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Quantitative Developmental Studies on the Otolith of Tilapia nilotica (*Oreochromis niloticus*) with Reference to Weight and Length

Ahmed M. Omar and Hanaa M. El-Ghazali*
Anatomy and Embryology Department, Faculty of Veterinary Medicine, Zagazig University, 44511, Egypt

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Abstract

Owing to the biological and ecological importance of the otolith and the significant role of Tilapia nilotica in aquaculture production, in addition to the less information about the relationships between the size in both otolith and fish individuals, this study was carried out. Forty-five fish specimens of variable length and weight Tilapia nilotica (*Oreochromis niloticus*) were collected from Al-Abbasa fish farms, Sharkia Governorate, Egypt. The lengths and weights of fish and their otoliths were recorded and the mean as well as the standard deviation were estimated. The different relationships between fish and otolith with regard to length and weight were identified by Pearson correlation coefficients. The means of Tilapia nilotica body weight and otolith weight were 225105.7 mg±182402.31 and 55.9743 mg±32.93714, respectively. Moreover, the means of fish body length and otolith length were 172.429 mm±74.8580 and 8.1571 mm±3.54984, respectively. In conclusion, there was a positive linear relationship between the developmental rate of fish and otoliths, taking the weights of fish and otoliths in consideration all over this research.

Keywords: Sagittal otolith, Tilapia nilotica, Length, Weight

Introduction

The otolith is an important part of stato-acoustic organ (organ of balance and hearing), which is intimately related to the internal ear of fish, where it is known as ear stones or crystals. These crystals are formed from calcium carbonate precipitations and are considered as one of the higher sensory organs such as lateral-line system [1]. The otolith has a biological and ecological importance in species differentiation, age and stocks assessment, individual growth and identification of the diet of predatory fish [2-13]. The morphology (shape and dimensions) of the otolith was reported to be correlated to the age of fish and ecosystem factors such as geographic location, water depth and environmental qualities for chemical and physical properties [14]. Otolith length, weight, width and volume were related to fish length and species-specific and substantial differences were reported within intimately related species [15]. Fish farming in Egypt reached up to 74% of total fish production. Tilapias originated from Egypt more than 4000 years ago and they represented 75.5% of total aquaculture production [16]. The major aquaculture species was the Nile tilapia (*Oreochromis niloticus*) as reported by FAO [17]. The otoliths of Tilapia nilotica appeared as cloudy white crystals, located in a deep fossa at the base of the cranial cavity just under the brain, and were in a direct contact with the semicircular canals and sensory hair cells of the internal ear where they were important in the process of balance, hearing and equilibrium [18]. To the best of our knowledge, there were no large scale studies on the development or analysis of otolith-fish size relationship for Tilapia nilotica in Egypt. This study was carried out to fulfill the relationships between the lengths and weights of the otolith and the fish species under investigation.

Material and Methods

This work was carried out on 45 Tilapia nilotica (*Oreochromis niloticus*) specimens of variable ages which were collected from Al-Abbasa fish farms, Sharkia Governorate, Egypt. Thirty-five fish individuals were used for the detection of the relationships of the otolith length and weight with the body length and weight of fish. Ten fish specimens were examined for the detection of the differences between the various measurements of the right and left otoliths and to evaluate the sex effects on these measurements.

***Corresponding author e-mail: (dr_h1980@hotmail.com), Anatomy and Embryology Department, Faculty of Veterinary Medicine, Zagazig University, 44511, Egypt.**

