Ecology of the Quillback (*Carpiodes cyprinus*) of Dauphin Lake, Manitoba

by

Brian Parker

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ABSTRACT

The ecology of the quillback (Carpiodes cyprinus) of Dauphin Lake, Manitoba, was studied during the open water periods of 1984 and 1985. Spring spawning runs were monitored with a fish fence on the Ochre River while quillback were collected from Dauphin Lake in beach seining surveys carried out each summer. Quillback spawning migrations commenced when water temperatures reached 5 C but were confined to pulses of runoff following snowmelt and precipitation events. Movements were concentrated in the mid-afternoon and early night hours. Some migrants moved upstream as far as 32 km but others only 1.6 km. Spawning was observed, usually over riffles, at water temperatures of 7 to 18 C in late April to mid June. The mean fork length (FL) of spawning adults was 420 mm and mean weight 1770 g. Fecundity ranged from 51,600 to 360,000 in fish of 970 to 3150 g (358 to 507 mm FL) and was linear with wet weight where $\ln(fec) = 2.35 + 1.27 \ln(\text{wet weight})$. Large (>1200 g) females had significantly heavier ova and greater % wet gonad weight than small individuals. The maximum recorded % gonad weight was 22.5%. Hatching of larvae occurred 229.8 degree days after spawning. Mean total length of newly hatched larvae was 7.95 mm. Larvae drifted overnight while still in the prolarval stage. Overnight predation on larvae by shiners (Notropis cornutus and N. hudsonius) and darters (Etheostoma nigrum and Percina shumardii) was recorded. Adults marked with Floy FD anchor tags had an 8.6% annual tag loss rate. The mean growth rate of tagged adults was less than 7.5 mm/year.

Commercial exploitation of the marked population was <1% per year and recreational exploitation negligible. Fin ray ageing was validated, but only to age 8, and otoliths, opercles, vertebrae and scales were validated to the same age by comparison. Otoliths gave the oldest ages thereafter. Male quillback mature at 4, 5 or 6 years of age and females at 6, 7 or 8 years at minimum fork lengths of 280 and 345 mm respectively. The largest individual captured was a pre-spawn female of 560 mm FL (626 mm TL) and about 4 kg wet weight. Length-weight relationships were ln(wet weight) = -9.839 + 2.834 ln(FL) for spent adults and ln(wet weight) = -12.136 + 3.243 ln(FL) for juveniles. Quillback ate small (<.6 mm diam.) benthic items including chironomids, entomostracans and Difflugia. Large quantities of sand and organic detritus usually were present in stomachs. The diet of large (>200 mm FL) and small quillback from inshore samples was very similar. Several quillback taken offshore consumed nearly 100% entomostracans but very little sand suggesting that facultative midwater feeding may occur. Post-spawning migrants consumed small quantities of fish eggs. Preferred substrates were loose sandy to sandy-silty combinations in areas sheltered from wave action. Young-of-year (YOY) were taken only in shallow inshore waters, while adults preferred deeper water except on hot, calm days when they could also be taken inshore.

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INTRODUCTION

The carpsuckers (Catastomidae: Ictiobinae: Carpiodes spp.) are a group of morphologically similar suckers (Cornelius 1966) that are widespread across much of south-eastern North America (Fig. 1). The river and highfin carpsuckers and the quillback (C. carpio, C. velifer and C. cyprinus respectively) all occur in the United States while only the latter is known from Canada (Scott and Crossman 1979). Carpsuckers usually are of limited commercial or recreational importance and there have been few comprehensive reports on any of the species; in particular, none on Canadian populations of C. cyprinus.

The river carpsucker has been the most extensively studied species to date but most authors provide little more than age and growth data (Elkin 1954, Purkett 1957, Bass and Riggs 1958, Morris 1965, Stucky and Klassen 1971) with few studies directed to or including fecundity (Behmer 1965, 1969b), diet (Buchholz 1957, Brezner 1958, Walburg et al 1971, Summerfelt et al 1972) or behavioural analyses (Behmer 1969a).

Except for a study on quillback larval development by Gerlach (1973) most studies on quillback ecology have been ancillary to work on the highfin carpsucker. Vanicek (1961) provided age and growth data on both species with other authors including, in addition, fecundity analyses (Woodward 1973, Woodward and Wissing 1976) and presumed evidence of competition among the species (Beecher 1979).

