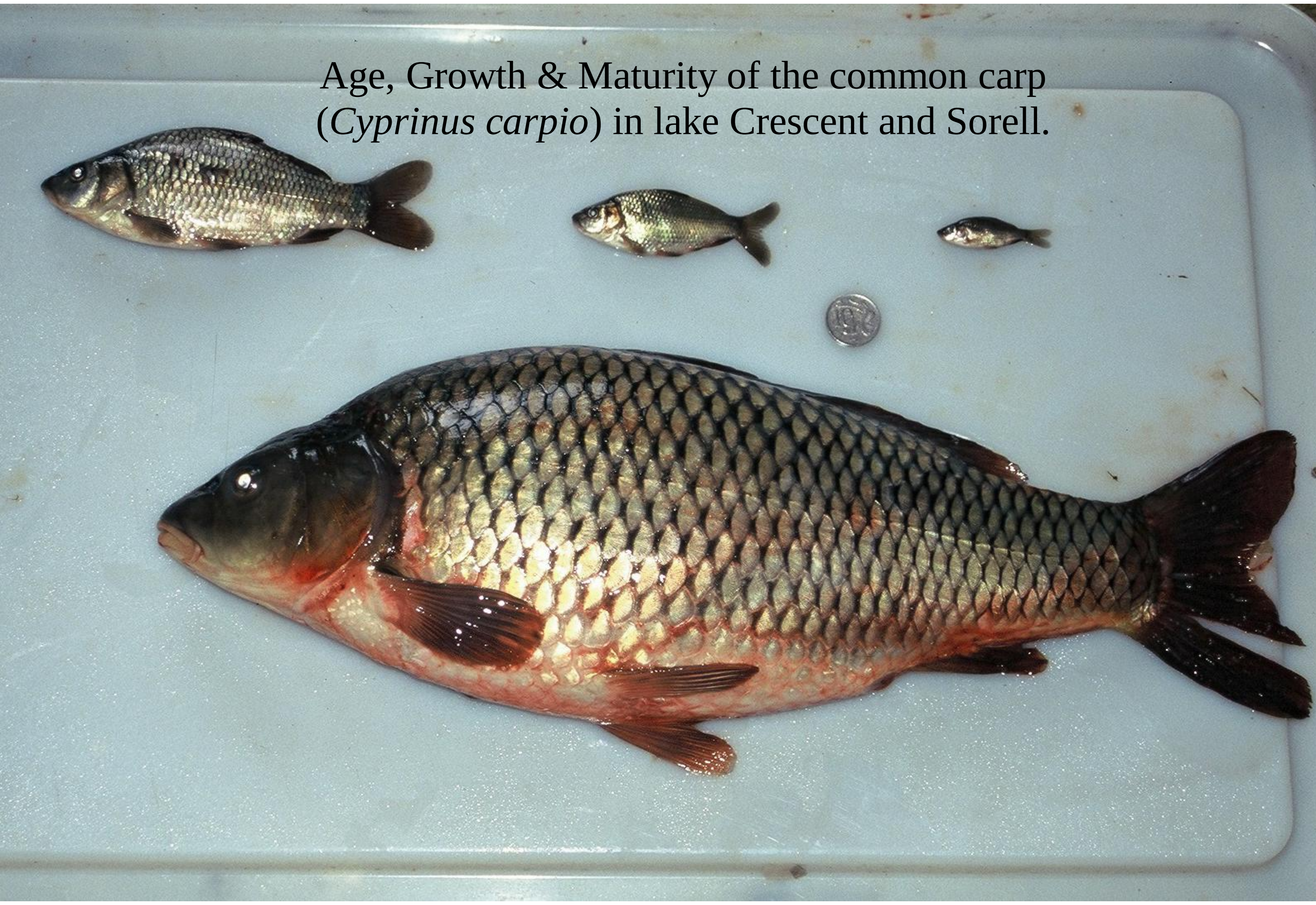
Age, Growth & Maturity of the common carp (*Cyprinus carpio*) in lake Crescent and Sorell.



Technical Report No. 4

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This report is part of a series of documents, which provide information and details of carp eradication efforts in lakes Sorell and Crescent as part of the Lakes Sorell and Crescent Carp Management Project.

The aim of the project is to control the spread of carp within the state of Tasmania, with a view to their eradication.

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1. 0 Introduction

The study of age and growth is essential in fisheries stock assessment and management (Nash 1998). In commercial fisheries age and growth provides information on the productivity of a stock and at what rate it can be sustainably harvested. In the case of deliberately fishing out a stock as in the case of carp in Tasmania it also provides essential information which can be used to make the process as effective as possible. Studying the growth rate of carp in lakes Crescent and Sorell allows us to predict what fishing gear will be needed in the coming season including what size gillnets to use at what time of the year to maximise catching efficiency. Knowing the age of maturity allows us to prepare for the behavioural changes such as spawning aggregations and thus have the necessary resources at the ready.

