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CATCHABILITY, MORPHOMETRIC RELATIONSHIPS AND CHEMICAL COMPOSITION OF THE EXOTIC CRAYFISH *Procambarus clarkii* OF THE RIVER NILE AND ITS POSSIBILITY FOR EXPLOITATION IN EGYPT

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ABSTRACT

The exotic crayfish *Procambarus clarkii* has been successfully inhabited the river Nile in Egypt and its economic importance is becoming more apparent. Up till now, *P. clarkii* is unexploited in Egypt, so it is not subject to catch by the fishermen in the river Nile. Therefore, the present work was carried out on the catch efficiency of *P. clarkii* as catch per unit effort by the designed traps and to determine the seasonality of its relative abundance during the year. Morphometric relationships of body length and body weight with the abdominal length, carapace length, abdominal weight and skeleton and wastes weight were studied. The average of dress-out percentage (abdominal muscle %) was 15.5 $\pm$ 1.06 and 19.0 $\pm$ 1.04 for males and females, respectively. The chemical composition of both inedible parts (skeleton and wastes) and unmarketable crayfish were determined and evaluated to produce the crayfish meal. This study aims to manage the wild stock in the river Nile using traps and exploitation the yield in two directions; the edible part dressed-out for human consumption and the inedible part for processing crayfish meal as a source for animal diets.

Keywords : Crayfish, catchability, traps, relative abundance, morphometry, fishmeal, river Nile

INTRODUCTION

The crayfish *Procambarus clarkii* is one of the most important species of about 400 species of fresh water crayfishes in the world (Huner, 1989). Its distribution area has been expanded around the world largely from human introductions (Huner, 1977 and Huner and Avault, 1978). Over 60,000 tons of *P. clarkii* are produced annually in the USA and China (Huner *et al.,* 1993). *P. clarkii* is a large prolific, aggressive burrower species and well adapted to survive in shallow areas with drastic seasonal fluctuations in water levels (Huner and Barr, 1983). It has also good adaptability to burrow environments, aerial exposure, polymorphism, rapid growth, high fecundity and disease resistance (Huner and Lindovist, 1995).

In Egypt, the crayfish *P. clarkii* was accidentally introduced to the river Nile during 1980's (Ibrahim *et al.,* 1995). Within the last few years, it has been successfully established in various sites of the river Nile and its branches, particularly in the Delta region and extented southwords to Giza Governorate (Soliman *et al.,* 1998a). On the other hand, the crayfish *P. clarkii* most certainly became a valuable human food replacing the expensive marine crustaceans (Emam and Khalil, 1995). Some studies were carried out that dealt with various aspects of this species including their ecology (Ibrahim *et* *al.,* 1995 and 1996), population dynamics (Emam and Khalil, 1995) and reproductive biology (Soliman *et al.,* 1998b).

However, the economic importance of *P. clarkii* in Egypt is anticipated to increase by time. The present work was carried out on the catchability, seasonality abundance, physical morphometic relationships and chemical composition of *P. clarkii* that inhabits the river Nile. The study aims to determine and evaluate the following points :

- Traps catchability as catch per unit effort (CPUE).
- The dress-out percentage of abdominal muscle (edible part %) and its chemical composition as a human food.
- The chemical analysis of the inedible parts (skeleton and wastes) and the entire body of unmarketable crayfish as a guide to produce the crayfish meal for exploiting their yield and managing their wild stock in the river Nile.

