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OBSERVATIONS ON THE BIOLOGY OF THE GIANT KOKOPU, *GALAXIAS ARGENTEUS* (GMELIN 1789)

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ABSTRACT

Giant kokopu, *Galaxias argenteus* (Gmelin 1789), were occasionally caught in nets set for eels in Lake Pounui, Wairarapa, between July 1977 and April 1977. As these fish are regarded as rare in many parts of New Zealand, all specimens were initially tagged and released. Length-weight relationships were calculated from the eighteen individual fish caught, while age and growth, feeding, and reproductive state were recorded from six fish kept for examination.

INTRODUCTION

The family Galaxiidae is widely distributed in southern temperate regions, with New Zealand having thirteen species (McDowall 1978). The largest member of the family, *Galaxias argenteus* the giant kokopu, is endemic to New Zealand and its offshore islands. Little is known of the life history of the giant kokopu and with the increasing loss of swamps and wetlands, McDowall (1978) considered that "it should be regarded and treated as a threatened species."

The present contribution, while dealing with relatively few fish, is the first specific study of *G. argenteus*.

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METHODS

During research on freshwater eels (*Anguilla* spp.) in Lake Pounui, Wairarapa (41°21'S, 175°07'E), occasional specimens of *G. argenteus* were captured in unbaited hoop nets (fyke nets). Initially, all specimens were measured (fork length to the nearest mm) and weighed (10 g intervals), then tagged and released. The tags used were 10 mm x 2 mm, serially numbered and made of stainless steel. They were inserted subcutaneously in fish which had previously been anaesthetised in 3% benzocaine solution. During April 1978, six *G. argenteus* were captured and killed for age and sex determination, and stomach analysis.

Opercular bones, removed for age determination, were stored in 40% isopropyl alcohol. Unfortunately, the operculae from one fish were subsequently mislaid. Stomachs and gonads were removed and preserved in 10% formalin.

Operculae were prepared by dropping into boiling water for a few minutes after which the adhering tissue was easily rubbed off. They were then dried at room temperature for 24 h, placed in a petri dish and immersed in paraffin oil. Using bright side-illumination, alternate light and dark bands were observed at increasing distances along the radius from the point of articulation. As the middle section of each operculum had a convoluted outer margin, the number of dark bands and their distance from the articulation point was read from the top half of the operculum.

Five of the six fish killed were females and fecundity was estimated by counting the eggs in a weighed sub-sample of the ovary. Gonadosomatic indices were calculated by expressing gonad weight as a percentage of total body weight.

Food organisms were identified to class only and the number and wet weight of each food item was recorded for each stomach. When estimating the number of food organisms, some approximations were required as items were often fragmented.

RESULTS

The eighteen fish recorded ranged in length from 182 - 336 mm (mean length 260 mm) with a corresponding range in weight of 80 - 570 g (mean 239 g). The length-weight expression from these data was exponential and described by the equation.

$$\log W = 2.8011 \log L - 4.3870 \quad (r = 0.9807, n = 18)$$

where W = total weight in grams and L = fork length in mm

Relative condition factors, K_b, were then calculated from

$$K_b = \frac{W}{\hat{W}}$$

where W = observed weight and $\hat{W}$ is the calculated weight for that fish by substitution of the fish length into the above length-weight expression. The condition factors obtained ranged from 0.81 - 1.14 (mean 0.95) with no obvious trends according to size or month of capture.

It was assumed that the alternate light and dark bands on the opercular bones were annual in formation with the narrower and denser (dark) bands corresponding to winter growth and the wider (light) bands corresponding to summer growth. Accordingly, summation of these zones gave the ages of the fish.

Lengths at previous age classes were calculated by direct back calculation using the expression

$$L_t = \frac{r_t}{R} \times L$$

where L_t = estimated length at time t, r_t = operculum radius (mm) at time t, R = total operculum radius, and L = fork length (mm). The small number of fish did not warrant any further transformation of the data.