Scales were first used for aging fish in 1898. Studies in the early 1980s demonstrated that scale ages in some species can result in serious underestimates of age (Beamish and McFarlane 1987). The occurrence of daily growth rings in fish otoliths has been known only since Giorgo Pannela's 1971 publication in Science, "Fish Otoliths: Daily Growth Layers and Periodical Patterns" (Summerfelt 1987). Otolith aging has been used extensively throughout the 1990s and is still considered the most reliable method of aging carp. Vilizzi and Walker (1999) recommended using opercular bones and whole otoliths in routine age determination of carp. Vilizzi and Walker studied the age and growth of carp in Lakes Crescent and Sorell in 1997 and validated their otolith readings with Marginal Increment Analysis.

This report outlines and compares the methods used to age carp populations in lakes Crescent and Sorell.

2.0 Materials and Methods

All carp captured by the Carp Management Team since 1995 have been weighed, measured and gonad staged. A target sample of 20 pairs of otoliths a month are collected from each lake. Fork length is recorded using standard fish measuring boards and is taken from the tip of the closed mouth to inside apex of the caudal fin. Weights are measured using 6000g electronic scales for dead fish and 2kg and 5kg spring scales for fish released into the lake. Since 1998 a proportion of the male and juvenile carp population has been tagged with plastic anchor floy tags and released.

Tag numbers are recorded on recapture. Gonads are removed, weighed and staged according to the following stages:

1 = Immature, gonad tissue developing

2 = Gonad non-vascularised, eggs/milt visible

3 = Mature, vascularised but not running

4 = Running ripe

5 = Spent

2.1 Age estimation using otoliths (Central Aging Facility, Victoria)

Carp otolith (lapillus) samples have been collected from Lakes Crescent and Sorell since 1995. In 2001 over a thousand pairs of otoliths were sent to the Central Ageing Facility (CAF) in Victoria for age estimation. A total of 957 age estimates were determined from lapillus otoliths

2.1.1 Preparation of otoliths

Lapillus otoliths were embedded in rows of five in blocks of polyester resin and three or four sections approximately 0.3 mm thick were transversely cut through their centres with a modified gem-cutting saw. Sections were mounted on microscope slides under cover slips with further polyester resin. Sections were then viewed with transmitted light at 15.75 times magnification (1 x primary objective, 25 x magnification and 0.63 x secondary magnification). Each of the otolith sections were examined on the same magnification for ageing. All sections of each row of otoliths were inspected and the section closest to the primordium was used for subsequent ageing.

Lapilli were ground in a plane of maximum cross-sectional area. Otoliths were attached to a heated glass slide using Crystal Bond. Emery paper (1200 grit) was used to grind the lapilli until the otolith was at a stage where a daily age estimate could readily be determined. Increments were counted using a compound microscope at 400x magnification.

2.1.2 Counts and measurements

A customised image analysis system was used to view the sections, count marked increments, and measure their positions. A frame grabber in a personal computer captured an image from a video camera mounted on the dissecting microscope, and displayed it on the computer monitor. Using the screen cursor, a transect was drawn on the otolith image from the primordium to the edge of the section. The positions of increments along this transect, and of the otolith edge, were then marked with the cursor. The customised image analysis system then recorded the number of increments marked, and the distances from the primordium to each of the increments and to the edge of the otolith. These data were transferred automatically to an Excel spreadsheet linked to the image analysis system via dynamic data exchange.

All counts were initially made without knowledge of fish size, sex, location or date of capture, to avoid the potential for biasing age estimates.

Once age estimates were completed, the ageing data were combined with information on fish length and sex, location and date of capture, and otolith weight, for subsequent analyses.

2.1.3 Otolith weights

Otolith weight is a useful diagnostic tool in assessing potential errors in age estimates and for examining patterns of otolith growth. Otoliths tend to grow linearly in length and width with increasing fish size, and to grow linearly in thickness and weight with increasing fish age. In long-lived species, plots of otolith weight against estimated age will therefore show an increasing slope at older ages if the ages have been underestimated. Such underestimation has often occurred for species when whole otoliths have been used, when it was necessary to section otoliths to reveal all the annual increments. Also a large variation about the relationship may indicate of a lack of precision in the estimates.

All otoliths were weighed to the nearest 0.001 g on an electronic balance.

2.1.4 Data Analysis

Repeated readings of the same otoliths provide a measure of intra-reader variability. They do not validate the assigned ages but provide an indication of size of the error to be expected with a set of age estimates, due to variation in interpretation of an otolith. Beamish and Fournier (1981) have developed an **index of average percent error** (IAPE), which has become a common method for quantifying this variation. The IAPE is calculated as:

$$IAPE = \frac{100}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij}-X_j|}{X_j}\right]$$

where N is the number of fish aged, R is the number of times fish are aged, X_{ij} is the ith determination for the jth fish, and X_j is the average estimated age of the jth fish. The index has the property that differences in age estimates for younger fish will contribute more to the final value than will the same absolute error for older fish (Anderson *et al*. 1992).

