

FINAL SCIENTIFIC REPORT
MISSIONS 84-2 and 84-14

Assessment of the queen conch (Strombus gigas)
population and predation studies of hatchery
reared juveniles in Salt River Submarine Canyon,
St. Croix, V. I.

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ABSTRACT

For the past two years studies on queen conch have been on-going in the Salt River Submarine Canyon on St. Croix in the Virgin Islands. This small canyon between 50 and 100 feet (approx. $28,770\text{m}^2$) supports an adult population of well over 300 individuals of which 242 have been tagged, weighed and measured. Because of the continuous saturation diving missions conducted by NOAA's Undersea Research Program in the Hydrolab, observations on this population are frequent. This population has been protected from extensive fishing because of inaccessibility due to depth and a reluctance on the part of local fishermen to disturb the Hydrolab research site in operation for the past eight years.

Patterns of seasonal migration and behavior have become apparent from these continuous observations. During the winter season the conch migrate down the slope and have been found between 80 and 100 feet buried in the sand. It is expected that many may travel considerably deeper as sightings have been made at 150 ft. In March the conch become very active on the grass and algal flats between 50 and 70 ft. Mating and egg laying have been observed from March well into October.

This deep water population is much larger, in length and weight, than any shallow water population previously studied. Deep water populations such as these could represent most of the reproductive capability of the conch in this area. Deep area closures are suggested for similar sites and adult placement in these areas proposed as a management technique to insure continued re-population of shallow waters.

During the December 1984 Hydrolab mission, the introduction of juvenile hatchery reared conch were studied in the canyon. During the initial sampling stages all unprotected juveniles introduced near the reef or on the canyon flats were attacked and killed by hermit crabs of the single species, Dardanus venosus. In agreement with the studies at the University of Miami and the University of

Puerto Rico we find that juveniles (in this study between 40 and 60 mm in length) cannot be introduced into the natural environment and be expected to survive unless they are protected. Of interest, but without present explanation, unprotected juvenile conch released in the vicinity of the habitat, where there was considerable diver and operational activities, were not attacked by preators even when known predators were introduced into cages with juvenile conch.

INTRODUCTION

As queen conch populations decline throughout the Caribbean, hatchery construction and operation are on the rise increasing knowledge of mariculture as an effort to combat a possible crisis in the decline of this valuable fishery species. However, our knowledge in the area of introduction techniques to insure survival of hatchery reared juveniles is essentially non-existent. In fact, predation on juveniles has been found to be so high that caged growout may be the only solution (Iverson, Jory & Bannernot, 1985 and Appeldoorn & Ballantine, 1983). In addition, management of natural populations is either ineffective or non-existent at promoting increases or stabilizing existing populations. Research in juvenile seeding and growout along with effective management techniques must be a primary focus in any plan to enhance conch populations.

Since January of 1984 studies on queen conch have been on-going at Salt River Submarine Canyon, St. Croix in the Virgin Islands as part of the research conducted by the National Undersea Research Program at West Indies Laboratory. In this small submarine canyon between 50 and 100 ft (approximately $28,770 \text{ m}^2$) there is an adult population estimated from capture-recapture studies of well over 300 individuals of which 242 have been tagged, weighed and measured. Our effort has been concentrated on studying this population in this semi-enclosed and protected habitat in order to compare population characteristics of the queen conch below 65 ft. with the many comprehensive studies on this animal in shallower waters. Two Hydrolab saturation diving missions have been devoted to the study of queen conch; mission 84-2 and 84-14 in February and December of 1984. Numerous sightings have also been reported over this 2 year period by aquanauts working on other saturation missions. Many important difference exists in this deep water populations which lead to proposed management recommendations.

METHODS

Study Site

The study site is located in Salt River Submarine Canyon on the north shore of St. Croix in the U. S. Virgin Islands (Fig.1). The canyon begins at the barrier reef outside of the Salt River estuary, where the underwater habitat Hydrolab sat in 51 ft of water, and extends downward reaching a depth of 12,000 ft. The canyon is approximately 360 ft wide and is bounded by a steep vertical wall to the west and gently sloping wall on the east (Josselyn, et al., 1983). The floor of the canyon is composed of medium sand to silt. Halophila decipiens is abundant and is found dispersed in patches throughout the study area. Halimeda and Caulerpa are also present within the canyon between 55 and 65 ft. At depths from 75 to 90 there is a pronounced bottom disturbance by Callianassa (Robblee and McIvor, 1983). Drift material is common in the canyon; Thalassia testudinum, Syringodium filiforme, Halophila decipiens and algae from the genera Dictyota, Dictyopterus, and Dilophus compose most of the drift (Josselyn et al., 1983). Fish herbivores are numerous in the canyon (Robblee and McIvor, 1983), and herbivorous invertebrates are also present, such as the urchins Tripneustes ventricosus and Meioma and of course, the queen conch, Strombus gigas (Coulston, 1984a). Predators of the queen conch found in the study site include, the southern stingray, several species of hermit crabs, eagle rays, apple murex and tulips (Coulston, 1984a).

