Preliminary growth and nutrition studies with the captive hawksbill turtle, *Eretmochelys imbricata*

EARLY 1970s

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INTRODUCTION

Of the eight species of marine turtles which are known to exist today the hawksbill (*Eretmochelys imbricata*) is probably the most endangered with extinction. Commercial exploitation for "tortoise-shell" has been the principal factor in placing this animal in such an undesirable position. Although the hawksbill's natural history has to some extent been defined (Carr *et al.* 1966), considerable knowledge is lacking concerning the requirements necessary for captive culture, particularly with respect to the areas of reproduction, nutrition and disease. With the continuing declines in natural populations, it has become increasingly important that baseline data relating to these fields be collected. Although the life cycle has not yet been completed with any of the marine turtles in captivity, studies designed to ascertain the nutritional requirements can proceed by judiciously utilizing animals collected from the wild.

The principal diets of hawksbills held in public aquaria and other display facilities usually consist of chopped fish, squid and other aquatic animals. Such items are attractive and ingestion readily occurs. In the natural environment the hawksbill is also generally considered to be carnivorous. Analyses of juvenile and adult stomach contents have revealed that crustacea and other invertebrates are the principal source of nutrition. A dearth of information, however, exists on the natural feeding habits of the hatchling due to the absence of contact with man after emerging from the nest and entering the ocean at the natal beach. Few studies have been conducted on the nutrition and growth of the young captive hawksbill (McVey, 1971; Witzel,1972). The present preliminary study was therefore initiated to evaluate the growth promoting abilities of both natural and formulated diets fed to young hawksbills held in captivity.

EXPERIMENTAL PROCEDURE

Two hundred newly hatched hawksbills averaging 41 mm straight line carapace length and 30 mm straight line carapace width were collected on February 14, 1972 from a natural nest on Nuulua Islet (14° 2' S 172° 21' W), Western Samoa. Initial weights were not taken due to the absence of a scale. At 24 days of age 20 of these animals were transported to Hawaii for nutrition and growth studies while remaining numbers were subsequently released. Upon arrival individuals were found to average 16.4 g in weight, 47 mm in length and 38 mm in width. Prior to shipment animals were reported to have been fed chopped fish (unknown species) and clams (*Penna* sp.), while during a subsequent 14 day adjustment period they received combinations of chopped smelt (*Hypomerus* sp.), squid (*Loligo* sp.) and shrimp (*Penaeus* sp.). Immediately preceeding the start of the experiment 16 animals were distributed equally at random into four 85 l aquaria fitted with recirculating power filters (Dynaflow 425, Maywood, New Jersey). Individuals in each group ranged from 22-24 g in weight, 50-51 mm in length and 40-42 mm in width. Aquaria were maintained under laboratory conditions which provided 13 hours of light per day. Activated charcoal and fiber material were replaced in the filters as necessary and sea water was changed weekly. Minimum and maximum air temperature readings taken daily showed an average minimum of 21°C during the cooler months with an average maximum of 28°C. During the warmer months the minimum averaged 23°C and the maximum 32°C. Experimental diets and ingredients used in the study are displayed in Table 1. Group 1 received diet 305 mixed with 45% frozen squid (305-Squid). Ingredients were processed several times through a meat chopper fitted with a die containing 4 mm holes. The resultant soft extruded strands of feed exhibited satisfactory water stability. Preliminary tests indicated that diets 305 and 303 would not remain stable when mixed into a dough with water alone and extruded. Oven drying produced a hard stable pellet, however, this was rejected by the young turtles. The use of squid as both a binder and nutrient source therefore provided a reasonable method to introduce experimental feedstuffs. Group 3 received diet 303 mixed with 45% squid (303-Squid) in a manner similar to the preparation of 305-Squid. After three weeks, this group was changed to Oregon Moist Pellets which had been coated with raw blended chicken egg and steamed briefly to enhance stability. After three more weeks group 3 received diet 305 mixed with frozen chicken viscera (305-Viscera) until the end of the study. Group 2 received chopped smelt and squid throughout the experiment while group 4 received these items for the first 24 weeks after which diet 321 was fed. Due to the presence of high gluten wheat flour, diet 321 displayed satisfactory stability after adding 40% water and processing through the meat chopper. All feeds were kept frozen until the day before use, at which time an appropriate quantity was thawed under refrigeration.