To establish confidence intervals to these estimates of precision, a bootstrap technique was employed on the individual error estimates following methods described by Efron and Tibshirani (1993). Five hundred samples of error estimates (each the same size as the original) were randomly taken with replacement from the repeat readings, and a new IAPE calculated for each. The mean of these replicate IAPE's is the mean bootstrap IAPE and the standard deviation is the standard error of the mean. The bootstrap procedure exaggerates any bias present in the original estimate, so it is necessary to correct for this by adding the difference between the original statistic and the bootstrap mean, to the original estimate. The bias-corrected bootstrapped IAPE is thus calculated as

Bias-corrected IAPE = Original IAPE + (Original IAPE- Mean Bootstrap IAPE)

The 95% confidence interval was calculated as

95 % C.I. = Bias-corrected IAPE ± (1.96 Standard Error of Bootstrap IAPE)*

3.0 Results

3.0.1 Interpretation

Age estimates were determined by counting incremental structure along a transect from the primordium to edge on either the dorsal or ventral side. Figures 1-4 illustrate the position of increments found in otoliths for fish aged between 0+ and 3+ years respectively. A lot of incremental structure is visible in otolith sections which makes age estimation difficult, however, once the reader became more familiar with the morphological and incremental structure increments were relatively easy to count.

The presence of a spawning check in the otolith was not found. Whether the increments counted were deposited as a result of spawning activities or natural changes in environmental conditions is unknown. Increments counted may have been formed as a result of spawning. Because carp otoliths can be very interpretational with many growth checks present it is too difficult to attribute an increment or check to a particular event.

Interpretation of otoliths was based on those developed for carp captured in Victoria. Validation of annual increment periodicity has been completed on carp using oxytetracycline staining techniques (in press).

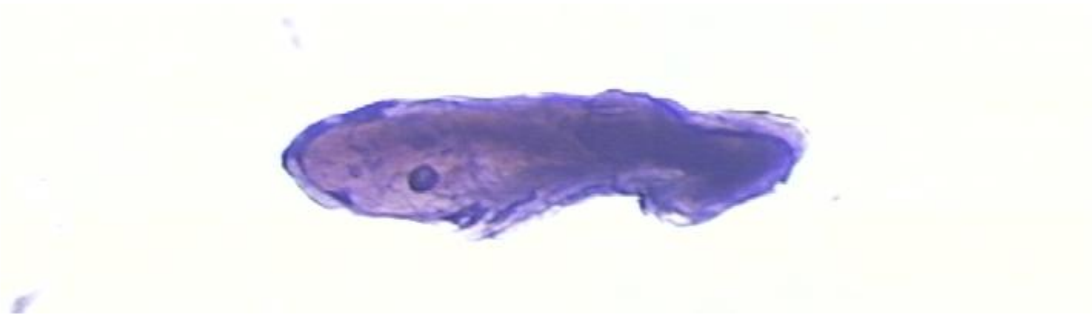

Figure 1: Transverse section of a carp lapillus (I). Arrows indicate position of increments. Estimated age 0 years.

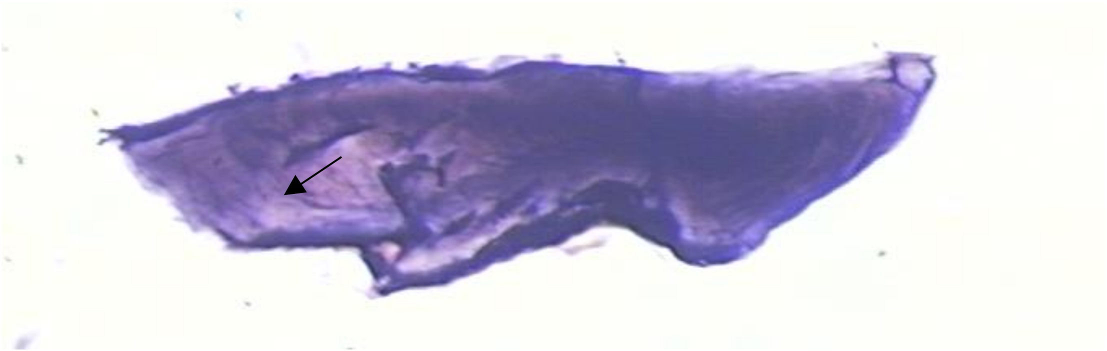

Figure 2: Transverse section of a carp lapillus (II). Arrows indicate position of increments. Estimated age 1 years.