MATERIALS AND METHODS

Five traps were used for harvesting the specimens of *P. clarkii* twice monthly during 1998. The traps were cylindrical in shape (80 cm length x 40 cm diameter) with two funnel entrances in the opposite ends and made from flexible wire net of mesh size 1.0 cm. The traps were located parallel to the western side of the river Nile steam at Giza and serial to each and about 100 meters apart in a shallow water of about one meter depth. For attraction the crayfish, the traps were baited with catfishes, set in the afternoon and retrieved later after 24 hours. Each crayfish of the five traps was recorded for sex, body weight (BW) to the nearest 0.1 g, body length (BL) from the tip of rostrum to the end of telson (1mm), carapace length (CL) from the tip of rostrum to posterior median margin of Cephalothorax (1mm) and abdominal length (AL) to the end of telson (1mm). Then, the crayfishes were boiled in water for 5 minutes after measuring and allowed to cool. The abdominal muscles (edible parts) were removed from a represented sample of the boiled crayfishes and the dress-out percentages were obtained from the following equation:

$$\text{Dress-out (\%)} = \frac{\text{abdominal muscle weight (g)}}{\text{Body weight (g)}} \times 100$$

Both edible parts and inedible parts (skeleton and wastes) and also the entire body of another sample were ground with a mortar and pestle prior to determination of the dry matter, crude protein, crude lipid and ash according to the methods of AOAC (1990). All analyses were performed in duplicate for each pooled sample. Data were compared using the General Linear Model procedure of the statistical analysis system (SAS, 1990) for one-way analysis of variance.

RESULTS

Catchability:

Table (1) shows the relative abundance of the harvested crayfishes *Procambarus clarkii* during the different months of the year. It is obvious that the catch and catch per unit effort (CPUE) were increased during the warm period of the year from March to October with two peaks in April and September. Males dominated the catch all over the year, while the catchability of both males and females followed the same trend of gradual increase and decrease throughout the year. The CPUE of *P. clarkii* (combined sexes) ranged from 141 to 810 with an average of 483 $\pm$ 217.2 grams /trap / day, and fluctuated in number between 3.1 and 16.6 with an average of 10.2 $\pm$ 4.42 crayfishes / trap / day during the year. On the other hand, the relative abundance of small and large crayfish in the catch was low, while the medium size which ranged between 10 and 14 cm dominated the catch (Figure 1).

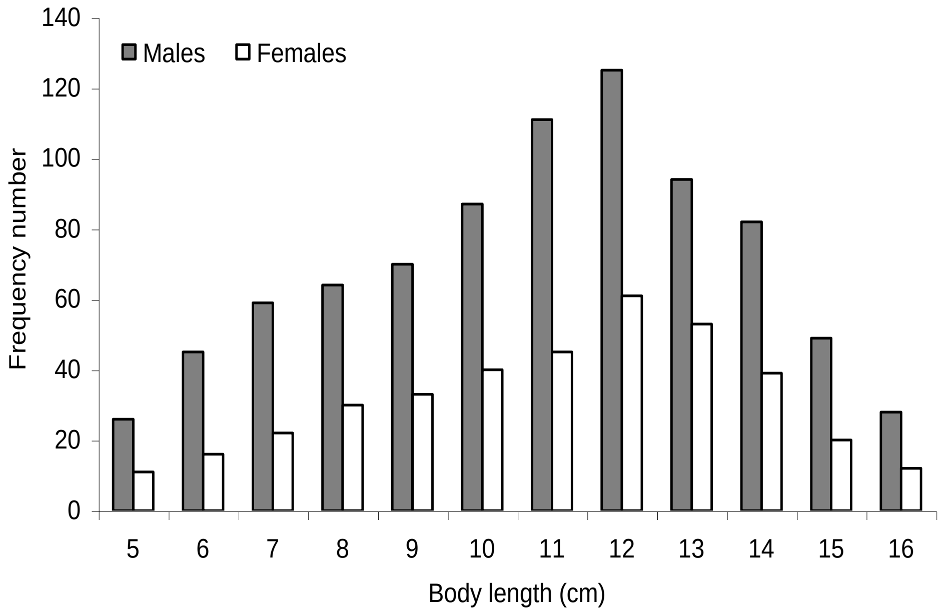


Figure 1. Length frequency distribution of males and females of the crayfish *P. clarkii* harvested from the river Nile.

