Mediterranean Marine Science

Vol 6, No 1 (2005)

Glass eels (Anguilla anguilla) growth in a recirculating system

P. ANGELIDIS, I. POURNARA, G. PHOTIS

doi: 10.12681/mms.196

Mediterranean Marine Science
Vol. 6/1, 2005, 99-106

Glass eels (*Anguilla anguilla*) growth in a recirculating system

P. ANGELIDIS [1], I. POURNARA[2] and G. PHOTIS[1]

[1] Laboratory of Ichthyology and Ichthyopathology,
Veterinary Medicine School,
Aristotle University of Thessaloniki,
POB 395, 541 24 Thessaloniki, Greece

[2] Department of Crystallography,
Birkbeck College, University of London, U.K

e-mail: panangel@vet.auth.gr

Abstract

On a commercial eel farm, which uses a recirculation system, 400,000 glass eels were farmed for a period of 328 days at 20º – 23º C. The physicochemical parameters of the farm water were kept at normal conditions during the experiment. The NO_2^- was kept between 1.0 and 3.0 mg/l. By the end of the experiment, 4,582 kg of fish feed were consumed and 2,939 kg of eels were produced (177,523 eels with mean final individual body weight of 16.6g and mean food conversion ratio of 1.625). The glass eels showed a high variability in their capacity to grow.

Keywords: Glass eels; Eels; Anguilla; Growth.

Introduction

In contrast to the traditional methods of farming eels in open air earth ponds, the recirculation systems are increasingly utilized in the modern eel farming industry (KAMSTRA *et al.* 1998, YANG *et al.* 2001). Minimal amounts of water, controlled farming conditions (pH, dissolved O_2, temperature, food consumption) and disease control are some of the recirculation systems' advantages compared to the traditional eel farming systems. Moreover, they are capable of removing and neutralizing the dissolved toxic compounds from the farming water. Several types of recirculation systems have been developed in order to farm the fish under optimal conditions. In Greece, during the last decade ten recirculation eel farming systems have been constructed using different water purification systems. Their efficiency to grow elvers is not the same. In addition, the quality of the construction and the farmer's experience play a key role on the system's efficiency. During the last years, recirculation systems are running better and better and their efficacy

has become satisfactory. The eels grow from the glass eel stage to commercial size (≥ 120g) in almost 14 - 18 months.

A number of attempts has also been made to grow glass eels in these systems. Glass eels are much more sensitive than elvers and yellow eels, and thus they need to be handled carefully. In 1991 (P. ANGELIDIS, unpublished data), glass eels were grown in an experimental recirculation system in Nea Mihaniona, Northern Greece. Within 8 months, the derived elvers had only reached 10g of their mean individual weight (MIW). A second attempt was carried out in a commercial recirculation eel farm system with unsatisfactory results (FOTIS *et al*.2000).

We believe that the success of a recirculation eel farm depends to a high degree on its capacity to start each eel batch with glass eels; thus we carried out this study in order to assess this assumption. In this study, fresh mussel meat as a glass eel raw starter food, was introduced for the first time in Greece. To avoid technical problems the farm set up was designed and constructed according to our previous experience in glass eel farming. On the other hand, samples of eels were examined weekly by a veterinarian fish pathologist to minimise the impact of the pathogens on the eels' viability and growth. Also the water parameters shown in the Table 1 were constantly monitored. This study was conducted on a commercial recirculation eel farm that had purchased glass eels for the first time.

Materials and Methods

Fish

Four hundred thousand glass eels (total weight 120 kg, mean individual weight 0.3g) arrived at a commercial eel farm in the region of Thessaloniki, Greece. The fish originated from France and they were transported by a special tank truck in brackish water (10‰ NaCl). The journey lasted about 48 hours. During the transportation, the tank water (16°C) was renewed twice and constantly aerated.

Table 1
Physicochemical parameters of the farm water.

