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A Preliminary Observation on the Pond Culture of European Eel, *Anguilla anguilla* (Linnaeus, 1758) in Egypt: Recommendations for Future Studies

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Abstract: An experiment was conducted to assess the potential of the European eel, *Anguilla anguilla* for earthen pond aquaculture without supplementary feeding at Lake Manzala, Egypt. Juvenile *A. anguilla* of mean length 11.7 cm and 2.4 g weight were stocked in earthen ponds measuring 3 feddans (about 12,600 m^2) and 1 m deep. Stocking was done in May 2003 at a rate of 5000 fish $feddan^{-1}$ in a polyculture system including tilapia and mullets and fed mainly on natural occurring prey (natural spawned tilapia) and small shrimp. The eels were culture for a period of 2 years, May 2003 to April 2005. Sampling for growth and survival were evaluated yearly. At the end of the culture period, the gross weight of the harvested eels was measured and the net pond production calculated by the difference between weight stocked and weight harvested. Temperature varied from 11.5 to 28.2°C and 12.2 to 29.3°C; P^H, 7.3 to 8.9 and 7.5 to 8.8; Dissolved Oxygen (DO), 5.2 to 9.8 mg L^{-1} and 4.1 to 8.3 mg L^{-1}; and Salinity, 2.5 to 5.5 psu and 3.0 to 6.8 psu for first year and second year, respectively. At the end of the culture period, *A. anguilla* attained average weight of 121.4 g $fish^{-1}$ at the end of the first year and a weight range of 152.5 to 430 g $fish^{-1}$ with an average of 280.36 g $fish^{-1}$ at the end of the second year. Survival rate ranged from 91% during the first year to 100% during the second year. Net eel production was 540.18 kg $feddan^{-1}$ at the end of the first year and 723.36 kg $feddan^{-1}$ at the end of the second year. Daily increments in weight per fish were 0.33 and 0.44 for first and second year, respectively. This experiment demonstrated the possibility of cultivation of eels as well as the higher growth rate in earthen ponds. The aquaculture strategy of eel with high stocking densities through low cost artificial feeds are recommended in future studies.

Key words: European eel, *Anguilla anguilla*, Earthen fish pond, Lake Manzala, Egypt

INTRODUCTION

Eels are found in marine, brackish and fresh waters worldwide (Nandlal, 2005). It is a potential candidate for aquaculture after trout and carp (Altun *et al*., 2005). According to Arial (1991), eels are generally classified as warmwater fish and 19 species, including sub species of the *Anguilla* genus, are distributed throughout the world. Four species are commercially important viz., the European eel, *Anguilla anguilla*, the Asian eel, *A. japonica*, the North American eel, *Anguilla rostrata* and the Australian eel, *Anguilla australis*. The European eel *A. anguilla* has long been an important economic resource for fishermen in the Atlantic and Mediterranean coasts (Melia *et al*., 2006). Similarly, this species is also widely valued along the eastern and southern coasts of Turkey (Ozogul *et al*., 2005). Worldwide, the annual aquaculture production of freshwater anguillid eels is estimated at around 230000 Mt, valued at over US$ 1.1 billion (FAO, 1999). The wild stocks of *A. anguilla* stock, have however, been declining since the early 1970s, with official catches diminishing from >20000 t in 1968 to c. 7000 t at the end of the 1990s (Melia *et al*., 2006). According to O'Sullivan (1997), despite the increased global demand for cultured eels, eel production has declined worldwide in recent years due to the combined effects of over fishing and environmental degradation, negatively impacting on recruitment. In view of the above factors, eel culture presents an opportunity to bridging the gap between supply and demand of eels worldwide (Nandlal, 2005).

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A wide variety of production systems such as cages, ponds, tanks and raceways are being used for aquaculture in agriculture, freshwater and marine environments in Egypt (Jamu and Ayinla, 2003). In Egypt, aquaculture is concentrated on inland farms, with the main species culture being tilapia and mullets. However, high productivity of these systems has led to over supply of the two species, with consequent decline in market prices. Hence, there is a need to investigate new species amenable for culture under the existing conditions as a strategy for diversifying market opportunities for the cultured species in Egypt and the whole world as well. Various species of eels have been cultured under both extensive and intensive systems in Japan, the Far East countries, Americas and Europe (Altun *et al*., 2005). However, *A. anguilla* remains one of the most important and valuable commercial species in Egypt with a wide market and great customer appeal. Moreover, Lake Manzala, Egypt presents an ideal location and environment for eel culture due to access to warm ambient water which is conductive for good growth rates for eel.