Morphometric relationships:

The relationships of body length and body weight with the practical morphometric parameters including; abdominal length, carapace length, abdominal weight and skeleton and wastes weight were computed for 840 males and 382 females of the crayfish *P. clarkii* . Four different mathematical plots were used for each relation, namely; absolute-absolute, absolute-logarithmic, logarithmic-absolute, and logarithmic-logarithmic. The coefficient of correlation " r ", the regression constant " a " and " b " value for the different plots were compared. It was found that the logarithmic relation gave the highest r^2 value. Therefore, it was selected for a good representation of the following relationships:

1) Relationship between body length and body weight:

Log. BW = - 0.63 + 2.14 Log. BL, or BW = 0.23 * $BL^{2.14}$

r = 0.9978 for males

Log. BW = - 0.65 + 2.12 Log BL, or BW = 0.22 * $BL^{2.12}$

r = 0.9966 for females

Where BW is the body weight (g), BL is the body length (cm), and r is the correlation coefficient. The graphical representation of this relationship is given in Figure 2.

2) Relationship between body length and abdominal muscle weight:

Log. AMW = - 1.71 + 2.40 Log. BL, or AMW = 19.49 * 10^{-3} * $BL^{2.40}$

r = 0.9983 for males

Log. AMW = - 1.68 + 2.43 Log BL, or AMW = 21.07 * 10^{-3} * $BL^{2.43}$

r = 0.9977 for females

Where AMW is the abdominal muscle weight (g), BL is the body length (cm), and r is the correlation coefficient. The graphical representation of this relationship is shown in Figure 2.

3) Relationship between body length and skeleton and wastes weight:

Log. SWW = - 0.65 + 2.08 Log. BL, or SWW = 22.20 * 10^{-3} * $BL^{2.08}$

r = 0.9976 for males

Log. SWW = - 0.67 + 2.04 Log BL, or BW = 21.58 * 10^{-2} * $BL^{2.04}$

r = 0.9977 for females

Where SWW is the skeleton & wastes weight (g), BL is the body length (cm), and r is the correlation coefficient. This relationship is graphically represented in Figure 2.

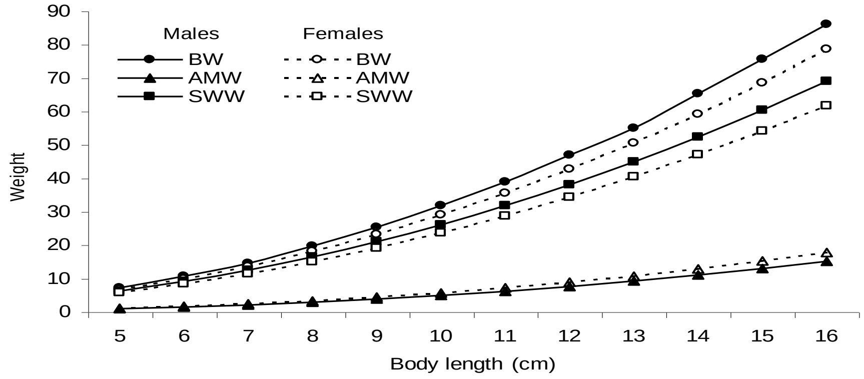


Figure 2. The relationships between the body length (BL) and each of body weight (BW), abdominal muscle weight(AMW) and skeleton and wastes weight (SWW) for males and females of the crayfish *P. clarkii* harvested from the river Nile .

4) Relationship between body length and abdominal length:

Log. AL = - 0.53 + 1.21 Log. BL, or AL = 0.30 * $BL^{1.21}$

r = 0.9984 for males

Log. AL = - 0.41 + 1.13 Log BL, or AL = 0.39 * $BL^{1.13}$

r = 0.9966 for females

Where AL is the abdominal length (cm), BL is the body length (cm), and r is the correlation coefficient. The graphical representation of this relationship is given in Figure 3.

