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(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 $\ln(\text{wet weight}) = -9.839 + 2.834 \ln(\text{FL})$ for spent adults and $\ln(\text{wet weight}) = -12.136 + 3.243 \ln(\text{FL})$ 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 were usually obtained from the 3rd or 4th rather than the first or 2nd fin rays and consequently fin clips of less than the first 3 fin rays were discarded.

All recaptures of fish of fin age 3 through 8 at the time of tagging were validated for the addition of one annulus after 1 year at large. Only 24 of 55 could be validated from fin age 9 and onwards (Appendix 9). Of the four at large 2 years each, only one formed 2 annuli, one formed a single annulus and the others showed no annulus formation. Therefore, fin rays could only be validated for annulus formation up to fin ray age 8 for Dauphin Lake _C. cyprinus_.

Figure 14 shows, for quillback of specific otolith age, the mean age provided from the pelvic fins, scales, operculars and vertebrae of all aged quillback in that otolith age class. Similar ages up to age 8 were obtained using all of the structures and because pelvic fins had been validated to that age all structures were considered validated by comparison. Beyond age 9 otoliths consistently provided the highest ages of all structures (Appendix 10). The presumed annuli were always clear and age estimates were very precise between readings. Quillback otolith development was similar to that described by Power (1978) for lake whitefish (_C. clupeaformis_).

Opercular sections gave ages similar to those given by otoliths but were usually 1 to 2 years lower especially in older quillback. Dissolution of bone from the interior of larger opercles obviously had removed early annuli in numerous cases and this probably accounted for much of the age differences seen between the two structures. Opercular annuli, like those of otoliths, were very clear and age determinations were correspondingly precise. Operculars were sectioned because they were too thick to read whole in larger specimens.

Vertebral age estimates were the same as for otoliths and opercles until an otolith age of 10 years when differences were first noted. Annuli were difficult to discriminate on the outer edges of vertebrae in large adults because they became very crowded.

Fin rays and scales provided the lowest age estimates of any of the structures used. Consequently, most adult quillback were aged with otoliths while smaller fish were aged by size class or with pelvic fin sections.

Seine catch data (Fig. 13) show 1984 cohort growth was from approx. 8 mm TL at hatch in May or June, to 57 to 96 mm FL (64 to 107 mm TL) in September 1984 and to 111 to 160 mm FL (124 to 179 mm TL) in September 1985. Because the mean size of the 1984 cohort in May 1985 was not greater than in September 1984 it appears that growth, at least of juveniles, was largely confined to the May to September period in 1984.

The growth rates of marked adults at large 1 year and returning to the Ochre River in 1985 were highly variable, ranging between -2 and +24 mm. Many of the increments were less than the presumed accuracy of measurement of +/- 5 mm. High variability of individual growth rates also was suggested from the lengths of aged quillback; quillback of

420 mm FL ranged from 16 to 52 years of age. Average growth rates of marked fish by size class (Table 4) showed a trend towards declining growth rate in length as length increased. Average annual growth rates for larger adults were less than 8 mm/year; assuming that there was no effect of tagging on growth. These values were similar to those indicated by plots of age versus length for Dauphin Lake quillback (Fig. 15).

Male quillback matured at 4, 5 or 6 years of age at a minimum FL of 280 mm (313 mm TL) while females rarely matured by age 6 but more frequently by 7 or 8 years of age at a minimum FL of 345 mm (386 mm TL). After maturity, females of any given age are on average larger than males of the same age (Fig. 15, Appendices 11 and 12).

Length-weight relationships (Fig. 16) for the spent adults of 1984 and separately the juveniles of 1985 were ln(wet weight) = -9.839 + 2.834 ln(FL) (r^2 = .87) and ln(wet weight) = -12.136 + 3.243 ln(FL) (r^2 = .99) respectively (Fig. 17). The difference between slopes is significant at P = .995.

Dietary Analysis

The diet of large and small quillback taken inshore was similar (Fig. 17, Appendices 16, 17, 20 and 21). The most important identifiable components by volume for large individuals were chironomids, 5.5%; ostracods, 2.9%; cladocerans, 15.2%; copepods, 6.8%; and *Difflugia*, 6.6%. Comparative volumes for small inshore fish were chironomids, 7.7%; ostracods, 10.7%; cladocerans, 5.2%; copepods, 6.8%

and *Difflugia* 5.4%. Stomachs of fish from both size classes contained large amounts of sand (37.6 and 31.9% respectively) and flocculents (21.3 and 21.9% respectively), here interpreted as organic detritus. Although filamentous algae, diatoms and plant parts were present in stomachs, they never formed more than a minute part of an individual's diet.

Virtually no sand or flocculent material was found in the stomachs of quillback taken offshore in 1983. Entomostracans and chironomids were the major food items at 48.7 and 15.2% of stomach volume respectively (Fig. 17, Appendices 16, 17 and 19). Three quillback taken from Stoney Point in 1985, over loose sandy bottoms, but where the water is relatively deep had similar gut contents to the 1983 offshore samples with up to 95% of gut volume consisting of entomostracans and few sand particles present.

The stomachs of 6 adults taken from the winter commercial fishery in 1985 were empty and suggested that feeding may be reduced in the winter months.

Most food items in these groups were less than .6 mm in diameter, but adults occasionally took items up to 2 to 3 mm in diameter. The larger food items included fingernail clams, sponges, amphipods and insect exuviae.

Seven of 9 spent adults sampled on their return to Dauphin Lake after spawning in May 1985 had been actively feeding in the Ochre River. The largest identifiable component of the diet was fish eggs (6.3%

by volume) followed by chironomids (1.8%) and plant parts (1.5%); usually seeds and woody tissue. Large amounts of coarse 2-3 mm sand (67.9%) and flocculent materials (21.0%) also were ingested (Fig. 17, Appendices 16, 17 and 18). Most feeding quillback in the Ochre River were observed at the tail of riffle areas over loose sandy bottoms. Fish holding in deeper pools were never seen feeding.

The feeding behaviour of laboratory held juveniles involved the excavation of a series of small pits in sandy rather than gravelly areas of aquaria. The protrusibility of the jaws allowed penetration to at least 1 cm into the substrate without requiring individuals to significantly deviate from a horizontal orientation. Unwanted particles were ejected through the lower gill cover while food items were retained; presumably between the gill rakers and the palatal organ.

At least three intestinal parasites were found in quillback stomachs including: an acanthocephalan, Neoechinorhynchus carpiodii; a trematode, Lissorchis gullaris and a Carryophyllid tapeworm, Monobothrium hunteri (identified by A. Szalai).

Meristics, Morphometrics, and Tubercle Distribution

Morphometric and meristic values for Dauphin Lake C. cyprinus are summarized in Appendices 22, 23 and 24.

All fish examined showed tubercle development (Appendices 25 and 26). Casual observation of other quillback in the spawning run suggested that probably 100% of males and >90% of females bore at least some tubercles.

Tubercle distribution on the head was similar to Huntsman's (1967) Fig. 1B except that the top of the head frequently was covered with many small tubercles that continued up the dorsal crest to the base of, and often along, the first dorsal ray. Male quillback also bore tubercles on the cornea of the eye but numbers were very variable, ranging from 1 or 2 tubercles to a series completely surrounding the pupil.

Up to the first 11 pectoral and 8 pelvic rays bore tubercles although only the first 1 or 2 rays of each had tubercles on both the upper and lower surfaces. While pectoral and pelvic fin tubercles were found on most individuals a smaller number, mostly males, also had tuberculate anal and caudal fins.

Tubercles on the body ranged from absent, to present along the full length of the lateral line scale series, with heaviest concentrations on the first 3 or 4 scale rows above and below the lateral line. Scales in this region usually carried 5 to 18 tubercles with fewer per scale outside this area. A few, usually less than 10 or 15, of the anterior belly scales, particularly of males, carried 1 or 2 tubercles.

Patterns of tubercles frequently were not bilaterally symmetrical on any individual fish. Female quillback were generally less tuberculate than were males, but the most tuberculate individual examined was a female. After the spawning period, Dauphin Lake quillback had reduced tubercle development at least through the end of January the following year.

DISCUSSION

Ochre River Spawning Migrations

Quillback migration in the Ochre River was limited by both water temperature and discharge. Pulses of upstream movement occurred over a range of water temperatures above $5^{o}C$,indicating temperature probably would limit migration only when less than $6^{o}C$ during very early snowmelt runoff or following late season snowfalls as occurred between April 27 to 29, 1984. Low discharge prevented migration, even when temperatures were in the range considered optimal for spawning. In early April 1984 water temperatures reached $12^{o}C$ but quillback present in the lower Ochre River would not pass the first riffle. Discharge was low at this time, and reduced water depth over the riffle seems to have prevented quillback from ascending the Ochre River.

Corroborating this possibility, when north or north-west winds caused water levels to rise in the lower river as far as the fence site the passage of quillback, both up and downstream, increased even though discharge did not. This suggests that absolute water depth was critical for migrating quillback. However, since water depth usually was closely related to discharge in the Ochre River discharge must be considered a factor that regulated quillback migrations above the first riffle.

Temperature was judged an important regulator of migrations in both white (Catastomus commersoni) and longnose (C. catastomus) sucker migrations (Barton, 1980, Geen et al, 1966). Only Barton (1980) noted that discharge was important, but discharge may never have been limiting in the Geen et al (1966) study. Indeed, the low levels of discharge that apparently prevented quillback migration in the Ochre River appeared to have no significant effects on the white sucker and walleye runs underway at the same time.

Migrations of quillback 30 to 32 km upstream placed the adults at the base of the Riding Mountain escarpment where extensive riffle and presumably good spawning areas were found. The actual distance of upstream migration for each pulse of migrants probably was dependent on the levels of discharge reached during the migration period. During periods of low discharge riffles and shallow sandy runs probably acted as physical barriers to quillback movement.

The long residence times of adult quillback in the Ochre River in 1985 might be indicative of stranding of adults by declining water levels after they migrated well upstream to spawn in that year. The large flush of spent individuals in June of that year corresponded with the highest discharges since that years' spring flood and may have allowed quillback held upstream to return to Dauphin Lake. Many spent quillback were seen holding in deeper upstream pools prior to the discharge event and were presumed trapped by shallow riffle areas. In 1984 such an event was not recorded but this may have been due to removal of the fish fence before a number of quillback visible upstream had been washed downstream, or perhaps because Ochre River discharges were high for an extended period in 1984 and little stranding of spawners occurred.

Spawning temperatures of 7 to 18°C are the lowest recorded to date for quillback reproduction. Spawning occurred at 16 to 24°C in Florida (Beecher 1979), 10 to 22°C in Indiana (Currie and Spacie 1984) and 19 to 28°C in Ohio (Woodward and Wissing 1976). Water temperatures in the Ochre River and other Dauphin Lake tributaries reach these higher ranges but only in summer when discharges are very low and spawning migrations would not be possible. Also, only a very short growing season would be available for larval quillback if spawning were delayed into the summer months.

The preference for spawning with freshets, also noted by Currie and Spacie (1984) in Indiana rivers, may be an adaptation to allow spawning over more stable riffle substrates that were accessible only during high-water periods. Egg attrition rates probably were very high on the mobile sand substrates used when water levels forced quillback from the preferred riffle areas. Dauphin Lake quillback were never seen spawning over muddy substrates as was reported for the species by Harlan and Speaker (1956).

Dauphin Lake quillback appeared to be annual spawners, as indicated by the return of tagged adults of both sexes to the Ochre River in 1985.

Fecundity, Egg and Larval Measurements

Dauphin Lake quillback fecundities are the highest carpsucker fecundities reported to date, but they are also from the largest individuals sampled for fecundity so far. Woodward (1973) found fecundities of 25,500 to 63,779 in quillback of 315 to 1032 g wet weight. Woodward's (1973) largest female was the only fish with either a weight or a fecundity reaching the ranges of the Dauphin Lake population (Fig. 9). Fecundities of river carpsucker of 4,430 to 154,000 in fish of 182 to 737 grams (Behmer 1969b) and 4,828 to 149,744 in females of 244 to 358 mm TL (Buchholz 1957) were reported from 2 Iowa populations. This suggested, because of the high fecundities reported in the small adults, that other carpsucker populations may have had smaller ova, on average, than Dauphin Lake quillback.

Within the Dauphin Lake quillback population small females bore smaller ova than did larger, older individuals but there were no data available to determine if this phenomenon was restricted to the Dauphin Lake population or whether it might be solely responsible for the apparent differences in egg size between carpsucker populations.

A strong positive correlation has been found between egg size and larval size in herring (*Clupea harengus*, Blaxter and Hempel 1963), anchovies (*Engraulis anchoita*, Ciechomski 1966), arctic char, (*Salvelinus alpinus*, Wallace and Aasjord 1983) and Pacific salmons (Onchorhynchus spp., Beacham et al. 1985, Beacham and Murray 1985). Large larvae showed lower mortality rates from failure to commence feeding (Blaxter and Hemple 1963, Ciechomski 1966, Wallace and Aasjord 1983), had larger mouths and were capable of taking a wider range of prey sizes (Wallace and Aasjord 1983). Increased size would improve swimming performance and their ability to escape predators and to find food (Mills and Mann 1985). These factors intuitively give large larvae a survival advantage over their smaller brethren and thus larger quillback might be expected to produce larger and hence higher quality offspring than small females. This should give large females a significant reproductive advantage over small females and favour large adult size and late age of maturity as was seen in the Dauphin Lake quillback population.

Two large females, on gross examination, contained eggs of two size classes. Both Buchholz (1957) and Behmer (1965) have reported this condition in the river carpsucker. Behmer (1965) felt that this indicated multiple spawning in the species. There was no evidence of multiple spawning in Dauphin Lake quillback in part because no partially spent non-spawning fish were ever taken. Ochre River migrants were, at least superficially, either fully mature or fully spent when taken. Also, no quillback were taken during the summer months that appeared as though they would have been able to spawn before the next spring. Even if multiple spawning had occurred, low water discharges in tributaries to Dauphin Lake would have pre-empted stream spawning in the late spring or summer months. Further, larvae resulting from late spawning would have a restricted growing season in which to transform to and grow as juveniles. Large juvenile size was positively correlated with over-winter survival in cyprinids (Mills and Mann 1985) and suggests that late spawned quillback would have suffered reduced survival over the winter months.

Gerlach (1973) recorded for newly hatched quillback a mean length of 5.5 mm TL in Indiana, or much smaller than recorded here or by Gaboury (1985) for quillback larvae in the Valley River, Manitoba (8.2 mm TL).

This study confirmed the observations of Gaboury (1985) and Gale and Mohr (1978) that quillback drift mainly while in the pro-larval stage. Quillback larvae probably left the spawning rivers before they transformed into juveniles because during 5 years of DFO sampling no postlarvae and only 5 juvenile quillback were taken in streams entering Dauphin Lake. Postlarval quillback were taken only from Dauphin Lake, albeit in low abundance.

Nocturnal drifting has a presumed survival advantage in reducing predation on larval stages, but in this study virtually all cyprinids and many darters taken at night had consumed sucker larvae. Forage fishes could exact a heavy toll on larval fishes if they were present in high densities. A large number of cyprinids and darters move into the Ochre River each spring, presumably to spawn, but perhaps also to utilize the abundant food resource that larval fishes represent. Larval quillback could have been particularly susceptible to this form of predation because they were smaller than the white suckers with which they commonly drifted and would have been available to a greater size range of predators.

Dauphin Lake Sampling

Juvenile quillback were seemingly confined to shallow water areas as noted for other carpsucker populations (Becker, 1983, Beecher 1979 and Buchholz 1957). In way of supporting evidence, otter trawling by DFO staff in 1983 more than .5 km offshore failed to produce any juvenile quillback in 176 three to seven minute trawls(J. Babaluk pers. comm.). Five large adults were taken though and if juveniles were present they should have been more susceptible to the gear than the adults. Large quillback commonly were taken by seining in shallow inshore water but primarily on hot, calm days. With the exception of these days there appears to have been a marked segregation of adult from juvenile quillback of 0+ to 2+ years of age. This could have been a facultative adaptation to reduce intraspecific competition between adults and juveniles that shared a common dietary specialization but perhaps represented the relegation of juveniles to areas of suboptimal habitat by the large population of adult quillback in the manner of Johnson (1976).

Quillback recruitment was highly variable between years despite similar magnitudes of their spawning runs, at least between 1984 and 1985. The near failure of the 1986 year class was most probably due to an extreme late spring flood that affected many of the tributaries of Dauphin Lake. Extensive erosion of the stream channels occurred and may have destroyed any quillback ova present. Virtually no larval drift was recorded in the Ochre River between May 10 and 22nd, 1986, during which time walleye, white sucker and quillback drift should have taken place (W.G. Franzin, pers. comm.).

The difference in 1984 and 1985 year classes is more difficult to explain, since larval drift was qualitatively good in both years. Because improved production of larvae has been found for Valley River quillback in years of high discharge (Gaboury 1985) a strong year class was expected in 1985, due to the high, but not catastrophic, discharges recorded that year. Indeed, the local walleye population produced a strong year class in 1985 probably in response to the high water levels. Beecher (1979) noted reduced abundance of carpsuckers in years of high flow, but he studied rivers open to the Gulf of Mexico and quillback larvae could have been lost to saltwater.

Strong year classes of English cyprinids appeared to be correlated with warm summer water temperatures that allowed greater larval growth and overwinter survival rates (Mills and Mann 1985). The recruitment of rainbow trout (*Salmo gairdneri*) in sub-alpine lakes also may be dependent on summer water temperature (Donald and Alger 1986). Recruitment in Dauphin Lake quillback which are near their northern limit of range; a range that is not limited by direct physical barriers to northward expansion could be affected similarly. Quillback preferred water temperatures near 29 to 30°C in Indiana (Becker 1983) or well above the ranges usually encountered in Dauphin Lake.

Mean water temperatures at 1 m depth at Methley Beach for the period July 4 to August 28 were 22.3 C in 1984 but only 18.6 C in 1985 (P. Schaap pers. comm.) so temperature related effects on recruitment cannot be ruled out.

Some form of population self-regulation through intraspecific competition may also affect juvenile recruitment. YOY quillback occupy the same habitat as and consume similar food items to 1+ and 2+ quillback. If one year class or a group of year classes has been particularly successful, as perhaps the 1984 year class was, then it is possible that succeeding year classes will be repressed by the abundant year class(es) until they approach maturity and move further offshore into deeper water. The strong 1984 year class in Dauphin Lake may have suppressed the 1985 cohort in this way. The suppression of YOY alewife by established alewife through diet has been proposed by O'Gorman and Schneider (1986). This mechanism could lead to alternating periods of good and poor recruitment as has been reported for lake whitefish (*C. clupeaformis*) by Healey (1980). Cyclical recruitment might be detectable in age class distributions but insufficient numbers of quillback were reliably aged to claim that such a pattern is evident in Dauphin Lake. A long term evaluation of environmental variables and year-class strengths would be required to evaluate the relative importance of either possibility.