The life cycle of eels is complex and has not yet been completely clarified (Tanaka *et al*., 2001). Tsukamoto (1992) defined the spawning area of *A. japonica* as lying on the western coasts of the Mariana Islands, based on the observed presence of many small young leaf-shaped leptocephalus stage larvae (7.9 to 24.5 mm TL, 10 to 40 days after fertilization) during the summer period.

Several studies have investigated the biology and ecology of eels in the world (Starkie, 2003; O'Sullivan *et al*., 2003; Altun *et al*., 2005). Further, the management and restoration of the European eel population in natural water bodies has been described by several researchers (Eric, 2002; Russell and Potter, 2003). Masaaki *et al*. (2003) studied the water metabolism in the eel acclimated to seas water. Muller *et al*. (2003) studied the effects of various hormones of the sexual maturity of European eel females. Juan *et al*. (2004) studied the effect of environmental factors, especially ammonia on eel reared in tanks. Semi-automated feeding controllers for eels under culture have also been described (Chang *et al*., 2005). Research and available literature on *A. anguilla* and *A. japonica* shows wide differences observed during husbandry, growth and feed utilization under culture trials (Heinsbroek, 1989; Altun *et al*., 2005). The culture of the *A. anguilla* species hasn't been carried out on a commercial basis and this study presents the first steps towards commercialization of this species for aquaculture.

Feed expenditure constitute 30-70% of total expenditure in fish culture and for this reason different methods have been essayed to gain benefit from every kind of feed source especially in the countries with developed aquaculture sector (Yildirim *et al*., 1999). The overall goal of the aquaculture is to reduce production costs. maximize production and increase profitability (Yildirim *et al*., 1999). The present study was carried out to assess the potential of the European eel, *A. anguilla* for culture under the existing conditions within the Lake Manzala area without use of supplementary feeding, under earthen pond systems. The study further recommends avenues for further research in the commercialization of this species the earthen aquaculture industry in Egypt.

MATERIALS AND METHODS

Study site and experimental units: The experiment was carried out over a period of two years, from May, 2003 through April, 2005. Earthen ponds of rectangular shape measuring 3 feddans (about 12,600 m^2 area) and average water depth of 1 m located in the southern part of Lake Manzala, Egypt, were used. Productivity was based on the natural productivity of the ponds hence the experimental ponds were kept free from any shading through out the day. Water supply to the culture units was pumped from the lake and the existing polyculture systems of the ponds, integrating both tilapia and milkfish, maintained. Sampling for physico-chemical parameters was done once a week between 09.00 h and 12:00 h from specific points of the pond at a depth of 20-30 cm below the surface. A mercury thermometer was used to measure water temperature (°C), while salinity (psu) was measured with a salinometer. Digital electronic meters (Model YSI-58, USA and Jenway Model-3020) were used to measure Dissolved Oxygen (DO) (mg^{-1}) and pH on site, respectively, according to the standard procedures and methods as defined in APHA (1992).

Fish stocking and sampling: The pond was stocked with the juveniles of *A. anguilla* obtained from the northern part of lake Manzala, at the rate of 5000 fish $feddan^{-1}$ (about 0.85 fish m^{-2}) at the initial stocking in first year. The juveniles used in the stocking ranged from 0.7 to 7.0 g average weight per fish. Total lengths of the stocked juveniles eels ranged from 8.6 to 17.1 cm $fish^{-1}$. Before stocking *A. anguilla* juveniles, the experimental pond were stocked with milk fish and tilapia in polyculture systems to provide nutrition for the cultured eels, preying the occurring prey of spawned tilapia fingerlings in the ponds. Additional feeding supplement was done with wild collected *Tilapia zillii* fingerlings and small shrimps of the *Palaemon* sp.

Twenty four random samples of the fish were taken during the 2 year study period (12 samples/year), where 12-15 juveniles eels were randomly sampled monthly by using basket traps. The samples were measured for weight and length to the nearest 0.01 g and 0.01 cm, respectively.

At the end of the first year experiment, the pond was harvested and a complete census of all eels done, where all the harvested individuals were counted; weighed and length measurements taken. All harvested eels were restocked for the second year studies. To ensure complete harvest, the eels were harvested initially by netting and any remaining individuals harvested by complete draining of the earthen ponds and hand picking any eels in the ponds.