5) Relationship between body length and carapace length:

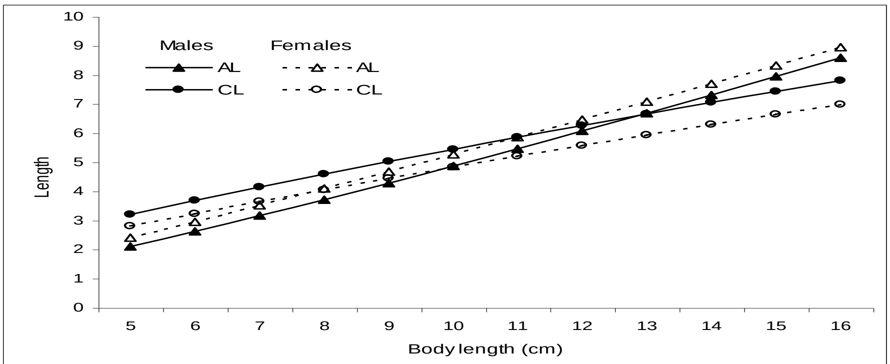
Log. CL = - 0.03 + 0.77 Log. BL, or CL = 0.93 * $BL^{0.77}$

r = 0.9945 for males

Log. CL = - 0.10 + 0.78 Log BL, or CL = 0.79 * $BL^{0.78}$

r = 0.9968 for females

Where CL is the carapace length (cm), BL is the body length (cm), and r is the correlation coefficient. This relationship is shown in Figure 3.



6) Relationship between body weight and abdominal muscle weight:

Log. AMW = - 1.00 + 1.12 Log. BW, or AMW = 0.10 * $BW^{1.12}$
r = 0.9998 for males
Log. AMW = - 0.94 + 1.13 Log BW, or AMW = 0.12 * $BW^{1.13}$
r = 0.9995 for females

Where AMW is the abdominal muscle weight (g), BW is the body weight (g), and r is the correlation coefficient. The graphical representation of this relationship is given in Figure 4.

7) Relationship between body weight and skeleton & wastes weight:

Log. SWW = - 0.04 + 0.98 Log. BW, or SWW = 0.92 * $BW^{0.98}$
r = 0.9989 for males
Log. SWW = - 0.04 + 0.97 Log BW, or SWW = 0.91 * $BW^{0.97}$
r = 0.9978 for females

Where SWW is the skeleton & wastes weight (g), BW is the body weight (g), and r is the correlation coefficient. This relationship is graphically represented in Figure 4.