Tag Return Analysis

The 8.6% annual tag loss rate was similar to that reported for

Floy anchor tags by Franzin and McFarlane (1987) for white sucker at 10% and by Ebener and Copes (1982) for lake whitefish at 11.1%. Growth of filamentous algae on the tags was especially prominent on fish in the Ochre River during periods of low flow when the water was clear and warm. Several fresh tag scars were noted at that time indicating algal growth may have affected tag retention as suggested by Ebener and Copes (1982).

On the basis of low tag return rates from the commercial fishery, incidental commercial exploitation of the quillback population was very low, despite an intensive winter gillnet fishery for northern pike (E. lucius) and walleye (S. vitreum). Even under an assumption of 50% loss of tagged adults in the first 6 months at large, commercial exploitation would still have been less than 2% of the adult population per year. Because tags may increase the probability of capture by gillnets these exploitation rates may have been higher than for the unmarked population of quillback. The combined exploitation of quillback by both commercial and sport fishermen probably was negligible for the Dauphin Lake quillback population at least in 1984 and 1985.

It is unlikely that either population estimate accurately reflects the true size of the Dauphin Lake quillback population. Both estimates should have overestimated the true population size due to tag loss and the growth of juveniles into the target population. The estimate from spawning run recaptures could be biased up or downwards depending on whether or not spawners in Dauphin Lake return or have a propensity to return to the same stream to spawn each year. In support of the estimate, quillback appear to disperse widely over Dauphin Lake following spawning and tag returns to the Ochre River in 1985 were lower than expected if quillback returned to spawn in the same stream every year. Also, quillback marked in the Valley River by Manitoba Department of Natural Resources staff (Gaboury 1985) were recaptured in the 1984 and 1985 spawning runs in the Ochre River further suggesting that homing is unlikely in Dauphin Lake quillback.

The Methley Beach population estimate probably was the least accurate, in part due to the removal of marked fish, while unmarked individuals were released, but might be considered as a high estimate for the Dauphin Lake population. The upper 95% confidence limit of approximately 50,000 adults indicates that the density of adult quillback in Dauphin Lake probably was < 1/ha. Such a low density would explain in part the low catch by the commercial fishery and the difficulties the author encountered in capturing quillback outside the spawning season. A lack of protruding mouthparts, fin spines and teeth in addition to a steeply sloping brow may also account in part for the low exploitation of Dauphin Lake quillback in entanglement gear. The large average size of Dauphin Lake quillback may also have limited their capture in the 4.5 inch gillnets used by most commercial fishermen.

Age and Growth Analysis

The use of scales for aging fish has come under attack for its inaccuracy (Beamish 1973) especially with respect to older, slower growing individuals. O'Gorman and Schneider (1986) have documented the complete failure to form annuli on the scales of entire age classes of alewife (Alosa pseudoharengus) as their growth rates declined. Beamish and McFarlane (1983) have recommended the use of fin rays for aging suckers as they appeared to yield more accurate age estimates than did scales. However, the use of fin rays for aging Dauphin Lake quillback greater than 8 years of age appears to be unsatisfactory. Quinn and Ross (1982) also found difficulties aging unexploited white suckers older than 7 years of age with fin ray sections. The aging of riverine white sucker populations with fin rays also has proven difficult (Beamish 1973). Erickson (1983), Barnes and Power (1984), Skurdal et al (1985) in studies on a variety of species found, as reported in the present work, that otoliths provided the highest ages of any of the structures used. Fin rays, where used always gave younger ages than otoliths but greater ages than scales.

Unfortunately, few studies have attempted otolith age validation. Because the use of otoliths requires the destruction of their donors, any further attempts to validate aging structures for Dauphin Lake quillback will require some form of internal mark applied through the use of tetracycline or other injections.

The oldest aged quillback was assessed an age of 52 years. This is the oldest reported age for any Canadian sucker and much higher than the 23 years reported for white suckers by Beamish and Harvey (1969). Power (1978) has found lake trout and whitefish from unexploited northern lakes to exceed 50 and 60 years of age respectively. Dauphin Lake quillback appeared essentially to be unexploited and individuals of great age might be expected in this population. The high survival rates of adults necessary to reach great age have been recorded even in alewife where 92 to 99% annual survival rates have been estimated (O'Gorman and Schneider 1986). There seems to be no obvious reason why survival rates of Dauphin Lake quillback could not be of a similar magnitude.

For comparison of growth data with other studies length at annulus formation was calculated from quillback caught between September 15 and May 15 during which period growth was assumed to be negligible (Appendices 13 and 14). Fork lengths were converted to total lengths with a conversion factor of fork to total lengths obtained through morphometric analysis where TL = approx. 1.118 x FL. Scales were used for aging in all other studies however, and the growth estimates therein might best be considered as the maximum possible growth rates for the respective locations.

Dauphin Lake quillback grew faster than studied Iowa populations (Woodward 1973, Vanicek 1961, Fig. 16, Appendix 15). Florida (Beecher 1979) and Nebraska (McCarraher et al 1971) populations were consistently greater in length at age than the Dauphin Lake population, but most of the difference results from an initial difference in the length of age 1 fish. Growth between 2 and 3 years of age is 111, 101 and 97 mm/year for the Dauphin Lake, Florida and Nebraska fish respectively. Given the great latitudinal variation of the populations and differences in habitat type, the similarity of growth rates is noteworthy. This seems to be an exception to the theory that more northerly populations of a species are slower growing than southerly ones. Perhaps, as suggested by Healey (1980), there is a maximum growth rate that all populations of a species will tend to, regardless of their geographic location.

The differences in slope between juvenile and adult length-weight regressions suggests positive allometric growth until maturity followed by negative allometric growth after maturity. In way of confirmation, the relative body depth of quillback increased until a maximum was reached near 300 mm TL whereupon it declined with further increases in length (Fig. 18). The change occurred at approximately the length at which quillback reach sexual maturity and may be due to a reallocation of energy from growth to reproductive purposes.

The maximum length of 560 mm FL (626 mm TL) was similar to that reported for quillback in the United States (Trautman 1957) but much larger than reported elsewhere in Canada at about 457 mm TL (Scott and Crossman 1979).

Dietary Analysis

Dauphin Lake quillback consumed a broad range of usually small benthic and planktonic invertebrates, similar to that found eaten by other carpsucker populations (Buchholz 1957, Brezner 1958, Summerfelt et al 1972, Walburg et al 1971 and Beecher 1979). The size range of items taken by Florida quillback, where most items fell through a .85 mm sieve, was similar to that of Dauphin Lake quillback where few items were > .6 mm in diameter. Quillback pharyngeal arches reflect the small size of items consumed because they are thin and are not suited to the mastication of large food particles (Eastman 1977).

The similarity of diet between adult and juvenile quillback suggests that there may be competition between the groups for food resources.

The feeding behaviour of captive juveniles indicates that quillback probably do not pick individual food particles off the bottom but rather sort food in the pharyngeal cavity after drawing both inorganic and organic particles up from the bottom. The quillback palatal organ has a large complement of taste buds (Miller and Evans 1965) and a muscular response to small particles that would enable them to select food items from a stream of particles passing between the palatal organ and their long, fine gillrakers. Quillback have large vagal lobes of the brain, this further suggests adaptation to the oral sorting of food items (Miller and Evans 1965). Despite this suite of adaptations quillback still ingest large quantities of sand particles when feeding, which perhaps, when they pass through the muscular "gizzard" help break down associated food items.

Most individuals taken offshore and a number taken inshore had gut contents that contained virtually no inorganic or flocculent particles, but rather extremely large numbers of either copepods or cladocerans. Substrates were sufficiently loose in the capture locations that numerous inorganic particles and flocculents should have been ingested if these individuals had been feeding on the bottom. This suggests that at times Dauphin Lake quillback may act as facultative planktivores if they encounter dense patches of zooplankton.

Quillback were observed feeding in the Ochre River only on their downstream run. The large number of fish eggs consumed indicates that quillback could be egg predators of other, commercially valuable fishes. However, only shorthead redhorse were spawning at the time egg predation was observed and the larvae of other species should have hatched and drifted out of the Ochre River by the time quillback were observed feeding.

Meristics, Morphometrics, and Tubercle Distribution

Meristic and morphometric values generally were similar to those reported by Scott and Crossman (1979) with the exception of gillraker counts and lengths. Scott and Crossman (1979) characterize quillback gillrakers as "short, approximately 2 mm in length" but this study confirms the observations of Stewart et al (1985) that gillrakers are approximately 2.3% of total length. Large quillback from

Dauphin Lake frequently had gillrakers exceeding 15 mm in length.

Adult Dauphin Lake *C. cyprinus* have higher gillraker counts (38 - 48) than reported by either Scott and Crossman (1979) (25 - 29) or Stewart et al (1985) (31 - 37) but lower than Florida quillback (approx. 43 - 58, Beecher 1979). The lower counts reported by Stewart et al (1985) may reflect only the smaller size of the fish they examined. Juvenile quillback have lower gillraker counts than adults in both Dauphin Lake and Florida (Beecher 1979). Adult gillraker counts might prove fruitful for taxonomic purposes: Beecher (1979) also noted differences in gillraker counts between Florida quillback and highfin carpsuckers.

Huntsman (1967) and Madsen (1971) described nuptial tubercle distribution of quillback from the midwestern United States. Dauphin Lake quillback are more tuberculate than described in either of these studies. Neither author described tubercles occurring on the dorsal surface of the head, the cornea of the eye or the anal and caudal fins of this species.

Preservation of samples in formalin improved the visibility of tubercles as noted by Alt (1971) for coregonids. Also, 3 individuals held for a further 3 months in 50% isopropyl alcohol displayed tubercles more prominently due to the shrinkage of fleshy tissue, especially in the head region. Similar preservation and storage would be recommended for further studies of tubercle distributions.

Three of the male quillback examined for this study have been placed in the University of Manitoba fish collection, but as of thesis completion they had not been assigned a catalogue number.

OVERVIEW

The Dauphin Lake quillback population showed at least one of the characteristics of unexploited populations of northern fishes (Johnson 1976, Power 1978) adapted to unpredictable environments. Adults were large and usually long-lived, which allowed for the amelioration of possibly frequent spawning and/or recruitment failures. This is an important life history feature in light of the susceptibility of quillback spawning streams to flash-flooding events and the possibility of temperature related or other stresses on the Dauphin Lake population brought about by the proximity of the population to the species northern range limits.

Under heavier exploitation,longevity would certainly be reduced with possible coincident declines in age and size at maturity and changes in fecundity and egg size (Healey 1978). This would reduce the population's ability to withstand environmental fluctuations and hence it would be prone to more dramatic oscillations than noted up to the present.

Hopefully, this study has provided sufficient general information on quillback life history to allow the formulation of more directed research on this population and has added to the limited pool of information available on this species in Canada.

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Fig. 1. Approximate ranges for: A, _C._ _cyprinus_: B, _C._ _carpio_ and C, _C._ _velifer_ after Lee et al. (1980).

A

B

C

Fig. 2. Location of the study area.

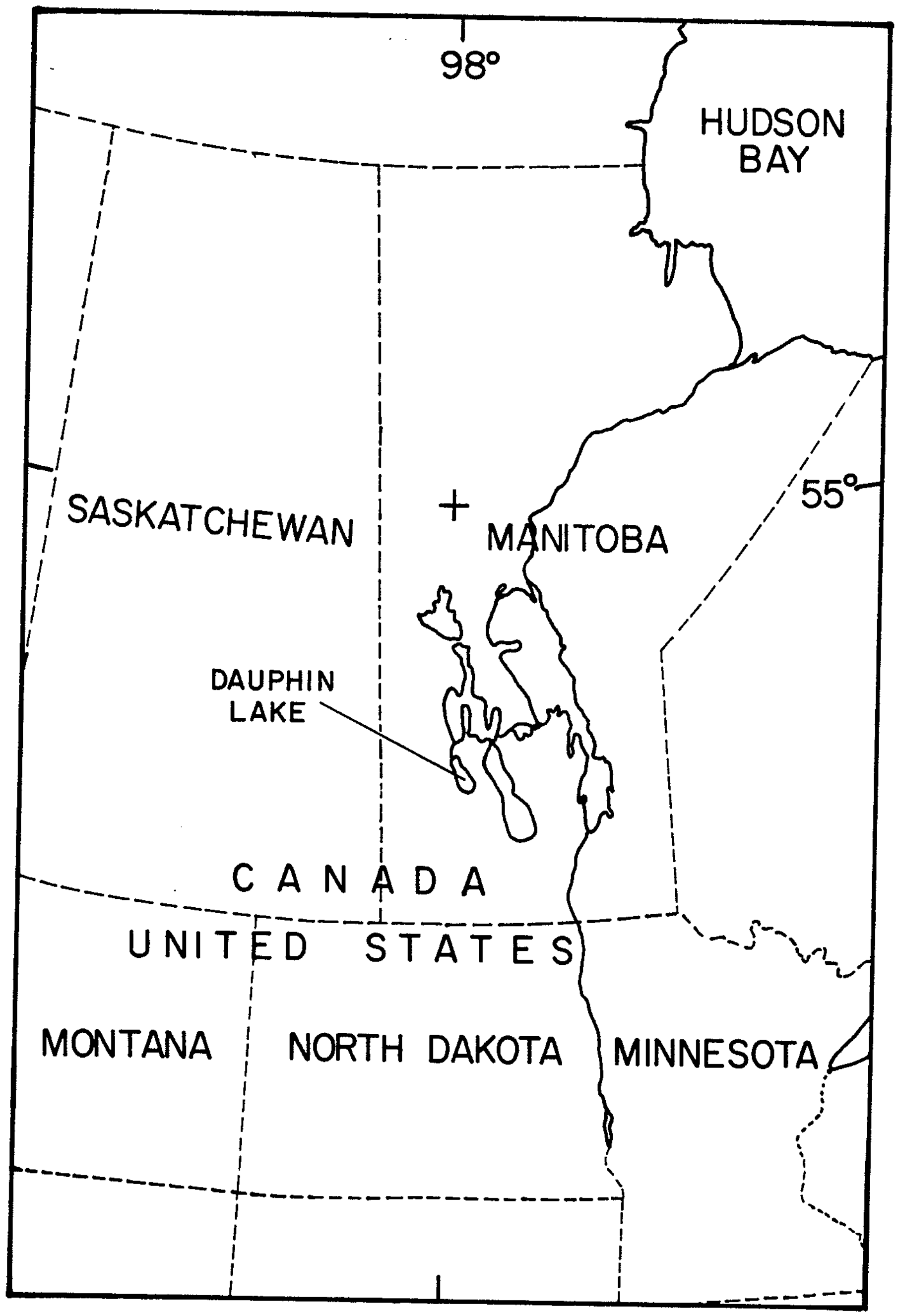

98°
HUDSON
BAY
55°
SASKATCHEWAN
MANITOBA
DAUPHIN
LAKE
C A N A D A
U N I T E D   S T A T E S
MONTANA
NORTH DAKOTA
MINNESOTA

Fig. 3. Location of the fish fence and seining sites used in 1984 and 1985. A, Valley River mouth; B, Stoney Point Beach; C, west side of Ochre River; D, east side of Ochre River; E, Welcome Beach; F, Methley Beach; G, Oak Brae; H, Ochre River fence site.

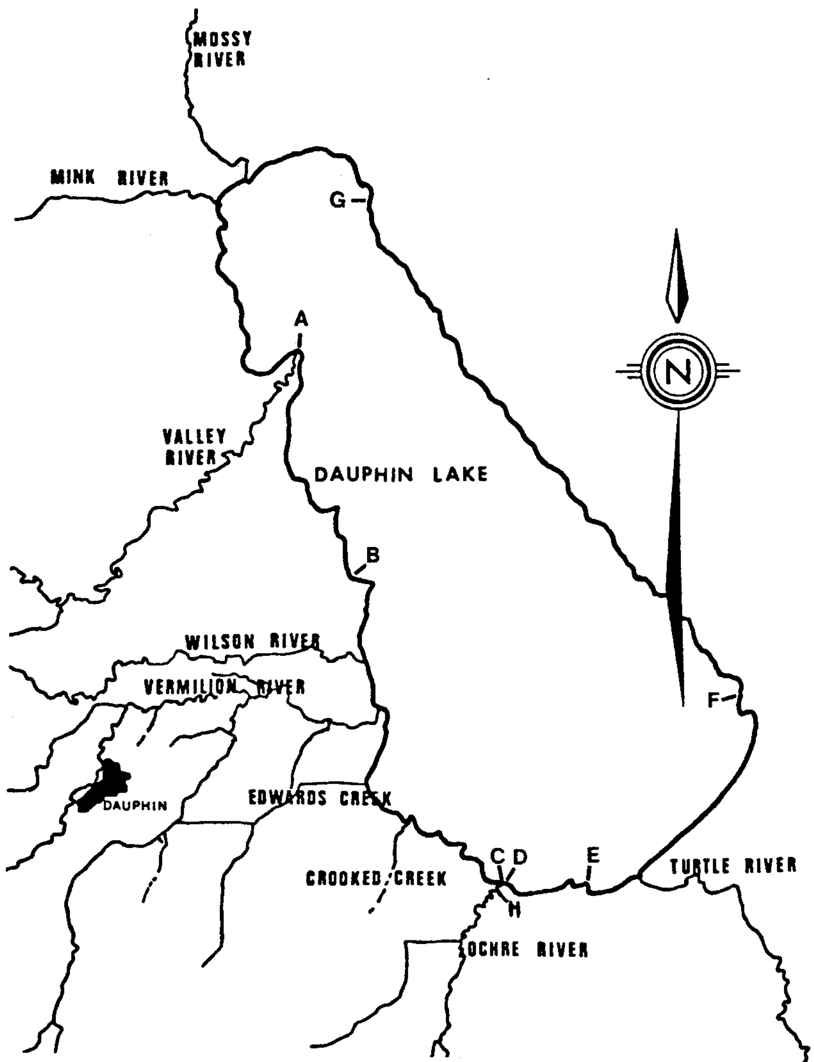

MOSSY RIVER
MINK RIVER
G
A
VALLEY RIVER
DAUPHIN LAKE
B
WILSON RIVER
VERMILION RIVER
DAUPHIN
EDWARDS CREEK
CROOKED CREEK
C D
H
E
F
TURTLE RIVER
OCHRE RIVER
N

Fig. 4. Location of opercular section used for aging.

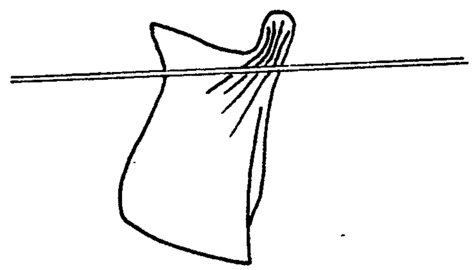


Fig. 5. Daily counts of migrating quillback and records of 9:00 a.m. water temperature and depth for the Ochre River in 1984. Dashed lines, between points of inflection, cover missing data points.

