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(Accepted 5 June 1994)



## Release and Recovery of Japanese Eel, *Anguilla Japonica*, in Taiwan

### Abstract

Japanese eel, *Anguilla japonica*, is one of the most important species of fish culture in Taiwan. Elvers for the culture are collected from estuaries during their upstream migration in winter. Due to their unpredictable supply, the elvers were frequently imported from foreign countries to meet the demand. To increase the natural production of the elvers, hormone-induced maturation eels have been released by the Taiwan Fisheries Research Institute since 1976, and the eels released have been tagged since 1987 to study their migration route, growth and other biological characteristics. This paper describes the hormone-induced maturation processes, tagging techniques, and recovery status of the eel.

**Key words:** Japanese eel (*Anguilla japonica*), Hormone-induced maturation, Tagging and releasing, Migration.

The Japanese eel, *Anguilla japonica* (Temminck & Schlegel), is one of the commercially important species of fish culture in Taiwan. Large number of elvers are caught in estuaries from November to March during their upstream migration<sup>(1)</sup>. Due to the rapid development of eel culture industry, the demand of elvers for aquaculture has been increased to approximately 50 tons per year, but, the supply of elvers from the natural stock in most years was below 10 tons<sup>(2)</sup>. Therefore, a lot of elvers were imported to meet the demand for aquaculture in Taiwan (Table 1).

To increase the production of elvers, a program of releasing hormone-induced maturation eels have been conducted since 1976. Moreover, to increase our knowledge on seaward migration behavior of the

released eels and to evaluate the result of the releasing program, a basic study on the hormone-induced maturation, tagging techniques and related biological characteristics of the released eels have also been conducted since 1987. This paper describes the hormone-induced maturation processes, tagging techniques and the recovery of the tagged eel.

### Materials and Methods

Two- to three-year eels from culture ponds were used in this experiment. The females were always larger, approximately one to two individuals/kg, while the males were approximately three to four individuals/kg. they were immediately stocked in an

Liao, I. C., C. L. Kuo, T. C. Yu and W. N. Tzeng (1994) Release and recovery of Japanese eel, *Anguilla japonica*, in Taiwan. J. Taiwan Fish. Res., 2 (1):1-6

This paper was partially presented in the World Fisheries Congress (Abstract 6.20), May 3-8, 1992, Athens, Greece.

**Table 1.** Production and imports of Japanese eels, *Anguilla japonica*, in Taiwan from 1973 to 1993.

Year	Production of elver (kg)	Imported (kg)		
		Elver	Eel fry	Young eel
1973	5,000	20,000	---	---
1974	11,000	7,000	2,000	---
1975	2,000	33,000	4,000	---
1976	2,000	22,000	3,500	---
1977	7,000	7,000	4,700	---
1978	36,679	8,004	34,811	121,690
1979	3,602	27,828	36,336	160,054
1980	2,050	15,595	10,550	56,084
1981	5,362	23,008	22,053	83,760
1982	3,500	9,472	16,983	34,367
1983	18,000	8,615	7,189	44,428
1984	8,637	33,102	10,753	41,996
1985	3,194	27,261	32,267	37,194
1986	3,381	11,351	3,000	28,478
1987	21,002	27,964	61,709	87,019
1988	6,945	23,000	37,700	109,774
1989	25,023	25,988	28,473	33,463
1990	10,852	24,330	35,224	283,166
1991	31,021	19,201	19,869	241,902
1992	8,024	19,874	11,023	62,680
1993	2,406	2,067	4,626	49,262

octagonal concrete tank (14 m x 14 m x 1.4 m) in the Lukang Branch of the Taiwan Fisheries Research Institute (TFRI), and were acclimated with seawater. After two weeks, the salinity in the tank was adjusted to 24 to 26‰.