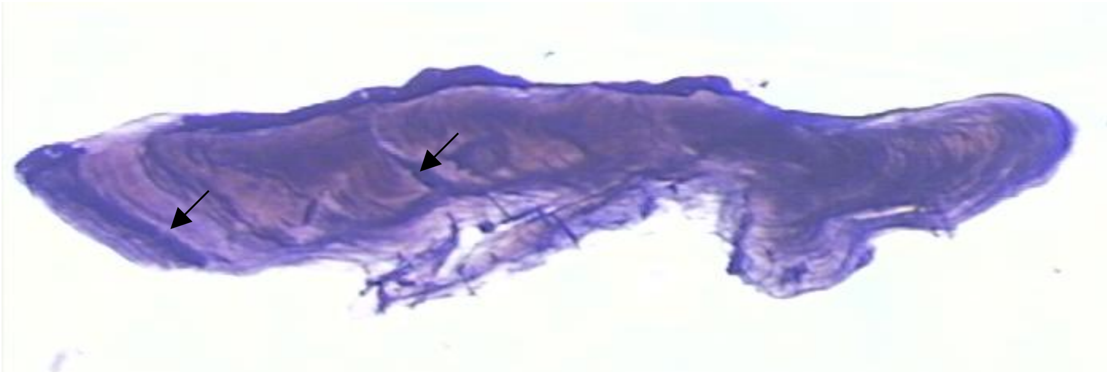

Figure 3: Transverse section of a carp lapillus (III). Arrows indicate position of increments. Estimated age 2 years.

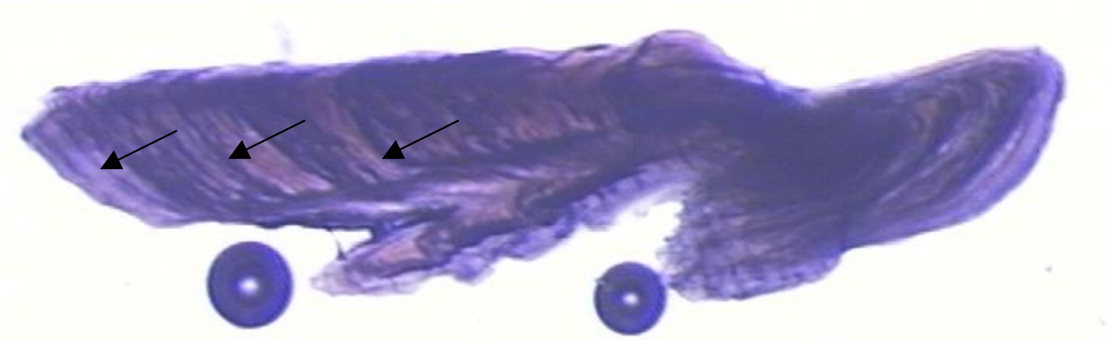

Figure 4: Transverse section of a carp lapillus (IV). Arrows indicate position of increments. Estimated age 3 years.

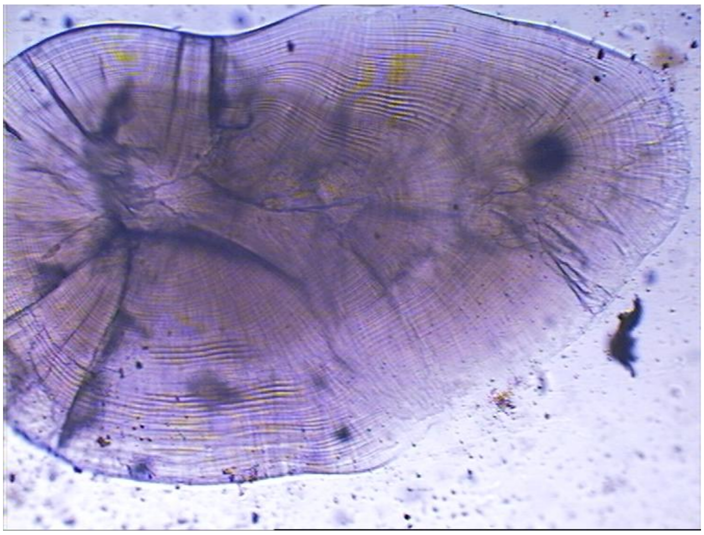

Figure 5: Ground sagitta used for daily age estimation.

3.0.2 Precision of age estimates

A total of 371 samples were re-aged. The IAPE for repeated readings was 4.82% which indicates the precision of the age estimates to be at an acceptable level. Experience with a range of species indicates that values should be less than 5% (Morison *et al*. 1998). The bias-corrected bootstrap IAPE was 4.83% with a 95% confidence interval of 3.9-5.7%. These figures are comparable to repeated readings from carp captured in Victoria.

3.0.3 Daily age estimation

Both sagitta and lapilli were used to estimate daily age of juvenile fish. Increments were relatively easy to recognise and were counted from the primordium to the edge along a transect of clearest incremental clarity. Back-calculating the age to determine hatch date revealed that carp hatched between October and November.