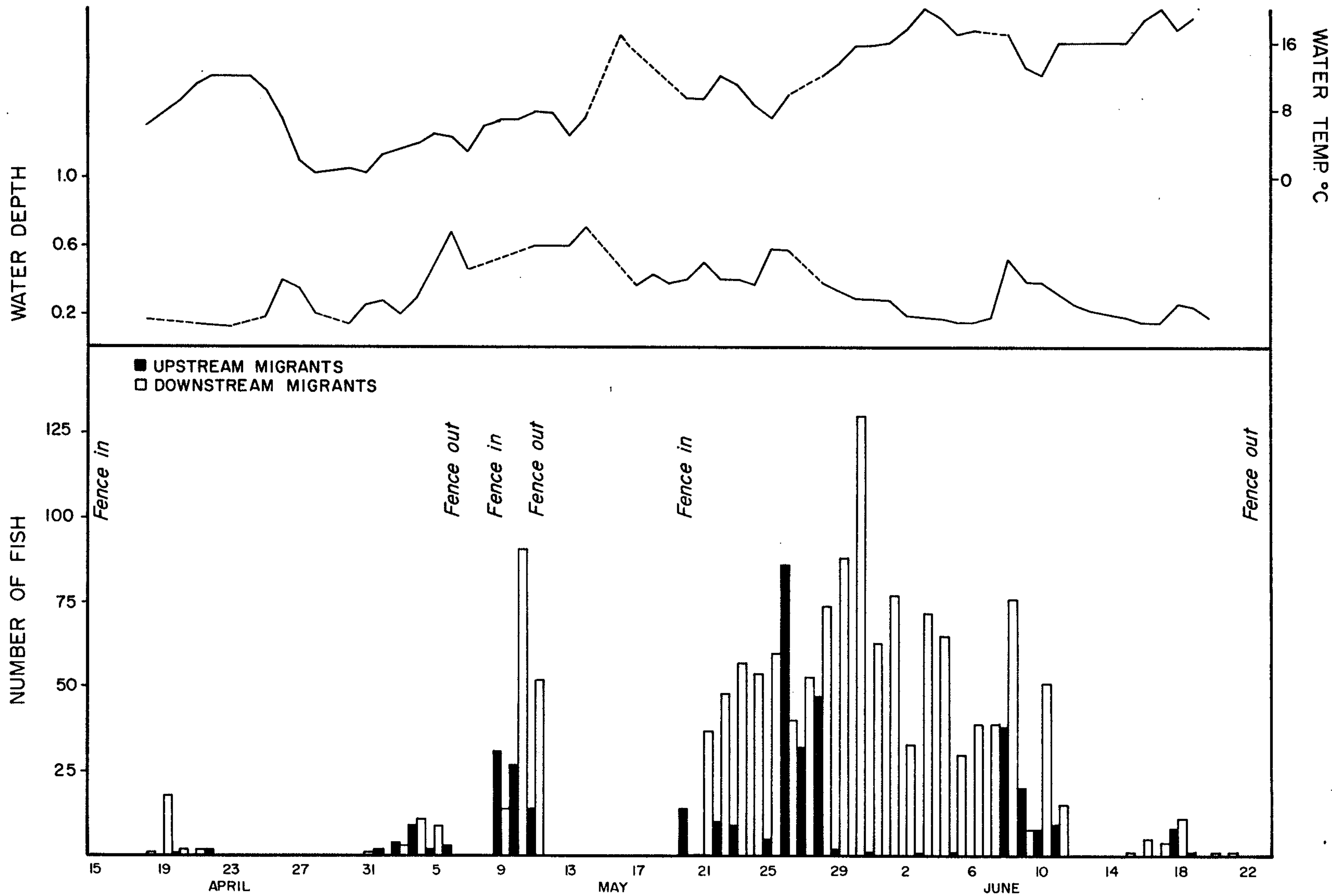

WATER DEPTH
1.0
0.6
0.2
WATER TEMP °C
16
8
0
UPSTREAM MIGRANTS
DOWNSTREAM MIGRANTS
NUMBER OF FISH
125
100
75
50
25
Fence in
Fence out
Fence in
Fence out
Fence in
Fence out
15
19
23
27
31
5
9
13
17
21
25
29
2
6
10
14
18
22
APRIL
MAY
JUNE

Fig. 6. Daily counts of migrating quillback and records of mean daily water temperature and depth for the Ochre River in 1985. Dashed lines, between points of inflection, cover missing data points.

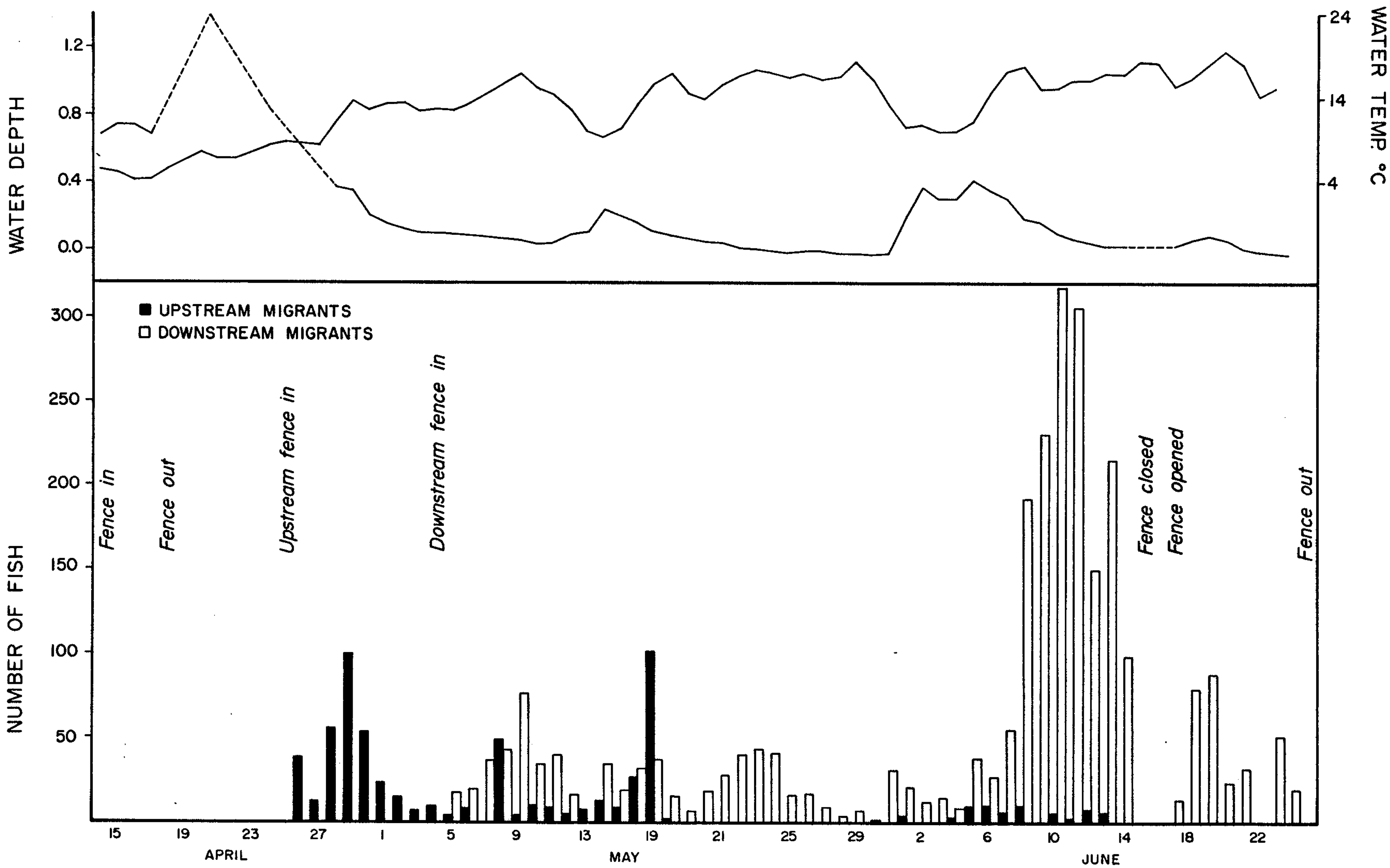
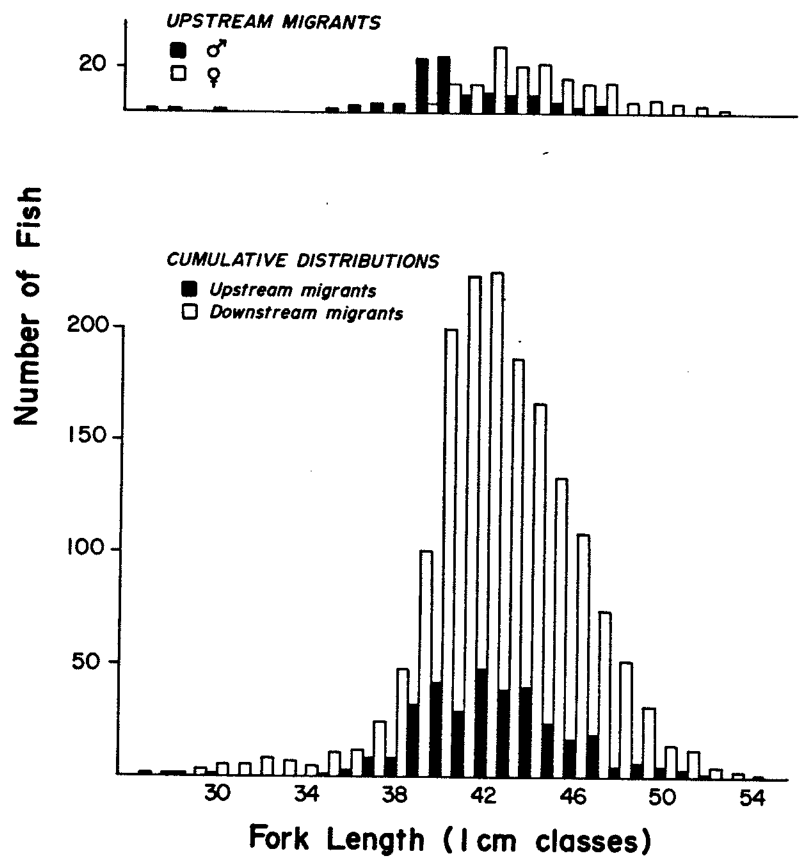
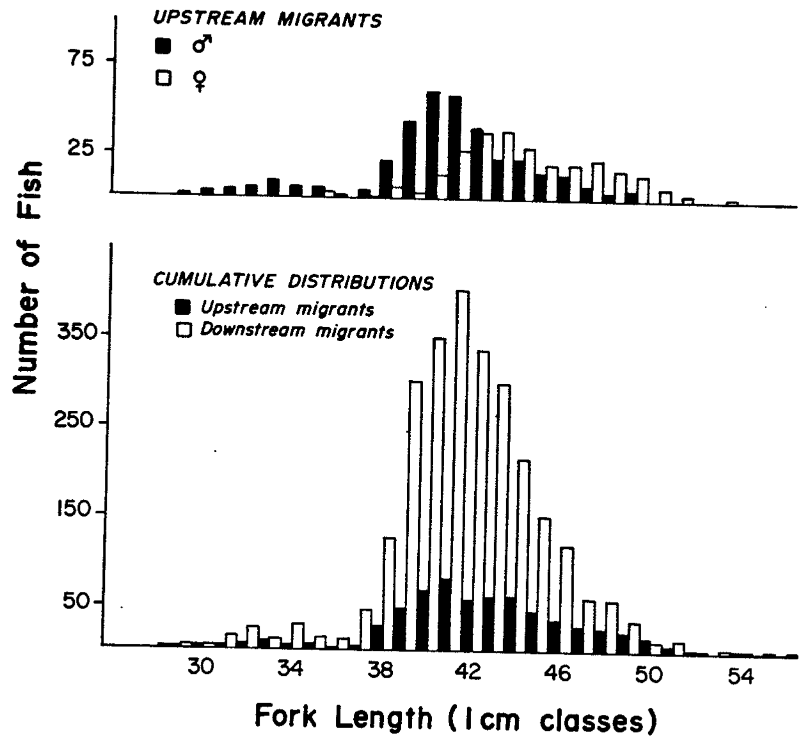

WATER DEPTH
WATER TEMP. °C
1.2
0.8
0.4
0.0
24
14
4
UPSTREAM MIGRANTS
DOWNSTREAM MIGRANTS
NUMBER OF FISH
300
250
200
150
100
50
Fence in
Fence out
Upstream fence in
Downstream fence in
Fence closed
Fence opened
Fence out
15
19
23
27
1
5
9
13
19
21
25
29
2
6
10
14
18
22
APRIL
MAY
JUNE

Fig. 7. Fork length distributions by sex for upstream migrants and the cumulative downstream run of 1984.



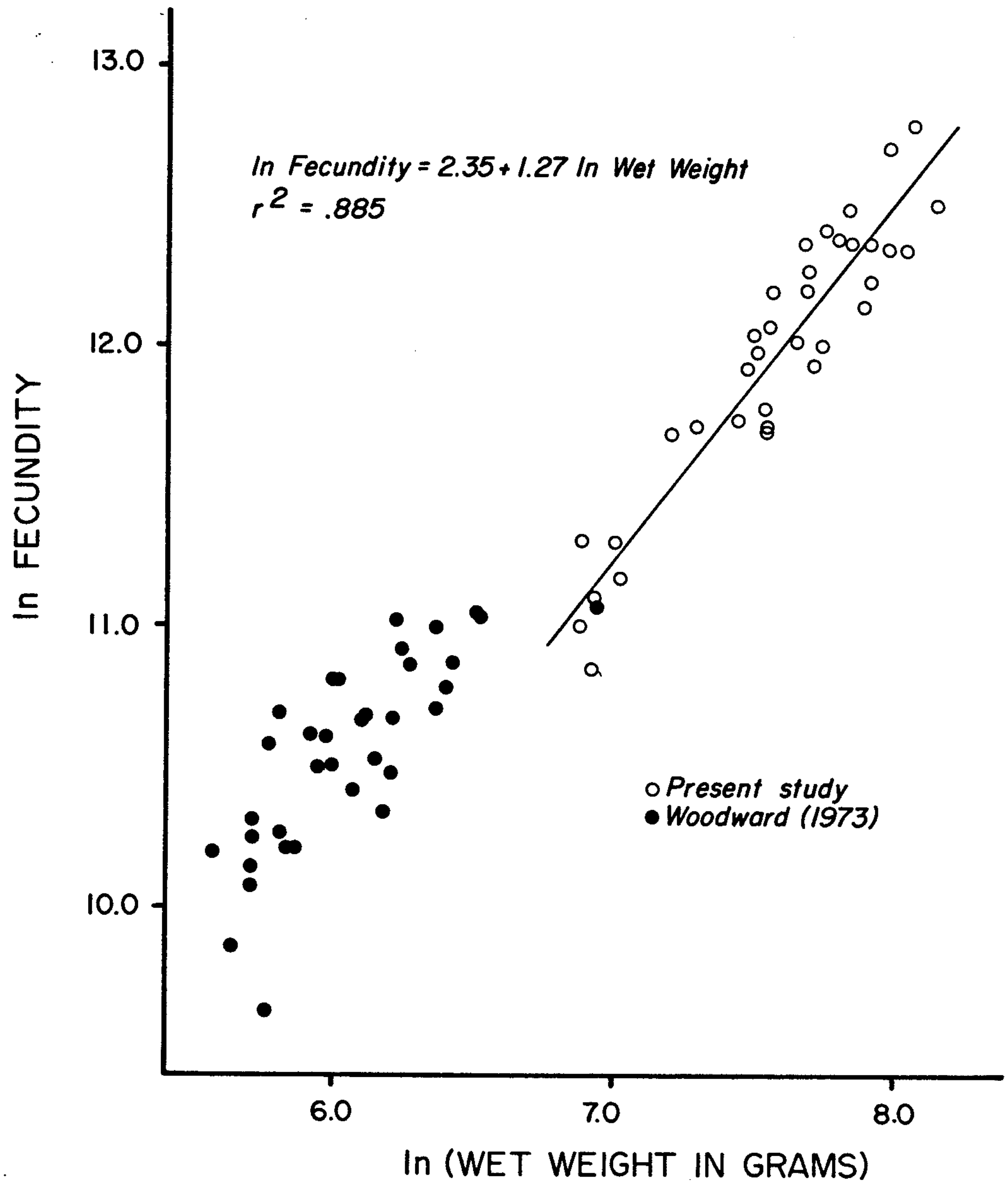
UPSTREAM MIGRANTS
♂
♀
20
Number of Fish
CUMULATIVE DISTRIBUTIONS
Upstream migrants
Downstream migrants
200
150
100
50
30
34
38
42
46
50
54
Fork Length (1 cm classes)

Fig. 8. Fork length distributions by sex for upstream migrants and the cumulative downstream run of 1985.



UPSTREAM MIGRANTS
♂
♀
75
25
Number of Fish
CUMULATIVE DISTRIBUTIONS
Upstream migrants
Downstream migrants
350
250
150
50
30
34
38
42
46
50
54
Fork Length (1cm classes)

Fig. 9. Fecundity of Ochre River and Ohio (Woodward 1973) quillback.



ln Fecundity = 2.35 + 1.27 ln Wet Weight
r 2 = .885
13.0
12.0
11.0
10.0
ln FECUNDITY
6.0
7.0
8.0
ln (WET WEIGHT IN GRAMS)
Present study
Woodward (1973)

Fig. 10. Mean dry weights of 1,000 ova for Ochre River quillback. Circled weights are from adults that had 2 size classes of ova.