Tagging

Beginning in February, 1984 queen conch were tagged using electrical ties wrapped around the spire with a Dymo label attached. Most of the ties remained on the animal, but the Dymo labels readily fell off. Beginning in March the method of tagging changed. Holes were drilled through the shell and Floy spaghetti tags were inserted through the holes and Pettit underwater patching compound was

applied on the outside of the shell to secure the tag. This method of tagging, which is very successful, is still being continued on both adults and juveniles.

Population Sampling

The population was sampled at periodic intervals since February of 1984 and regularly at monthly intervals since October of 1984. During saturation mission 84-14 (between November 29 and December 6, 1984) the canyon floor was intensely searched from the habitat to the 100 ft contour line for queen conch. Recaptured marked conch were recorded and unmarked ones were taken to the habitat for tagging and measuring.

During routine sampling periods divers read tags, record depth and activity of the conch and brought unmarked conch to the surface for tagging, weighing and measuring. The conch were then returned to their area of capture. The year has been divided into four periods consisting of three months each for statistical purposes and with observational justification (DEC-JAN-FEB, overwintering; MAR-APR-MAY, up canyon migration; JUN-JUL-AUG, peak activity; and SEP-OCT-NOV, downward canyon migration). During each three month period the conch were marked with different colored flagging tape. Conch recaptured from a previous three month period, as determined by the color of the flagging tape, were also brought to the surface to be re-weighted and re-measured.

Introduction of Hatchery Raised Juveniles

During the seven day saturation mission in December of 1984 hatchery reared juveniles obtained from Tradewinds Industries, Inc. were used to examine predation in the canyon. Covered and uncovered cages constructed of 1/2" mesh hardware cloth were set up as shown in Figure 1. They represented locations close to the reef and mid-canyon which were to be observed at regular intervals. Cages were also placed just outside of the habitat (also close to a reef), in front of the

viewing port for continued 24 hour observations. Table 1 summarizes the experimental design and the number of conch placed in covered and uncovered cages.

On the last day of the mission 65 juvenile conch were tagged and released just outside of the habitat near "A" line. The 4 individuals in covered cage 10 and the 4 individuals in covered cage 8 were also left on the bottom for future observation.

RESULTS

Tagging/Recapture Study

A summary of tagged queen conch capture-recapture data appears in Table 2. Also included in the table is a tagging study initiated by Larson during mission 84-9 (Larson, 1984) where 71 conch were tagged using surveyors flagging tape. We have used these marked conch to estimate an adult population size of 335 individuals in the canyon by the Petersen method (Bower & Zar, 1977). Other calculations made of population size for each routine sampling range from 197 to 335. In all these calculations the number of marked individuals were based on those with permanently secured Floy tags. The low number is probably the result of the conch overwintering below 80 ft. buried in the sand. We know that 242 have been tagged and assume, considering known mortalities, 230 are alive and in the canyon.

Table 2 indicates egg laying and mating by marked conch, sex is noted when it could be easily determined, and mortalities are recorded. The proportion of adults, young adults (where the lip is just beginning to flare) and juveniles are also indicated. Juveniles were not frequently found during routine sampling. The greatest number were found during the December saturation mission, between 80 and 100 ft, buried in the sand. As noted (Table 2), once captured the juveniles are rarely seen again. It will take long periods of searching using saturation diving

to determine if the juveniles spend most of their time buried or they are simply the victims of predation.

Patterns of seasonal migration have become apparent from these continued mark and recapture studies. The overwintering is estimated to begin sometime during the month of November when the water temperature (measured at 50 ft) drops from about 28.5 C to 26.0 C. This overwintering was observed during the December saturation mission when most of the conch were found between 80 and 100 ft buried in the sand. Around March they migrate up the slope and a considerable number of them are found on the grass and algal flats around 65 ft. Because of the inability to spend time at deeper depths searching out the conch, we are not at all certain what the activity is below 80 ft. Sighting by aquanauts do indicate that conch are abundant and reproductively active well below 80 ft. from about March to November.

Salt River Submarine Canyon Population Structure

The Salt River Canyon queen conch population is much larger, in length and weight, than any shallow water population previously studied (Fig. 2). In the adult conch weight is a much better indicator of age as conch decrease in length with age from erosion (Randall, 1964) and we have found no correlation between weight and length. In the juvenile population there is a correlation ($R=.91^{**}$) between length and weight allowing either measurement to be used efficiently to measure conch age. Table 3 summarizes weight and length of adults within each three month period and mean weights and length divided into 1, 2 and 3 year classes as determined by peaks in the frequency distribution (Fig. 3). The hatchery reared juvenile weight and length is also summarized in Table 3.