In order to maintain water quality in the aquaria, all feeding was carried out in separate containers measuring 30 cm in diameter. Approximately 5 cm of water was placed in each container thus enabling the animals to readily ingest feed particles on the bottom. When the water became cloudy feeding would stop, therefore, water was changed two or three times as needed during a feeding period. Initially the young turtles were fed in sea water, however, this was gradually diluted with fresh water. After 6 weeks fresh water was used exclusively for feeding purposes.

During the early part of the experiment three feedings a day were conducted. As the animals grew older this was reduced to two times a day, once in the morning (0900-1100 hours) and once in the evening (1800-2000 hours). After 15 weeks food was offered only once daily in the evening. Uneaten food was collected and subtracted from the amount offered in order to determine apparent feed consumption. Individual body weights were obtained weekly and carapace measurements were made at four week intervals.

RESULTS AND DISCUSSION

The mean body weight gains by three week periods are shown in Table 2. ~~The group receiving~~ (305-~~squid~~) grew at a greater rate than any of the other treatment groups. This was true for carapace length and width (Figures 1 and 2) as well for body weight gains. There was little difference in the gain of group 3 during periods 1 (303-~~squid~~) and 2 (Oregon Moist Pellets) when compared to group 1 ~~which received 305-squid~~. There was also very little difference in the rate of gain between groups 1 and 3 from the third through the sixth periods, however, group 1 continued to increase its gain in each subsequent period while group 3 as well as 2 and 4 tended to slow up in their rate of gain.

Considerable variation existed between the two groups receiving smelt and squid. Turtles in group 4 grew so poorly during the first two periods that a wider variety of foods had to be offered (e.g. shrimp, tuna flesh) as well as more frequent feedings. Under such ministrations they regained their appetites after two weeks and were returned to the original diet. By comparison, group 2 made good gains for the first three periods. The rate of gain decreased, however, during the fourth period, but gradually increased thereafter. At the end of the eighth period when the rate of gain of the two ~~smelt-squid~~ groups were approximately the same, group 4 was changed to ~~prepared~~ diet 321. The rate of gain of this group for the ninth period was depressed somewhat as a result of this change. After ~~an adjustment~~ to the feed ~~was made~~, gain increased during the tenth period.

Figures 1 and 2 show the relative carapace lengths and width s of the experimental groups at four week intervals, while Figure 3 compares the body weights over the same period. The ratio between the final carapace length and width was fairly constant for all groups, averaging between 1.23 and 1.25. The percent increase in carapace lengths for the entire experimental period was very similar to the percent increase in carapace width. While both carapace length and carapace width were related to body weight, the percent increase in body weight for all treatment groups was much greater than the percent increase in carapace dimensions. This observation suggests that body weight gain is a more sensitive measure of treatment effects than are carapace measurements.

Table 3 displays the mean daily dry matter feed consumption and feed conversion values for each three week period. During periods 2 through 5 feed measurements taken at each of the two daily feedings revealed that 65% of the total was consumed in the evening. Although very little is known about the feeding behavior of young hawksbills in the wild, greater feed consumption in captivity during the evening hours may reflect the animals natural habits.

The groups receiving the formulated diets were generally less efficient in their food utilization than were the groups receiving diets of smelt and squid. The efficiency of feed utilization of group 1 (305-Squid) was fairly uniform throughout the study averaging 1.1 of dry feed consumed per gram of gain in body weight. Group 3 which received diet 305-Viscera was less efficient with an average feed conversion of 1.5. The feed conversion of groups 2 and 4 averaged 1.0 and 0.9 of smelt and squid (dry weight) per gram of body weight gain for groups 2 and 4, respectively. The first period after group 4 was changed to diet 321 the feed conversion was much poorer, although the efficiency of utilization greatly improved during the following period, suggesting an adaptation to the formulated feed. This also appeared to be true for groups 1 and 3 which had poorer feed conversion for the first period than during the subsequent periods.