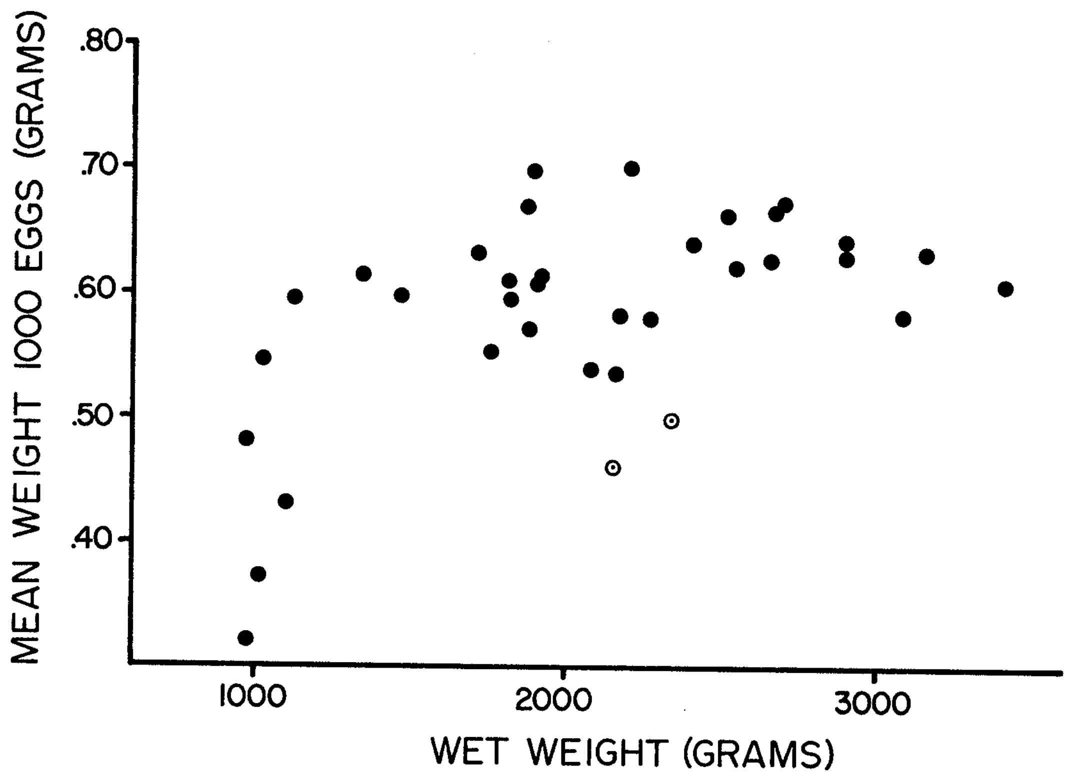

MEAN WEIGHT 1000 EGGS (GRAMS)
.80
.70
.60
.50
.40
1000
2000
3000
WET WEIGHT (GRAMS)

Fig. 11. Percent wet gonad weight as a function of total wet weight for Ochre River quillback.

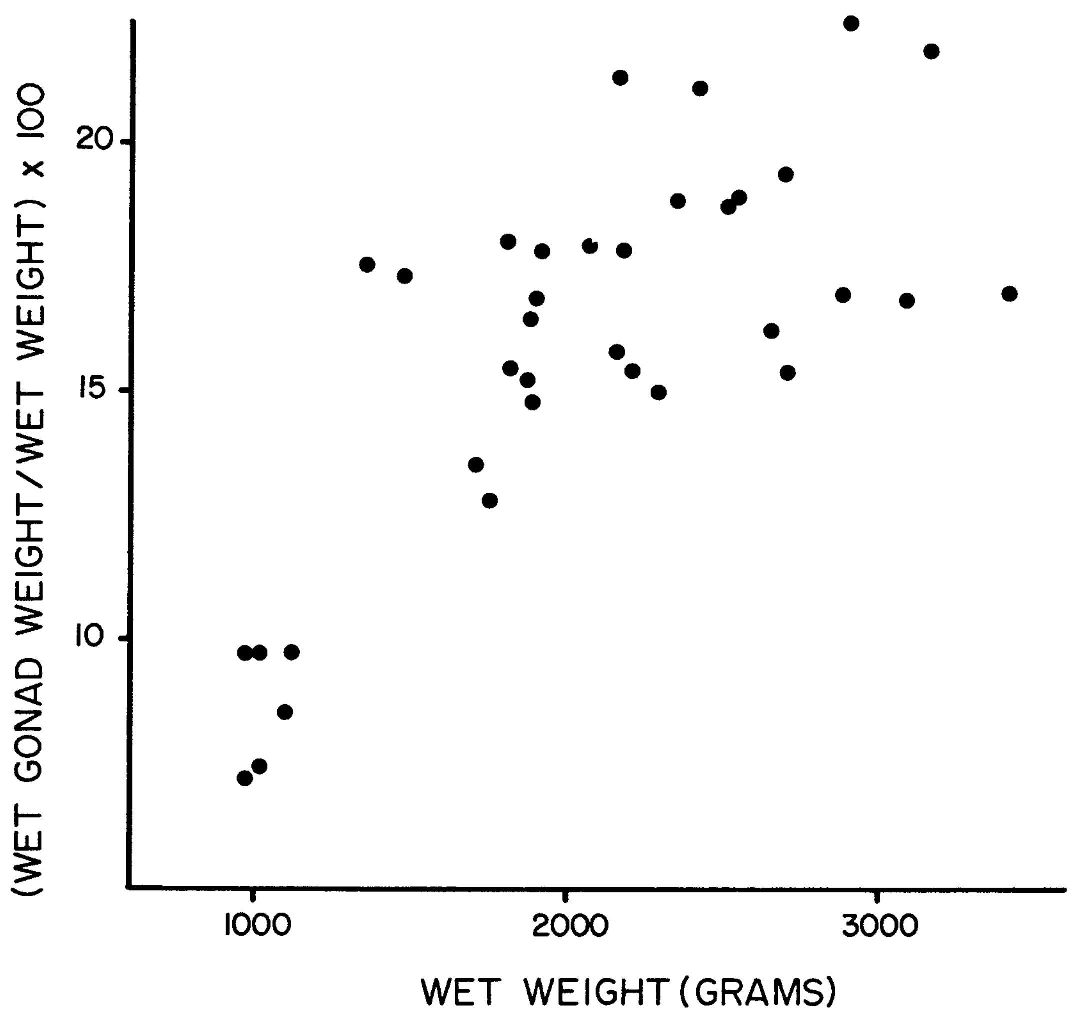

(WET GONAD WEIGHT/WET WEIGHT) x 100
20
15
10
1000
2000
3000
WET WEIGHT (GRAMS)

Fig. 12. Location and number of tag recaptures, for both individually numbered and batch mark tags, from Dauphin Lake and the Ochre River fence site.

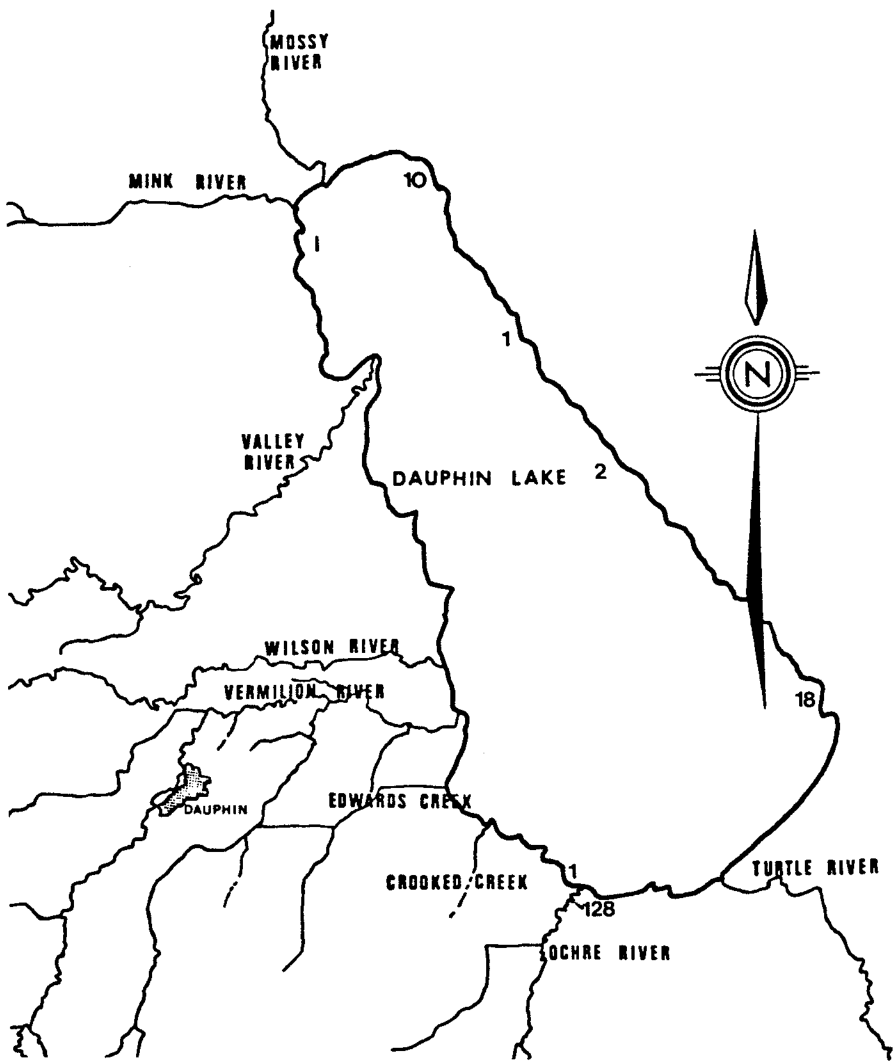
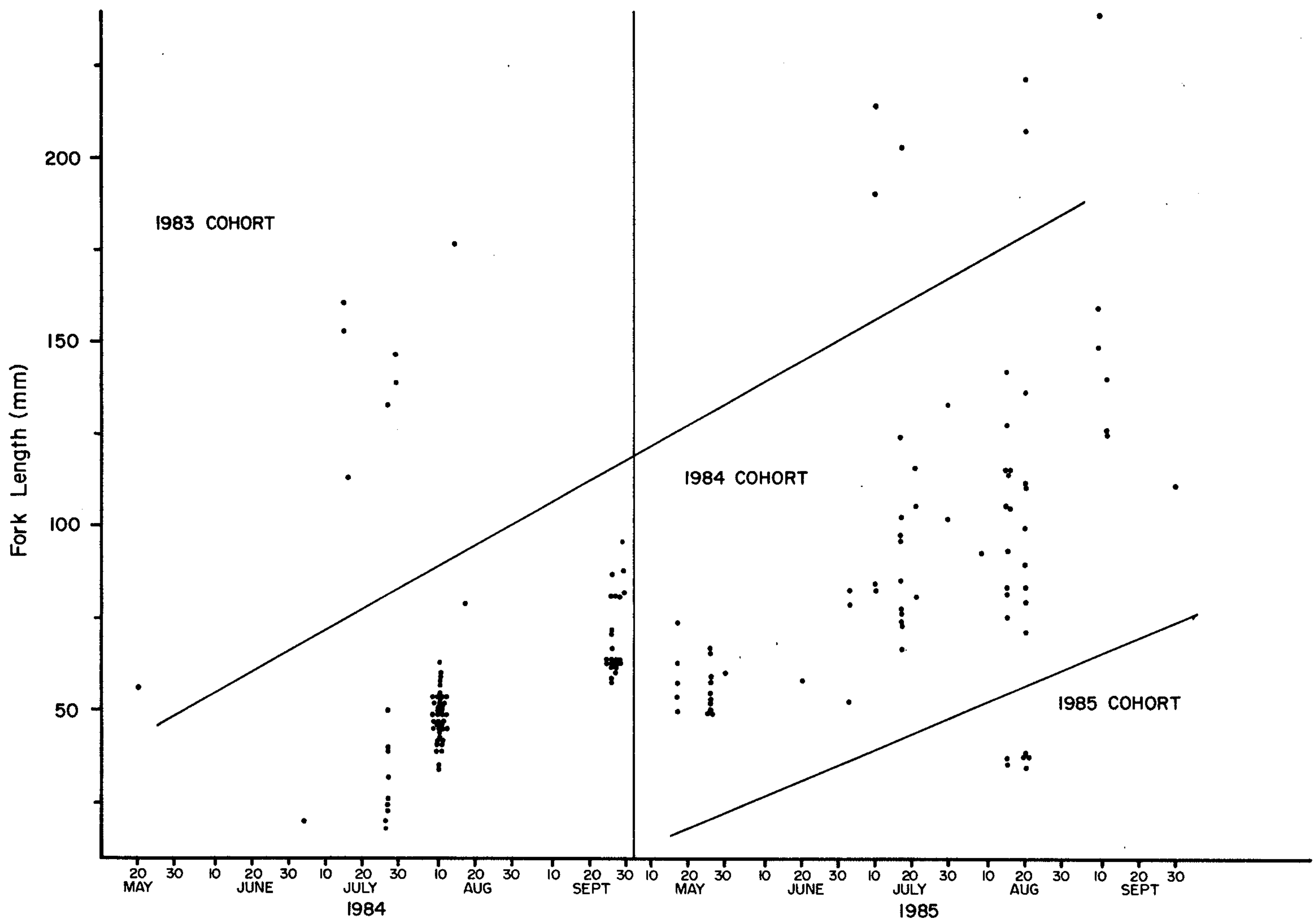
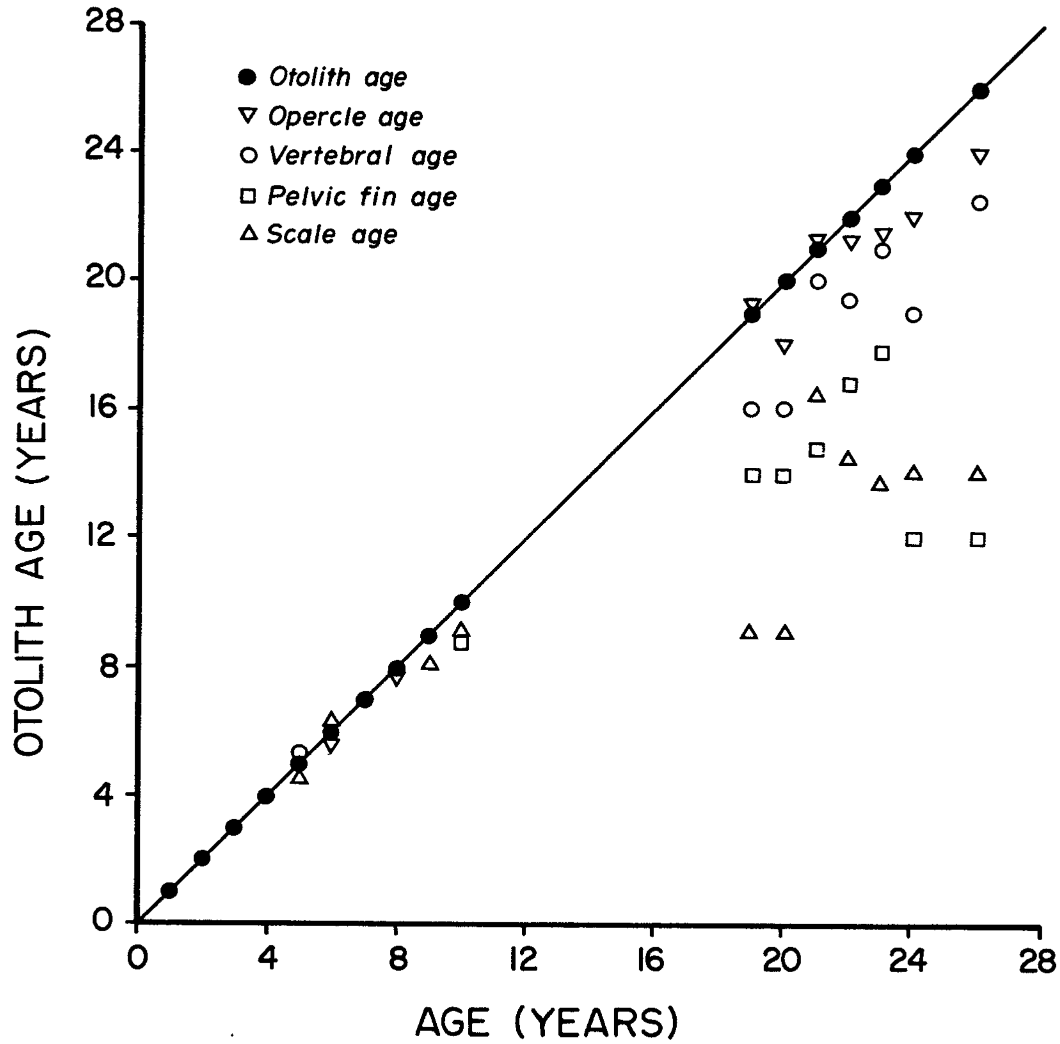

MOSSY RIVER
MINK RIVER
10
1
1
VALLEY RIVER
DAUPHIN LAKE
2
N
WILSON RIVER
VERMILION RIVER
18
DAUPHIN
EDWARDS CREEK
CROOKED CREEK
1
128
TURTLE RIVER
OCHRE RIVER

Fig. 13. Fork lengths of juvenile quillback taken in 1984 and 1985.



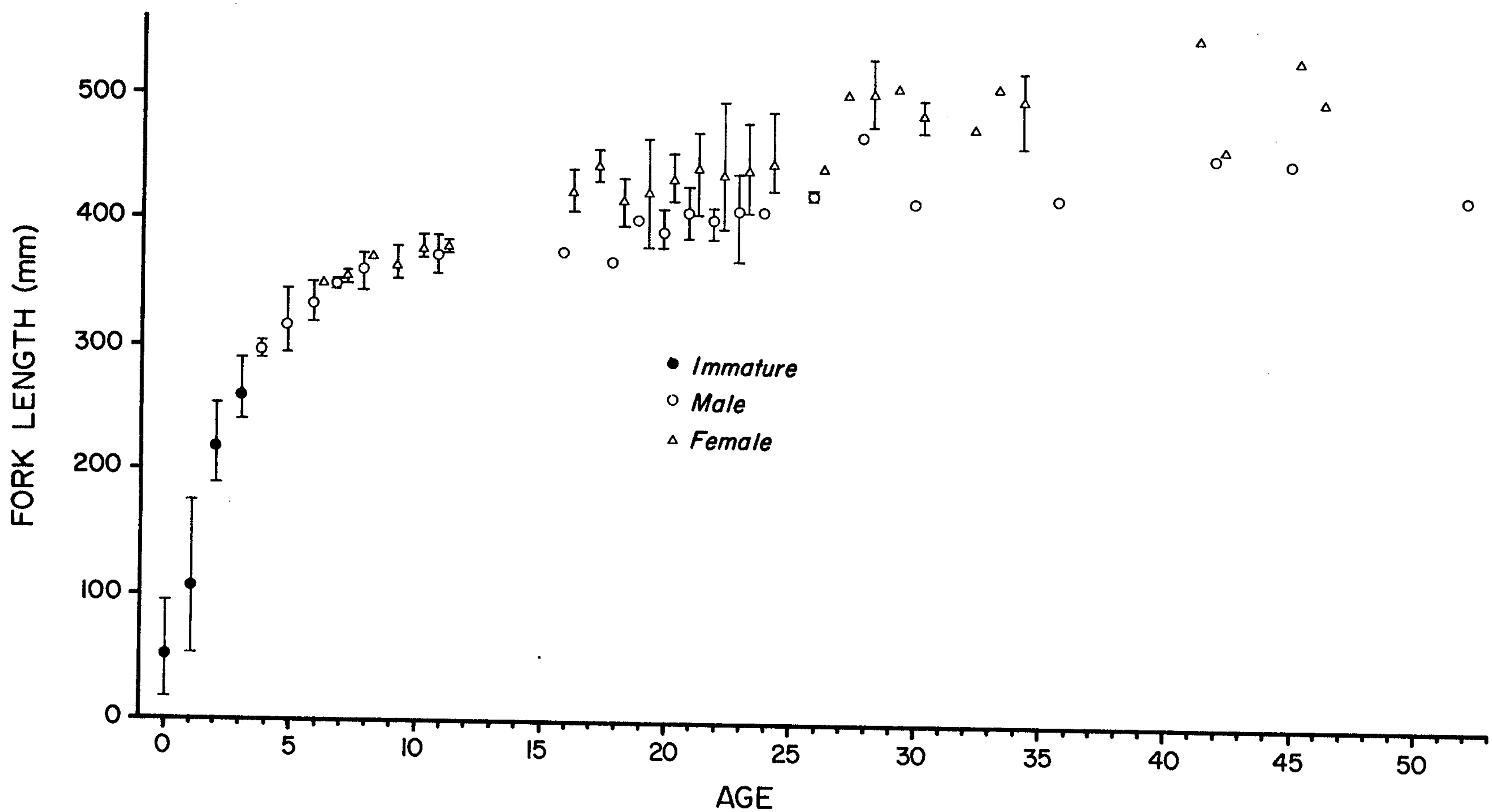
Fork Length (mm)
200
150
100
50
1983 COHORT
1984 COHORT
1985 COHORT
20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
MAY
JUNE
JULY
AUG
SEPT
1984
MAY
JUNE
JULY
AUG
SEPT
1985

Fig. 14. Mean ages provided by opercles, vertebrae, scales and pelvic fin sections from individuals of fixed otolith ages. Where only one symbol is shown all ages equalled otolith age.



