Estimation of Growth of the Golden Perch *Macquaria ambigua* based on a tagging program between 1959 and 1970

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ABSTRACT

A tagging/recapture program was carried out on large freshwater fish species in the Murrumbidgee and Murray Rivers to examine their growth. Internal body tags were found to be more reliable than opercular tags. Adequate recapture data for further analysis was only obtained for Golden Perch *Macquaria ambigua*. Monthly frequency of recapture appeared to follow angling pressure. The length/weight relationship curves of recaptured fish at tagging and recapture are similar ($y=1.49E\text{-}06x^{3.393}$ and $y= 7.32E\text{-}06x^{3.1374}$ respectively), supporting the use of the data for growth analysis. Von Bertalanffy growth curves $[\mathbf{L_t}=\mathbf{L_\infty}(1\text{-}e^{-k(t-t_o)})]$ were constructed, where $\mathbf{L_t}$ =length at time **t**; and for all fish recovered $\mathbf{L_\infty}$ (asymptotic length) = 550.6 mm, **k** (growth parameter) =0.2458 and $\mathbf{t_o}$ (hypothetical age in years at zero length) = 0.1333. The parameters determined for Murrumbidgee females indicated a more rapid growth than males. Murray River fish grew more rapidly than Murrumbidgee fish. Values of $\mathbf{L_\infty}$ and **k** based on the method of Gulland, and Garrod, were 575mm and 0.3985 respectively for all fish.

It is concluded that differences in the two river systems, for example in water temperature, flooding, breeding, fish stocking and angler pressure account for different growth rates.

Key words: Growth curve, von Bertalanffy growth curve. *Macquaria ambigua* growth curves.

Introduction

The estimation of growth rate in warm water fishes in rivers in inland New South Wales has proved difficult, because the environment does not always induce regular deposition of indicators of age on bony structures as found in temperate fish species (Llewellyn 1966; Garrod 1963). Breeding, as well as winter checks, often create ring formation in bony structures, but in many cases breeding is not regular because it depends on floods. Tagging fish can provide valuable information on the time intervals between ring formations if sufficient numbers are available on recapture.

Growth in fish, although a very complex process, is usually measured by the increase in length or weight with time, and growth in conjunction with age is important to the effective management of fish populations. It is important to know the age and length when fish first breed and when they are first caught, particularly if there is a size limit on angled fish, as this may influence recruitment. These factors also help in assessing the ability of a population to recover after a slump, to assess environmental stress in a population, and to determine the population structure and size.

Records show approximately 200 Murray Cod *Maccullochella peelii peelii* had been tagged successfully in 1940 at Loch 15 fish ladder at Euston by the Victorian authorities which demonstrated that tagging was feasible but no recovery information has been published. To try and determine the pattern of laying down growth rings in bony structures in warm water fish, efforts with an ongoing tagging program were increased by New South Wales Fisheries in 1964, using Internal Body Tags (IB tags). Recovery rate was considered to be low, because the IB tags that were used were not visible externally, and were therefore not readily found by the angler.

An assessment of tagging methods was carried out between 1964 and 1965 using captive fish at the Narrandera Fisheries Centre, NSW, to determine if external body tags could be used to improve the rate of return and quality of data supplied on recapture. External opercular tags had the clear advantage that they were more visible to the angler but had a greater chance of loss. External tags available at that time were not always successful, as often they caused a sore at the point of entry and, in many cases, eroded the surrounding tissues and some fell out. As a result, in 1964, it was decided to continue with the use of IB tags, but from 1966 onwards, most fish were double tagged with monel opercular tags and IB tags to see which of these methods provided a better return from wild releases. More recently evaluation of coded wire tags and visual implant tags for marking smaller fish have proved successful (Crook and White 1995; Ingram 1993) but return via anglers using these methods requiring the identification of individual fish is in most cases not practical. For example, binary-coded wire tags require special equipment for reading and detection (Anderson 1988), as is the case for most modern tagging methods. These devices are not readily available to the angler; therefore tags with addresses that are easily visible such as the IB tag and monel opercular tag were used in this study (Appendix 1 photo 2).

The results of a joint tagging program undertaken mainly by the Victorian Fisheries Wildlife Department between 1959 and 1964 and New South Wales State Fisheries between 1966 and 1970 are presented here. All species caught were tagged during 1966 to 1970 to maximize the use of trapped fish with the intention of examining growth of all species in which adequate numbers were trapped and eventually recovered. A total of 3368 fish of six different species were tagged and released in the Murray and Murrumbidgee Rivers during this program. Sufficient tag recoveries for estimation of von Bertalanffy growth curves, using tag and recovery data, were only obtained for Golden Perch *Macquaria ambigua* (Photo 1). These data are provided here and compared with conspecific growth curves from tag and recapture data from South Australia (Reynolds 1976) and Lake Keepit, NSW (Battaglene 1991).