The resulting back calculated lengths based on the five fish available, are given in Table 1. When these data are graphed, an allometric pattern of growth is indicated, with increasing size represented by decreasing length increments between successive age classes.

Ford-Walford graphs were constructed for those fish of age 8+, using L_t as the X-axis and L_{t+1} as the Y-axis. (The remaining two fish were not included as they each gave only four pairs of X and Y values for the regression analysis). The regression fitted to the data for each fish cut the diagonal drawn at 45^o from the X and Y axes. The value of X corresponding to this intercept, L_∞ , is the theoretical maximum size for that fish as predicted from the data. These values are also given in Table 1 together with their mean of 414mm.

Of the six fish kept for examination, four were tagged. One of these had a badly lacerated tail and could not be measured accurately. The average annual growth increments in length of the other three fish are given in Table 2, together with the increments for two fish as predicted from their Ford-Walford graphs.

Five of the six fish examined were gravid females. One fish was nearly ripe as gentle stroking of the abdomen caused a trickle of eggs at the genital aperture. The ovaries were composed of two equal lobes, containing regular spherical eggs. The gonadosomatic indices (G.S.I.) ranged from 8.2 - 16.9 (mean = 11.4) with the largest value being for the ripe fish. Measurements from a composite sample of 250 preserved eggs were: mean diameter 1.74 mm, range 1.42-2.10, (S.D. = 0.14). Fecundity estimates ranged from 8,800 to 25,700 eggs, with a mean value of 14,5000 (mean fish length 28.3 mm). Some relationship between fecundity and fish length was apparent, with the largest fish being the most fecund. However, the fewest eggs, 8,800, were from a fish of 286 mm, while the smallest fish, 242 mm had 9,000 eggs.

A male fish caught and tagged on April 27 1977 (248mm) was 'running ripe' as normal handling produced milt flow. The male examined (182 mm) was also 'ripe' as gentle abdominal pressure produced some milt. The testes appeared to discharge directly into the cloaca as no distinct vas deferens were found. The weight of the testes was to 20 g, giving a G.S.I. of 12.5.

TABLE 1. BACK CALCULATED LENGTHS (mm) PER AGE CLASS OF FIVE ADULT *G. ARGENTEUS*, WITH L ∞ VALUES CALCULATED FOR FISH OF AGE 8+.

		Age Classes											
		0	1	2	3	4	5	6	7	8	9	10	11	L^{∞}
Fish Number	Total Length													
1	182	76	112	126	150	166								
2	336	104	141	176	200	240	259	272	288	299	310	320		376
3	286	77	104	129	171	200	230	244	257	268				398
4	253	78	104	124	149	177	204	220	235	249				468
5	242	83	121	148	190	220								
Mean														414

TABLE 2 - RECORDED AND PREDICTED GROWTH OF TAGGED *G. ARGENTEUS* IN LAKE POUNUI, WAIRARAPA.

Length at tagging (mm)	Days till recapture	Increase in length (mm)	Increase in wt (g)	Length increment (mm yr^{-1})	Predicted increment (mm yr^{-1})
330	553	6	65	4.0	6.7
234	519	19	60	13.4	16.3
296	192	1	0	1.9	-

A summary of the stomach contents of the six fish examined appears in Table 3. The table is subdivided into food considered to be terrestrial or aquatic in origin. One stomach contained large numbers of intact cranefly larvae and pupae, but as previously indicated, food was generally fragmented. The weight of stomach contents expressed as a percentage of total body weight ranged from 0.7 - 4.2%.

TABLE 3 - ANALYSIS OF STOMACH CONTENTS OF SIX ADULT *G. ARGENTEUS* FROM LAKE POUNUI, WAIRARAPA (+ = less than 0.1%).

