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The Growth of the Red-Ear Turtle Pseudemys scripta elegans in a Thermal Lake in Southwestern Illinois

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THE GROWTH OF THE RED-EAR TURTLE PSEUDEMYS SCRIPTA ELEGANS IN A THERMAL LAKE IN SOUTHWESTERN ILLINOIS

(TITLE)

BY

DIANA AVALOS

THESIS

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INTRODUCTION

Due to the increased demand for nuclear and electrical energy, the number of thermally altered aquatic environments is rapidly increasing. Lakes and reservoirs receiving heated effluents provide an ideal situation for studying the effects of increased heat on natural populations of organisms. From an environmental standpoint, such studies are critical to ascertain possible harmful effects of the higher temperatures.

This project is part of a long-range study being conducted at Lake Baldwin (Randolph and St. Clair Counties, Illinois) by E. O. Moll to determine the effects of a heated aquatic environment on growth, reproduction and movements of turtles, especially the red-ear turtle, Pseudemys scripta elegans. This portion of the study compares a population of Pseudemys scripta elegans from Lake Baldwin with similar populations from two nearby unheated lakes (Dry and Diewald's Lakes). Objectives of this initial study were to determine whether growth rate is affected in turtles inhabiting heated lakes.

Numerous studies have been conducted on the growth of various species of aquatic turtles; Pseudemys scripta elegans by Cagle (1946), Moll and Legler (1971); Pseudemys concinna suwaniensis by Jackson (1970); Chrysemys picta by Sexton (1965), Gibbons (1967), Ernst (1971); Deirochelys

reticularia by Gibbons (1969); *Malaclemys* by Barney (1922), Hildebrand (1929); *Trionyx ferox* by Breckenridge (1955); *Sternotherus odoratus* by Tinkle (1961). Only Gibbons (1970) and Christy et al. (1971) have conducted specific studies on the effects of thermal environments on growth and reproduction in *Pseudemys scripta scripta*. These studies concluded that the addition of heated effluents accelerated growth even after the pond had returned to normal temperatures.

Study Area

Lake Baldwin is a 2,200-acre artificial impoundment located in Randolph and St. Clair Counties, southwestern Illinois. It was constructed in 1968 by the Illinois Power Company to receive heated effluents from the Baldwin Power Plant. Water temperature data on Lake Baldwin are scarce as readings are taken irregularly. Table 2 shows available readings on Lake Baldwin as well as several comparable readings from the two control lakes.

The lake averages eight feet in depth, maximum depth being 48 feet. The 15.4 miles of shoreline are surrounded by berm on three sides. The west shore has been planted in wheat to attract waterfowl. Aquatic macrophytes consist almost entirely of *Myriophyllum* spp.; some *Potomageton* spp. also occur. Aquatic vegetation is concentrated in small

bays but by July has grown well into the lake. Vertebrate fauna are abundant. Carp (Cyprinus carpio), shad (Dorosoma cepedianum), sunfish (Lepomis spp.) and bullheads (Ictalurus melas) naturally occur and channel catfish (Ictalurus punctatus) and largemouth bass (Micropterus salmoides) have been introduced. Pseudemys scripta elegans is by far the dominant turtle (93% of all captures). Chrysemys picta, Chelydra serpentina and Sternotherus odoratus were also captured.

Diewald's Lake is a two-acre unheated farm pond located about one mile northwest of Lake Baldwin. It has overgrown, steep, muddy banks, a shallow muddy bottom (maximum depth about 8 feet) and contains little aquatic vegetation. Pseudemys scripta elegans and Chelydra serpentina are both abundant.

Dry Lake, another control, is the backwater of an oxbow of the Kaskaskia River. It is approximately four acres in size. It floods during the spring and the banks remain muddy through most of the summer. Pseudemys scripta elegans seems to be the dominant species but all the Lake Baldwin species were captured here as well as one Trionyx spinifer.

TABLE OF CONTENTS

MATERIALS AND METHODS

Turtles were captured in baited (carp and sardines) hoop nets (Legler, 1960) and trammel nets (50' x 8' and 100' x 8'). A hacksaw was used to mark the shell margin with a different combination of notches following a code system designed by Cagle (1939). Separate data records were kept for each individual including sex, approximate age, date and specific location of capture, weight and linear measurements: maximum straight-line carapace length measured at the midline, carapace width measured at right angles to the midline, maximum plastral length, carapace height, midline length of right abdominal scute, and midline length of right pectoral scute, and all visible annuli on the right pectoral scute. Scutes and annuli were measured to the nearest 0.1 millimeter; all other measurements were rounded to the nearest millimeter.

Turtles were sexed on the basis of secondary sexual characteristics or by dissection. Elongated foreclaws and an enlarged tail base differentiated males from females and immatures. Turtles larger than 120 millimeters but lacking long foreclaws were considered to be immature females. Unsexed juveniles were also placed with the females as it appears that juveniles of both sexes grow at approximately the same rate (Moll and Legler, 1971).

Twenty-six turtles were dissected and the gonads and digestive tracts removed. Ovaries and oviducts were preserved in 10 percent formalin. Eggs were measured and incubated to obtain data on hatchlings. Clutch size and length of eggs were recorded for each female. Overall length and pectoral length of the subsequent hatchlings were measured.

Stomach contents of the 26 preserved turtles were examined to determine possible dietary differences in the two populations. Stomachs and small intestines were analyzed for approximate percentages of animal and plant matter ingested. Contents of the digestive tract were removed and placed in finger bowls. Matter recognizable as either plant or animal was separated and measured by water displacement. Amount of vegetation and amount of animal matter were added and a percentage of the total volume calculated for each. These percentages are shown in Table 1.

Means of the pectoral scute measurements were taken for each season of growth for turtles having complete pectoral scute records. Turtles without initial growth rings were then fitted into categories formed by turtles of known ages. For example, a male Baldwin turtle of unknown age with a growth ring measuring 16.02 millimeters would be fitted into a category with known three-year-olds (mean = 15.91 ± 2.48). Means of two-year-olds and four-year-olds are 12.04 ± 2.29 and 18.36 ± 2.06 respectively.