Aging of *M. ambigua* has been refined more recently by Anderson *et al*. (1992) using thin sectioned otoliths. Analysis of the progression of modes in length-frequency distributions, qualitative and quantitative marginal increment analysis, and age estimates of fish with a known stocking history were used to validate results.

Macquaria ambigua is widely distributed in the Murray Darling System. It breeds in response to floods at temperatures above 23°C, when females are about 4year old (above 400mm) and males 2-3 year old (above 190mm). They produce ½ million pelagic eggs at 2.5kg in weight which hatch in up to 33hr, and five days later the larvae start to swim and feed. Reynolds (1983) inferred that these pelagic eggs and larvae would travel around 500 km downstream before being able to maintain themselves against the flow. This movement is compensated by an upstream movement of juvenile and adult fish to the upper reaches of the rivers. It is these extensive upstream movements, particularly during floods (Llewellyn 1968), leading them into backwaters, billabongs, off stream lakes and the influence of various major rivers, which play an important role in the growth rates of this species. Recruitment to the population is dependent on floods and an increase in food supply which stimulate breeding (Lake 1967).

Methods

All *M. ambigua* were caught using drum or fyke nets (Appendix 1 photo 3b), with a diagonal mesh ≥11.0 cm, during spring-river floods when catches were highest (Llewellyn 1968). Only fish >30 cm in length or > 500 g in weight were captured. An IB tag (Llewellyn 1968), a plastic tag possessing a number, instructions and address details for forwarding information, was inserted into the abdominal cavity through a ventro-lateral incision angled anteriorly, about 2.5 cm anterior to the vent (Appendix 1 photo 3a) (Llewellyn, 1968). From 1968 to 1970, opercular tags also, with address details, were clipped to the upper area of the operculum of the fish using a pliers-like applicator (Llewellyn 1968). The tag numbers, species of fish, weight, total length, sex where possible, locality, and date of tagging were recorded for all fish tagged and released. The success of the double tagging was assessed by comparison of the numbers of each tag recovered. Monthly tag recovery rates were also determined.

Length/weight relationships were determined for recaptured *M. ambigua*, using data taken at the time of tagging and at the time of recovery, using the equation.

$$\mathbf{W = aL^b} \ (Y = aX^b)$$

where, W = weight, L= Length, “a” is a constant and “b” is an exponent generally lying somewhere between 2.5 and 4 (b = 3 for isometric growth). This was determined to enable comparisons to be made between the data collected at time of tagging and the time of recapture, since it was anticipated that recapture data would vary in reliability, because it would depend on the methods used by anglers to determine the measurements and the accuracy of the data provided.

The von Bertalanffy growth curves for recovered *Macquaria ambigua* were determined separately for all fish, male, female, and fish of unknown sex from the Murrumbidgee River; and for all fish that had been tagged and recaptured (spent most of their time free) in the Murrumbidgee River and the Murray River using the Fabens (1965) Program (Gallucci *et al.* 1996). All fish tagged in the Murray River were of unknown sex. The von Bertalanffy growth function is of the form:-

$$L_t = L_\infty (1 - e^{-k(t-t_o)})$$

where $\mathbf{Lt}$ = length of individual at time $\mathbf{t}$, $\mathbf{L_\infty}$ = asymptotic length of individual at t_∞, $\mathbf{k}$ = Brody coefficient growth parameter and $\mathbf{t_o}$ = hypothetical age at zero length. The Fabens (1965) program has three parts. Firstly it calculates $\mathbf{k}$ and $\mathbf{L_\infty}$ from the two lengths (length at tagging and length at recapture) and the time interval between measurements, by an iterated least squares method. It uses up to twenty iterations with the final values for $\mathbf{k}$ and $\mathbf{L_\infty}$ truncated at five significant figures. The second part uses size at age data and the values of $\mathbf{k}$ and $\mathbf{L_\infty}$ from above to determine $\mathbf{t_o}$, using a least squares estimate if two or more records of known age fish are used as in this study. Preferably these records should be from small fish. The final part of the program selects a finite number of ages spread over the growth curve and calculates the length at each of these ages for plotting the growth.

An estimate of the growth of tagged fish was also determined using the method of Gulland (1973) and Garrod (1963) by plotting the increment per unit time ($\mathbf{L_2}$-$\mathbf{L_1}$/ $\mathbf{a}$) (length increment in mm divided by time free $\mathbf{a}$ in years), against the length at the mid point of the increment ($\mathbf{(L_1+L_2)/2}$), ($\mathbf{L_1}$ length at tagging, $\mathbf{L_2}$ length at recapture). Results from this plot are expected to be variable because the time intervals free are generally small.

