Special Publication No. 10
November 1984

MANUAL ON TAGGING OF MARINE ANIMALS

Shigeo Hayase[1], Damri Somjaiwong[2]
and
Somsak Chullasorn[2]

Training Department
Southeast Asian Fisheries Development Center

---

1 Training Department, Southeast Asian Fisheries Development

2 Marine Fisheries Division, Department of Fisheries, Thailand

CONTENTS

	Page
INTRODUCTION	1
1. NATURE OF TAGGING EXPERIMENTS	2
1.1 Definition of Mark and Tag	2
1.2 Planning a Tagging Experiment	2
2. OBJECTIVES OF TAGGING EXPERIMENTS	3
2.1 Investigation of Movement	3
2.2 Investigation of Mixing between Different Stocks	3
2.3 Estimation of Population Parameters	3
2.3.1 Mortality rate	3
2.3.2 Growth rate	3
2.3.3 Age determination	4
2.3.4 Population size	4
2.3.5 Exploitation rate	4
3. MATERIALS AND METHODS	5
3.1 Materials	5
3.1.1 Fishes for experiment	5
3.1.2 How to collect live specimens	5
3.1.3 Types of tag	7
3.1.4 Tagging equipment and method	12
3.1.5 Recording of release data	18
3.1.6 Releasing the tagged fish	18

Page

3.1.7 How to treat the obtained data 19

3.1.7.1 Recapture of tagged fish and recovery of tags 19

3.1.7.2 Determining migration pattern of tagged fish 30

3.1.7.2.1 Direction of migration ... 30

3.1.7.2.2 Distance and period of migration 34

3.2 Shrimps 37

3.2.1 How to collect live specimens 37

3.2.2 Marking methods and equipment 38

3.2.3 Releasing the tagged shrimp 46

3.2.4 Noteworthy points for data analyses 47

3.2.4.1 Biases 47

3.2.4.2 Growth 51

3.2.4.3 Mortality 51

3.3 Cephalopods 53

3.3.1 Method of collecting live specimens 53

3.3.2 Tagging equipment and the method of attaching tags 54

3.3.3 Release 55

3.3.4 Recapture 56

Page

3.3.5 Data analysis 58

3.3.5.1 Distribution and migration 58

3.3.5.2 Some parameters in dynamics of squid population 59

4. CONCLUSION 61

5. REFERENCES 63

INTRODUCTION

It was in 1893 that an eminent Danish fisheries biologist, C.G. Joh Petersen, first tagged plaice by attaching to them a numbered bone disc for the purpose of estimating the exploitation rate and the size of population. From this beginning, tagging and marking techniques have become an indispensable tool in the study of fish populations. Indeed, there are now very few species of fish of major commercial importance which have not been tagged or marked by one means or another, and the technique has been extended to molluscs, crustaceans, and sea mammals. Its applications range from a simple estimation of fish migration in connection with the discrimination of a unit stock of a species, to vitally important estimation of the abundance of stock, growth and mortality rate of exploited fish populations.

In Southeast Asian contries, especially in Thailand, there have been some attempts to carry out tagging experiments during the last two decades. However, as the applications of tagging techniques have become more varied, and the questions asked of the resulting information more demanding, so have the shortcomings of various techniques become more apparent and serious. Although a manual concerning materials and methods used in marking experiments in fishery research was produced by R. Jones in 1979, it has not been put into practical use in the Southeast Asian countries. It has been apparent for some years now that a manual on tagging techniques best suited to the Southeast Asian conditions should be made available to the fisheries scientists in the region. The Seminar on Shared Stocks of Pelagic Fishes, held in Bangkok in August 1981, made a recommendation to that effect.

The present manual is the result of a collaboration between the Research Division of the Training Department, Southeast Asian Fisheries Development Center, and the Pelagic Section of Marine Fisheries Division, Department of Fisheries, Thailand. In this manual we deal with some practical aspects of conducting tagging experiments in the waters of Southeast Asian region, such as the choice of tags and animals to be tagged, methods of handling and tagging animals, ways of assuring the reporting of tagged animals recaptured by fisheries, etc. The success of tagging experiments in the tropical waters depends, we believe, on such practical considerations.

The manuscript was reviewed by V. Hongskul, R. Jones, J.A. Gulland, S. Tanaka and S. Shindo, who offered a number of useful suggestions. The original illustrations and the redrawings were done by N. Ruangsivakul and the reproductions appear with the kind permission of the publishers of the sources cited.

1. NATURE OF TAGGING EXPERIMENTS

1.1 Definition of Mark and Tag

In his "Materials and Methods Used in Marking Experiments in Fishery Research", R. Jones (1979) made the following distinction between a mark and a tag:

> A "mark" is anything external, or internal, incorporated into the integument of an animal that can be used for recognition purposes. The word "tag" is usually reserved for identification marks that are attached externally or inserted internally. For example, a piece of plastic inserted into the integument or body cavity, or attached externally, is usually referred to as a "tag". A patch on the integument produced by the dye, a tattoo needle or a branding iron, on the other hand, is usually termed a "mark". Thus a tag is a mark, whereas a mark is not necessarily a tag. Some animals can be distinguished from others due to the presence of particular parasites or meristic characters. These natural forms of identification are normally referred to as "biological tags" or "biological marks".

If we want to obtain only the information of mass at the population level, e.g. the population size or mortality rate of an exploited fish population, it is sufficient to conduct a marking experiment. But when more detailed biological data on marked individuals of a single species are required, a tagging experiment is more suitable.

Experiments also vary, from those in which there are very large numbers of marked and unmarked animals to those in which there are very few. For example, a very large number of individuals may have to be marked if there is to be high expectation of getting some returned by commercial fishermen. On the other hand, if the object of the experiment is to study the behaviour of a single individual carrying a particular kind of mark, such as a sonic tag, then it may be sufficient to mark only one animal at a time (Jones, 1979).

The present manual deals only with the practical aspects of tagging, because marking experiments have not yet been done in the Southeast Asian countries.

1.2 Planning a Tagging Experiment

Typically, a release-recapture experiment involves the following sequence of operations: 1) capture of animals to be tagged; 2) handling and holding the animals during the tagging operation; 3) tagging process; 4) release of the tagged animals; 5) subsequent recapture of the animals and the detection or recovery of the tag (Jones, 1979).

The likelihood of success for a release-recapture experiment depends on the result of planning which is closely related to the objectives of the experiment. The factors that may operate to reduce the likelihood of success are : 1) mortality of tagged individuals; 2) loss of tags through shedding or deterioation; 3) disproportionate distribution of fishing pressure; and 4) failure to detect or report tagged animals during the recovery process.

Therefore such factors as species and size of fish, method of capture and amount of handling, duration of experiment, steps of tagging operation, numbers to be tagged, and method of recovery and publicity, should be taken into account when planning an experiment.

2. OBJECTIVES OF TAGGING EXPERIMENTS

There are a number of reasons for conducting tagging experiments and the principal ones are listed below.

2.1 Investigation of Movement

This is one of the commonest reasons for tagging. The object is to release one or more tagged animals at a known point (or points) and to learn something about their movements from the distribution of those animals that are subsequently recaptured (Jones, 1979).

2.2 Investigation of Mixing between Different Stocks

This is a special case of 2.1 where the species is known to be distributed in the form of distinct populations or stocks. Tagging experiments provide one way of investigating whether such local groups are independent or not (Jones, 1979).

2.3 Estimation of Population Parameters

2.3.1 Mortality rate

The total mortality rate of a group of tagged individuals can be estimated. This can be done from the way in which the rate of recovery of tagged individuals declines with time (Jones, 1979).

2.3.2 Growth rate

The growth rate of tagged individuals can be studied. This can be done by determining the change in body size of an individual from the time of liberation to the time of recovery (Jones, 1979).

2.3.3 Age determination

The age determination of tagged individuals can be made successfully. This can be done by holding tagged fish in live boxes to ascertain the growth increments periodically.

2.3.4 Population size

Estimates of the ratio of tagged and untagged animals in a sample can be used to determine the size of the untagged population (Jones, 1979).

2.3.5 Exploitation rate

Estimates of the ratio of tagged and untagged animals in a sample can be used to determine the exploitation rate of a population.

As mentioned above, there is a wide variety of objectives of tagging experiments, and for each of them a particular tagging technique may be more suitable than all the others. It is therefore important to identify clearly the purpose of the experiment and to choose a technique accordingly.

However, the investigations and estimates based on tagging experiments involve various biases. For example, if we want to obtain an estimate of population parameters in particular, a number of factors can bias mortality estimates based on tagging experiments, and there is likely to be some additional mortality of tagged fish, either initially, due to the process of capture, handling and tagging, or subsequently, due to the presence of the tag on the fish. Loss of tags, non-reporting of tags, migration of tagged individuals away from the recapture area, can also bias the results. These factors all lead to overestimates of the mortality rate of the untagged individuals.

The discussion in the present manual, however, has been limited to the selected fish species and invertebrates in the aspects of tagging techniques for these animals, including some minor results of its application such as their migrations.

The more theoretical topics, such as the statistical methods of designing tagging experiments and estimating population parameters from the results have been treated here by way of suggestions.

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Fishes for experiment

In Thailand, a tagging program for several important fish species was initiated by the Department of Fisheries in 1959, then advanced by the Pelagic Section of Marine Fisheries Division in 1976. It is still conducted at present for the purpose of getting information on age and growth of fish in nature, as well as for the estimation of fish migration (Somjaiwong and Chullasorn, 1974). Initially, tagging experiments were conducted for the commercially important pelagic fish species, such as mackerels: Indo-Pacific mackerel - *Rastrelliger neglectus*, Indian mackerel - *Rastrelliger kanagurta*, Big-eye scad - *Selar crumenophthalmus*, Round scad - *Decapterus* spp., and Trevally - *Caranx* spp. (Fig. 1). Recently the experiments have included tuna-like fishes such as Spanish mackerel - *Scomberomorus* spp.. However, among those species, Indo-Pacific mackerel has become the main target of tagging experiments because of its commercial importance, and because it is easily handled.

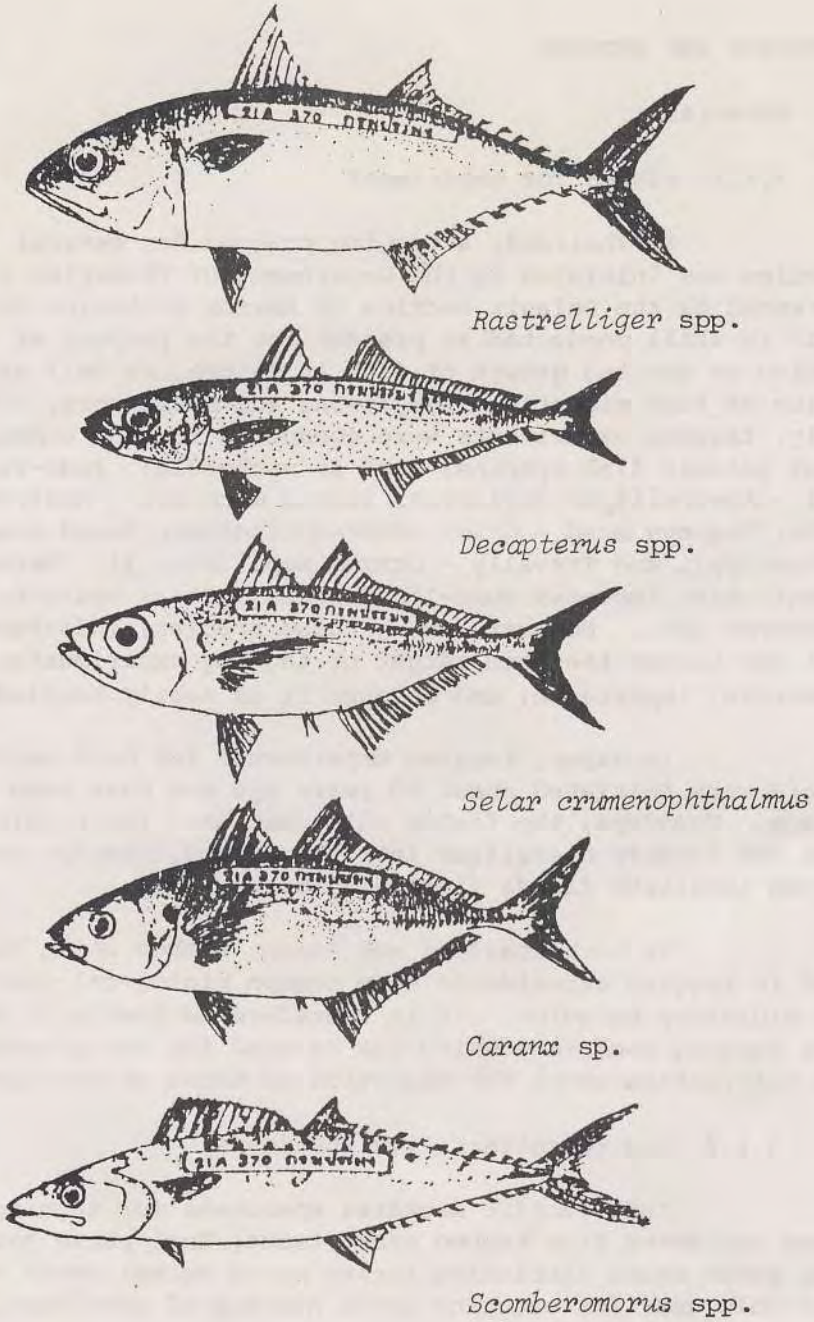
In Japan, tagging experiments for both mackerels and yellowtail were initiated about 60 years ago and have been going on ever since. Nowadays, the fishes which are used for tagging purposes in Japan are roughly classified into two groups, namely; salmon-like fishes and tuna-like fishes (including mackerels).

In both Thailand and Japan, fishes which have been included in tagging experiments have common biological characteristics, such as migratory behavior. It is therefore advisable to develop a suitable tagging technique which can be used for the purpose of getting information about the migration of those shared stocks.

3.1.2 How to collect live specimens

Indo-Pacific mackerel specimens for tagging purposes have been collected from bamboo stake traps, Thai purse seines, etc. The thai purse seine (including luring purse seine) seems to be the most suitable gear for catching large numbers of specimens. However, it is necessary to take great care in handling of specimens.

The sample size of specimens varies depending on the purpose of the experiment, but usually 500-1,000 fish are used.



Rastrelliger spp.

Decapterus spp.

Selar crumenophthalmus

Caranx sp.

Scomberomorus spp.

Fig. 1 Some of the fish species included in tagging experiments in Thailand.

The body size of specimens in experiments ranges from 10 to 16 cm in standard length. Generally, the young mackerel of 10-16 cm in standard length can be collected in the Gulf of Thailand and the Andaman Sea during the period from May to July.

3.1.3 Types of tag

In the early stages of tagging in Thailand, in the 1960s, a direct attachment was commonly used. At this stage, the dart tag, "spaghetti" tag and Petersen tag were used for tagging experiments.