This procedure was followed for all turtles lacking the areolar. In cases where several rings were visible, the turtles were aged by the closest fit of all visible rings. In no case were any years skipped. Those rings present were always categorized in exact sequential order by years. In this way, turtles which could not be aged solely on the basis of the number of growth rings could still be assigned an age on the basis of known pectoral scute lengths. Plastral lengths of the turtles were plotted against calculated ages for each turtle. For example, the male Baldwin turtle with a growth ring measuring 16.02 millimeters and classified as a three-year-old had a plastral length of 105 millimeters. This plastral length was plotted against the turtle's assumed age of three years.

Males and females from the two study areas were grouped by plastral lengths irrespective of age to determine how they compared in size. Each turtle was placed in a size category within a 10 millimeter range. The total number of individuals in each category was then divided by the total number of animals of that sex from each study area yielding the percentage of animals making up the particular size category. Only turtles six years or younger were included owing to the age of the lake. Older Baldwin turtles were assumed to be founders and not natives of the lake.

In an attempt to estimate plastral lengths from growth rings, the recorded pectoral and plastral lengths for *Pseudemys scripta* of the two areas were fitted into a regression curve. Pectoral and plastral lengths at the time of capture were used for this graph. Measurements of previous growth rings were then drawn horizontally to where they intercepted the regression curve. The intercept was assumed to be the approximate plastral length of the turtle when that particular growth ring was formed. For example, a male turtle from Lake Baldwin with a growth ring of 13.8 millimeters would have been 109 millimeters in plastral length when that ring was formed. By using many individual growth rings in this manner, it is possible to reconstruct probable plastral lengths for previous years (Moll and Legler, 1971). Then the number of rings themselves can be used to compare the reconstructed measurements of turtles of known ages. These reconstructed plastral lengths will be referred to as the calculated plastral lengths. Means of the reconstructed plastral measurements were then calculated for each year of growth (Fig. 5 and 6). A Student's t-test was used to determine if actual and calculated results differed significantly.

RESULTS

From March, 1974 to April, 1975, 320 individuals of *Pseudemys scripta elegans* were captured from the three lakes; 237 from Lake Baldwin (136 males, 101 females and immatures); 81 from the two control sites, Dry and Diewald's Lakes (27 males, 54 females and immatures). Of the total, 16 were recaptured during the project. Twenty-six (18 from Lake Baldwin, 8 from the control lakes) were preserved and the rest marked and released.

Comparison of plastral lengths between Baldwin and control turtles indicate Baldwin turtles are generally larger (Fig. 1 and 2). Females under 200 millimeters in length from both areas are similarly abundant in both populations. However, 22 percent of the Baldwin females exceeded 200 millimeters in length as opposed to only eight percent of females from control areas. The apparent dearth of immature females (between 150 and 170 millimeters for controls and 130 and 150 for Lake Baldwin) is characteristic of sliders. Moll and Legler (1971) noted that Panamanian *Pseudemys scripta* females seemed to "disappear" between 155 and 210 millimeters. They may be in deeper water at this time or are merely reluctant to enter traps. Apparently this absence immediately precedes maturity.

Although sample sizes for males were highly variable,

males too appeared to show a difference in abundance of larger individuals. No turtles from control lakes exceeded 160 millimeters in plastral length. Twenty-nine percent of the Lake Baldwin males exceeded this size, and two individuals approached 200 millimeters in length. Small individuals were rare owing to difficulty in sexing individuals under 120 millimeters in length. The lack of individuals between 120 and 130 millimeters in the control group was probably due to small sample size (N = 26). For this reason, the category 120 to 130 millimeters cannot be assumed to be the pre-maturation disappearance discussed for females above. Results of the size percent frequency charts show that in a random group of turtles aged one to six years, the incidence of larger turtles is much greater in Lake Baldwin than in either of the control areas.

Sexton (1959) demonstrated that it was possible to calculate the age of a turtle even though earlier growth rings were absent. Growth records of turtles which bore complete records on the pectoral scute (starting with the areolar) were placed in columns according to age (as determined by the number of growth rings). The areolar was considered to be the size of the pectoral scute at the time of hatching. A discrepancy arose in calculating the first full season of growth in that it cannot be known for certain whether a particular turtle emerged from a nest in the fall

following hatching or whether it overwintered in the nest. Turtles hatched late in the season overwinter in the nest, the first growth taking place the following spring. Conversely, turtles hatching in late summer could grow for several months that first season. Therefore, whereas some turtles showed marked growth between the areolar and the following ring, others showed very little growth, although their actual growth rates may have been very similar. This partial season of growth is referred to as the year of hatching (Moll and Legler, 1971). The decision as to whether the first growth ring is actually a full year's growth is subjective. However, for Baldwin males, the mean size of the "hatching" ring was 7.82 ± 0.93 (N = 10). The mean for those males thought to have completed a full year of growth was 12.04 ± 2.71 (N = 63). There was no overlap in the numbers so the year of hatching category was retained. In those turtles, the ring subsequent to the "year of hatching ring" was used to designate size after the first full season of growth (year one).

Students t-tests performed for each year between actual Baldwin male plastral measurements and actual control plastral measurements indicate that, in general, the two populations differ in growth rates (Fig. 3). Among one-year-old males, the degrees of freedom value was small due to the difficulty of sexing one-year old individuals. The

second year does not differ significantly in the two male populations (t = 1.19, df = 39), but the third year Baldwin males reach a significantly larger size (t = 3.87, df = 40). Fourth year mean lengths are also significant (t = 2.44, df = 19). By the fifth and sixth years, mean sizes are still greater although not significantly so (t = 1.74, t = 1.00).

Results of the t-test between actual Baldwin female lengths and actual control female lengths are similar to those between males. There is very little difference during the first two years of growth. Sample size, especially from the control population is small (Fig. 4). During the third season of growth, Baldwin females appear to grow significantly faster (t = 5.00). The two populations differ significantly during the fourth and fifth years (t = 3.64, t = 4.13). Although the sixth year value is not significant (t = 2.08), Baldwin individuals still maintain a greater mean size.

