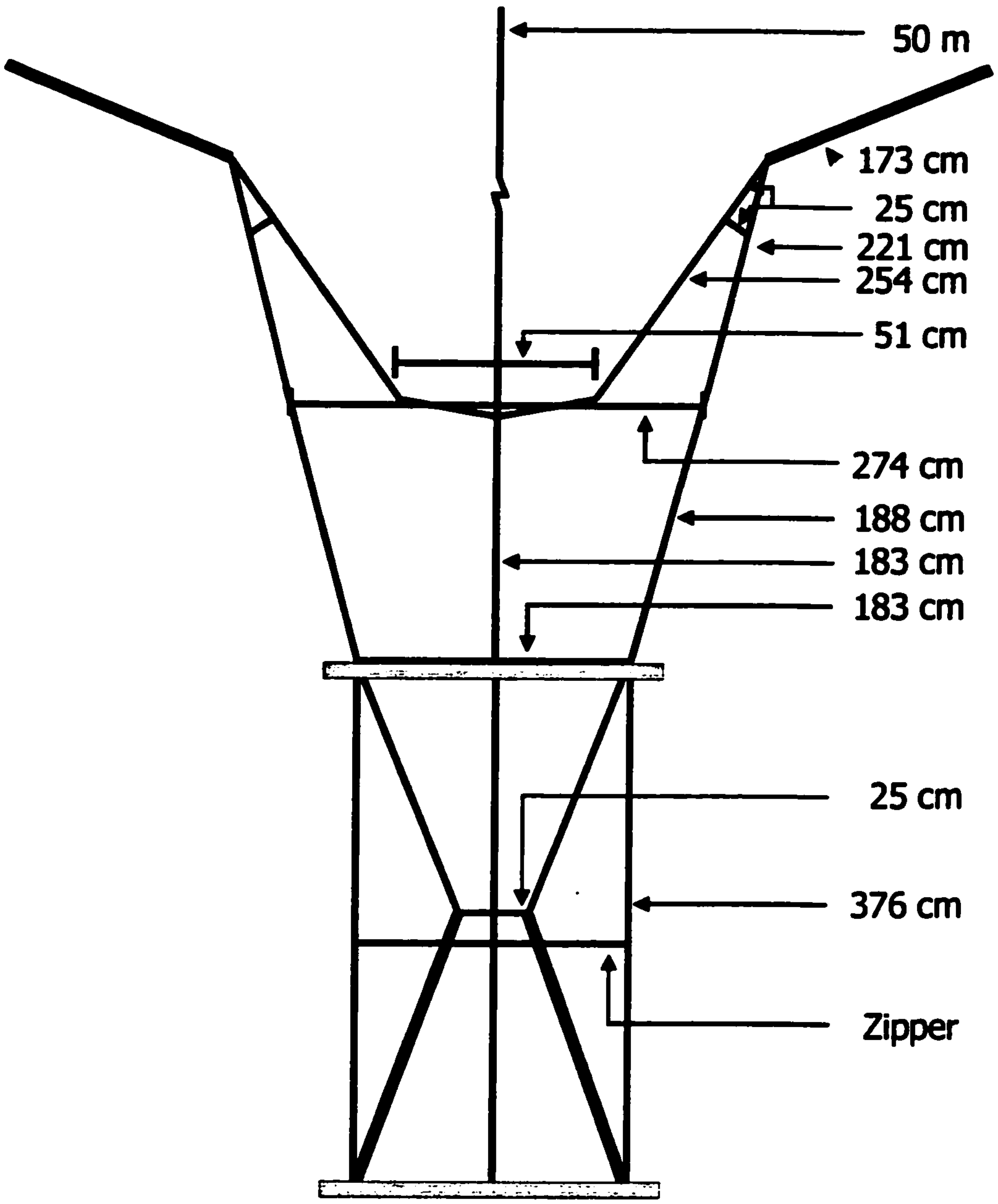
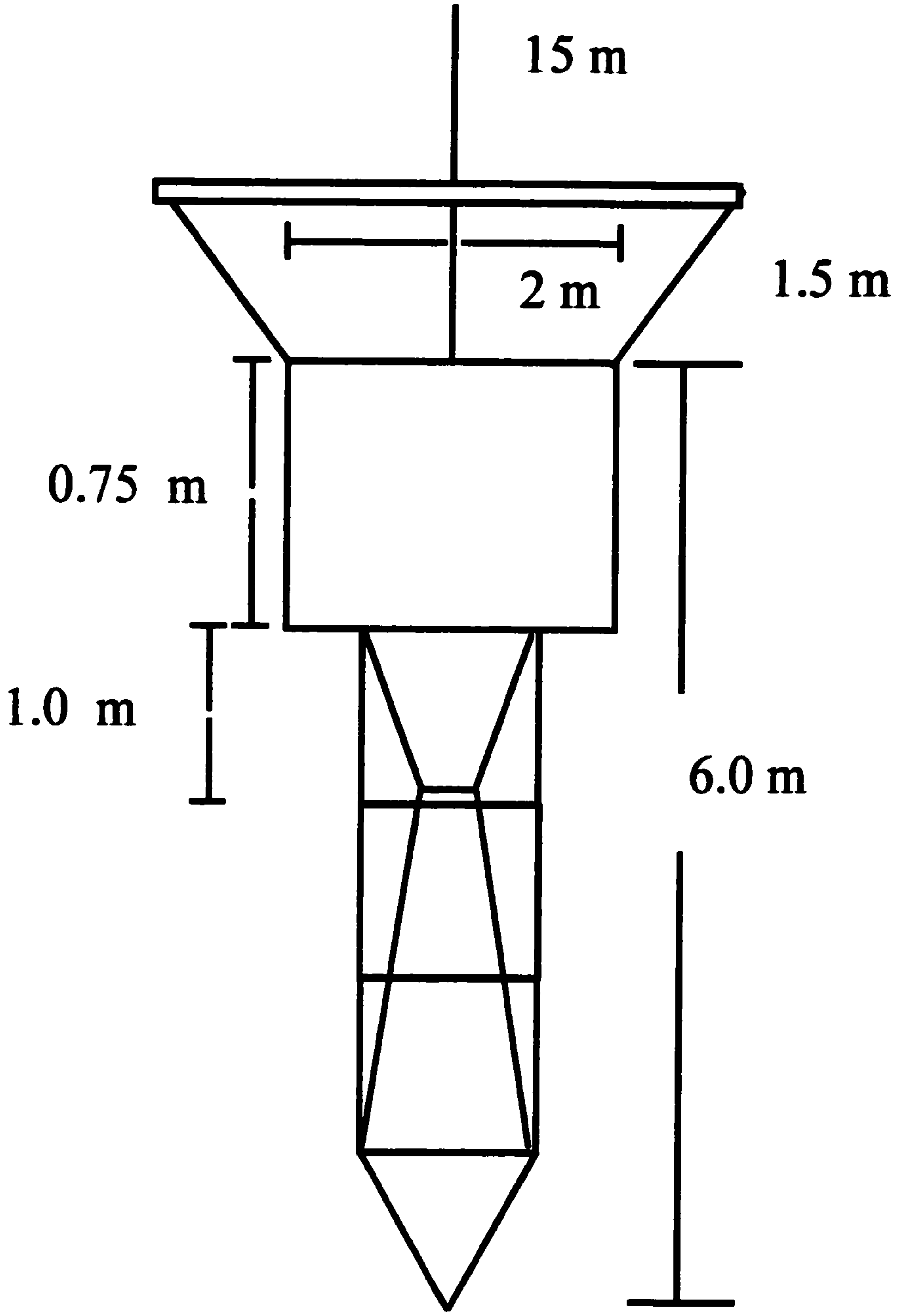
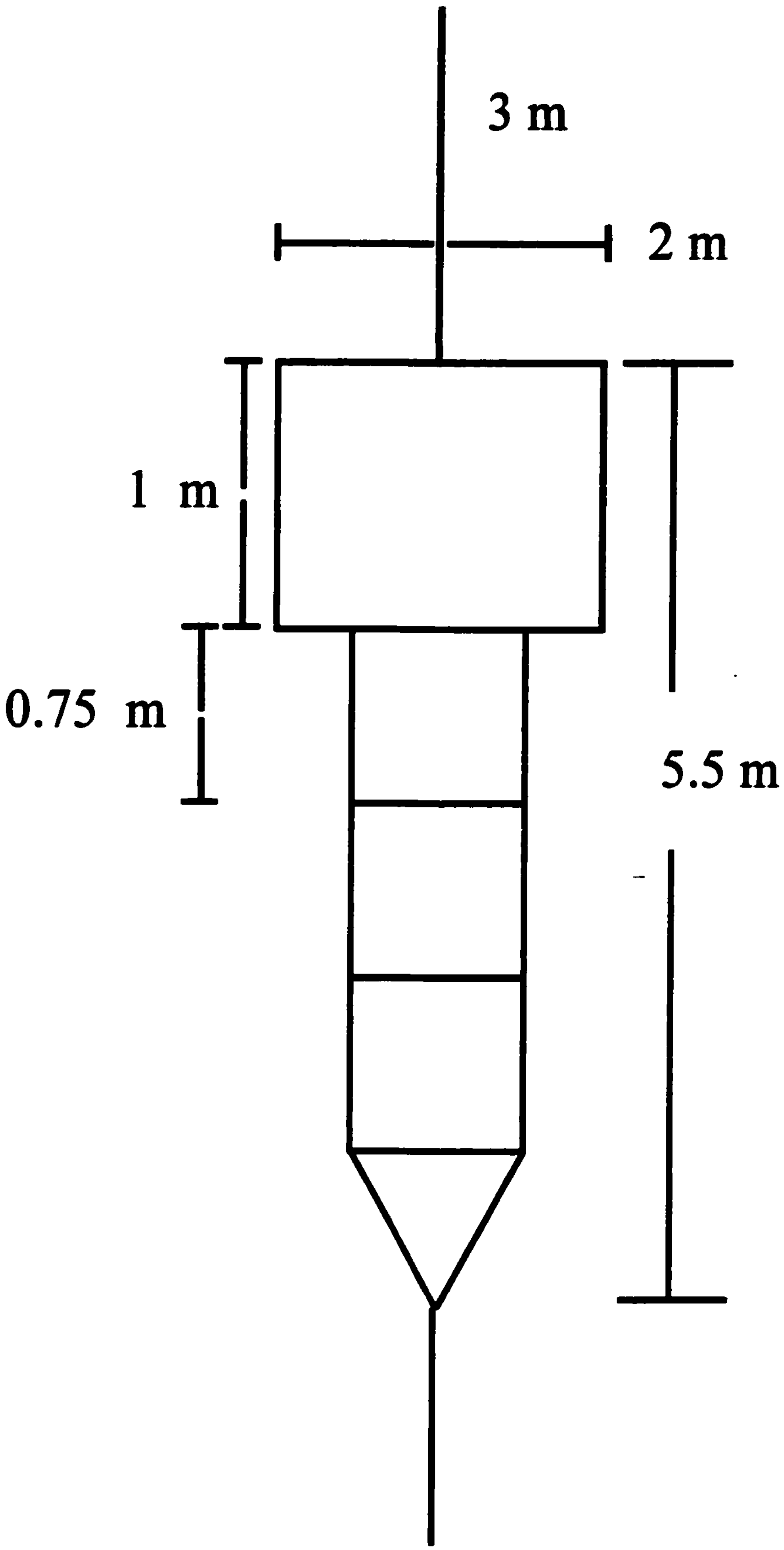
Appendix A. Diagram of the large trap-nets that were used in this experiment. Measurements are all in metres unless otherwise stated. Thin lines represent netting material, double thick lines represent rope material, gray filed boxes are wood.


