AN ESTIMATE OF THE EXPLOITATION RATE OF
Anguilla japonica ELVERS IMMIGRATING INTO
THE COASTAL WATERS OFF SHUANG-CHI
RIVER, TAIWAN

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Wann-Nian Tzeng (1984) An Estimate of the Exploitation Rate of *Anguilla japonica* Elvers Immigrating into the Coastal Waters off Shuang-chi River, Taiwan. *Bull. Inst. Zool., Academia Sinica* 23(2): 173–180. Based on the daily catch data of elvers in the coastal waters off Shuang-chi River in northeastern Taiwan from December 1982 to March 1983, the number of shoals immigrated into the coastal waters was determined and their initial population size were estimated by Delury method. The present study reveals that there were seven dominant elver shoals immigrated to the coastal waters in this period. The duration of fishing days for each shoal was different. The longest period lasted for 9 days, while the shortest one lasted only 4 days. Average fishing period was 6 days. Their initial population size were estimated as 916.4–23,780.9 elvers. Exploitation rate reached 44.1–75.4% of the initial immigrating population size.

Since the beginning of eel culture in Taiwan in 1965, the elvers which are drifted from open sea toward coastal waters and concentrated on estuary (Bertin, 1965; Tesch, 1977) have become an important larval fishery resources in estuaries. There are four species of anguillids in Taiwan, namely *Anguilla japonica*, *A. marmorata*, *A. celebesensis* and *A. bicolor pacifica*. Among them, *A. japonica* is most abundant and suitable for cultivation. The fishing season for the elvers is from November to February, in which the peak catch happens in December and January (Tzeng, 1983b). In general, fishermen caught the elvers during their upstream migration at night. Fishig gears include hand net and boat beam trawling net in inner river. Recently, due to the severe pollution of the river and the heavy demanding of elver (Tzeng, 1983 a), the fishing area of elvers was extended from inner river to estuaries and coastal waters. Fishing method was also strengthened to include set net at river mouth and hand trawling at coastal waters. In addition, price of elvers has also substantially increased (Shang, 1973). Therefore, fishing effort is also intensified. Consequently, possible overexploitation is concerned by fishery biologists. However, there are yet no any studies have been conducted.

The purpose of this study is to analyze the exploitation rate of the elvers for better understanding of the status of exploitation of elver resources in Taiwan.

MATERIAL AND METHOD

From December 1982 to March 1983, questionnaries of daily catch of elvers were collected from 70 local fishermen who harvested elvers in the coastal waters off Shuang-chi River in northeastern Taiwan (Fig. 1).
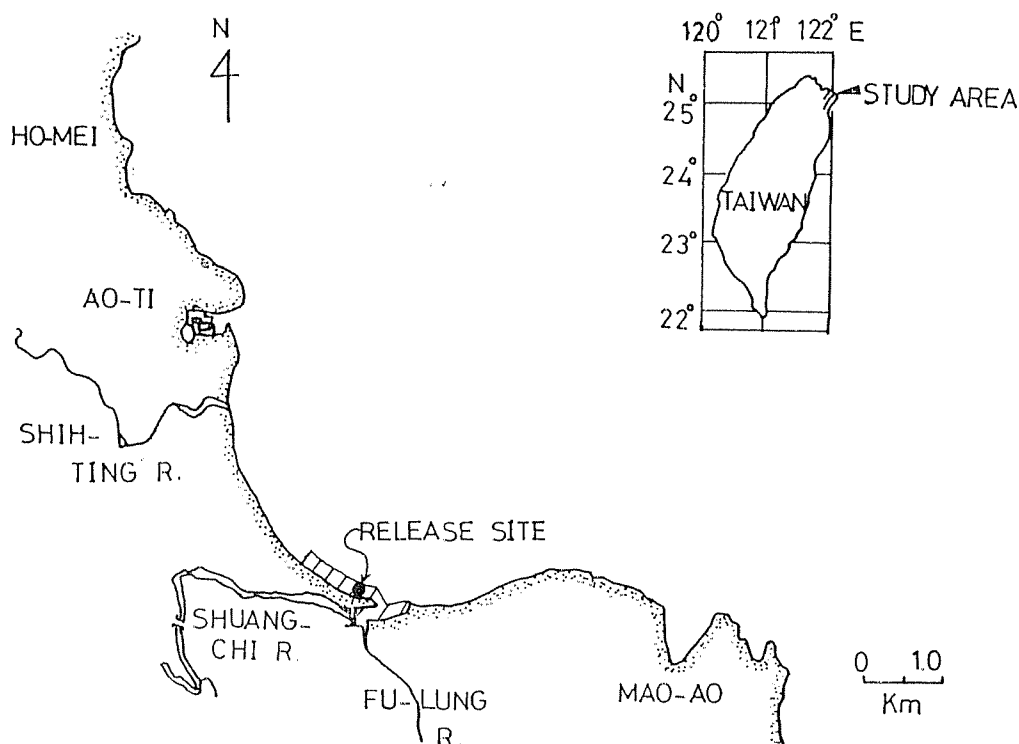
Fig. 1.   The relase site (●) and the fishing ground of elvers (Ⅲ) in the
coastal waters off Shuang-chi River, northeastern Taiwan.