Fish growth, expressed as daily increment in weight (g fish^{-1}) or the increase in body weight per day (% day^{-1}) was calculated based the following formula:

$$DGR = (W_2-W_1)/t$$

Where, W_1 is the initial live body weight (g), W_2 is the final live body weight (g) and t is the time in days.

Survival rates (%) were estimated as: No. of fish harvested/no. of fish stocked ×100. Net production kg feddan^{-1}) was calculated by deducting the biomass stocked from the biomass harvested.

The mean fish weight (g) was determined in terms of gain in weight:

$$GW = (W_2-W_1)/W_1 \times 100$$

Where, W_1 is the initial live body weight (g), W_2 is the final live body weight (g).

Statistical analysis: Variations in physico-chemical parameters and growth data were tested by using one-way ANOVA and any difference at 5% level of significance using the Tukey test.

RESULTS

Physico-chemical parameters: Mean values of some water quality parameters such as temperature, pH, dissolved oxygen and salinity were calculated to provide an overview of changes in the eel culture earthen ponds during the experimental period as shown in Table 1. Water temperature varied from 11.5 to 28.7°C with an average of 18°C during the first year and from 12.2 to 29.2°C with an average of 19.8°C during the second year depending upon environmental variation.

There were no significant variations in temperatures between two years during this study. The water pH varied from 7.3 to 8.9 with an average of 7.8 during the first year and varied from 7.5 to 8.8 with an average of 8.1 during the second year. Dissolved oxygen content varied from 5.2 to 9.8 mg L^{-1} with an average of 6.6 mg L^{-1} during the first year and ranged from 4.1 to 8.3 mg L^{-1} with an average of 5.9 mg L^{-1} during the second year. Water salinity ranged from 2.5 to 5.5 psu with an average of 4.2 psu during the first year and ranged from 3 to 6.8 psu with an average of 4.8 psu during the second year depending upon the tide in the lake, drainage water discharged into the lake and the seasonal variations. The variations of pH, dissolved oxygen and salinity were similar ($p>0.05$) between two years and within the productive range.

Growth and production of eel: The mean values for body weights were 121.38 and 280.36 g fish^{-1} at the end of the first and second year, respectively. The survival rates were high (91%) during the first year and there were no mortality during the second year. The net production (kg feddan^{-1}) was 540.18 and 723.36 for the first and second year, respectively. The results of the present experiment demonstrated that eels grew fast in the first year with a percentage increase (% weight gain fish^{-1}) of 4915.7% and then growth declined towards the end of the second year with a percentage increase of 131%. The growth performance for the first and second year were significantly different ($p>0.05$), when increase in biomass was taken into consideration (Table 2).

Table 1: Summary of water quality variables measured in the experimental earthen pond at Lake Manzala, Egypt during May, 2004 to April, 2005

	1st year (May, 2003 to April, 2004)			2nd year (May, 2004 to April, 2005)		
Parameters	Min	Max	Mean	Min	Max	Mean
Temperature (°C)	11.5	28.2	18.0	12.2	29.3	19.8
pH	7.3	8.9	7.8	7.5	8.8	8.1
Dissolved oxygen (mg L^{-1})	5.2	9.8	6.6	4.1	8.3	5.9
Salinity (psu)	2.5	5.5	4.2	3.0	6.8	4.8

Min: minimum; Max: maximum

Table 2: Growth performance of the European eel, *Anguilla anguilla* (L. 1758) cultured in the earthen pond at Lake Manzala, Egypt during May, 2004 to April, 2005

Parameter	First year	Second year
Average initial weight (g fish^{-1})	2.42	121.38
Average finial weight (g fish^{-1})	121.38	280.36
Average initial total length (cm fish^{-1})	11.66	40.58
Average final total length (cm fish^{-1})	40.58	54.41
Stocking rate (fish feddan^{-1})	5000.00	4550.00
Survival rate (%)	91.00	100.00
Total weight at stocking (Kg feddan^{-1})	12.10	552.28
Rearing period	1 year	2 years
Total production (kg feddan^{-1})	552.28	1275.64
Net production (kg feddan^{-1})	540.18	723.36
Gain in weight (g fish^{-1})	118.96	158.98
% gain in weight	4915.00	131.00
Daily increment in weight (g fish^{-1})	0.33	0.44
Daily increment (kg feddan^{-1} day^{-1})	1.48	1.98