	Occurrence (maximum=6)	Number (%)	Weight (%)
A. Terrestrial			
Diplopoda			
millipede	1	0.9	0.1
Arachnida			
spiders	6	19.3	10.3
Insecta			
Hymenoptera - bees	3	2.2	2.5
wasp	1	0.4	+
ant	1	6.0	0.3
Lepidoptera - larvae	1	0.4	0.2
Diptera -fly	1	0.4	+
cranefly larvae	1	3.0	2.0
" pupae	2	37.4	31.3
Coleoptera - scarab and carabid beetles	6	12.4	9.4
Hemiptera - shield bug	3	1.3	0.4
Dermaptera - earwig	1	0.4	0.1
B. Aquatic			
Nematomorpha - gordian worm	1	1.3	0.7
Crustacea			
Amphipoda	1	0.4	+
Insecta			
Hemiptera - water boatmen	4	9.0	1.1
Odonata - damselfly larvae	1	0.4	0.1
Coleoptera - water beetle	1	0.4	0.3
Osteichthyes			
Anguilliformes - eel	2	2.2	7.6
Unidentified fish remains	1	2,2	15.0
Vegetation	2	-	0.3
Miscellaneous remains	5	-	18.0

The mean theoretical maximum size of *G. argenteus* in the present study is 414 mm. McDowall (1978) considered that giant kokopu larger than 300 mm are uncommon and the largest seen by him was 380 mm. Clarke (1899) reported *G. kokopu* (= *G. argenteus*) growing to 580 mm and 2.7 kg, while a 1.8 kg specimen was caught in the early 1970's in the Te Awainanga River, Chatham Islands (P. R. Todd, pers. comm.). Using the length-weight expression of the present study, this latter weight corresponds to a length of 535mm.

Predicted growth increments were in fair agreement with recorded increments (Table 2). Although predicted data are not available for the third fish in this table, recorded growth was much less than anticipated when compared with other fish. Eldon (1969) recorded juvenile *G. argenteus* were 95 mm long at 14 months. Assuming an initial size of 52.5 mm (median length of juveniles arriving in freshwater given by McDowall 1970), this is equivalent to a size of 89 mm after one year. This is within the range of lengths (76 - 104 mm) back calculated for one year old fish (age class 0) in the present study.

Growth has been studied in several galaxiid species: *G. maculatus* (Jenyns) (McDowall 1968); *G. divergens* Stokell, (Hopkins 1971); *G. vulgaris* (Cadwallader 1978); *G. fasciatus* (Hopkins 1979). Of these species, *G. fasciatus* is the largest and hence the most comparable to *G. argenteus*. Growth rates given by Hopkins (1979) for female *G. fasciatus* from a Banks Peninsula stream conform closely to those of *G. argenteus* in the present study.

The presence of ripe male and female fish in late April indicates that some spawning in *G. argenteus* must take place in autumn; McDowall (1970) suggested autumn or early winter as the spawning period. Hopkins (in press) found that spawning in *G. fasciatus* occurred from the end of April to mid June. The mean female G.S.I. value in the present study was 11.4 which is relatively low in comparison to the value of 19.8 given by Hopkins for mature female *G. fasciatus*. This probably indicates that not all the female *G. argenteus* had achieved their maximum ovarian development. Accordingly, egg diameters would not indicate maximum size, although the diameters recorded are amongst the largest for galaxiid species.

McDowall (1970) considered that fecundity and egg size reflected life history pattern, with the five diadromous galaxiid species having numerous small to moderately sized eggs, while the other species (which all complete their life history in freshwater) have fewer but larger eggs. The fecundity data for *G. argenteus* are consistent with this theory, although comparison of egg sizes of the diadromous species (present data, McDowall 1968, 1970 and Hopkins in press) suggests that egg size is related to species size. Thus the smallest diadromous species, *G. maculatus*, has the smallest eggs and vice versa.