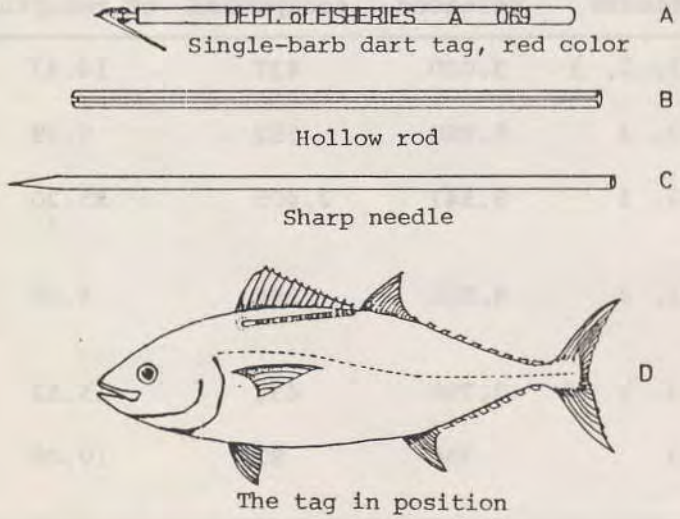
Later, seven types of different colored tags were tested in order to find one suitable for Indo-Pacific mackerel. It was found that the red color nylon dart tag is the most convenient for use in the Gulf of Thailand (Somjaiwong and Chullasorn, 1974) (Table 1). This type of tag is still used at present (Fig. 2).

Table 1-1 Recoveries data in each year (after Somjaiwong & Chullasorn, 1974)

Year of release	Color of tag	Area of release	Number released	Number recaptured	Percentage of recapture
1960	White, yellow	1, 2, 3	3,020	437	14.47
1961	Yellow, orange	2, 3	5,880	552	9.39
1962	Red, yellow, green, blue	2, 3	9,547	2,405	25.20
1963	Red, yellow, green	1, 3	4,831	284	5.88
1964	Red	2, 3	2,790	433	15.52
1965	Red, yellow	3	796	80	10.05
Total for all years	Red, yellow green, orange, blue, white	1, 2, 3	26,864	4,191	15.60

Table 1-2 Comparisons of the color of tag in each fishing area (after Somjaiwong & Chullasorn, 1974)

Year of release	Area of release	Color of tag	Number released	Number recaptured	Percentage of recapture
All 6 years	1	Red	515	32	6.21
		Green	160	8	5.00
		Yellow	708	46	6.49
	2	Red	3,220	1,250	38.82
		Yellow	2,810	716	25.48
		Green	1,565	411	26.26
		Blue	970	431	44.43
	3	Red	4,559	341	7.48
		Yellow	5,338	272	5.10
		Green	2,341	216	9.23
		Orange	4,435	452	10.19
		White	243	16	6.58



A single-barb dart (A) is inserted into the fish's body under the first dorsal fin with a hollow rod (B). On the tag is written the name of organization which is conducting the tagging experiment, and the date of release.

Fig. 2 Tagging equipment (B,C) and the tag (A) in position (D) on Indo-Pacific mackerel in the Gulf of Thailand (redrawn from Somjaiwong *et al.*, (1970).

The early tagging experiments conducted in Japan between 1920 and 1940 revealed that the collar tag was suitable for yellowtail (Fig. 3-1) and Atkins tag for salmon[1] (Fig. 3-2).

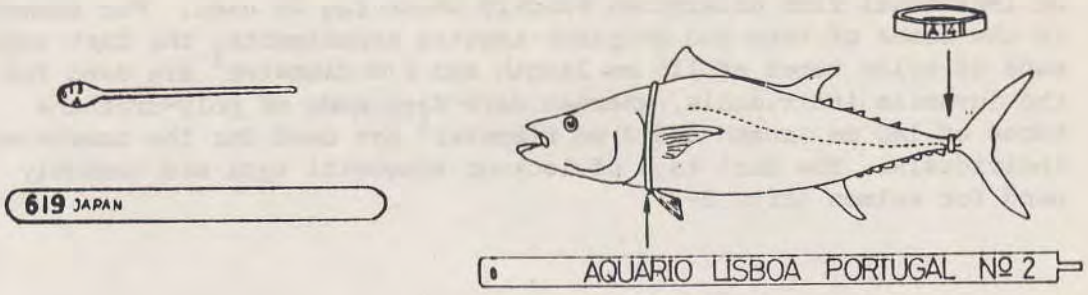


Fig. 3-1 Collar tags (redrawn from Rounsefell and Kask, 1943). These tags are suitable for yellowtail, small tuna, common mackerel etc.

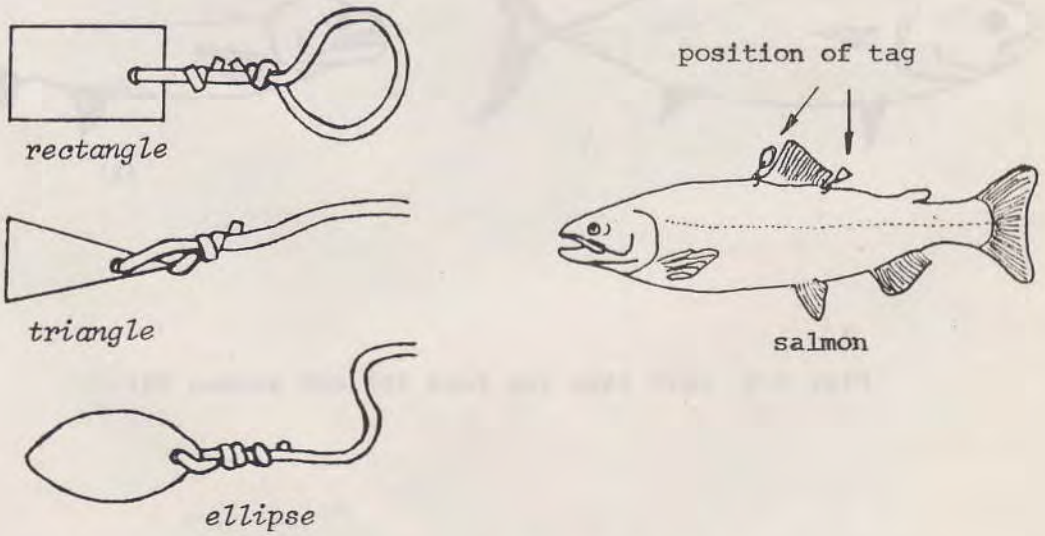


Fig. 3-2 Atkins tags (redrawn from Jakobsson, 1970). A simple tag consisting of a bead or a flat plate attached to the fish by a thread or a piece of wire. These tags were introduced by C.G. Atkins on the Pacific salmon in 1872.

[1] In studies of salmon conducted by the International North Pacific Fisheries Commission in the eastern Bering Sea, the Dennisson injection tag and the Carlin dangler tag were used.

After the Second World War up to now, several types of dart tags have been used for tuna, skipjack and salmon. The size of individual fish determines exactly which tag is used. For example, in the cases of tuna and skipjack tagging experiments, the dart tags made of nylon tubes of 115 mm length and 2 mm diameter[1] are used for the juvenile individuals, whereas dart tags made of poly-urethane tubes of 140 mm length and 3 mm diameter[2] are used for the common-sized individuals. The dart tags of lock-on spaghetti type are commonly used for salmon (Fig. 3-3).

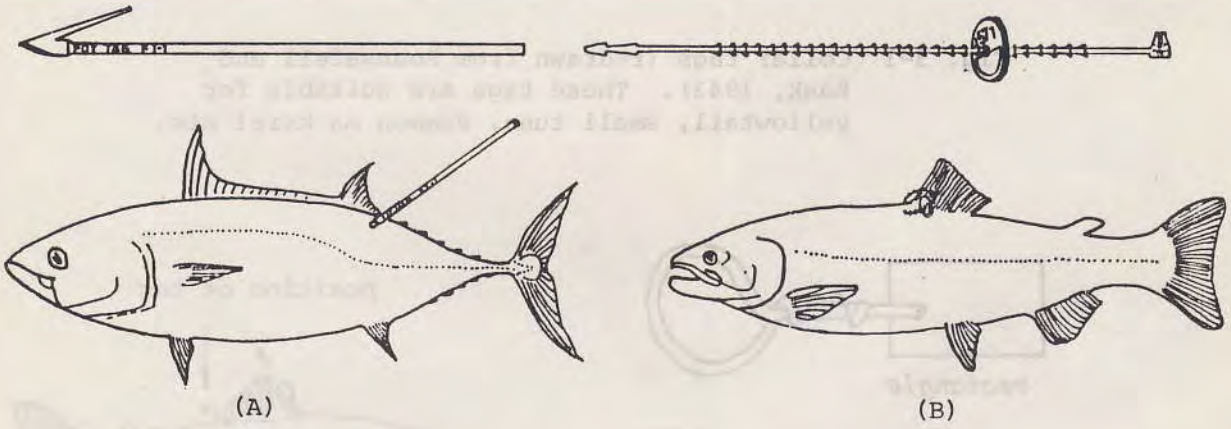


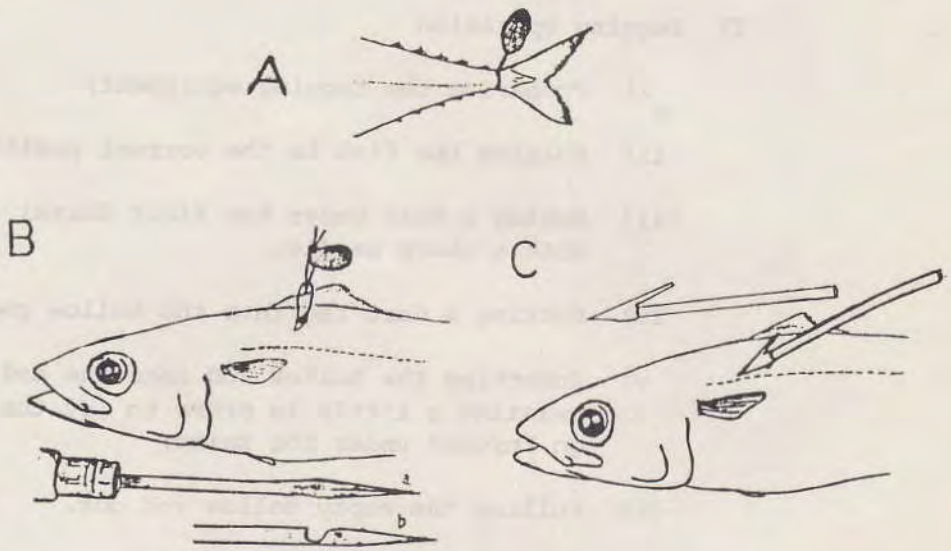
Fig. 3-3 Dart tags for tuna (A) and salmon (B)

---

[1] American manufacturer : Floy Tag & Manufacturing, Inc. Seattle, Washington, USA.

[2] Japanese manufacturer : Fuyo Sangyo Co. Ltd., Tokyo, Japan.

As regarding the Japanese common mackerel, *Scomber japonicus*, tagging experiments have been carried out during the last fifty years. Indeed, two hundred and twenty-one tagging experiments on the Pacific sub-population of the Japanese common mackerel have taken place between 1950 and 1968. They revealed that the Atkins type of tag (Fig. 4) fastened on to the caudal peduncle, was the most suitable one and had the highest recapture rate.



A: Atkins tag, fastened on caudal peduncle.

B: Atkins tag, fixed on dorsal fin base.
a, b: Tagging tools.

C: Dart tag, thrust into dorsal fin base.
The tagging tool is shown above.

Fig. 4 Types of tag and tagging position for Japanese mackerel (after Usami and Matsushita, 1974).

3.1.4 Tagging equipment and method

The procedure of tagging operation, in the period between 1960 and 1965 in Thailand, was as follows (Somjaiwong and Chullasorn, 1974):

1) Collecting live fish speciesmens by bamboo stake traps or Thai purse seines;

2) Holding the speciesmens in a floating pen for 2-3 days until they have recovered;

3) Tagging operation

   i) Preparing the tagging equipment;

   ii) Holding the fish in the correct position;

   iii) Making a hole under the first dorsal fin with a sharp needle;

   iv) Putting a dart tag into the hollow rod;

   v) Inserting the hollow rod into the hole, twisting a little in order to let the tag go through under the spine;

   vi) Pulling the empty hollow rod out.

4) Holding the tagged fish in the floating pen for 3-4 days, or until they are strong enough to be released;

5) Transferring the fish to a particular area and releasing them.

The procedure of tagging operation for tuna which has been conducted in eastern Indonesian waters is as follows (Yonemori, Uktolseja and Merta, 1984):

1) Preparation

   i) Washing and cleaning tag applicators with detergent;

   ii) Putting tag into applicator and placing in a tag holder (Fig. 5) in numerical order;

iii) Covering the deck where fish are landed with foam rubber sheeting in order to prevent shock and damage to fish;

iv) Arranging tagging cradles (Fig. 6) at the most convenient place for tagging;

v) Keeping the tagging cradles and foam rubber sheets wet with running sea water to prevent loss of fish scales.

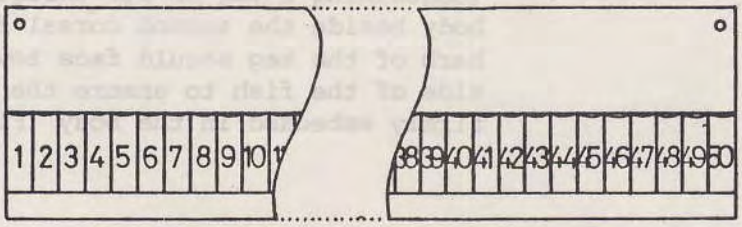


Fig. 5 Tag holder

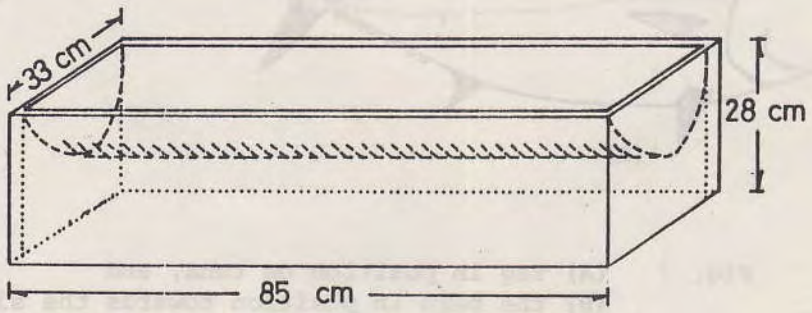


Fig. 6 Tagging cradle

a: vinyl sheet

b: length mark

2) Tagging operation

i) Selecting only active fish for tagging. Avoiding fish injured on eye or gill;

ii) Placing the selected fish on the tagging cradle (covering the eyes with hand or wet cloth when the fish is too active. This will pacify the fish);

iii) Measuring the fork length to nearest cm on the cradle and stabbing applicator (containing a tag in it) obliquely into the body beside the second dorsal fin. The barb of the tag should face towards the side of the fish to ensure the tag is firmly embedded in the body (Fig. 7).

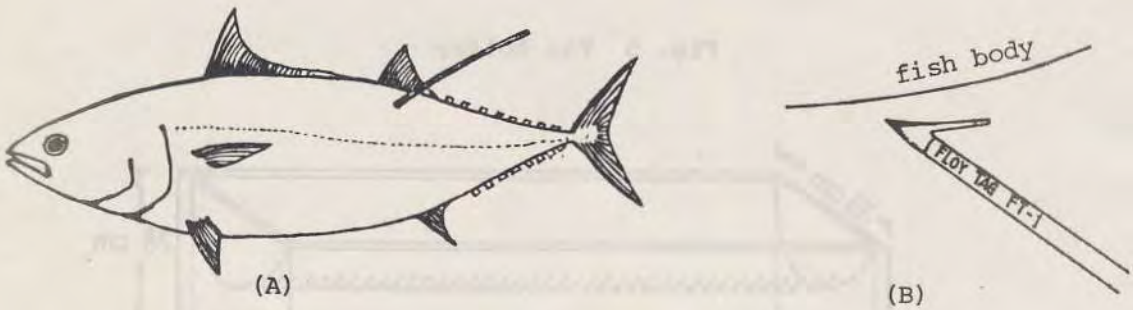


Fig. 7 (A) Tag in position on tuna, and
(B) the barb in position towards the side of fish

3) Immediately releasing the tagged fish into the sea over the side of ship.