Results

Summary of fish tagged and recovered

A total of 3368 fish were tagged in the Murray and Murrumbidgee Rivers, 1021 by Victoria and the rest by New South Wales. 2059 *Macquaria ambigua*, 1241 *Bidyanus bidyanus* Silver Perch , 83 *Maccullochella peelii peelii* Murray Cod, 13 *Tinca tinca* Tench, 12 *Tandaus tandanus* Freshwater Catfish, and 6 *Perca fluviatilis* English Perch were tagged and released. Up to October 1979, 183 *Macquaria ambigua*, 18 *B. bidyanus* and 17 *Maccullochella peelii peelii* were recaptured, but none of the other species. The percentage recovery at that time was 8.9%, 1.5% and 20.5% for *Macquaria ambigua*, *B. bidyanus* and *Maccullochella peelii peelii* respectively.

Time frequency of recaptures

The monthly frequency of recapture was calculated from 182 of the 183 *Macquaria ambigua* recaptured (Fig. 1). This monthly frequency for recapture follows expected angling frequency, increasing during spring when water temperatures are rising (September to November), but angling pressure is also high in August, December and January which were vacation periods at that time.

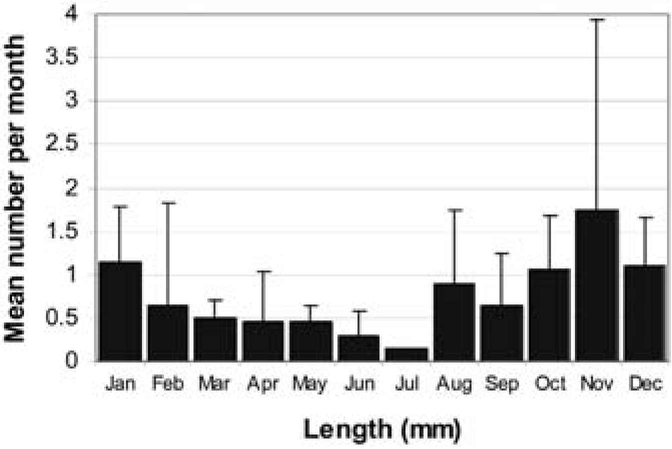

Figure 1. Mean monthly recapture frequency of Golden Perch with standard error bars from 1960 to 1979 (20 years).The large error bar in November was due to 10 fish being recaptured on one day of drum netting (n= 182).

Double tagged fish

In the case of double tagged fish, the IB tag was recovered in almost every case, and the external, opercular tag was less often recovered (Table 1). Of 1263 fish double tagged, 68 IB tags and 31 opercular tags were returned of which 40 were returned with only the IB tag found and only 3 with the opercular tag only, suggesting that opercular tags were more likely to be lost. Some fish were recovered with "U" shaped notches in the operculum, and some were seen with the tag hanging off the operculum, very loose, but still just attached, suggesting that opercular tags were lost as a result of erosion of the operculum.

Length /weight relationship

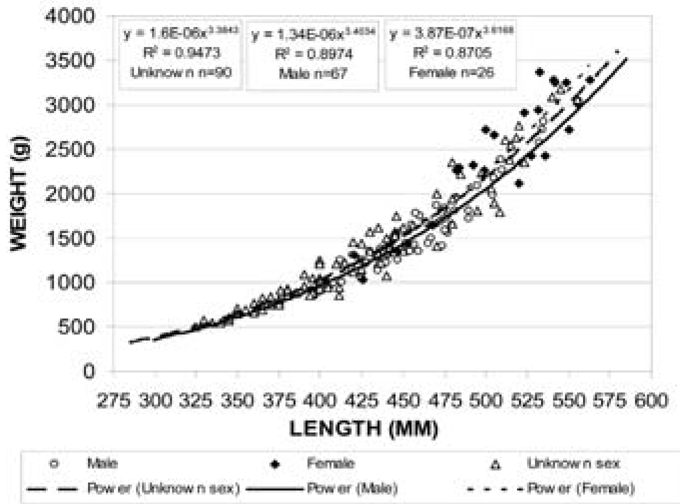

Figure 2. Length weight relationship of Golden Perch at tagging for male, female and unknown sex fish, for all fish that were recovered. Results are in scientific or exponential notation; hence 2E-06 =2 $\times 10^{-6}$

The relationship between length and weight was calculated from the 183 fish that were eventually recaptured, from data collected at the time of tagging (Fig. 2). Only 78 of these fish had adequate recapture data for length/weight assessment (Fig, 3). In many recaptured fish, measurements provided by the public were unreliable and/or omitted. The limited range of sizes of tagged and recovered fish restricts the range over which the length/weight relationship can be accurately assessed. The relationships at tagging (Fig. 2), in which length and weight were carefully recorded, shows a close pattern for females, males and unknown sex; but females over 1500 g showed an increase in weight at any length caused by the onset of gonad maturation in some females, also shown to a lesser extent in fish of unknown sex since a proportion of these would also have been females. The length/weight relationships for recaptured male, female and unknown sex fish (Fig. 3) (data from angler returns) were widely spaced indicating a much greater difference of weight at any length between the sexes, based on smaller sample size and less reliability in the recapture measurements. Inaccuracies in weight were far more likely than in length, because if the fish were not weighed before

Table 1. Fish double tagged with Internal Body Tags and opercular tags.