Observations, with supporting data, indicate that most conch are sexually active March through November. June, July and August seems to be the peak in reproductive activity, aquanauts have reported observing many mating pairs and a

considerable number of egg masses throughout the canyon. One mating pair was observed and one female was seen laying eggs during the December mission. One female was observed laying eggs twice both in June and September. There is no doubt from the number of matings and egg masses observed that this population is an important contributor at providing offsprings for future generations.

Age Determinations of Queen Conch

Continued increases in conch weight over time have allowed us to make estimates of their age. Table 4 provides information of weight gain and length change over varying monthly periods. The average weight gain per month was calculated to be 33.2 ± 20.6 gm ($n=30$). In all cases conch gained weight. The amount of adult weight gain is not a function of age as there is no correlation between amount of weight gained and weight at first capture. Figure 4 provides a graph of the weight gained over time. From the graph, it is apparent that regardless of age, adult conch gain weight at a similar rate.

Consistent weight gain allows us to make reasonable estimates of the age of the conch in the canyon. The heaviest conch captured weighed 4.5 kg. At approximately 3 years of age conch reach sexual maturity, at this time they have an easily recognized thin flared lip (Berg, 1976). The mean weight estimate of 3 year old conch is 999.9 ± 172.2 g. Therefore, using weight gain/month and the assumption that a conch in the canyon weighs about 1 kg at 3 years of age, we determined that the largest conch is possibly 12 years old (using means) with a probable range of 8.4 - 26 years (considering variation).

Juvenile Predation Study

Juvenile queen conch left unprotected in mid-canyon and at the reef-edge were rapidly found and killed by hermit crabs of the single species, Dardanus venosus. We were actually able to observe an attack where the crab held the conch by the

foot and pulled for at least three hours until it was pulled free from the shell. Hermit crabs are presumed to be the major predator of juvenile conch in the canyon. In all cases hermit crabs were found inside the shells although the removal of the conch was never observed. In contrast, only one conch near the habitat was killed during the 6 days of observations even with repeated introductions of D. venosus , Petrochirus diogenes into the cages and the observation that an octopus that moved freely throughout most of the open cages over a several hour period (D. venosus did kill and occupy a shell in one of the covered cages). Introduced predators showed no recognition of the conch nor did the conch exhibit any predator avoidance behavior. This could be due to unnatural substances in the water around the habitat that could interfere with chemoreception (e.g., waste water containing detergents). Diurnal migration has been thought to occur in natural juvenile populations, however hatchery reared juveniles may exhibit modified behavior. The only significant activity that was observed upon introduction of conch to cages was that they moved up against the sides of the cage and stayed there the entire time. After a few days, several of the conch were found partially buried, however, no pattern of burying and surfacing was ever observed.

To date, of the 65 juveniles released, 54 have never been found. Three were recaptured three months later, one of which was found at 115 ft. buried in the sand. Three tags have been found, 2 shells found crushed and two shells were occupied by D. venosus .

Conch left in covered cages mid-canyon and near the reef were alive and buried 3 months later. However, within a week after this observation, all four conch in the reef cage were occupied by D. venosus , the cage was found not to have been closed well letting in predators. The other four caged conch were released at that time. They had grown noticeable larger and had a distinct change in the new shell color and pattern.

DISCUSSION

With the relaxation of fishing pressure in Salt River Submarine Canyon since 1978, queen conch have been able to live basically undisturbed in a natural environment. We have been able to study these animals as a natural area closure experiment. Because the large conch are not being selectively removed by fishermen we have found a much older group of individuals than found by previous investigators. The age of conch in the canyon is well above the maximum ages previously suggested by Berg (1976) and Hesse (1979) with our largest conch being a minimum of 8.4 years of age and a maximum of 26. With continued monthly recaptures and measurement, a much more accurate aging account can be calculated in the future.

The canyon is well populated with reproductively active queen conch almost continually producing egg masses. Many times over divers report numerous mating pairs and egg masses scattered throughout the canyon floor. The egg masses have been mainly found around 70 ft. where the sandy slope begins to drop rapidly. Extremely large masses of eggs have been observed in the canyon, much larger than those normally observed in shallower waters.

Juvenile conch releases are not practical at this time until further techniques are devised to increase their survival, therefore management of natural populations is our immediate concern. It is our recommendation that careful consideration be given to protecting large, reproductively active populations existing in deeper water. Laws preventing the taking of conch with SCUBA gear might be a very efficient management tool to insure the production of larvae for populating shallow as well as deep areas. Area closures in selected deep water sites and the introduction of adults to enhance egg production to these areas, if the carrying capacity allows, can also be considered as management techniques. The continued study of the Salt River Canyon population and search for similar

conch enriched areas, or potentially conch enrichment areas, is planned with the hope of offering a more complete and detailed management plan in the future.

ACKNOWLEDGEMENTS

This research was supported by the National Oceanic and Atmospheric Agency Grant #NA85-AA-H-UR018 and is contribution #6 to the National Undersea Research Program.