The two methods described here differ very much from each other, especially in the procedure of releasing the tagged fish.

As regards the effect of holding tagged plaice for various periods before release, Beverton and Bedford (1963) summarised their findings as follows:

1) The death rate in the holding well was increasingly condition-specific up to five days. The death rate among the best condition fish, however, remained small or nil. The return rate of tagged plaice released after being held for periods of two, three and five days was also more condition-specific than the immediate releases.

2) Their initial tagging mortality, if released immediately after being caught and tagged, is likely to be small.

Similar results have been obtained by the experiments on some pelagic fish species inhabiting the seas around Japan (Nakai and Hattori, 1952). Thus it appears that holding the tagged fish for various periods before release tends to affect the mortality of tagged individuals in the sea after release. In the US, Europe and Japan the tagging procedure is faster and simpler because the fish are generally released immediately after tagging.

In the experiments where fish are released immediately after tagging on board, it is desirable to prepare some portable or deck tanks to hold the fish before tagging (Fig. 8-1).

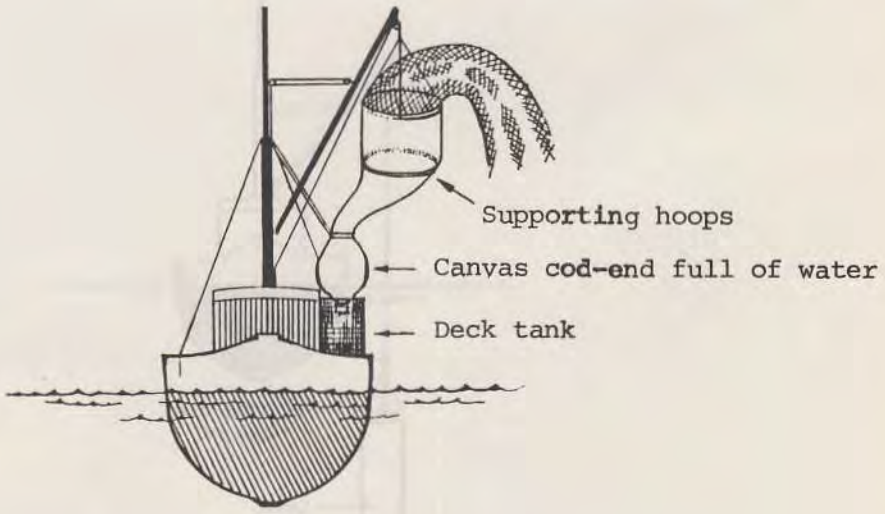


Fig. 8-1 Bailing from bunt to holding tanks. Fish are released into the tank by untying the bottom of the canvas cod-end (redrawn from Jones, 1979).

Usually, a fish is first anaesthetized with Tricaine Methaneulfonate (MS 222), Urethane, Chloretone or similar substances, its body length is then measured and finally it is tagged (Fig. 8-2).

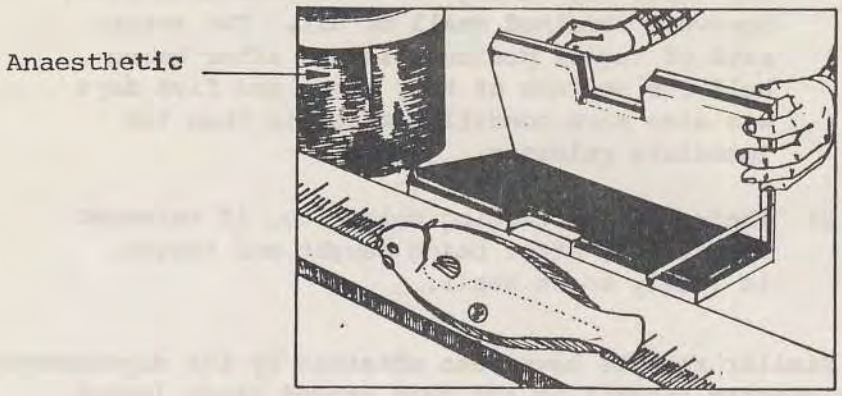


Fig. 8-2 Tagging procedure by using anaesthetics (after Kotthaus, 1963).

When dealing with physoclistous deep water fish (that is, fish with no air duct between air-bladder and alimentary canal), the use of lowering cage or lowering cylinder may be essential, because some fish will have inflated air-bladders and may not be able to dive due to their increased buoyancy (Jones, 1979) (Fig. 8-3).

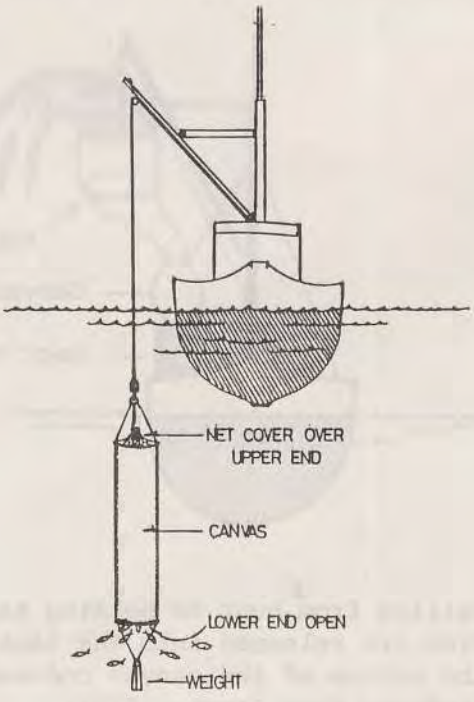


Fig. 8-3 Lowering cylinder (redrawn from Sandemon & Rees, 1963)

A more complicated tagging procedure in Thailand is probably due to the fact that delicate fish are chosen for tagging experiments, and hence the specimens must be handled with greater care. In the US, Europe and Japan, a lot of released specimens of tagged fish are easily obtainable on deck at any time of tagging experiment.

After 1965, new tagging techniques were developed. Special applications such as a tagging gun and needles facilitated the work and made it possible to increase the number of tagged specimens. This improved tagging equipment is shown in Fig. 9.

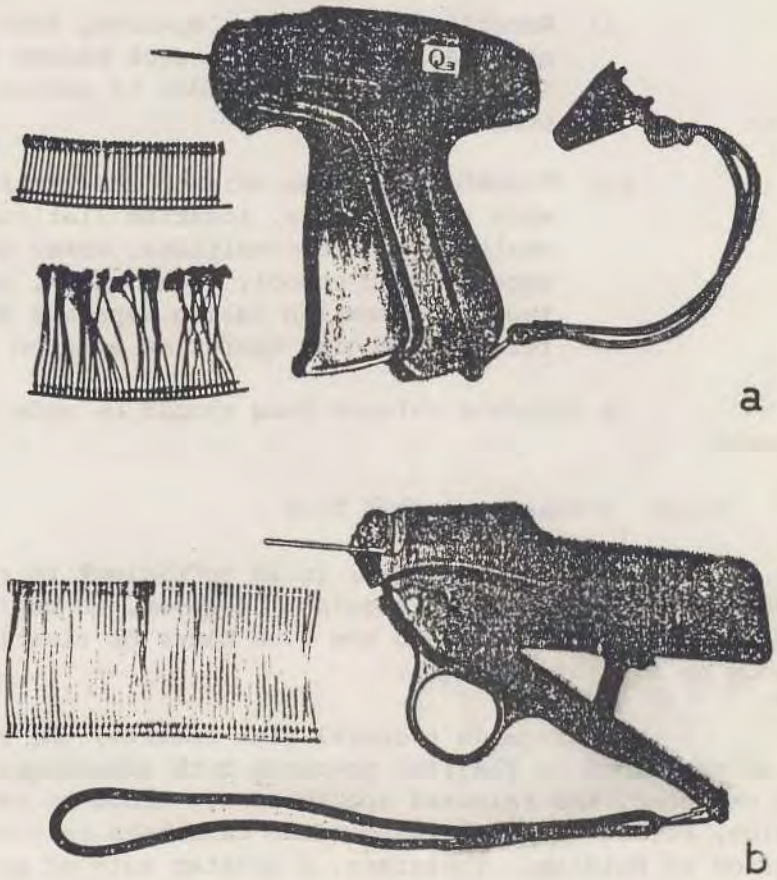


Fig. 9 Examples of tagging guns for applying anchor tags.

a : Japanese design : Banok 103-S supplied by Rigosha & Co. Ltd.,

b : American design : Dennison mark II Swiftacher Gun 08945 supplied by Floy Tag Manufacturing Inc,.

Gun tagging allows deep penetration for a better angle of the tag flow along the back of the fish.

3.1.5 Recording of release data

The items which would be recorded before releasing differ according to tagging purposes, however, basic information such as tag number, species and body length of each tagged fish are recorded in all cases.

In the progress report on tuna tagging in eastern Indonesian waters, Yonemori, Uktolseja and Merta (1984) gave the following advice on recording data;

i) Recording tag number, species, fork length and physical condition for each tagged fish (a cassette tape recorder is useful for this purpose);

ii) Transferring these data to the RELEASE FORM along with release data, location (latitude, longitude), weather and sea conditions, water temperature, type of fish school, total catch, etc., for every tagging operation (using separate RELEASE FORM for each tagging operation even on the same day).

A separate release form should be made for each tagging experiment.

3.1.6 Releasing tagged fish

Most of the time, it is sufficient to release the fish into water immediately after tagging. However, in Thailand the tagged fishes are kept temporarily in the live boxes or floating pens until they show no sign of weakness.

As regards tropical fish species, the releasing technique which is practiced in Thailand presents both advantages and disadvantages. On the one hand, the released specimens are known to be in normal healthy condition, because several inspections have been carried out throughout the period of holding. Therefore, a greater rate of recapture can be expected under the system of returning reports. On the other hand, this method is not suitable when dealing with a lot of specimens in a short time.

The release area is usually located near the tagging site.

3.1.7 How to treat the obtained data

3.1.7.1 Recapture of tagged fish and recovery of tags

Tags can be recovered in several ways, as follows: 1) on board ship at sea, by fishermen handling the fish; 2) on the quayside by a docker discharging, sorting and weighing the fish; 3) on the premises of a wholesaler or at the fish market, where fish is filleted and packed; and 4) at a retail shop.

In Thailand most of the recaptured fish in the experiments with Indo-Pacific mackerel have been reported by fishermen.

In the tagging experiments conducted from 1960 to 1965, a total of 26,864 Indo-Pacific mackerel with dart tags were released in the four areas in the Gulf of Thailand. Of these, 4,191 or 15.6 per cent were subsequently recaptured. During 1970-75 experiments 12,921 tagged fish were released in the three areas, and 849 or 6.57 per cent of them were recaptured and reported by fishermen.

Table 2 shows one of examples of the data treatment. In this table, the recapture rates are tabulated by different years and by different release areas.

Table 2. Yearly changes in recapture rate of Indo-Pacific mackerel tagged in three areas in the Gulf of Thailand, from 1970 to 1975 (adapted from Somjaiwong, 1980).

Year	Release areas	Number of released fish	Number of recaptured fish	Recapture rate
1970	II	544	76	13.97
	III	3,438	71	2.07
1971	II	915	55	6.01
	III	1,014	26	2.56
1972	II	1,062	53	4.99
	III	1,494	208	13.92
1973	II	1,355	78	5.76
	III	134	13	9.70
1974	II	1,046	19	1.82
1975	I	1,919	250	13.03
1970-1975	I-III	12,921	849	6.57
Yearly average of recapture rate	Release area	I	13.03	
		II	6.51 (s.d. = 4.49)	
		III	7.06 (s.d. = 5.75)	

By using the data shown in Table 2, we can demonstrate, for example, that the yearly average of recapture rate in areas II and III is nearly the same as the recapture rate for all six years of experiment during 1970-75, although with a heavy fluctuation between years.

Generally, in any fish species there is a tendency for the recapture rate to be directly proportional to the fishing pressure (intensity) towards the target fish stock (Kurogane, 1963). But in the case of Indo-Pacific mackerel, as shown in Table 2, it is uncertain whether there is a tendency for the recapture rate to increase as the fishing intensity increases.

As shown by the 1981-83 experiments conducted on the west coast of Thailand, there is no significant difference in recapture rate for different years, nor for different release areas with some minor exceptions. Table 3-1 gives the relevant data, as well the number after release.

Table 3-1 Results of the tagging experiment with *Rastrelliger brachysoma* on the west coast of Thailand, 1981-83.

Year	Number of released fish	Number of recaptured fish	Recapture rate	Days lapsed after release	Release area
1981	513	8	1.56	22 - 131	Ko Terutao, Satul
1/1982	242	4	1.65	14 - 71	Ko Langu, Satul
2/1982	832	24	2.88	10 - 150	Ko Langu, Satul
Total 1982	1,074	28	2.61	10 - 150	
1/1983	478	7	1.46	1 - 111	Ko Terutao, Satul
2/1983	694	3	0.43	13 - 21	Ko Terutao, Satul
3/1983	722	2	0.28	21 - ?	Ko Bulon, Satul
4/1983	697	2	0.29	14 - 20	Ko Bulon, Satul
5/1983	659	26	3.94	1 - 140	Ko Terutao, Satul
6/1983	546	5	0.91	4 - 146	Ko Terutao, Satul
7/1983	544	2	0.37	5 - 31	Ko Bulon, Satul
8/1983	459	1	0.217	?	Ko Bulon, Satul
Total 1983	4,799	48	1.0	1 - 146	
1981-83	6,386	84	1.32	1 - 149	

Table 3-2 shows details of time elapsed between release and recapture of Indo-Pacific mackerel on the west coast of Thailand.

Table 3-2 Elapsed time between release and recapture of Indo-Pacific mackerel on the west coast of Thailand, 1981-84.

year / Days elapsed	1981	1982	1983	1984
	Number of released fish			
	513	1,074	4,799	526
	Number of recaptured fish			
0-30	1	13	23	58
31-60	5	10	12	35
61-90	-	2	7	7
91-120	1	2	4	...
121-150	1	1	2	...
151-180	-	-	-	...
Total	8	28	48	100
Recapture rate (%)	1.56	2.61	1.00	19.01

From Table 3-2, we can draw further inferences as follows: 1) the number of recaptured fish is predominant within 30-60 days after release, and decreases almost exponentially as the number of elapsed days increases (Fig. 10-1); 2) the magnitude of decreasing trend of recaptured fish, however, is different by years (Fig. 10-2); 3) the recapture of tagged fish continues until about 150 days after release, regardless of differential experimental years (Fig. 10-3).

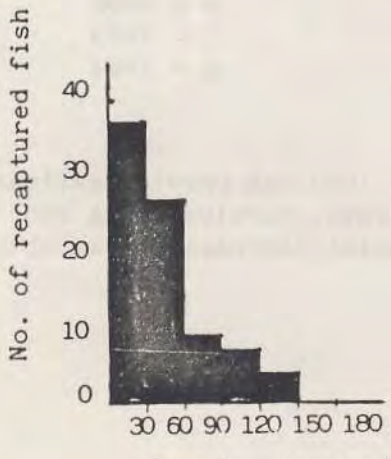


Fig. 10-1 Days elapsed from to recapture, and number of recaptured Indo-Pacific mackerel, on the west coast of Thailand, 1981-83.