Parameter		Value
T° (temperature)	°C	21.5 + 1.5
O_2	mg/l	7.2 + 0.2
PH		7.6 + 0.4
NH_3	mg/l	0.4 + 0.3
NO_2^-	mg/l	2.0 + 1.0

Farm set up

The eel farm is a four-meter high building thermo-isolated by 50mm thick polyurethane panels of the 'sandwich' type. The farm is equipped with a special glass eel growth section. This section consists of 8 circular polyester tanks of 2.5m^3 each (diameter 2450mm), a mechanical filter (drum filter, 40μ mesh size) with a continuous back wash system and a plastic biological filter (trickling filter) with a specific surface of 6.000m^2 (30m^3, 200m^2/m^3). There is also an oxygen reactor (1m^3) functioning with pure oxygen and one ultra violet disinfecting unit (UV) with six bulbs of 40 watts each. The recirculation of the fish tank water takes place twice per hour by two centrifugal pumps. In each cycle, the water is passed through the mechanical filter, the biological filter, the oxygen reactor and the UV unit.

The farm is supplied with ground water by a 150m borehole. The ground water is stocked in a 40m^3 indoor concrete tank under aeration to eliminate the dissolved gas, before it is used on the farm. This system was elaborated by Hezy BV (Arie de Bondt, Bergambacht, NL) adapted by P. Angelidis and constructed by I. Kiosses (603 00 Eginio Pierias, Greece).

Glass eel farming procedure

The 400,000 glass eels were placed in 6 out of the 8 circular polyester tanks. In each tank, two or more plastic cylindrical meshes with a diameter of 150mm and length of 1200mm were suspended to allow the fish to rest. During the first ten days, the fish tanks were supplied with water from the stock tank and the system was open. The fish tank water was renewed

three times per day. An air blower assured the oxygenation of the water.

At the beginning of the experiment, the fish density of the tank water was 8kg/m^3. On the first day, the glass eels were preventatively treated with antibiotic baths (Oxytetracyclin HCl 20.0mg/l of tank water for one hour) and on the following days with anti-fungal (NaCl at a concentration of 30‰ for one hour) and anti-external parasite baths (Formaline 38%, 250ml/m^3 for one hour). The presence of skin and gill parasites was checked on a weekly basis.

The dissolved oxygen (Oxyguard hand meter) and the pH (WTW hand meter) of the water were constantly measured. The oxygen reactor was automatically correcting the oxygen concentration in the farm water. The NH_3 and the NO_2^{-2} were measured once per week by a photometer (Hanna C103 and Hanna instruments HI 93708–0, and Nitrite high range reagent, respectively). The physicochemical parameters of the farm water are shown in Table 1. Its temperature was kept between 20 and 23°C and an automatic band feeder distributed the commercial food in each fish tank.

Food

For the first three days, each tank was supplied with 5 – 10 fresh mussel flesh pieces three times per day. From the 4th until the 30th day, the food was a wet mixture consisting of fresh mussel flesh and commercial food characterized as starter.

Its quantity was augmented every day to achieve 10% of the fish's biomass by the 30th day. The quantity of the mussel flesh was progressively decreased in favour of the starter. After the 30th day and until the 90th day, the fish received a mixture consisting of the starter and a commercial special food [Food No 2: food dimension: 2mm, proteins: 48.2%, fat: 25.5%, fibre: 0.5%, humidity 8.0%, phosphor (% of the starch):1.3, ash: 6.9%] for the first stage of the glass eel nutrition. At the same time, dry food (No2) was introduced into the fish tanks by the automatic band feeders. The daily total food quantity was almost 10% of the fish's biomass and it was distributed three times per day. The quantity of the starter in the mixture was progressively decreased and there was no starter by the end of the 50th day. Also, the quantity of the wet mixture was decreased and thus only dry food was distributed after the 40th day.

Feed No 2 was distributed between the 90th and the 150th day and then the eels received feed food No 3 [food dimension: 3mm, proteins: 48.2%, fat: 25.5%, fibre: 0.5%, humidity 8.0%, phosphor (% of the starch):1.2, ash: 6.9%] until the 328th day which was the end of the study period. The food compositions are also presented in Table 2.

The daily-distributed food quantity was gradually decreased from 10% to 5% during

Table 2
Eel food and its composition (%) in each farming period.

Life Period (days)	Food type	Food dimension mm	Proteins	Fat	Fibre	Humidity	Phosphor Starch*	Ash
0 - 3	Mussels							
4 – 30	Mussels + Starter	0.6 – 0.9	56	14.2	0.6	8.0	3.0	7.6
30 - 90	Starter + No1	1.5	49.1	25.5	0.5	8.0	1.3	6.5
90-150	No 2	2	48.2	25.5	0.5	8.0	1.3	6.9
150-328	No 3	3	48.2	25.5	0.5	8.0	1.2	6.9

* This value concerns the % of the starch.

the period of 40th –150th day and it was further reduced to 2% until the end of the experiment.