3.1 Comparison of otolith ages with observed ages

Inland Fisheries Service fyke net surveys detected new cohorts of juvenile carp in Lake Crescent in January 1997 and in Lake Sorell in January 2001. These cohorts have provided continuing observable growth and age information. Daily aging carried out by Central Aging Facility on the Sorell carp fry otoliths from January and February 2001 indicated that the fish were between 2 and 3 months old.

In December, 1998 75 adult and 291 juvenile carp were tagged and released during a Petersen mark-recapture study. Of these 366 tagged fish 72 were captured and retained in the initial Petersen recapture. The majority of the remainder were sporadically caught over the following 5 years providing useful growth data. From November 30, 1999 all sexually mature males were tagged and released to provide a growing pool of recapture information.

Juvenile carp tagged during the December 1998 Petersen study were spawned in 1996 (i.e. 2 years old). This can be deduced by comparing growth rates with the Sorell 2000 cohort which was daily aged. The first of the tagged Crescent juveniles reached 400 mm fork length in February 2000 (Figure 6) when over 3 years old and it took till September 2003 for any to reach 450 mm. Otolith aging yielded an age of 1 year for five 400 mm plus carp and 43.6% of 2 year otolith aged carp were over 400 mm (Figure 7)

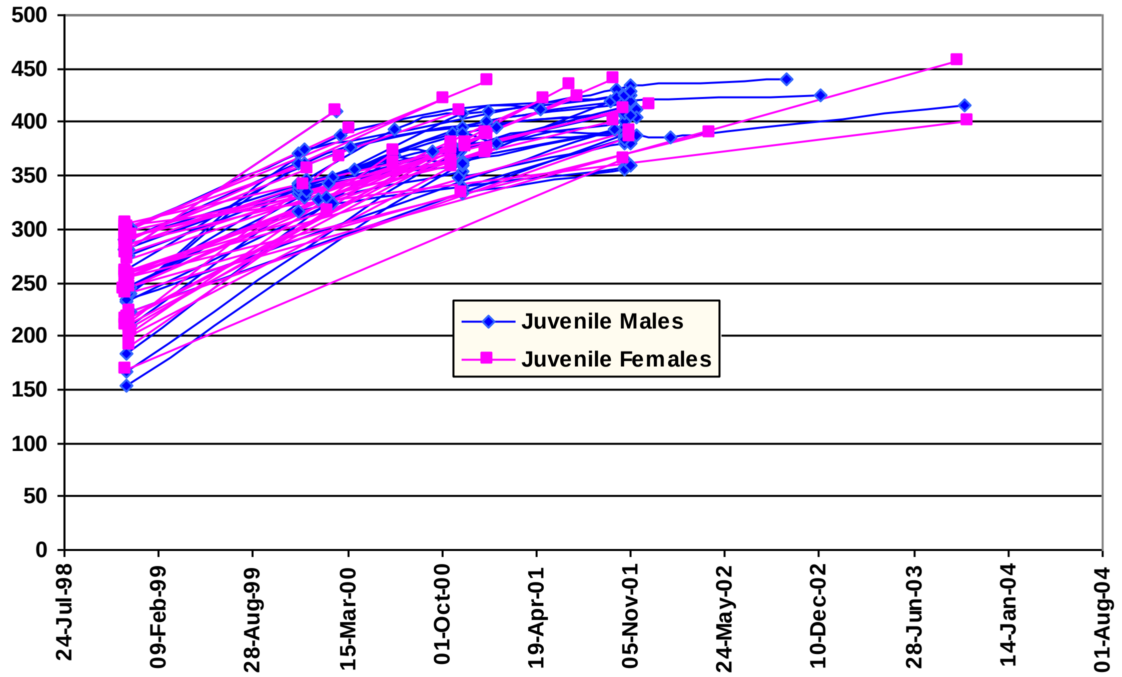

Figure 6 Fork lengths of released and recaptured tagged juvenile carp in Lake Crescent