A total of 120 kg of female eels were used for inducing maturation. They were big with high fat content. Those with body weight of approximately 500 to 1,000 g were selected and placed into four rectangular tanks (6 m x 3.3 m x 1 m). On October 30, 1987, the first hormone injection was conducted by using 500~1,000 I.U. of H.C.G. (Human Chorionic Gonadotropin) mixed with 1~3 pituitary

glands from the common carp (*Cyprinus carpio*), 0.5 cc of vitamin and 0.5 cc of saline solution<sup>(3-6)</sup>. Thereafter, five more injections were made on the dates of November 6, November 13, November 20, November 27, and December 3. Correspondingly, males with body weight from 300 to 400 g were received an injection on each day of November 20 and 27.

After completing the hormone injection, the eels were tagged on December 10 and 11, 1987. First, they were hauled out from the tanks and put in the tanks filled with ice and water at 2°C to reduce the activity. After measuring the length and weight, they

**Table 2.** Release of hormone-induced maturation Japanese eel, *Anguilla japonica*, from 1976 to 1993.

	Date	Quantity		Releasing Site
		kg	No.	
1	Oct. 30, 1976	300	675	22°36'N, 120°00'E
	Nov. 19, 1976	1,208	2,718	22°36'N, 120°00'E
2	Oct. 22, 1978	1,548	3,484	22°15'N, 120°28'E
3	Dec. 14, 1979	500	1,125	22°15'N, 120°28'E
4	Feb. 25, 1981	2,000	4,500	22°15'N, 120°28'E
5	Jan. 8, 1982	300	675	22°15'N, 120°28'E
6	Nov. 20, 1983	1,000	2,290	22°15'N, 120°28'E
7	Dec. 27, 1986	1,000	2,250	22°15'N, 120°28'E
8	Dec. 19, 1987	1,200	1,440	22°24'N, 120°20'E
9	Dec. 17, 1988	1,200	2,050	22°24'N, 120°20'E
10	Dec. 23, 1989	1,200	1,474	22°24'N, 120°20'E
11	Dec. 26, 1990	2,700	18,00	22°24'N, 120°20'E
12	Dec. 18, 1991	1,748	2,905	22°24'N, 120°20'E
13	Mar. 26, 1993	2,250	5,805	22°24'N, 120°20'E

were tagged with anchor tags (BANO' K 203 standard type, US pin, 45 mm). The tagged eels were put back to the tanks filled initially with 12°C water, and then transferred to the another eel-culture tanks. A total of 379 individuals eels were tagged.

The tagged eels were put into bags filled with ice, seawater and compressed air from 1:30 on December 19, 1987. They were transported by motor vehicle from the Lukang Branch to the Kaohsiung Harbor, and then transported by the research vessel Hai-Fu of TFRI to the releasing site (120° 20' E, 22° 24' N), and were released at 11:50. The releasing site was near a local spawning ground of the Japanese eel proposed by Kuo (1971)<sup>(7)</sup>, but it has not been validated<sup>(8,9)</sup>.