Special thanks are due to Leroy Creswell and Trade Winds Industries, Inc. for providing juveniles for the predation study, to the operational staff of Hydrolab: Dr. William Schane, Richard Rounds, Bruce Nyden, Richard Campagna, Beth Dutton and support divers Flint Stultz, Paul Preston and Cary Humphries. We also greatly appreciate the assistance of Dr. Susan Williams, surface scientist during mission 84-14 and the many aquanauts and support divers that provided sighting records while working in the canyon.

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Fig. 1. Topographical Canyon Map with cage locations and identification numbers shown. Upper left: Location of Salt River Submarine Canyon on St. Croix. Upper right: Location of Salt River Submarine Canyon and associated Salt River Bay.

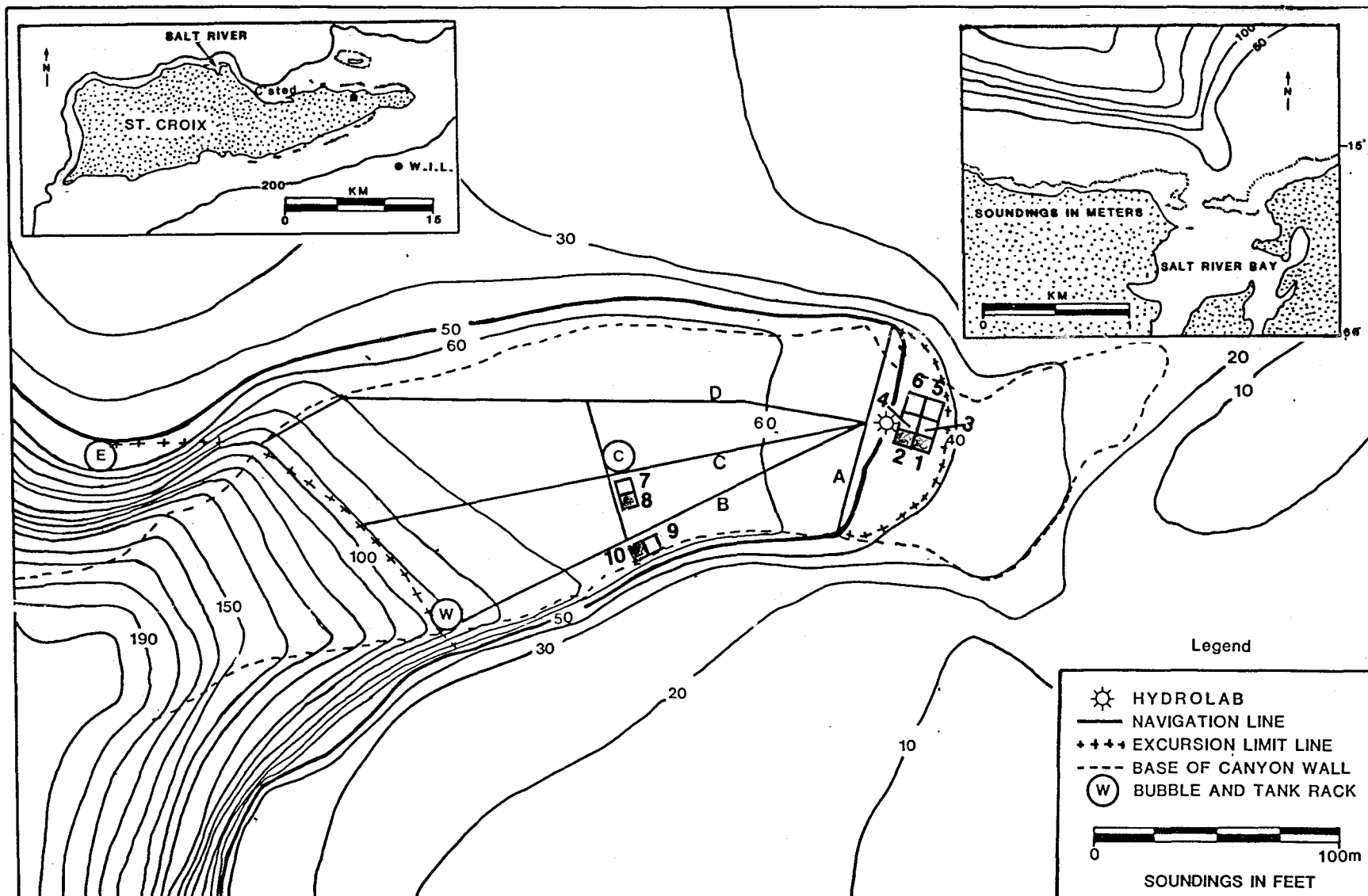


Fig. 2. Mean and upper range of conch shell length from Salt River Submarine Canyon population (Hurley, 1980; Williams, 1983; Coulston 1984 and 1985 samples) compared to other studies (Randall, 1965 and Berg, 1976).