However, there remains a lack of broadly based biological

studies on any population of quillback. The present study was undertaken to provide a reasonably complete life history of C. cyprinus from Dauphin Lake, Manitoba (approx. 51 17'N: 99 14'W).

STUDY AREA

Dauphin Lake, Manitoba, and its tributary streams are currently the focus of a Canada Department of Fisheries and Oceans (DFO) research effort aimed at rehabilitating the declining walleye (Stizostedion vitreum) population there. This study was made possible through the cooperation of Dauphin Lake Walleye Rehabilitation Project staff who operated a fish fence on the Ochre River and maintained a sampling program on Dauphin Lake.

Dauphin Lake is a large, shallow, turbid prairie lake located about 20 km northeast of Dauphin, Manitoba (Fig. 2). It has a surface area of approximately 500 km^2, a mean depth of 2.34 m and a maximum depth of only 3.1 m. Stewart-Hay (1951) has described the lake and its surrounds in detail.

The Ochre River originates in Riding Mountain National Park at about 660 m asl before descending the Riding Mountain escarpment and crossing the former Lake Agassiz floor to enter Dauphin Lake at about 256 m asl. The Ochre River drains an area of >420 km^2 (Penner and Oshoway 1982). The lower 30 km are generally of low gradient (approx. 1.8 m per km) and are slow flowing with riffles interspersed with sand and mud bottomed pools. On the escarpment, gradients average approximately 9 m/km and the river is composed of virtually continuous, often unstable, riffle areas. The headwaters have not been directly modified by man due to their inclusion in Riding Mountain Park but outside the park the basin is subject to heavy agricultural usage and

some meander cutting and ditching of tributaries has taken place. The Ochre River probably is the least modified drainage entering Dauphin Lake. The river is prone to flash flooding during snowmelt and precipitation events but is usually reduced to near zero flow during the summer months.

MATERIALS AND METHODS

Ochre River Spawning Migrations

Fish spawning migrations were monitored with a two-way fish fence (modified from Anderson and McDonald 1978) operated on the Ochre River about 1.6 km upstream from Dauphin Lake (Fig. 3) from April 15 to June 22, 1984 and April 14 to June 25, 1985. High water levels prevented fence operation over the periods May 6 to 9 and May 11 to 20, 1984 and April 18 to 25, 1985.

Staff gauge readings were taken at about 10:00 h (local time, GMT - 6 h) daily at the fence site except during several high water periods when the gauge washed out. Water levels from April 19 to 25, 1985 were estimated from markers set into the bank at 10:00 h each day. Water temperatures were taken to the nearest .1^{o}C by hand-held thermometer in 1984 at about 9:00 h while in 1985 a Robert-Shaw recording thermograph was operated at the fence site. Mean daily temperatures for 1985 were calculated directly from the thermograph charts.

Fish were passed in both directions at least twice daily with enumeration as often as once an hour when runs were heavy. Fork lengths (FL) were taken for all quillback in both years, while wet weights to the nearest 10 grams were recorded for fish taken in 1984 only. The sex of all upstream migrants was determined by external appearance and/or stripping. Quillback were considered 'green'

(usually applicable only to females) if they had not spawned and stripping failed to produce freely flowing sexual products; running if sexual products were freely flowing and spent if in post-spawning condition. Due to difficulties in determining the sex of some spent fish, downstream migrants frequently were not classified by sex.

In 1984, 857 adult quillback on their downstream migration were marked with individually numbered Floy anchor tags. Only fish in good condition were tagged and no anaesthetic was used. Tags were applied near the anterior end of the dorsal fin such that the T-bar interlocked with the dorsal pterygiophores. A portion of the first 2 to 5 rays from the left pelvic fin were taken from all marked fish for aging purposes. A further 115 individually numbered and 402 batch mark, unnumbered Floy tags were applied to 517 adults in 1985 but none were finclipped. Fish marked in 1984 and passing the fence in either, or both directions in 1985 were recorded by tag number and had the left pelvic fin clipped for age validation material. Quillback that had previous pelvic fin clips but no tags were considered to have shed their tags.

Fecundity, Egg and Larval Measurements

A total of 43 pre-spawn females were sampled from the Ochre River fence site for fecundity analysis: 35 in 1984 and 8 in 1985. Round weight to the nearest 10 grams and fork length were recorded for all individuals. The ovaries were removed from the body cavity, weighed to the same limit and preserved in Gilson's solution for three

months before examination.