The quantity of the daily-distributed food was adjusted every 15 days according to the estimation of the weight gain of the fish within these 15 days. This estimation was based on our previous unpublished data. The right adjustment was performed according to the real weight the fish had on the grading days.

In order to overcome the difficulty in determining the consumed food quantity under farm conditions so as to calculate the food conversion rate [FCR - quantity of food that was eaten / (final fish weight - initial fish weight)] we introduced the distributed food conversion rate [DFCR - quantity of food that was distributed / (final fish weight - initial fish weight)].

Eel handling

The glass eels, the elvers and the yellow eels were graded on the 46th, 76th, 115th, 157th, 198th, 241st, 276th and 328th day by a special eel grader. After each grading, the fish continued to be farmed in groups with similar individual body weight. During the studied period, the fish received bath treatments, applied by the veterinarian inspector (fish pathologist), to control external parasitic and fungal infections.

Fish clinical examination

The behaviour of the fish in the tanks was observed every week by the veterinarian inspector. At the same time, samples were taken to examine the skin scrapings and gill tissues by light microscope for the presence of fungal and external parasites.

Statistic analysis of the results

The fish were weighed all together at each grading day. The mean individual weight (MIW) was calculated as the total fish weight over the number of fish corresponding to this total fish weight. The mean growth rate is the percent (%) per day = 100 X [(final weight/initial weight)/number of days between measurements].

Results

The field experiment lasted for 328 days. The experiment started with 400,000 glass eels (120kg). The glass eels had a mean individual weight (MIW) of 0.3g. By the end of the experiment, 177,523 eels remained with a MIW of 16.56g and the total eel weight was 2,939kg (Table 3).

The total distributed food amount was 4,582kg (Fig. 4). The mean DFCR was 1.625 (4,582kg food / (2,939kg – 120kg) weight gain). The DFCR, the eels' weight, the distributed food amount, the percentage of growth and the observed mortality in each farming period are shown in Table 3.

The highest mortality rates were observed during the first 76 days. These were 25% for the first 46 days and 34% for the following 30 days (Fig. 1). The mean growth rate evolution (%) is shown in Figure 2. ($GR = [(W_2/W_1) / (t_{2-1})]*100\%$ W1: initial fish weight, W2: final fish weight, t2-1: farming period in days. The highest mean growth rate (5.5%) was observed in the second farming period lasting 39 days (between the 76th and the 115th day). By the end of the experiment, the observed mean growth rate was 2.9% in a period of 52 days.

Figures 3 and 4 show the DFCR evolution related to the mean individual eel weight and the food quantity distributed, respectively. Both figures show that the DFCR was greater when the fish were small and consequently, small amounts of food were distributed. Figure 4 shows the correlation between the distributed food and the MIW.

Between two consecutive gradings (a farming period), the fish showed large diversions in their growth rates even when they belonged to the same eel group (same MIW). The fish showed growth rates as high as 1,100% and as low as 0% (Table 4) (within the same

Table 3
Details of the eel groups for each farming period between two consecutive grading days.

	Day								
	0	**46**	**76**	**115**	**157**	**198**	**241**	**276**	**328**
Weight (KG)	120	141	216	461	728	1,043	1,472	1,932	2,939
n (eel number)	400,000	299,299	198,338	185,968	184,438	178,283	178,017	177,700	177,523
MIW (W/n) (g)	0.30	0.47	1.09	2.48	3.95	5.85	8.20	10.87	16.56
Mean Final Growth %	2.6	5.1	5.5	3.8	3.5	3.3	3.8	2.9	
Total Mortality %	25.2	33.7	6.2	0.8	3.34	0.15	0.2	0.1	
Total Food Distributed (kg)	75	194	310	525	635	753	659	1,431	
DCFR (on the distributed food)*	3.57	2.59	1.27	1.97	2.02	1.76	1.43	1.42	

* DCFR formulation appears in the material and methods.

Table 4
Analysis of the eel growth (GW %) and the corresponding eel population (n %) for each MIW group based on the initial eel weight (IW) (g) on each sampling period.