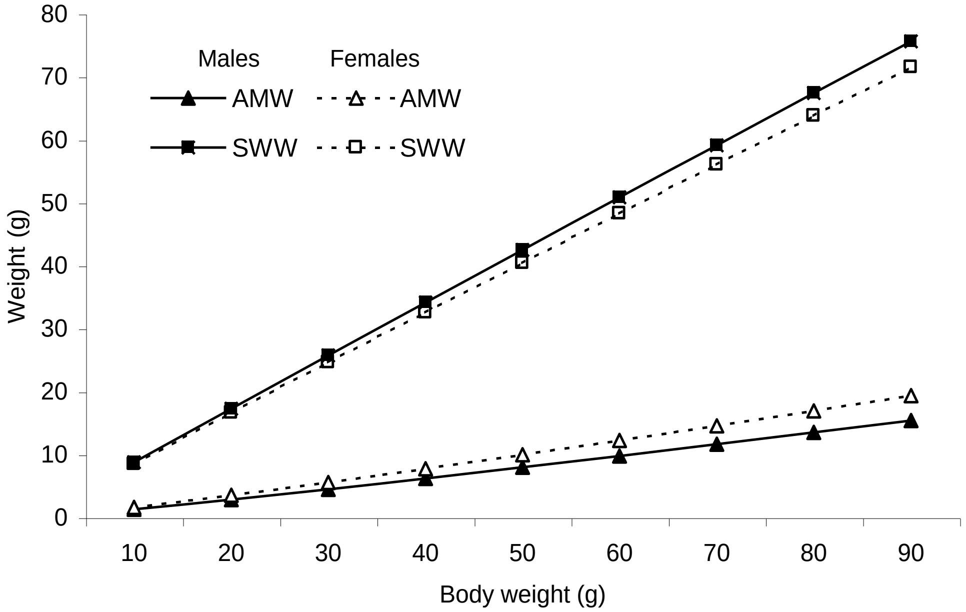


Figure 4. The relationships between the body weight (BW) and both of abdominal muscle weight (AMW) and skeleton & wastes weight (SWW) for males and females of the crayfish *P. clarkii* harvested from the river Nile.

Dress–out percentage:

The dress-out percentages, which meaning the percentage of edible part (abdominal muscle %) for males and females of *P. clarkii* are represented in Figure 5. The data refer to the priority of females than males in the dress-out percentage of all sizes. A gradual increase in the percentage of dress-out was observed with the increase of the animal weight for both sexes. On the other hand, the overall average of dress-out percentage was 15.5 ± 1.06 and 19.0 ± 1.04 for males and females respectively.

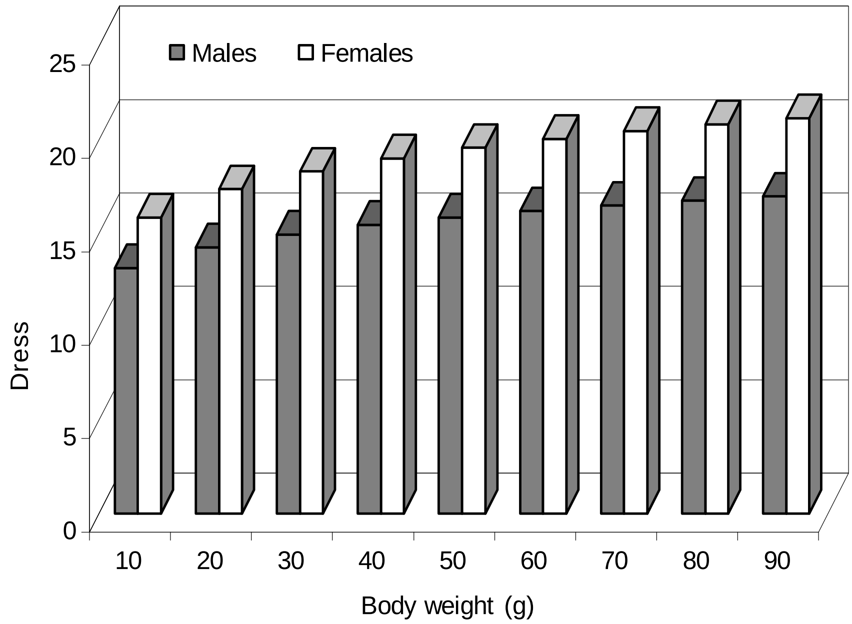


Figure 5. The dress-out percentage (edible part %) for males and females of the crayfish *P. clarkii* harvested from the river Nile.

Chemical composition of crayfish:

The edible part (abdominal muscle %) of the *P. clarkii* as a human food, represented a minor percentage of about 18% for the combined sexes (Figure 5), while the inedible part (skeleton and wastes) represented a major percentage of about 82% of the entire body. Table 2 shows the chemical composition of the entire body and both of edible and inedible parts as fresh and dry weights. The results indicated that the moisture content in the abdominal muscle was relatively higher than in the entire body and the skeleton and wastes. The muscle contained the highest percentage of protein (71.5%) and the lowest percentage of ash (20.6%) on the dry matter basis. In contrast, the skeleton and wastes contained the lowest percentage of protein (53.8%) and the highest percentage of ash (34%). On the other hand, the whole body contained a moderate content of protein (62.2%) and ash

(27.0%). The content of both of lipid and total carbohydrates was low in muscle and it relatively increased in the entire body and finally in the skeleton and wastes (Table 2).