50 m
173 cm
25 cm
221 cm
254 cm
51 cm
274 cm
188 cm
183 cm
183 cm
25 cm
376 cm
Zipper

Appendix B. Diagram of the hoop-nets that were used in this experiment. Measurements are all in metres unless otherwise stated. Thin lines represent netting material, gray filed boxes are wood.


15 m
2 m
1.5 m
0.75 m
1.0 m
6.0 m

Appendix C. Diagram of the Minnow-nets that were used in this experiment. Measurements are all in metres unless otherwise stated. Thin lines represent netting material, double thick lines represent rope material.


3 m
2 m
1 m
0.75 m
5.5 m

Appendix D. Sample calculations using the Fraser Lee length at age back calculation equation. 25 mm is the starting length of ossification of the opercle bone (Present Study).

$$\mathbf{LT_{\mathit{i}} = L_{oss} + (LT_t - L_{oss})[(DF_t - DF_{t-1}) / (TLB))]}$$

Where:

LT_t = Length at time "t" in mm; **TL** = Total length of fish in mm; **L_{oss}** = Total length of fish at ossification in mm; **LB** = Total length of bone in mm; **DF_t** = Distance from focus at time "*t*" in mm; **DF_{t-1}** =- Distance from focus at time "*t-1*") in mm; **TLB** = Total length of bone in mm.

When

LT_3 = ?
TL = 650 mm
L_{oss} = 25 mm
LB = 75 mm
DF_3 = 45 mm
DF_2 =40 mm
TLB = 75 mm

$$LT_3 = 25 + (650-25)[(45 - 40) / (75))]$$

$$LT_3 = (25) +(625) [(5) / (75))]$$

$$LT_3 = (25) \bullet [41.67]$$

$$LT_3 = 66.67 \text{ mm}$$

Appendix E. Sample calculation of using the Schnable (1938) single mark recapture estimation

N_t = Total number of fish in sample area at time "*t*", C_t = Total captures at time "*t*", M_t = Total marked fish in population, R = Total recaptures, R_t = Total recaptures at time "*t*", m = total number of fish examined
*** for this equation R and R_t are considered equal**

Estimation

$$N_t = \frac{\sum(C_t M_t)}{R}$$

Standard deviation

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{\left(\sum R_t M_t\right)^2}{\sum(C_t M_t)}}{m-1}\right)}$$

Data

$N_{125} = ?$ $\sum(R_t M_t) = 134$
$C_{125} = 72$
$M_{125} = 69$ $\sum(C_t M_t) = 2491$
$R = 3$
$R_{125} = 3$
$m = 72$

Step 1.

$$N_t = \frac{\sum(C_t M_t)}{R}$$

Step 2.

$$N_t = \frac{2491}{3}$$

Step 3.

$$N_t = 830.333$$

Standard deviation

Step 1.

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{\left(\sum R_t M_t\right)^2}{\sum(C_t M_t)}}{m-1}\right)}$$

Step 2.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71}\right)}$$

Step 3.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71}\right)}$$

Step 4.

$$\frac{1}{s^2} = 0.07336$$

Step 5.

$$s^2 = 13.632$$

Appendix F. Sample calculation of using the Schnable (1938) with Gerking (1954) modification single mark recapture estimation

N_t = Total number of fish in sample area at time "t", C_t = Total captures at time "t", M_t = Total marked fish in population, R = Total recaptures, R_t = Total recaptures at time "t", m = total number of fish examined
*** for this equation R and R_t are considered equal**

Estimation

$$N_t = \frac{\sum (C_t M_t)}{R+1}$$

Standard deviation

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{\left(\sum R_t M_t\right)^2}{\sum (C_t M_t)}}{m-1} \right)}$$

Data

$N_{125} = ?$

$C_{125} = 72$

$M_{125} = 69$

$R = 3$

$R_{125} = 3$

$m = 72$

$\sum(R_t M_t) = 134$

$\sum(C_t M_t) = 2491$

Step 1.

$$N_t = \frac{\sum (C_t M_t)}{R+1}$$

Step 2.

$$N_t = \frac{2491}{4}$$

Step 3.

$$N_t = 622.75$$

Standard deviation

Step 1.

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{\left(\sum R_t M_t\right)^2}{\sum (C_t M_t)}}{m-1} \right)}$$

Step 2.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71} \right)}$$

Step 3.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71} \right)}$$

Step 4.

$$\frac{1}{s^2} = 0.07336$$

Step 5.

$$s^2 = 13.632$$

Appendix G. Sample calculation using the Schumacher and Eschmeyer (1954) Single mark recapture estimation

N_t = Total number of fish in sample area at time "*t*", C_t = Total captures at time "*t*", M_t = Total marked fish in population, R = Total recaptures, R_t = Total recaptures at time "*t*", m = total number of fish examined
*** for this equation R and R_t are considered equal**

Estimation

$$N_t = \frac{\sum (C_t M_t^2)}{\sum (M_t R_t)}$$

Standard deviation

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{(\sum R_t M_t)^2}{\sum (C_t M_t)}}{m-1}\right)}$$

Data

$N_{125} = ?$
$\sum(R_t M_t) = 134$
$C_{125} = 72$
$M_{125} = 69$
$\sum(C_t M_t) = 2491$
$R = 3$
$R_{125} = 3$
$\sum(C_t M_t^2) = 96782$
$m = 72$

Step 1.

$$N_t = \frac{\sum (C_t M_t^2)}{\sum (M_t R_t)}$$

Step 2.

$$N_t = \frac{96782}{2491}$$

Step 3.

$$N_t = 722$$

Standard deviation

Step 1.

$$\frac{1}{s^2} = \sqrt{\left(\frac{\sum\left(\frac{R_t^2}{C_t}\right) - \frac{(\sum R_t M_t)^2}{\sum (C_t M_t)}}{m-1}\right)}$$

Step 2.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71}\right)}$$

Step 3.

$$\frac{1}{s^2} = \sqrt{\left(\frac{2 - \frac{134^2}{2491}}{71}\right)}$$

Step 4.

$$\frac{1}{s^2} = 0.07336$$

Step 5.

$$s^2 = 13.632$$

Appendix H. Population estimation using the Jolly Serber estimation for the Gatineau River, Gatineau, Quebec.

Population estimation

$$N_i^* = \frac{\beta_i^* \cdot (C_i + 1)}{m_i + 1} = \frac{\left(\left(\frac{(m_i + 1) \cdot K_i}{R_i + 1}\right) + m_i + 1\right) \cdot (C_i + 1)}{m_i + 1}$$

Survival Estimation

$$S_i^* = \frac{\beta_{i+1}}{\beta_i^* - m_i + M_i} = \frac{\left(\frac{(m_{i+1}) \cdot K_{i+1}}{R_{i+1} + 1}\right)}{\beta_i^* - m_i + M_i}$$

Recruitment Population

$$B_i^* = N_{i+1}^* - S_i^*(N_i^* - C_i + M_i)$$

Standard deviation for B^*_i

$$s^2_{B^*} = \sqrt{\left(0.5 \cdot (N_i^* - C_i + M_i)\right)^2 \left(\frac{s^{2^2}_{S_i^*}}{(S_i^* + 1)^2} + \frac{s^{2^2}_{N_i^*}}{(N_i^* - C_i + M_i)^2}\right)}$$

Standard deviation for β

$$s^2_{\beta^*} = \sqrt{(\beta_i^*)^2 \left(\frac{Ki_1}{(Ki_i + 1)^2} + \frac{R_i}{(R_i + 1)^2}\right) + m_i}$$

Standard deviation for N_i^*

$$s^2_{N^*} = \sqrt{(N_i^*)^2 \left(\frac{s^{2^2}_{\beta_i} + m_i}{\beta_i^2} + \frac{R_i}{R_i^2 + 1}\right)}$$

Standard deviation for S^*_i

$$s^2_{S^*} = \sqrt{(S_i^*)^2 \left(\frac{s^{2^2}_{\beta^*_{i+1}}}{\beta^2_{i-1}} + \frac{s^{2^2}_{\beta_i^*}}{(M_{i+1} + 1)^2}\right)}$$

Standard deviation for S^*_i

$$s^2_{S^*} = \sqrt{(S_i^*)^2 \left(\frac{R_{1,3}}{R^2_{1,3}} + \frac{R_{2,3}}{R^2_{2,3}}\right)}$$

N_i^* = Population size at time "i" for small population; M_i = New marks in the population at time "i"; C_i = Total captures examined at time "i"; R_i = First time recaptures at time "*i*"; m_i = Total recapture events at time "i"; K_i = the sum of all recaptures after time "i"marked before time "i", B^*_i = recruitment for small population at time "i"; S^*_i = survival rate for small population at time "i"; β^*_i = correction factor for multiple recaptures at time "i" for small population; N_i = Population size at time "i" for; M_i = New marks in the population at time "i"; B_i = recruitment for population at time "i"; S_i = survival rate for population at time "i"; β_i = correction factor for multiple recaptures at time "i".