The questionnaries include fishing date, fishing efforts, fishing method, species, yield and weather conditions. Fishermen categorized the elvers into white-type and black-type according to caudal pigmentation. The white-type was sold to eel farms, but the black-type has not been cultured in Taiwan. The former is *A. japonica*, while the latter includes the other three species (Tzeng, 1983a). Because the white-type elver is commercially important species and the dominant one, only the catch statistics of white-type elvers were used in this study.

Catch per unit fishing effort (CPUE; number of elver/per person/per night) was viewed as an index of the relative abundance of elvers in the fishing ground. To understand the tendency of elver recruitment, the moving average of CPUE in three successive days were computed. According to daily change of CPUE,

migration of elvers in the fishing ground was traced. Maximal CPUE indicated that recruitment had completed. After that, due to fishing and emigration, CPUE decreased gradually. CUPE would increase again when the next recruit immigrated into the fishing ground. The original population size of each shoal was calculated by Del>ry method (Delury 1947, 1951, 1954)

$$L_n C_t / X_t = L_n q N_0 - q \Sigma X_t$$

where,

L_n: natural logarithm

C_t: catch in number on t-th day

N_0: initial population size

q: catchability-the fraction of the population taken by 1 unit of fishing effort

X_t: fishing effort in man-night on t-th day

ΣX_t: cumulative fishing effort until t-th day in number of man-night

Then, according to the amount of recruitment and cumulative catch, the rate of exploitation of each immigrating shoal was estimated, i. e.

$$E = \Sigma C_t / N_0$$

where,

  E: rate of exploitation
  ΣC_t: cumulative catch
  N_0: initial population size

Furthermore, based on the recaptured data of marked elvers released on December 17, 1982, January 12 and February 12, 1983

(Tzeng, 1984) as well as the catch data of unmarked elvers in the same place and similar fishing period, instantaneous rate of emigration and immigration was computed by using Ketchen method (Ketchen 1953, Ricker 1958).

RESULTS

1. Recruitment

According to the fluctuation of daily CPUE (Fig. 2), it was found that there are seven dominant elver shoals immigrated into the coastal waters off Shuang-chi River during the period from December 1982 to March 1983.
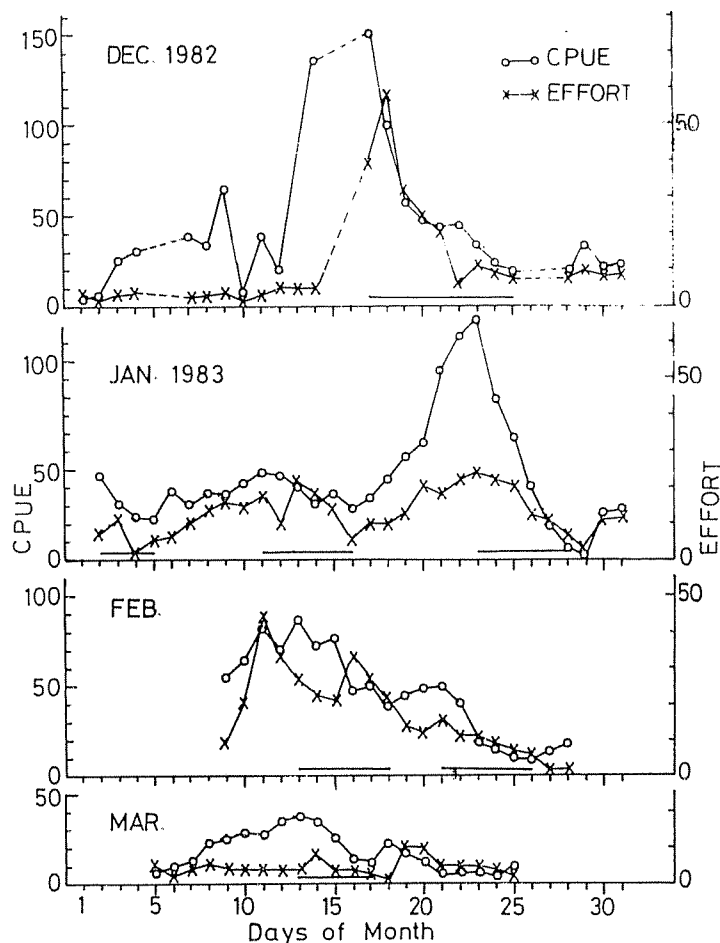