SHELL LENGTH (cm)

STUDY

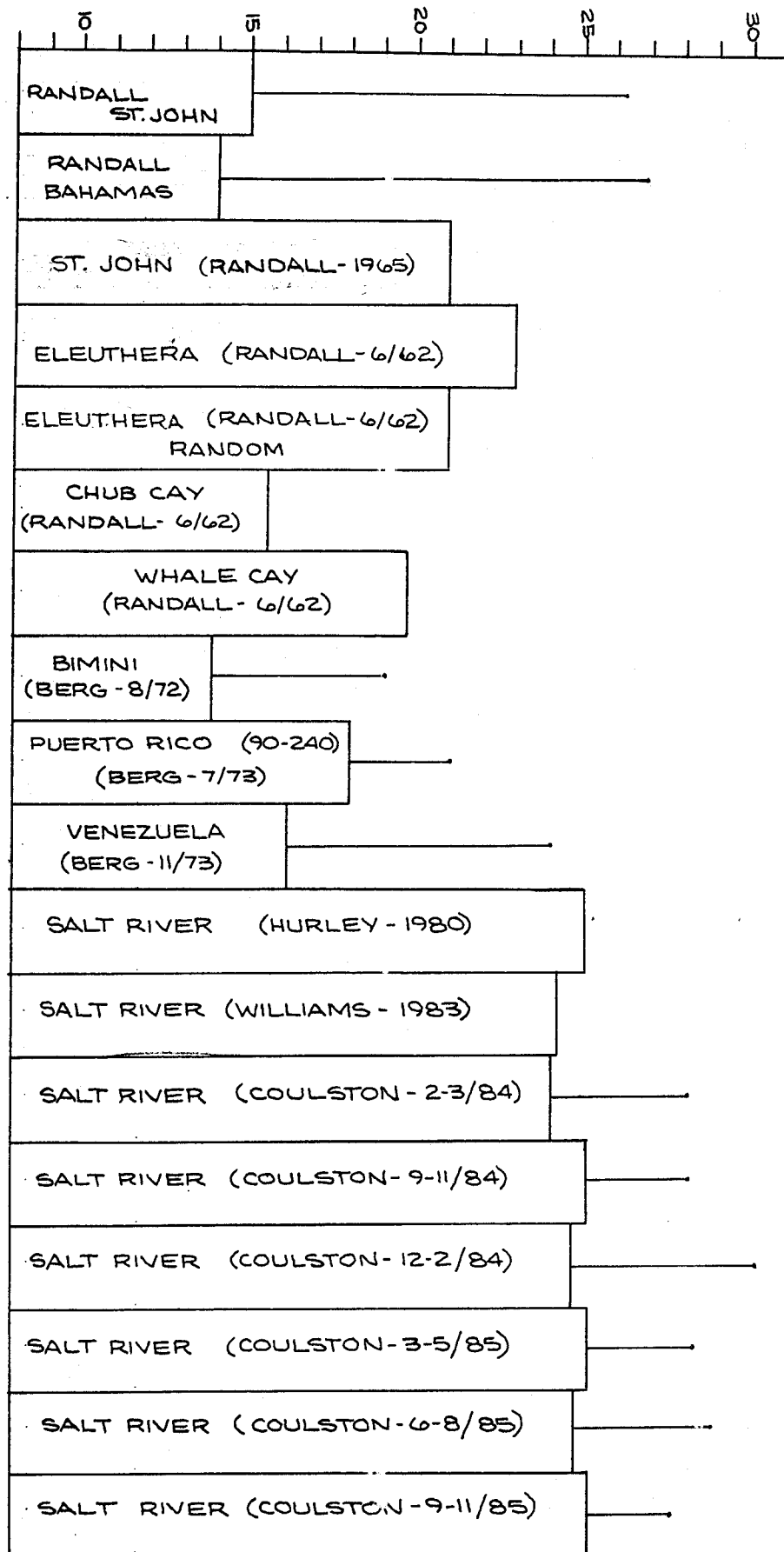


Fig. 3. Frequency distribution of queen conch weights from the Salt River Submarine Canyon population sampled in 1984 and 1985 compared to the St. John population sampled by Randall (1965).