	Numbers double tagged	Recovered with IB tag only		Recovered with opercular tag only		Recovered with both tags		Total of tagged fish recovered
		Number	Percentage	Number	Percentage	Number	Percentage	
Golden Perch	481	31	6.4	2	0.4	18	3.7	51
Silver Perch	696	3	0.4	1	0.1	3	0.4	7
Murray Cod	68	6	8.8	-	-	7	10.3	13
English Perch	2	-	-	-	-	-	-	-
Freshwater Catfish	3	-	-	-	-	-	-	-
Tench	13	-	-	-	-	-	-	-
Totals	**1263**	**40**	**3.2**	**3**	**0.2**	**28**	**2.2**	**71**

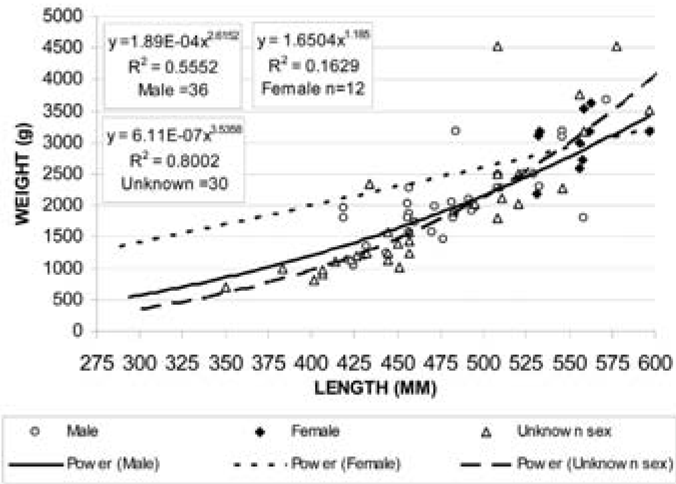

Figure 3. For comparison with Figure 2. Length weight relationship of Golden Perch at recapture for male, female and unknown sex fish, for those recoveries which had adequate length and weight data.

cleaning, weight may have been estimated after the tag was found when cleaning had commenced. The low r^2 value and value of "b" in the length weight relationship for females (Fig.3) could be attributed to the small number of females recaptured. However, comparisons between the curves of length /weight of all fish together at tagging and recapture (Fig. 4) show that the similarity warrants the use of the recovery data for growth curve determination.

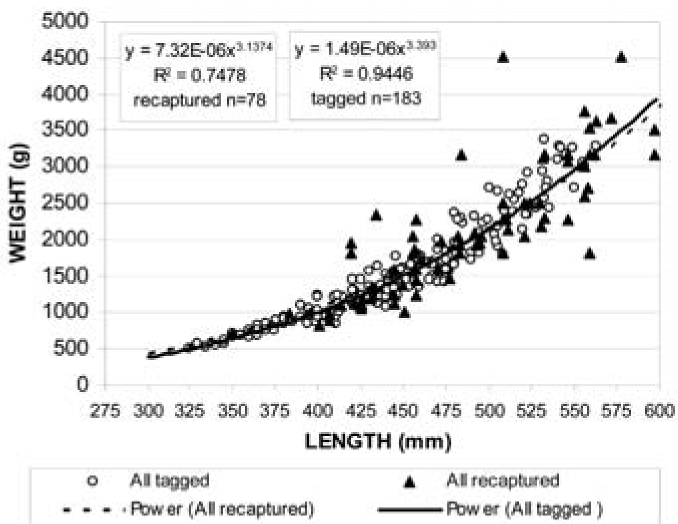

Figure 4. Length weight relationships of recovered Golden Perch at tagging and at recapture (all sexes grouped). Equations are in scientific or exponential notation; hence 2E-06 =2 $\times 10^{-6}$.

Von Bertalanffy's Growth curve (Fabens 1965)

One hundred and thirty six of the 183 (ie. 74.3%) of the *Macquaria ambigua* recaptured could be used to determine the von Bertalanffy growth curve (Fabens 1965) (Table 2). $\mathbf{L}_\infty$ calculated for all recaptured *M. ambigua* was 550.6 mm (Table 2, Fig. 5), reaching over 500 mm length at about 10 years of age. Female *M. ambigua* from the Murrumbidgee River attained a greater $\mathbf{L}_\infty$ (599.0 mm) than males (533.7 mm)