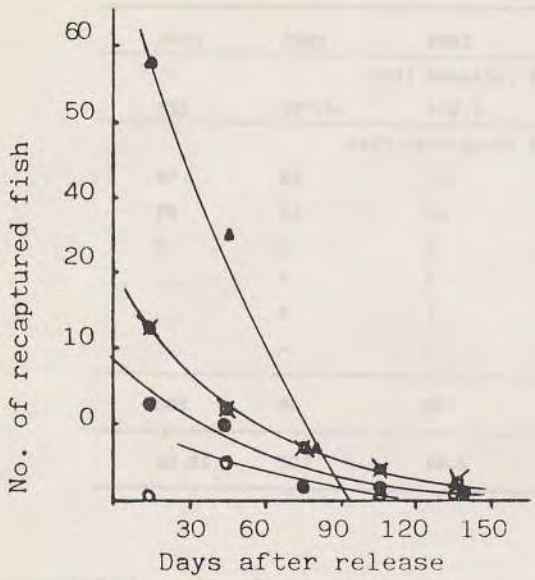


Fig. 10-2 The number of recaptured fish by days lapsed after release (adapted from Chullasorn, 1984)

O:: 1981 experiments
● : 1982 "
x : 1983 "
▲ : 1984 "

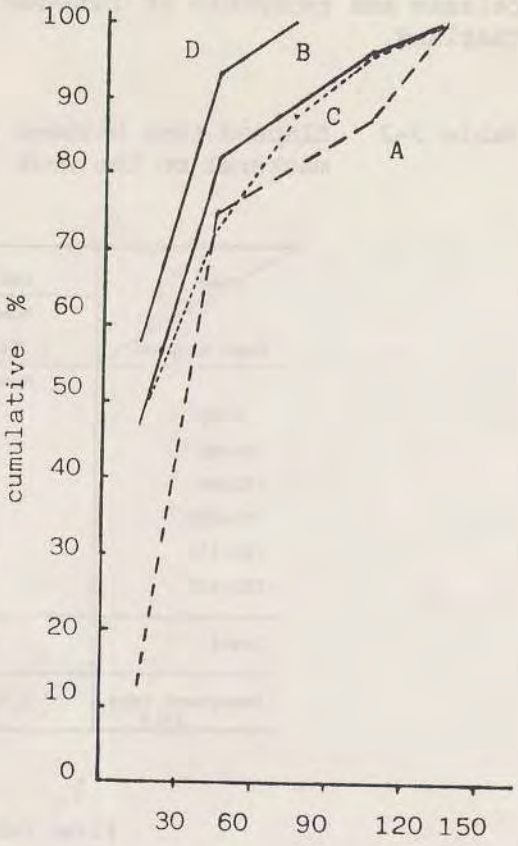


Fig. 10-3 Cumulative percentage curve of recaptured fish. (adapted from Chullasorn, 1984)

A = 1981 experiments
B = 1982 "
C = 1983 "
D = 1984 "

Table 3-2 and Fig. 10-2 can provide estimates of population parameters such as mortality rate, survival rate and exploitation rate, in conditions of exponential decreases of recaptured fish.

Table 4 shows the recapture rate of several fish species in the seas around Japan.

Table 4. Some examples of recapture rate of pelagic fish species in the seas around Japan (adapted from Kurogane, 1963).

Species	Year	Area	Number of released fish	Recapture rate (%)	Data source
Sardine	1936-1937	Hokkaido	30,000	0.09	Hujikawa &Nakazima(1938)
	1950-1954	Kyushu	32,000	1.60	Tsujita (1961)
Herring	1949-1957	Hokkaido	77,000	4.65	Hokkaido Reg.Fish. Res.Lab.(1958)
Japanese mackerel	1924-1938	Whole Japan	24,000	0.66	Kasahara & Ito (1953)
	1952-1959	Japan Sea	7,300	2.58	Machinaka (1960)
	1953-1959	Kyushu	32,000	1.41	Tsujita (1961)
Jack mackerel	1952-1955	Northwest Kyushu	19,000	8.6	Murakami & Hakamada (1957)
Yellow-tail	1917-1938	Whole Japan	4,100	17.1	Matsushita (1953)
	1955-1958	Japan Sea	2,400	2.6	Nagata (1959)
Salmons	1928-1942	North Hokkaido	33,000	4.9	Hirano (1953)
Skipjack	1935-1937	Pacific Ocean	1,700	0.65	Tohoku Reg.Fish.Res.Lab.(1952)
Albacore	1957-1959	North Pacific	940	0.95	Suda (1961)

Tagging techniques for different fish species may be different from each other, however, the yellowtail shows the highest recapture rate, whereas the recapture rate of mackerel shows low value similar to those seen in Table 3-1 for Thailand.

The differences in the recorded recapture rate among fish species may be due to differences in commercial value of tagged fish, as well as the unequal visibility of tags when the recaptured fish are handled. The average body size of a tagged Indo-Pacific mackerel is 10-16 cm in standard length and it was therefore considered that the net selectivity and discarding of small fish at sea may also be responsible in certain circumstances for the lower return rate. The higher return rate of yellowtail may be due to their larger body size (more than 20 cm in one-year class) and their higher commercial values.

If we want to investigate the ecological aspects of the fish, it is desirable to use the sample specimens which are classified into yearly cycles of life or developmental stages of fish.

Table 5 shows an example of yearly changes in recapture rate of yellowtail which were classified by different year classes. In this table, the yearly average recapture rate shows fairly high values (8.1-15.5%) and the rate has been increasing steadily since 1960, especially for two-year and three-year class specimens.

A similar result was reported in release-recapture experiments where fish specimens were classified by yearly life cycle (Fig. 11).

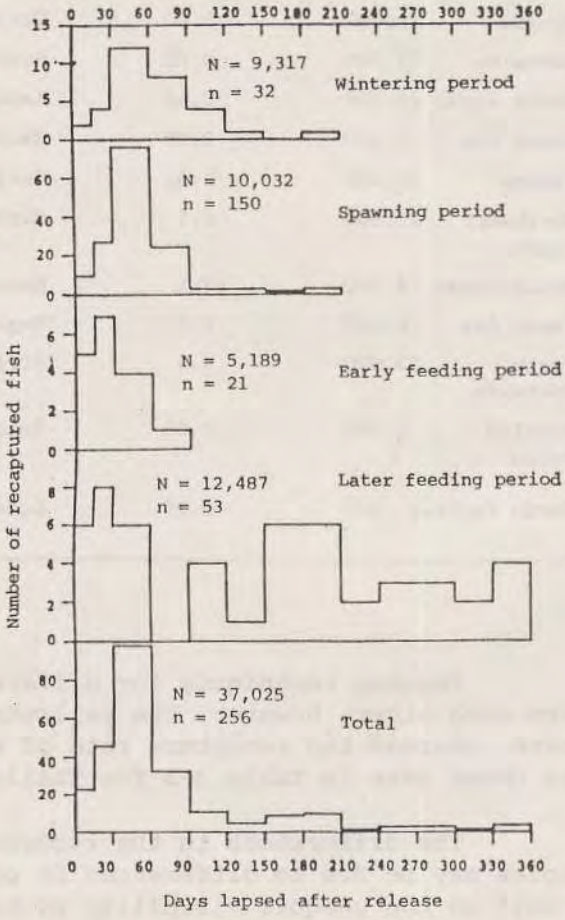


Fig. 11 Relationship between the number of recaptured Japanese common mackerel and days elapsed after release, classified by yearly cycle (after Usami & Matsushita, 1974).

N : number of released fish
n : number of recaptured fish

Table 5 Yearly changes in recapture rate of yellowtail, according to year class, tagged and released in Tsushima warm current waters (after Watanabe, 1979).

Period	Year	1 year class				2 and 3 year class				4 year class and over				All year classes		
		Release points	Number of released fish	Number of recaptured fish	Recapture rate	Release points	Number of released fish	Number of recaptured fish	Recapture rate	Release points	Number of released fish	Number of recaptured fish	Recapture rate	Number of released fish	Number of recaptured fish	Recapture rate
Pre-war	1923	1	208	18	8.7	1	17	0	0	-	-	-	-	225	18	8.0
	1924	-	-	-	-	1	64	11	17.2	-	-	-	-	64	11	17.2
	1925	-	-	-	-	2	46	5	10.7	-	-	-	-	46	5	10.7
	1926	1	128	9	7.0	-	-	-	-	-	-	-	-	128	9	7.0
	1927	-	-	-	-	4	54	3	3.9	-	-	-	-	54	3	5.5
	1928	-	-	-	-	4	107	13	12.1	1	19	2	10.5	126	15	11.9
	1929	-	-	-	-	5	39	3	7.6	-	-	-	-	39	3	7.6
	1930	-	-	-	-	3	79	4	5.1	-	-	-	-	79	4	5.1
	1932	-	-	-	-	1	0	1	-	-	-	-	-	0	1	-
	1933	-	-	-	-	-	-	-	-	1	0	2	-	0	2	-
	1934	1	55	0	0	-	-	-	-	-	-	-	-	55	-	-
	1935	-	-	-	-	-	-	-	-	1	10	3	30.0	10	3	-
	1936	-	-	-	-	-	-	-	-	1	4	2	-	4	2	-
	Total	3	391	27	6.9	21	406	40	9.8	4	33	9	27.2	830	76	9.2
Post-war	1956	3	260	8	3.1	2	206	5	2.4	-	-	-	-	466	13	2.8
	1957	2	338	2	0.6	6	611	9	1.5	1	20	0	0	969	11	1.1
	1958	1	72	21	29.2	1	100	3	3.0	-	-	-	-	172	24	14.0
	1959	2	88	13	14.8	1	55	1	1.8	7	124	4	3.2	267	18	6.7
	1960	1	62	7	11.3	1	100	28	28.0	6	85	14	16.5	247	49	19.8
	1961	1	45	17	37.8	-	-	-	-	8	65	10	15.4	110	27	24.5
	1962	1	100	23	23.0	-	-	-	-	8	60	3	5.0	160	26	16.3
	1963	-	-	-	-	1	100	30	30.0	7	40	1	2.5	140	31	22.1
	1964	1	3	1	-	-	-	-	-	-	-	-	-	3	1	-
	1965	-	-	-	-	1	98	15	15.3	-	-	-	-	98	15	15.3
	1966	-	-	-	-	2	117	22	18.8	-	-	-	-	117	22	18.8
	1967	2	287	62	21.6	-	-	-	-	-	-	-	-	287	62	21.6
	1968	-	-	-	-	5	225	53	23.5	-	-	-	-	225	53	23.6
	1969	3	296	15	5.1	1	101	15	14.8	-	-	-	-	397	30	7.6
	1970	-	-	-	-	1	51	10	19.6	-	-	-	-	51	10	19.6
	1971	1	3	0	-	1	50	13	26.0	-	-	-	-	53	13	24.5
	Total	14	1,554	169	10.8	23	1,814	204	11.2	37	394	32	8.1	3,762	405	10.8
Yearly average of recapture rate				Pre-war	5.2				8.1				20.2			8.1
				Post-war	16.3				15.4				7.1			15.9

Remarks: The main gear of recapture of tagged fish was the set-net

Figure 11 suggests that the highest recapture rate, which is in the spawning period, may be the natural result of the interaction between the ecological phase of mackerel which migrate in large groups toward the spawning grounds and the strongest fishing intensity during the spawning period.

Thus the reported recapture rate varies widely by several factors and it seems to be quite difficult to choose one factor which has the strongest effect on the rate of recapture. However if it is true that the success of tagging experiments depends upon the achievement of high recapture rate of tagged fish, we must publicize the importance of tagging experiment, because a higher recapture rate of tagged fish could be achieved by strengthening communication between researchers and fishermen and by giving publicity to tagging experiments.

It has been found useful to publish posters and notices which explain the purpose of tagging, and to offer reward to anyone who returns a tag and supplies information. Figures 12-1,2,3,4 show examples of such reward notices.

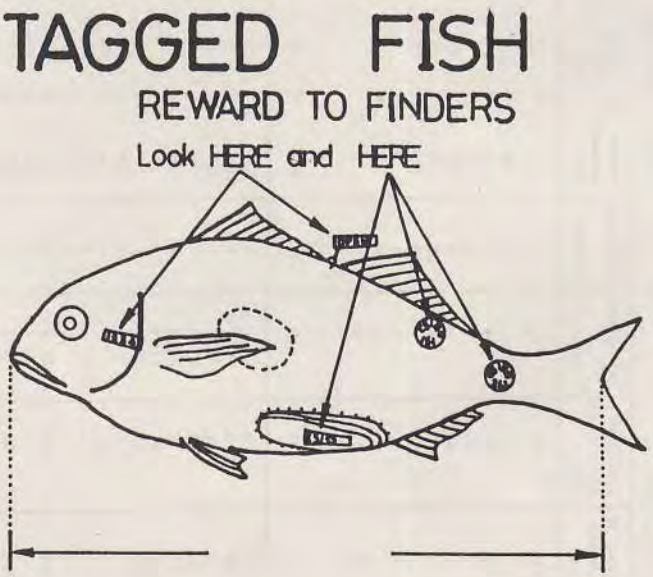


Fig. 12-1 Reward notice used in Lake Macquarie (Australia) investigation (after Thomson, 1963).