FREQUENCY

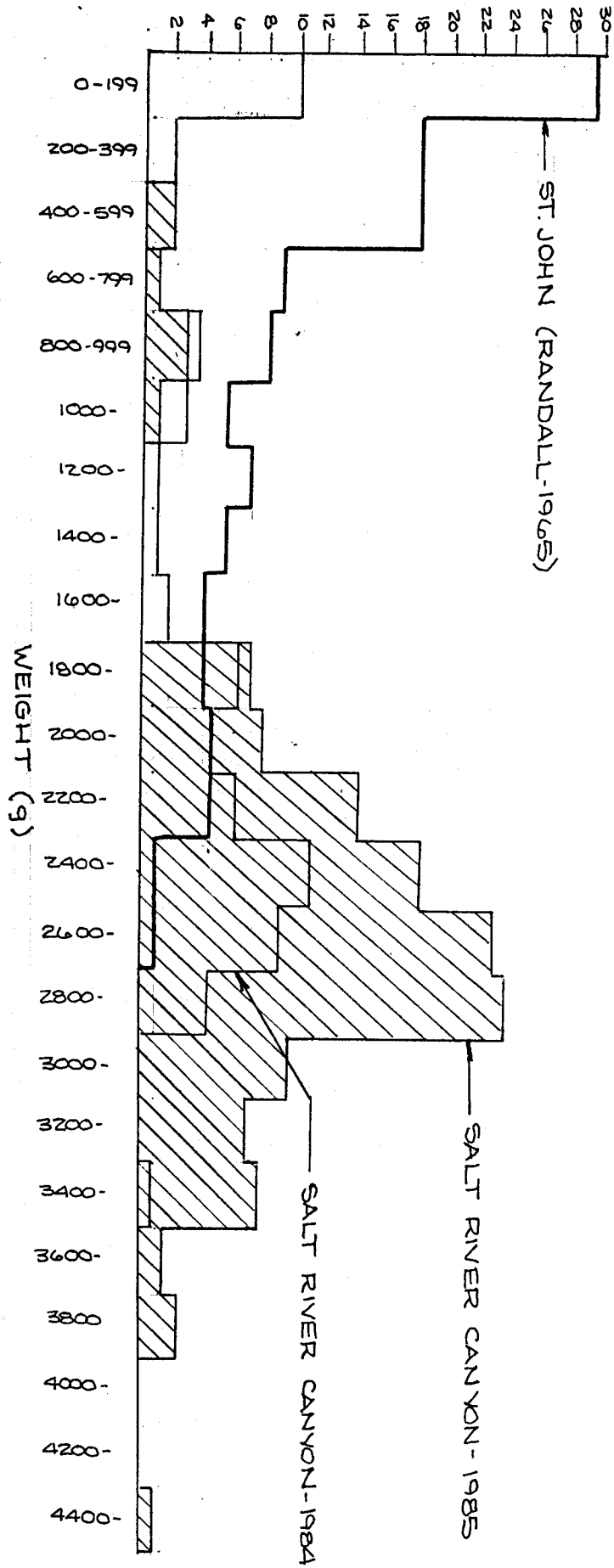


Fig. 4. Change in weight of queen conch over
indicated periods of time.