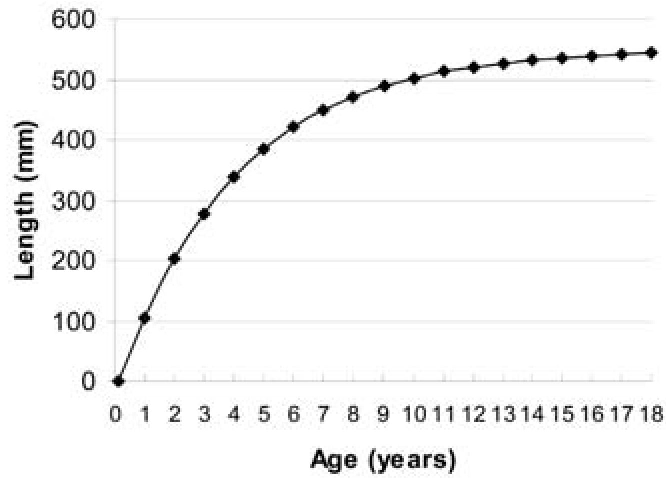

Figure 5. Von Bertalanffy's growth curve (Fabens) for all recaptured *M. ambigua* from Murrumbidgee and Murray Rivers combined (see Table 2 for data).

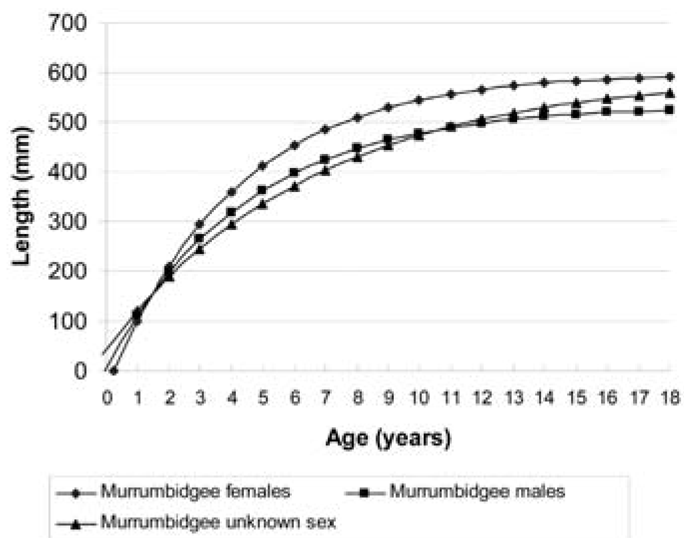

Figure 6. Von Bertalanffy's growth curve (Fabens) for male, female and unknown sex Murrumbidgee River *M. ambigua* (see Table 2 for data).

Table 2. Von Bertalanffy parameters for Figures 5-7. Standard errors for each parameter are provided in brackets; where "n" in sample is ≥ 20.

Number of. Fish	n	k	L_∞	t_o	Correlation coefficient r^2
Murrumbidgee females	20	0.245 (0.128)	599.0 (33.1)	0.249 (2.579)	0.0098
Murrumbidgee males	44	0.225 (0.073)	533.7 (15.2)	-0.042 (0.362)	0.1310
Murrumbidgee unknown sex	17	0.149 -	597.6 -	-0.518 -	0.0012
All Murrumbidgee fish	81	0.172 (0.044)	570.6 (18.4)	-0.350 (0.599)	0.0778
All Murray fish	49	0.487 (0.182)	532.3 (28.8)	0.733 (0.292)	0.0708
Total fish	**136**	**0.246 (0.055)**	**550.6 (13.7)**	**0.133 (0.085)**	**0.2107**

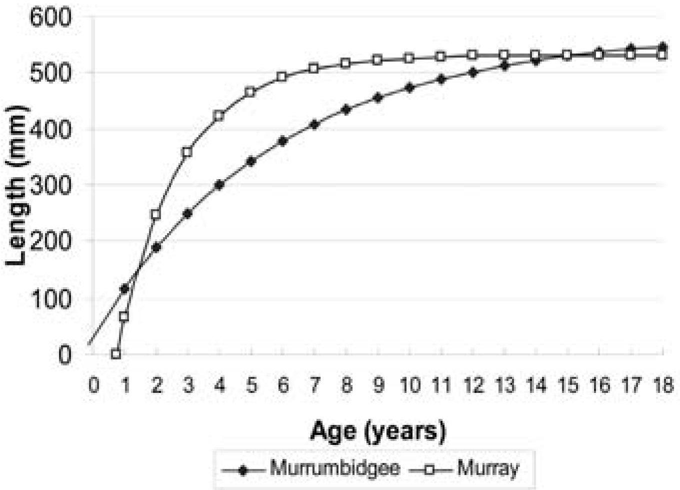

Figure 7. Comparison of the Von Bertalanffy's growth curve (Fabens) for recaptured *M. ambigua* from the Murrumbidgee River and the Murray River (see Table 2 for data).