McVey (1971) reported that two groups of 20 newly hatched hawksbills grew from 12.3 g to 361 g in 180 days when reared in 3.7 m tanks and fed on a mixed diet of tuna, sardines and benthic algae. Very little of the algae was consumed. Growth rates were slower in the present experiment since at 185 days of age (period 7) groups 1, 2, 3 and 4 averaged only 295, 198, 269 and 235 g respectively. Witzell (1972) indicated that hatchling hawksbills gain between 100 and 120% in weight during the first four weeks in captivity. Diets consisted of varying amounts of chopped fresh fish, fish eggs and intestines, razor clams and sea urchins. Hatchlings used in the present study only weighted 16.4 g when received at 24 days of age, therefore suggesting that growth during these early days may have been less than maximum. Stress during this period may have been responsible for the decreased gains during subsequent months. Temperature may also have been a critical factor. Although this data was not presented in McVeys (1971) work, the lower latitude of his experiment (Koror, Palau-7° N) was probably considerably warmer than that of Hawaii (21 ° N).

Table 1. Percent composition of experimental diets ~~and ingredients~~

Ingredient	303	305	321
	[illegible]	[illegible]	[illegible]
Corn, ground (8.9% protein)	36.9	31.35	25.65
Wheat flour, high gluten (18.6% protein)	[illegible]	[illegible]	20.00
Soybean meal (44% protein)	50.9	50.00	38.10
Tuna meal (54% protein)	5.0	10.00	10.00
Meat and bone meal (45% protein)	2.5	5.00	5.00
Alfalfa meal, dehydrated (17% protein)	3.0	3.00	[illegible]
Defluorinated phosphate	1.0	[illegible]	[illegible]
Salt, iodized	0.4	0.40	0.25
Microingredient mix	0.25[a]	0.25[a]	1.00[b]
DL methionine	0.1	[illegible]	[illegible]
Calculated protein	30.0	32.95	30.41

	Dry matter	Protein
Squid	21.1	14.7
Smelt	23.5	18.6
Chicken viscera	28.9	

odd

a Microingredient mix provided the following in mg or units/kg: vitamin A, 8818 I.U.; vitamin D_3, 2205 I.C.U.; vitamin E, 8.3 I. U.; riboflavin, 4.4; d-Ca pantothenate, 8.1; niacin, 33.1; choline chloride, 440.9; thiamine, 2.2; folic acid, 0.33; vitamin B_{12}, 0.011; BHT, 125; menadione sodium bisulfite, 2.2; Mn, 60; I, 1.2; Fe, 19.8; Cu, 2; Co, 0.2; and Zn, 44.1.

b Microingredient mix provided the following in mg or units/kg: vitamin A, 11000 I.U.; vitamin D_3, 1320 I.C.U.; vitamin E, 440 I.U.; riboflavin, 44; d Ca pantothenate, 88; niacin, 165; thiamin, 22; folic acid, 6.6; vitamin B_{12}, .055; menadione sodium bisulfite, 5.5; pyridoxine, 22; biotin, .55; ascorbic acid, 880; inositol, 880; PABA, 880; and ethoxyquin, 330.

Summary and Conclusion

Young hawksbill turtles, 24 days of age, were reared in 85 l aquaria for 210 days and fed either a mixture of chopped frozen squid (Loligo sp) and chopped frozen smelt (Hypomerus sp), or a mixture comprising a formulation using common feedstuffs mixed with 45% frozen squid (diet 305-S) or frozen chicken viscera (diet 305-V). In addition, one group of turtles received only a formulated diet (321) for the final 6 weeks of the study.

All groups made satisfactory gains, although the animals fed diet 305-S gained at a greater rate than all other treatment groups. The animals receiving the chicken viscera diet grew at an equivalent rate to those fed 305-S until the 7th three-week period when their rate of gain slowed. The group receiving the complete formulated diet 321 continued to gain throughout the 6-week period.

Feed efficiency was generally superior for the control groups receiving squid and smelt followed by 305-S, 305-V, and 321.

The results of this study demonstrate that young hawksbill turtles can be adapted to aquaria conditions and trained to accept diets formulated from commonly available commercial feedstuffs. This makes it possible to study the nutritional requirements of the hawksbill utilizing inexpensive ingredients. The results with diet 321 suggests that this or a similar low cost formulation may be used by conservation-minded groups or individuals raising hatchlings past the critical stage to increase the natural stocks of this species.

Table 3. Mean daily dry matter feed consumption and feed conversion of hawksbill turtles fed different experimental diets.