Table 2. The chemical composition of entire body (BE), abdominal muscle (AM) and skeleton and wastes (SW) of the crayfish *P. clarkii* (combined sexes) harvested from the river Nile,(X+SD).

Composition (%)	Fresh weight			Dry weight		
	BE	AM	SW	BE	AM	SW
Moisture	76.0 ± 1.92	78.8 ± 2.10	73.5 ± 1.87	0 --	0 --	0 --
Dry matter	24.0 ± 0.66	21.2 ± 0.57	26.5 ± 0.89	100 --	100 --	100 --
Crude protein	14.93 ± 0.34	15.16 ± 0.46	14.26 ± 0.30	62.2 ± 1.40	71.5 ± 1.91	53.8 ± 1.25
Lipid	1.46 ± 0.14	1.04 ± 0.08	1.91 ± 0.17	6.10 ± 0.57	4.90 ± 0.35	7.20 ± 0.69
ASH	6.48 ± 0.22	4.37 ± 0.18	9.01 ± 0.23	27.0 ± 0.92	20.6 ± 0.73	34.0 ± 0.97
*Fiber & carbohydrates	1.13 ± 0.07	0.64 ± 0.04	1.33 ± 0.11	4.70 ± 0.28	3.00 ± 0.17	5.00 ± 0.46

*** The values were calculated by the difference.**

DISCUSSION AND CONCLUSION

The exotic crayfish *P. clarkii* has become a substantial member of the aquatic invertebrate fauna in the river Nile especially in the Cairo sector of Egypt. The suitability of the river Nile ecology with regard to feeding condition and relatively high water temperature throughout most of the year (14-31 C^o, Tharwat, 1995) has surely favored the quick and easy invasion of *P. clarkii*, which has been reported to prefer warm water (Riegel, 1959 and Espina *et al.,* 1993). The choice of traps sites was based on our field observations that the muddy shallow waters with some vegetation are preferred by *P. clarkii* , which is in agreement with Huner and Barr (1991) in Louisiana. However, in Mexico, Compos and Rodriguez Almaraz (1992) reported the presence of P. clarkii in muddy water of 0.2 - 2.5 m depth and sometimes with no aquatic vegetation. It is worth mentioning that the aggressive behavior of *P. clarkii* against the fish population around, particularly the popular Nile fish *Oreochromis nilotcus* (Bolti), resulted in considerable loss of this species, both adult and young, which are either killed, severely attacked or injured (Soliman *et al.,* 1998a). On the other hand, Huner and Barr (1991) pointed out that crawfish biomass was high in comparison with other consumers that cannot readily use living or dead vegetation as food, and actually *P. clarkii* can save energy in the ecosystems by converting detritus into living tissue that would otherwise be lost to higher trophic animals. The decline of the harvested females, it may be attributed to their reproductive behavior for egg laying in their burrows. This observation was recorded by Huner and Barr (1991), who noted that the female begins digging a burrow after mating. Once the females retired in their burrows, they do not leave their burrows in as great numbers as do the males. The relative abundance of different sizes of *P. clarkii* harvested all the year round in the present work also indicates the highly recruited and future expansion in the river Nile. Although the yield of *P. clarkii* stands as an important human food in many countries of the world, being a rich source of protein (Huner and Barr, 1991), their stock in Egypt is so far under exploitation. Lately, it has been introduced to the fishmarkets around Giza and has proved to be a popular human food. Up till now, the observations indicate that the crayfish is undesirable for Egyptian consumers as a food, this fact leads to increase the crayfish population year after year in the river Nile and most of inland water resources without any management or control. So, the work must be done in two directions ; the first is the management of the natural population of this animal by encouraging the fishermen to catch it, the second is to exploit the harvested yield of the crayfishes by using it in the animal diets. The chemical analysis of the crayfish meal and meal of its wastes in comparison with the chemical composition of the commercial types of fishmeal, shrimp meal, meat meal and meat and bone meal are shown in Table (3). The data reveal that the protein contents of both crayfish meal and crayfish waste meal were higher than of meat meal and meat and bone meal. Ash contents in the two types of crayfish meals were higher than in the meat meal only, but both of waste crayfish meal and meat and bone meal were approximately equal in their ash contents (31.28 and 31.50, % respectively). On the other hand, The protein content of the different types of shrimp meals varied between 43.0 and 58.5 % with an average of 50.62 %, this average is lower than the protein content of crayfish meal and slightly higher than in waste crayfish meal. Moreover, the ash content was relatively higher in both crayfish meal (24.8 %) and waste crayfish meal than of the mean value of 21.18 % in shrimp meal. This result can be attributed to the presence of a pair of strong claws of the crayfishes. However, Herring and Menhaden fish meals were superior to all types of other meals with respect to their high contents of protein ranging from 67.4 to 74.4 %. While, the crayfish meals contained the highest values of ash content compared with the other types of meals. Based on the present study, *P. clarkii* abdominal muscle seems to be a promising inexpensive source of animal protein for human consumption.