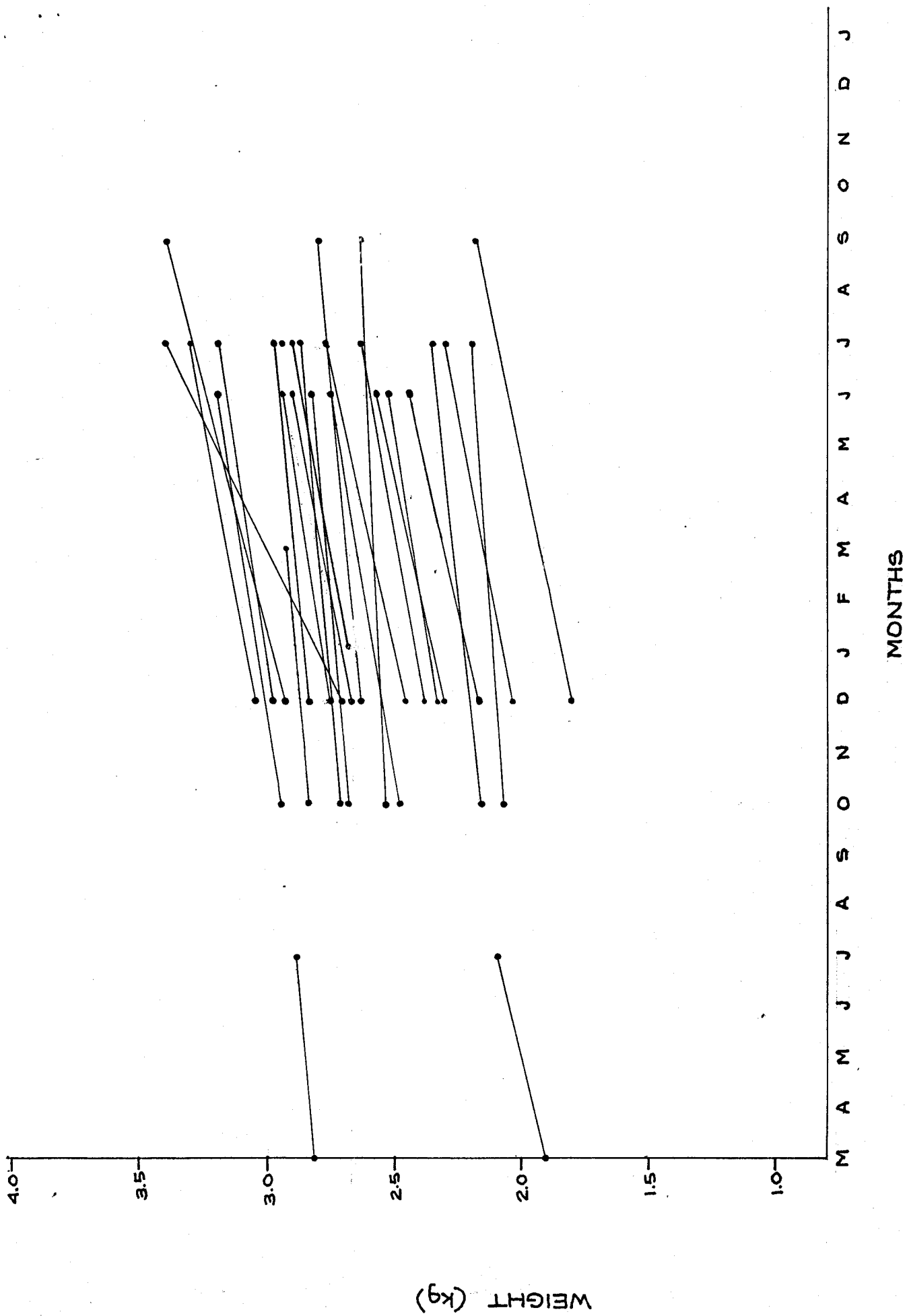


Table 1. Summary of hatchery reared juvenile conch predation study.

<u>LOCATION/CAGE#</u>	<u>NUMBER OF CONCH</u>	<u>DESCRIPTION</u>
<u>COVERED CAGES</u>		
Habitat (#1)	5	5 of 5 unharmed after 6 days, all remained on the surface, 2 partially buried on day 6
Habitat (#2)	10	8 or 10 unharmed after 6 days, 1 unaccounted for, 1 occupied by hermit crab
Mid-Canyon (#8)	4	4 of 4 unharmed after 5 days, all remained on the surface, 1 partially buried day 5
Reef-edge (#10)	4	4 of 4 unharmed after 5 days, all remained on the surface, 1 partially buried on day 3
<u>UNCOVERED CAGES</u>		
Habitat (#3)	5	5 of 5 unharmed after 6 days, all remained on surface
Habitat (#4)	5	5 of 5 unharmed after 6 days, all remained on surface
Habitat (#5)	10	10 of 10 unharmed after 6 days, all remained on surface
Habitat (#6)	5	5 of 5 unharmed after 6 days, all remained on surface
Mid-Canyon (#7)	4	day 1: 1 being attacked by hermit crab, 2 already outside with hermit crabs inside, 1 buried (on day 2 occupied by hermit crab)
Reef-edge (#9)	4	day 1: 1 occupied by hermit crab, 2 unaccounted for and 1 unharmed day 2: 2nd occupied by hermit crab, later the 2 unaccount for were found occupied by hermit crabs

NOTE: All hermit crabs attacking juvenile conch were Dardanus venosus.

Table 2. Summary of queen conch captured, marked and recaptured during specified study months. Also included is a breakdown of Adults, Young adults and juveniles and male, female, mortalities, tags found, egg laying and mating pairs are indicated where known.

Study Month	Number Marked	A	YA	J	Number of months after marking of last recapture																			SEX		DEAD	TAG FOUND	EGG LAYING	MATING PAIRS		
					Never	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	?					M	F
2/3 FEB MAR	101 (58 Wires) (36 RT)	98	2	1	58	-	-	-	-	-	-	-	-	2	1	1	11	-	-	1	7	1	8	2	96	2	3	6	4	2	1
7 JUL	16 (71)*	15		1	1 (42)*	-	-	-	-	1	-	-	1	-	-	-	5	1	5	2					14 (71)	1	1	(1)		1	1
10 OCT	21	10	3	8	6(5J)-	2	-	-	5	-	-	5	-	-	3	-									19	2			3		
11 NOV	2	1		1	0	-	-	-	-	-	-	-	-	-	1	-									2			1(1)	1		
12 DEC	26	17		9	10(8J)-	-	1	-	-	-	7	1	4	3											24	2	1		1	1	
14 FEB	13	11		2	2	2	-	1	1	1	2	4	-												12	1					
15 MAR	14	13		1	3	1	-	1	4	2	5	-													14					1	
17 MAY	3	3			1	-	1	-	1	-															2	1				1	
18 JUN	11	8	2	1	4	-	2	4	1																8	1	2		1	1	
19 JUL	18	17		1	10	-	6	2																	17	1				3	
20 AUG	4	4			4	-	-																		4					2	
21 SEP	10	10			10	-																			10	1			1	1	
22 OCT	3	2		1																					3					1	
TOTALS	242	209	7	26	99																					5	11	7	5	10	13

242 -(7 dead) -(5 tags found) = 230 presently assumed marked and alive in the canyon.