Otolith age
Opercle age
Vertebral age
Pelvic fin age
Scale age
OTOLITH AGE (YEARS)
AGE (YEARS)
0
4
8
12
16
20
24
28

Fig. 15. Fork length at age for Dauphin Lake C. cyprinus.



FORK LENGTH (mm)
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
45
50
AGE
Immature
Male
Female

Fig. 16. Length-weight relationships for spent adult and juvenile quillback.

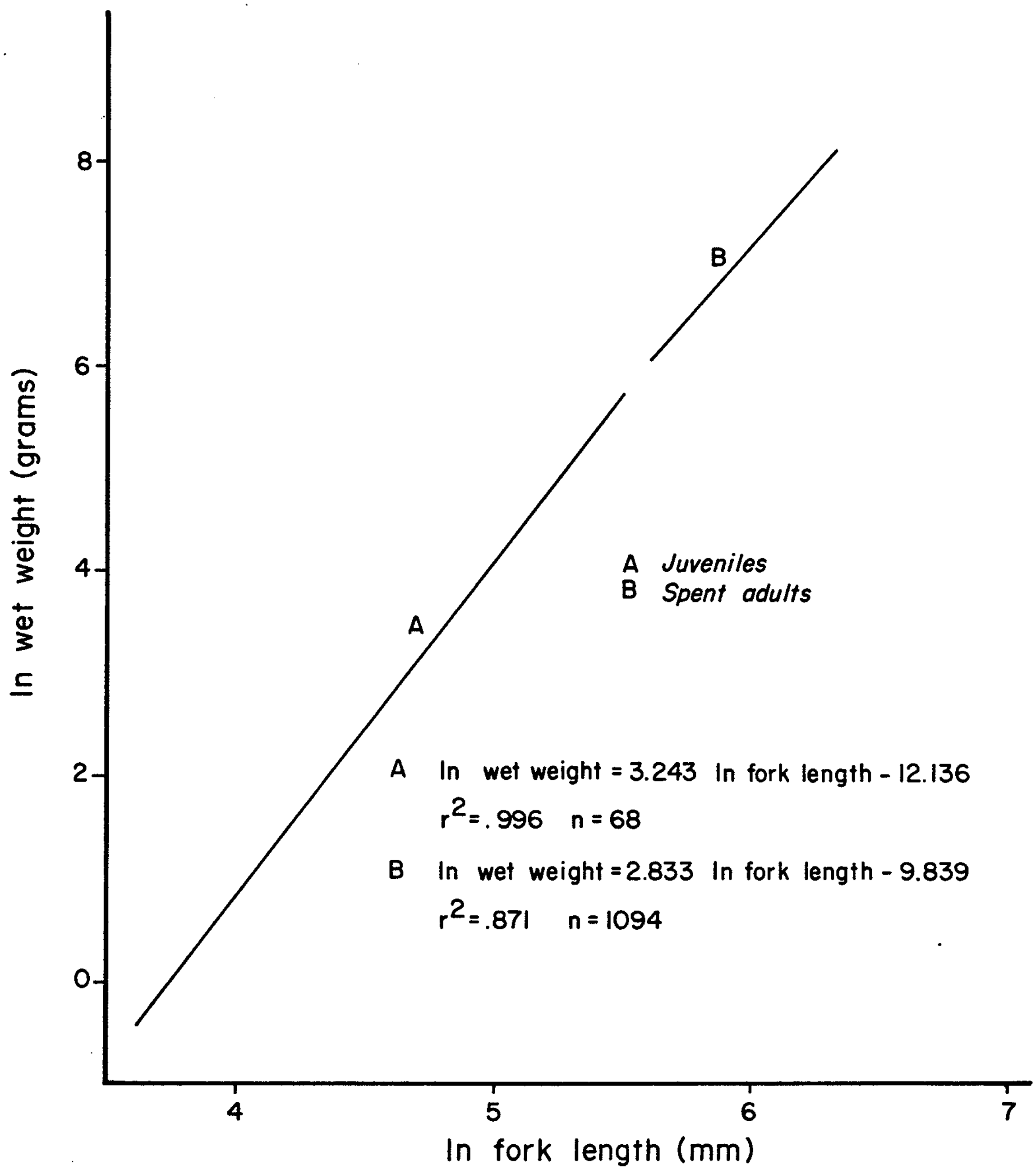
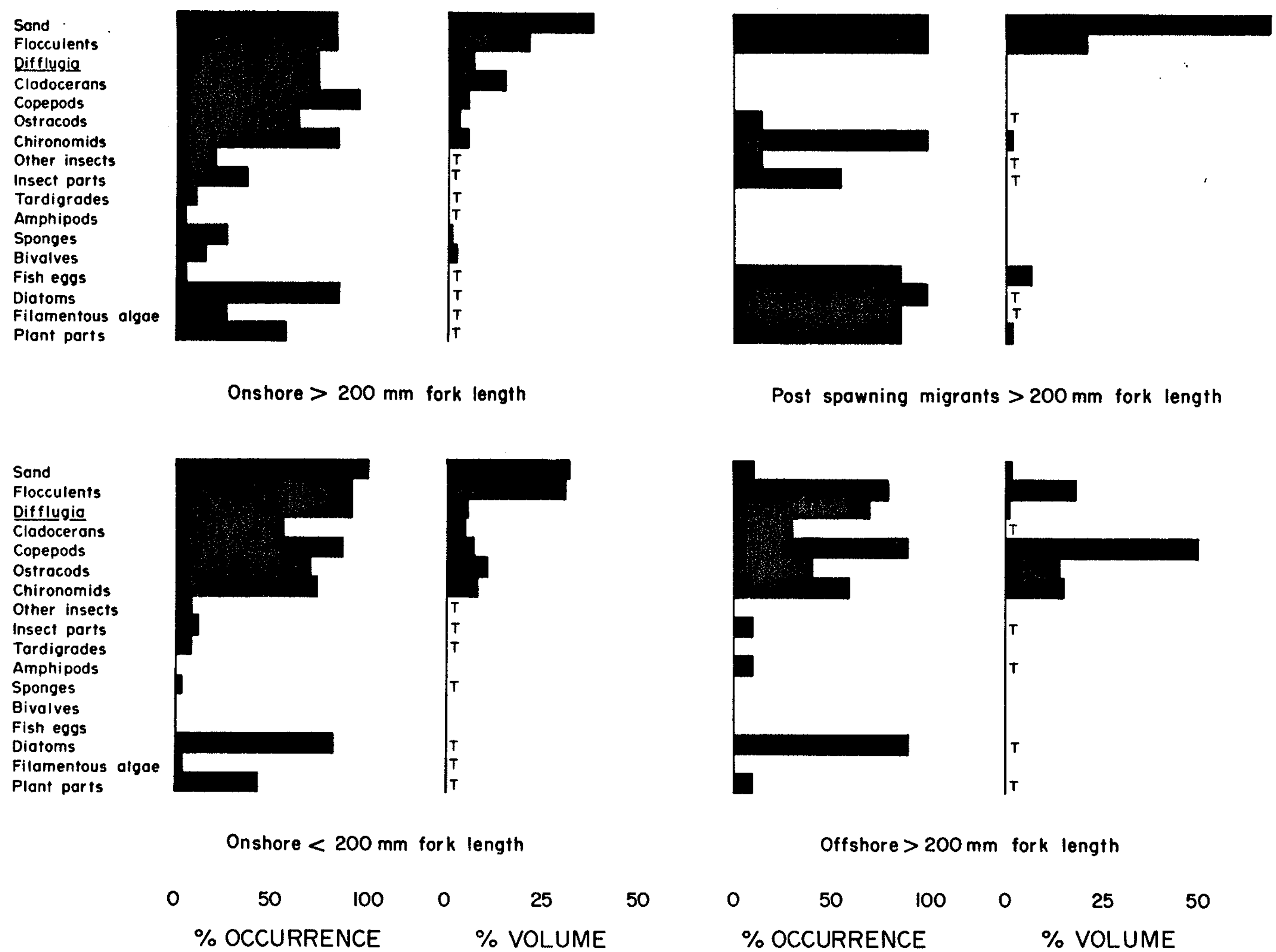

ln wet weight (grams)
8
6
4
2
0
4
5
6
7
ln fork length (mm)
A
B
A Juveniles
B Spent adults
A ln wet weight = 3.243 ln fork length - 12.136
r² = .996 n = 68
B ln wet weight = 2.833 ln fork length - 9.839
r² = .871 n = 1094

Fig. 17. Percent occurrence and volume of food items in Dauphin Lake and Ochre River quillback stomachs.



Sand
Flocculents
Difflugia
Cladocerans
Copepods
Ostracods
Chironomids
Other insects
Insect parts
Tardigrades
Amphipods
Sponges
Bivalves
Fish eggs
Diatoms
Filamentous algae
Plant parts
T
Onshore > 200 mm fork length
Post spawning migrants > 200 mm fork length
Onshore < 200 mm fork length
Offshore > 200 mm fork length
0 50 100
% OCCURRENCE
0 25 50
% VOLUME

Fig. 18. Total length at annulus formation for five populations of *C. cyprinus*.

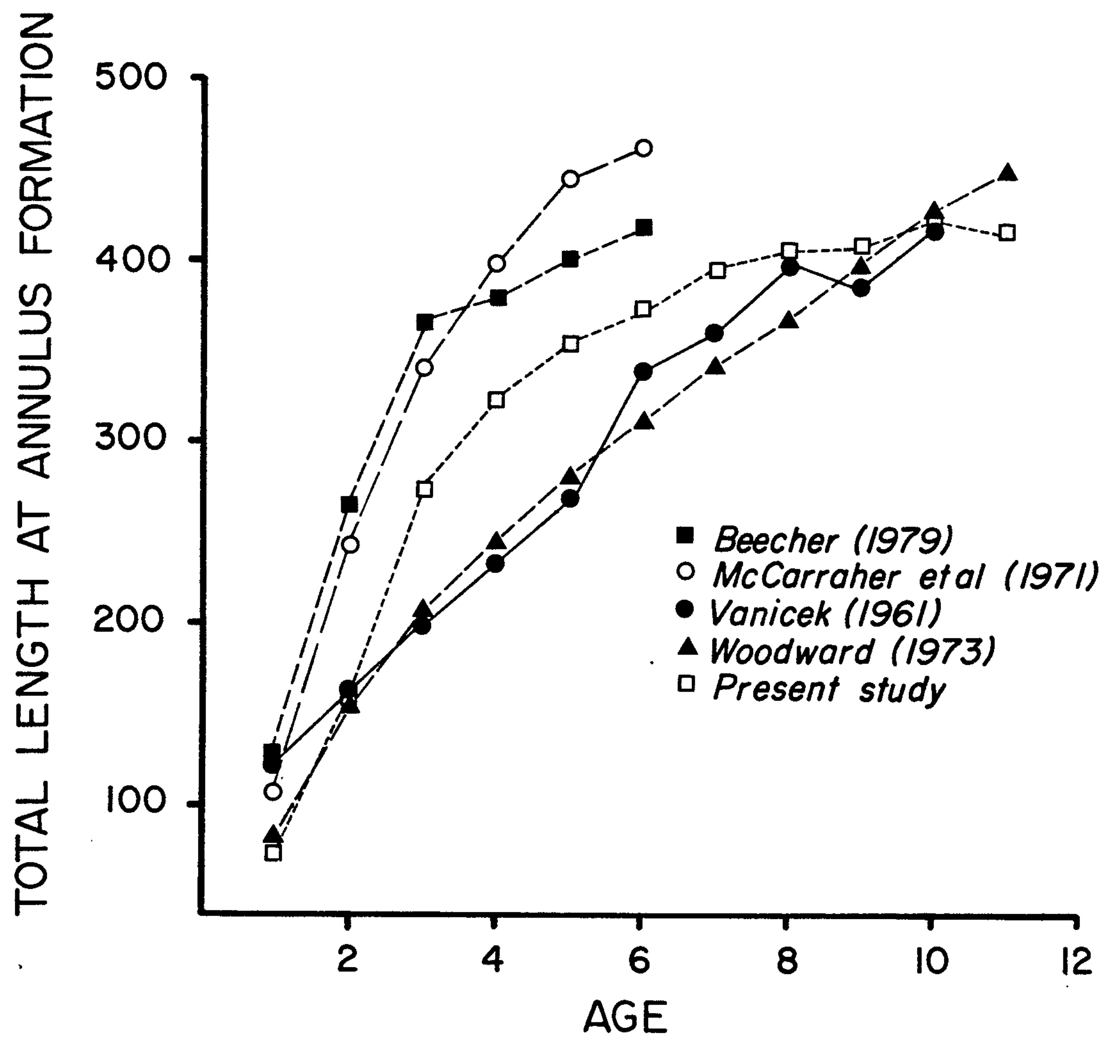
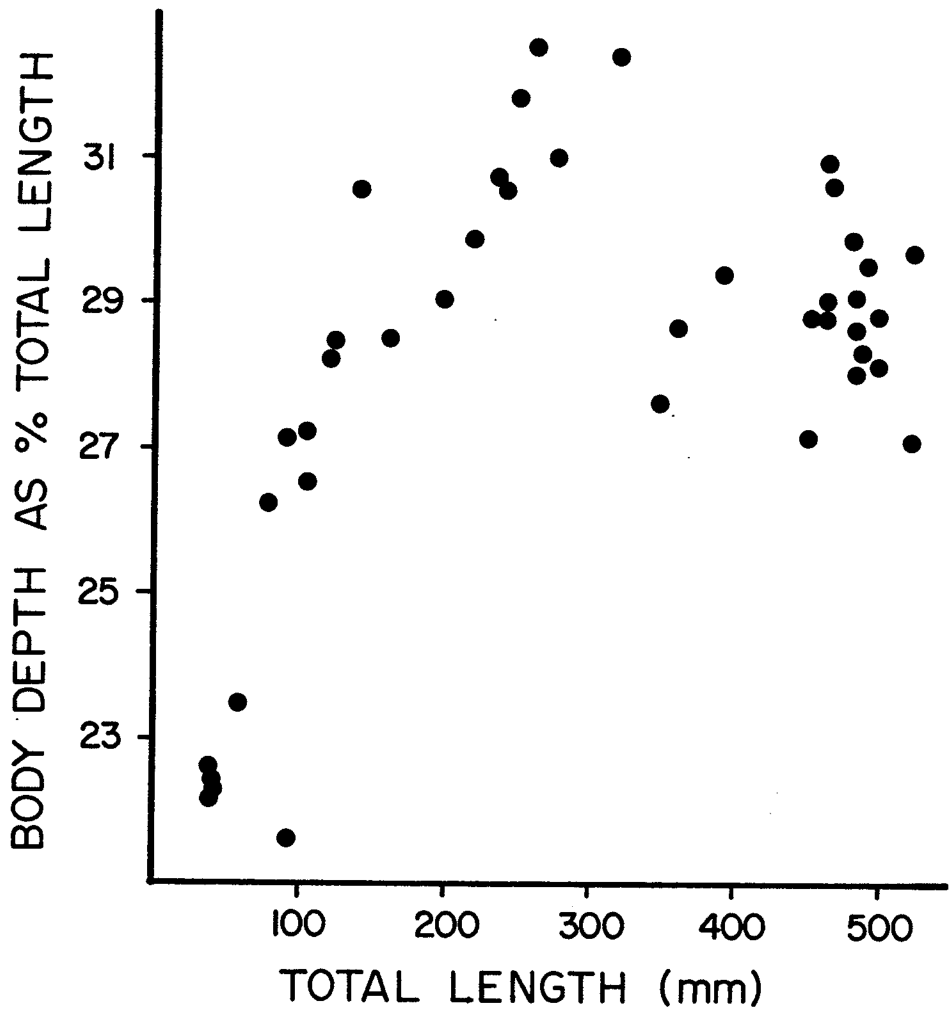

TOTAL LENGTH AT ANNULUS FORMATION
500
400
300
200
100
2
4
6
8
10
12
AGE
Beecher (1979)
McCarraher et al (1971)
Vanicek (1961)
Woodward (1973)
Present study

Fig. 19. Change in body depth, expressed as % TL, with increasing fish length.



BODY DEPTH AS % TOTAL LENGTH
31
29
27
25
23
100
200
300
400
500
TOTAL LENGTH (mm)

Table 1. Fork length, wet weight, and estimated fecundity for 35 quillback sampled from the Ochre River in 1984.

Fish #	Fork length (mm)	Wet weight (g)	Fecundity
1	497	2070	166,600
2	473	2150	173,100
3	356	970	59,200
4	503	3080	229,300
5	455	2340	248,400
6	531	3410	270,600
7	478	2160	214,100
8	467	2270	163,500
9	503	2890	331,700
10	476	2415	238,600
11	515	2540	236,600
12	465	2170	198,600
13	502	2645	187,400
14	372	970	81,000
15	370	1010	51,600
16	380	1015	66,100

Table 1. Continued.

Fish #	Fork length (mm)	Wet weight (g)	Fecundity
17	415	1870	129,400
18	459	2200	151,900
19	445	1900	174,400
20	430	1710	125,000
21	370	1100	80,500
22	432	1755	149,600
23	480	2510	266,500
24	444	1815	158,500
25	497	2685	235,000
26	434	1910	196,000
27	499	2695	203,300
28	507	3150	359,900
29	398	1470	122,000
30	387	1120	71,100
31	405	1805	170,300
32	522	2890	231,300
33	401	1340	118,100
34	434	1880	123,000
35	435	1890	121,100

Table 2. Fork length and mean dry weight of 1,000 ova for large (>390 mm FL) and small (<390 mm FL) quillback taken in 1985.

Fish #	Fork length (mm)	Mean weight of 1,000 ova (g)
1	441	.6062
2	392	.6684
3	415	.6007
4	510	.6130
5	382	.5310
6	373	.4034
7	389	.5384
8	345	.2610

Table 3. Catch per unit effort for YOY quillback from the west side of the Ochre River in 1984, 1985 and 1986.