T-tests between actual and calculated plastral lengths were performed to determine the reliability of the method of calculating past plastral lengths. T-test values for the third and fourth years for both males and females from Baldwin differed significantly (t = 2.24, t = 2.05 ♂♂; t = 2.60, t = 3.57 ♀♀). The first, second, fifth, and sixth year calculated plastral lengths corresponded well to actual

plastral length means (t = 2.01, t = 0.45, t = 0.78, t = 0.66 ♂♂; t = 1.81, t = 1.64, t = 0.25 ♀♀). However, the two actual populations (both males and females) showed dramatic changes in growth rates during the third and fourth years (Fig. 3 and 4). This difference is not reflected in the calculated means; Figures 5 and 6 are much flatter curves. Because they do not reproduce the entire actual growth curve, calculated plastral lengths were assumed inaccurate and were not included in any further manipulations of the data.

Calculated means for control individuals did not correspond with the fourth year growth spurt of the actual control population. Among control males, four out of six years tested differed significantly (t = 3.36, t = 3.64, t = 2.74, t = 3.01). Among control females, second, third and fourth years differed significantly (t = 3.58, t = 3.95, t = 2.42). These significant differences in t-test values indicate that the calculated method cannot be applied to the real control population in this study.

A final t-test was performed between the calculated control means and the calculated Baldwin means for both males and females. This was done to compare the differences in mean plastral lengths of the calculated populations. Except for the first year, Baldwin calculated means differed significantly from calculated means from the control. This

was the case for both males and females. This was also not an accurate reproduction of the actual data which show significant differences only during the third and fourth years for males and the third, fourth and fifth years for females.

Another consideration in assessing greater growth in Baldwin turtles is whether hatchlings of the two populations differ. Areolar comparisons were performed to determine whether size of Baldwin and control hatchlings differ. Areolar comparisons were statistically insignificant for both males ($t = 2.05$, $df = 29$) and females ($t = 1.48$, $df = 43$). This indicates that there are no differences in hatchling sizes and growth rate differences are the result of environmental conditions in the two areas.

To determine if growth differences were associated with food differences, digestive tract contents of 26 (18 Baldwin, 8 control) turtles were analyzed (Table 1). Digestive tracts of many individuals were empty; others contained only carp (used as trap bait) in the stomach and/or feces in the large intestine. Although data from this small sample can not be considered conclusive, they suggest that Baldwin turtles might consume greater percentages of vegetation than do turtles from unheated lakes. Only one of 18 Baldwin stomachs examined contained animal food (other than trap bait) and it contained only one bivalve shell and a decapod chela. These could have been swallowed accidentally with vegetation as no other parts or meat were evident.

Of the eight control stomachs, two showed considerable amounts of dipteran larvae and no vegetation. Both were collected in May. Other Dry Lake turtles showed only bait carp and some vegetation. Possibly the control turtles have access to greater amounts of meat at least during some months of the year.

An attempt was made to analyze seasonal variations in food between the two study areas. Unfortunately *Pseudemys scripta* from the control areas were only preserved during May as opposed to March, May, June, July, October and December for those from Lake Baldwin. December was the only month in which no food was found in the stomachs. Presumably, Baldwin turtles feed for at least seven months, from March to October. Whether turtles are actually growing during this entire period is unknown. Approximately 70 percent of May captures showed no new growth for the season.

Results of weight-plastral length comparisons of the two populations show differing lines for males and females (Fig. 7 and 8). However, ratios of the two populations appear very similar in both males and females, indicating that individuals from Lake Baldwin have not sacrificed weight gain in attaining greater plastral lengths. The graphed curve appears nearly linear for males and curvilinear for females. This discrepancy may be due to added weight of the eggs in mature females, causing the ratio of length to

weight to decrease in these individuals. If the control populations were heavier at a certain size than Baldwin turtles, it could be supposed that greater plastral length observed in Figures 3 and 4 may not be accompanied by normal corresponding weight. This is apparently not the case in Lake Baldwin.

DISCUSSION

It appears that turtles from thermally altered Lake Baldwin demonstrate significantly higher growth rates than nearby nonheated lakes. This could be due to the effect of higher temperatures on several aspects of *Pseudemys scripta* natural history.

It is possible that the higher temperatures have a direct effect on growth by accelerating metabolic rates of the turtles. Hutton et al. (1960) and Rapatz and Musacchia (1957) demonstrated that oxygen consumption increased significantly when temperature was increased in *Pseudemys floridana mobilensis* and *Chrysemys picta*, respectively. As yet no long-term studies have been conducted on temperature affecting actual growth as well as oxygen consumption. Moll and Legler (1971) indicated that warmer temperatures aided in digestion in *Pseudemys scripta*. It would be reasonable to assume temperature could directly accelerate growth in poikilotherms just as it does in many simple life systems. The direct effect of temperature may be an important factor increasing growth rates in Lake Baldwin.

Increased growth rate may be due to increased productivity indirectly resulting from higher temperatures in Lake Baldwin. Christy et al. (1971) suggested that higher growth rates in turtles from a thermal pond may be due to an increase in primary productivity. Theoretically, a

greater amount of food would be available to turtles, resulting in greater growth. *Myriophyllum* spp., the dominant aquatic plant is very abundant and was found in seven out of ten stomachs from Lake Baldwin. In an earlier paper, Gibbons (1967) indicated that the quality of food ingested may be of great importance to growth rates in *Chrysemys picta*. Comparing growth of a highly polluted river population with a population from a clear pond with abundant aquatic vegetation, he found higher growth in the river. He attributed greater growth of the river turtles to higher protein content of their food. Stomach analyses indicated 75 percent invertebrates in the river turtles whereas the stomachs of pond turtles averaged only five percent invertebrates. He concluded that as diet becomes more carnivorous, growth rate increases.

Dry Lake and Lake Baldwin closely approximate the two areas studied by Gibbons. Lake Baldwin is relatively clear with abundant aquatic vegetation like Gibbon's pond; Dry Lake, a river backwater, is muddy through most of the year and contains few aquatic macrophytes. The stomach analyses showed little if any differences in dietary composition between the two study areas. Although sample sizes were too small to be significant, presence of dipteran larvae indicate that turtles from Dry Lake may have access to greater amounts of insect food than turtles from Lake

Baldwin. However, Lake Baldwin individuals may be consuming greater quantities of food. Gibbons (1967) did not believe abundance of food was a significant factor in growth rates of *Chrysemys picta*. Dry and Diewald's Lakes contained little aquatic vegetation whereas Lake Baldwin was nearly choked with vegetation by the middle of July. It is difficult to assess the actual amount of food consumed in a natural habitat. Stomach contents are ureliable as they indicate only whether the animal has eaten recently and give no indication of total quantity of food consumed.