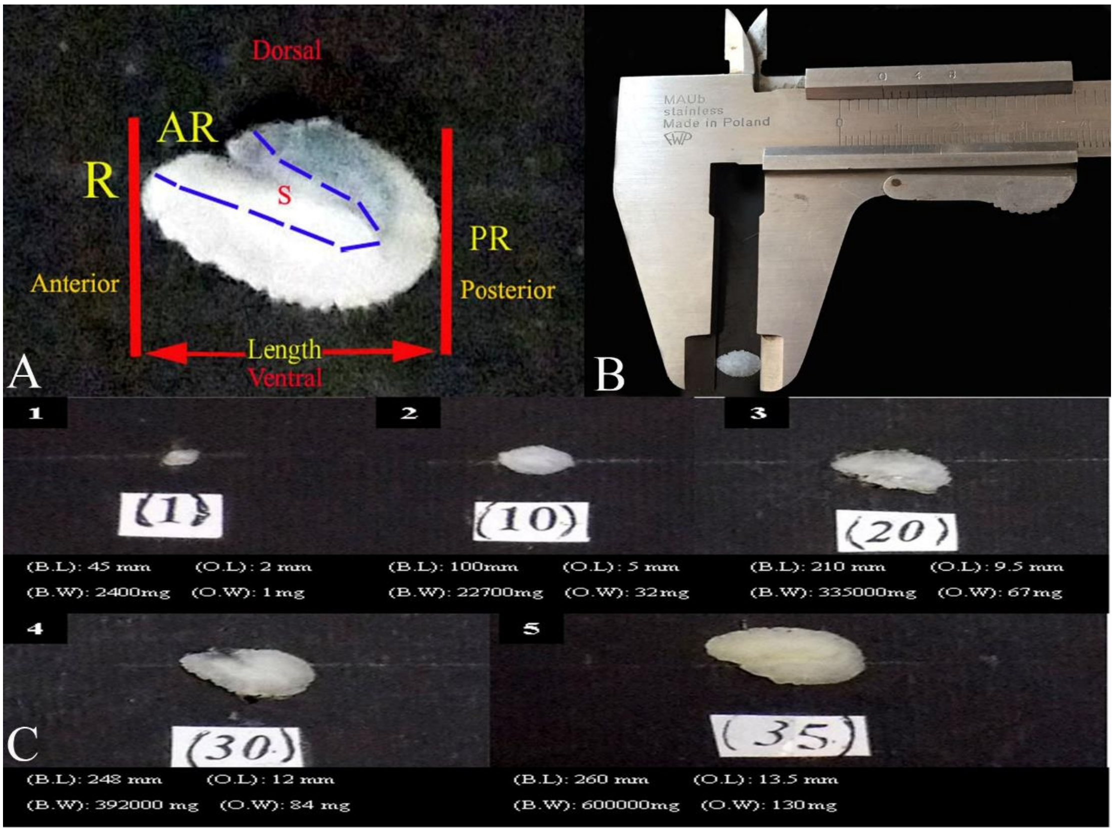

Figure (1): A: a photomacrograph of right sagittal otolith of Tilapia nilotica (medial view) showing the length of the otolith from rostrum (R) to postrostrum (PR) also showing antirostrum (AR), and sulcus (S). B: a photomacrograph of right sagittal otolith of Tilapia nilotica (medial view) measured (in millimeters) using a caliper for detection of the otolith length. C: a photomacrograph of the sagittal otoliths of the examined fish number 1 (1), 10 (2), 20 (3), 30 (4) and 35 (5) showing: the development of the otoliths by increasing in the length and weight.

All specimens were identified and then measured to the nearest millimeters for body length (B.L); measured by the graduated tape from the tip of the snout to the posterior end of the last vertebra (to the beginning of the caudal fin). Also, the total body weight (B.W) (in milligrams) was measured by the digital scale. The sagittal otoliths were removed, cleaned with distilled water and kept dry in the room temperature. The otolith length (O.L) was measured (in millimeters) using a caliper (along the rostrum to the postrostrum axis) (Figures 1A and B) according to the nomenclature of Secor *et al*. [14] and Smale *et al*. [19]. The otolith weight (O.W) was measured by digital scale.

The data were collected, arranged, summarized and then analyzed using SPSS/PCT system package [20] to detect the mean and standard deviation of length and weight of the fish and otoliths. The relationships of the otolith length and weight with the body length and weight of fish were estimated by using the pearson correlation coefficients by using the following equation:

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left(\sum X2 - \frac{(\sum X)2}{n}\right)\sum Y2 - \frac{(\sum Y)2}{n})}}$$

Where:

r=Pearson correlation coefficient

X= body weight (mg) or body length (mm)

Y= otolith weight (mg) or otolith length (mm)

∑=summation - sum of all values in range of series

The differences between right and left otoliths were detected by using a paired t-test. The figures of the obtained otoliths of all examined fish (45 individuals) were plotted to show the clear differences in their size and length.