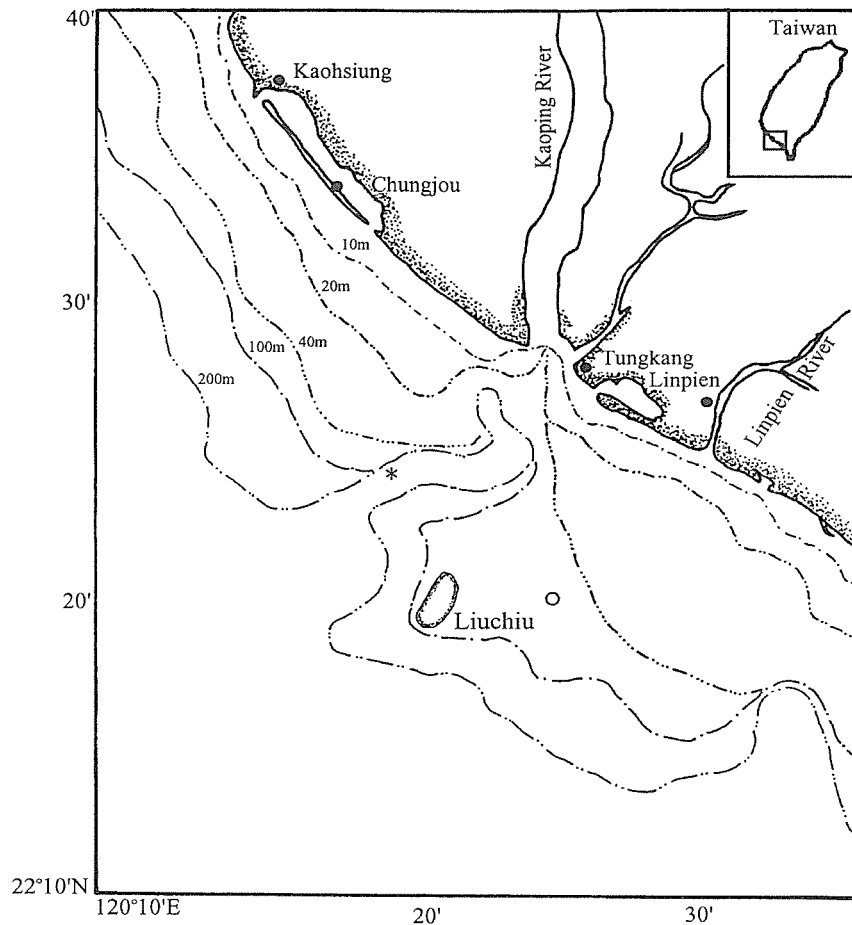
## Results and Discussion

A total of 1,200 kg eels, approximately 1,440 individuals, were released in the area 120° 20' E, 22° 24' N on December 19, 1987 (Table 2). One tagged eel was recaptured by a trawler on January 7, 1988 in the southwestern offshore of Tungkan, Pingtung (Fig. 1). The eel measured 84 cm in length and 832 g in weight. It was 80 cm in length and 910 g in weight when it was released on December 19, 1987.

The natural production of elvers in Taiwan has been in consistent. Furthermore, the artificial propagation techniques of eels still depends on a major breakthrough and developments in the near future. Releasing hormone-induced maturation eel is the only way to ensure a sufficient supply of natural elvers at the moment. Based on programs of 13 eel releasing in 1976-1993, the number of released eels had been limited (Table 2). Therefore, increasing the number of released eels, choosing the appropriate sites for releasing, and conducting more well-designed studies of the eel's life cycle, are the most important subjects in the future.

The spawning ground of Japanese eel is located approximately in the area west of Mariana Islands (14 ~ 16° N, 134 ~ 143° E)<sup>(10)</sup>. The environmental condition of spawning ground has remained unknown.

After hatching, leptocephalus drifts with the ocean current, metamorphoses into glass eel and then entered to estuaries as elvers. The early life history of the eel including the hatching date, stock identification, larval migration, daily age at arriving the estuary and recruitment dynamic of the elver, have been well investigated<sup>(1,8-13)</sup>. However, the seaward migration of matured eel was still remained



**Fig. 1.** The isobath and releasing (O) and recovery sites (\*) of Japanese eel, *Anguilla japonica*, in southwestern waters of Taiwan.

unknown, because the matured eels during their seaward migration were in the deep ocean and not easily to be caught. Until now, only five matured females with total length ranging 635–838 mm and gonad indices 2.72–5.56 were caught by a shrimp trawler at a depth of 30 m in the coast of Kyushiu, Japan<sup>(14)</sup>.

In this study, we did not kill the recovered eel, so it was difficult to speculate whether this eel would continue to mature and gonad would continue to develop. However, the eel had moved to the nearby deep marine canyon (Fig.1), probably linking to the deep-sea spawning migration.

The Japanese eel is widely distributed in the northwestern pacific ocean south from Philippines, through Taiwan, China, Korea and north to Japan. For cultivation, the elver resources have been overexploited in most of these countries. Releasing the hormone-induced maturation eel to increase the production of elvers in Taiwan was the first attempt in the world. The hormone-induced eel being released was even few, but we believed that it was contributable to the eel population. Therefore, it should be extended to the other countries, China, Japan and Korea, to become an international program.