Another possible factor in accelerated growth may be a longer annual growth period. Thus, Lake Baldwin turtles may not actually grow faster but for a longer period of time each season. Cagle (1950) found that *Pseudemys scripta* in Illinois grew from May 1 to October 1. Several stomachs from Lake Baldwin turtles captured in October were filled with vegetation. Stomachs from early December captures were empty. It is unknown whether feeding continued during this month. It may be that winter fat is accumulated at this time. Jackson (1970) found that *Pseudemys concinna suwaniensis* in a Florida spring with constant temperature showed an inherent decrease in growth during the winter months. This phenomenon could not be accounted for by temperature and food alone. Moll and Legler (1971) found that growth was cyclic in tropical *Pseudemys scripta*. If

this is true for *Pseudemys scripta elegans*, growth in Lake Baldwin may inherently cease during the winter despite the higher temperatures. Turtles captured in March showed no recent growth on the carapace. Many older turtles captured in May had not yet started growth as indicated by the lack of lighter, soft areas on the scutes. Apparently growth does cease at some time during the winter at Lake Baldwin.

Another manifestation of greater growth lies in possible reproductive differences in the two study areas. Data were available for only one Dry Lake female and eight Lake Baldwin females. This was not considered to be sufficient for a comparison. Many additional individuals would have to be dissected in order to quantify differences in reproduction between the two study areas.

Christy et al. (1971) indicated that turtles receiving the benefits of thermal effluents demonstrate greater growth even after the water temperature returns to ambient. That is, turtles given a "head start" will continue to show greater growth throughout their lives. If Lake Baldwin hatchlings are larger initially, this may account for some of their larger size. A comparison of all visible areolar lengths on the pectoral scute showed no significant differences ($t = 2.05$ ♂♂, $t = 1.48$ ♀♀) in the two populations. Figures 3 and 4 concur with this as there is no significant difference in plastral lengths between

the two populations until the third season. Higher growth rate does not appear to be a result of larger hatchlings. It appears from the curves in Figures 3 and 4 that greater growth is continuous. The factor or factors are constantly present. The only significant slope change in the two growth curves occurs in the third year at which time Baldwin females and males exhibit dramatic growth spurts.

CONCLUSION

In this study a significantly greater growth rate has been demonstrated in turtles from a lake receiving heated effluent. The actual factor or factors responsible for this accelerated growth are unknown at this time. Greater reproductive effort resulting in larger hatchlings is doubtful. Differences in amount of protein in the diet is probably not significant. Longer annual feeding may be occurring but more data are necessary to assess this factor thoroughly. Higher metabolic rates due directly to the increased water temperature may be a factor. Not enough is known concerning metabolic rates to quantify the effects of temperature on growth. Probably, the observed growth rates are a product of several factors imposing a constant favorable environment resulting in larger, apparently fit chelonians.

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Table 1. Results of stomach analyses of *Pseudemys scripta* from the control lakes and Lake Baldwin.

	Turtle	Age class	% vegetation	% animal
Lake Baldwin	2174	immature	95	5
	2139	immature	--	--
	2111	immature	75	25
	2137	adult	95	5
	2175	adult	--	--
	2114	adult	100	--
	2159	adult	99	1
	2182	adult	--	--
	2119	adult	100	--
	2112	adult	100	--
	2142	adult	100	--
	2162	adult	--	--
	2066	adult	--	--
	2180	adult	--	--
Control lakes	2151	immature	100	--
	2147	adult	--	--
	2150	adult	30	70
	2153	adult	5	95
	2152	adult	--	--
	2149	adult	90	10

Table 2. Water temperatures (°C) in thermal Lake Baldwin and two unheated control lakes.

Date	Baldwin	Dry	Diewald's	Difference
14 October 1973	25.8	No data	No data	
14 March 1974	18.0	No data	11.0	+7.0
25 June 1974	25.2	No data	No data	
19 July 1974	35.2	No data	No data	
1 December 1974	8.5	3.0	No data	+5.5
21 March 1975	16.0*	12.0	No data	+4.0
15 May 1975	22.3	No data	No data	

*Power plant shut down for two weeks previous to reading.

Figure 1. Percent frequency chart for males from thermal Lake Baldwin and two control ponds.