Year	# YOY caught	# seine hauls	YOY/seine haul	Corrected YOY/seine haul*	Seine size
1984	66	13	5.08	15.24	10m
1985	6	11	0.55	0.55	36m
1986	1	8	0.13	0.13	36m
1986	0	8	0.00	0.00	10m

* assuming the 31.5 m seine fishes three times the area of the 10 m seine.

Table 4. Mean annual growth rates by size class for Dauphin Lake *C. cyprinus* in mm/year.

Size class (mm FL)	# of observations	Mean	Range
300 - 319	1	24	
360 - 379	10	7.2	0 - 15
380 - 399	20	6.8	0 - 21
400 - 419	35	4.9	-2 - 19
420 - 439	24	5.0	-1 - 11
440 - 459	17	3.6	-1 - 11
460 - 479	3	4.3	1 - 8
480 - 499	2	3.5	3 - 4

Appendix 1. Water temperature, depth and quillback catch records for the fence site on the Ochre River in 1984 and 1985. fo = fence out, up = upstream migrants, down = downstream migrants.

Date	1984 temp. (°C)	1984 depth (m)	1984 quillback up	1984 quillback down	1985 temp. (°C)	1985 depth (m)	1985 quillback up	1985 quillback down
April 13	-	-	fo	fo	3.1	-	fo	fo
14	-	-	fo	fo	5.5	.68	-	fo
15	-	-	fo	fo	5.2	.74	-	fo
16	-	-	fo	fo	4.2	.74	-	fo
17	-	-	-	fo	4.3	.68	-	fo
18	6.0	.17	-	1	5.6	> .75	-	fo
19	7.5	-	-	18	6.5	> .75	fo	fo
20	9.0	-	1	2	7.5	> .75	fo	fo
21	11.0	.14	-	2	6.8	1.39	fo	fo
22	12.0	.13	2	-	6.8	> .85	fo	fo
23	12.0	.13	-	-	7.5	> .85	fo	fo
24	12.0	-	-	-	8.4	.84	fo	fo
25	10.5	.18	-	-	8.7	-	fo	fo
26	6.8	.40	-	-	8.5	.60	39	fo
27	2.0	.35	-	-	8.3	-	13	fo
28	0.5	.20	-	-	11.2	.38	36	fo
29	0.8	-	-	-	13.6	.35	100	fo
30	1.0	.14	-	-	12.6	.20	54	fo

Appendix 1. Continued.

Date	1984 temp. (°C)	1984 depth (m)	1984 quillback up	1984 quillback down	1985 temp. (°C)	1985 depth (m)	1985 quillback up	1985 quillback down
May 1	0.5	.26	-	1	13.2	.15	24	fo
2	2.8	.28	2	-	13.4	.12	15	fo
3	3.3	.20	4	3	12.4	.10	7	fo
4	4.0	.30	8	11	12.6	.10	10	fo
5	5.2	.48	2	9	12.5	.09	4	18
6	4.8	.68	-	3	13.1	.08	8	20
7	3.0	.48	fo	fo	14.0	.07	1	37
8	6.2	-	fo	fo	15.6	.06	54	43
9	6.8	-	7	31	16.8	.05	4	77
10	6.8	.56	27	91	15.0	.03	10	35
11	7.8	.60	5	52	14.3	.04	9	40
12	7.6	-	fo	fo	12.5	.09	5	16
13	-	.60	fo	fo	9.8	.10	8	1
14	7.0	.71	fo	fo	9.2	.24	13	35
15	-	-	fo	fo	10.2	.20	9	19
16	16.3	-	fo	fo	13.1	.16	27	32
17	-	.37	fo	fo	15.7	.10	101	37
18	13.0	.43	fo	fo	16.8	.08	2	37
19	-	.38	fo	fo	14.6	.07	-	6
20	9.3	.40	14	fo	13.8	.05	1	19

Appendix 1. Continued.

Date		1984 temp. (°C)	1984 depth (m)	1984 quillback up	1984 quillback down	1985 temp. (°C)	1985 depth (m)	1985 quillback up	1985 quillback down
May	21	9.2	.50	-	37	15.4	.04	1	28
	22	12.0	.40	10	48	16.5	.01	-	40
	23	11.0	.40	8	57	17.2	.00	-	43
	24	8.5	.37	-	54	16.9	-.01	-	46
	25	7.0	.58	5	60	16.4	-.02	-	16
	26	9.8	.57	86	40	16.8	-.01	-	71
	27	-	-	32	53	16.1	-.01	-	9
	28	12.0	.38	47	74	16.4	-.02	-	3
	29	13.5	.33	2	88	18.3	-.02	-	7
	30	15.5	.29	-	130	16.4	-.03	-	1
	31	15.6	.29	1	63	13.0	.02	-	31
June	1	16.0	.28	-	77	10.5	.20	4	21
	2	17.5	.19	-	33	10.8	.37	-	12
	3	20.0	.18	1	72	9.9	.30	-	16
	4	19.0	.17	-	65	9.9	.30	3	8
	5	17.0	.15	1	30	11.2	.41	9	38
	6	17.4	.15	-	39	14.6	.35	10	27
	7	-	.18	-	39	17.2	.30	6	55
	8	17.0	.52	38	76	17.7	.18	9	192
	9	13.0	.39	20	8	15.0	.16	-	216

Appendix 1. Continued.

Date		1984 temp. (°C)	1984 depth (m)	1984 quillback up	1984 quillback down	1985 temp. (°C)	1985 depth (m)	1985 quillback up	1985 quillback down
June	10	12.0	.38	8	51	15.2	.09	5	228
	11	16.0	.32	9	15	16.1	.06	2	306
	12	16.0	.25	-	-	16.1	.04	7	150
	13	16.0	.21	-	-	16.9	.02	5	215
	14	16.0	.20	-	-	16.7	.02	-	99
	15	16.0	.18	-	1	18.3	-	fo	fo
	16	18.5	.15	-	5	18.0	-	fo	fo
	17	20.0	.15	-	4	15.3	.02	-	14
	18	17.5	.26	8	11	16.2	.06	-	79
	19	19.0	.24	1	-	17.9	.08	-	88
	20	-	.17	-	1	19.5	.06	-	24
	21	-	-	-	1	18.2	.00	-	32
	22	-	-	fo	fo	14.1	-.01	-	-
	23	-	-	fo	fo	15.2	-.02	-	51
	24	-	-	fo	fo	-	-.03	-	20

Appendix 2. Wet weight, wet gonad weight, % wet gonad weight, mean weight of 1,000 ova, S.D. of mean weight 1,000 ova and total dry weight of ova for 35 quillback sampled from the Ochre River in 1984.

Fish #	Wet weight (g)	Wet gonad weight (g)	% wet gonad weight	Mean weight 1,000 ova(g)	S.D. mean weight	total weight dried ova(g)
1	2070	370	17.9	.5417	.0051	90.2421
2	2150	340	15.8	.4701	.0039	81.3665
3	970	90	9.3	.4810	.0021	28.4559
4	3080	520	16.9	.5844	.0033	133.9804
5	2340	440	18.8	.4984	.0010	123.7841
6	3410	580	17.0	.6101	.0036	165.0906
7	2160	440	20.4	.5378	.0060	115.1417
8	2270	320	14.1	.5808	.0027	94.9740
9	2890	490	17.0	.6414	.0034	212.7533
10	2415	510	21.1	.6441	.0026	153.6513
11	2540	480	18.9	.6208	.0051	146.9054
12	2170	390	17.9	.5485	.0012	116.0859
13	2645	430	16.3	.6293	.0119	117.9468
14	970	70	7.2	.3216	.0039	26.0509
15	1010	190	17.1	.5494	.0025	28.3317
16	1015	75	7.4	.3713	.0036	24.5365
17	1870	285	15.2	.6598	.0025	85.3603
18	2200	340	15.5	.7009	.0050	106.4603

Appendix 2. Continued

Fish #	Wet weight (g)	Wet gonad weight (g)	% wet gonad weight	Mean weight 1,000 ova(g)	S.D. mean weight	total weight dried ova(g)
19	1900	320	16.8	.6062	.0022	105.7053
20	1710	230	13.5	.6326	.0023	79.0470
21	1100	95	8.6	.4338	.0007	34.9360
22	1755	225	12.8	.5548	.0017	83.0322
23	2510	470	18.7	.6622	.0045	176.4960
24	1815	280	15.4	.5953	.0042	94.3514
25	2685	520	19.4	.6676	.0043	156.8768
26	1910	340	17.8	.6108	.0011	119.7057
27	2695	415	15.4	.6724	.0038	136.7256
28	3150	660	21.0	.6342	.0011	228.2591
29	1470	255	17.3	.5985	.0036	73.0233
30	1120	110	9.8	.5856	.0052	41.6351
31	1805	325	18.0	.6096	.0020	103.7861
32	2890	650	22.5	.6310	.0029	145.9215
33	1340	235	17.5	.6158	.0059	72.7366
34	1880	310	16.5	.5723	.0012	70.3736
35	1890	280	14.8	.6988	.0149	84.6046

Appendix 3. Total lengths of 50 quillback larvae, in mm, preserved at the time of hatch.

7.84	7.99	7.90	7.92	8.13
7.74	7.96	7.80	7.95	7.96
7.85	7.93	7.69	7.93	8.11
7.83	7.76	8.01	8.02	8.06
8.04	7.98	8.00	7.86	7.94
8.06	7.89	8.06	8.06	7.94
8.16	8.05	7.73	8.27	7.94
7.61	8.03	8.05	8.07	8.16
8.07	8.10	7.77	7.81	8.11
8.01	7.78	8.00	7.85	7.91

Appendix 4. Seine catches from the 1984 seining program, west side of the Ochre River only. Date = DDMMYY.

Date	FL (mm)	wet weight (g)
200584	56	3.4
040784	20	-
150784	161	81.1
	153	77.9
010884	43	1.45
	51	2.34
	45	1.58
	45	1.65
	44	1.59
	34	0.64
100884	59	4.50
	52	3.07
	35	.80
	54	3.21
	54	3.21
	47	2.08
	60	4.49
	51	2.74
	57	3.87
	63	5.13

Appendix 4. Continued.

Date	FL (mm)	wet weight (g)
100884	52	2.76
	52	2.93
	54	3.17
	45	1.86
	50	2.47
	54	3.23
	55	3.23
	39	1.17
	41	1.34
	42	1.46
	41	1.52
	49	2.40
	50	2.34
	45	2.40
	46	1.97
	49	2.10
	39	1.19
	47	2.28
	53	2.94
	58	3.96
100884	49	2.44
	47	2.02

Appendix 4. Continued.

Date	FL (mm)	wet weight (g)
	45	1.71
	49	2.37
	42	1.53
	45	1.96
	46	1.92
170884	79	10.66
260984	59	3.39
	62	4.32
	72	6.71
	67	5.51
	64	4.69
	71	6.34
	62	4.26
	81	10.11
	58	3.95
	63	4.97
260984	64	4.96
	63	4.97
	63	5.52
	64	4.94
	87	11.91

Appendix 4. Continued.

Date	FL (mm)	wet weight (g)
270984	64	5.24
	61	3.94
	82	10.54
	63	4.77
	82	11.38

Appendix 5. Seine catch records for 1985. mor = west side of the Ochre River, met = Methley Beach, stp = Stoney Point, wlc = Welcome Beach, okb = Oak Brae, mvr = mouth of the Valley River, FL = fork length. Date = DDMMYY.

Date	Location	FL (mm)	Wet Weight (g)
170585	mor	73.90	6.12
	mor	49.92	1.48
	mor	62.96	3.11
	mor	57.62	2.75
	mor	54.23	1.81
260585	mor	67.02	4.19
	mor	57.74	2.40
	mor	52.04	1.99
	mor	50.11	1.68
	mor	66.13	4.37
	mor	53.10	2.11
	mor	59.31	2.60
	mor	55.23	2.31
	mor	49.91	1.61
	mor	49.56	1.76
300585	met	60.51	3.00
200685	mor	58.39	2.72
030785	mor	52.89	1.93

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
	mor	82.76	9.86
	mor	78.74	8.05
040785	mor	-	-
040785	met	-	-
040785	stp	-	-
040785	wlc	-	-
050785	okb	1 large adult	
100785	mor	214.57	179.00
	mor	190.35	134.34
	mor	82.64	9.99
	mor	84.54	11.00
100785	okb	426	1727
100785	stp	-	-
100785	wlc	-	-
100785	okb	-	-
100785	mvr	-	-
170785	okb	-	-
170785	mvr	-	-
170785	wlc	-	-
170785	mor	241	289
	mor	203	-

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
	mor	300	614
170785	mor	124.95	35.29
	mor	102.72	16.63
	mor	98.00	16.29
	mor	96.95	15.63
	mor	85.49	9.12
	mor	77.44	7.22
	mor	77.09	6.82
	mor	73.85	6.02
	mor	66.96	4.15
	mor	74.46	6.52
170785	stp	401	1266
	stp	327	697
	stp	395	1265
	stp	380	1137
210785	met	81	-
	met	116	-
	met	106	-
240785	okb	-	-
240785	mvr	-	-
240785	stp	-	-

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
240785	mor	-	-
250785	met	-	-
300785	wlc	-	-
300785	mvr	-	-
300785	okb	392	1182
300785	stp	420	1562
	stp	362	1026
	stp	434	1750
	stp	388	1259
	stp	395	1218
	stp	417	2009
300785	mor	345	895
	mor	388	1143
	mor	428	1520
	mor	413	1453
	mor	357	1086
	mor	102.40	18.83
	mor	133.24	42.10
310785	met	-	-
080885	met	93.04	14.05

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
080885	okb	-	-
080885	stp	-	-
080885	wlc	-	-
080885	mor	-	-
080885	mvr	-	-
150885	mor	127.90	34.98
	mor	143.48	48.30
	mor	115.36	22.54
	mor	105.52	28.50
	mor	114.18	29.25
	mor	105.14	19.62
	mor	93.20	13.56
	mor	37.38	0.80
	mor	75.41	7.11
	mor	82.05	9.56
	mor	83.85	8.68
	mor	35.96	0.69
150885	met	-	-
150885	wlc	-	-
150885	mvr	-	-
150885	stp	-	-

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
150885	okb	-	-
200885	met	83.84	11.26
200885	stp	-	-
200885	wlc	-	-
200885	mvr	-	-
200885	mor	207.79	162.67
	mor	221.94	230.46
	mor	136.56	56.97
	mor	110.74	22.00
	mor	111.54	21.66
	mor	89.90	11.70
	mor	99.84	18.39
	mor	79.53	7.99
	mor	71.58	5.58
	mor	38.85	0.85
	mor	38.08	0.75
	mor	34.75	0.57
	mor	38.10	0.69
200885	okb	2 large adults	
280885	wlc	-	-
280885	met	-	-

Appendix 5. Continued.

Date	Location	FL (mm)	Wet Weight (g)
280885	stp	433	1505
	stp	433	1864
280885	mor	398	1313
	mor	416	1591
090985	stp	239	296
	stp	533	3184
	stp	436	1756
	stp	548	2943
	stp	149	62.20
090985	met	159.90	70.48
110985	met	126.08	33.25
	met	125.44	33.72
	met	140.16	46.73
110985	mor	252	344
	mor	368	-
	mor	430	-
	mor	425	-
240985	met	-	-
240985	mor	-	-
240985	stp	-	-
300985	mor	111	-

Appendix 6. Tag return data for marked quillback. Oru = upstream migrant in the Ochre River, ord = downstream migrant in the Ochre River. FL = fork length. Date = DDMMYY.

Tag no.	Date tagged	FL (mm)	Recap date	location	FL (mm)	Recap date	location	FL (mm)
1269	030684	440	260485	oru	439			
1562	140684	418	260485	oru	426			
1287	020684	415	280485	oru	418	310585	ord	417
1500	120684	377	280485	oru	385	090585	ord	385
1175	060684	402	280485	oru	407	100585	ord	403
1748	280584	484	280485	oru	487			
1366	030684	432	290485	oru	438			
1758	240584	?	290485	oru	471	180585	ord	463
1252	030684	384	290485	oru	393	260585	ord	390
1530	150684	454	290485	oru	454	260585	ord	452
1340	010684	445	300485	oru	445			
1674	300584	403	070585	ord	410			
1198	010584	417	080585	oru	417	120685	ord	415
1727	260584	403	080585	oru	415	240585	ord	413
1032	100584	425	080585	ord	428			
1240	050684	426	080585	ord	432			
1187	050584	471	090585	ord	472			
1134	080684	399	090585	ord	410			
1159	060684	391	100585	oru	401	210585	ord	399

Appendix 6. Continued.

Tag no.	Date tagged	FL (mm)	Recap date	loca-tion	FL (mm)	Recap date	loca-tion	FL (mm)
1433	130684	422	100585	ord	433			
1210	040684	417	110585	ord	436			
1395	300584	405	120585	ord	407			
1437	130684	397	120585	ord	406			
1362	030684	443	120585	oru	450	260585	ord	446
1205	040684	404	120585	ord	410			
1676	240584	432	140585	ord	434			
1250	050684	374	140585	oru	387	210585	ord	380
1196	030584	449	140585	oru	453			
1447	130684	444	150585	ord	444			
1185	050584	477	150585	ord	485			
1297	030684	435	150585	oru	440			
1364	030684	395	150585	oru	399	210585	ord	396
1049	120684	398	160585	oru	413	290585	ord	406
1635	290584	387	160585	ord	395			
1327	310584	424	160585	ord	430			
1432	130684	401	170585	oru	407			
1729	270584	432	170585	ord	433			
1237	050684	383	170585	ord	388			
1289	020684	415	170585	ord	413			
1148	080684	395	170585	ord	408			

Appendix 6. Continued.

Tag no.	Date tagged	FL (mm)	Recap date	loca-tion	FL (mm)	Recap date	loca-tion	FL (mm)
1665	300585	420	170585	ord	426			
1481	120684	411	200585	ord	419			
1486	120684	427	200585	ord	432			
1186	050584	384	200585	ord	387			
1443	130684	369	220585	ord	375			
1146	080684	420	230585	ord	425			
1891	220584	391	230585	ord	391			
1324	310584	427	230585	ord	431			
1288	020684	446	240585	ord	452			
1482	120684	421	240585	ord	432			
1063	120684	440	260585	ord	448			
1155	070684	418	310585	ord	423			
1468	120684	427	310585	ord	429			
1192	040584	422	050685	ord	426			
1156	070684	445	060685	ord	457			
1361	030684	441	070685	ord	443			
1376	300584	410	080685	ord	417			
1640	290584	442	080685	ord	444			
1401	130684	404	080685	ord	408			
1753	240584	456	080685	ord	456			

Appendix 6. Continued.