Table 1: The different measurements and the Mean ± SD of Tilapia nilotica and their otoliths

Case No.	**Body Length (B.L) mm**	**Body Weight (B.W) mg**	**Otolith Length (O.L) mm**	**Otolith Weight (O.W) mg**
1	45	2400	2	1
2	60	4200	2.6	7
3	65	8100	3	9
4	70	10500	3.5	11
5	72	10900	3.5	12
6	75	12000	4	12.5
7	80	17300	4.3	13
8	85	20000	4.3	14.1
9	90	21300	4.5	28
10	100	22700	5	32
11	105	25400	5.1	37
12	115	30000	5.2	40
13	125	32900	6	45
14	150	120000	7	50
15	160	170000	8	53
16	170	200000	8.5	55
17	190	250000	8.6	58
18	200	300000	9	62
19	250	320000	9.1	65
20	210	335000	9.5	67
21	220	338000	9.6	70
22	225	340000	9.7	73
23	230	350000	10	74
24	233	300000	10	76
25	235	360000	11	77
26	240	370000	11	79
27	242	375000	12	79
28	243	380000	12	79.5
29	247	384000	12	80
30	248	392000	12	84
31	248	400000	12	86
32	248	437000	12	89
33	249	440000	13	91
34	250	500000	13	120
35	260	600000	13.5	130
Mean	172.429	225105.7	8.1571	55.9743
Std. Deviation	74.8580	182402.31	3.54984	32.93714

Results

In the current study, the different measurements of fish and otoliths are shown in Table (1). The minimum body weight of Tilapia nilotica was 2400 mg while the maximum body weight measured 600,000 mg with a mean of 225,105.7 mg±182,402.31. The minimum otolith weight was one mg and the maximum was 130 mg with a mean of 55.9743 mg±32.93714. On the other hand, the shortest body length was 45 mm and the longest was 260 mm with a mean of 172.429 mm±74.8580. The shortest otolith length was two mm and the longest was 13.5mm with a mean of 8.1571 mm±3.54984 (Table 1).

The interpretation about the different measurements of fish and their otolithic crystals which were examined in this research cleared that, the smallest fish individual of 2400 mg body weight had an otolith of one mg, also the fish measured 45 mm body length and had an otolith of two mm. In addition, due to the continuous growth and quantitative developmental changes the largest fish individual of 600,000 mg body weight and 260 mm body length had an otolith of 130 mg in weight and 13.5 mm in length respectively (Figure 1C).

Positive linear relationships between lengths of fish and otoliths (Figure 2A) and between the weights of fish and otoliths (Figure 2B) were observed. Also, these positive linear relationships were detected between fish length and weight (Figure 2C) and otolith length and weight (Figure 2D). These relationships were statistically significant with a correlation of 0.961, 0.979, 0.963 and 0.970 for body and otolith weight, body and otolith length, body weight and length and otolith weight and length, respectively, with P value <0.0001.