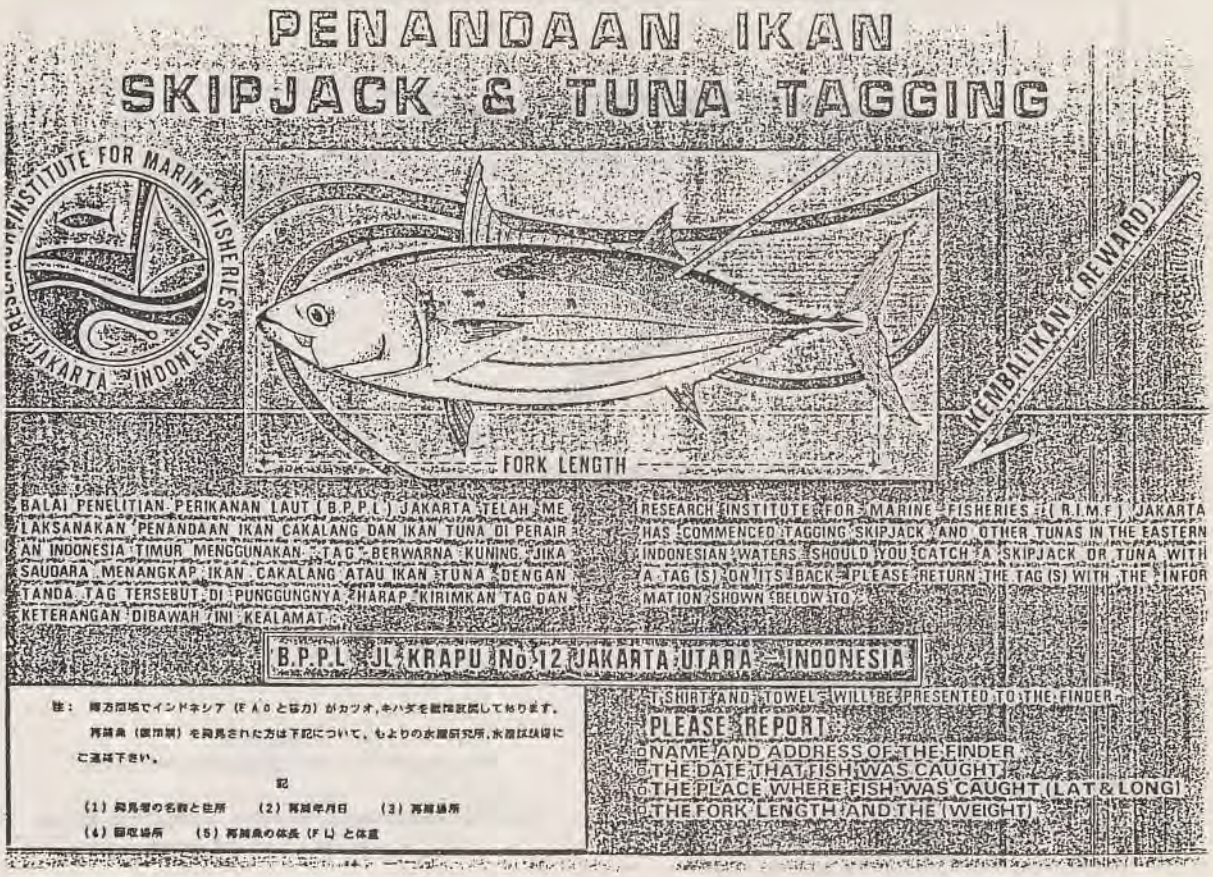
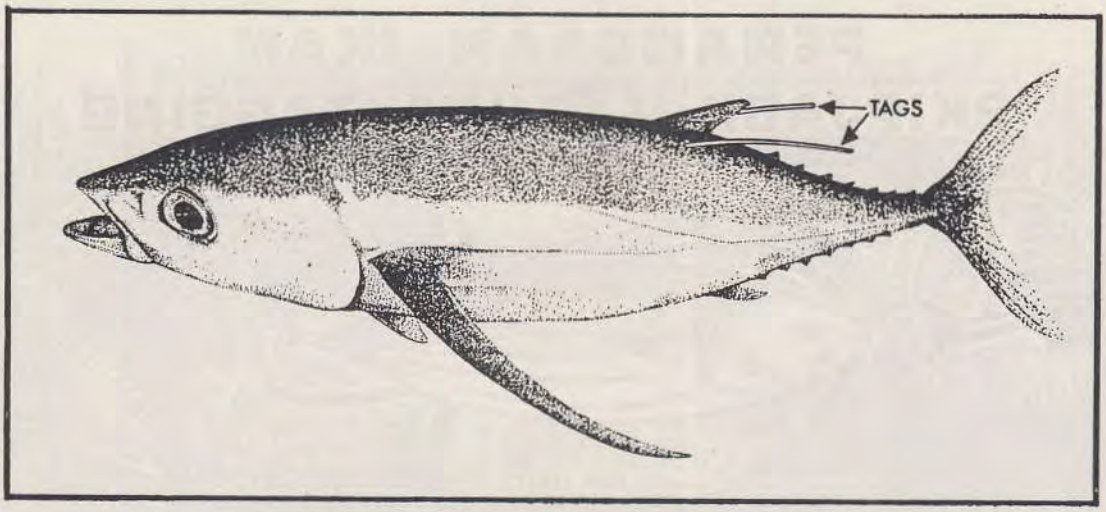


Fig. 12-2 Reward notice of skipjack and tuna tagging program Conducted jointly by Indonesia and FAO (Source: Indo-Pacific Tuna Program, FAO, 1984).

NEW ZEALAND ALBACORE TAGGING



30969 Reward F.R.D. MARINEDEPT. WGT. N.Z. Length 30969

The Fisheries Research Division is tagging albacore tuna in the New Zealand region as part of a programme to gather information on growth, abundance and migration and dispersal in the South Pacific Ocean. Each fish will carry one or two yellow plastic tags, bearing the lettering as shown above.

In a preliminary exercise we have used tags from the Commonwealth Scientific and Industrial Research Organisation. These bear the following legend:

REWARD C.S.I.R.O. CRONULLA
AUST. LENGTH 00000

REWARD

A reward of 50c (N.Z.) will be paid on receipt of either type of tag and the following information:

Tag number
Date and place of capture
Fish length (from tip of snout to fork of tail)

Your cooperation is sought in returning the tag and the above information to:

The Director
Fisheries Research Division
P. O. Box 19062
Wellington, New Zealand

Fig. 12-3 Reward notice used in New Zealand albacore tagging program (source: IPFC/12/REF 23).

REWARD FOR RETURN OF TAGGED FISH

Tag No.: .....

Date : .....

I, Mr./Mrs./Miss.....acknowledge receipt of Ringgit .....as reward for the return of (Number) ..... tagged fish.

Signature .....

DETAILED INFORMATION ON TAGGED FISH RECOVERED

Tag No..... Colour of Tag .....

Total extreme length (LX) ..... m.m Body length (LB).....,m.m.

Date caught .....

Area where tagged fish was recovered .....

Type of fishing gear .....

Depth of water.....metres. Distance from shore.....miles

Total catch of Chub mackerel .....kgs.

Name of Recorder.....

Please note: Fish length should be measured in m.m. from the tip of the snout to caudal peduncle (LB), and also from snout to the extreme end of the tail (LX) (as shown in diagram above).

Fig. 12-4 Part of the reward notice used in the current Malaysian-Thai Joint Tagging Programme. The notice, written in both Thai and English, has been distributed to local fishermen.

3.1.7.2 Determining migration pattern of tagged fish

3.1.7.2.1 Direction of migration

The tagging experiments of Indo-Pacific mackerel conducted on the east coast of the Gulf of Thailand (Somjaiwong and Chullasorn, 1974) revealed that most of the tagged fish were recovered in the release areas except for some large-sized groups which moved out in search of food and spawning grounds (Fig. 13). The experiments carried out in 1970-75 (Somjaiwong, 1980) showed that the majority of tagged fish migrated from the release areas toward the shore. The tagging experiments conducted in 1981-83 along the west coast of Thailand (Chullasorn, 1984), on the other hand, showed that although most of the fish moved only a short distance from the release areas, some appeared to prefer northward migration during March-April and August-October, and southward migration during June-July (Fig. 14).

These three groups of results suggest that despite some differences in migration pattern among different size groups of tagged specimens, the movement of tagged fish whose body size is 10-16 cm in standard length is limited to short distances, and they are not likely to cross the Gulf of Thailand.

Fig. 13 The migration route of tagged fish released in fishing area III (Prachuap) of the Gulf (after Somjaiwong and Chullasorn, 1974)

Fig. 14 The migration route of tagged fish released on the west coast of Thailand, 1981-83 (Chullasorn, 1984).

The direction of movement of tagged fish can be traced on the basis of the frequency distribution chart divided into eight directions. Figure 15 shows an example of the distribution and movement of the sea bream in the Yellow Sea ascertained by tagging experiments in 1964.

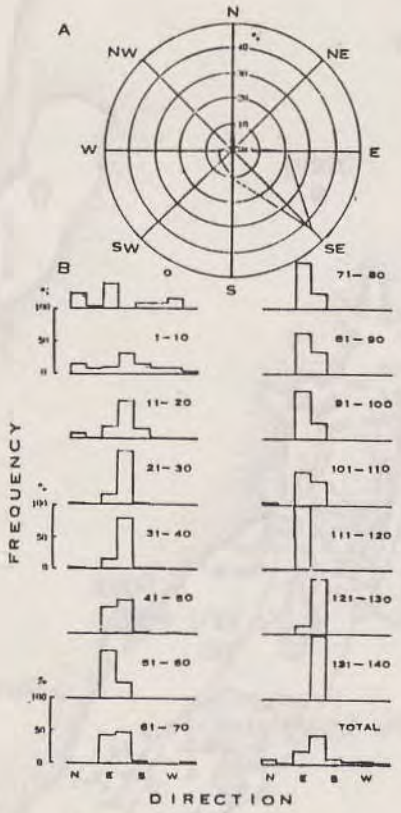


Fig. 15 A: Frequency distribution (per cent) of the recovered sea bream found in each direction.

B: Frequency distribution (per cent) of the tagged fish recovered in each direction. Numbers indicate the days after releasing (after Okada, 1966).

The above figure indicates that the tagged sea bream move in all directions within 30 days after libration, but thereafter, most of them travel east or southeast toward their wintering areas.

In the case of the Pacific sub-population of adult mackerel in the seas around Japan, there were examples of fish which were recovered 480 nautical miles away from the tagging place, and of others that were recaptured when the fish revisited the release site (Fig. 16).

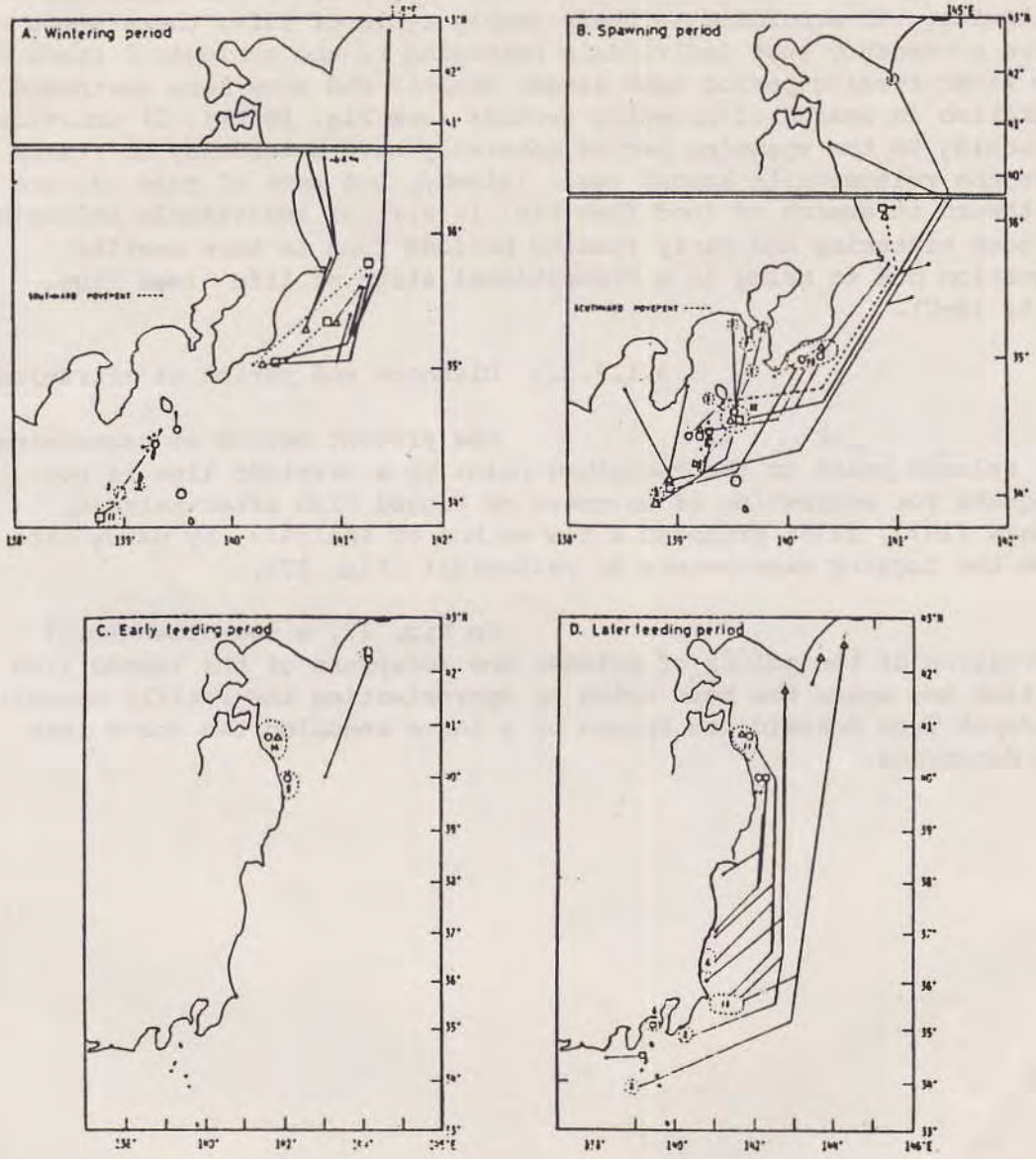


Fig. 16 Movement of the adult mackerel classified by yearly cycle of life at the time of release during three periods for different stock sizes (after Usami and Matsushita, 1974).

Release position
○ : 1950-59
△ : 1960-65
□ : 1966-68

Recapture position
• : A fish

Numerals indicate number of recaptured fish. Dotted circles indicate recapture area.

From Fig. 16, we can infer the following: 1) according to their yearly cycle of life, there seems to be a tendency that individuals belonging to the ecological phase of the later feeding period make larger schools and show long southward migration in search of spawning grounds (see Fig. 16-D); 2) individuals belonging to the spawning period generally have a tendency to remain near the release site around small islands, but some of them migrate northward in search of food (see Fig. 16-B); 3) individuals belonging to both wintering and early feeding periods tend to have smaller migration due to being in a transitional stage of life (see Figs. 16-A, 16-C).

3.1.7.2.2 Distance and period of migration

The present method of connecting the release point to the recapture point by a straight line is not adequate for estimation of movement of tagged fish after release. Tanaka (1972, 1975) proposed a new method of analysis, by using data from the tagging experiments of yellowtail (Fig. 17).

In Fig. 17, a two-dimensional expression of the points of release and recapture of the tagged fish in time and space has been tried by approximating the Pacific coastline of Japan from Hokkaido to Kyushu by a curve reducing the space into one dimension.

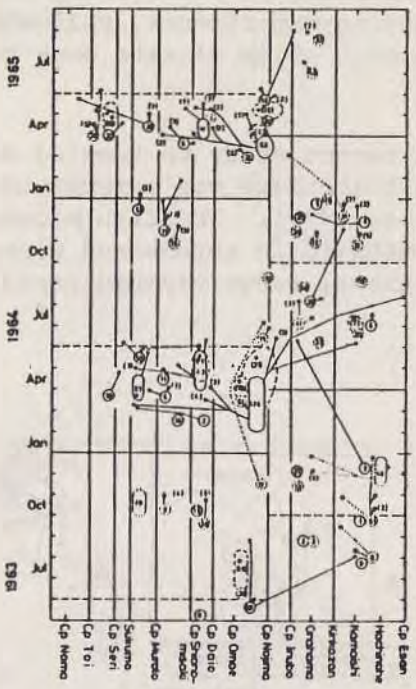


Fig. 17(A) Graph showing the relation between release and recapture in time and space.

The space is expressed approximately by one dimension on the abscissa. Circle of real or dotted line with figure in it: point and the number of fish of release. Small circle or circle of broken line with or without figure in parentheses: point and the number of fish of recapture ((1) is ommitted). Real line with black small circle: fish ≥ 60 cm. Dotted line with white small circle: fish < 60 cm. (after Tanaka, 1972)

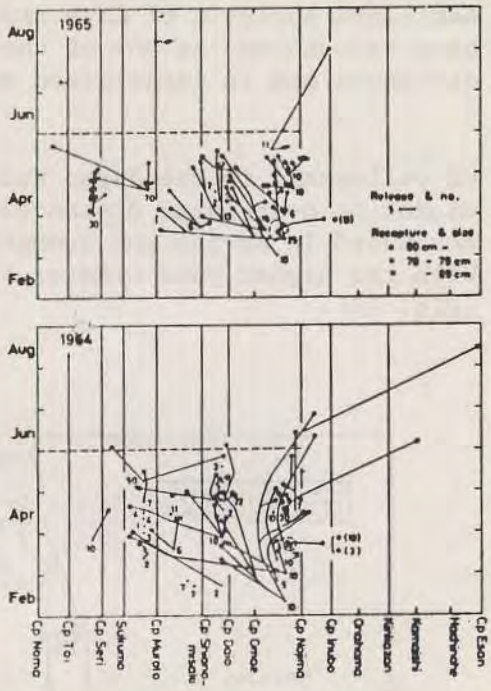


Fig. 17(B) Detailed graph of the movement of large sized fish released in Tokai-Nankai Region in spring season.