Fecundity was estimated from preserved ova rinsed free of ovarian tissue. Five groups of 1000 eggs each were counted and then dried, as well as the remainder of the ova, for 48 hours at approximately 21°C. All groups were weighed to the nearest .0001 g on a Mettler AE160 balance. Fecundity was estimated by division of the mean 1000 egg weight into the total dry weight of eggs.

Two female and 3 male quillback from the Ochre River were spawned together on May 16, 1985. After water hardening for 1 hour, without hardening agents, the fertilized ova were transferred to and held in the Mobile Walleye Hatchery currently under development by DFO. The hatchery used Ochre River water at its prevailing temperature regime over the full incubation period. The number of degree days to hatch was calculated from mean daily temperatures derived from the Robert-Shaw thermograph operated at the fence site. Upon hatching 50 larvae were sampled and preserved in 10% formalin. Total lengths (TL) were measured to the nearest .01 mm with dial calipers.

Dauphin Lake Sampling

The seining schedule in 1984 consisted of approximately weekly 100 m hauls with a 10 m bagless seine, on either side of the Ochre River mouth, during the period July 4 to September 30. The eastern shore had a wave-washed hard-packed sand and gravel substrate devoid of vegetation. A plume of Ochre River water often extended down the east shore for .5 km or more and there usually was a noticeable onshore

current. The western shore was more protected from wind action and had both submergent and emergent vegetation. The substrate was sandy with silt and mud patches and there usually was no noticeable current.

The seining program was expanded in 1985 to a weekly seining effort with a 31.5 m bag seine from July 1 to September 29. Seining locations included the west side of the Ochre River mouth, Welcome Beach, Methley Beach, Stoney Point Beach, an unnamed beach 2 km south of Oak Brae and an unnamed beach off the east side of the mouth of the Valley River (Fig. 3). The Oak Brae, Valley River and Welcome Beach sites were not seined in September. One 100 to 150 m seine haul perpendicular to the shore was made at each site except at Oak Brae and Stoney Point where 2 and 3 shorter hauls were made respectively, due to a more steeply sloping lake bottom.

Welcome Beach had a cobble shoreline with a hard-packed clay-sand substrate beyond 10 m offshore. Methley Beach had sand bars alternating with gravel strips and a scattering of large boulders close to shore. The Valley River site was clean hard sand and was very similar to the abandoned site on the east side of the Ochre River. Oak Brae had a soft silty-sandy bottom with pockets of cobble and submergent vegetation. Stoney Point had a loose sandy-gravelly base with occasional larger boulders. There was usually a strong onshore current at this location.

All quillback taken by seining were sampled. Fish under 200 mm FL were immersed in 10% formalin on capture and measured to the nearest

.01 mm FL and weighed to the nearest .01 grams on return to camp. Larger quillback were held cool until return to camp and were measured to the nearest mm FL and weighed to the nearest gram.

Age and Growth Analysis

Validation of fin ray aging was attempted with seine caught juveniles of 1985 and 96 tagged and recaptured fish taken either at the Ochre River fence in 1985 or by commercial fishermen in November and December of the same year.

All clipped fins, an initial left pelvic clip from the time of tagging and a right pelvic clip from the time of recapture for each fish, were dried and coated in a cold cure epoxy. Sections .65 to .85 mm thick were taken with an Isomet low-speed diamond saw as close to the fin base as possible. Fin sections were mounted on glass slides with Diatex mounting medium and read under transmitted light. Right and left fins from recpatured marked fish were compared to assess annulus formation, whereas the fin ray age of juveniles was compared to the putative year-size class to which they belonged.

In addition, 27 mature quillback and 34 juveniles were sampled for scales, vertebrae, otoliths, operculars and pelvic fins to provide a comparative assessment of age between different structures. A further 32 adults were sampled for 4 of the 5 structures and 21 for 3 of the 5 in different combinations.

Slides of longitudinal sections of vertebrae were prepared in the same manner as for pelvic fins. Cross sections of .60 mm

thickness (Fig. 4) were taken from operculars and mounted on slides for aging. Otoliths were burnt in a gas flame in the manner of Christensen (1964) but were then embedded in epoxy and cross-sectioned through the sulcus with the isomet saw. Otoliths were not broken as described by Christensen (1964) because they disintegrated when a needle was pushed through the sulcus. A drop of glycerine was applied to the cut surface of the otolith to provide better resolution of presumed annuli just before examination. All of the above structures were examined under reflected light. Scale samples were pressed between 2 slides and viewed with transmitted light. Individual structures from any fish were examined without knowledge of the age given by any other structure for the same fish.