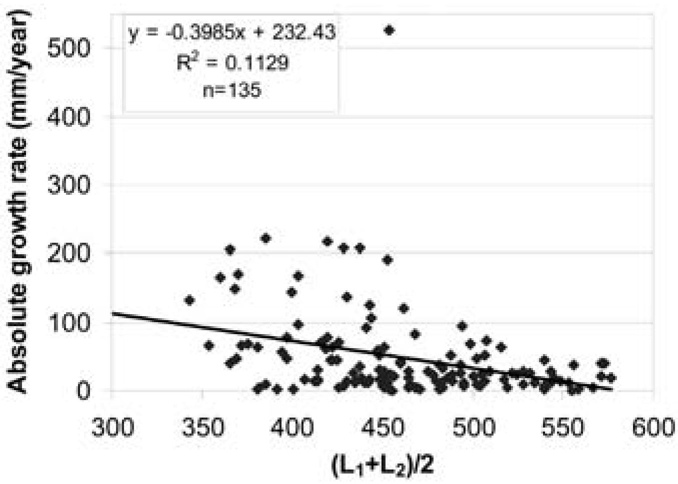

Figure 8. Growth in length of *Macquaria ambigua* as determined by the recapture of all fish (Garrod 1963). L_1 length at tagging and L_2 length at recapture. (n=135).

and the slope of the curve indicated that their growth rate was slightly faster even though their $\mathbf{t_o}$ value was positive (Fig. 6). For all Murrumbidgee River fish and all Murray River fish plotted separately, $\mathbf{L_\infty}$ was 570.6 and 532.3 respectively (Table 2, Fig. 7). Comparisons between fish from the Murrumbidgee and Murray Rivers showed that growth was much quicker in fish in the Murray River, but that these differences decreased as asymptotic length was approached (Fig. 7). Fish from the Murray River were all of unknown sex.

The Brody coefficient growth factor **k**, a measure of the intrinsic growth rate for *M. ambigua* was 0.246 for all recaptured fish (Table 2). Females (0.245) from the Murrumbidgee River showed a slightly higher rate than males (0.225). There was a large difference in **k** values between all fish from the Murrumbidgee and Murray Rivers (0.172 and 0.487 respectively).

Tagging of fish less than 20 cm in length was not possible at that time, and thus data are lacking on growth of small *M. ambigua* in the wild. Thus accurate determination of the time when length would theoretically be zero ($\mathbf{t_o}$) is limited. However $\mathbf{t_o}$ was determined using two samples of known age *M. ambigua* grown in ponds at the Narrandera Fisheries Centre, the only data of known age fish available to the author at that time. These mean lengths and weights are as follows:-

Length = 111.3 mm ± SE 2.846. Weight = 19.2 g ± SE 1.135. 14 months old. n = 20.

Length = 194.9 mm ± SE 4.539. Weight = 106.8 g ± SE 6.470. 21 months old. n =72.

Growth estimate by method of Gulland (1973) and Garrod (1963)

The growth in length as determined by the method of Gulland (1973) and Garrod (1963) using 136 of the recaptured fish is shown in Figure 8. The slope of this regression line gives a value for **k** of 0.399 and the point where the line transects the x axis gives a value for $\mathbf{L_\infty}$ of 575 mm. The coefficient of determination of 0.1129 is low indicating the variability of the data which is to be expected when most of the time intervals are small. Two data points, one off the graph, probably result from errors in recapture data.

Discussion

Results from the double tagging experiment (Table 1), indicated that the most reliable tags were the IB tags, which supported continuation of use of these tags. The small number of opercular tags being returned suggested that many of the opercular tags were falling off the fish. Results indicated that few IB tags were being missed even though they were not obvious, having been inserted into the abdominal cavity. Another tagging program in South Australia had been using external International Orange Floy 67C Anchor tags with considerable success, reducing or eliminating ulceration around the tag site and subsequent tag loss (Reynolds 1983). This tagging program, in operation in the Murray River, South Australia between 1974 and 1976 (Reynolds 1976), reported that 162 (14.6 %) of the 1125 *M. ambigua* tagged were recaptured, but only 37 were suitable for growth analysis because many were not measured (tag only returned), or were inaccurately measured. It is likely that the labeling on the tags contributed to this lack of information. The tags were marked "SA Fish and a number" only. On the IB tags in this study, the following was printed (*Fish No*. "Give date place length, reward 50c" on reverse side "N.S.W. Vic. Fish Dpts, Box 30 GPO Sydney"). The Von Bertalanffy Growth Curve for Murray River fish from the Reynolds (1976) study gave a **k** value (intrinsic growth rate) of 0.53 compared with 0.49 in this study. Jones (1974) obtained a lower **k** value of 0.33 for fish from the lower Murray using otoliths to age fish.

Between 1981 and 1985 a study was carried out on the impounded population of *M. ambigua* in Lake Keepit (Battaglene 1991). He recaptured 206 (9.2%) of the 2238 fish tagged. He obtained **k** values for males 0.40 and for females 0.29. The recovery rate of 8.9% in this study was comparable with the 9.2% in the Lake Keepit study but both were less than the 14.2% in the South Australian study (Reynolds 1976). **k** values in the Lake Keepit female fish (0.29) were similar to Murrumbidgee River females (0.24), but males were much higher (0.4) than in this study (0.22).