Sample Data Matrix for Jolly Seber equation adapted from Ricker (1971)

Time	New Marks (M_i)	Total Captured (C_i)	Recaptured Fish Marked in Time "*i*"					K_i
1	M_1	-	-	-	-	-		-
2	M_2	C_2	$R_{1,2}$	-	-	-	m_2	$K_i = R_{1,3}+R_{1,4}+R_{1,5}$
3	M_3	C_3	$R_{1,3}$	$R_{2,3}$	-	-	m_3	$K_i = R_{1,4}+R_{1,5}+R_{2,4}+R_{2,5}$
4	M_4	C_4	$R_{1,4}$	$R_{2,4}$	$R_{3,4}$	-	m_4	$K_i = R_{1,5}+R_{2,5}+R_{3,5}$
5	-	C_5	$R_{1,5}$	$R_{2,5}$	$R_{3,5}$	$R_{4,5}$	m_5	-
Total			R_1	R_2	R_3	R_4		

Sample calculation using June 7 1999 corresponding to time 12. The values for time 11, 12 and 13 are:

N_{11} =904.667	N_{12} =289.44	N_{13} =447.583
M_{11} =22	M_{12} =31	M_{13} =33
C_{11} =22	C_{12} =35	C_{13} =40
R_{11} =5	R_{12} =9	R_{13} =5
m_{11} =0	m_{12} =4	m_{13} =7
K_{11} = 10	K_{12} = 11	K_{13} = 14
B^*_{11} = -272.535	B^*_{12} = 90.783	B^*_{13} = 636.018
S^*_{11} = 0.621	S^*_{12} = 1.250	S^*_{13} = 0.676
β^*_{11} = 39.33	β^*_{12} = 40.200	β^*_{13} = 87.333
β_{11} = 36.667	β_{12} = 38.100	β_{13} = 84.00

Sample Calculations

Population estimation

$$N^*_{12} = \frac{\left(\left(\frac{(M_{12}+1)\cdot K_{12}}{R_{12}+1}\right)+m_{12}+1\right)\cdot(C_{12}+1)}{m_{12}+1} = \frac{\left(\left(\frac{(31+1)\cdot 11}{9+1}\right)+4+1\right)\cdot(35+1)}{4+1} = 289.44$$

Survival Estimation

$$S^*_t = \frac{\left(\frac{(M_{t+1})\cdot K_{t+1}}{R_{t+1}+1}\right)+m_t}{\beta^*_t - m_t + M_t} = \frac{\left(\frac{33\cdot 14}{5+1}\right)+7}{40.2-4+31} = 1.25$$

Recruitment Population

$$B^*_t = N^*_{t+1} - S^*_t(N^*_t - C_t + M_t)$$
$$B^*_t = 447.583 - 1.25(289.44 - 35 + 31)$$
$$B^*_t = 90.783$$

Standard deviation for B^*_t

$$s^2_{B^*} = \sqrt{(0.5\cdot(N^*_t - C_t + M_t))^2\left(\frac{s^{2^2}_{S^*_t}}{(S^*_t+1)^2}+\frac{s^{2^2}_{N^*_t}}{(N^*_t - C_t + M_t)}\right)}$$
$$s^2_{B^*} = \sqrt{(0.5\cdot(289.440-35+31))^2\left(\frac{0.684}{2.25^2}+\frac{21893.831}{(289.440-35+31)^2}\right)}$$
$$s^2_{B^*} = 90.076^*$$

** roundingerror*

Standard deviation for β

$$s^2_{\beta^*} = \sqrt{(\beta^*_t)^2\left(\frac{Ki_1}{(Ki_t+1)^2}+\frac{R_t}{(R_t+1)^2}\right)+m_t}$$
$$s^2_{\beta^*} = \sqrt{(40.2)^2\left(\frac{11}{(11+1)^2}+\frac{9}{(9+1)^2}\right)+4}$$
$$s^2_{\beta^*} = 16.519$$

Standard deviation for N^*_t

$$s^2_{N^*} = \sqrt{(N^*_t)^2\left(\frac{s^{2^2}_{\beta} + m_t}{\beta^2_t}+\frac{R_t}{(R_t+1)^2}\right)}$$
$$s^2_{N^*} = \sqrt{(289.440)^2\left(\frac{272.891+4}{40.2^2}+\frac{4}{(5)^2}\right)}$$
$$s^2_{N^*} = 147.966$$

Standard deviation for S^*_t

$$s^2_{S^*} = \sqrt{(S^*_t)^2\left(\frac{s^{2^2}_{\beta_{t+1}}}{\beta^2_{t-1}}+\frac{s^{2^2}_{\beta^*}}{(M_{t+1}+1)^2}\right)}$$
$$s^2_{S^*} = \sqrt{(1.25)^2\left(\frac{1540.897}{84^2}+\frac{272.891}{34^2}\right)}$$
$$s^2_{S^*} = 0.827$$

Standard deviation for S^*_1

$$s^2_{S^*} = \sqrt{(S^*_t)^2\left(\frac{R_{1,3}}{R^2_{1,3}}+\frac{R_{2,3}}{R^2_{2,3}}\right)}$$
$$s^2_{S^*} = \sqrt{(1.5)^2\left(\frac{0}{0}+\frac{0}{0}\right)}$$
$$s^2_{S^*} = 0$$

Appendix I. List of the captures of all *M. carinatum* in the Mississippi River, Lanark, Ont. Temp, temperature in degrees Celsius, Location; T, trapnets; M, minnow nets; H, hoopnets; numbers represent the date (dd/mm/yy); reach where taken (ALM=Almonte, BLA=Blakeny, CED =Cedar Hill, Pak = Pakenham); Fish number, sequence of when the fish was taken from the net; SL, standard length in mm; FL, fork length in mm; TL, total length in mm; weight, mass in grams; sex, 1 =female, 2= male.

Temp	Location	Month	Fish number	tag	species	stan	fork	tail	weight	sex
	T20907CED	7	4	KEPT	RIVER REDHORSE	552	631	695	3466	1
25	T21607CED	7	14	N12	RIVER REDHORSE	549	626	690	3661	1
25	T21607CED	7	15	N13	RIVER REDHORSE	521	589	642	2810	2
25	T21707CED	7	12	N14	RIVER REDHORSE	502	570	624	2720	1
25.5	T11707CED	7	10	N15	RIVER REDHORSE	513	582	651	2940	1
16	T13010BLA	10	1	N40	RIVER REDHORSE	518	586	655	2770	1
16	T13010BLA	10	2	N41	RIVER REDHORSE	497	570	617	2380	1
16	T13010BLA	10	4	N42	RIVER REDHORSE	494	540		2106	2
16	T13010BLA	10	5	N43	RIVER REDHORSE	517	585	645	2907	1
16	T13010BLA	10	6	N44	RIVER REDHORSE	434	510	573	2825	1
16	T13010BLA	10	8	N45	RIVER REDHORSE	478	540	612	2060	2
16	T13010BLA	10	9	N46	RIVER REDHORSE	566	630	687	3093	1
16	T13010BLA	10	13	N47	RIVER REDHORSE	531	598	658	2675	1
16	T13010BLA	10	14	N48	RIVER REDHORSE	537	602	671	2770	1
16	T13010BLA	10	15	N49	RIVER REDHORSE	541	609	667	3130	1
16	T13010BLA	10	17	N50	RIVER REDHORSE	503	572	634	2850	1
16	T13010BLA	10	20	N51	RIVER REDHORSE	516	570	633	1822	1
16	T13010BLA	10	22	N52	RIVER REDHORSE	537	608	673	2054	1
16	T13010BLA	10	23	N53	RIVER REDHORSE	556	622	686	3483	1
16	T13010BLA	10	25	N54	RIVER REDHORSE	526	590		2760	1
16	T23010BLA	10	13	N55	RIVER REDHORSE	514	585	644	2215	1
16	T23010BLA	10	14	N56	RIVER REDHORSE	511	576	637	2510	1
16	T11510CED	10	6	N59	RIVER REDHORSE	556	625	694	3619	1
22.5	T11007CED	7	17	N60	RIVER REDHORSE	506	574	635	2731	2
25	T21507CED	7	27	NO TAG CP	RIVER REDHORSE	504	582	646	2498	2
16.5	T20506CED	6	5	Y51	RIVER REDHORSE	497	566	624	2596	2
16.5	T20506CED	6	4	Y52	RIVER REDHORSE	562	636	706	2739	1
26	T12606CED	6	1	Y55	RIVER REDHORSE	554	638	708	3397	1
19.5	M20206CED	6	2	Y57	RIVER REDHORSE	537	605	666	2980	1
25	M31507CED	7	2	Y57	RIVER REDHORSE	536	601	656	2842	1
19.5	T20206CED	6	17	Y69	RIVER REDHORSE	570	630	695	3761	1
19.5	T20206CED	6	19	Y70	RIVER REDHORSE	560	621	684	3453	1
19.5	T20206CED	6	1	Y71	RIVER REDHORSE	590	647	710	3738	1
19.5	T20206CED	6	2	Y72	RIVER REDHORSE	515	572	629	2230	2
19.5	T20206CED	6	7	Y73	RIVER REDHORSE	572	640	705	3590	1
19.5	T20406CED	6	10	Z00	RIVER REDHORSE	559	638	706	3364	1
16	T11510CED	10	7	Z00	RIVER REDHORSE	572	645	706	3741	1
19.5	T20406CED	6	2	Z01	RIVER REDHORSE	505	579	642	2295	2
19.5	T20406CED	6	1	Z02	RIVER REDHORSE	562	638	703	3796	1
19.5	T20907CED	7	27	Z09, KEPT	RIVER REDHORSE	525	601	661	3175	2
19.5	T20907CED	7	3	Z10	RIVER REDHORSE	531	694	668	2929	1
19.5	T20206CED	6	20	Z11	RIVER REDHORSE	530	595	662	2952	2
19.5	T20406CED	6	12	Z80	RIVER REDHORSE	541	613	663	3579	1
19.5	T20406CED	6	28	Z81	RIVER REDHORSE	576	650	710	3667	1
26	T12606CED	6	2	Z82	RIVER REDHORSE	476	557	617	2645	2
19.5	T20406CED	6	53	Z82	RIVER REDHORSE	491	559	620	2810	2
19.5	T20406CED	6	9	Z97	RIVER REDHORSE	596	653	720	4136	1
19.5	T20406CED	6	11	Z98	RIVER REDHORSE	526	610	673	3007	1
19.5	T20406CED	6	21	Z99	RIVER REDHORSE	553	632	698	3595	1
17	M30406CED	6	2		RIVER REDHORSE	502	571		2392	2
19.5	T20206CED	6	6		RIVER REDHORSE	510	575	630	2533	2
19.5	T20906PAK	6	38		RIVER REDHORSE	565	646	705	3739	1
17.5	T30406CED	6	2		RIVER REDHORSE	517	594	656	2730	
23.5	T10907CED	7	36		RIVER REDHORSE	554	620	689	3631	