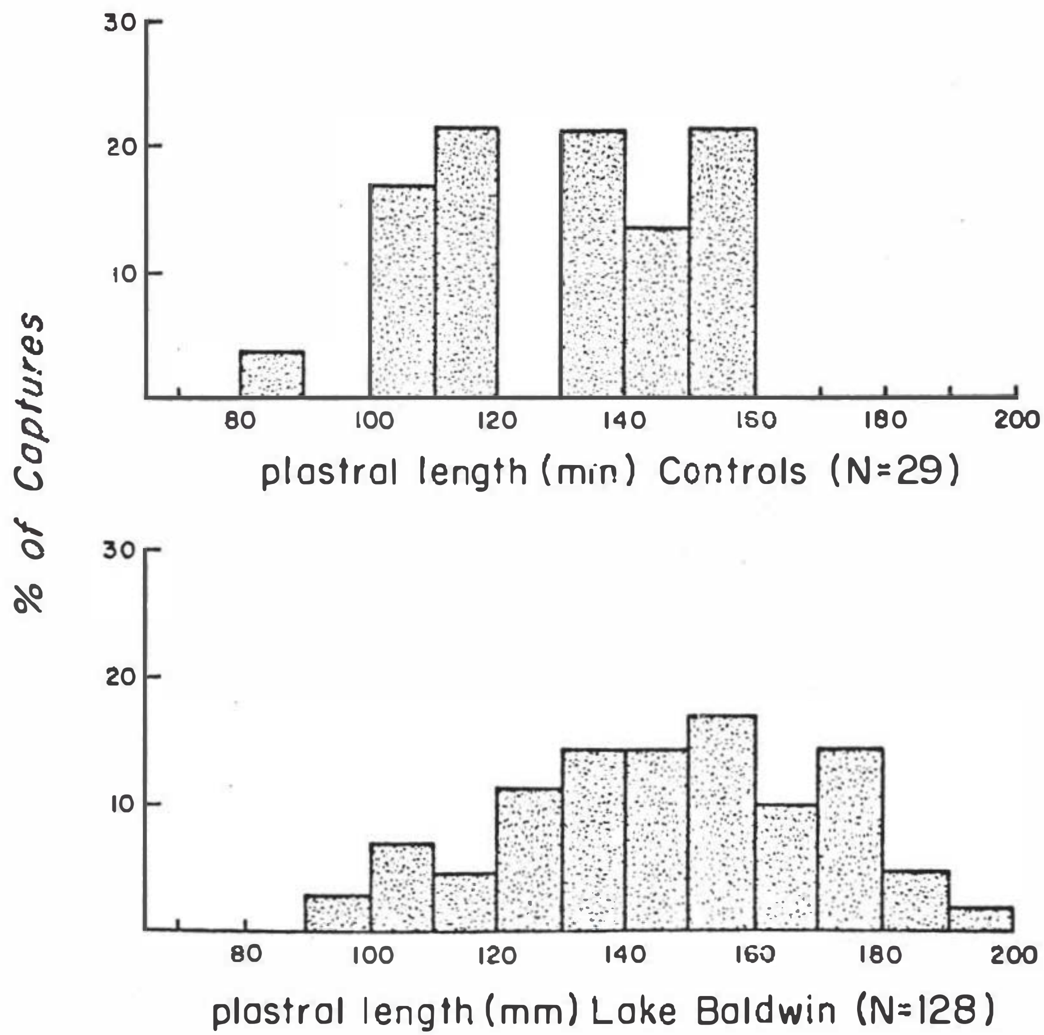

Figure 2. Percent frequency chart for females and immatures from thermal Lake Baldwin and two control ponds.

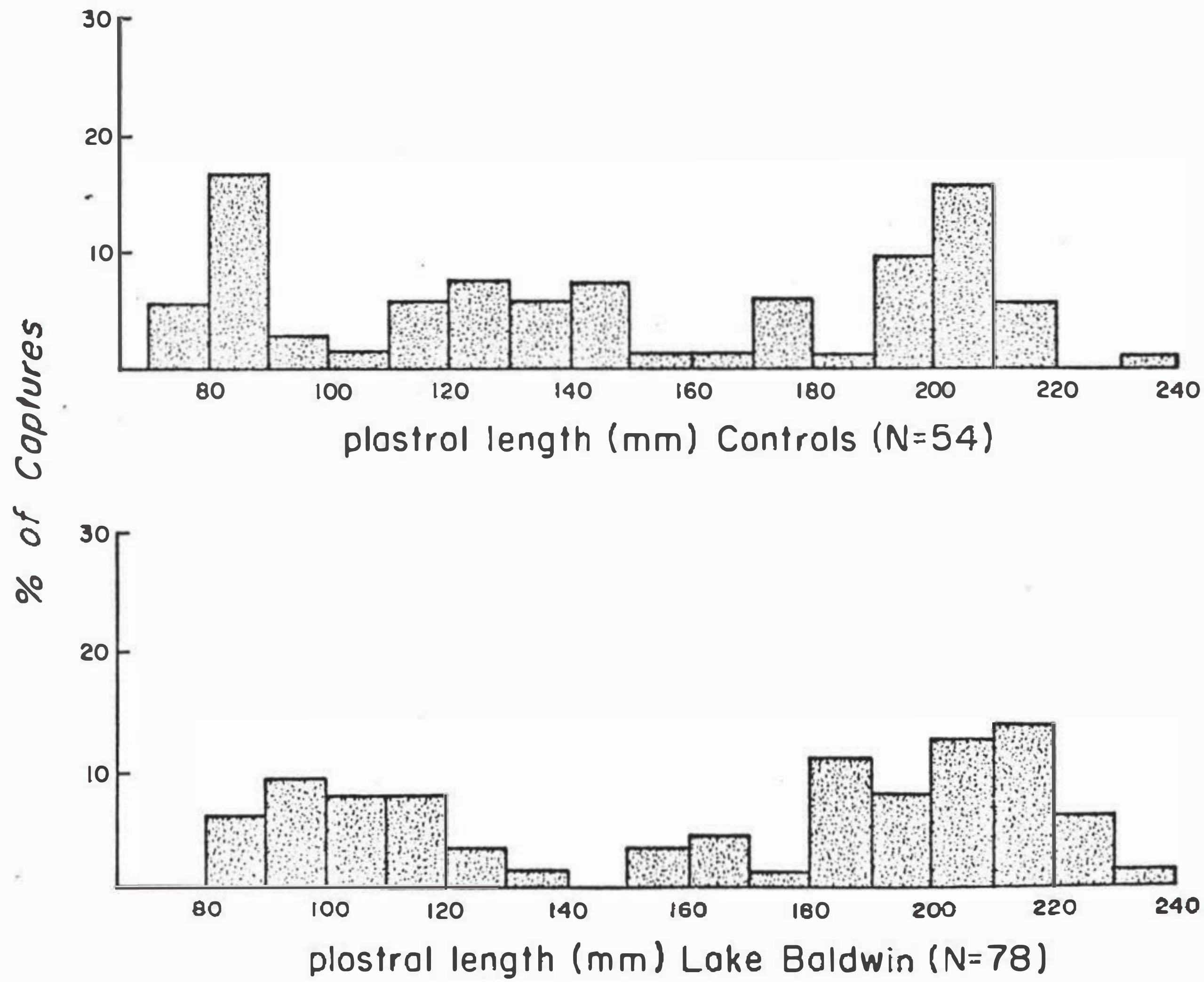

Figure 3. Plastral lengths of actual Lake Baldwin males (solid circles) and actual control males (open circles) vs. age.

