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Optimal Growth Temperature of American Eel, *Anguilla rostrata* (Le Sueur)

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ABSTRACT

The optimal growth temperature of American eel, *Anguilla rostrata* (Le Sueur), elvers were investigated based on the specimen imported from subtropical Haiti, Central America. The eel was reared for 104 days in 16 ℃, 20 ℃, 24 ℃, 28 ℃ and 32 ℃, respectively. The optimal growth temperatures of the eel were estimated to be 28.33 ℃ in length and 29.0 ℃ in weight. This implies that the growth of American eel elver was faster in early summer and autumn than mid-summer and winter.

***Key words**: American eel, Growth, Temperature.*

INTRODUCTION

There are 18 species of Anguillid eel in the world (Ege, 1939; Tesch, 1977; Castle and Williamson, 1974). European eel (*A. anguilla*) was the most abundant, followed by American eel (*A. rostrata*), Japanese eel (*A. japonica*) and Australian eel (*A. australia*). These four species are temperate species, but subtropical oceanic origin and has adapted to thermally diverse environments during the growth phase and the spawning migration. The development stages of the eel include leptocephalus, glass eel, elver, yellow eel and silver eel. Elvers are harvested for stocking during their upstream in the estuary (Tzeng, 1985). The preferred temperature of the elver at arriving estuary varied with latitude (Haro, 1991). Several researches have attempted to find out preferred temperature of the eel, but the results disagreed (Sadler, 1979; Barila and Stauffer, 1980; Walsh *et al.*, 1983; Karlsson *et al.*, 1984; Tongiorgi *et al.*, 1986; Haro, 1991; Chen and Chen, 1991).

The eel farming is a very important aquaculture industry in Taiwan. Recently, due to the decrease in the catch of Japanese eel elver in Taiwan, the supply of the elver is insufficient to meet the demand for aquaculture (Tzeng, 1997). Thus, elvers of the other eel species were imported to supplement those of Japanese eel. Among them, the American eel elver is the best candidate because its geographic distribution and habit are mostly analogous to Japanese eel. To find out the best cultivation condition for the American eel, many environmental factors have been considered, including the water quality, artificial feed, and disease control. Temperature is one of the important environmental factors influencing activity and growth of the eel (Nyman, 1972; Vollestad, 1986).

This paper is to investigate the optimal growth temperature of American eel.

MATERIAL AND METHOD

A total of 100 American eel, *Anguilla rostrata*, elvers captured from Haiti was acclimated for three days at the temperature of 24 ℃. Then the temperature was adjusted 0.2 ℃ hr^{-1} to 5 different temperature regimes, 16 ℃, 20 ℃, 24 ℃, 28 ℃ and 32 ℃. The experimental design comprised

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10 groups at a combination of 5 temperature regimes and two duplicates. Ten elvers were reared in each tank at a density of 1 l^{-1}. The experimental temperatures were chosen to simulate the natural range of the seasonal temperature of Taiwan. The elvers were fed daily with tubifex until satiation during the 104-day rearing period from Jan 3 to April 16, 1996. Photoperiod was weekly adjusted according to ambient condition and the maximum and minimum temperatures of the rearing tank were monitored. The elvers were sacrificed and their length and weight were measured at the end of the experiment. The specific growth rate (SGR) of each elver was calculated as follows:

$$SGR = [ln \text{ final length (weight)} - ln \text{ initial length (weight)}]/[\text{Time in days}] \quad (1)$$

Initial length and weight of the elver were assumed to be 4.77 cm and 0.057 gm, which were the mean length and weight of the elvers before rearing. The duration of rearing was 104 days.

The mean (± SD) length of the fish between repeated group was tested with t-test. The difference in mean length among 5 different temperature regimes was tested with Scheffe's multiple range test. The relationships between fish length and weight and the temperature were fitted by a quadratic equation:

$$SGR = a+bT+cT^2 \quad (2)$$

where SGR = specific growth rate, T = Temperature and a, b and c are constant.

RESULTS

1. Effect of temperature on fish growth in length and weight

The mean total length of the elvers after 104 day rearing was all not significantly different between repeated groups in each of the five temperature regimes (t-test, p=0.11-0.77). However, the Scheffe's test indicated that the growth rate in length and weight of the fish was significantly different between rearing temperature regimes. The mean total length of the fast-growing group (13.47 ± 2.55 cm) at the temperature of 28 ℃ was approximately two-fold of the slow-growing one at 16 ℃ (7.03 ± 0.71 cm), while mean body weight of the fast-growing group was approximately eight-fold (2^3) of the slow-growing group (28 ℃ : 4.70 ± 2.23 g vs. 16 ℃ : 0.59 ± 0.20 g) (Table 1). This is because the relationship between total length and body weight of the elvers was a cubic equation (Fig. 1):

$$y = 0.0013\ x^{3.1133} \quad (2)$$

2. Optimal growth temperature

The relationship between specific growth rate (SGR) in length and the rearing temperature was fitted with a quadratic equation as follows (Fig. 2a):

$$y = -0.017 + 0.0017\ x - 3E\text{-}05\ x^2 \quad (3)$$

Table 1. Scheffe's test of mean total length and body weight among different temperature.