Appendix J. List of the captures of all *M. carinatum* in the Gatineau River, Gatineau, Quebec. Water, water temperature in degrees Celsius, label; E, electrofishing; numbers represent the date (dd/mm/yy); Fish number, sequence of when the fish was taken from the net; Pass, number of run for that date; Bank Side, location of run; S.L., standard length in mm; F.L., fork length in mm; T.L., total length in mm; weight, mass in grams; sex, f =female, m = male; stage, gonadal maturity according to Nikolscky (1963)

Water °C	Label	Date$	Fish_Num	Pass	Tag	Bank_Side	Species	S.L.	L.F.	L.T.	Mass	Sex	Stage
7	EL290499GAT	29-Apr-99	15	1	Y36	Gatineau	River Redhorse	516	590	664	3580	F	4
10	EL080599GAT	08-May-99	26	2	N16	Hull	River Redhorse	526	593	654	3522	F	4
10	EL080599GAT	08-May-99	27	2	N63	Hull	River Redhorse	518	584	647	3881	M	4
10	EL080599GAT	08-May-99	28	2	N61	Hull	River Redhorse	512	581	646	4122	M	4
12.5	EL100599GAT	10-May-99	1	1	N34	Gatineau	River Redhorse	621	695	768	6000	F	4
12.5	EL100599GAT	10-May-99	2	1	N17	Gatineau	River Redhorse	497	568	639	5437	F	4
12.5	EL100599GAT	10-May-99	3	1	N18	Gatineau	River Redhorse	506	579	641		M	4
12.5	EL100599GAT	10-May-99	1	3	N21	Gatineau-Hull	River Redhorse	506	585	652	3780	M	5
12.5	EL130599GAT	13-May-99	1	1	N84	Gatineau	River Redhorse	586	650	735	4893	F	4
12.5	EL130599GAT	13-May-99	2	1	N82	Gatineau	River Redhorse	522	614	667	3770	F	4
12.5	EL130599GAT	13-May-99	3	1	N81	Gatineau	River Redhorse	552	610	677	3824	M	4
12.5	EL130599GAT	13-May-99	4	1	N65	Gatineau	River Redhorse	420	511	657	2853	M	4
12.5	EL130599GAT	13-May-99	5	1	N66	Gatineau	River Redhorse	522	582	657	3794	F	4
14	EL250599GAT	25-May-99	1	1	N19	Gatineau	River Redhorse	461	530	689	2586	M	4
14	EL250599GAT	25-May-99	1	2	L58	Hull	River Redhorse	492	561	623	2722	M	4
14	EL250599GAT	25-May-99	2	2	L57	Hull	River Redhorse	507	525	645	3458	F	4
14	EL250599GAT	25-May-99	3	2	L56	Hull	River Redhorse	445	485	548	2724	M	4
13.5	EL270599GAT	27-May-99	4	2	N38	Gatineau	River Redhorse	482	555	612	2873	F	4
13.5	EL270599GAT	27-May-99	1	3	N20	Centre	River Redhorse	512	568	646	3350	F	4
13.5	EL270599GAT	27-May-99	2	3	N22	Centre	River Redhorse	465	525	525	2825	M	5
13.5	EL270599GAT	27-May-99	7	3	N23	Centre	River Redhorse	523	589	682	3290	M	4
13.5	EL270599GAT	27-May-99	13	3	N24	Centre	River Redhorse	434	492	557	2235	M	4
13.5	EL270599GAT	27-May-99	14	3	N27	Centre	River Redhorse	472	535	603	2776	M	5
13.5	EL270599GAT	27-May-99	15	3	N28	Centre	River Redhorse	502	560	621	2950	M	4
17	EL310599GAT	31-May-99	2	1	N36	Gatineau	River Redhorse	532	568	604	4080	F	4
17	EL310599GAT	31-May-99	3	1	N25	Gatineau	River Redhorse	462	527	590	2080	M	4
17	EL310599GAT	31-May-99	4	1	N35	Gatineau	River Redhorse	626	652	685	4520	F	4
17	EL310599GAT	31-May-99	5	1	N34	Gatineau	River Redhorse	455	515	580	2220	M	5
17	EL310599GAT	31-May-99	1	2	N33	Hull-centre	River Redhorse		523	588	2220	M	5
17	EL310599GAT	31-May-99	2	2	N32	Hull-centre	River Redhorse		578	638	3830	F	4
17	EL310599GAT	31-May-99	3	2	N31	Hull-centre	River Redhorse		540	598	2650	M	5
17	EL310599GAT	31-May-99	4	2	N26	Hull-centre	River Redhorse		556	606	2830	M	4
17	EL310599GAT	31-May-99	14	2	N30	Hull-centre	River Redhorse	522	590	656	3810	F	4
17	EL310599GAT	31-May-99	15	2	N29	Hull-centre	River Redhorse	558	624	695	4610	F	4
17	EL310599GAT	31-May-99	16	2	Z94	Hull-centre	River Redhorse	485	555	612	3960	M	4
17	EL310599GAT	31-May-99	17	2	I00	Hull-centre	River Redhorse	464	525	596	2730	M	5
17	EL310599GAT	31-May-99	18	2	I01	Hull-centre	River Redhorse	506	555	596	2900	M	5
17	EL310599GAT	31-May-99	19	2	I02	Hull-centre	River Redhorse	485	526	590	2450	M	4
17	EL310599GAT	31-May-99	20	2	I03	Hull-centre	River Redhorse	455	510	575	2710	M	4
17	EL310599GAT	31-May-99	21	2	I04	Hull-centre	River Redhorse	445	512	577	2470	F	4
18	EL030699GAT	03-Jun-99	1	1	I39	Gatineau	River Redhorse	495	562	640	2902	M	5
18	EL030699GAT	03-Jun-99	2	1	I38	Gatineau	River Redhorse	502	572	626	2902	M	5
18	EL030699GAT	03-Jun-99	1	2	I37	Centre	River Redhorse	527	585	659	3269	F	4
18	EL030699GAT	03-Jun-99	2	2	I36	Centre	River Redhorse	487	547	620	2739	M	4
18	EL030699GAT	03-Jun-99	3	2	I05	Centre	River Redhorse	535	612	672	4169	M	4
18	EL030699GAT	03-Jun-99	4	2	I06	Centre	River Redhorse	491	554	627	3267	M	4
18	EL030699GAT	03-Jun-99	3	3	I09	Hull	River Redhorse	475	538	604	2850	F	4
18	EL030699GAT	03-Jun-99	4	3	I10	Hull	River Redhorse	497	560	630	2956	M	5
18	EL030699GAT	03-Jun-99	5	3	I11	Hull	River Redhorse	555	625	678	4010	M	4
18	EL030699GAT	03-Jun-99	6	3	I12	Hull	River Redhorse	498	563	617	3125	M	5
18	EL030699GAT	03-Jun-99	7	3	I13	Hull	River Redhorse	507	580	647	3392	M	5
18	EL030699GAT	03-Jun-99	8	3	I14	Hull	River Redhorse	503	579	644	3242	M	5
18	EL030699GAT	03-Jun-99	9	3	I15	Hull	River Redhorse	513	585	644	3499	M	5
18	EL030699GAT	03-Jun-99	10	3	I16	Hull	River Redhorse	467	537	607	3800	F	4
18	EL030699GAT	03-Jun-99	11	3	I17	Hull	River Redhorse	492	552	601	3425	F	4
18	EL030699GAT	03-Jun-99	12	3	I18	Hull	River Redhorse	592	590	660	4204	F	4
18	EL030699GAT	03-Jun-99	13	3	I20	Hull	River Redhorse	513	609	672	3806	F	5
18	EL030699GAT	03-Jun-99	14	3	I21	Hull	River Redhorse	542	553	617	2845	M	5
18	EL030699GAT	03-Jun-99	15	3	I22	Hull	River Redhorse	486	540	602	2760	M	4
18	EL030699GAT	03-Jun-99	16	3	I23	Hull	River Redhorse	472	565	630	3408	F	4
18	EL030699GAT	03-Jun-99	17	3	I24	Hull	River Redhorse	501	540	597	2521	F	5
18	EL030699GAT	03-Jun-99	1	3	I07	Hull	River Redhorse	245	275	318		M	5
18.5	EL070699GAT	07-Jun-99	3	1	I25	Gatineau	River Redhorse	492	555	610	2944	M	4
18.5	EL070699GAT	07-Jun-99	4	1	I27	Gatineau	River Redhorse	521	594	666	3981	F	4
18.5	EL070699GAT	07-Jun-99	5	1	I31	Gatineau	River Redhorse	471	540	605	2925	M	4
18.5	EL070699GAT	07-Jun-99	7	1	N31	Gatineau	River Redhorse	462	532	583	2534	M	4
18.5	EL070699GAT	07-Jun-99	9	1	I18	Gatineau	River Redhorse	566	632	695	4949	F	4
18.5	EL070699GAT	07-Jun-99	12	1	I32	Gatineau	River Redhorse	472	535	594	2469	M	4
18.5	EL070699GAT	07-Jun-99	14	1	I28	Gatineau	River Redhorse	557	628	695	5010	F	4
18.5	EL070699GAT	07-Jun-99	16	1	I08	Gatineau	River Redhorse	542	618	679	2866	M	4
18.5	EL070699GAT	07-Jun-99	21	1	I19	Gatineau	River Redhorse	502	578	643	3311	F	4
18.5	EL070699GAT	07-Jun-99	25	1	I26	Gatineau	River Redhorse	447	524	573	2280	M	4
18.5	EL070699GAT	07-Jun-99	26	1	I30	Gatineau	River Redhorse	465	535	598	2564	M	5
18.5	EL070699GAT	07-Jun-99	3	2	I33	Hull	River Redhorse	524	595	662	3359	M	5
18.5	EL070699GAT	07-Jun-99	14	2	I35	Hull	River Redhorse	443	494	558	2067	M	4
18.5	EL070699GAT	07-Jun-99	16	2	I38	Hull	River Redhorse	495	554	618	2833	M	5
18.5	EL070699GAT	07-Jun-99	27	2	L37	Hull	River Redhorse	461	525	592	2300	M	4
18.5	EL070699GAT	07-Jun-99	36	2	L36	Hull	River Redhorse	451	509	564	2257	F	4
18.5	EL070699GAT	07-Jun-99	1	3	L35	Gatineau	River Redhorse	452	507	568	2354	M	5
18.5	EL070699GAT	07-Jun-99	5	3	L34	Gatineau	River Redhorse	485	525	600	2685	M	5
18.5	EL070699GAT	07-Jun-99	10	3	L33	Gatineau	River Redhorse	461	518	579	2343	M	4
18.5	EL070699GAT	07-Jun-99	11	3	L31	Gatineau	River Redhorse	512	278	654	3408	F	4
18.5	EL070699GAT	07-Jun-99	14	3	L30	Gatineau	River Redhorse	425	485	542	1719	M	5
18.5	EL070699GAT	07-Jun-99	20	3	L29	Gatineau	River Redhorse	462	515	585	2429	M	5
18.5	EL070699GAT	07-Jun-99	22	3	L28	Gatineau	River Redhorse	466	530	593	2494	M	5
18.5	EL070699GAT	07-Jun-99	1	4	N24	Hull	River Redhorse	522	590	651	3389	F	5
18.5	EL070699GAT	07-Jun-99	3	4	L32	Hull	River Redhorse	431	492	555	1996	F	4
18.5	EL070699GAT	07-Jun-99	4	4	L27	Hull	River Redhorse	535	612	689	4042	F	4
18.5	EL070699GAT	07-Jun-99	5	4	L26	Hull	River Redhorse	498	566	632	3450	F	4
18.5	EL070699GAT	07-Jun-99	6	4	L25	Hull	River Redhorse	425	482	544	1767	M	5
18.5	EL070699GAT	07-Jun-99	7	4	L24	Hull	River Redhorse	472	535	600	3082	F	4
18.5	EL070699GAT	07-Jun-99	16	4	L18	Hull	River Redhorse	432	480	540	1851	F	4