Tag no.	Date tagged	FL (mm)	Recap date	loca-tion	FL (mm)	Recap date	loca-tion	FL (mm)
1828	300584	429	080685	ord	433			
1670	300584	475	080685	ord	479			
1633	290584	389	080685	ord	394			
1688	250584	388	090685	ord	409			
1642	290584	392	090685	ord	392			
1157	070684	414	090685	ord	419			
1428	130684	405	100685	ord	410			
1074	120684	429	100685	ord	432			
1469	120684	404	100685	ord	416			
1204	040684	400	100685	ord	404			
1671	300584	494	100685	ord	498			
1219	040684	412	100685	ord	416			
1271	030684	430	100685	ord	438			
1949	200585	388	100685	ord	389			
1071	120684	402	100685	ord	402			
1214	040684	384	100685	ord	393			
1174	060684	375	110685	ord	390			
1265	030684	453	110685	ord	457			
1658	140684	393	110685	ord	396			
1492	120684	415	110685	ord	422			
1528	150684	423	110685	ord	434			
1054	120684	?	110685	ord	312			

Appendix 6. Continued.

Tag no.	Date tagged	FL (mm)	Recap date	location	FL (mm)	Recap date	location	FL (mm)
1257	030684	415	110685	ord	417			
1348	020684	300	110685	ord	324			
1470	120684	417	110685	ord	422			
1654	290584	413	120685	ord	412			
1582	130684	443	120685	ord	446			
1551	130684	439	120685	oru	438	210685	ord	-
1421	130684	444	120685	ord	453			
1201	040684	407	120685	ord	410	130685	oru	411
1772	240584	455	120685	ord	458			
1153	070684	376	120685	ord	381			
1282	050684	412	130685	ord	417			
1614	210584	400	130685	ord	402			
1653	290584	438	130685	ord	443			
1166	060684	383	130685	ord	392			
1636	290584	399	130685	ord	405			
1136	080684	376	130685	ord	384			
1516	130684	376	130685	ord	384			
1229	040684	408	140685	ord	414			
1892	220584	413	140685	ord	418			
1373	030684	401	140685	ord	408			
1170	060684	431	140685	ord	438			

Appendix 6. Continued.

Tag no.	Date tagged	FL (mm)	Recap date	loca-tion	FL (mm)	Recap date	loca-tion	FL (mm)
1113	100684	388	140685	ord	402			
1575	140684	402	140685	ord	412			
1130	080684	377	180685	ord	380			
1263	030684	427	180685	ord	434			
1226	040684	409	180685	ord	412			
1596	130684	378	190685	ord	378			
1110	100684	441	190685	ord	444			
1675	300584	420	190685	ord	419			
1262	030684	372	190685	ord	378			
1652	290584	409	190685	ord	415			
1367	030684	408	210685	ord	410			
1752	240584	414	210685	ord	414			
1221	040684	393	230685	ord	393			
1111	100684	397	240684	ord	400			

Appendix 7. Tag return records for quillback recaptured from Dauphin Lake. Mil = near Million, okb = Oak Brae, mor = mouth of the Ochre River, met = Methley Beach, p = caught by project staff and c = caught by commercial fishermen. FL = fork length. Date = DDMMYY.

Tag no.	Date tagged	FL (mm)	Recap. date	Location	FL (mm)	Recap. by
1586	130684	420	130884	mil	420	p
1566	140684	434	84/85*	mil	-	c
1790	230584	420	84/85*	okb	-	c
1567	140684	438	84/85*	okb	-	c
1409	130684	421	84/85*	okb	-	c
1216	040684	411	84/85*	okb	-	c
1597	130684	450	84/85*	okb	-	c
1273	030684	385	84/85*	okb	-	c
1509	130684	355	290785	mor	361	p
1438	130684	424	220885	met	439	p
1119	110684	448	200885	met	459	p
1971	160585	469	210885	met	471	p
1819	280584	474	200885	met	482	p
1338	010684	454	190885	met	459	p
1876	220584	506	160885	met	506	p

*taken in the 1985/86 commercial fishery, exact date of capture unknown.

Appendix 7. Continued.

Tag no.	Date tagged	FL (mm)	Recap. date	Location	FL (mm)	Recap. by
1997	170585	435	060985	met	440	p
1767	240584	451	060985	met	460	p
1963	150585	393	050985	met	394	p
1430	130684	399	230885	met	412	p
1854	270584	413	85/86*	okb	-	c
1112	100684	333	85/86*	okb	350	c
1605	220584	394	85/86*	okb	425	c
1259	030684	369	85/86*	okb	369	c
1375	030684	398	85/86*	okb	398	c

*taken in the 1985/86 commercial fishery, exact date of capture unknown.

Appendix 8. DFO pound net catches of quillback from Methley Beach in 1985.

Day	# of quillback	# of 1985 tags
227	27	1
228	85	1
231	60	1
232	38	2
233	64	1
234	99	0
235	90	0
238	10	0
239	65	0
240	6	0
241	12	0
242	19	0
245	35	0
246	16	0
247	34	2
248	6	3

Appendix 9. Validation of annulus formation in pelvic fin sections for marked quillback at large for 1 year. Fin age = initial age.

Fin age	# validated	# not validated
3	1	0
5	1	0
6	1	0
7	1	0
8	3	0
9	2	2
10	2	2
11	2	2
12	4	2
13	2	5
14	3	7
15	3	3
16	2	3
18	2	2
19	1	0
20	0	1

Appendix 10. Mean ages from operculars, vertebrae, pelvic fin sections and scales in comparison to assigned otolith ages (Number of samples in brackets).

Otolith age	Opercular age		Vertebral age		Fin Ray age		Scale age	
3	3	(1)	3	(1)	3	(1)	3	(1)
4	4	(1)	4	(1)	4	(1)	4	(1)
5	5	(3)	5.2	(6)	5	(6)	4.8	(4)
6	5.5	(4)	6.5	(6)	6	(5)	6.3	(5)
7	7	(4)	7	(4)	7	(4)	7	(4)
8	7.5	(2)	8	(2)	8	(2)	8	(2)
9	9	(1)	9	(1)	9	(1)	9	(1)
10	10	(1)	10	(1)	9	(1)	9	(1)
19	19	(1)	16	(1)	14	(1)	9	(1)
20	18	(1)	-		-		-	
21	21.1	(7)	20.2	(5)	14.8	(4)	15.5	(4)
22	21.1	(11)	19.4	(10)	16.8	(6)	14.1	(7)
23	21.4	(14)	21	(10)	17.8	(9)	13.7	(10)
24	22	(4)	19	(2)	12	(1)	14	(1)
26	24	(2)	22.5	(2)	12	(1)	14	(1)
36	36	(1)	24	(1)	18	(1)	-	
46	45	(1)	40	(1)	-		22	(1)

Appendix 11. Fork length at age for all aged male quillback.

Unsexed immature fish to age 3+ included.

Age (+)	Mean FL (mm)	Range	# of obs.
0	52.8	18 - 96	101
1	105.9	53 - 177	53
2	218.4	190 - 252	7
3	258.7	241 - 289	3
4	297.6	289 - 304	3
5	317.9	294 - 345	16
6	332.7	319 - 349	12
7	348.5	345 - 352	3
8	359.0	345 - 373	2
11	372.5	357 - 388	2
16	375.0	-	1
18	368.5	368 - 369	2
19	402.0	-	1
20	392.3	380 - 410	3
21	408.0	388 - 428	2
22	403.3	387 - 412	6
23	410.1	369 - 440	16
24	408.0	-	1
26	422.0	418 - 426	2

Appendix 11. Continued.

Age (+)	Mean FL (mm)	Range	# of obs.
28	463.0	-	1
30	416.0	-	1
34	420.0	-	1
42	457.0	-	1
45	451.0	-	1
52	425.0	-	1

Appendix 12. Fork length at age for all aged female quillback.

Age (+)	Mean FL (mm)	Range	# of obs.
6	348.0	-	1
7	355.8	350 - 360	4
8	370.0	-	1
9	364.2	355 - 380	5
10	376.3	370 - 389	3
11	380.0	375 - 385	2
16	423.5	405 - 441	3
17	443.5	432 - 455	2
18	416.0	398 - 434	2
19	424.0	380 - 467	7
20	435.5	417 - 454	2
21	444.4	406 - 472	9
22	437.6	395 - 497	11
23	440.3	408 - 480	8
24	446.4	425 - 489	8
26	444.0	-	1
27	502.0	-	1
28	504.0	478 - 531	3
29	510.0	-	1
30	498.7	416 - 499	3

Appendix 12. Continued.

Age (+)	Mean FL (mm)	Range	# of obs.
32	467.0	-	1
33	507.0	-	1
34	499.7	462 - 522	3
41	548.0	-	1
42	460.0	-	1
45	533.0	-	1
46	500.0	-	1

Appendix 13. Fork length at annulus formation for immature and male quillback.

Annulus	Mean FL (mm)	Range	# of obs.
1	65.5	50 - 90	40
2	146.2	125 - 177	6
3	245.5	239 - 252	2
4	289.0	-	1
5	317.3	294 - 345	15
6	331.6	319 - 349	11
7	345.0	-	1
8	359.0	-	1
11	357.0	-	1
18	369.0	-	1
20	410.0	-	1
21	428.0	-	1
22	399.0	-	1
23	400.6	369 - 414	5
26	422.0	418 - 425	2
28	468.0	-	1
30	416.0	-	1

Appendix 14. Fork length at annulus formation for female quillback.

Annulus	Mean FL (mm)	Range	# of obs.
6	348	-	1
7	355.8	350 - 360	4
8	370.0	-	1
9	364.2	355 - 380	5
10	376.3	370 - 389	3
11	380.0	375 - 385	2
16	425.3	405 - 441	3
17	443.5	432 - 455	2
18	416.0	398 - 434	2
19	427.0	380 - 407	6
21	453.8	444 - 468	5
22	445.8	416 - 497	4
23	441.0	408 - 480	3
24	437.7	425 - 459	3
26	444.0	-	1
27	502.0	-	1
28	504.0	478 - 531	3
29	510.0	-	1
30	489.7	473 - 499	3
32	476.0	-	1

Appendix 14. Continued.

Annulus	Mean FL (mm)	Range	# of obs.
33	507.0	-	1
34	518.5	515 - 522	2

Appendix 15. Length at annulus formation, in mm, for five populations of *C. cyprinus*.

State Author annulus	Florida 1 Beecher(1979)	Iowa 2 Vanicek(1961)	Ohio Woodward(1973)
1	128	124	84
2	265	165	156
3	366	201	206
4	380	234	242
5	400	269	280
6	418	340	312
7	-	361	342
8	-	399	368
9	-	386	398
10	-	419	428
11	-	-	448

1. Appalachicola River only.

2. Converted to mm from inches.

Appendix 15. Continued.

State Author	Nebraska McCarraher et al (1971)	Present Study
annulus		
1	108	73
2	243	163
3	340	274
4	398	323
5	446	355
6	462	372
7	-	395
8	-	406
9	-	407
10	-	421
11	-	416

Appendix 16. Percent occurrence of food items in grouped quillback stomach data. FL = fork length.

Taxon	inshore <200 mm FL	inshore >200 mm FL	offshore >200 mm FL	Ochre River
sand	100.0	84.2	10.0	100.0
flocculents	91.3	89.5	80.0	100.0
Difflugia	91.3	73.7	70.0	0
cladocerans	56.5	73.7	30.0	0
copepods	87.0	94.7	90.0	0
ostracods	69.6	63.2	40.0	14.3
chironomids	73.9	84.2	60.0	100.0
other insects	8.7	21.0	0	14.3
insect parts	13.0	36.8	10.0	57.1
tardigrades	8.7	10.5	0	0
amphipods	0	5.3	10.0	0
sponges	4.3	26.3	0	0
bivalves	0	15.8	0	0
fish eggs	0	5.3	0	85.7
diatoms	82.6	84.2	90.0	100.0
fil. algae	4.3	26.3	0	85.7
plant parts	43.5	57.9	10.0	85.7

Appendix 17. Percent volume of food items in grouped quillback stomach data. FL = fork length. t = trace.

Taxon	inshore <200 mm FL	inshore >200 mm FL	offshore >200 mm FL	Ochre River
sand	31.9	37.6	1.5	67.9
flocculents	30.9	21.3	18.3	21.0
Difflugia	5.4	6.6	1.1	0
cladocerans	5.2	15.2	.5	0
copepods	6.8	5.6	48.7	0
ostracods	10.7	2.9	13.7	t
chironomids	7.7	5.5	15.3	1.8
other insects	t	t	0	t
insect parts	t	t	t	t
tardigrades	t	t	0	0
amphipods	0	t	t	0
sponges	t	1.0	0	0
bivalves	0	2.3	0	0
fish eggs	0	t	0	6.3
diatoms	t	t	0	t
fil. algae	t	t	0	t
plant parts	.6	.6	t	1.5

Appendix 18. Individual stomach contents, by % volume, for quillback feeding in the Ochre River following spawning. t = <.5% of stomach contents, FL = fork length, Date = DDMM.

Date FL (mm)	2405 345	2405 409	2405 418	2405 402	2405 426	2505 432	2605 409	2605 357	2605 356
sand	80.0	75.0	-	-	20.0	75.0	70.0	60.0	40.0
flocculents	10.0	10.0	-	-	70.0	5.0	5.0	25.0	10.0
mucous	t	5.0	-	-	5.0	10.0	15.0	10.0	35.0
<u>Difflugia</u>	-	-	-	-	-	-	-	-	-
cladocerans	-	-	-	-	-	-	-	-	-
copepods	-	-	-	-	-	-	-	-	-
chironomids	2.0	t	-	-	5.0	t	t	t	2.0
ostracods	-	-	-	-	t	-	-	-	-
insect parts	t	t	-	-	-	-	-	t	t
other insects	-	-	-	-	t	-	-	-	-
tardigrades	-	-	-	-	-	-	-	-	-
amphipods	-	-	-	-	-	-	-	-	-
plant parts	t	t	-	-	t	t	-	t	5.0
fil. algae	t	t	-	-	t	t	-	t	t
sponges	-	-	-	-	-	-	-	-	-
molluscs	-	-	-	-	-	-	-	-	-
fish eggs	5.0	8.0	-	-	-	5.0	10.0	5.0	5.0
diatoms	t	t	-	-	t	t	t	t	t

Appendix 19. Individual stomach data, by % volume, for quillback >200 mm FL taken offshore in 1983. Location is the closest shoreline marker, where mor = mouth of the Ochre River, wil = the Wilson River and met = Methley Beach. t = <.5% of stomach contents, FL = fork length, date = DDMM.

Date Location	- mor	1608 mor	0908 wil	0608 met	0707 mor	2008 met
sand	-	-	-	-	-	-
mucous	-	-	-	-	-	-
flocculents	4.0	t	95.0	3.0	t	-
<u>Difflugia</u>	1.0	1.0	1.0	2.0	-	2.0
cladocerans	-	-	-	-	1.0	-
copepods	95.0	99.0	4.0	95.0	-	90.0
chironomids	-	-	-	t	-	5.0
ostracods	-	-	-	-	99.0	3.0
insect parts	-	-	-	-	-	-
other insects	-	-	-	-	-	-
tardigrades	-	-	-	-	-	-
amphipods	-	-	-	-	-	-
plant parts	-	-	-	-	-	-
fil. algae	-	-	-	-	-	-
sponges	-	-	-	-	-	-
molluscs	-	-	-	-	-	-
fish eggs	-	-	-	-	-	-
diatoms	t	t	-	t	t	t

Appendix 19. Continued.

Date Location	2008 met	2607 mor	0608 met	0508 met	0408 mor
sand	-	10.0	-	-	-
mucous	-	35.0	-	-	-
flocculents	35.0	t	45.0	-	-
Difflugia	t	t	-	-	5.0
cladocerans	t	1.0	-	-	-
copepods	5.0	5.0	t	-	95.0
chironomids	60.0	25.0	50.0	-	t
ostracods	-	20.0	5.0	-	-
insect parts	-	t	-	-	-
other insects	-	-	-	-	-
tardigrades	-	-	-	-	-
amphipods	-	2.0	-	-	-
plant parts	-	t	-	-	-
fil. algae	-	-	-	-	-
sponges	-	-	-	-	-
molluscs	-	-	-	-	-
fish eggs	-	-	-	-	-
diatoms	-	-	-	-	-

Appendix 20. Individual stomach data, by % volume, for quillback >200 mm FL taken onshore. Mor = mouth of the Ochre River, met = Methley Beach, okb = Oak Brae, stp = Stoney Point, t = <.5% of stomach contents, FL = fork length, date = DDMM.

Date Location FL (mm)	1007 mor 190	1007 mor 214	1007 mor 246	1007 okb 426	1707 mor 240	1707 stp 327
sand	20.0	30.0	5.0	45.0	35.0	30.0
flocculents	25.0	35.0	5.0	45.0	30.0	t
mucous	5.0	5.0	-	3.0	5.0	55.0
<u>Difflugia</u>	t	25.0	80.0	t	5.0	5.0
cladocerans	t	t	t	-	t	t
copepods	1.0	t	t	t	t	t
chironomids	15.0	5.0	5.0	2.0	5.0	t
ostracods	30.0	t	5.0	t	8.0	t
insect parts	t	t	-	t	t	-
other insects	-	-	-	t	-	-
tardigrades	-	-	-	-	-	-
amphipods	4.0	-	-	-	-	-
plant	t	t	t	t	t	t
fil. algae	-	-	-	t	-	-
sponge	-	t	-	-	-	-
molluscs	-	-	-	5.0	-	-
fish eggs	-	-	-	-	t	-
diatoms	t	t	t	t	t	t

Appendix 20. Continued.

Date Location FL (mm)	1707 stp 401	1807 mor 387	3007 mor 345	3007 mor 388	3007 mor 413	3007 mor 428
sand	50.0	20.0	50.0	70.0	35.0	-
flocculents	25.0	30.0	15.0	5.0	30.0	-
mucous	10.0	10.0	20.0	25.0	10.0	-
Difflugia	t	t	-	-	t	-
cladocerans	t	t	-	-	-	-
copepods	t	10.0	5.0	t	-	-
chironomids	t	5.0	10.0	t	25.0	-
ostracods	-	-	-	t	-	-
insect parts	5.0	t	-	-	-	-
other insects	-	-	-	-	-	-
tardigrades	-	-	-	-	-	-
amphipods	-	-	-	-	-	-
plant parts	-	-	t	-	-	-
fil. algae	-	-	-	t	-	-
sponges	-	t	-	-	-	-
molluscs	10.0	25.0	-	-	-	-
fish eggs	-	-	-	-	-	-
diatoms	t	t	t	t	t	t

Appendix 20. Continued.

Date Location FL (mm)	3007 okb 392	2008 mor 208	2008 mor 221	2008 mor 222	2808 met 418
sand	-	40.0	15.0	60.0	70.0
flocculents	-	30.0	20.0	15.0	15.0
mucous	-	10.0	5.0	5.0	10.0
<u>Difflugia</u>	-	-	t	t	t
cladocerans	-	t	t	-	t
copepods	-	t	50.0	8.0	t
chironomids	-	5.0	5.0	10.0	3.0
ostracods	-	-	t	t	2.0
insect parts	-	t	-	-	-
other insects	-	-	t	-	t
tardigrades	-	-	2.0	-	-
amphipods	-	-	-	-	-
plant parts	-	-	5.0	t	t
fil. algae	-	t	-	t	t
sponges	-	15.0	t	-	-
molluscs	-	-	-	-	-
fish eggs	-	-	-	-	-
diatoms	-	t	t	t	t

Appendix 20. Continued.