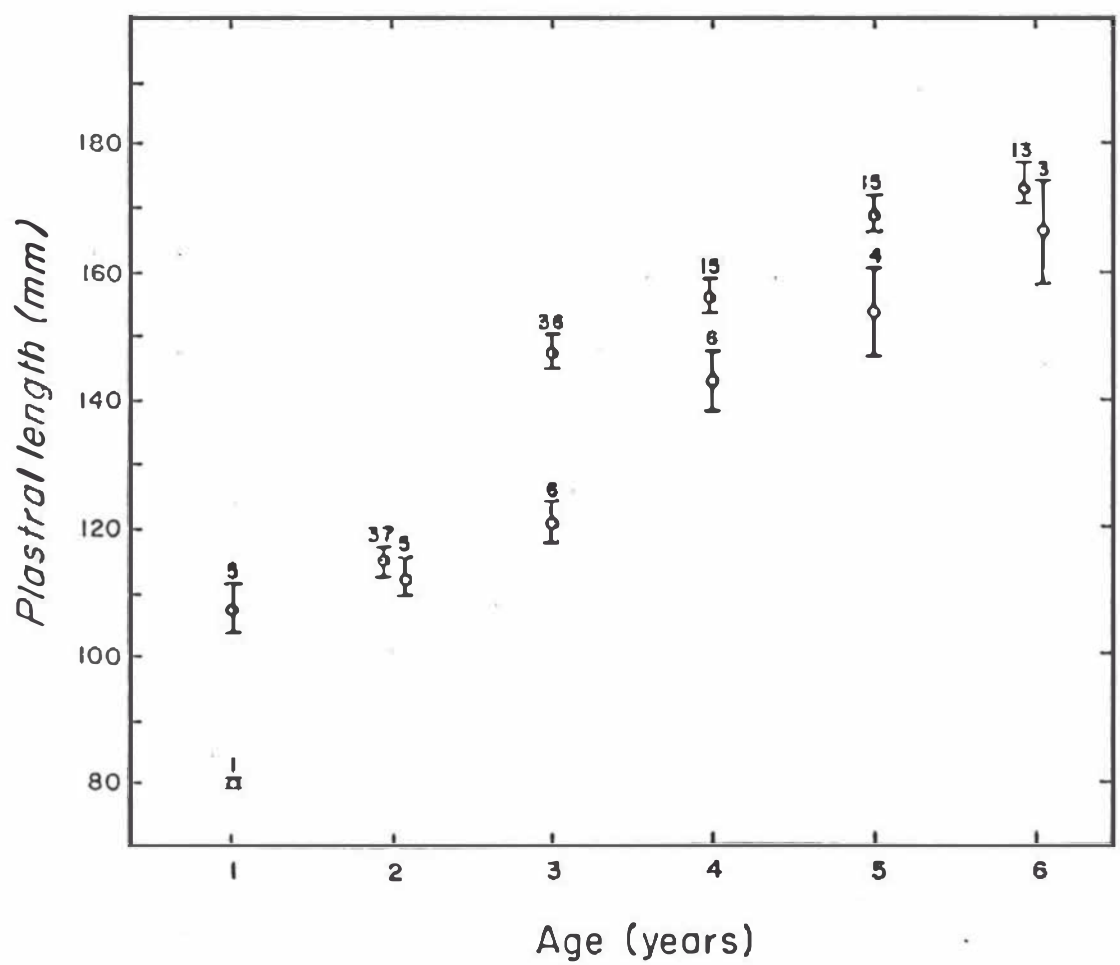

Figure 4. Plastral lengths of actual Lake Baldwin females (solid circles) and actual control females (open circles) vs. age.

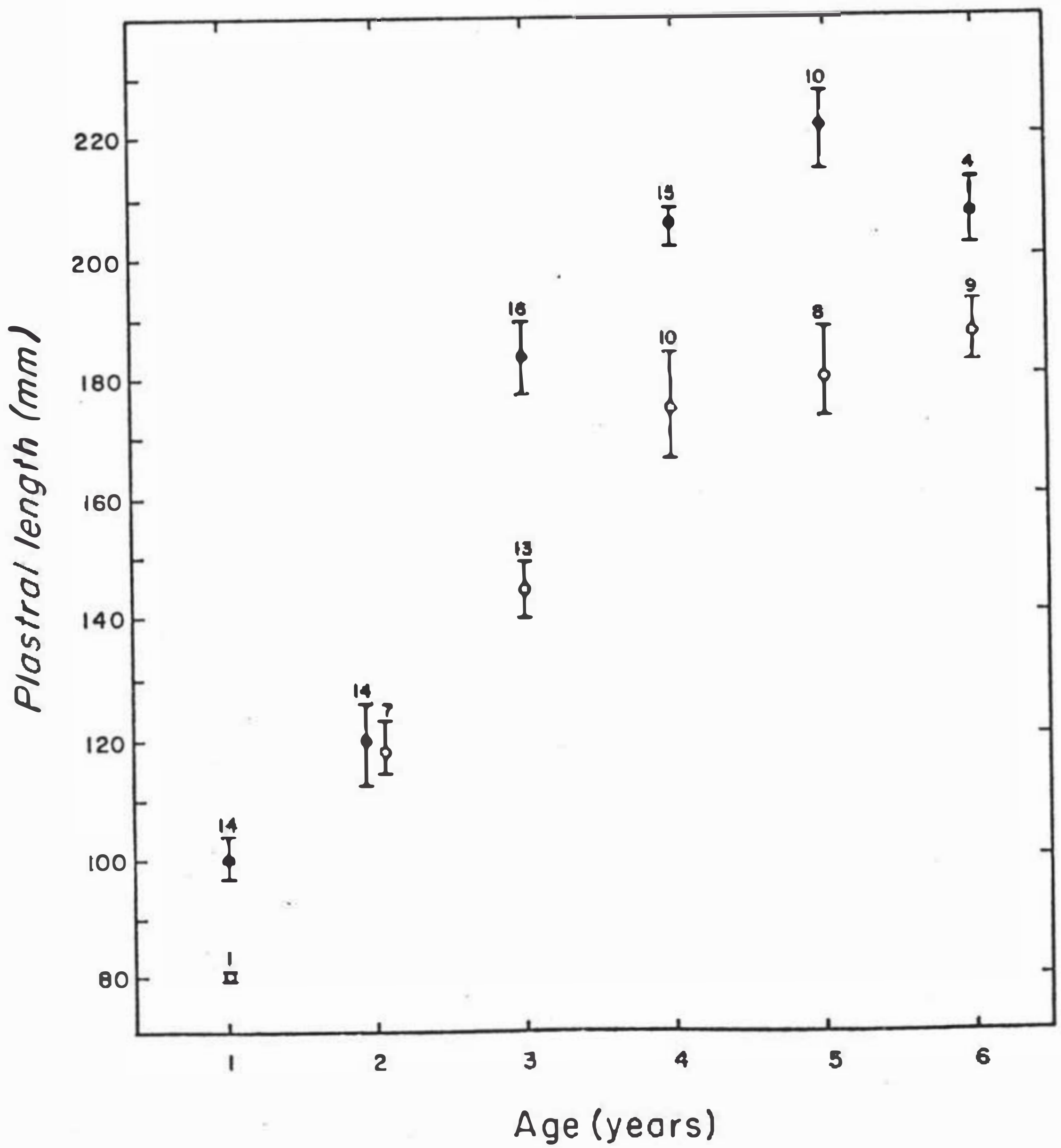

Figure 5. Plastral lengths of "calculated" Lake Baldwin males (solid circles) and "calculated" control males (open circles) vs. age.