Anderson *et al* (1992) estimated the von Bertalanffy growth parameters for *M. ambigua* from the Murray Darling Basin using otoliths for aging. He estimated $\mathbf{L}_\infty$ 507mm, $\mathbf{t}_o$ 0.420 years and **K** 0.454, whereas for all fish in this study the $\mathbf{L}_\infty$ was slightly higher (550.6 mm) and $\mathbf{T}_o$ and **K** values were lower (0.133 years and 0.246 respectively). These differences could be due to the location from which the majority of the sample was taken.

The Gulland (1973) and Garrod (1963) method of estimating growth parameters produced a **k** value of 0.399, above that of the von Bertalanffy (Fabens 1965) method (0.25), and the values for L_∞ were 575 and 550 mm respectively. This method provided a plot of each record and identified two records one off the graph that were well outside the range of the other data.

Growth curves determined from back calculating length at known times from regularly marked checks on bony structures is not always reliable for *M. ambigua* from the inland river systems. Checks can occur at irregular intervals, particularly when adult fish spawn, which occurs during floods, and probably during droughts especially during winter. Both floods and droughts occur at irregular intervals. Mobility of fish can further complicate this picture. Fish are known to travel up to 800 km along a river course, and can move readily from the influence of the flood pattern of one river system into that of another system in a relatively short period (one season). Furthermore, during high floods, fish are often trapped in billabongs and lakes as flood waters recede and may remain many years in these billabongs or lakes before a similar flood releases them back into the river. During periods in a billabong or lake they grow more rapidly than river fish and are unlikely to breed because of the lack of a flooding stimulus within each billabong or lake. Consequently, it is often difficult to relate any checks found on bony structures of *M. ambigua* to a regular seasonal pattern. However recent developments using thin sectioned otoliths have in part overcome some of these problems (Anderson *et al.* 1992).

In this study, the known age pond fish used for the estimate of $\mathbf{t}_o$ were 111.3 mm at 14 months and 194.9 mm at 21 months, this compared with estimates from river fish of 102 mm at 12 months and 165 mm at 24 months (Roughley 1961; from J. O. Langtry's work). Older river fish were smaller than pond fish.

Environmental factors are likely to have a large influence on growth rate and adult size. Le Cren (1958) mentioned that rare individual fish much larger than the average were a phenomenon, frequent in perch populations (referring to *Perca fluviatilis*). The maximum weight on record for *M. ambigua* is 23.6 kg (cleaned weight, Roughley 1961), well in excess of 4.44 kg the estimated weight of L_∞ (599.0 mm) for female *M. ambigua* in this study. This large fish was captured in a lake isolated from the river. In ponds at the Narrandera Fisheries Centre where *M. ambigua* were artificially spawned, after eighteen months at least one of the progeny would be many times the size of the remaining progeny, and had probably attained that size by cannibalism. Fish growth in ponds mentioned above also seemed to be greater than river fish in the second year of growth. Very large *M. ambigua* are seldom caught in the river system, but are frequently found in lakes (pers. obs.). Thus it appears that lake fish may have a different growth curve from river fish, and that differences may occur between lakes, also, depending on their degree of isolation, the watershed, population mixing, and the available food supply. In some lakes too, there is often a lack of suitable flooding for stimulation of regular spawning, a requirement for breeding (Lake 1967)), and the lack of an associated change in food supply apparently needed for breeding (Collins and Anderson 1999). This would result in additional energy usually required for gonad development, being channeled into fish growth in the lake environment. These studies suggest that the growth of *M. ambigua* can be influenced greatly by the energy budget available to the fish and the competing demands on that energy. This balance is clearly different in different river systems.

The more rapid growth in Murray River fish may be due to a reduced frequency of flooding and differing temperature regimes. It has been shown, for example, that there is a reduced minimum winter river temperature plume below Hume Weir in some years (Llewellyn 1983). This is likely to result in reduced spring breeding of fish in this area of the river, which would then provide greater energy for growth. This is supported by the suggestion that *M. macquaria* populations have declined particularly in the upper reaches of the Murray River. Since the sex of recaptured fish in the Murray was not known, it is possible that a larger proportion of females were captured in this river which could have contributed in part to the elevated growth rates.

The recent prolonged drought would cause shrinking water bodies, concentration and decline of existing fish populations and consequently a diminishing food source per fish, a feature that is common also in other vertebrate groups in the arid inland (*eg*. Kangaroos, Bayliss (1978) and waterfowl (Wong 1994). The result would be a declining growth rate for the period of the drought a feature which would be reversed as soon as the drought broke and food became plentiful again. Other factors that may affect growth rates is the abolition of commercial fishing which could reduce growth rate because of increased survival of fish which are feeding on a biota which is controlled by other environmental factors. Conversely higher fishing pressure in an area could increase growth rate giving rise to a higher $\mathbf{L}_\infty$ value, because the food resource present would be spread between fewer remaining fish. The escalating population of alien species such as European Carp *Cyprinus carpio* could cause a significant decline in growth rate as a result of direct competition for food and the increase in turbidity caused by roiling, making the food less readily available; whereas native predatory carnivorous fish could benefit from such introductions.