		Length (cm)		Weight (g)	
Temp (℃)	n	Mean ± SD	Homogeneous Group	Mean ± SD	Homogeneous Group
16	18	7.03 ± 0.71	A	0.59 ± 0.20	A
20	19	8.25 ± 1.28	B	1.07 ± 0.48	AB
24	20	10.50 ± 1.83	C	2.48 ± 1.20	BC
28	19	13.47 ± 2.55	D	4.70 ± 2.35	D
32	18	11.25 ± 1.89	C	2.73 ± 1.21	C

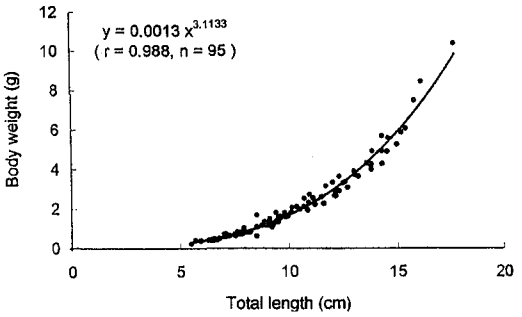

Fig. 1. The relationship between body weight and total length of American eel elvers.

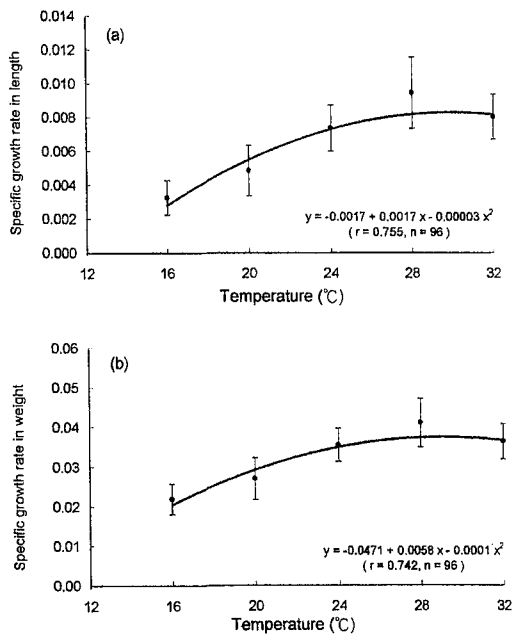

Fig. 2. The relationship between specific growth rate in length (a) and weight (b) of American eel elvers and water temperature.

$$(r = 0.755, n = 96)$$

The growth rate of the elvers increased with increasing temperature, but it was depressed at high temperature. The optimal growth temperature in length was estimated to be at 28.33 ℃.

Similarly, the relationship between SGR in weight of the elvers and the rearing temperature was as follows (Fig. 2b):

$$y = -0.0471 + 0.0058\,x - 1E\text{-}04\,x^2 \quad (4)$$
$$(r = 0.742, n = 96)$$

The optimal growth temperature in weight was 29.0 ℃.

The optimal growth temperature of the elvers was similar between length and weight.

DISCUSSION

The optimal growth temperature of American eel, *A. rostrata*, elver was estimated to be 28.3 ℃ in length and 29.0 ℃ in weight, respectively. European eel, *A. anguilla* was estimated to be 22-23 ℃ (Sadler, 1979). Yellow phase American eel cease feeding, show reduced activity and become torpor (metabolically depressed) at temperature below 10 ℃ (Walsh *et al.*, 1983). The European eel enter a state of torpor at temperature varying from 1 to 3 ℃ for fish acclimated at 23 ℃ or below to 29 ℃ (Sadler, 1979). This indicated that the optimal temperature for growth and activity was higher in American eel than European eel. The spawning ground of American and European eels was overlapped in the Sargasso Sea at about 25 °N, but that of European eel was slightly northerly (McCleave *et al.*, 1987; Kleckner and McCleave, 1988). These two species migrated with current separately to American coast and European coast. The water temperature was generally higher in the American coast than in European coast. This indicates that the difference in optimal growth temperature between two species was genetically determined. In practice, the European eel should be cultivated in cold water and American eel in warm water.

The natural water temperature in Taiwan was approximately 16 ℃ in winter and 32 ℃ in summer. The optimal growth temperature in length and weight of American eel elvers in this experiment was 28.3 ℃ and 29.0 ℃, respectively. This implies that the growth of American eel elvers will be depressed in mid-summer and winter. On the other hand, growth rate of the fish

was associated with food availability. The supply of food was similar, but growth rate different among different temperature regimes. This indicated that the water temperature would influence food uptake, and subsequently growth rate. Recently, the American eel elver was cultivated with recycling system. To increase growth period and growth rate of the fish, the temperature of the rearing system should be adjusted in summer and winter.

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美洲鰻成長的最適溫度

曾萬年・王友慈・王佳惠

近年來，由於台灣所生產的鰻線，不足以供應養殖，業者紛紛進口美洲鰻鰻線加以應急。爲了瞭解美洲鰻鰻線的最適成長溫度，分別將鰻線飼養在16 ℃, 20 ℃, 24 ℃, 28 ℃及32 ℃ 的五種溫度之下，104天之後測量其成長情形。利用二次曲線模擬結果，發現美洲鰻鰻線體長及體重的最適成長溫度，分別爲28.33 ℃及29.0 ℃。本實驗暗示，美洲鰻在台灣的自然環境下，春至夏初及秋季成長較快，而冬季及盛夏成長遲緩。控制在適溫下，可延長生長期及成長率。

關鍵詞：美洲鰻，成長，溫度。