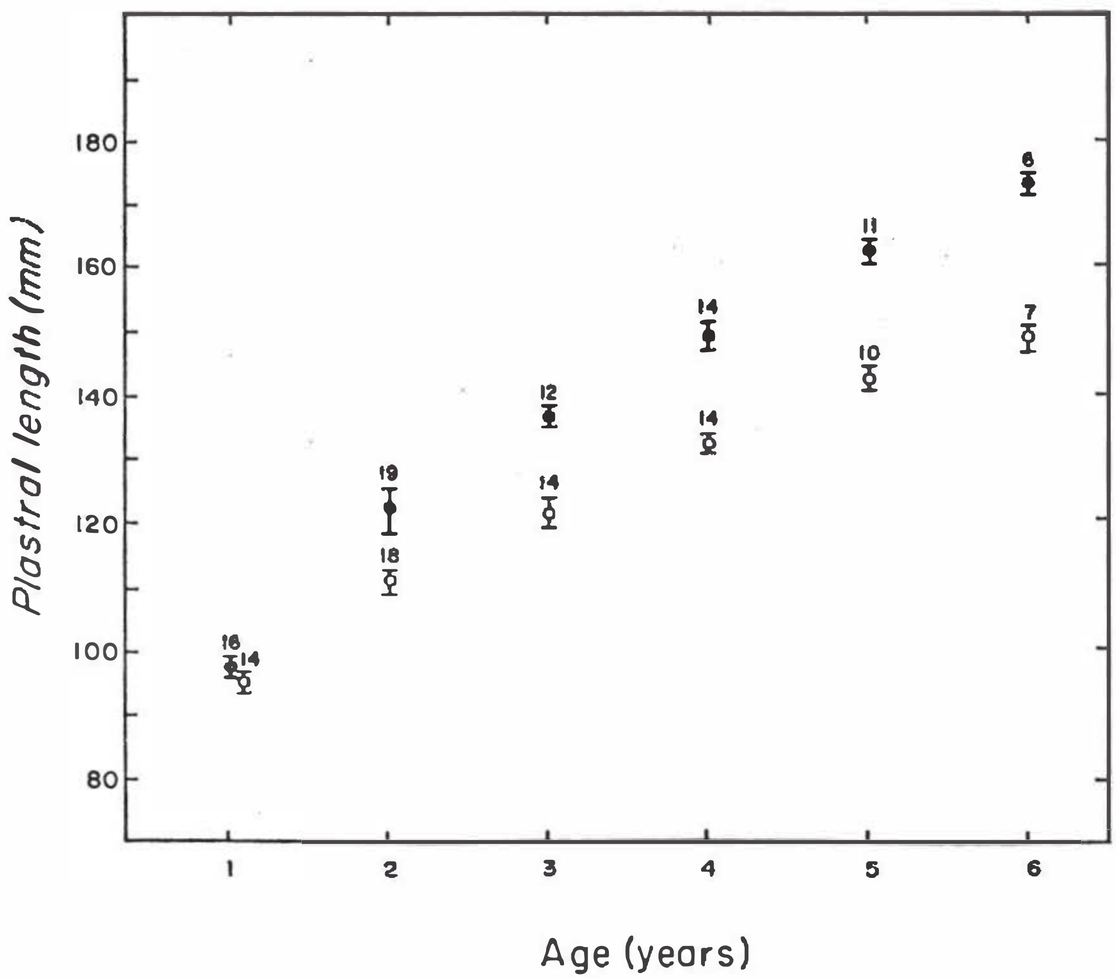

Figure 6. Plastral lengths of "calculated" Lake Baldwin females (solid circles) and "calculated" control females (open circles) vs. age.