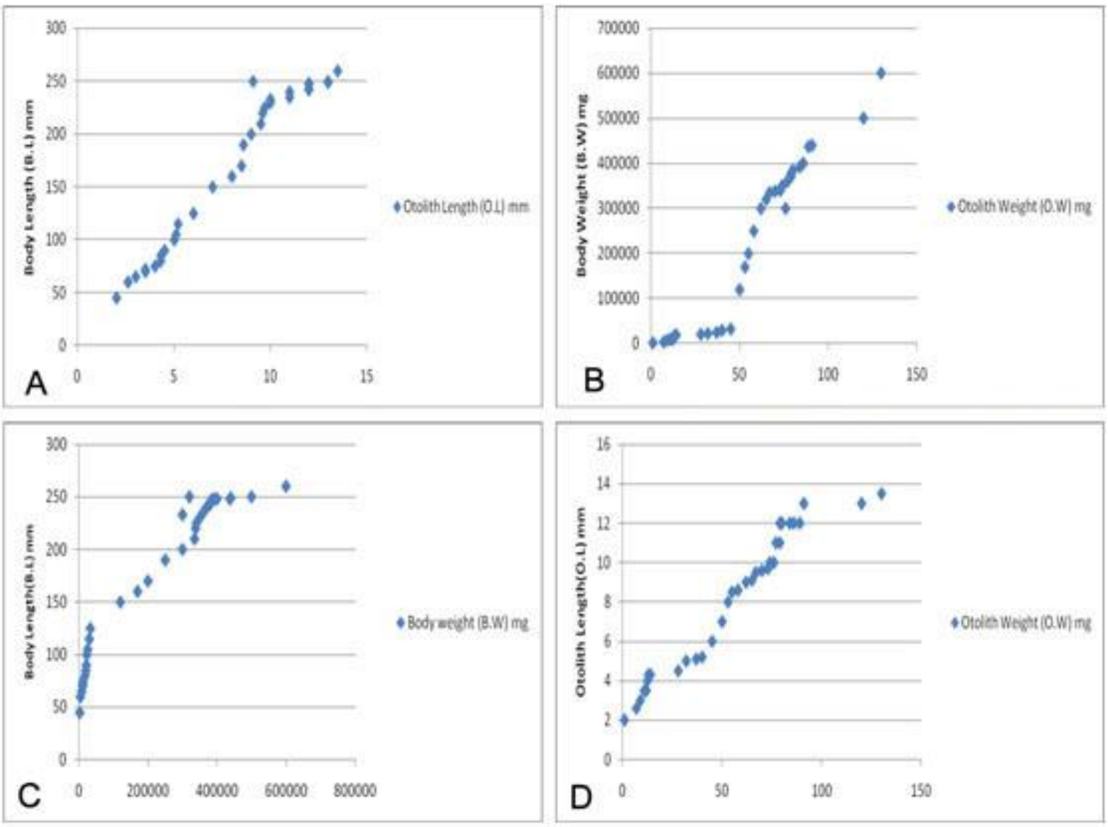

Figure (2): Histograms showing: A: Body length- otolith length relationships in Tilapia nilotica. B: Body weight- otolith weight relationships in Tilapia nilotica. C: Body length- body weight relationships in Tilapia nilotica. D: Otolith length - otolith weight relationships in Tilapia nilotica.

The present study clarified a good relationship between the weight of otoliths and fish, as well as, the length of both otoliths and fish individuals. Also, the progressive changes in length and weight of fish and their otoliths gave a marked indication about the growth and development of each (Figure 3A). In the present investigation, the mean lengths of the right and left otoliths were 7.6 and 7.5 mm, respectively while the mean weights were 42 and 41 mg, respectively. The differences between the measurements (length and weight) of both otoliths were statistically insignificant (P>0.05) (Figure 3B).

By comparing the measurements of both otolith of male and female fish of the same body weight (225,000 mg). The length of otolith was 7 mm and the weight was 30 mg (for both otolith) in female, while it was 30 mm and 40 mg for right and left otoliths of male, respectively (Table 2 and Figure 3C).