Length-weight relationships were determined for the spent downstream migrants of 1984 and seine caught juveniles of 1985. Lengths and weights were transformed with natural logs prior to regression analysis.

Dietary Analysis

Stomachs were removed from 49 adult and juvenile quillback caught in seines in 1985, 9 post-spawning migrants taken from the Ochre River in May 1985 and 6 adults taken by the commercial fishery in December of the same year. In addition, 11 stomachs were examined from fish caught more than 1 km offshore by DFO staff in the summer of 1983.

Stomachs were considered to be that portion of the gut from just anterior to the muscular "gizzard" to its first bend where it

doubles back on itself. Stomachs were preserved in 10% formalin for 5 to 7 days and then held in 70% ethanol until examination. Gut contents were examined under a dissecting microscope at magnifications up to 500X to ensure the evaluation of microscopic food items. Occurrence and the estimated % volume (by eye) of each taxon were recorded for each stomach. Trace volumes were arbitrarily assigned a value of 0.5%. Total volumes were corrected to total 100% after a "mucous and gut lining" category had been deleted.

Individual stomach data were combined for fish in the following groups: winter fishery; 1983 offshore; 1985 inshore <200mm FL and 1985 inshore >200 mm FL. Average volumes of <0.5% for any taxon, in any group, were considered only as "trace."

Meristics, Morphometrics and Tubercle Distribution

Counts and measurements were taken from a combination of spring spawning migrants and fish caught through the summer. All fish were preserved in 10% formalin for at least 1 month and rinsed in water for 3 to 4 days before examination. Characters were recorded according to the definitions of Hubbs and Lagler (1964) with the exception of head length, which was measured from the tip of the snout to the posterior edge of opercular bone. All measurements were taken with dial calipers to the nearest .01 mm.

Tubercle distributions were based on 12 female and 11 male quillback taken from the Ochre River downstream run between May 20 and 25 1985. These fish were initially taken for meristic and morphometric

study and without regard for the degree of their tuberculation. All individuals were held as above except that three males were re-examined after 3 months storage in 50% isopropyl alcohol.

RESULTS

Ochre River Spawning Migrations

Daily counts of migrating quillback, 9:00 h water depth and mean daily water temperature for the Ochre River in 1984 and 1985 are given in Figs. 5 and 6 respectively (Appendix 1). Quillback runs commenced before water temperatures reached 6°C on April 15, 1984 and at less than 7°C between April 18 and 23, 1985 when a single quillback was taken in a trap net at the fence site after the fence had washed out. Northern pike (Esox lucius), white sucker (Catastomus commersoni) and walleye (Stizostedion vitreum) had commenced their upstream migrations (in the order given) before the first quillback was taken. The shorthead redhorse (Moxostoma macrolepidotum) was the last of the larger species of fish to run in the Ochre River. A small number of silver redhorse (Moxostoma anisurum) also ran up the Ochre River each year.

Upstream movements of quillback coincided with declining discharges and rising water temperatures following runoff peaks caused by snowmelt and precipitation events. Each pulse of runoff was accompanied by a successively smaller pulse of upstream migrant quillback from mid April until late June when runs ceased.

Quillback ran as far as 30 km up the Ochre River in 1983 (S. Harbicht pers. comm.) and 1985 (equivalent to a vertical gain of 53 m from lake level). In 1984 they were reported from 32 km upstream

(about 63 m above lake level). However, lengthy migrations were noted only after periods of high discharge; migrants running upstream during minor peaks of discharge often migrated no further than 2 to 3 km.

Both up and downstream movements of quillback occurred primarily in the mid-afternoon and just after dark. Migrating quillback showed a strong tendency to school, even well after spawning, unlike any of the other suckers that ran in the Ochre River.

Quillback spawning was intermittent in the Ochre River and generally followed peaks in discharge. Spawning was observed at temperatures between 7 and 17°C from April 16 to June 8, 1984 and at temperatures between 7 and 18°C from April 25 to June 4, 1985.