D 46		D 76		D 115		D 157		D 198		D 241		D 276		D 328	
MIW	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**	**MIW**	**n%/GW%**
	31 / 0		73 / 186		78 / 50				32 / 0		63 / 0		81 / 0		95 / 18
0,3	19 / 20	**0,28**	24 / 329	**0,8**	20 / 388	**1,3**	100 / 54	**2,5**	68 / 100	**2,26**	37 / 121	**1,5**	18 / 233	**1,7**	5 / 312
	37 / 80		3 / 864		2 / 625				0,3 / 1100				1 / 567		
	13 / 197														
			67 / 122		48 / 0		27/ 0		18 / 0		70 / 0		92 / 2		99 / 17
		0,36	30 / 233	**1,2**	35 / 225	**3**	40 / 67	**2,8**	81 / 79	**5**	30 / 100	**4,9**	6 / 104	**6**	1 / 317
			4 / 650		17 / 383		33 / 150						2 / 512		
			54 / 48		54 / 44		15 / 0		46 / 0		78 / 0		8 / 0		72 / 47
		0,54	37 / 122	**2,7**	46 / 115	**3,7**	50 / 35	**5,6**	53 / 79	**10**	22 / 200	**9,42**	73 / 6	**17**	26 / 194
			9 / 400				34 / 103		2 / 436				17 / 218		2 / 429
							1 / 251						2 / 537		
			46 / 0						79 / 0						
		0,89	35 / 35			**5,1**	51 / 32	**10**	21 / 194			**40**	34 / 0	**67**	1 / 0
			19 / 203				49 / 128						66 / 50		99 / 34

MIW group and the same farming period). In all the farming periods, the highest growth rates were observed in eel groups with small MIW.

Discussion

In the present study, the glass eels and the produced elvers and yellow eels showed a quite satisfactory growth during the 328 days of the total farming period. The 120kg (400,000 individuals) glass eels produced 177,523 elvers and yellow eels weighing 2,939kg and the total distributed food amount was 4,582kg. The mean DFCR was 1.625. This elvers' biomass was produced despite the initial high mortality rates (total mortality 55.5%). The high level of mortality can be mainly explained by the lack of the farmers' experience of growing glass eels. It is also possible that the continuous presence of NO_2^{-2} between 1.0 and 3.0mg/l (LOSORDO *et al.* 2000 suggest that the NO_2^{-2} values should be maintained between 0.2 and 5.0mg/l) increases the mortality rates by decreasing the appetite of the glass eels during the first stage of their farming period. The mortality shown during the second (between 46th and 76th day) farming period (33.7%) is indubitable due to the complete lack of intake of food by these fish.

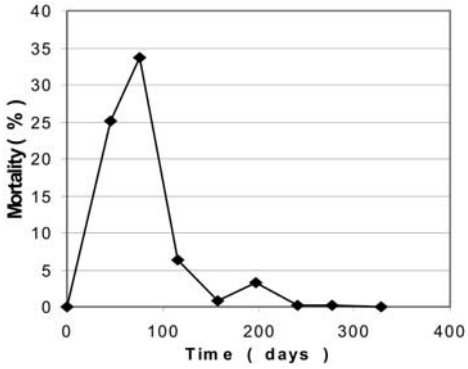

Fig. 1: Mortality.

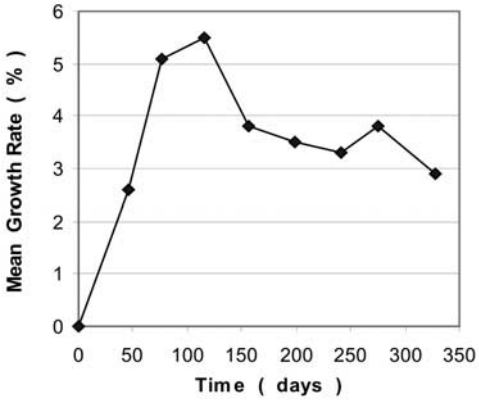

Fig. 2: Mean Growth Rate Evolution.