Analysis by weight of stomach contents showed a high proportion (57%) of food organisms regarded as terrestrial in origin. However, all fish were collected six and seven days after a major flood while water levels were still slightly higher than average. Higher water levels mean an increased area for foraging and this may have resulted in some bias towards

All fish tagged were released at the same site, and the distance from this site to the place of recapture is given in Table 4. With two exceptions (tag numbers D719 and E330) fish were caught closer to their original capture site than to tagging site. One fish (tag D977) was recaptured twice at the site of original capture which was 750 m in a direct line from the tagging site.

The release site of tagged fish was in 'open water' but of the 24 captures and recaptures recorded over the 21 month period, 17 (70%) were from a raupo (*Typha orientalis*) swamp habitat, three (13%) from rushes/sedges (*Juncus* spp. and *Scirpus* spp.) habitat, and four (17%) from 'open water'. The swamp habitat comprised only 20% of the lake margin but obviously this was the preferred habitat. As the swamp areas were quite localised, the apparent 'homing' shown by some fish may be due to a return to a preferred habitat rather than to a specific locality. However, the movements of fish D977 indicate a return to a specific area.

TABLE 4 - MOVEMENTS OF TAGGED *G. ARGENTEUS* IN LAKE POUNUI, WAIRARAPA.

Tag No.	Capture Date	Recapture(s)		
		Date	Distance from tagging site (m)	Distance from original capture site (m)
D977	25.11.76	25. 3.77	750	0
	25. 3.77	27. 4.78	750	0
D719	3. 7.76	25.11.76	50	550
D809	19.10.76	26. 4.78	600	350
D944	15.11.76	26. 4.78	750	0
E330	11.10.77	21. 4.78	50	100
Mean Distance			492	167

DISCUSSION

A length-weight 'b' coefficient of 3 indicates isometric growth but this is seldom achieved. The value of 2.8011 obtained here for *G. argenteus* is close to this theoretical one and within the 'normal range' of 2.5 - 3.5 (Carlander 1969). Some seasonal changes in the condition factor of *G. argenteus* are anticipated, especially immediately after spawning, since the G.S.I. of females may exceed 17. Although there are too few data in the present study to indicate such trends, Cadwallader (1978) noted seasonal changes in condition of *G. vulgaris* Stokell.

Eldon (1969) suspected that *G. argenteus* is long lived and that its potential life span could exceed six years. The largest fish in the present study, 336 mm, had completed twelve years growth. In a study of age and growth in the banded kokopu, *G. fasciatus* Gray, Hopkins (1979) recorded the oldest fish at nine years (length 245 mm).

terrestrial food organisms in the diet. Winged insects and perhaps other 'terrestrial' organisms in the diet were probably caught at the surface. *G. argenteus* are known to feed on the surfact and can be caught with floating artificial or natural bait (G. A. Eldon, pers. comm.).

The fish remains in the stomachs indicate that large specimens of *G. argenteus* are partly piscivorous. Observations by the author of an adult *G. argenteus* in an aquarium (unpubl. data) are similar to those recorded by Eldon (1969), namely that the fish is capable of rapid acceleration and deceleration. This behaviour characterises predatory fish adapted for taking prey by ambush. In body shape and fin configuration, *G. argenteus* is similar to the pike *Esox lucius* L (a northern hemisphere predatory fish) to the extent that *G. argenteus* was originally placed in the genus *Esox*.

G. argenteus is found in a variety of habitats including swamps, swampy creeks, some lakes, and occasionally in gravelly streams, but always in association with abundant cover (McDowall 1978). In the present study, swamp was the preferred habitat. There is some evidence of homing behaviour although interpretation of this is complicated by the discontinuous and restricted swamp habitat. Distinct home range behaviour was noted by Cadwallader (1978) for *G. vulgaris* in the Glentui River, but this has not been recorded for other galaxiid species.

Current pastoral development practices such as swamp drainage and stream channelising, have deprived *G. argenteus* of much of its original habitat. This, together with the apparent incompatability between *G. argenteus* and the introduced brown trout *Salmo trutta* L (McDowall 1978), is a very real threat to the continuing existence of the giant kokopu.

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