Date Location FL (mm)	2808 stp 433	0909 stp 239	0909 stp 436	0909 stp 533	0909 stp 548
sand	-	25.0	-	-	-
flocculents	-	45.0	5.0	-	-
mucous	-	15.0	-	-	-
<u>Difflugia</u>	-	t	-	t	-
cladocerans	-	t	90.0	95.0	99.0
copepods	-	15.0	5.0	2.0	t
chironomids	-	-	-	t	-
ostracods	-	t	-	3.0	-
insect parts	-	-	-	-	-
other insects	-	t	-	-	-
tardigrades	-	t	-	-	-
amphipods	-	-	-	-	-
plant parts	-	-	t	-	-
fil. algae	-	-	-	-	-
sponges	-	t	-	-	-
molluscs	-	-	-	-	-
fish eggs	-	-	-	-	-
diatoms	-	t	t	-	-

Appendix 21. Individual stomach data, by % volume, for quillback <200 mm FL taken inshore, Mor = mouth of the Ochre River, met = Methley Beach, t = <.5% of stomach contents. FL = fork length, date = DDMM.

Date Location FL (mm)	1705 mor 50	1705 mor 74	2605 mor 52	2605 mor 58	2605 mor 67	0307 mor 53
sand	50.0	15.0	30.0	20.0	10.0	10.0
mucous	10.0	5.0	30.0	15.0	70.0	-
flocculents	15.0	60.0	20.0	5.0	10.0	80.0
<u>Difflugia</u>	25.0	5.0	10.0	-	3.0	10.0
cladocerans	-	-	5.0	-	-	t
copepods	-	10.0	5.0	60.0	5.0	t
chironomids	-	t	t	-	-	-
ostracods	-	2.0	-	-	t	-
insect parts	-	-	-	-	-	-
other insects	-	-	-	-	-	-
tardigrades	-	-	-	-	-	-
amphipods	-	-	-	-	-	-
plant parts	t	2.0	-	t	2.0	t
fil. algae	-	-	-	-	-	-
sponges	-	-	-	-	-	-
molluscs	-	-	-	-	-	-
fish eggs	-	-	-	-	-	-
diatoms	-	t	t	t	t	t

Appendix 21. Continued.

Date Location FL (mm)	0307 mor 79	0307 mor 83	1007 mor 83	1007 mor 85	1707 mor 67	1707 mor 74
sand	-	t	20.0	30.0	20.0	15.0
mucous	-	5.0	10.0	15.0	30.0	5.0
flocculents	-	-	30.0	20.0	10.0	75.0
Difflugia	-	-	2.0	t	20.0	t
cladocerans	-	95.0	2.0	2.0	t	t
copepods	-	t	10.0	t	t	t
chironomids	-	-	-	5.0	10.0	t
ostracods	-	-	20.0	30.0	-	t
insect parts	-	-	-	-	-	-
other insects	-	-	-	-	-	-
tardigrades	-	-	-	-	-	-
amphipods	-	-	-	-	-	-
plant parts	-	-	t	-	-	t
fil. algae	-	-	-	-	-	-
sponges	-	-	-	-	-	-
molluscs	-	-	-	-	-	-
fish eggs	-	-	-	-	-	-
diatoms	-	-	-	t	-	t

Appendix 21. Continued.

Date Location FL (mm)	1707 mor 97	3007 mor 162	0808 met 93	1508 mor 75	1508 mor 93	1508 mor 115
sand	30.0	55.0	50.0	10.0	30.0	60.0
mucous	10.0	15.0	10.0	-	10.0	15.0
flocculents	50.0	25.0	5.0	5.0	10.0	10.0
<u>Difflugia</u>	2.0	t	10.0	t	t	t
cladocerans	t	-	t	-	t	-
copepods	t	t	t	t	t	t
chironomids	t	5.0	15.0	5.0	30.0	5.0
ostracods	5.0	t	10.0	75.0	20.0	5.0
insect parts	-	-	-	-	-	t
other insects	-	-	-	-	-	-
tardigrades	-	-	-	t	-	-
amphipods	-	-	-	-	-	-
plant parts	t	-	-	-	-	t
fil. algae	-	-	-	-	-	-
sponges	-	-	-	-	-	-
molluscs	-	-	-	-	-	-
fish eggs	-	-	-	-	-	-
diatoms	t	t	t	t	t	t

Appendix 21. Continued.

Date Location FL (mm)	1508 mor 128	1508 mor 143	2008 mor 39	2008 mor 80	2008 mor 84
sand	25.0	35.0	-	-	-
mucous	5.0	5.0	-	-	-
flocculents	40.0	-	-	-	-
Difflugia	2.0	2.0	-	-	-
cladocerans	-	1.0	-	-	-
copepods	t	2.0	-	-	-
chironomids	t	35.0	-	-	-
ostracods	25.0	20.0	-	-	-
insect parts	t	-	-	-	-
other insects	-	-	-	-	-
tardigrades	-	-	-	-	-
amphipods	-	-	-	-	-
plant parts	-	-	-	-	-
fil. algae	-	-	-	-	-
sponges	2.0	-	-	-	-
molluscs	-	-	-	-	-
fish eggs	-	-	-	-	-
diatoms	t	t	-	-	-

Appendix 21. Continued.

Date Location FL (mm)	2008 mor 90	2008 mor 100	2008 mor 111	0909 mor 160
sand	10.0	40.0	40.0	20.0
mucous	10.0	10.0	10.0	2.0
flocculents	40.0	40.0	45.0	30.0
<u>Difflugia</u>	t	t	t	2.0
cladocerans	-	t	-	3.0
copepods	-	-	t	30.0
chironomids	35.0	5.0	2.0	5.0
ostracods	3.0	-	t	2.0
insect parts	-	-	t	-
other insects	-	-	t	t
tardigrades	-	-	-	t
amphipods	-	-	-	-
plant parts	2.0	-	t	-
fil. algae	-	-	-	-
sponges	-	-	-	-
molluscs	-	-	-	-
fish eggs	-	-	-	-
diatoms	t	t	t	t

Appendix 22. Summary of morphometrics and gillraker counts for Dauphin Lake quillback. TL = total length.

Size Range (mm TL)	Body Depth/TL	Peduncle Depth/TL	Head Depth/TL
30 - 49	.221 - .232	.094 - .104	.242 - .254
50 - 99	.217 - .271	.101 - .108	.216 - .243
100 - 199	.265 - .305	.111 - .116	.207 - .234
200 - 299	.298 - .318	.087 - .119	.198 - .217
300 - 399	.275 - .323	.103 - .114	.197 - .208
400 - 499	.271 - .301	.097 - .109	.186 - .210
500+	.270 - .296	.101 - .118	.191 - .208

Appendix 22. Continued.

Size Range (mm TL)	Interorbital width/HL	Eye Diam. /HL	Snout Length /HL
30 - 49	.304 - .338	.238 - .253	.290 - .298
50 - 99	.341 - .389	.235 - .266	.298 - .325
100 - 199	.366 - .431	.206 - .234	.300 - .369
200 - 299	.397 - .428	.191 - .206	.307 - .374
300 - 399	.389 - .416	.171 - .181	.346 - .380
400 - 499	.375 - .464	.147 - .177	.344 - .407
500+	.400 - .452	.163 - .173	.339 - .363

Appendix 22. Continued.

Size Range (mm TL)	Eye diam. /snout length	No. of gillrakers	Longest Gillraker as % TL
30 - 49	.799 - .859	18 - 23	.017 - .020
50 - 99	.723 - .893	23 - 34	.019 - .026
100 - 199	.598 - .748	31 - 39	.025 - .029
200 - 299	.464 - .553	38 - 45	.025 - .027
300 - 399	.465 - .500	42 - 48	.023 - .029
400 - 499	.386 - .586	39 - 47	.023 - .029
500+	.454 - .486	40 - 46	.024 - .029

Appendix 22. Continued.

Size Range (mm TL)	Dorsal base /TL	Long/Short Dorsal Ray	Longest Dorsal Ray /Dorsal Base
30 - 49	.284 - .306	3.5 - 4.2	.549 - .605
50 - 99	.283 - .300	3.8 - 5.1	.670 - .845
100 - 199	.289 - .315	4.0 - 5.5	.701 - .937
200 - 299	.304 - .341	3.4 - 7.4	.798 - .982
300 - 399	.310 - .340	4.8 - 9.5	.711 -1.137
400 - 499	.321 - .415	5.1 - 7.2	.520 - .909
500+	.342 - .355	5.2 - 7.8	.605 - .838

Appendix 23. Raw morphometrics for Dauphin Lake quillback. All measurements in mm.

Fish Number	Total length	Fork length	Wet weight(g)	Body depth	Peduncle depth
1	463.08	416.00	1426	134.45	46.05
2	451.36	399.32	1191	122.54	46.89
3	482.76	435.23	1687	140.01	51.12
4	468.23	414.10	1576	143.21	50.96
5	481.13	429.98	1645	137.82	49.02
6	483.01	428.64	1492	135.44	46.82
7	452.00	408.51	1355	130.16	45.96
8	462.72	410.73	1421	132.89	48.14
9	521.88	465.32	1835	141.16	52.74
10	347.77	312.02	510	95.89	35.98
11	392.64	355.94	846	115.32	42.46
12	264.96	246.90	281	86.05	30.69
13	249.24	221.94	230.46	79.38	29.68
14	276.45	241.09	289	85.41	29.96
15	237.79	207.79	162.67	72.70	20.84
16	339.79	300.65	614	109.80	38.82
17	218.56	190.35	134.34	65.31	24.45
18	481.19	426.11	1727	143.68	49.40
19	235.75	214.56	179	72.31	25.62
20	520.53	468.76	2242	154.31	55.36

Appendix 23. Continued.

Fish Number	Total length	Fork length	Wet weight(g)	Body depth	Peduncle depth
21	464.99	416.83	1579	143.58	48.72
22	491.64	444.43	1820	144.95	53.35
23	358.01	322.00	641	102.55	38.21
24	498.98	446.91	1958	143.86	49.10
25	500.26	440.82	1822	140.48	59.21
26	482.67	430.43	1627	136.20	47.46
27	103.56	93.20	12.56	27.48	11.56
28	198.79	175.63	-	57.40	22.52
29	58.60	52.89	1.93	13.68	5.91
30	94.14	83.84	11.26	20.39	10.31
31	122.02	110.74	22	34.42	13.94
32	124.13	111.54	21.66	35.25	13.81
33	89.84	79.53	24.38	9.56	15.76
34	89.84	79.53	7.99	24.38	9.56
34	41.53	38.08	0.75	9.36	4.33
35	38.40	34.75	0.57	8.89	3.92
36	42.10	38.10	0.69	9.29	3.94
37	141.66	127.90	34.98	43.29	16.39
38	162.66	143.48	48.30	46.38	18.10
39	79.67	71.58	5.58	20.90	8.32
40	43.34	38.85	0.85	9.70	4.36

Appendix 23. Continued.

Fish number	Head depth	Head length	Snout length	Orbit diam.	Interorb. width
1	82.46	91.85	35.41	14.46	36.54
2	78.71	84.05	28.94	15.01	34.44
3	86.95	101.32	36.96	15.86	42.08
4	75.85	93.16	36.45	16.21	39.04
5	77.91	96.12	34.55	15.88	40.00
6	82.54	100.34	37.53	15.78	37.66
7	82.18	91.48	34.98	13.49	38.42
8	82.40	93.92	36.44	16.47	36.17
9	85.84	102.00	36.56	16.61	41.06
10	57.99	68.44	23.69	11.82	28.48
11	70.97	81.79	30.04	13.98	31.82
12	49.90	54.31	18.34	11.18	21.55
13	46.55	54.12	20.25	9.40	22.92
14	48.68	55.00	19.40	10.50	22.41
15	40.18	47.11	17.03	9.06	19.59
16	60.46	70.16	26.67	12.68	29.38
17	36.91	43.23	13.27	8.69	18.49
18	85.16	93.82	64.88	16.58	41.50
19	41.90	47.27	16.95	9.37	19.50
20	90.72	99.59	33.78	16.43	45.02

Appendix 23. Continued.

Fish number	Head depth	Head length	Snout length	Orbit diam.	Interorb. width
21	-	93.80	38.18	15.73	41.12
22	-	95.96	29.24	17.12	44.53
23	-	72.22	25.00	12.50	30.14
24	-	99.13	34.90	16.64	40.66
25	-	104.09	37.82	18.00	41.68
26	84.16	98.38	39.58	15.46	41.95
27	18.00	24.24	8.01	5.42	8.87
28	34.93	42.00	13.96	8.66	17.20
29	10.07	13.74	4.10	3.66	5.21
30	17.67	20.34	6.60	4.81	7.91
31	22.18	26.54	8.81	6.22	10.14
32	21.94	27.43	8.24	6.16	10.45
33	15.76	20.82	6.41	5.31	7.61
34	7.50	10.34	3.08	2.46	3.40
35	6.76	9.36	2.76	2.37	3.16
36	7.47	10.18	2.95	2.52	3.24
37	26.36	32.39	11.96	7.16	12.91
38	29.18	33.73	11.36	7.17	14.54
39	14.26	19.34	6.28	4.54	6.59
40	11.04	11.04	3.26	2.78	3.36

Appendix 23. Continued.

Fish number	Mouth width	Dorsal base length	Longest dorsal ray	Shortest dorsal ray
1	14.58	162.10	118.81	18.56
2	14.31	161.35	111.64	17.80
3	16.76	165.15	103.49	17.61
4	18.91	154.62	140.56	19.48
5	17.42	176.08	101.43	21.13
6	16.02	170.26	88.52	19.88
7	15.00	169.30	96.72	16.04
8	15.88	156.50	103.34	19.64
9	19.94	178.36	120.04	19.90
10	11.38	118.32	85.27	12.91
11	13.15	122.61	87.23	18.26
12	9.46	90.44	81.15	11.00
13	9.38	76.48	66.00	19.28
14	10.08	86.14	73.83	11.69
15	8.90	74.11	65.09	13.22
16	12.84	105.26	105.46	16.00
17	8.29	66.34	65.16	13.08
18	20.74	200.00	114.68	20.15
19	8.56	72.74	58.07	14.14
20	17.24	185.06	111.98	21.36

Appendix 23. Continued.

Fish number	Mouth width	Dorsal base length	Longest dorsal ray	Shortest dorsal ray
21	14.83	149.35	121.54	17.95
22	17.62	179.54	121.82	19.68
23	9.95	114.05	129.62	13.69
24	17.70	177.94	101.42	19.56
25	18.16	171.50	143.86	18.45
26	17.59	172.54	96.95	18.96
27	4.04	29.95	22.01	5.44
28	8.39	62.56	53.65	9.74
29	2.59	16.68	11.21	2.92
30	2.81	27.61	20.34	5.09
31	5.13	38.34	26.86	6.45
32	5.17	37.65	26.41	6.56
33	3.19	26.92	18.04	4.75
34	1.70	12.34	6.78	1.94
35	1.21	11.74	6.32	1.74
36	1.17	12.63	7.62	1.81
37	4.91	42.80	40.12	8.63
38	6.97	50.46	38.39	8.73
39	2.91	22.54	19.04	3.76
40	1.55	12.34	7.47	2.04

Appendix 23. Continued.

Fish number	Anal base length	Anal ray long	Number gill-rakers	Length longest gillraker
1	36.44	71.16	42	12.46
2	37.00	64.53	42	10.93
3	36.17	66.46	44	11.14
4	36.04	73.34	44	11.77
5	38.62	66.79	40	11.80
6	38.44	63.45	47	12.14
7	41.55	62.78	46	12.04
8	37.46	62.01	45	13.45
9	39.91	68.66	46	15.23
10	31.00	47.30	48	7.86
11	29.86	58.32	42	11.32
12	23.24	49.11	42	6.80
13	17.80	38.91	42	6.03
14	18.96	43.10	39	7.47
15	16.95	37.32	45	6.38
16	25.94	54.60	45	9.19
17	13.69	35.57	38	5.56
18	41.21	70.30	41	11.56
19	16.12	34.60	40	6.48
20	41.55	76.00	40	12.61

Appendix 23. Continued.

Fish number	Anal base length	Anal ray long	Number gill-rakers	Length longest gillraker
21	31.76	61.14	43	12.02
22	39.05	69.85	42	12.74
23	27.79	54.21	46	9.76
24	40.00	70.64	43	11.66
25	37.05	69.80	44	12.59
26	37.64	-	39	12.77
27	7.03	14.93	31	2.68
28	14.96	30.34	39	5.78
29	3.88	7.66	23	1.09
30	7.42	13.84	25	2.44
31	9.20	17.43	33	3.49
32	8.99	18.58	36	3.56
33	6.16	13.38	34	2.06
34	2.56	6.44	21	0.82
35	2.24	5.00	18	0.64
36	2.36	7.62	18	0.76
37	9.03	24.34	36	3.64
38	12.24	23.00	34	4.12
39	4.78	-	28	1.92
40	3.00	-	23	0.84

Appendix 24. Summary of fin ray and scale counts for Dauphin Lake quillback. (No. of observations in brackets).

Character	Counts					
dorsal rays	25(4)	26(8)	27(10)	28(7)	29(5)	30(2)
pelvic rays	9(8)	10(28)				
anal rays	7(35)	8(1)				
caudal rays	18(35)	19(1)				
pectoral rays	16(7)	17(14)	18(14)			
lat. line scales	37(6)	38(13)	39(10)	40(3)	41(2)	

Appendix 25. Occurrence of tubercles on male and female Dauphin Lake quillback.

location	male (11)	female (12)
pectoral rays	11	6
pelvic rays	11	6
first anal ray	7	1
first dorsal ray	10	6
caudal rays	1*	0*
top of head/nape	11*	7*
opercle/cheek	11	10
lateral line scales	11	5
belly scales	6	1
cornea of eye	5*	0*

* evident only after preservation.

Appendix 26. Detailed occurrence of tubercles on pectoral and pelvic fins and the lateral line scale series. Number of observations in brackets.

males							
pectoral rays							
1 through	3(1)	4(1)	7(3)	8(1)	9(1)	10(2)	11(2)
pelvic rays							
1 through	3(3)	4(1)	5(4)	6(3)			
lateral line							
scales 1 through	18(1)	23(1)	34(1)	37(1)	38(5)	39(2)	
females							
pectoral rays							
1 through	0(6)	2(1)	4(1)	5(1)	6(2)	11(1)	
pelvic rays							
1 through	0(6)	2(2)	3(2)	4(1)	5(1)		
lateral line							
scales 1 through	0(7)	25(1)	37(1)	39(3)			