Stocking of fish may also impact on growth rates. Although this practice augments poor natural breeding success it means larger numbers of fish are present to exploit the same food resource, thereby possibly reducing their growth rate particularly under conditions where the food resource is limiting the fish population.

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APPENDIX I

Photo 1. Golden Perch *Macquaria ambigua.*

APPENDIX I

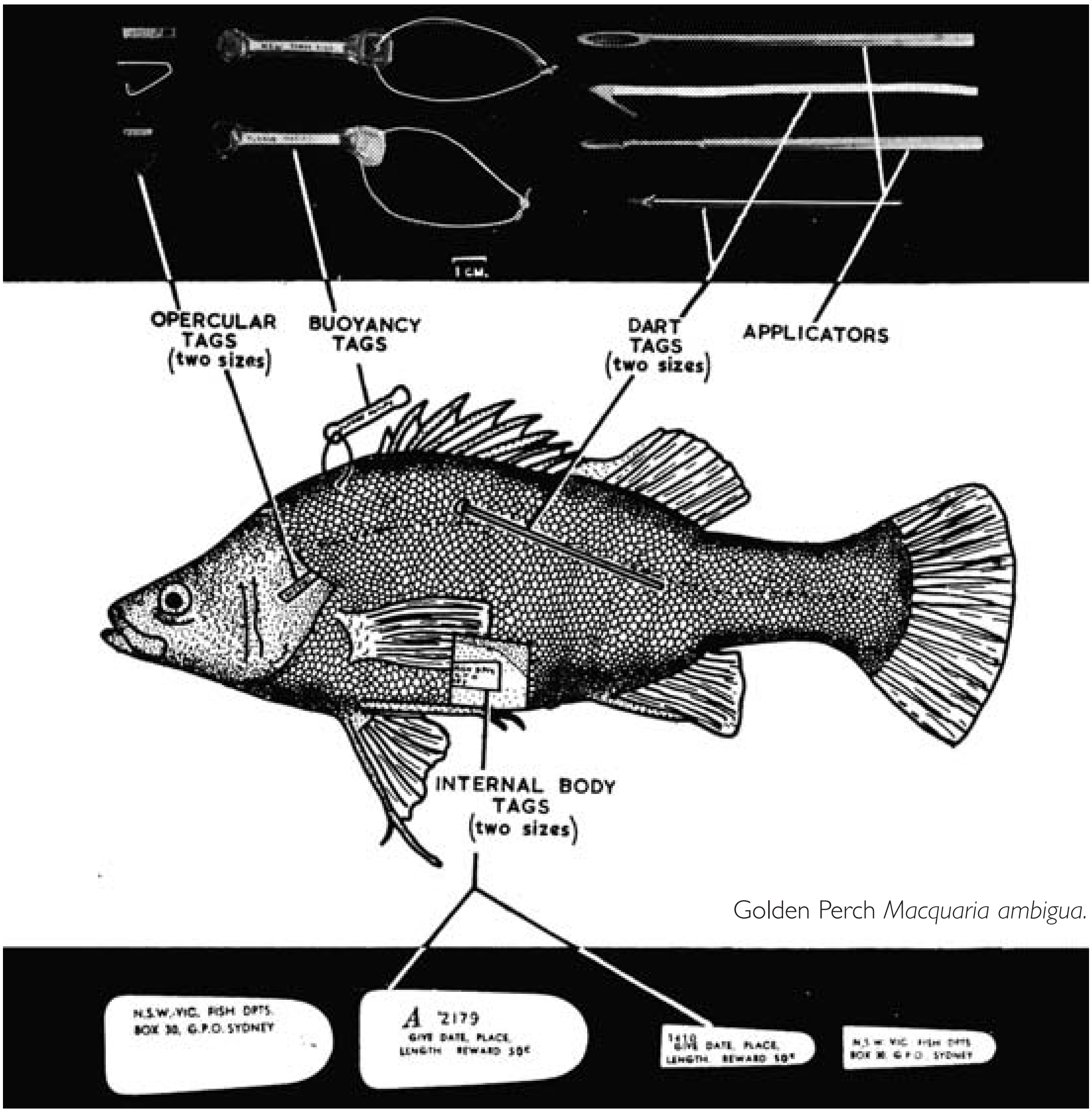

Photo 2 (above). Original diagram showing some of the types of fish tags used in the 1960's. The Opercular and Internal Body Tags (IB tags) were used in this study.

Photo 3a (left). Inserting a large Internal Body Tag (IB tag) into a *Maquaria ambigua.*

Photo 3b (left bottom). A drum net used in trapping a majority of fish in this study. The entrance faces downstream and relies on the movement of fish upstream.