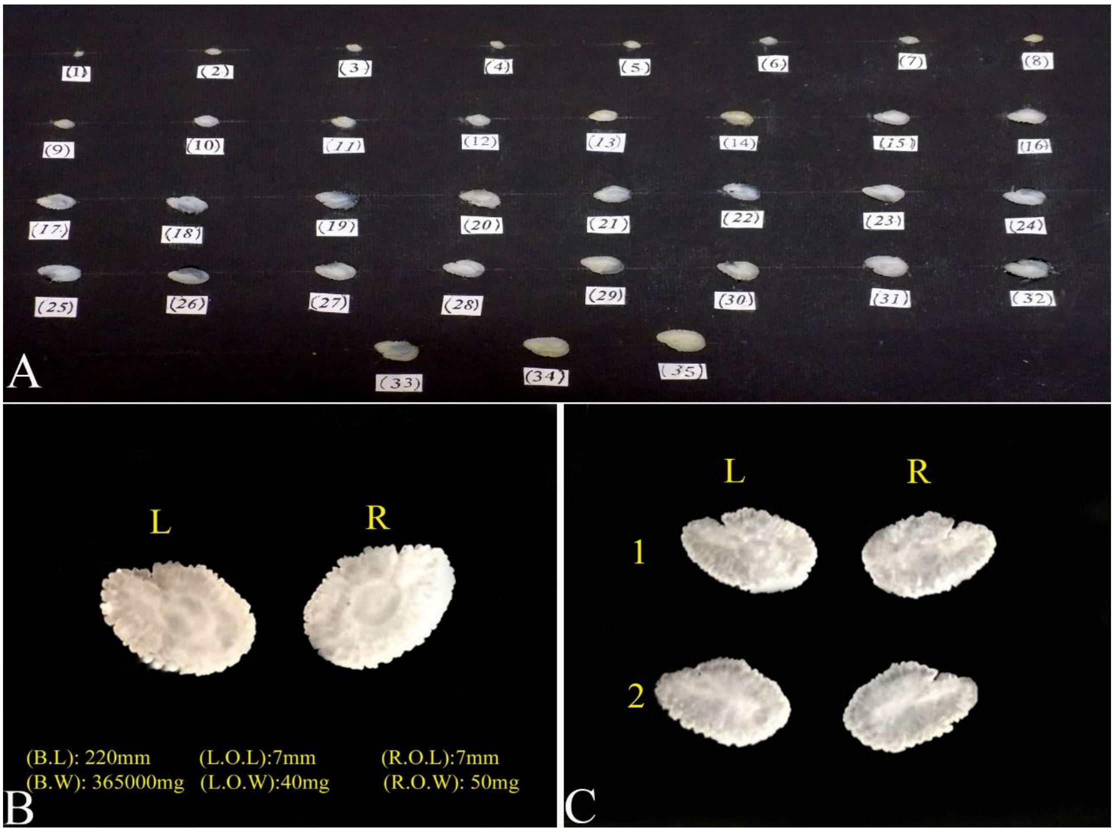

Figure (3): A: a photomacrograph of the sagittal otoliths of the examined fish (35 individuals) showing: the clear differences in their size and lenght. B: a photomacrograph of the sagittal otoliths of the examined fish showing: the insignificant difference between the right (R) and left (L) otoliths (length and weight). C: a photomacrograph of the sagittal otoliths of the examined fish showing: the otoliths of male (1) and the otoliths of female (2) fish had the same body weight and the same otolith length and weight.

Discussion

Concerning the different measurements of Tilapia nilotica (*Oreochromis niloticus*), the present study revealed that, the mean body length was 172.429 mm ± 74.8580 which came in a line with Bwanika *et al*. [21] who added that the size of *O. niloticus* (of both sexes) captured in Lake Nyamusingiri ranged between 5 and 26 cm. Regarding the relationship between fish length and otolith length, there was linear relationship between the two parameters. Similar findings were recorded by Hunt [15], Morat *et al*. [22], Longenecker [23] and Jawad *et al*. [24]. This relationship was clear until the fish reached the greatest size, thereafter the otolith only increased in thickness. The strong linear correlation between fish lengths and otolith lengths was found in younger individuals than the older ones [15,25]. In fresh water fish, there was a strong relationship between otolith length and fish size [26].

Concerning the effect of age on the otolith length and weight, the results revealed that, whenever the fish increased in length and weight (grown), the otolith increased also in length and weight. These results were in agreement with those of Secor and Dean [27], who reported that, the larger and heavier otoliths were detected in slower growing groups of fish individuals than the faster growing groups. Significant interaction was found between age and fish size that produced an effect on the otolith size.

Table 2: Elucidate the measurements of the right and left otoliths of Tilapia nilotica classified according to sex and the results of paired t-test.

Number	sex	Body Length (B.L) mm	Body Weight (B.W) mg	Otolith Length (O.L) mm		Otolith Weight (O.W) mg	
				Right	Left	Right	Left
1	Male	228	355000	9	8	50	50
2	Male	198	275000	8	7	50	40
3	Male	190	275000	7	8	40	40
4	Male	220	365000	7	7	50	40
5	Male	185	225000	7	7	30	40
6	Male	202	280000	7	7	40	40
7	Male	233	420000	9	9	50	50
8	Female	215	325000	8	8	50	50
9	Male	175	200000	7	7	30	30
10	Female	197	225000	7	7	30	30
Mean				7.6	7.5	42	41
Std. Deviation				0.8433	0.7071	9.189	7.379
P value				>0.05		>0.05	

The development and growth of the otolithic crystals (ear stones) was observed in the present study, where there was a good relationship between the size of each otolith and the size of fish individual. These findings were supported by other studies where the otolith grew as a core in the larvae and increased in size gradually by precipitation of calcareous crystals (Calcium carbonate crystals) [28-30]. The otoliths might be used in the determination of fish age specially in marine fish, while in fresh water fish the scales were used for this purpose [30]. In fresh water fish, scales were not accurate estimators of largemouth bass age relative to otolith sections. Whole otoliths were found to be relatively accurate and precise age predictors. The aging errors associated with whole-otolith aged largemouth bass were not biologically significant [31]. Ageing precision was greater with fin rays and otoliths than scales and negatively related to fish length for all ageing structures [32].