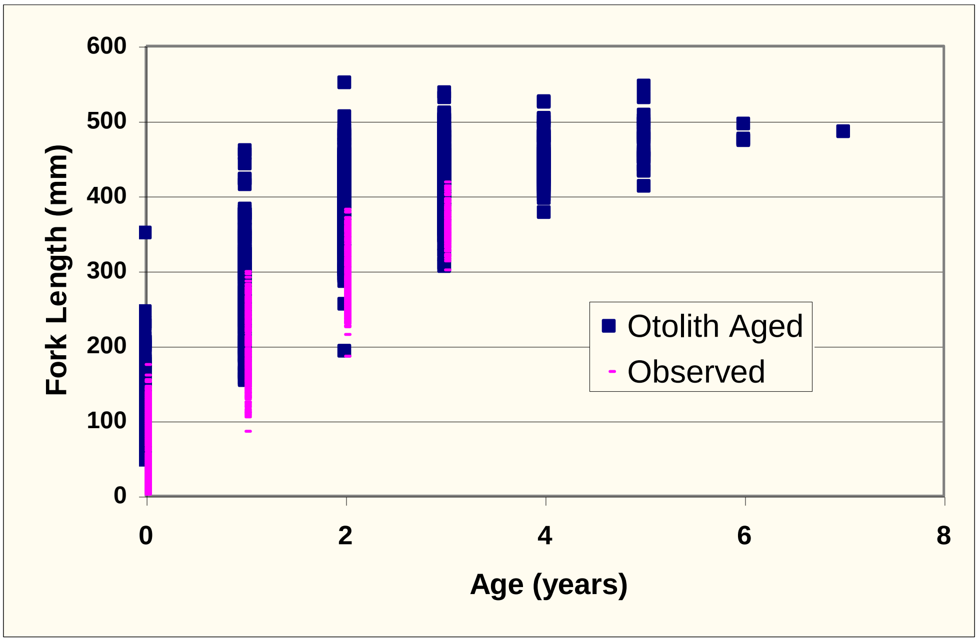

Figure 7 Comparison of lengths of otolith aged and observed age carp

If we assume that the 1998 adult tagged fish which were between 400 mm and 450 FL (Figure 8) were at least 3 years old then the youngest fish to reach 500 mm FL was 6 years old. Most of the adult marked fish had not reached 500 mm FL at 7 years. By contrast the otolith aged carp included two year 2 and three year 3 fish greater than 500 mm FL (Figure 7).

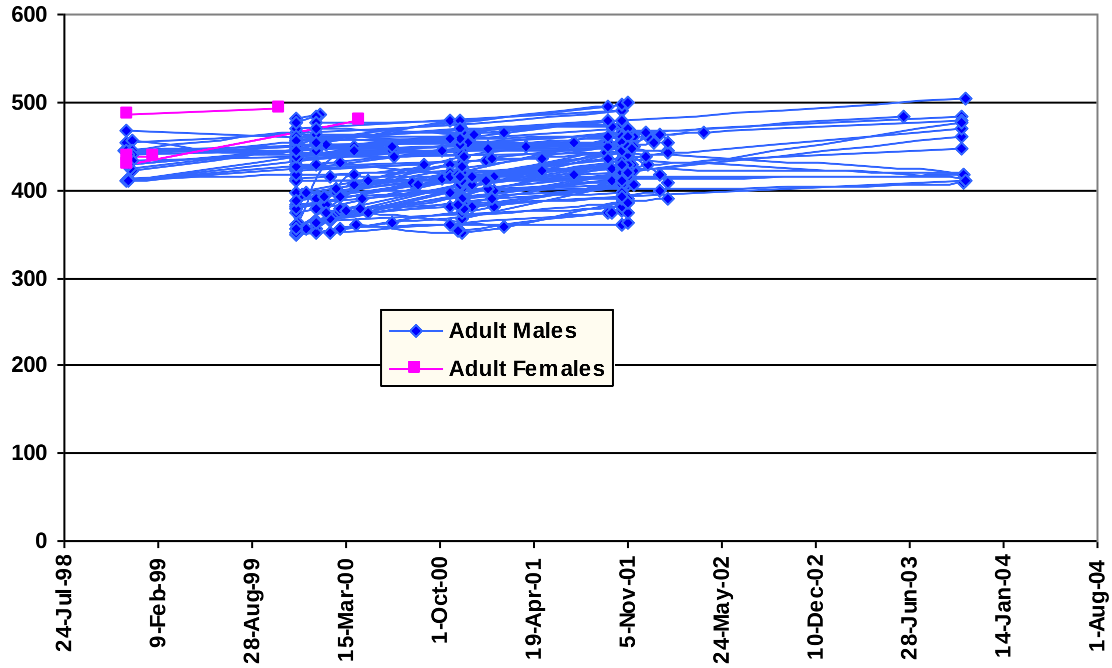

Figure 8 Fork lengths of released and recaptured tagged adult carp in Lake Crescent

For the Sorell 2000 cohort, observed growth rates support the accuracy of the daily aging by CAF of carp fry. Again, however, there are discrepancies between observed growth and yearly aging. A total of 643 year 0 carp were captured by April 2001. Fork lengths for these fish ranged from 59 to 174 mm. Otolith aging yielded 72 year 0 carp of which 19 were greater in length than the longest observed year 0 carp. The contrast between observed and otolith aged fish (Figure 7) increases to 56.4% of the 282 year 3 CAF aged carp being greater in fork length than the largest of the 244 year 3 Sorell fish captured by IFS.