Spawning usually occurred in riffle areas over coarse to fine gravel substrate, especially when river discharge was high. As discharge declined spawners moved to progressively deeper and slower reaches with loose sandy bottoms, but were never seen spawning over muddy substrates. Usually spawning groups consisted of 2 to 5 individuals although the membership of groups frequently changed. Individuals were very active and often engaged in spawning acts over 50 m stretches of river bottom, especially when water levels were low and quillback were working sandy runs.

In both 1984 and 1985 the first downstream migrants were large (>450 mm FL) spent females. As the downstream run progressed the sex ratio increased in favour of male quillback. Since both the 1984 and

1985 upstream runs were largely missed due to fish fence washouts it was not possible to determine a migratory sequence, by sex, for the upstream runs.

One hundred twenty-eight of 857 quillback marked in 1984 returned to spawn in the Ochre River in 1985. Ninety-four quillback marked in 1984 that ran upstream between April 18 and 25, 1985, when the fish fence was washed out returned downstream after a minimum average of 39.2 days (range 12 to 60). Sixteen previously marked adults that returned after April 25 stayed upstream an average 29.5 days (range 9 to 46). Most quillback, both marked and unmarked returned to Dauphin Lake following the high water period of June 2 to 6, 1985, that saw the highest water levels since the snowmelt flood, regardless of when they passed upstream.

Nearly all downstream migrants were spent in both 1984 and 1985 except during the period May 9 to 11, 1984, when many prespawn females returned to Dauphin Lake. This anomalous behaviour was coincident with culvert removal and bridge construction .75 km upstream from the fish fence.

Distributions of fork length for downstream migrants were very similar between 1984 and 1985 (Figs. 7 and 8). Mean fork lengths were 419.7 mm (approx. 469 mm TL) and 421.4 mm (approx. 471 mm TL) for 1984 and 1985 respectively.

Females were on average larger than males in both years, based on upstream migrants only (Figs. 7 and 8) with means of 443.6

and 449.0 mm FL for females and 413.0 and 409.1 mm FL for males in 1984 and 1985 respectively. The longest female taken was 560 mm FL (626 mm TL) and weighed approximately 4 kg while the longest male was 521 mm FL (581 mm TL) and about 2.7 kg wet weight.

Fecundity, Egg and Larval Measurements

The fecundity of Ochre River quillback ranged from an estimated 51,600 in a 1010 g, 370 mm FL female to 360,000 in a female of 3150 g and 507 mm FL (Table 1). Fecundity increased as a linear function of wet weight, but the data were transformed with natural logs to meet homogeneity of variance assumptions of linear regression. The relationship of the transformed data was ln (fecundity) = 2.35 + 1.27 ln (wet weight) (r^2 = .885, Fig. 9).

Within the Dauphin Lake population, large quillback (>1200 g or >390 mm FL) had significantly heavier ova than smaller females, (Appendix 2) at .6092 and .4571 g dry weight per 1000 ova respectively (t = 4.704, df = 5, a<.005, two sample T-test for samples of unequal size and variance (Snedecor and Cochran 1980) Fig. 10). A similar occurrence was noted in 1985 when mean dry weights of 1,000 ova for 4 large and 4 small females were respectively .6221 and .4334 g (Table 2).

There was a significant difference in wet gonad weight expressed as a percentage of wet body weight between large and small quillback. The mean % wet gonad weight for small females was 9.91% and for large females 17.25% (t = 4.7, df = 4, a <,005. Appendix 2). The maximum % wet gonad weight recorded was 22.5%. There was a trend towards

increasing % wet gonad weight as wet weight increased (Fig. 11), considering even large females only.

Eggs fertilized on May 6, 1985, were successfully incubated until larvae hatched on May 23 after 229.8 degree days. Hatching of quillback larvae was synchronous and nocturnal as for white sucker and walleye larvae reared in the same facility. The mean length of 50 newly hatched and preserved prolarvae was 7.95 +/-.02 mm TL (Appendix 3).

Virtually all quillback larvae taken in DFO larval drift studies on the Ochre River in 1984 and 1985 drifted overnight and in the prolarval stage. Overnight predation on drifting larvae by common (Notropis cornutus) and spottail (Notropis hudsonius) shiners and johnny (Etheostoma nigrum) and river (Percina maculata) darters was recorded. Up to 17 larvae were found in an individual predators stomach. The length of time for which the predators had been feeding is unknown.

Dauphin Lake Sampling

Sixty-nine quillback were caught in 1984 (Appendix 4), all from the west side of the Ochre River mouth over sandy-silty substrates. No quillback were taken from the east shore site over hard packed sand and gravel substrates.