18.5	EL070699GAT	07-Jun-99	18	4	L23	Hull	River Redhorse	495	560	613	2719	M	4
18.5	EL070699GAT	07-Jun-99	19	4	L22	Hull	River Redhorse	598	664	735	6118	F	4
18.5	EL070699GAT	07-Jun-99	20	4	L21	Hull	River Redhorse	454	505	568	2240	F	4
18.5	EL070699GAT	07-Jun-99	24	4	L20	Hull	River Redhorse	418	472	528	1942	F	4
18.5	EL070699GAT	07-Jun-99	25	4	L00	Hull	River Redhorse	513	575	653	2985	M	4
18.5	EL100699GAT	10-Jun-99	1	1	N66	Gatineau	River Redhorse	511	585	650	3952	F	4
18.5	EL100699GAT	10-Jun-99	2	1	L17	Gatineau	River Redhorse	592	670	745	6520	F	4
18.5	EL100699GAT	10-Jun-99	3	1	L16	Gatineau	River Redhorse	532	600	684	3746	M	5
18.5	EL100699GAT	10-Jun-99	4	1	L15	Gatineau	River Redhorse	471	540	604	3054	F	6
18.5	EL100699GAT	10-Jun-99	5	1	N51	Gatineau	River Redhorse	497	572	642	3085	M	5
18.5	EL100699GAT	10-Jun-99	6	1	I35	Gatineau	River Redhorse	425	487	552	2125	M	5
18.5	EL100699GAT	10-Jun-99	7	1	L14	Gatineau	River Redhorse	471	542	542	3825	F	4
18.5	EL100699GAT	10-Jun-99	8	1	L12	Gatineau	River Redhorse	495	637	637	3581	F	5
18.5	EL100699GAT	10-Jun-99	9	1	CNR	Gatineau	River Redhorse	473	548	608	2921	M	5
18.5	EL100699GAT	10-Jun-99	10	1	L11	Gatineau	River Redhorse	505	567	638	3321	F	4
18.5	EL100699GAT	10-Jun-99	1	2	L09	Hull-centre	River Redhorse	475	544	608	2589	M	5
18.5	EL100699GAT	10-Jun-99	2	2	L08	Hull-centre	River Redhorse	433	514	575	2153	M	5
18.5	EL100699GAT	10-Jun-99	2	2	L10	Centre	River Redhorse	491	555	625	3831	F	4
18.5	EL100699GAT	10-Jun-99	3	2	L07	Hull-centre	River Redhorse	485	548	618	2850	F	4
18.5	EL100699GAT	10-Jun-99	4	2	L06	Hull-centre	River Redhorse	576	650	714	4776	M	5
18.5	EL100699GAT	10-Jun-99	5	2	L04	Hull-centre	River Redhorse	490	570	637	3801	F	4
18.5	EL100699GAT	10-Jun-99	6	2	L32	Hull-centre	River Redhorse	462	524	593	2328	M	5
18.5	EL100699GAT	10-Jun-99	7	2	L00	Hull-centre	River Redhorse	505	570	645		M	5
18.5	EL100699GAT	10-Jun-99	8	2	L01	Hull-centre	River Redhorse	501	574	655	3138	M	5
18.5	EL100699GAT	10-Jun-99	9	2	O60	Hull-centre	River Redhorse	454	555	677	2178	F	4
18.5	EL100699GAT	10-Jun-99	10	2	O61	Hull-centre	River Redhorse					M	5
18.5	EL100699GAT	10-Jun-99	12	2	O62	Hull-centre	River Redhorse	437	500	608	2180	F	4
18.5	EL100699GAT	10-Jun-99	13	2	O63	Hull-centre	River Redhorse	433	486	545	2194	M	5
18.5	EL100699GAT	10-Jun-99	3	3	O64	Hull	River Redhorse	495	562	630	2846	M	5
18.5	EL100699GAT	10-Jun-99	4	3	O65	Hull	River Redhorse	585	644	705	5135	F	4
18.5	EL100699GAT	10-Jun-99	5	3	O66	Hull	River Redhorse	647	647	710	4336	M	5
18.5	EL100699GAT	10-Jun-99	7	3	O67	Hull	River Redhorse	502	592	661	3014	M	5
18.5	EL100699GAT	10-Jun-99	9	3	O68	Hull	River Redhorse	485	556	642	3989	M	5
18.5	EL100699GAT	10-Jun-99	10	3	O69	Hull	River Redhorse	465	536	593	2415	M	5
18.5	EL100699GAT	10-Jun-99	11	3	O70	Hull	River Redhorse	532		670	3808	M	5
18.5	EL100699GAT	10-Jun-99	12	3	O71	Hull	River Redhorse	493	557	630	2956	M	5
18.5	EL100699GAT	10-Jun-99	13	3	I18	Hull	River Redhorse	552	620	683	5935	F	4
18.5	EL100699GAT	10-Jun-99	14	3	O72	Hull	River Redhorse	465	530	594	2602	M	5
18.5	EL100699GAT	10-Jun-99	15	3	O73	Hull	River Redhorse	430	487	548	1915	M	5
18.5	EL100699GAT	10-Jun-99	16	3	O74	Hull	River Redhorse	482	547	612	2805	M	5
18.5	EL100699GAT	10-Jun-99	17	3	O75	Hull	River Redhorse				2865	M	5
18.5	EL100699GAT	10-Jun-99	18	3	I04	Hull	River Redhorse	441	570	573	2492	F	4
18.5	EL100699GAT	10-Jun-99	19	3	O76	Hull	River Redhorse	482	545	609	3101	F	4
18.5	EL100699GAT	10-Jun-99	20	3	O77	Hull	River Redhorse	495	576	636	2630	F	4
18.5	EL100699GAT	10-Jun-99	21	3	N31	Hull	River Redhorse	457	530	592	2503	M	5
19	EL140699GAT	14-Jun-99	1	1	O78	Gatineau	River Redhorse	575	657	724	4637	F	6
19	EL140699GAT	14-Jun-99	2	1	O79	Gatineau	River Redhorse	482	552	616	2682	F	6
19	EL140699GAT	14-Jun-99	1	2	O99	Hull	River Redhorse	427	486	549	1938	M	5
19	EL140699GAT	14-Jun-99	2	2	O98	Hull	River Redhorse	415	477	535	2020	M	5
19	EL140699GAT	14-Jun-99	3	2	O97	Hull	River Redhorse	432	495	554	1985	F	5
19	EL140699GAT	14-Jun-99	4	2	O96	Hull	River Redhorse	442	514	573	2205	M	5
19	EL140699GAT	14-Jun-99	6	2	O94	Hull	River Redhorse	473	541		2562	M	5
19	EL140699GAT	14-Jun-99	8	2	O93	Hull	River Redhorse	423	602	682	4147	F	4
19	EL140699GAT	14-Jun-99	9	2	O90	Hull	River Redhorse	461	514	583	3634	F	6
19	EL140699GAT	14-Jun-99	10	2	O88	Hull	River Redhorse	522	595	653	3103	M	5
19	EL140699GAT	14-Jun-99	11	2	O87	Hull	River Redhorse	442	503	563	2161	M	5
19	EL140699GAT	14-Jun-99	12	2	O86	Hull	River Redhorse	432	550	613	3009	F	6
19	EL140699GAT	14-Jun-99	13	2	O21	Hull	River Redhorse	487	565	690			
19	EL140699GAT	14-Jun-99	14	2	O85	Hull	River Redhorse	412	480	545	1945	M	5
19	EL140699GAT	14-Jun-99	15	2	O84	Hull	River Redhorse	412	475	525	1832	F	6
19	EL140699GAT	14-Jun-99	19	2	O83	Hull	River Redhorse	441	505	564	2144	M	5
19	EL140699GAT	14-Jun-99	20	2	O80	Hull	River Redhorse	485	500	567	2166	F	6
19	EL140699GAT	14-Jun-99	21	2	O19	Hull	River Redhorse	555	588	625	3841	M	5
19	EL140699GAT	14-Jun-99	24	2	O18	Hull	River Redhorse	405	461	521	1604	M	5
19	EL140699GAT	14-Jun-99	25	2	O17	Hull	River Redhorse	458	535	594		F	6
19	EL140699GAT	14-Jun-99	1	3	O16	Hull-île	River Redhorse	425	481	542	1734	M	5
19	EL160699GAT	16-Jun-99	1	1	L40	Gatineau	River Redhorse	582	670	742	5930	F	5
19	EL160699GAT	16-Jun-99	2	1	O80	Gatineau	River Redhorse	442	505	572	2090	F	0
19	EL160699GAT	16-Jun-99	4	1	L41	Gatineau	River Redhorse	485	560	625	2889	F	5
19	EL160699GAT	16-Jun-99	5	1	L42	Gatineau	River Redhorse	502	581	650	3840	F	4
19	EL160699GAT	16-Jun-99	7	1	L33	Gatineau	River Redhorse	485	552	635	3436	F	6
19	EL160699GAT	16-Jun-99	8	1	L43	Gatineau	River Redhorse	522	593	667	4103	F	6
19	EL160699GAT	16-Jun-99	1	2	L44	Hull	River Redhorse	465	546	613	2536	M	5
19	EL160699GAT	16-Jun-99	2	2	Z96	Hull	River Redhorse	572	640	705	4791	M	5
19	EL160699GAT	16-Jun-99	3	2	N65	Hull	River Redhorse	492	555	618	2822	M	5
19	EL160699GAT	16-Jun-99	4	2	L46	Hull	River Redhorse	475	543	604	2404	F	5
19	EL160699GAT	16-Jun-99	5	2	L45	Hull	River Redhorse	514	575	647	3140	M	5
19	EL160699GAT	16-Jun-99	6	2	L56	Hull	River Redhorse	475	532	593	2510	M	5
19	EL160699GAT	16-Jun-99	7	2	L47	Hull	River Redhorse	523	595	672	4805	F	6
19	EL160699GAT	16-Jun-99	9	2	L48	Hull	River Redhorse	465	535	602	2992	F	6
19	EL160699GAT	16-Jun-99	10	2	L49	Hull	River Redhorse	485	575	635	3630	F	5
19	EL160699GAT	16-Jun-99	11	2	N25	Hull	River Redhorse	455	520	581	2620	M	5
19	EL160699GAT	16-Jun-99	12	2	I13	Hull	River Redhorse	495	575	640	3080	M	5
19	EL160699GAT	16-Jun-99	13	2	L50	Hull	River Redhorse	465	542	613	3290	F	6
19	EL160699GAT	16-Jun-99	64	3	L54	Île-herbier	River Redhorse	502	585	627	3124	M	5
19	EL210699GAT	21-Jun-99	1	1	O76	Gatineau	River Redhorse	485	545	690	2576	F	6
19	EL210699GAT	21-Jun-99	2	1	L62	Gatineau	River Redhorse	510	578	637	3140	M	6
19	EL210699GAT	21-Jun-99	4	1	L63	Gatineau	River Redhorse	465	530	603	2456	M	5
19	EL210699GAT	21-Jun-99	5	1	L64	Gatineau	River Redhorse	475	540	598	2500	F	6
19	EL210699GAT	21-Jun-99	6	1	L65	Gatineau	River Redhorse	465	523	584	2600	F	6
19	EL210699GAT	21-Jun-99	1	2	L66	Hull	River Redhorse	455	535	603	2340	M	5
19	EL210699GAT	21-Jun-99	2	2	O76	Hull	River Redhorse	455	500	590	2448	M	6
19	EL210699GAT	21-Jun-99	3	2	L67	Hull	River Redhorse	492	560	624	2650	M	6