The number of recaptured fish is indicated in parentheses only for cases of more than one fish.
(after Tanaka, 1972)

The figures illustrated in this way indicate the following : 1) the large-sized fish (mostly adults) migrate southward in the Tohoku (north of Cape Nojima) and Tokai-Nankai (south of Cape Nojima) regions in the winter-spring season and migrate northward in the summer-autumn season; 2) the small-sized young fish show north-south migration within the Tohoku Region but present no evidence of movement within the Tokai-Nankai Region or between those two regions; 3) the southward migration of the large-sized fish in the Tokai-Nankai Region seemed to have occured about one month earlier in 1964 than 1965, suggesting a yearly variation in timing of migration.

According to the results of above-mentioned analysis of data from the tagging experiments, yellowtail has been recoganized as one of the fish species which migrate over great distances and in large-sized schools.

A recent study on tagging experiments of yellowtail in the Japan Sea, showed that there was a repeated seasonal migration over large distances (Watanabe, 1979). The fish migrated northward in spring and summer, and southward in autumn and winter. With the higher year classes the migrational range widened rapidly (Fig. 18).

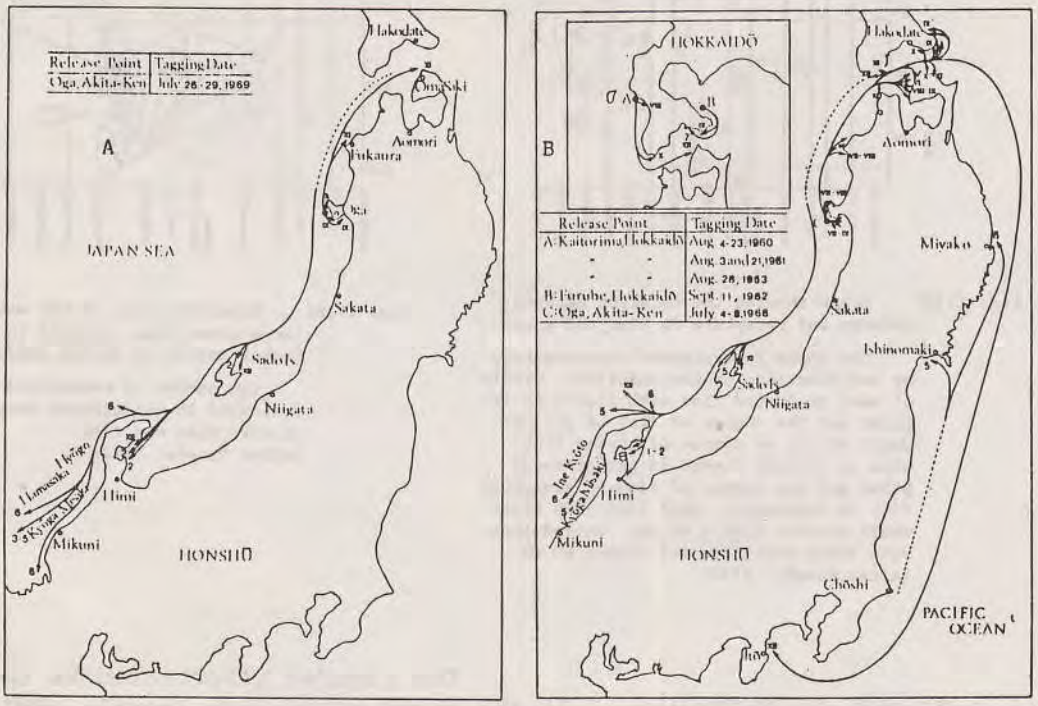


Fig. 18 Migration of tagged yellowtail (after Watanabe, 1979)

A: Two-year and three-year class of tagged yellowtail along the west coast of Oga, Japan.

B: Three-year class fish along Oga coast and four-year class fish along Hokkaido coast.

We can also calculate the speed of movement of tagged fish on the basis of reliable information about the distance and the number of days after release.

Furthermore, developing of a migration model and population dynamics of large-sized yellowtail in the Pacific Ocean along the Japanese coast inferred from tagging experiments, produced estimates of the fishing rate, transfer rate and the rate of disappearance of this fish (Tanaka, 1979).

If we wish to conduct experiments with juvenile (small-sized) fish, marking techniques with color stains (neutral red, brilliant and Nile blue sulphate etc.), or with chemical elements such as Europium[1] are also available. However, such techniques are complex, require supervision by highly skilled personnel and use of expensive equipment (such as the radioactive element tracer) and are therefore unsuitable for use in the Southeast Asian Region.

3.2 Shrimps

In a particular case of shrimp tagging experiments, Garcia and Le Reste (1981) pointed out the two main difficulties:

1) the small size of shrimps and their consequent frailty;

2) the moulting process. Any disturbance in this process can produce growth irregularities or increased mortality.

3.2.1 How to collect live specimens

In carring out this operation, the maximum precautions must be taken to avoid damaging the shrimps. Use of the trawl should preferably be avoided when possible, particularly in estuaries, where stake nets or traps are better. If trawling is unavoidable, it should be carried out in short hauls (10-15 minutes for example).

The procedure of holding the specimens in a floating pen for several days before tagging is nearly the same as for fish. However, the problems of maintenance of live shrimps may arise if the salinity of the surface-water in a floating pen is very different from that near the bottom of the sea, where shrimps live.

The temperature should also be monitored; it may sometimes be necessary to stop tagging during the hot hours of the day, especially in tropical regions.

---

1 This is a radioactive element which enters into the body of fish together with food.

3.2.2 Marking methods and equipment

In his paper entitled "a review of crustacean marking methods with particular reference to Penaeid shrimp", Farmer (1981) categorized the marking methods as follows:

1) Mutilation: Tail clipping, Eyestalk ablation

2) Vital staining (stains: neutral red, Trypan blue and Nile blue sulphate etc.) by: immersion, feeding, or injection

3) Spraying (granular fluorescent pigment: ultra-violet)

4) Tattooing (Vaseline-pigment: Staturn Yellow, Blaze Orange, Arc Yellow, Neon Red etc.)

5) Labelling (with radionuclides)

6) Tagging: a) external tags (Petersen disc tags, Atkins tags, anchor tags, tube tags, vinyl streamer tags, suture tags, carapace tags, sonic tags)

b) Internal tags (metal tags, PVC tags).

Each of the above methods was developed with a particular purpose in mind and, therefore, we should select the one which best suits our needs. In all cases, the use of an anaesthetic might be advisable to reduce activity of shrimps during marking.

Mutilation method by tail clipping is a simplified method of short-term marking of experimental shrimps. The mark is not easily detected during casual examination and therefore fishermen cannot be relied upon to report the recaptured specimens.

Intra-muscular injection of vital stains

For this marking method vital stains such as Trypan blue, Nile blue sulphate and fast green FCF are used.

The standard equipment consists of 0.5 or 1 cc tuberculin syringes with very small hypodermic needles. An automatic syringe is shown in Fig. 19.

Fig. 19 Automatic injection system (from Neal, 1969, FAO)

The filtered staining solution is injected laterally through the articular membrane, between the fifth and sixth (or third and forth) abdominal segment.

Shrimps of less than 60 mm in total length can be injected through the first abdominal segment (see Fig. 20-①)

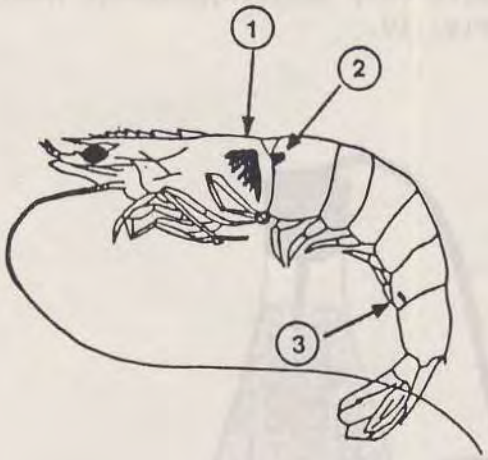


Fig. 20 Different types of internal marks: ① injected stain, ② internal vinyl tag, and ③ fluorescent dye. (after Garcia and Reste, 1981)

The stain injected into the vascular system through the dorsal abdominal artery settles in the gills where it can persist for several weeks[1]. The natural colouring of shrimp either before or after death must be considered in the choice of stains, as red, blue and green are part of the natural coloration of one or more species.

A drawback of this technique, however, is in the risk of rapid fading of the colour which can produce an artificial reduction in the recovery by fishermen.

---

[1] Garcia and Reste (1981) reported that shrimps carrying still visible marks have been recaptured after 6 months (Fast Green FCF) and 10 months (Trypan Blue).

Spraying by granular fluorescent pigment

A fluorescent pigment (dye), such as Ultra-violet can be used for marking. This can be accomplished as using a fluorescent product dissolved in paraffin oil (Klima, 1965). The dye has strong persistence (see Fig. 20-3) but requires the use of Ultra-violet light and the personal supervision by a scientist for detection. Therefore, it does not seem suitable for practical use in the Southeast Asian countries.

Tattooing by vaseline-pigment marks are also not easily detected by inexperienced, persons and therefore have to be used in conjunction with other marking methods if shrimps are to be returned by fisherman.

Labelling method using radionuclides

Requires close supervision by highly skilled personnel. This method is potentially dangerous to the environment and should not be used for shrimp population studies.

Vinyl streamer tag has been developed very recently by Marullo *et al.*, (1976) in conjuction with the Floy Tag and Manufacturing Inc., USA.

The tag is attached to a sewing needle and during tagging the needle is inserted through the articular membrane between the first and second abdominal segments. (Fig. 21)

Fig. 21 Modified design of streamer tag with the rounded end hooked through the eye of the needle (black vinyl) (A) and tag in position on shrimp (B) (after Farmer, 1981).

This streamer tag is light and flexible, therefore, shrimps can be tagged easily and rapidly. Several experiments have indicated that this type of tag used with large shrimp having a total length between 80 and 100 mm causes negligible mortality. And tagged individuals regain equilibrium and do not appear to have any difficulty in swimming or burrowing.

Petersen disc tag is available for shrimp, but this tag is not really suitable for smaller individuals or species of shrimp since it causes serious physical injury to the animal. Tagging mortality can be unacceptably high and tagging wounds may lead to subsequent infection.

Atkins tag (Fig. 22) consists of a nylon thread passing through the first abdominal segment of the shrimp from side to side tied in a loop and carrying a coloured and numbered plastic disc (Ruello, 1977).

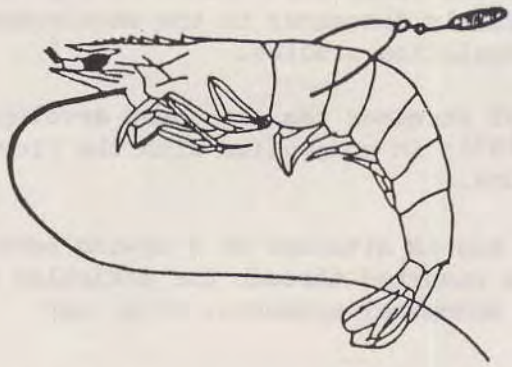


Fig. 22 Atkins tag attached to shrimp (after Garcia and Reste, 1981).

Tagging is carried out with the aid of a needle which has had a cut made in the side of the eye.

The main advantage of this type of Atkins tag is that there is no physical injury to the shrimp. However, some tags are probably lost during molting.

Anchor tags (Fig. 23) are generally applied by means of a tagging gun which results in severe injury to the abdominal musculature. As a result tagging mortality is high, particularly among smaller shrimps.

Fig. 23 Anchor tag (after Farmer, 1981)

It is probable that anchor tags affect the growth of the shrimps and in view of the high tagging mortality observed when using this method, the use of anchor tags should be discouraged. They may however be used in studying migration routes.

The choice of a tag is crucial to many aspects of tagging experiments for shrimps since they molt regularly and some tags are lost during molting.

In order to avoid the above-mentioned disadvantage, Rodriguez (1976) used rectangular brass tags for shrimps (Fig. 24) with the following precautions: 1) at the time of tagging, the spawner must not be soft-shelled or molting; 2) the actual tagging must be done at all times in the water. Raising the shrimp to the surface causes undue stress; 3) the spawner must be held firmly, but not so tightly as to cause undue pressure; 4) after tagging, keep the shrimps in fiberglass tanks for six hours for observation before stocking them in cages and pens.

Rodriguez concluded that the eyestalk tagging method was suitable for shrimps because a tag can be attached without causing injury and has no effect on the rate of growth, maturity, molting and other behavior of the shrimp. In addition, it is easily identifiable and remains in place throughout the animal's life.

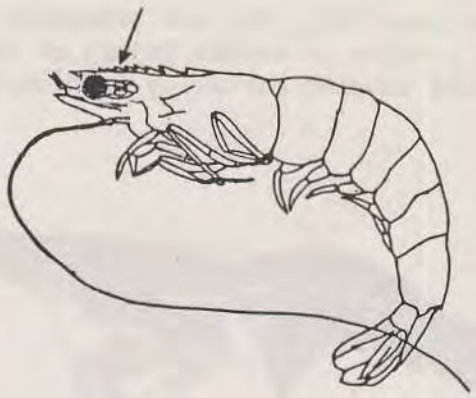


Fig. 24 A shrimp with tagged eyestalk (after Rodriguez, 1976). Brass tags measuring 5 x 20 mm and numbered consecutively encircle the eyestalk like a small bracelet.

No method of marking shrimp at present meets all the criteria of tagging experiments. It is therefore necessary to select one of the existing methods for each particular study. For this purpose the basic types of shrimp marking methods are listed in Table 6 together with details of their specific limitations.

From Table 6, it may be concluded that no one single marking method will be ideal for both juvenile and adult shrimp. The fluorescent pigment in petroleum jelly may be the most successful for small shrimp, whilst the Floy streamer tag and brass tag may be more suitable for large shrimp. It is unfortunate that flurescent pigment marking is unlikely to be detected by fishermen and therefore sampling of juvenile shrimp on the nursery grounds will have to be conducted using trained fisheries staff. Brass tags may have the same problem. This contrasts with the more than adequate returns of Floy streamer tags on adult shrimps from fishermen.

In view of the results of these tag evaluation studies it is considered that the selection of a tag type for a particular experiment should depend largely on the size of shrimp to be tagged. For small shrimp ranging from 15 to 30 mm carapace length, the Atkins tag has been shown to be effective (Ruello, 1970, 1975, 1977). However, for tagging larger mature shrimp (over 30 mm in carapace length) which are not easily restrained without causing injuries through crushing, the faster applied toggle, streamer, or even Petersen disc tags are generally considered more useful (Penn, 1981).

Table 6 Summary of the basic crustacean marking methods together with details of their specific limitations and suitability for Penaeid shrimp (after Farmer, 1981).