On the other hand, the unmarketable crayfishes and the inedible parts such as skeleton and wastes can also be exploited for producing a valuable type of fishmeal. Their utilization would contribute in the control and management of the wild population of *P. clarkii* in the river Nile, throughout catching it by traps.

Table 3. Comparison of chemical analysis between crayfish meal and crayfish waste meal *P. clarkii* and the commercial fish and shrimp meals .

Source	Moisture (%)	Protein (%)	Lipids (%)	ASH (%)	Authors
Crayfish meal	8.0	57.2	5.6	24.8	Present study
Crayfish waste meal	8.0	49.5	6.6	31.28	Present study
Shrimp meal	7.6	43.0	6.1	27..7	Mohamed (1995)
Shrimp	__	53.0	10.8	28.5	Ilian *et al.*(1985)
Shrimp meal	__	58.5	9.0	11.0	Tolokoniov *et al.*(1984)
Brine shrimp	11.6	50.8	5.1	19.0	Corazza and Saylor (1983)
Shrimp meal	__	51.0	5.3	14.3	Lawson and Sugden (1974)
Shrimp meal	10.0	47.4	3.1	26.6	Titus (1971)
Herring fish meal	7.2	72.4	8.0	11.7	Samy *et al.*(1986)
Herring fish meal	__	73.9	5.5	12.7	Bjornsted *et al.*(1974)
Menhaden fish meal	__	70.9	11.5	18.9	Sibbald and Wolynetz (1984)
Local fish meal	4.6	58.3	20.5	10.6	Samy *et al.*(1986)
Local meat meal	5.7	49.4	21.8	13.6	Samy *et al.*(1986)
Meat & bone meal	9.3	46.1	9.4	31.5	Waring (1969)

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كفاءه الصيد ، العلاقات المورفولوجيه ، والتركيب الكيميائى لإستاكوزا المياه العذبه الدخيله على نهر النيلِ وإمكانيه الإستفاده منها فى مصر