3.2 Length-Frequency Growth Data

Over two thousand carp have been captured to date from a single cohort spawned in Lake Sorell in Spring 2000. The fact that this is a distinct cohort with a large sample size (which can be distinguished reliably from other cohorts) provides a unique study base. Monthly length-frequency graphs provide useful growth information for these fish. Daily growth checks evident on juvenile otoliths have placed the hatching date at between October and November. Initial growth is very rapid with juveniles reaching a median length of 125mm in their first summer (Figure 9).

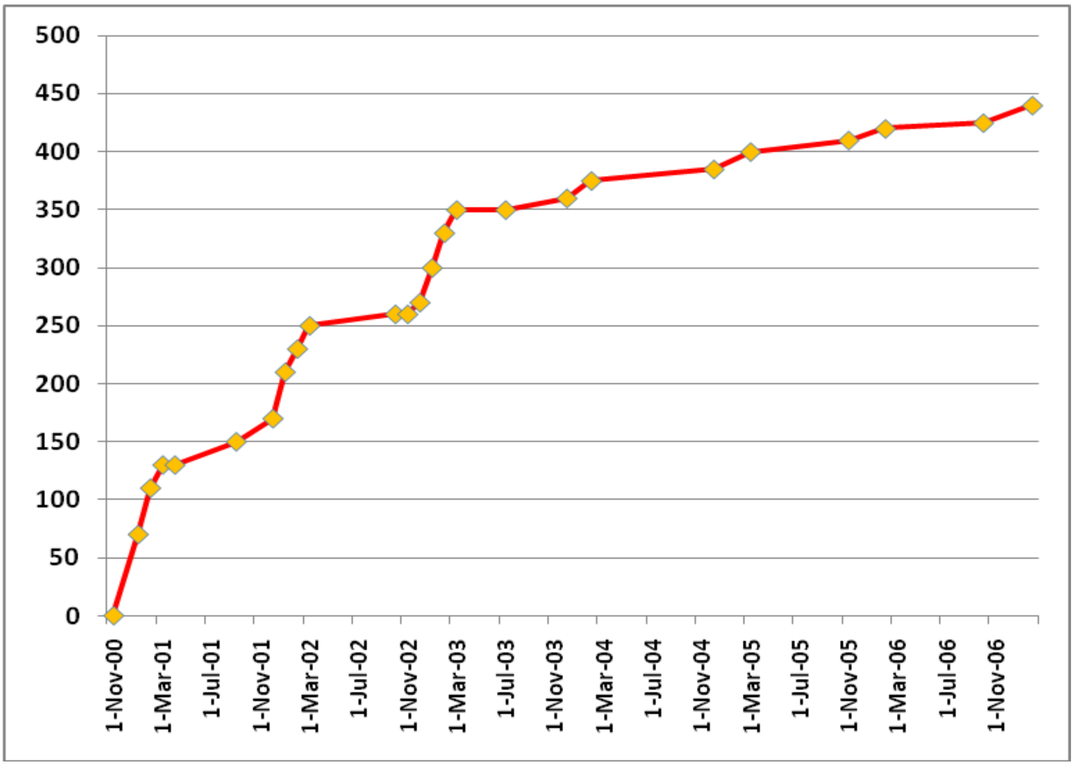

Figure 9: Median monthly fork length (mm) for Sorell 2000 cohort

Winter growth is minimal. The second and third summers of growth provide steady growth rates with median increases to 250mm and 351mm respectively. The fourth summer reveals a distinct slowdown in growth with median length only increasing to 375mm.

Lake Crescent length-frequency data for juvenile cohorts is harder to interpret because of the existence of two juvenile cohorts which become indistinguishable as they grow. Growth rates for both lakes, however, appear to be similar (Figure 10).