Seine catches of quillback in 1985 (Appendix 5) like those of 1984, were greater over soft rather than firm substrates. No quillback were taken from the Welcome Beach or Valley River sites where the substrate was hard-packed sand. Only 10 of the 110 quillback

caught were taken over hard substrates and all were juveniles taken from Methley Beach. Seventy-four quillback (11 adults, 63 juveniles) were taken from the west shore of the Ochre River mouth. Adults were taken most frequently from Stoney Point (15) and sometimes from Oak Brae (4) where water depth increased rapidly as one moved offshore. All but two juveniles were taken from the Ochre River and Methley Beach sites where the shorelines slope very gently into deeper water and there are extensive shallow-water areas. The other two juveniles were taken from Stoney Point but both of them were larger individuals of age 3+.

There appeared to be differences in the relative strengths of the 1984, 1985, and 1986 year classes on the basis of seine catches of YOY quillback on the west side of the Ochre River (Table 4). Sixty-six YOY were taken in 1984 with a 10 m seine but only 6 in 1985, when a 31.5 m seine was used. Taking into account that seine size was increased, catch rates of 1984 YOY were about 30 times greater than for YOY in 1985 (Table 3). Further DFO seining in 1986, with the 31.5 m seine at bi-weekly intervals, took only 1 YOY quillback from the west side of the Ochre River (S. Harbicht pers. comm.). There was thus nearly a 100-fold difference in YOY abundance between 1984 and 1986 based on seine catches.

Tag Return Analysis

One hundred and twenty eight of 857 quillback tagged in 1984 returned to the Ochre River in 1985 (Appendix 6). Eleven recaptured

quillback were pelvic finclipped but not tagged and were assumed to represent fish that had lost their tags. A tag loss rate of 8.6% for quillback at large 1 year was indicated.

Tagged fish were recaptured all over Dauphin Lake during the non-spawning period (Fig. 12) indicating widespread dispersal of spawners from the Ochre River.

Only seven marked quillback were taken in the 1984-85 commercial fishery (Appendix 7). Assuming that all mechanical tag failure occurred prior to the onset of the fishery and that no death of marked fish occurred only 792 of an original 857 tagged quillback would still have borne tags when the fishery opened. The exploitation rate of marked fish under this assumption was 0.88%. Two of a potential 473 1985 tags were returned from the 1985-86 commercial fishery yielding (assuming the same tag loss rate as previously) an estimated 0.42% exploitation rate. An additional 5 1984 marks were also returned from the 1985-86 fishery. Assuming no death and two years tag loss at 8.6% per year and accounting for all known removals the 1985-86 exploitation rate of fish marked in 1984 was 0.75%.

No tags were returned by dipnetters on any watercourse entering Dauphin Lake despite widespread dipnetting of suckers (mostly C. commersoni) for home canning. Only one group of dipnetters was ever observed deliberately capturing quillback on the Ochre River.

A one-sample Petersen estimate based on numbers of quillback in the 1985 downstream run in the Ochre River gave a whole lake

population estimate, assuming that adults do not return to a fixed stream to spawn every year, of 18,089 +/- 2812 adults over 370 mm FL.

The same estimate was applied to DFO pound net catches from Methley Beach over a 15 day period in August 1985 considering only those fish marked in 1985 (Appendix 8). All catches were lumped and considered as one sample. An estimate of 32,712 +/- 18,972 adults >370 mm FL was obtained.

Age and Growth Analysis

Pelvic fin rays were validated for aging quillback to age 2+ by comparison of fin age to the size class to which an individual belonged. Cohorts of juveniles formed non-overlapping size classes at any particular point during the open-water season (Fig. 13). The first annulus was usually distinct from the ray centre until age 3+ but at greater ages the first distinct ring was usually the second annulus as found by Beamish (1973) for C. commersoni.

Validation of annulus formation in the pelvic fin rays of adult quillback was based on the recapture of 92 finclipped, tagged fish returning to the Ochre River in 1985 after one year at large and 4 recaptures from the commercial fishery after the marked individuals had been at large from May 1984 to December 1985.

Thirty-five fin pairs could not be validated for annulus formation because one or both of the fin sections were unreadable for one of a variety of reasons, including fin regrowth following injury, poor readability of presumed annuli or poor fin clipping. Higher ages