Group-treatment	1	2	3	4	5	6	7	8	9	10	Mean
	Three-week periods										
				Daily consumption, grams							
1 305-~~Squid~~	c	1.0	1.4	1.4	2.4	3.3	4.7	7.5	9.1	8.7	
2 Smelt-squid ~~Control 1~~	c	0.5	0.7	0.5	1.2	1.7	2.1	4.2	6.0[a]	4.5[a]	
3 305-~~Viscera~~	b,c	b,c	1.3	3.2	2.4	3.2	4.6	6.1	8.5	6.1	
4 ~~Control 2~~ Smelt-squid	c	c	c	1.2	1.7	2.1	2.2	4.5	5.8	5.8	
				Feed/gain[d]							
1 ~~305-Squid~~ 305-Squid	c	1.4	1.2	0.9	1.1	1.1	1.2	1.1	1.1	0.9	1.1
2 Control 1 ~~Smelt-squid~~	c	0.5	0.6	1.4	0.9	1.0	0.9	1.2	1.7[a]	0.9[a]	1.0
3 305 ~~Viscera~~	b,c	b,c	1.1	2.3	1.1	1.1	1.5	1.4	1.7	1.2	1.5
4 Control 2 ~~Smelt-squid~~	c	c	c	0.8	0.9	0.9	0.9	1.1	1.0	1.0	0.9

a Group 2 [illegible] two periods

b Group 3 received 303-squid for the first period, Oregon Moist Pellets for the second period, and thereafter received 305-Viscera

d Feed consumed (dry matter basis) per unit gain.

c Data not taken

lift for footnotes

Table 2. Mean body weight gain (g.) per 3 week period of young hawksbill turtles fed different experimental diets.

Group - treatment	Three-week periods 1	2	3	4	5	6	7	8	9	10	Total gain
	Mean body weight gain, grams										
1 305-Squid	8	15	24	33	46	63	83	143	174	203	792
2 Smelt-Squid	9	20	24	10	28	36	48	73	75[a]	104[a]	427
3 305-viscera	9[b]	13[b]	24	29	45	62	64	91	105	107	549
4 Smelt-Squid	7	12	21	32	40	49	51	86	122	122	542

[a] Group 2 received diet 321 for the last 2 periods

[b] Group 3 received 303-Squid for the first period, Oregon Moist Pellets for the second period, and thereafter received 305-Viscera.

7 pd
171 da

272
175
246
212

8 pd
193 day

415
248
337
298
324

Table 2. Body weight gain and feed conversion of young Hawksbill turtles fed different experimental diets.

Treatment		1	2	3	4	5	6	7	8	9	10	Total
		Three-week Periods										
Mean body weight gain, g.												
1	305S 1/	8	15	24	33	46	63	83	143	174	203	792
2	305V 2/	9 2/	13 2/	24	29	45	62	64	91	105	107	549
3	Control 1	7	12	21	32	40	49	51	86	122	122	542
4	Control 2	9	20	24	10	28	36	48	73	75 5/	104 5/	427
Feed/gain 3/												Mean
1	305S 1/	4/	1.4	1.2	0.9	1.1	1.1	1.2	1.1	1.1	0.9	1.1
2	305V 2/	4/	2.3	1.1	2.3	1.1	1.1	1.5	1.4	1.7	1.2	1.5
3	Control 1	4/	4/	4/	0.8	0.9	0.9	0.9	1.1	1.0	1.0	0.9
4	Control 2	4/	0.5	0.6	1.4	0.9	1.0	0.9	1.2	1.7 5/	0.9 5/	1.0

1/ 305S = diet 305 mixed with 40 to 50% frozen squid.

2/ Group 2 received diet 303 mixed with 40 to 50% frozen squid for the first 3 week period, Oregon moist pellets for the second 3 week period, and thereafter received diet 305 mixed with 40 to 50% frozen chicken viscera.

3/ Feed consumed (dry matter basis) per unit gain.

4/ Data not taken.

5/ Control treatment ~~1 and~~ 2 received diets 321 for last two periods.