Fig. 2. Daily changes of CPUE (Nos./man-night) and fishing effort (man-night) for the elvers caught by hand trawling in the coastal waters off Shuang-chi River, Dec. 1982-Mar. 1983. Horizontal bar indicates the duration of fishing period for each one of the elver shoals; i. e. the period from the day when recruitment of a shoal was complete to the day when another shoal began to immigrate.

The duration of fishing period for each one of the shoals, or the period from the day when recruitment of a shoal was complete to the day when another shoal began to immigrate, was indicated by the horizontal bar in Fig. 2. The duration of fishing days for each shoal was different. The longest period lasted for 9 days (17–25, December 1982), while the shortest one lasted only for 4 days (2–5, January 1983). Average fishing period was 6 days.

The peak of CPUE indicated a larger size of immigrants. As was shown in Fig. 2, the shoals immigrated into the coastal waters on December 17, 1982, January 23 and February 13, 1983 were larger. The other shoals which immigrated into the coastal waters on January 2, 11, February 21 and March 13, 1983 were smaller.

2. Initial population size and rate of exploitation

The initial population size of the 7 immigrating shoals was estimated to be 916.4–23,780.9 elvers (e. g. in Fig. 3; Table 1). Rate of exploitation on these shoals was calculated as 44.1–75.4% of the initial

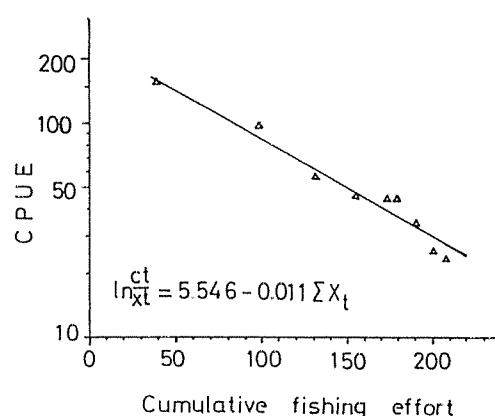$$\ln\frac{ct}{xt} = 5.546 - 0.011\,\Sigma X_t$$

Fig. 3. Regression of CPUE on cumulative fishing effort based on the catch data of elvers caught in the coastal waters off Shuang-chi River during the period of December 17–25, 1982.

population size (Table 1).

The rate of exploitation was further checked by mark-recapturure experiments of elvers in the coastal waters off Shuang-chi River on December 17, 1982, January 12 and February 12, 1983. The regression line of CPUE on cumulative effort (ΣX_t) in these three investigations was shown in Fig. 4. Their rate of exploitations were

TABLE 1

The initial population size (N_0), catchability (q) and rate of exploitation (E) estimated from the regression of CPUE on cumulative fishing effort based on catch data of 7 immigrating shoals of elvers

Duration		ΣX_t	ΣC_t	r	F-value	Estimated parameter		Rate of exploitation
Fishing Date	days					N_0	q	
1. Dec. 17–25, 1982	9	209	15817	−0.977	148.955**	23,780.9	0.01077	66.5%
2. Jan. 2–5, 1983	4	25	1022	−0.885	7.196ns	1,461.9	0.04906	69.9
3. Jan. 11–16	6	88	3516	−0.925	23.635**	7,973.4	0.00705	44.1
4. Jan. 23–28	6	97	6607	−0.915	20.519*	12,252.8	0.03517	53.9
5. Feb. 13–18	6	150	9118	−0.945	33.260**	16,492.1	0.00636	55.3
6. Feb. 21–26	6	58	1890	−0.984	125.213**	2,518.3	0.04378	75.1
7. Mar. 13–17	5	24	691	−0.966	36.325**	916.4	0.06055	75.4