19	EL210699GAT	21-Jun-99	5	2	L68	Hull	River Redhorse	465	535	602	2630	F	6
19	EL210699GAT	21-Jun-99	7	2	O64	Hull	River Redhorse	485	560	614	2845	M	6
19	EL210699GAT	21-Jun-99	9	2	L69	Hull	River Redhorse	486	569	632	3220	F	6
19	EL210699GAT	21-Jun-99	10	2	L70	Hull	River Redhorse	475	547	605	3230	F	6
19	EL210699GAT	21-Jun-99	11	2	L71	Hull	River Redhorse	465	520	586	2415	M	6
19	EL210699GAT	21-Jun-99	12	2	L72	Hull	River Redhorse	413	475	532	1800	M	5
19	EL210699GAT	21-Jun-99	13	2	L73	Hull	River Redhorse	415	485	549	1850	M	5
19	EL210699GAT	21-Jun-99	14	2	L74	Hull	River Redhorse	465	525	598	2145	M	5
19	EL210699GAT	21-Jun-99	16	2	L75	Hull	River Redhorse	425	480	538	1880	M	5
19	EL210699GAT	21-Jun-99	5	3	L35	Hull	River Redhorse	435	500	558	2150	M	6
19	EL210699GAT	21-Jun-99	6	3	L76	Hull	River Redhorse	475	548	616	2415	M	6
19	EL210699GAT	21-Jun-99	7	3	O10	Hull	River Redhorse	512	592	663	3380	F	6
19	EL210699GAT	21-Jun-99	8	3	L77	Hull	River Redhorse	505	588	628	2288	M	6
19	EL210699GAT	21-Jun-99	9	3	L78	Hull	River Redhorse	478	543	605	3160	M	6
19	EL210699GAT	21-Jun-99	10	3	L79	Hull	River Redhorse	542	623	691	3880	M	6
19	EL210699GAT	21-Jun-99	11	3	L83	Hull	River Redhorse	399	475	538	2316	M	5
19	EL210699GAT	21-Jun-99	12	3	L84	Hull	River Redhorse	485	550	623	2700	F	6
19	EL230699GAT	23-Jun-99	1	1	L85	Gatineau	River Redhorse	515	594	655	3840	F	6
19	EL230699GAT	23-Jun-99	2	1	L65	Gatineau	River Redhorse	455	530	595	2465	M	6
19	EL230699GAT	23-Jun-99	3	1	L86	Gatineau	River Redhorse	651	731	798	5858	F	5
19	EL230699GAT	23-Jun-99	4	1	L87	Gatineau	River Redhorse	481	558	624	2651	M	6
19	EL230699GAT	23-Jun-99	5	1	L64	Gatineau	River Redhorse	461	537	641	2410	F	6
19	EL230699GAT	23-Jun-99	6	1	L88	Gatineau	River Redhorse	401	465	534	1680		
19	EL230699GAT	23-Jun-99	7	1	L89	Gatineau	River Redhorse	495	580	648	2840	M	6
19	EL230699GAT	23-Jun-99	8	1	L90	Gatineau	River Redhorse	405	470	532	7845	M	6
19	EL230699GAT	23-Jun-99	9	1	L91	Gatineau	River Redhorse	445	515	575	2585		
19	EL230699GAT	23-Jun-99	11	1	L71	Gatineau	River Redhorse	455	523	590	2430	M	6
19	EL230699GAT	23-Jun-99	12	1	L92	Gatineau	River Redhorse	575	660	734	3460	F	6
19	EL230699GAT	23-Jun-99	13	1	L93	Gatineau	River Redhorse	415	485	548	1870	M	
19	EL230699GAT	23-Jun-99	16	1	O66	Gatineau	River Redhorse	461	540	608	2640	F	
19	EL230699GAT	23-Jun-99	18	1	O98	Gatineau	River Redhorse	412	477	535	1957	M	5
19	EL230699GAT	23-Jun-99	1	2	L94	Centre	River Redhorse	531	610	670	3200	F	5
19	EL230699GAT	23-Jun-99	3	2	L95	Centre	River Redhorse	495	571	638	3401	F	5
19	EL230699GAT	23-Jun-99	4	2	L96	Centre	River Redhorse	521	602	669	3840		
19	EL230699GAT	23-Jun-99	5	2	L27	Centre	River Redhorse	534	614	690	3840	F	
19	EL230699GAT	23-Jun-99	7	2	L97	Centre	River Redhorse	495	578	637	3111	M	5
19	EL230699GAT	23-Jun-99	8	2	L35	Centre	River Redhorse	412	482	534	1870	M	5
19	EL230699GAT	23-Jun-99	1	3	L98	Hull	River Redhorse	475	550	610	2726	F	6
19	EL230699GAT	23-Jun-99	2	3	I32	Hull	River Redhorse	445	517	577	2281		
19	EL230699GAT	23-Jun-99	3	3	L99	Hull	River Redhorse	535	618	674	3980		
19	EL230699GAT	23-Jun-99	4	3	L36	Hull	River Redhorse				2193	F	6
19	EL230699GAT	23-Jun-99	6	3	L25	Hull	River Redhorse	403	473	532	1615	M	5
19	EL230699GAT	23-Jun-99	7	3	I40	Hull	River Redhorse	502	586	648	2955	M	5
19	EL230699GAT	23-Jun-99	8	3	I41	Hull	River Redhorse	425	440	553	1742	M	5
19	EL230699GAT	23-Jun-99	9	3	N26	Hull	River Redhorse	435	510	571	2495		
19	EL230699GAT	23-Jun-99	10	3	I42	Hull	River Redhorse	475	543	615			
19	EL230699GAT	23-Jun-99	11	3	I43	Hull	River Redhorse	547	620	680	3500	F	6
19	EL230699GAT	23-Jun-99	12	3	O24	Hull	River Redhorse	475	543	608	2400	M	5
19	EL230699GAT	23-Jun-99	13	3	I44	Hull	River Redhorse	495	590	654	3530		
19	EL230699GAT	23-Jun-99	14	3	L49	Hull	River Redhorse	495	594	638	3222	F	6
19	EL230699GAT	23-Jun-99	15	3	I45	Hull	River Redhorse	562	580	588	3200	F	6
19	EL170699GAT	17-Jun-99	1	1	L53	Gatineau	River Redhorse	525	608	674	3400	M	5
19	EL170699GAT	17-Jun-99	2	1	L59	Gatineau	River Redhorse	495	575	644	3305	F	6
19	EL170699GAT	17-Jun-99	4	1	L60	Gatineau	River Redhorse	475	550	610	2935	M	5
19	EL170699GAT	17-Jun-99	5	1	L61	Gatineau	River Redhorse	403	470	531	1625	M	0
19	EL170699GAT	17-Jun-99	13	1	L62	Gatineau	River Redhorse	521	587	658	2275	F	6
19	EL170699GAT	17-Jun-99	2	2	O15	Centre	River Redhorse	502	573	629	2715	M	5
19	EL170699GAT	17-Jun-99	3	2	O16	Centre	River Redhorse	415	477	537	1920	M	5
19	EL170699GAT	17-Jun-99	4	2	O14	Centre	River Redhorse	425	485	544	1941	M	5
19	EL170699GAT	17-Jun-99	6	2	I07	Centre	River Redhorse	473	534	599	2462	F	6
19	EL170699GAT	17-Jun-99	7	2	O13	Centre	River Redhorse	455	516	579	2334	M	5
19	EL170699GAT	17-Jun-99	9	2	N20	Centre	River Redhorse	483	560	634	3366	F	6
19	EL170699GAT	17-Jun-99	11	2	O12	Centre	River Redhorse	457	524	586	2291	M	5
19	EL170699GAT	17-Jun-99	14	2	O11	Centre	River Redhorse	503	580	657	3971	M	6
19	EL170699GAT	17-Jun-99	15	2	O10	Centre	River Redhorse	510	590	658	3960	F	6
19	EL170699GAT	17-Jun-99	16	2	O09	Centre	River Redhorse	491	567	618	2710	M	5
19	EL170699GAT	17-Jun-99	1	3	O08	Hull	River Redhorse	494	570	632	3528	F	6
19	EL170699GAT	17-Jun-99	2	3	T23	Hull	River Redhorse	432	498	550	3758		
19	EL170699GAT	17-Jun-99	3	3	O07	Hull	River Redhorse	502	583	651	4307	F	6
19	EL170699GAT	17-Jun-99	4	3	I20	Hull	River Redhorse	540	612	673	3240	M	5
19	EL170699GAT	17-Jun-99	5	3	L55	Hull	River Redhorse	525	610	673	3432	M	5
19	EL170699GAT	17-Jun-99	8	3	O06	Hull	River Redhorse	490	555	658	2347	M	5
19	EL170699GAT	17-Jun-99	9	3	O05	Hull	River Redhorse	415	498	553	2944	F	6
19	EL170699GAT	17-Jun-99	11	3	L30	Hull	River Redhorse	410	475	530	1605	M	5
19	EL170699GAT	17-Jun-99	14	3	O04	Hull	River Redhorse	475	545	604	2910	F	5
19	EL170699GAT	17-Jun-99	25	3	L04	Hull	River Redhorse	495	568	638		F	5
19	EL170699GAT	17-Jun-99	1	3	O03	Ile	River Redhorse	455	528	585	2465	F	6
19	EL170699GAT	17-Jun-99	3	3	L00	Ile	River Redhorse	497	570	644	2860	M	6
19	EL170699GAT	17-Jun-99	4	3	O02	Ile	River Redhorse	525	606	678	4131	F	5
19	EL170699GAT	17-Jun-99	5	3	O01	Ile	River Redhorse	520	608	656	4162	F	4
19	EL170699GAT	17-Jun-99	6	3	O00	Ile	River Redhorse	521	590	664	3633	M	5
19	EL170699GAT	17-Jun-99	9	3	L06	Ile	River Redhorse	550	646	715	4624	M	
19	EL170699GAT	17-Jun-99	11	3	O59	Ile	River Redhorse	420	490	549			
19	EL170699GAT	17-Jun-99	14	3	O58	Ile	River Redhorse	478	555	620	3290	F	5
19	EL170699GAT	17-Jun-99	16	3	O57	Ile	River Redhorse	385	450	515	1720		0
19	EL170699GAT	17-Jun-99	20	3	O56	Ile	River Redhorse	450	535	597	2408	M	5