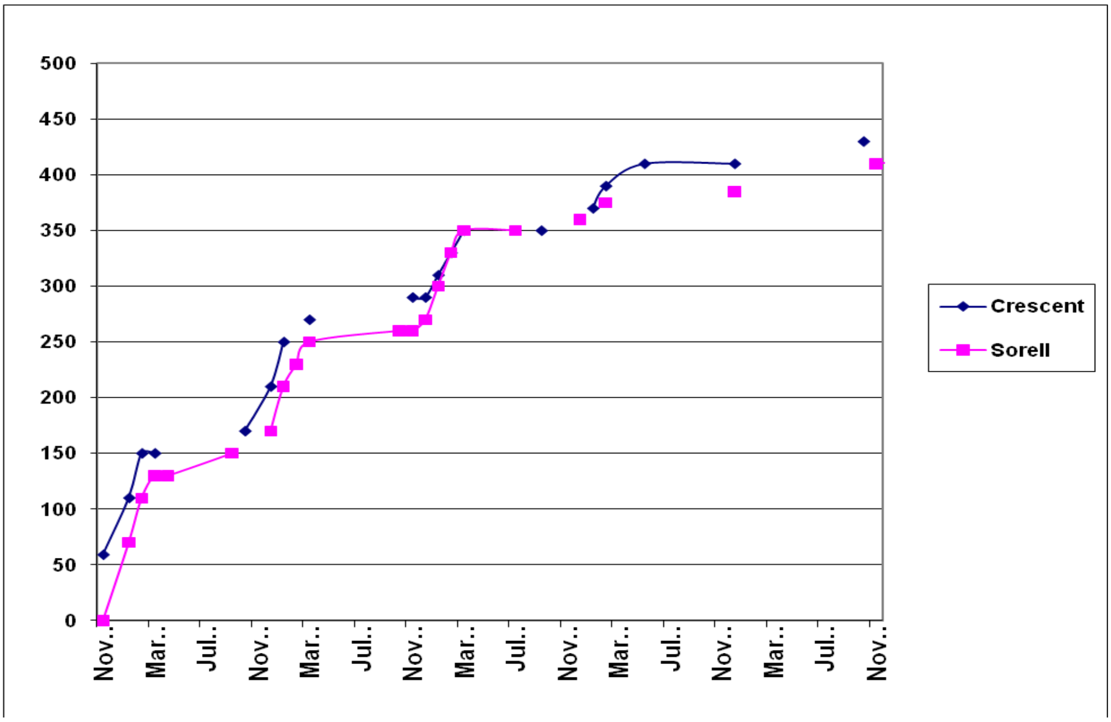

Figure 10: Monthly modal length-frequency for months with sample sizes > 30. Crescent cohort spawned late summer 1996. Sorell cohort spawned spring 2000.

3.3 Maturity

The first mature male from the Sorell 2000 cohort was caught in March 2003 making this carp two and a half years old. Of the males caught in November 2003, 35% were mature. This increased to 67% mature by the end of their third summer.

The first mature female was caught in January 2004, though the gonad weight was less than 10g. In February 2004 only 1 of 22 females caught was mature and this carried a 60g gonad. This indicates that most females need at least four years to mature. The Sorell maturity rates are mirrored in Lake Crescent with data (Table 1) revealing that the smallest mature female in the summer of 1996-97 was approximately 360mm long corresponding to an age of about three and a half years (Figure 10). The majority of Crescent females matured between fork lengths of 410 to 420mm (Table 1) which corresponds to a median age of five years (Figure 10)

The last immature female of the spring 1996 cohort was caught in September 2003 making it nearly seven years old.

	Summer 1996-97		Autumn 1996-97		Spring 1996-97		Summer 1997-98	
Lngth(mm)	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
330	0	0	0	0	0	0	0	0
340	0	0	0	0	0	0	1	0
350	0	0	0	0	0	0	0	0
360	0	1	0	1	1	0	0	0
370	4	1	1	0	0	0	0	1
380	3	0	3	3	0	0	1	4
390	3	2	2	0	1	1	2	3
400	5	5	3	3	0	2	7	7
410	6	7	4	7	3	2	5	21
420	2	7	1	7	5	1	9	43
430	2	1	0	10	2	5	4	48
440	0	5	1	9	0	3	3	34
450	0	0	1	5	0	1	2	33
460	1	2	0	2	2	0	0	21
470	0	1	1	0	0	1	1	11
480	0	0	0	1	0	0	0	3
490	0	0	0	1	0	1	0	5
500	0	0	0	0	0	0	0	3
510	0	0	0	1	0	0	0	2
520	0	0	0	0	0	0	0	1
530	0	0	0	0	0	0	0	1
540	0	0	0	0	0	0	0	0

Table 1: Maturity rates of Lake Crescent female carp. Highlighted numbers indicate modal values

4.0 Conclusion

Otolith aging, using the methods described in this report, has proved unreliable for the Tasmanian carp populations examined. Inconsistencies between otolith aging and observed growth are evident. It appears that several growth rings have been missed in many cases. The reasons for the discrepancies need to be established and it is recommended that a future study be implemented to examine the situation more closely with the aim of calculating a correction factor to enhance the utility of carp otolith aging in the Tasmanian context.

Glossary

Increment – The interval between like zones on a structure used for age-determination. The interval has an alternating bipartite composition and indicates a unit passage of time.

Primordium – A self-contained zone that represents the point of the initial growth of an otolith. Optically, it is a phase of growth within the core which is more opaque than the surrounding area of the core.

Otoliths – Calcareous growths in the ear apparatus of teleost fishes; there are three pairs in each ear canal called lapilli, sagittae and asterisci.

Maturity – The point at which the gonads are fully developed and capable of reproduction. In this study macroscopic criteria are used to determine maturity. The gonad becomes fully vascularised and the eggs become translucent, large and round.

Spawning Check – An abrupt discontinuity in a zone or band of the otolith caused by an interruption to fish growth due to spawning behaviour.

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