ΣX_t: cumulative fishing effort in man-night
ΣC_t: cumulative catch in number of elvers
r: correlation coefficient
F-value: the probability of significance of regression line is given as
        *: 5%, **: 1%, ns: non-significance.

$$\ln\frac{ct}{xt} = 3.208 - 0.029 \sum X_t$$

$$\ln\frac{ct}{xt} = 1.340 - 0.032 \sum X_t$$

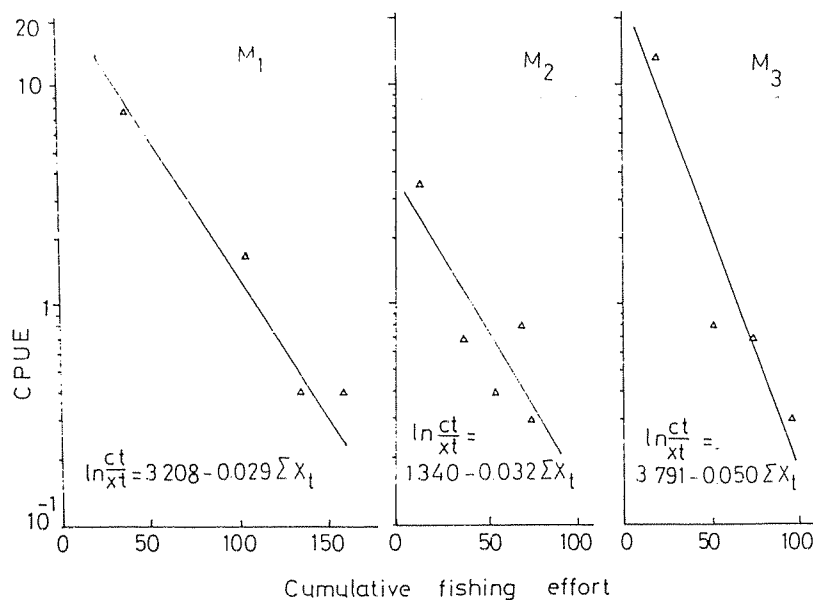$$\ln\frac{ct}{xt} = 3.791 - 0.050 \sum X_t$$

Cumulative fishing effort

Fig. 4. Regression of CPUE on cumulative fishing effort based on the mark-recapture data of elvers released in the coastal waters off Shuang-chi River. M1, M2 and M3 indicate three different investigated periods; i.e. Dec. 17-20, 1982, Jan. 12-16 and Feb. 12-15, 1983 respectively.

43.8%, 74.9% and 61.6% of the initial population size respectively (Table 2). This result is quite coincident with the previous estimation (Table 1).

3. Immigration and emigration

Number of immigration and emigration of elvers in the coastal waters off Shuang-chi River was estimated based on the mark-recapture data of elvers during the fishing periods of December 17-25, 1982, January 11-16 and February 13-18, 1983. The results obtained are listed in Table 3.

The instantaneous rate of emigration on January 1983, was 0.0289, three-fold larger than that on December and February, which were 0.0092 and 0.0093 respectively. Number of emigrants in these three investigations was 7,490.1, 2,792.9 and 3,655.7 elvers respectively. Emigrants constituted 31.5%, 35.0% and 22.2% of their corresponding estimated initial population size.

The instantaneous rate of immigration on December 1982, January and February 1983 was 0.0179, 0.0254 and 0.0432 respectively.

TABLE 2

Estimation of initial population size (N_0), catchability (q) and rate of exploitation (E) of elvers based on mark-recapture data of elvers released in the coastal waters off Shuang-chi River

Date of release	Number released	Observed period	$\sum X_t$	Recaptures	Estimated parameter		Rate of exploitation
					N_0	q	
1. Dec. 17, 1982	1275	Dec. 17-20	161	378	864.1	0.0286	43.8%
2. Jan. 12, 1983	1076	Jan. 12-16	75	88	117.6	0.0325	74.9
3. Feb. 12	1100	Feb. 12-15	107	527	893.8	0.0496	61.6

TABLE 3

Estimation of instantaneous rates, numbers of emigration and immigration of elvers