* Larson, R. 1984. 71 (-1 dead) marked, 29 recaptured, $N = (70)(139)/(29) = 335$ estimated population size (Peterson method).

Table 3. Weight and length of adult queen conch captured in Salt River Canyon grouped by 3 month periods. Juveniles, both naturally occurring and hatchery reared, are listed separately.

<u>Months</u>	<u>Weight(g)</u>			<u>Length(cm)</u>		
	$\bar{X}$	SD	n	$\bar{X}$	SD	n
Feb/Mar 84	no data			23.8	+1.3	63
				(20.0-28.0)		
Sep/Oct/Nov 84	2626.1	± 361.2	17	24.9	± 1.9	18
	(2004.8-3110.0)			(22.1-27.9)		
Dec/Jan/Feb 84/85	2521.7	± 463.8	39	24.5	± 1.6	39
	(1215.7-3050.0)			(21.5-30.0)		
Mar/Apr/May 85	2708.1	± 384.7	24	24.7	± 1.5	24
	(1910.6-3500.0)			(21.9-28.2)		
Jun/Jul/Aug 85	2787.2	± 494.1	75	24.4	± 1.6	75
	(1884.0-3900.0)			(21.2-28.5)		
Sep/Oct/Nov 85	2824.8	± 575.5	18	24.8	± 1.4	18
	(2142.1-4500.00)			(22.5-27.4)		
Junveniles (Salt River Canyon)	999.9	± 173.2	14	22.4	± 1.9	18
	(765.8-1440.0)			(18.0-25.7)		
	3rd year class					
	222.3	± 164.7	15	12.9	± 2.2	14
	(63.6-561.3)			(10.3-17.6)		
	2nd year class					
	3.3		1	6.9		1
	1st year class					
Juveniles (hatchery reared)	8.8	± 2.9	22	4.8	$\pm .8$	29
	(4.4-14.2)			(4.0-6.0)		

Table 4. Summary of changes in weight and length in queen conch over varying number of months, original weight at first capture and average weight change.

Number of Months	Months (Capt-Recapt)	Weight (gm)	Length (cm)	Original Weight	Average Weight gain per month
4	MAR-JUL	+ 195.1	- 0.1	1910.6	48.7
4	MAR-JUL	+ 76.8	+ 0.5	2814.0	19.2
5	OCT-MAR	+ 5.0	- 0.6	2336.3	1.0
5	OCT-MAR	+ 100.7		2840.0	20.1
5	FEB-JUL	+ 224.7	+ 1.2	2680.0	44.9
6	DEC-JUN	+ 101.0	0.0	2839.0	16.8
6	DEC-JUN	+ 268.1	- 3.5	2171.9	44.6
6	DEC-JUN	+ 233.9	+ 0.2	2672.1	38.9
6	DEC-JUN	+ 269.5	+ 0.2	2310.0	44.9
6	DEC-JUN	+ 189.9	+ 0.3	2326.3	31.6
7	DEC-JUL	+ 250.0	- 0.1	3050.0	35.7
7	DEC-JUL	+ 213.6	- 1.1	2760.5	30.5
7	DEC-JUL	+ 250.2	- 0.1	2385.0	35.7
7	DEC-JUL	+ 212.0	- 4.5	2988.0	30.2
7	DEC-JUL	+ 692.3	+ 0.1	2707.7	98.9
7	DEC-JUL	+ 269.6	+ 0.1	2034.4	38.5
7	DEC-JUL	+ 223.5	- 0.4	2461.2	31.9
7	DEC-JUL	+ 174.8	- 3.2	2770.0	24.9
8	OCT-JUN	+ 260.0	+ 0.2	2490.0	32.5
8	OCT-JUN	+ 113.9	- 2.9	2778.4	14.2
8	OCT-JUN	+ 706.4	+ 1.1	1138.4	88.3
9	OCT-JUN	+ 138.1	- 0.8	2683.0	17.2
9	OCT-JUN	+ 238.8	+ 0.1	2961.2	29.8
9	OCT-JUL	+ 116.0	0.0	2084.0	12.8
9	OCT-JUL	+ 200.0	- 0.1	2160.0	22.2
9	OCT-JUL	+ 177.0	- 1.1	2698.0	19.6
9	DEC-SEP	+ 181.9	- 0.2	2627.6	20.2
9	DEC-SEP	+ 447.3	+ 0.2	2952.0	49.7
9	NOV-SEP	+ 390.2	0.0	1805.1	43.3
11	OCT-SEP	+ 99.1	0.0	2535.9	9.0

Average Weight gain per month is 32.2 ± 20.6 g