Group	Type	Ideal size of shrimp	Speed of marking	Marking mortality	Effect on predation	Effect on growth	Method of detection	Permanence	Remarks
Mutilation	Tail clipping	Any size	Slow	Negligible	Nil	Nil	Trained staff	Poor	Gradually lost by regeneration
	Eye stalk ablation	Large	Slow	Significant	Nil	?	Trained staff	Good	-
Vital staining	Immersion	Any size	Fast	Nil if correct stain is used	Nil	Nil	Trained staff	Fades rapidly	-
	Feeding	Any size	Fast	Nil if correct stain is used	Nil	Nil	Trained staff	Fades rapidly	-
	Injection	Medium	Slow	Low	Nil	Nil	Trained staff	Fades rapidly	-
Spraying	-	Any size	Fast	Nil	Nil	Nil	UV light source	Poor	Gradually lost through moulting
Tattooing	-	Medium-large	Slow	Nil	Nil	Nil	Trained staff	Good	-
Labelling (radionuclides)	-	Any size	Fast	Nil	Nil	Nil	Gamma ray detection equipment	Poor	-
External tags	Petersen disc	Large	Slow	High	?	?	Fishermen	Good	-
	Atkins tag	Medium-large	Slow	Significant	?	?	Fishermen	-	-
	Anchor tag	Large	Slow	High	?	?	Fishermen	-	-
	Tube tag	Medium-large	Slow	Significant	?	?	Fishermen	-	-
	Streamer tag	Medium-large	Slow	High	?	?	Fishermen	-	-
	Brass tag	Medium-large	Slow	Negligible	?	Nil	Fishermen	Good	-
	Sonic tag	-	-	-	-	-	-	-	Not suitable
	Metal tag	Small-large	Slow	Negligible	Nil	Nil	Trained staff	Good	Used in conjunction with staining
Internal tags	PVC tag	small-large	Slow	Negligible	Nil	Nil	Trained staff	Good	Used in conjunction with staining

3.2.3 Releasing the tagged shrimp

This is one of the delicate steps in a shrimp tagging operation, because predation during the release can be an important cause of additional mortality. They should be released very near the bottom. For the actual return to the water, for example, a special cage may be useful which opens at the bottom by a "messenger" released from the surface, or an inexpensive plastic container (Fig. 25) which opens simply by pulling a rope (Garcia, 1973).

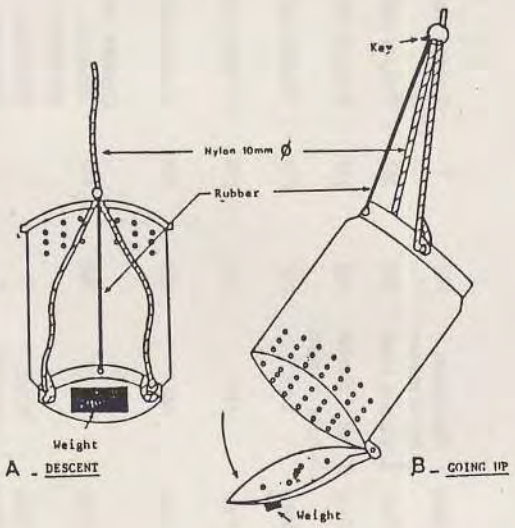


Fig. 25 Simple system for releasing shrimps at the bottom in shallow waters. The cage descends freely, a pull on the nylon rope opens it when the bottom is reached (from Garcia, 1973).

In a decision on the release area, physical and chemical factors (temperature, salinity, dissolved exygen, turbulence, etc.) must be considered very carefully, because these factors may affect substantial numbers of released shrimp if they fluctuate beyond the tolerance limits of the shrimp.

3.2.4 Noteworthy points for data analyses

Since the recovery of tags depends on reports by fishermen, such preliminary activities as dissemination of information through posters indicating clearly the type of mark used, its position, the return address and the reward offered are vitally important. Even when a successful recapture is obtained, there are still a number of factors that can influence estimates made from mark-recapture data.

3.2.4.1 Biases

Under practical considerations, Ricker (1958) reported three kinds of biases which he referred to as Type A, B and C biases (reviewed from Jones, 1981, Garcia and Reste, 1981).

Ricker's type A bias

When dealing with a single tagging experiment by the regression method, type A bias will tend to influence the intercept of the regression line but not necessarily its slope (Fig. 26-A). In this situation the slope of the regression is valid but the intercept tends to be too small. There are two main causes of this kind of error. First, if there is any mortality at the time of tagging then the number of effectively liberated shrimps will be smaller than expected. The result is that the number of live tagged shrimp is reduced proportionately throughout the whole of their life span. The effect is to reduce the intercept without necessarily affecting the slope of the regression. Secondly, if there is incomplete reporting of tags then a similar effect will be produced. If, as a first approximation, it is assumed that during any recapture period a fixed proportion of the tags are reported, the effect will influence the intercept but not necessarily the slope of the regression line.

Because type A error influences the intercept, its effect is to bias estimates of the fishing mortality rate (F). If the initial mortality or the degree of incomplete reporting of tags can be allowed for independently, it should be possible to apply a correction factor to allow for this kind of error.

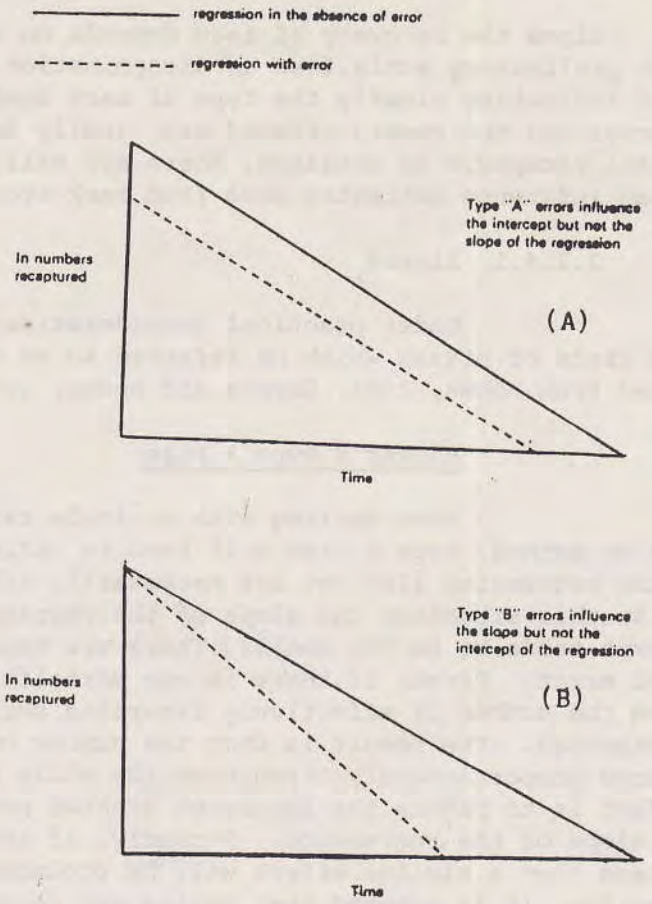


Fig. 26 A : Ricker's type A bias; B: Ricker's type B bias (from Jones, 1981).

Ricker's type B bias

This includes those which influence the slope of the regression line but not necessarily the intercept (Fig. 26-B). There are two cases of this kind of error : 1) type B error occurs if the mortality rate of tagged shrimp, subsequent to the moment of tagging, is greater than that of untagged shrimp for the remainder of their lives. If this occurs, estimates of the total mortality rate will tend to be overestimated by all methods, 2) this error also occurs if there are both a continuous loss of tags from tagged individuals and a continuous migration out of the fishing areas throughout the whole of the experiment. In both situations the slope of the regression will tend to be too great but the intercepts need not necessarily be influenced.

With type B error the estimate of total mortality rate (Z) will be biased but the estimate of F need not necessarily be invalid. Those errors, however, are difficult to detect and even more to quantify and correct. It is for this reason that tagging generally is considered to allow a value for Z to be obtained which can be broken down into F + X where X represents a "composite" mortality integrating tag losses, migration, tagging mortality and natural mortality M (Table 7). In addition, the combination of F values found by tagging with the Z value found, for example, by analysis of the age distributions allows a better value for M to be determined (Garcia and Reste, 1981).

Table 7. Weekly instantaneous mortality rates for *P. plebejus* in Moreton Bay from Lucas (1974), Somers (pers. comm.), and for *P. latisulcatus* in Cockburn Sound, from Penn (1976).

	Z	F	M	X	
Lucas (1974)					*P. plebejus*
inshore	0.448	0.056	-	0.392	13% recaptured
	0.447[a]	0.067[a]	-	0.380[a]	
offshore	0.165	0.032	0.133	-	21% recaptured
	0.172[a]	0.043[a]	0.129[a]	-	
Somers (pers. comm.)					*P. plebejus*
inshore					
Petersen disc	0.55	0.10	-	0.45	18% recaptured
vinyl streamer	0.54	0.11	-	0.43	21% recaptured
Penn (1976)					*P. latisulcatus*
Period:					
August-September	0.042[b]	0.009[b]	0.033[b]	-	6% recaptured
September-October	0.027[b]	0.012[b]	0.015[b]	-	6% recaptured
October-November	-	0.013[b]	-	-	4% recaptured

[a] Allowing for an initial tag loss of 25%

[b] Allowing for an initial tag loss of 20 %

Ricker's type C bias

This affects both Z and F. In this group are included those biases that make recaptures unusable in the initial period, and those arising from the difference in vulnerability between marked and unmarked shrimps because of : 1) modification in behaviour of tagged shrimps caused by the tags which affect the catchability at the beginning of the recapture period , and 2) differential distribution of tagged and untagged shrimps associated with a non-random distribution of fishing effort in the first time intervals.

The first type of error is of little importance when many tagged shrimps are still caught after a single or several biased intervals.

The problem of the differential distribution of tagged and untagged individuals is extremely important and tagging must be carefully planned to avoid this difficulty. The simplest way is to grid the whole distribution area and to tag each station, or if they are too numerous, a constant proportion of them.

The recapture rate is somewhat proportional to the size of tagged shrimps and many authors have noted that the percentage of recapture is less in small-sized shrimps (Fig. 27)

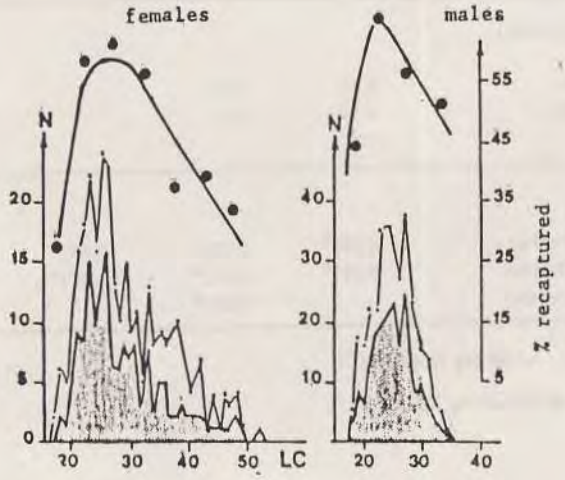


Fig. 27. Recapture rate as a function of size during the first month following the tagging (from Garcia, 1975).
unshaded = tagged shaded = recaptured

3.2.4.2 Growth

Considering the difficulty of analyzing size distribution of shrimps, tagging seems to be a fundamental technique for analyzing growth and its seasonal variations, in spite of the technical difficulty of tagging operation for shrimp and its effect on metabolism (molting etc.). Since growth is closely related to environmental conditions, it is extremely important to determine the concomitant hydroclimatic conditions to make it possible to compare results from one region with another.

To use Von Bertalanffy equation, which is originally expressed in length, it should be converted to an equation expressed in weight in the following way:

$$W_t = W_\infty (1 - e^{-k(t-t_o)})^n$$

The use of this type of curve means that growth is treated as a continuous function. Because of molting it would be more advisable to use stepwise function, especially in tropical regions where short-term stepwise molting occurs. It would therefore be very fruitful to demonstrate the bias resulting from the use of the Von Bertalanffy curve by comparison with a stepwise simulated growth model. The estimates of growth parameters based on the landings of commercially graded size categories of shrimp should also be employed.

3.2.4.3 Mortality

Although mortality due to the tagging operation and to the presence of a tag is the greatest problem of this research technique, such mortality is very difficult to demonstrate clearly, and even more to quantify, because the numbers tagged are always ridiculously small compared to the large numbers in the population.

It is obvious that such mortality depends on the conditions prevailing during the tagging operation. It would therefore be very fruitful during tagging experiments to also attemp to identify possible bias by indirect method: comparison of results obtained with different batches, for different sexes and in different seasons with several types of tags (see Table 7).

For the analysis of the data, it is probable that the recaptures obtained beyond the first 30 days after tagging will give the least biased result, for mortality as well as for the growth estimations.

On of the ways to solve the above-mentioned difficulties in analyzing mortality may be the method of combination of tagging, catch and effort data, proposed by Ketchen (1953) (Fig. 28).

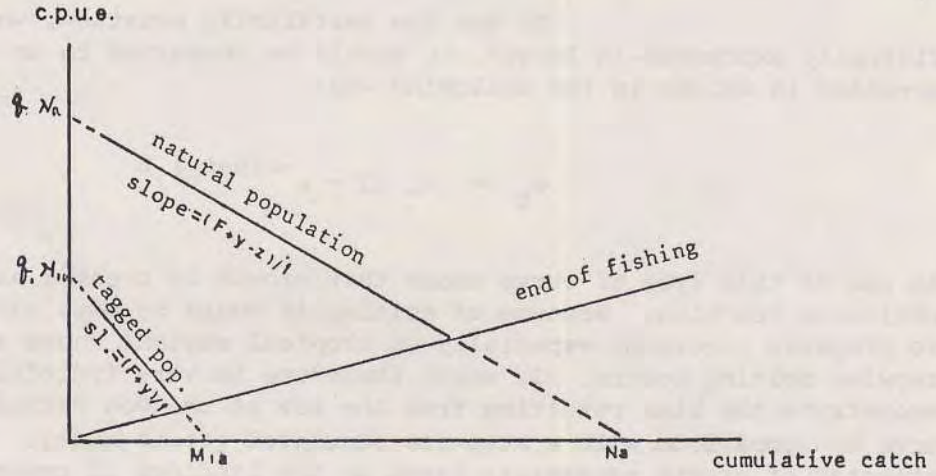


Fig. 28 Principles of the Ketchen's method (from Ricker, 1975).

F : fishing mortality

y : rate of emigration

z : rate of immigration

f : fishing effort

M_{1a} : number of initially tagged individuals

N_a : initial natural population

q : catchability coefficient (equivalent of slope)

3.3 Cephalopods

The cephalopod resources includes the following three groups: octopus, squids and cuttlefishes.

As regards the Southeast Asian fishery resources, however, squids (*Loligo* spp.) and cuttlefishes (*Sepia* spp.) are quite important commercially because they are predominantly shallow water (neritic) animals living between the shore and the edge of the continental shelf and upper slope in the Gulf, where it is assumed that there are good fishing grounds.

In the case of squids and cuttlefishes, tagging technique itself is not as difficult as for shrimps, and it is quite easy to obtain live specimens.

3.3.1 Method of collecting live specimens

Although in Thailand the best catch is obtained by trawls (Table 8), to minimize damage to specimens, the use of trawl should be avoided. Angling (automatic machine fishing) is now the most common method in Japan. However, this gear is not as popular as the cast-net or the stake trap in Thailand, therefore a modified stick-held dip-net (cast-net style) seems to be the most suitable gear for collecting large numbers of specimens. Even with this gear it is necessary to take great care to avoid damaging the squids.