Also, Al-Mamry *et al*. [33] recorded that, there was a relationship between the otolith size (otolith length, weight and width) and the length and weight of fish, a result which came in a line with the present findings.

The growth of otolith gave an accurate estimation of fish age and provided an easier way for fisheries biologists to estimate the age of fish [15, 34, 35]. These findings concur with our observations in this study where the size of otolith differed and increased according to the size and weight of fish.

The intimately relationship between the size of otolith and that of the fish which was observed during this study, was in agreement with the findings of Al-Mamry *et al*. [33] and Akin *et al*. [36] who claimed that, the otolith length and weight could be used to determine the age of fish.

In white seabass fish, the otolith growth could be used for estimating the age, also, the size of otolith and its growth showed high variability which was more significant in fish age determination [37].

The observations concerning the differences between the various measurements of the right and left otoliths were statistically insignificant (P>0.05). These findings were supported by other studies that considered the otolith pair were mirror images of each other [15, 22-24, 38-40]. The difference between the length of the right and left otolith was statistically insignificant (P>0.05) [41].

Due to the few number of female fish specimens, we decided to exclude these females but the important observations clarified in this study about the male and female fish specimens had the same body weight (225,000mg), otolith length (7 mm) and otolith weight (30 mg). These findings are in agreement with the observations of many authors who reported that, the sex difference had statistically non-significant effect on the otolith length [15,25,42]. There was no difference between females and males for mean length and weight values (t test, P>0.05) [41].

Conclusion

There was a good relationship between the weight of otoliths and fish, as well as the length of both otoliths and fish individuals. The advanced changes in length and weight of fish and their otoliths confirmed this relationship and displayed a clear evidence about the growth and development of each. Based on the above, the growth of otolith gave a proper evaluation of fish age, with taking into consideration that the differences between the various measurements of the right and left otoliths were statistically insignificant. Also, no differences between females and males for mean otolith's length and weight were observed.

Conflict of interest

None of the authors have any conflict of interest to declare.

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الملخص العربي

دراسات كمية تطورية على اصداف الأذن لأسماك البلطى النيلى مع الاشارة الى الوزن والطول

احمد محمد السيد عمر ، هناء محمد الغزالي*
قسم التشريح والأجنة- كلية الطب البيطري- جامعة الزقازيق- مصر

نظرا للأهمية البيولوجية والإيكولوجية لأصداف الأذن والدور الكبير لأسماك البلطي النيلي في انتاج وتربية الاحياء المائية و بالإضافة إلي وجود معلومات قليلة حول العلاقات بين حجم كلا من أصداف الأذن والأسماك قد أجريت هذه الدراسة. حيث تم تجميع عدد ٤٥ من أسماك البلطي النيلي (مختلفة الأوزان والأطوال والأعمار) والتي تم الحصول عليها من مزارع العباسه للاسماك بمحافظة الشرقية بجمهورية مصر العربية. وقد تم تسجيل أطوال وأوزان أسماك البلطي وأحجار الأذن الخاصة بها على حسب المتوسطات والإنحراف المعياري لها. وقد تم تقييم العلاقه بين الأسماك وأحجار الأذن من حيث الطول والوزن وفقا لمعاملات إرتباط بيرسون. و كانت نتائج المتوسطات لأوزان هذه الاسماك والأحجار ٢٢٥١٠٥.٧ مليجرام±١٨٢٤٠٢.٣١ و ٥٥.٩٧٤٣ مليجرام±٣٢.٩٣٧١٤ علي التوالي. كما كانت متوسطات أطوال الأسماك والأحجار ١٧٢.٤٢٩ ملليميتر±٧٤.٨٥٨٠ و ٨.١٥٧١ ملليميتر±٣.٥٤٩٨٤ علي التوالي .وقد اظهرت النتائج ان هناك علاقة وارتباط ايجابي واضح بين نمو الاسماك ونمو هذه الاصداف.