Table 1. Composition of Basal Diets

Ingredient	303	305	321
	%	(%)	(%)
Corn, ground	36.9	21.35	25.65
Wheat flour, high gluten	----	-----	20.00
Soybean meal (44% protein)	50.9	60.00	38.10
Tuna meal (54% protein)	5.0	10.00	10.00
Meat and bone meal (45% protein)	2.5	5.00	5.00
Alfalfa meal, dehydrated (17% protein)	3.0	3.00	-----
Defluorinated phosphate	1.0	-----	-----
Salt, iodized	0.4	0.40	0.25
Microingredient mix	0.35[1]	0.35[1]	1.00[2]
DL methionine	0.1	-----	-----
Calculated protein			

1. Microingredient mix provided the following in mg or units/kg vitamin A, 8818 I.U.; vitamin D_3, 2205 I.C.U.; vitamin E, 8.3 I. U.; riboflavin, 4.4; d Ca panthothenate, 8.1; niacin, 33.1; choline chloride, 440.9; thiamine, 2.2; folic acid, 0.33; vitamin B_{12}, 0.011; BHT, 125; menadione sodium bisulfite, 2.2; Mn, 60; I, 1.2; Fe, 19.8; Cu, 2; Co, 0.2; and Zn, 44.1. B_{12}

2. Microingredient mix provided the following in mg or units/kg:

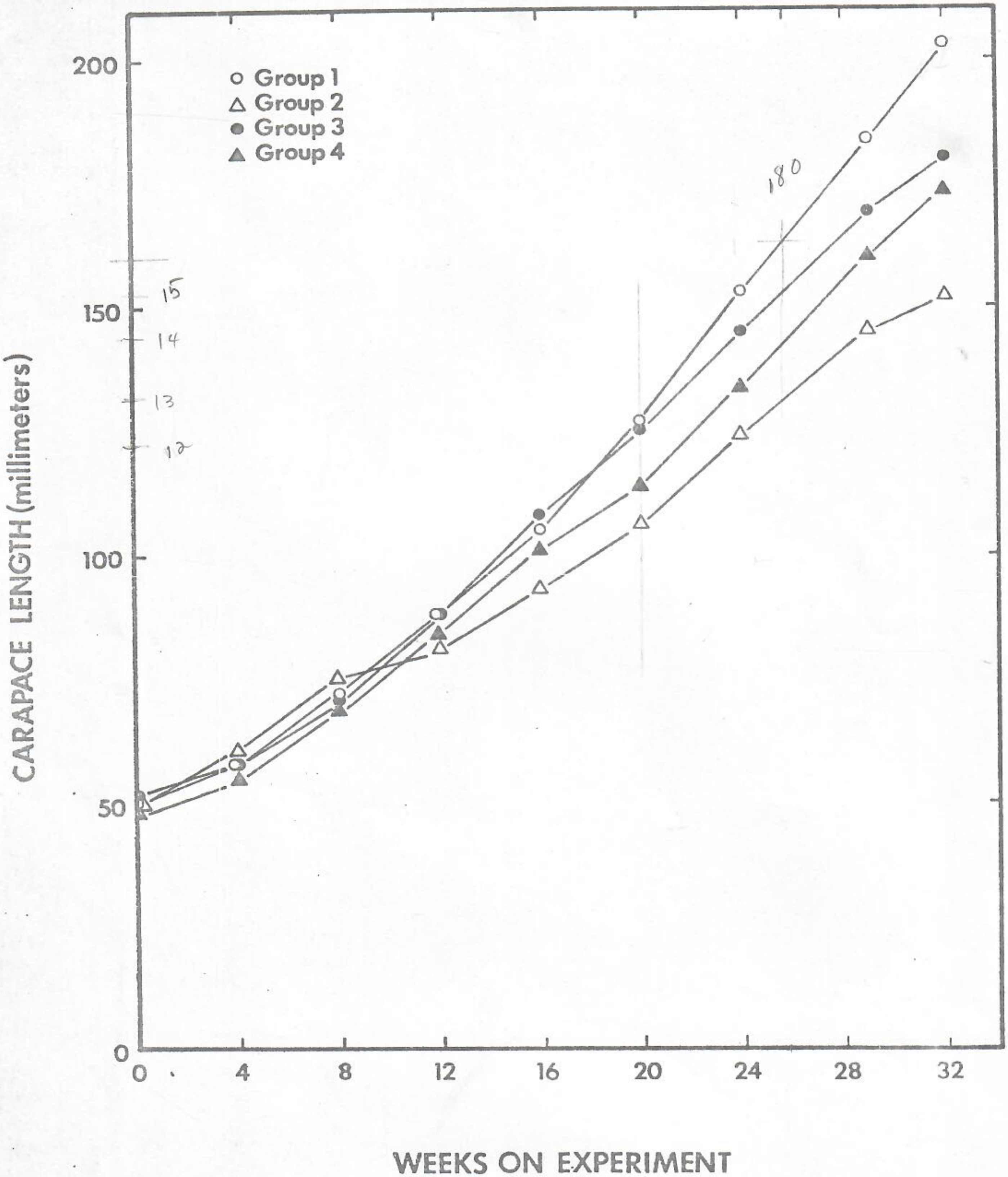

Group 1
Group 2
Group 3
Group 4
CARAPACE LENGTH (millimeters)
200
150
100
50
0
0
4
8
12
16
20
24
28
32
WEEKS ON EXPERIMENT