DISCUSSION

During the study period, variations of water temperatures are attributed to weather conditions and statistical tests showed no significant differences in temperatures between first and second year. The observed average temperatures were within the optimal ranges (18.3-37.8°C) for fish production in tropical ponds (Begum *et al*., 2003; Hossain *et al*., 2006). However, Boyd (1992) recommends optimal temperature for fish culture, in the range 26.06-31.97°C, if fish growth and consequently yields are to be optimized. It should also be noted that temperature alone may not account for variations in plankton as well as fish production, other factors such as high pH, alkalinity, carbon dioxide and nutrients are also responsible for the organic production (Pulle and Khan, 2003; Hossain *et al*., 2006). The variations in pH, dissolved oxygen and salinity for the both years were similar ($p>0.05$) and within the productive range (Wahab *et al*., 1994; Hossain *et al*., 2007).

The rapid development of aquaculture for global food security is gaining importance. This trend has led to intensification and diversification of aquaculture activities. The European eel is one of the most valuable commercial fish for aquaculture. The present work deals with the possibilities of cultivation of eels in earthen ponds without any supplementary feeding. The present results recorded survival rates of 91 and 100% for first and second year, respectively. This higher survival rates was partly because of the favorable conditions and the good water quality, beside the initial weights which were high (average 2.42 g and 11.66 cm). Various rates of survival for juvenile eels under culture conditions have been reported in the literature, such as 74-99% for *A. anguilla* glass eels being weaned (Kamstra and Heinsbroek, 1991); 20-95% for *A. japonica* elvers in nursery ponds; 40-60% for *A. anguilla* elvers in nursery tanks (Heinsbroek, 1991). In Japan, survival after 2-3 months of juvenile *A. japonica* and *A. anguilla* during the nursery pond phase was reported as 70-90 and 50-60%, respectively (Heinsbroek, 1991). Belpaire *et al*. (1990) reported survival rates of 40-94% for glass eels of *A. anguilla* held in earthen ponds for 6-7 months. However, the present study showed the higher survival rate than reported by other researchers (Kamstra and Heinsbroek, 1991; Heinsbroek, 1991; Belpaire *et al*., 1990).

The daily increment (g $fish^{-1}$) during the present study was 0.33 and 0.44 for the first and second year were higher than that recorded by Tanaka *et al*. (2001) where they recorded daily growth of 0.129 g day^{-1} at the end of day 100 after hatching in captivity which was nearly half that of wild specimens at the same days. They interpreted that the slow growth rate and the differences in body proportions of reared larvae compared to those from the wild specimens may be partly due to an incomplete diet, limited feeding period and different water temperature relative to their natural habitats. The present results proved that the cultivation of eels in earthen ponds is possible. Tanaka *et al*. (2001) reared the larvae of eel in aquaria for 100 days and raised the juveniles to 22.8 mm in total length. They found that age, total length and body proportions of the reared specimens overlapped with those of wild. However, according to Guven *et al*. (2001) the daily growth rate means of eel were between 0.295-0.500 g for *A. anguilla* in Turkish waters located very close to the present study sites.

The final weights of *A. anguilla* after the first and 2nd phase of this study were 121.38 and 280.36 g $fish^{-1}$ at the end of the first and second year, respectively; sizes which were acceptable as a good market sizes for consumers. The final net productions were 540.18 and 723.36 kg $feddan^{-1}$ for the first and second year, respectively, which means that the eel culture is highly profitable due to the high prices of these species.

Fish meal is the main component of majority of artificial fish feeds and one of the most expensive ingredients in the manufacture of artificial feeds, consequently increasing the overall costs of fish production. (Altun *et al*., 2005). During this study the strategy of aquaculture without any artificial feeds has been developed in Egypt, where the artificial fish meal unavailable and expensive. However, it is obvious that in addition to artificial feed discarded fish and fish wastes from the local fish markets may be utilize to improve the aquaculture strategy of eel in Egypt. Poultry wastes may also be used as artificial feeds. It may be recommended to apply higher stocking rate with low cost artificial feeds for the possible more growth or production in ponds and improved pond design, pond management strategies and improved harvesting techniques may also be suggested for the optimal growth of eel in the earthen ponds.

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