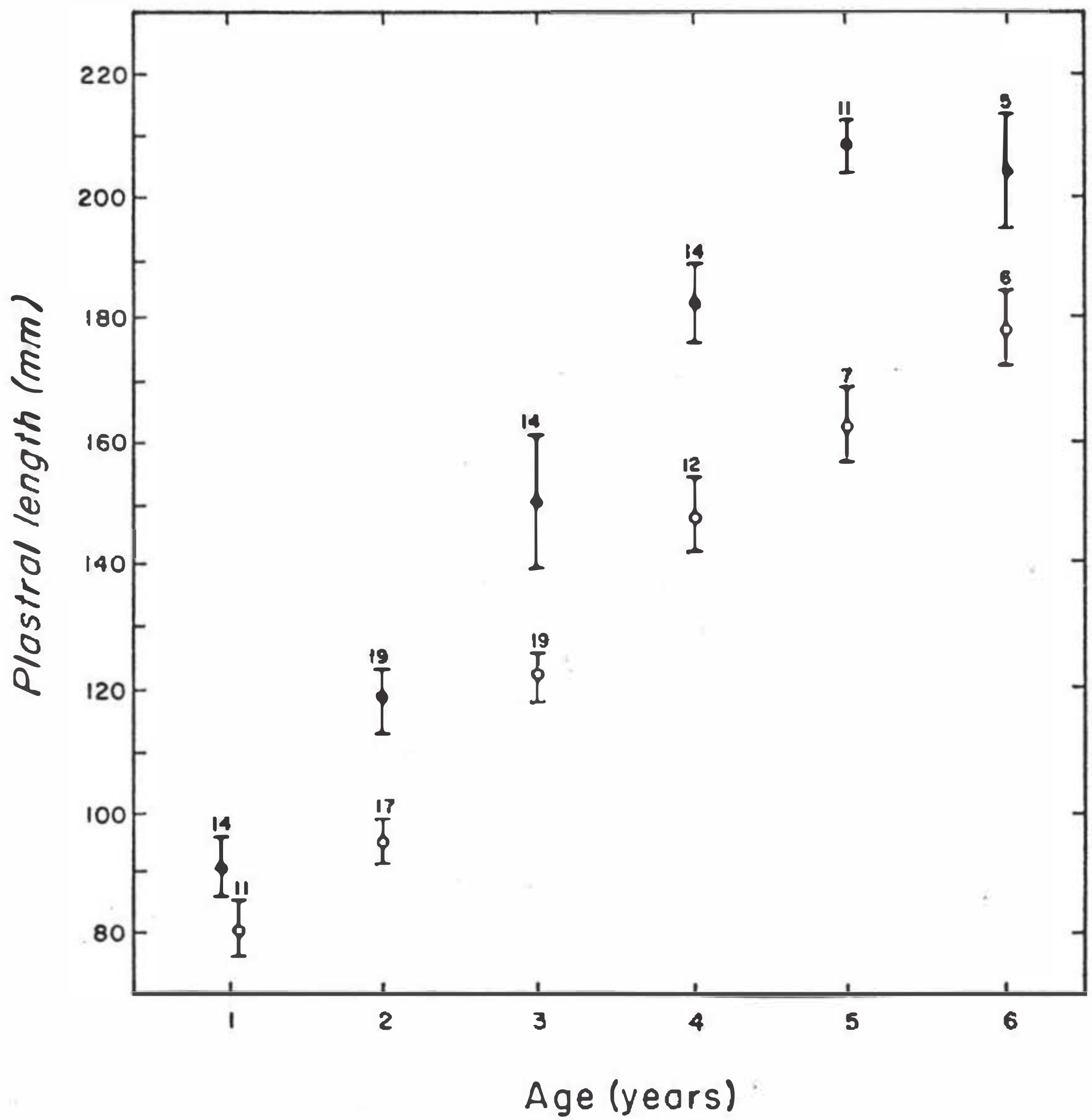

Figure 7. Weight vs. plastral length for males from the control lakes (open circles) and Lake Baldwin (solid circles).

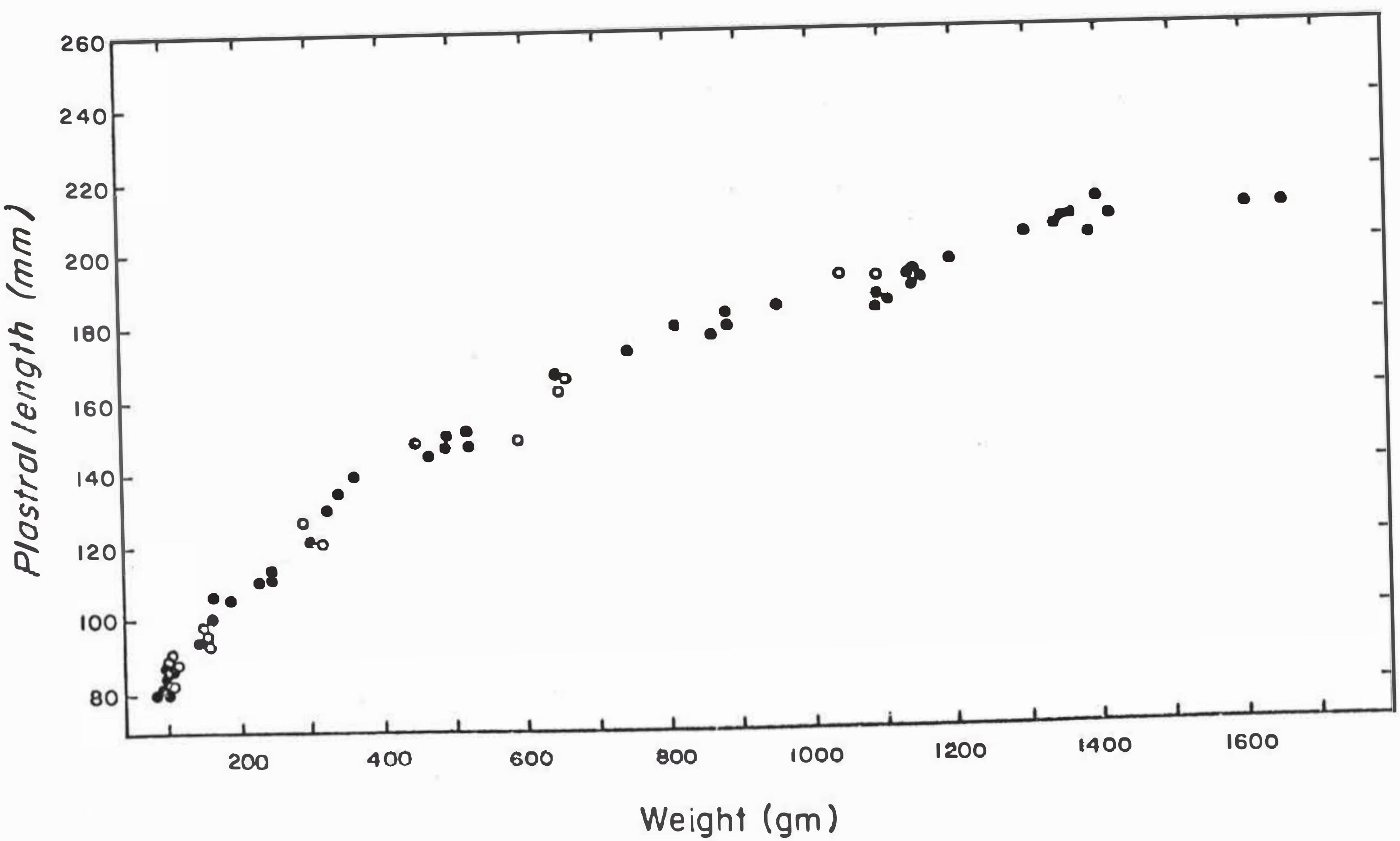

Figure 8. Weight vs. plastral length for females from the control lakes (open circles) and Lake Baldwin (solid circles).