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تعتبر إستاكوزا المياه العذبه *Procambarus clarkii* الدخيله على نهر النيل قد تأقلمت بنجاح وإنتشرت إلى حد كبير فى نهر النيل وفروعه والترع والمصارف وخاصه فى الوجه البحرى فى مصر وأصبح من الضرورى دراسه إمكانيه إستغلالها وأهميتها الإقتصادية التى قد تَزدادَ مع الوقتِ ، ومع ذلك فإنها لم تقاوم أو تستغلُ في مصر حتى الآن بل تقع فى شباك الصيادين عشوائيا ولكنها غير مستهدفه لعمليه الصيد . لذا فقد تناول البحث الحالى قابليه صيد إستاكوزا المياه العذبه بواسطه الجوابى الإسطوانيه الشكل وتقدير متوسط كميه المصيد من هذا الحيوان بالنسبه لجهد الصيد (CPUE) للجوبيه الواحده / اليوم شهريا خلال عام 1998 وذلك لمعرفه كفاءه الصيد بالجوابى والوفره النسبيه الموسميه لهذا الحيوان فى نهر النيل . وتم دراسه العلاقات المورفولوجيه بين كل من أطوال وأوزان الجسم لكل من ذكور وإناث الإستاكوزا وبين كل من طول البطن وطول الدرقه ووزن العضله البطنيه (الجزء المأكول) ووزن الهيكل والأحشاء (الجزء غير المأكول) وتم تمثيل هذه العلاقات فى صوره معادلات ورسوم بيانيه. وقد وجد أن متوسط نسبه التشافى أعلى فى الأناث حيث تصل إلى 19.0 % بينما فى الذكور تعادل 15.5 % . وقد تم دراسه التّركيب الكيميائي لكل من الجسم كاملا والأجزاءِ الغير صالحة للأكلِ (الهيكل والأحشاء) ومقارنته بالتركيب الكيميائى لأشهر أنواع مساحيق السمك التجاريه لتقييم إمكانيه الإستفاده منها فى إنتاج مسحوق الإستاكوزا كبديل لمسحوق السمك المستورد . وهذه الدّراسةِ تُهدّفُ إلى التحكم فى عشيره إستاكوزا المياه العذبه فى نهر النيل عن طريق المقاومه الميكانيكيه بصيدها بالجوابى على ضفاف النيل ، إمكانيه إستغلال المصيد من الإستاكوزا فى إتجاهين الأول هو الإستفاده من العضله البطنيه الصالحه للأكل بتشفيتها وتصنيعها كطعام للإنسان سواء للإستهلاك المحلى أو للتصدير والثانى هو إستغلال الأجزاء الغير صالحه للأكل مثل الهيكل والأحشاء وكذلك الإستاكوزا الكامله الغير صالحه للتسويق فى إنتاج مسحوق الإستاكوزا كبديل لمسحوق السمك .

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Table 1. Monthly catch and catch per unit effort for males and females of the crayfish *Procambarus clarkii* harvested from the river Nile.

Month	Catch weight (Kg)		Crayfish number (N)		Catch per unit effort (CPUE) Gram / trap / day			Catch per unit effort (CPUE) Number / trap / day		
	Males	Females	Males	Females	Males	Females	Total	Males	Females	Total
Jan.	1.014	0.404	21	10	101	40	141	2.1	1.0	3.1
Feb,	1.590	0.710	32	16	159	71	230	3.2	1.6	4.8
Mar.	4.105	1.487	85	33	411	149	560	8.5	3.3	11.8
Apr.	5.182	2.921	105	61	518	292	810	10.5	6.1	16.6
May	4.011	2.689	82	57	401	269	670	8.2	5.7	13.9
Jun.	3.598	2.035	77	43	360	204	564	7.7	4.3	12.0
Jul.	3.706	1.204	76	29	371	120	491	7.6	2.9	10.5
Aug.	4.203	1.377	86	32	420	138	558	8.6	3.2	11.8
Sep.	5.097	2.073	102	45	510	207	717	10.2	4.5	14.7
Oct	4.310	1.290	91	29	431	129	560	9.1	2.9	12.0
Nov.	2.386	0.816	51	20	239	82	321	5.1	2.0	7.1
Dec.	1.504	0.305	32	7	150	31	181	3.2	0.7	3.9
Total	40.706	17.311	840	382	4071	1731	5803	84	38.2	122.2
Mean	3.39	1.44	70.0	31.8	339	144	483	7.0	3.2	10.2
± SD	± 1.42	± 0.85	± 28.68	± 17.28	± 141.9	± 84.6	± 217.2	± 2.87	± 1.73	± 4.42

SD is the standard deviation of the mean values.