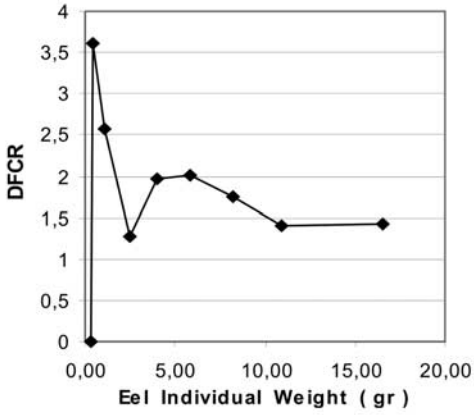

Fig. 3: Distributed Food Conversion. Rate (DFCR) related to the mean individual eel weight.

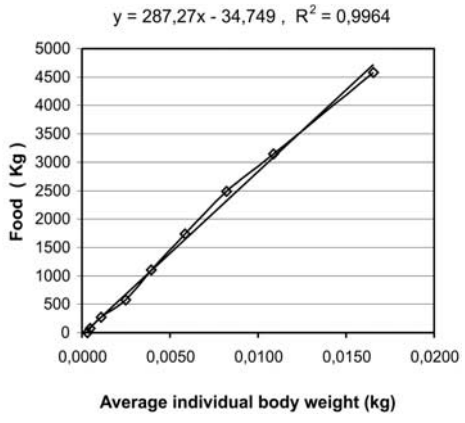

Fig. 4: Correlation between distributed food and individual body weight.

During the first days of the farming period, the glass eels showed a DFCR value of 3.61 (Table 3). This high DFCR is misleading because during those days a high percentage of the distributed food was uneaten and the mortality level of the fish was high. This high DFCR concerns only a short period of the total farming period during which the distributed quantity of the food was too low (Table 3). Thereafter, it cannot influence the total profitability of the eel farm even if the price of the starter food is high. The linear correlation between food distributed and individual body weight (Fig. 4) clearly demonstrate that there was a homogenous food intake.

Previous observation (FOTIS *et al.*, 2000) showed that on an eel farm with a recirculation system, the 20,000 elvers with MIW of 5.89g (total weight 117.8kg) produced a total weight of 478.8kg after 335 days of farming (36.3% of 5.95g MIW, 14.4% of 24.35g MIW, 6.7% of 48.95g MIW, 4.4% of 95.8g MIW, 3.4 % of 106.47g MIW, 5.6 % of 110.54g MIW and only 2.1% of 146.16g MIW). The total mortality during this experiment was as high as 27.1%. Thus, the growth rate was very low and the mortality rate was very high. The authors attributed the unsatisfactory results mainly to the malfunction of the applied water treatment system and to the observed diseases (gill necrosis, bulb disease, dactylogyrosis, trichodinosis).

In the present experiment, fresh mussel flesh was used as the food starter; other farmers use cod and plaice frozen ova for the same purpose The fish ova are sensitive to fungus development, if they are not properly conserved. This ova degradation often provokes massive glass eel mortality just after the toxic diet (personal observation). In the present experiment, the observed mortality cannot be attributed to such acute toxicity. Pathogens related directly with the mortalities were not detected.

After the first acclimatization period in the farm (46 days), the fish showed satisfactory mean growth rates as high as 5.5% during 39 days. The fish did not show homogenous growth rates. By the end of the experiment, there were elvers and yellow eels with a mean individual weight between 1.7g and 67g, respectively (Table 4). This high variability in the growth capacity of the fish that have been farmed exactly under the same conditions is very common in aquaculture and especially in the eel industry (DEGANI *et al.*, 1986).

Due to the farming system, we were not able to observe the growth capacity of individual fish. On each grading day, the fish were grouped and placed in tanks according to their weights. Thus, between two grading days we could only observe the growing capacity of fish belonging to the same tank. The effect of the eel stocking density on their fish growth and the growth variability was not examined.

The results concerning the eel growth capacity are shown in Tables 3 and 4. It is very difficult to draw conclusions from these results due to the wide variability. Nevertheless, some observations can be made.

In almost every farming period, the eels of the groups (same age for all the eels) with the smaller body weight showed larger growth capacity. The largest growth capacities are shown only in a small number of fish.