Appendix K. Habitat data in percent mean abundance of substrate types in the Mississippi River, Lanark, Ont. Data was gathered by means of visual inspection of a 1 m^2 quadrat taken ½ the distance of the net. Latitude and Longitude; is measured at he box of the net. Location; T, trapnets; M, minnow nets; H, hoopnets; numbers represent the date (dd/mm/yy); reach where taken (ALM=Almonte, BLA=Blakeny, CED =Cedar Hill, Pak = Pakenham, GAL=Galleta) Water and Air temperature are measured in degrees Celsius. Set time, time that the net was set; Pick up time, time net was removed from the water, In water, total time net was fishing, Secchi, Secchi depth measured in metres, Net (m); depth of the net at the start of the lead in cm Half, depth of the lead half way to the box in cm; Box, depth of the box in cm. Habitat was placed in the following categories: organic, this included detritus and leaf litter; silt, fine sediments <1 mm; sand, sediment > 1mm but < 2 mm; stone, sediments >3mm but <5cm; rock, sediments >than 5cm; emergent, plants including rushes, sedges, lilies and arrow leaf's; submergent, plants including *Elodea sp.*, *Potamogeton spp.*, *Vallisneria americana* and *Myriophyllum spp.*; wood, debris such as sticks, twigs and felled tree.