## Acknowledgements

The authors would like to express their thanks to the financial support of the Council of Agriculture and the Taiwan Eel Farming Industry Development Foundation. Thanks are also extended to the colleagues of the Lukang Branch and the Department of Fishery Biology, Taiwan Fisheries Research Institute for their helps in stocking and tagging the hormone-induced maturation eel, and the crew of research vessel Hai-Fu for their help in releasing of the tagged eels.

## References

1. Tzeng, W. N. (1985) Immigration timing and activity rhythms of the eel, *Anguilla japonica*, elvers in the estuary of northern Taiwan, with emphasis on environmental influences. Bull. Jap. Soc. Fish. Oceanogr., **47**, **48**: 11-28.
2. Hu, S. C. and T. C. Yu (1976) Study on the maturation induction of eel. Bull. Taiwan Fish. Res. Inst., **26**: 97-103.
3. Ishida, O. and T. Ishii (1970) Induced maturation of eel. Suisanzoshoku, **17**(5/6): 263-271.
4. Satoh, H., N. Nakamura and T. Hibiya (1962) Studies on the sexual maturing of the eel -- I. On the sexual differentiation and the maturing process of the gonads. Nippon Suisan Gakkaishi, **28**: 579-584.
5. Yamamoto, K., O. Hiroi, T. Hirano and T. Marioka (1972) Artificial maturation of cultivated male Japanese eels by Synahorin injection. Nippon Suisan Gakkaishi, **38**:1083-1090.
6. Yamamoto, K., T. Morioka, O. Hiroi and M. Omori (1974) Artificial maturation of female Japanese eel by the injection of salmonid pituitary. Nippon Suisan Gakkaishi, **40**: 1-7.
7. Kuo, H. (1971) Approach of eel elvers to the land in Taiwan. Fish Culture, **8**(1):52-56.
8. Tzeng, W. N. and Y. C. Tsai (1992) Otolith microstructure and daily age of *Anguilla japonica* elvers from the estuaries of Taiwan with reference to unit stock and larval migration. J. Fish Biol., **40**: 845-857.
9. Tabeta, O., K. Tanaka, J. Yamada and W.N. Tzeng (1987) Aspects of the early life history of the Japanese eel *Anguilla japonica* determined from otolith microstructure. Nippon Suisan Gakkaishi, **35**: 1727-1734.
10. Tsukamoto, K. (1992) Discovery of the spawning area for Japanese eel. Nature, **356**(6372): 789-791.
11. Tsukamoto, K., A. Umezawa, O. Tabeta, N. Mochioka and T. Kajihara (1989) Age and birth date of *Anguilla japonica* leptocephali collected in western north Pacific in September 1986. Nippon Suisan Gakkaishi, **55**: 1023-1028.
12. Tzeng, W.N. (1986) Resources and ecology of Japanese eel *Anguilla japonica* in the coastal waters of Taiwan. China Fish. Mon., **404**: 19-24.
13. Tzeng, W.N. (1990) Relationship between growth rate and age at recruitment of *Anguilla japonica* elvers in a Taiwan estuary as inferred from otolith growth increments. Mar. Biol., **107**: 75-81.
14. Ogata, T., K. Iwata, K. Kudo and M. Terayama (1991) A catadromous eel (*Anguilla japonica*) captured from Hyuga Nada. Bull. Jap. Soc. Fish. Oceanogr., **55**(3): 183-188.

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(1994 年 6 月 5 日接受)



## 種鰻標識放流與回收

### 摘要

日本鰻為台灣最重要的養殖對象之一。養殖所需的鰻苗均於冬季在河口溯河時捕撈，但由於產量不穩定，每年均須由國外進口大量鰻苗，以供業者所需。為增加鰻苗天然產量，本所自 1976 年起即實施種鰻之催熟與放流工作，而且自 1987 年起，在放流鰻體上植附標識，以研究其洄游路程、成長及其相關之生態特性。本文即敘述賀爾蒙之催熟過程、標識、放流技術以及回收等狀況。

**關鍵詞:** 日本鰻，催熟，標識放流，洄游