However, the comparison of the growth rates of the eels with similar MIW but between different periods (similar MIW but different age) showed that the younger eels have a higher capacity to grow (Table 4, Day 115: MIW 1.2 and Day 276: MIW 1.5). It is obvious that the growth capacity is related to the eel's age and to its body weight. However, this does not seem to be the case for the yellow eels with MIW of 100g or more where the females grew faster than the males (VOLLESTAD & JONSSON 1986, VOLLESTAD 1992, POOLE & REYNOLDS 1996, TZENG *et al.* 2000). These results show that it is catastrophic for farmers who do not have the ability to grow glass eels on their farms and thus are obliged to buy 'older' eels of 5 to 10g of MIW. Only if

these eels are young enough, can the farm's production be satisfactory.

If we observe the fish in the groups with the smaller body weight during each grading day, we can see fish that did not show any growth in the preceding farming period, but grow in the following periods as much as 233 % in 43 days (MIW 1.5 in the farming period of 198th to 241st day).

The majority of the fish showed higher growth rates (compared to the other eels in the same MIW – age group) in the high MIW eel groups of the same age. (i.e. on Day 276, 81% of the eels of the 1.5g MIW group, almost 92% of the 4.9g MIW group, 8% of the 9.42g MIW group and 34% of the 40g MIW group showed zero growth).

It is obvious that there was a depletion of the groups of those eels able to grow each grading day. Despite that, elvers always remain able to show satisfactory growth rates. We need to investigate what the "factor" is that controls some elvers to 'wake up' and grow. If the glass eel genome plays the most important role, it is for the moment impossible to schedule a genetic improvement or selection because of the particular mode of reproduction of eels. The sex maturation hormones must play a critical role on the growth but they only act when the eels have a body size of about 25cm long (ANDERSEN *et al.* 1996). Thereafter, the only factors that can be influenced for the time being are the farming conditions including the water quality, food, water temperature, fish density (kg b.w./m^3 or /m^2 ,oxygen, etc).

In the present study it was impossible, due to the farming type, to study the growth capacity of the eel groups as they were derived on the first grading day. In such an experiment, it could be possible to see how early the eel growth capacity can be recognized and if some eels that show a high growth rate at the beginning of the farming period lose it later. Moreover, interventions to improve the growth capacity of the eels could be studied. This kind of experiment needs many tanks, the same conditions in all the farming tanks and a high precision of food distribution, food intake, oxygen diffusion, etc. because of the small biomass that has to be used.

References

ANDERSEN D., BOETIUS I., OLESEN LARSEN L. & HJULMANN SEIDLER P., 1996. Effects of oestradiol-enriched diet and of feeding with porcine testicular tissue on macroscopic gonadal sex in European eels. *Journal of Fish Biology*, 48, 484-492.

DEGANI G., HAHAMU H. & LEVANON D., 1986. The relationship of eel *Anguilla anguilla* (L.) body size, lipid, protein, glucose, ash, moisture composition and enzyme activity (aldolase). *Comparative Biochemistry and Physiology*, 84, 739-745.

FOTIS G., FLOROU-PANERI P. & GAVRIILIDOU E., 2000. Effects of closed recirculating systems on growth of eel *Anguilla anguilla* (L.). *Animal Science Review*, 27, 55-66 (in Greek).

KAMSTRA A., VAN DER HEUL J.W. & NIJHOF M., 1998. Performance and optimisation of trickling filters on eel farms. *Aquaculture Engineering*. 17, 175-192.

LOSORDO T. & HOBBS A., 2000. Using computer spreadsheets for water flow and biofilter sizing in recirculating aquaculture production systems. *Aquaculture Engineering*, 23, 95-102.

POOLE, W. R. & REYNOLDS, J. D., 1996. Growth rate and age at migration of *Anguilla anguilla*. *Journal of Fish Biology*, 48, 633–642.

TZENG W. N., LIN H. R., WANG C. H. & XU S. N., 2000. Differences in size and growth rates of male and female migrating Japanese eels in Pearl River, *China Journal of Fish Biology*, 57, 1245–1253.

VOLLESTAD, L. A. & JONSSON, B., 1986. Life-history characteristics of the European eel *Anguilla anguilla* in the Imsa River, Norway. *Transactions of the American Fisheries Society*, 115, 864–871.

VOLLESTAD, L. A., 1992. Geographic variation in age and length at metamorphosis of maturing European eel: environmental effects and phenotypic plasticity. *Journal of Animal Ecology*, 61, 41–48.

YANG L., CHOU L. & SHIEH W. K., 2001. Biofilter treatment of aquaculture water for reuse applications. *Water Research*, 35, 3097-3108.