Fig 1

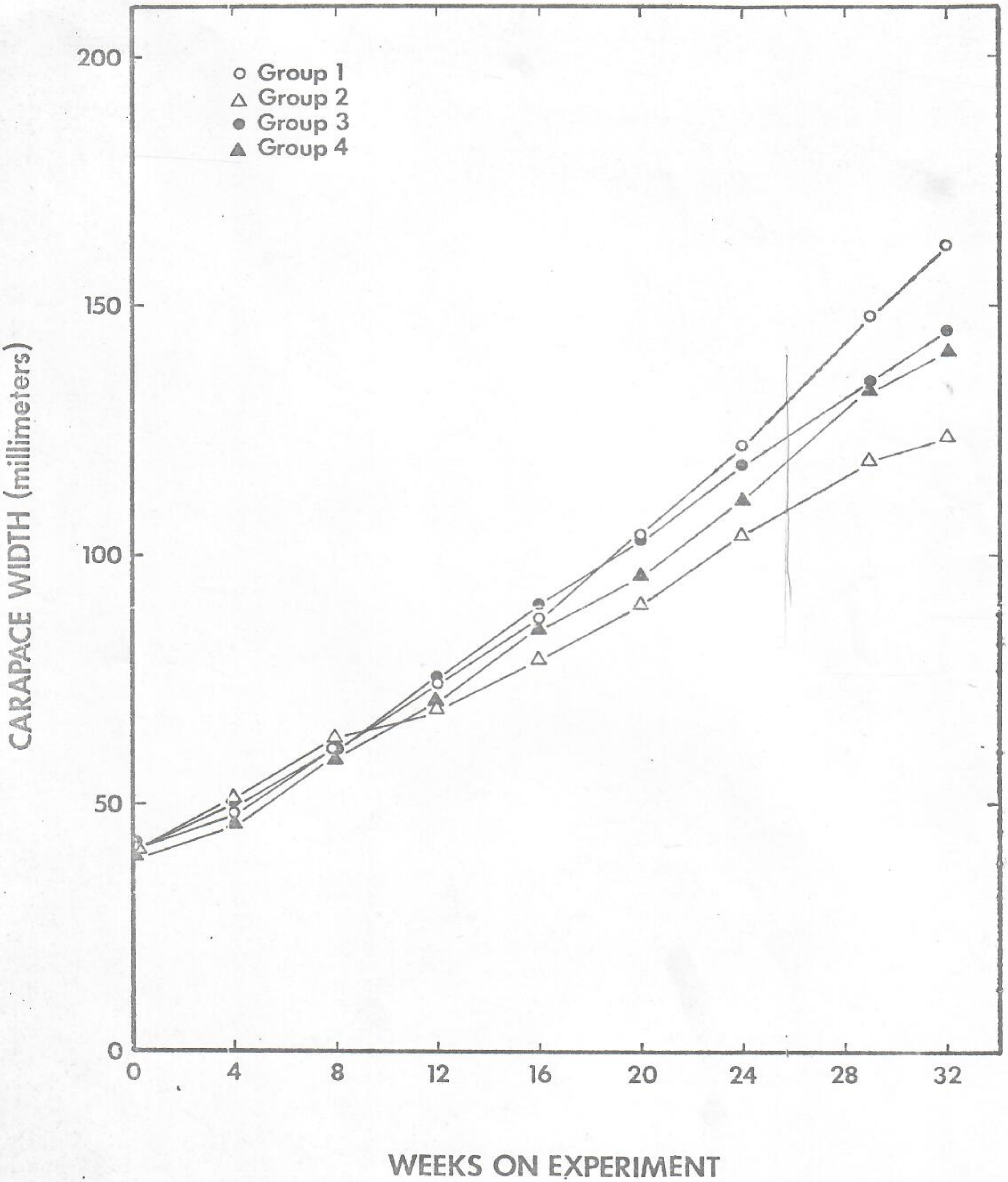
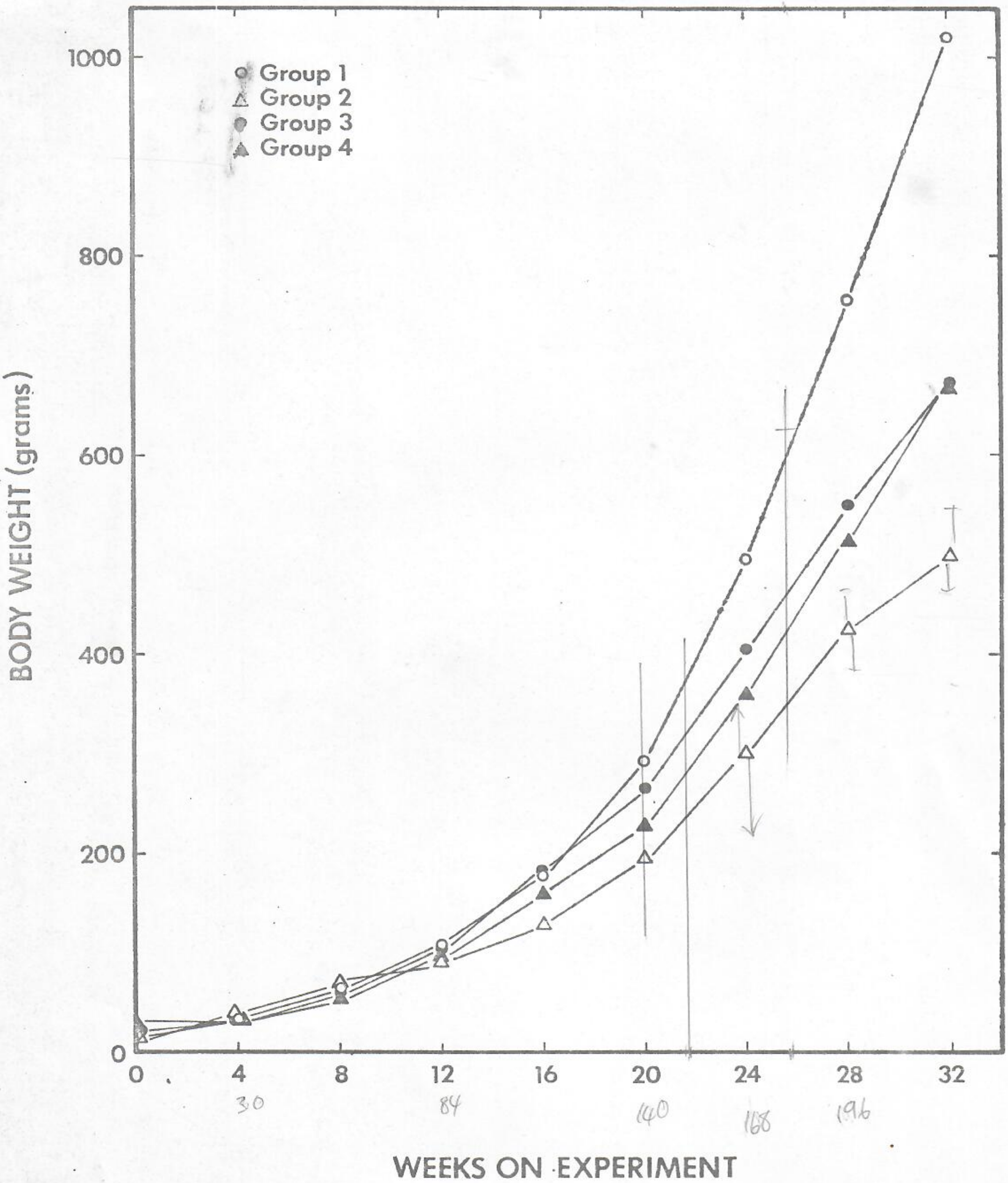

Group 1
Group 2
Group 3
Group 4
CARAPACE WIDTH (millimeters)
200
150
100
50
0
0
4
8
12
16
20
24
28
32
WEEKS ON EXPERIMENT

Fig 2



Group 1
Group 2
Group 3
Group 4
BODY WEIGHT (grams)
1000
800
600
400
200
0
0
4
8
12
16
20
24
28
32
30
84
140
168
196
WEEKS ON EXPERIMENT

Fig-3