Latitude	Longitude	Location	Net	Day	Month	Julian	Reach	Water tem	Air_temp	Set_time	Pick up_ti	In_water	Secchi	Net_(m)	Half	Box	Organic	Silt	Clay	Sand	Stones	Rock	Emergent	Submerge	Wood
45°16'07	76°14'50	T30406CE	T	4	5	125	Cedar Hill	18.5	16	13:00	14:30	25.50	2	100	250	300	0	0	0	0	0	0.8	0	0.1	0.1
45°28'12	76°14'58	H11905GA	H	18	5	139	Galletta	20	30	10:30	10:00	23.50	1.8	0	100	200	0	0	0	0	0.5	0.5	0	0	0
45°28'20	76°15'58	H21905GA	H	18	5	139	Galletta	20.5	30	10:30	9:45	23.25	1	0	150	200	0	1	0	0	0	0	0	0	0
45°20'05	76°16'30	M11805PA	M	18	5	139	Pakenham	22	30	12:30	14:30	26.00	2	0	250	400	0	0	0.5	0.5	0	0	0	0	0
45°20'14	76°17'09	T11805PA	T	18	5	139	Pakenham	22	30	11:30	14:45	27.25	1.5	0	200	250	0.1	0.1	0	0	0	0	0	0	0.8
45°14'27	76°13'00	T22005AL	T	20	5	141	Almonte	23	21	11:30	16:45	29.25	2.75	100	300	330	0.1	0.1	0.1	0.1	0	0	0	0	0.6
45°13'40	76°12'21	H12105AL	H	21	5	142	Almonte	20	30	12:03	11:03	23.00	2	0	40	75	0	0	0	0	0	1	0	0	0
45°14'29	76°14'50	M12105BL	M	21	5	142	Blakeney	19	30	13:40	16:30	26.83	2	0	100	130	0	0	0	0	0.5	0.5	0	0	0
45°14'48	76°13'51	T12105BL	T	21	5	142	Blakeney	20	19	10:45	14:04	27.32	2.5	100	220	220	0	0	0	0.1	0.8	0	0	0	0.1
45°15'00	76°14'30	M12205BL	M	22	5	143	Blakeney	22	30	13:00	13:00	27.00	2	0	350	450	0	0	0	0	0	0	0.5	0.5	0
45°15'05	76°14'18	M22205BL	M	22	5	143	Blakeney	26	25	15:30	15:00	23.50	2.75	0	220	340	0.1	0.1	0.1	0.1	0	0	0.3	0.3	0
45°14'97	76°14'07	M32205BL	M	22	5	143	Blakeney	19	18	12:37	15:00	26.38	2.75	0	360	450	0	0	0	0	0.3	0	0	0.7	0
45°15'30	76°14'37	T22205BL	T	22	5	143	Blakeney			13:00	13:30	24.50	2	100	475	500	0.1	0	0	0.25	0.25	0	0	0.4	0
45°15'83	76°14'88	T12605BL	T	26	5	147	Blakeney	26	26	15:03	13:30	22.45	2.5	100	220	220	0	0	0	0.1	0.8	0	0	0	0.1
45°15'10	76°14'35	H12705BL	H	27	5	148	Blakeney	19.5	26	12:53	10:33	21.67	2.5	100	250	400	0.25	0.25	0	0	0	0	0.5	0	0
45°15'72	76°14'79	M12705BL	M	27	5	148	Blakeney	19.5	17.5	11:11	10:00	22.82	2.75	100	220	275	0.5	0.1	0	0	0	0	0.2	0.2	0
45°15'37	76°14'49	M22705BL	M	27	5	148	Blakeney	19	19.5	10:20	10:20	24.00	1.75	30	200	250	0	0.5	0	0	0	0	0	0.5	0
45°15'88	76°15'03	M32705BL	M	27	5	148	Blakeney	20	19.5	10:40	10:40	24.00	2.25	50	80	120	0.1	0.5	0.1	0	0	0	0.1	0.2	0
45°14'84	76°13'89	T22705BL	T	27	5	148	Blakeney	20	22	11:00	11:30	24.50	2.5	0	700	800	0	0	0	0	0	1	0	0	0
45°14'90	76°13'55	T22805BL	T	28	5	149	Blakeney	21	28.5	11:30	14:53	27.38	2.75	0	700	800	0	0	0	0	0	1	0	0	0
45°14'55	76°13'44	T32805BL	T	28	5	149	Blakeney	20	22	15:50	15:57	24.12	2.5	100	250	400	0	0	0	0	0.95	0	0	0	0.05
45°15'83	76°14'88	T12905BL	T	29	5	150	Blakeney	21	21	11:45	16:30	28.75	2.5	100	220	220	0	0	0	0.1	0.8	0	0	0	0.1
45°16'04	76°14'47	H10206CE	H	2	6	154	Cedar Hill	19	18	16:30	13:44	21.25	1.5	0	130	160	0	0	0	0	0	0.8	0	0.1	0.1
45°16'19	76°14'53	M10206CE	M	2	6	154	Cedar Hill	19.5	21.5	15:40	15:00	23.33	1	0	0.75	1	0	0	0	0	0	0.7	0.05	0.2	0.05
45°16'13	76°14'53	M20206CE	M	2	6	154	Cedar Hill	19.5	16.5	14:00	14:00	24.00	1	100	100	100	0	0.2	0.2	0	0.1	0	0.45	0	0.05
45°17'06	76°16'04	M30206CE	M	2	6	154	Cedar Hill	19.5	17.5	16:53	10:48	17.92	3.2	0	1.25	2.5	0	0	0.1	0.1	0.2	0.4	0.1	0.1	0
45°16'74	76°15'88	T10206CE	T	2	6	154	Cedar Hill	19.5	21.5	14:00	11:30	21.50	2.5	100	460	300	0	0	0	0.5	0	0.5	0	0	0
45°16'09	76°14'54	T20206CE	T	2	6	154	Cedar Hill	19.5	17	14:30	12:21	21.85	3	0	200	230	0	0	0	0	0	0	0	1	0
45°16'23	76°15'03	M50406CE	M	4	6	156	Cedar Hill	17	16	13:10	16:16	27.10	1.75	130	130	130	0.3	0.3	0	0	0	0	0.3	0.1	0
45°17'57	76°16'43	T30406CE	T	4	6	156	Cedar Hill	17.5	17	13:40	14:45	25.08		0	300	360	0	0	0	0.1	0.1	0.8	0	0	0
45°17'06	76°16'04	M30506CE	M	5	6	157	Cedar Hill	18.5	18	15:45	13:00	21.25	3.5	0	1.25	2.5	0	0	0.1	0.1	0.2	0.4	0.1	0.1	0
45°17'15	76°16'17	M40506CE	M	5	6	157	Cedar Hill	18.5	10.5	16:00	13:10	21.17	2	0	100	275	0	0	0	0.1	0	0	0	0.9	0
45°20'20	76°17'10	M40806PA	M	8	6	160	Pakenham	19	18	11:00	12:00	25.00	0.5	0	50	50	0	0	0.425	0.425	0.15	0	0	0	0
45°20'06	76°17'07	H10906PA	H	9	6	161	Pakenham	17	20	12:45	17:00	28.25	2	0	60	170	0.4	0	0	0.5	0	0	0	0.1	0
45°21'24	76°16'13	H20906PA	H	9	6	161	Pakenham	20	30	11:00	13:15	26.25	2	30	130	300	0.05	0	0.8	0	0	0	0	0.1	0.05
45°19'46	76°17'23	M10906PA	M	9	6	161	Pakenham	20	22	10:00	17:00	31.00	3	0	100	200	0.1	0.2	0.7	0	0	0	0	0	0
45°20'17	76°17'04	M20906PA	M	9	6	161	Pakenham	19.5	18	10:30	17:30	31.00	2.75	0	180	150	0	0	0	0.45	0.05	0.25	0	0.05	0.2
45°20'11	76°17'13	M30906PA	M	9	6	161	Pakenham	18.5	30	11:30	17:15	29.25	1.5	90	90	150	0	0	0	0	0	1	0	0	0
45°20'15	76°17'19	T10906PA	T	9	6	161	Pakenham	18	22	10:00	9:30	23.50	1.5	0	100	460	0	0	0	1	0	0	0	0	0
45°20'14	76°17'09	T20906PA	T	9	6	161	Pakenham	17	22.5	12:00	14:48	26.80	2.5	100	160	160	0	0	0	0.6	0	0	0	0	0.4
45°20'46	76°17'05	T31106PA	T	11	6	163	Pakenham	21	19	12:08	10:45	22.65	2.5	0	250	460	0	0	0.5	0.5	0	0	0	0	0
45°21'24	76°16'13	H21206PA	H	12	6	164	Pakenham	20	19	15:07	10:45	19.72	2	30	130	300	0.05	0	0.8	0	0	0	0	0.1	0.05
45°20'14	76°17'09	T21206PA	T	12	6	164	Pakenham	19	19.5	12:15	12:48	24.51	2.5	100	160	160	0	0	0	0.6	0	0	0	0	0.4
45°21'42	76°17'12	M31606PA	M	16	6	168	Pakenham	19	30	13:45	13:40	23.92	2	30	130	300	0.05	0	0.8	0	0	0	0	0.1	0.05
45°16'51	76°15'48	H12506CE	H	25	6	177	Cedar Hill	27	24	13:00	13:15	24.25	2.75	100	225	300	0.1	0.2	0.05	0	0	0	0.1	0.25	0.3
45°17'19	76°16'05	M12506CE	M	25	6	177	Cedar Hill	26.5	24	11:00	11:00	24.00	3	0	256	300	0.4	0	0	0	0	0	0.15	0.45	0
45°16'20	76°16'10	M22506CE	M	25	6	177	Cedar Hill	27	24	11:45	13:30	25.75	1.5	0	200	300	0	0.2	0	0.1	0.3	0	0	0.4	0
45°19'40	76°17'20	M32506CE	M	25	6	177	Cedar Hill	26.5	24	10:30	11:47	25.28	3	0	100	200	0.1	0.2	0.7	0	0	0	0	0	0
45°15'05	76°14'19	T12506BL	T	25	6	177	Blakeney	26.5	22	14:00	12:15	22.25	2	100	475	500	0.25	0.25	0	0	0	0	0.5	0	0
45°16'52	76°15'48	T22506CE	T	25	6	177	Cedar Hill	28	30	14:00	14:00	24.00	2.75	100	300	525	0.4	0.4	0	0	0	0	0.1	0	0.1
45°17'03	76°16'03	H10907CE	H	9	7	191	Cedar Hill	23.5	24	12:10	13:50	25.67	2	0	50	180	0	0	0	0.2	0	0.8	0	0	0
45°17'40	76°15'22	M10907CE	M	9	7	191	Cedar Hill	23	27.5	11:30	11:30	24.00	3.3	100	150	300	0	0	0	0.2	0.2	0	0	0.6	0
45°17'17	76°16'08	M20907CE	M	9	7	191	Cedar Hill	24	27	11:50	12:07	24.28	4	0	250	470	0	0.1	0	0	0	0	0	0.9	0
45°16'30	76°16'57	M30907CE	M	9	7	191	Cedar Hill	24	24	15:00	16:45	25.75	1.5	0	200	300	0	0.2	0	0.1	0.3	0	0	0.4	0
45°17'16	76°16'07	T10907CE	T	9	7	191	Cedar Hill	23	25	13:00	14:40	25.67	3.9	100	300	350	0	0	0	0.1	0	0	0	0.9	0
45°17'12	76°16'02	T20907CE	T	9	7	191	Cedar Hill	23	25	13:55	10:48	20.88	3	0	130	200	2.75	0	0	0.2	0.2	0.2	0	0.4	0
45°17'04	76°16'07	H11507CE	H	15	7	197	Cedar Hill	23.75	22.5	11:20	11:35	24.25	2	0	75	250	0	0.1	0	0	0	0	0.1	0.8	0
45°16'27	76°15'14	M11507CE	M	15	7	197	Cedar Hill	25	30	11:45	14:02	26.28	3.25	75	200	245	0.1	0.1	0.3	0.1	0	0	0.1	0.15	0.15
45°16'09	76°14'56	M21507CE	M	15	7	197	Cedar Hill	25.5	27	12:50	13:00	24.16	3.2	100	220	350	0.1	0.1	0.3	0.1	0	0	0.1	0.15	0.15
45°16'17	76°15'01	M31507CE	M	15	7	197	Cedar Hill	24	33	12:20	13:25	25.08	2.75	210	310	350	0	0	0	0	0	0	0.1	0.9	0
45°17'12	76°16'14	T11507CE	T	15	7	197	Cedar Hill	24.5	30	13:35	13:35	24.00	3	20	100	300	0.15	0	0	0.05	0	0	0.1	0.2	0.4
45°16'08	76°14'54	T21507CE	T	15	7	197	Cedar Hill	26	29	14:20	12:15	21.92	3.5	100	250	300	0.15	0.1	0	0.05	0	0	0.1	0.2	0.4
45°17'12	76°16'14	T11607CE	T	16	7	198	Cedar Hill	25	28	12:00	13:40	25.67	3	20	100	300	0.15	0.3	0	0.05	0	0	0.1	0.2	0.4
45°16'08	76°14'54	T11510CE	T	15	10	289	Cedar Hill	22	20	14:35	13:10	22.58	2	100	250	330	0	0	0	0	0	0.1	0	0.9	0
45°17'12	76°16'14	T21510CE	T	15	10	289	Cedar Hill	22	20	15:00	14:30	24.00	2.75	0	150	375	0	0	0	0.1	0.3	0.4	0	0.2	0
45°14'54	76°13'52	H13010BL	H	30	10	304	Blakeney	16	8	14:50	14:00	23.17	1	0	100	100	0	0	0	0.8	0	0.2	0	0	0
45°14'56	76°13'44	T13010BL	T	30	10	304	Blakeney	16	22	11:00	15:10	28.17	2.75	0	175	250	0	0	0.9	0	0	0	0	0.1	0
45°14'57	76°14'02	T23010BL	T	30	10	304	Blakeney	16	8	13:00	15:17	26.28	3	0	250	300	0.05	0	0.45	0	0.45	0	0	0	0.05