Observed period		Instantaneous rate of			Initial population size	Catch in number	Number of	
Natural group	Marked group	Catch-ability	Emigra-tion	Immi-gration			Emi-grants	Immi-grants
1. Dec. 17-25, 1982	Dec. 17-20, 1982	0.0194	0.0092	0.0179	23,780.9	15,817	7,490.1	14,540.0
2. Jan. 11-16, 1983	Jan. 12-16, 1983	0.0036	0.0289	0.0254	7,973.4	3,516	2,792.9	2,454.0
3. Feb. 13-18	Feb. 12-15	0.0403	0.0093	0.0432	16,492.1	9,118	3,655.7	3,950.2

Number of immigrants was 14,540.0, 2,454.0 and 3,950.2 elvers and constituted 61.1%, 30.8% and 24.0% of their estimated initial population size respectively. It is clear that the number of emigrants and immigrants shared high percentages of the initial population size. Therefore, it seems that the catch of elvers not only depended on their initial population size but was also affected by emigrants and immigrants.

DISCUSSION

It was estimated that there were seven shoals of elvers immigrated into the coastal waters off Shuang-chi River during December 1982 through March 1983. A shoal was considered to be a group of elvers congregated in the coastal waters before upstreaming. Because of the calculated immigrants and emigrants constituted a high percentage of their estimated initial population size. It is possible that the member of a shoal may consist of heterogeneous cohorts. The heterogeneity was also proved by the diversed pigmentation of the elvers caught in the coastal waters at the same day (Tzeng, 1982). In addition, the occurrence of elver could also be related to tidal periodicity and other environmental factors (Tzeng, 1982; Higashi and Sakurai, 1974). Therefore, the number of shoals immigrated into the coastal waters and the magnitude of each shoal at various periods were also affected. The detailed mechanism of fluctuation of the shoals will be further studied in the future.

The exploitation rate of the elvers in the coastal waters off Shuang-chi River was estimated as 44.1-75.4%. These rates could be higher if the catches in the river were included. Besides, according to the mark-recapture data of elvers released in the said area on December 17, 1982, January 12 and February 12, 1983, the recapture rates were 46.1%, 59.6% and 57.4% respectively (Table 4). Therefore, the estimated rates of exploitation are considered to be rather reasonable.

In the last three years, annual production of elvers was about $10-30 \times 10^6$ pieces in Taiwan, while the demand for elvers was estimated as $200-300 \times 10^6$ pieces (Tzeng, 1983a). In other words, the elver catch in Taiwan supplied only 10% of the total demand. Therefore, deficiency of elvers was very serious. As mentioned above the rate of exploitation has reached 44.1-75.4%, indicated that the elver resources have been highly exploited. It is evident that self-sufficiency of elvers is quite impossible in Taiwan, even fishing effort is increased.

TABLE 4

Mark-recapture data of Anguillid elvers released in the coastal waters
off Shuang-chi River (after Tzeng, 1984)

	Release date	Release time	Number released	Observed period	Number and percentage of recapture							
					Coastal waters		River mouth		Inner river		Total	
					Nos.	%	Nos.	%	Nos.	%	Nos.	%
1.	Dec. 17, 1982	12:30 AM	1275	Dec. 17–Jan. 11	497	38.98	16	1.25	75	5.83	588	46.12
2.	Jan. 12, 1983	12:40 AM	1076	Jan. 12–Feb. 11	95	8.83	312	29.00	234	21.75	641	59.57
3.	Feb. 12	12:00 AM	1100	Feb. 12–Mar. 18	605	55.00	15	1.36	11	1.00	631	57.36

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雙溪河口域鰻線來游羣的漁獲率之試算

曾 萬 年

　　根據 1982 年 12 月至 1983 年 3 月，臺灣東北部雙溪沿岸海域，鰻線的每日漁獲量資料及部分標識放流資料。判斷漁期中鰻線來遊羣數，同時估算每一來遊羣的初期資源量及其漁獲率。藉此分析鰻線資源的利用狀態。

　　在調查期間的 12～3 月之四個月中，雙溪河口沿岸海域鰻線漁場，有 7 個明顯的來遊羣加入。每一羣被持續漁獲的日數，長短不一。最長的有 9 天，最短的為 4 天，平均為 6 天左右。來遊羣的平均資源量為 9,342.3 尾 (916.4～23,781.9 尾)。來遊羣被漁獲的比率平均為 62.9% (44.1～75.4%)，顯示鰻線靠岸之後，被漁獲的比率相當高。另外，由標識放流實驗的回收資料，也顯示再捕率很高，平均 54.4% (46.1～59.6%)。