Table 8. Catch by type of fishing method in Thailand (in metric tons) (after Voss, 1973).

Species	Year	Total	Otter trawl	Pair trawl	Cast-net	Stake trap	Other methods
Squid	1969	20 818	7 934	11 174	948	379	383
	1970	21 435	10 157	7 718	1 056	2 398	106
	1971	23 259	13 350	8 149	632	608	520
Cuttlefish	1969	10 415	6 851	3 366	35	55	108
	1970	11 326	8 246	3 033	-	-	47
	1971	13 232	9 161	3 809	31	-	231

The procedure of holding the specimens in a floating pen for several days before tagging is nearly the same as in the case of fish.

3.3.2 Tagging equipment and the method of attaching tags

Squids can be tagged by attaching external tags to the mantle. Park and Lim (1976) for example, used an arrow tag (strapped type) for the oceanic squid tagging (Fig. 29).

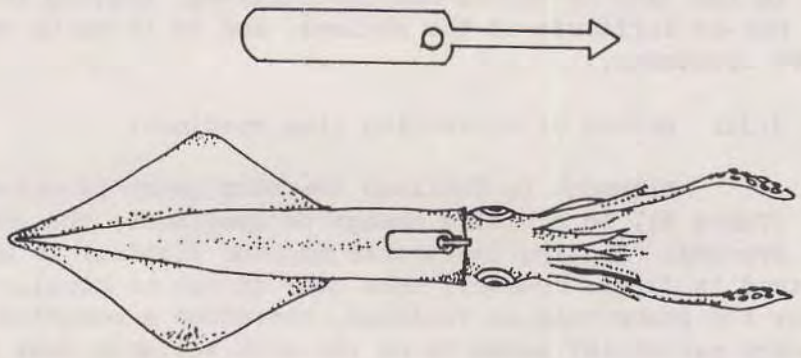


Fig. 29 Arrow tag for squid and tag in position (redrawn from Park and Lim, 1967).

In tagging experiments for the common squid *Todarodes pacificus* in the seas around Japan, anchor tags, Atkins tags and strap tags have been used commonly (Fig. 30).

When attaching a tag, maximum precautions must be taken to avoid the secondary effect of tagging as well as the loss of tag. A tag in position, for example, is one of the serious factors affecting the swimming abilities of squids. It is true that when the tag is not well placed there is a perceptible imbalance in the swimming movements.

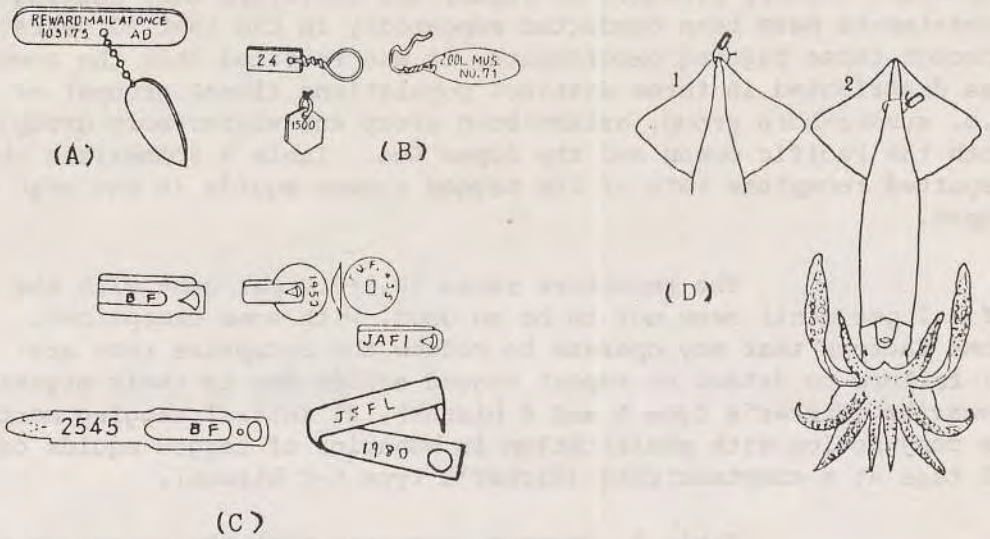


Fig. 30 Anchor tag (A), Atkins tags (B) and strap tags (C) for squids, and Atkins tags in position on the common squid, *Todarodes pacificus* (D).

From this viewpoint, it is advisable to place the tag in the latter dorsal edge of the mantle part (see Fig. 30-D), especially in small-sized specimens.

3.3.3 Release

The process of releasing the tagged squids is not as delicate as in the case of shrimps, but they should be released near a cape or in the open sea near a small island, because of their largely migratory behavior.

The sample size of released specimens varies depending on the purpose of experiment, but usually 1,000-3,000 tagged squid are used in an experiment.

3.3.4 Recapture

The common squid, *Todarodes pacificus*, is a very important fishery resource in Japan, and therefore many tagging experiments have been conducted repeatedly in the last 30 years. Through those tagging experiments, it was revealed that the common squid was distributed in three distinct populations (local groups) or "stocks", i.e. summer-born group, autumn-born group and winter-born group, in both the Pacific Ocean and the Japan Sea. Table 9 summarizes the reported recapture rate of the tagged common squids in the seas around Japan.

The recapture rates (0.5-7.0 per cent with the average of 2.2 per cent) seem not to be so good, with some exceptions. Some factors that may operate to reduce the recapture rate are: 1) failure to detect or report tagged squids due to their migratory behavior (Ricker's type A and B biases), 2) initial tagging mortality in conjunction with modification in behavior of tagged squids or loss of tags at a constant rate (Ricker's type A-C biases).

Table 9, however, suggests that the recapture rate may be enhanced by using yellow/red colored anchor tags or strap tags.

Table 9 Some examples of recapture rate of the tagged common squid in the seas around Japan.

	Year	Area	No. released	Recapture rate(%)	Type of tag	Data source
Japan Sea	1952-1957	Hokkaido	38,300	7.03	Atkins	Aratani *et al.* (1958)
	1967-1969	Hokkaido	14,500	0.65		Yasui *et al.* (1972)
	1950-1957	Whole area	32,700	1.11		Aratani *et al.* (1958)
	1950-1960	Southwest	17,300	2.90	Strap	Hamabe (1965)
	1965-1969	Northern part	7,300	0.81		Yasui *et al.* (1972)
	1966-1969	Offshore	61,200	0.45	Strap Anchor	Kasahara & Ito (1972)
	1979	Offshore	19,300	4.87	Anchor (yellow, red)	Machinaka *et al.* (1980)
Pacific Ocean	1968	Tsugaru	2,300	3.35		Yasui *et al.* (1972)
	1950-1970	Aomori	30,700	1.08	Atkins	Yasui *et al.* (1972)
	1956-1969	Iwate	27,300	3.21		Yasui *et al.* (1972)
	1970	Tohoku	1,300	1.00	Strap Anchor	Yasui *et al.* (1972)
	1968	Kanto	985	0.51		Yasui *et al.* (1972)
	1970	Kusimoto	766	4.96	Strap (yellow)	Toyama *et al.* (1972)
		Muroto	944	2.22	Strap (white)	Toyama *et al.* (1972)

Figure 31 shows an example of squid tagging with details of elapsed time between release and recapture. This experiment was conducted in the Japan Sea from May to October 1979.

This figure suggests: 1) the number of recaptured squid is the largest within the first ten days after release (36.5%) and decreases almost exponentially as the days elapsed increase, 2) the recapture which is concentrated in a short-term period means that the squid population has a tendency to stay rather a long time in the areas around the releasing site.

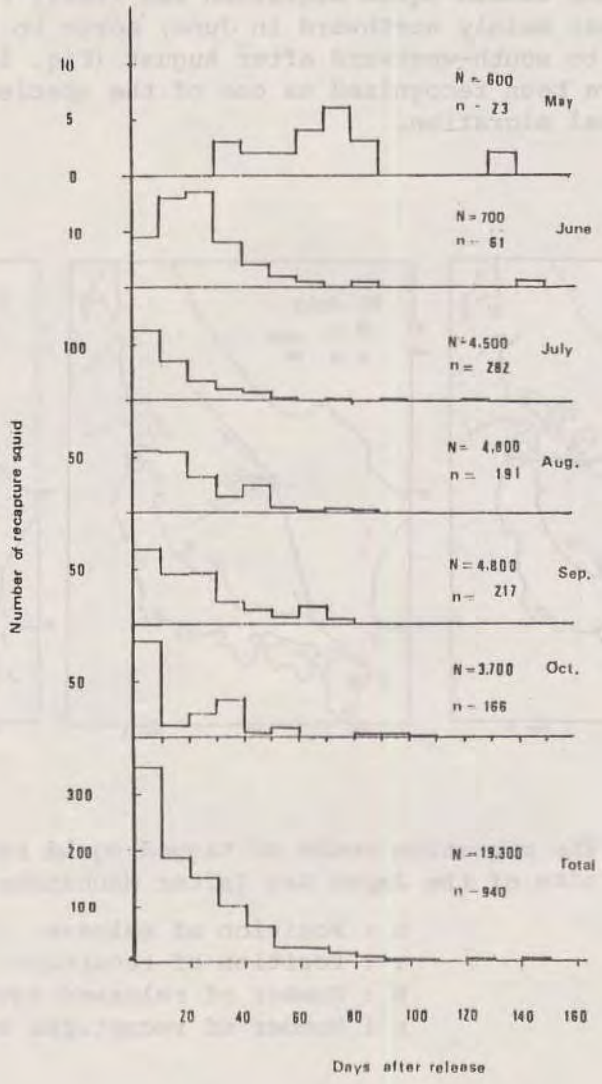


Fig. 31 Days elapsed from tagging to recapture and number of recaptured squid in the Japan Sea, from May to October 1979 (after Machinaka *et al.*, 1980).

N : Number of released squid
n : Number of recaptured squid

3.3.5 Data analysis

3.3.5.1 Distribution and migration

Tagging is a basic method for analyzing distribution and seasonal migration of squid population, in spite of rather low recapture rates.

By connecting the release point to the recapture point with a straight line, it was revealed that the possible direction of the common squid migration was likely to change with the seasons. It was mainly northward in June, north to south-eastward in July and west to south-westward after August (Fig. 32-A, B, C). Thus the squids have been recognized as one of the species which has a regular seasonal migration.

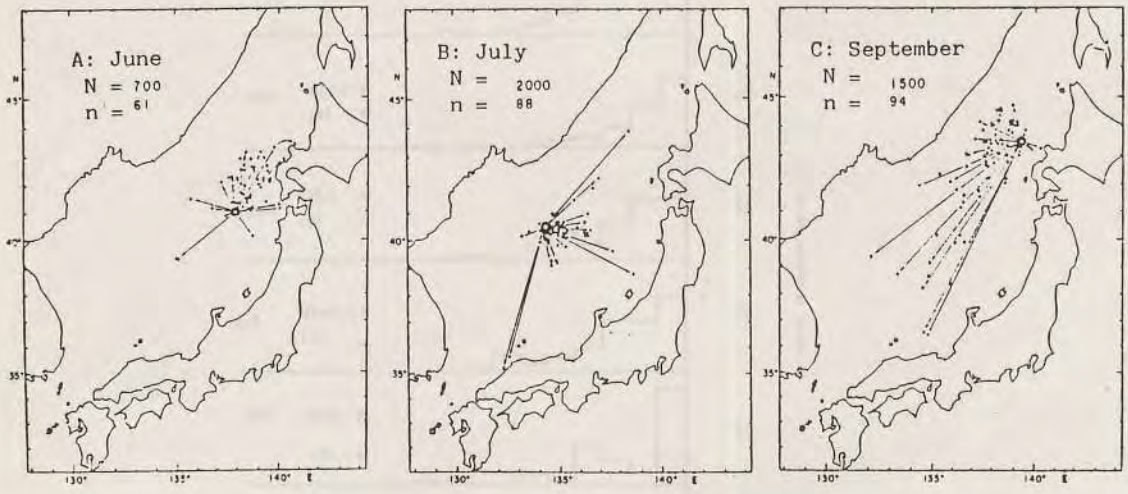


Fig. 32 The migration route of tagged squid released in each site of the Japan Sea (after Machinaka *et al.*, 1980).

o : Position of release
. : Position of recapture
N : Number of released squid
n : Number of recaptured squid

3.3.5.2 Some parameters in the dynamics of squid population

If sufficient data are available from the tagging experiments, we can estimate some parameters in the dynamics of squid population.

For example, based on the results of squid tagging experiments, Machinaka *et al.*, (1980) carried out estimates for Z, F, M and E values by using the methods proposed by Beverton and Holt (1954) and Tanaka (1966) (Fig. 33, Table 10). These can be summarized as follows: 1) both methods provided nearly the same values for the parameters such as the total mortality coefficient (Z), fishing mortality coefficient (F), mortality coefficient other than fishing (M); 2) according to Tanaka's method applied to the total of released squids, Z was estimated to be 0.443/10 days, F was 0.021/10 days, and M was 0.422/10 days, respectively.

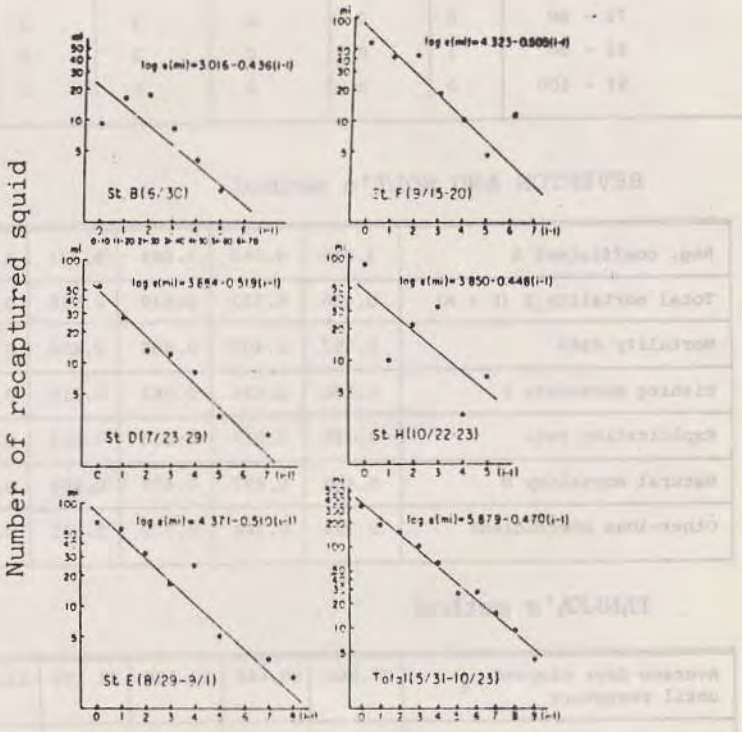


Fig. 33 Relationship between the days elapsed until recapture (i - 1) and the number of recaptured squid (m_i) in the tagging experiments in the Japan Sea, in 1979 (after Machinaka *et al.*, 1980).

Table 10 Results of estimated parameters in the dynamics of squid population (after Machinaka *et al.*, 1980).

These estimations were applied to the methods of Beverton and Holt (1954), and Tanaka (1966).

ST. No.		B	C	D	E	F	G	H	Total
Date of release		6.30	7.13-20	7.23 . 29	8.29-9.1	9.15-20	9.22 . 23	10.22 . 23	5.31-10.23
No.of released squid		700	3,020	1,480	5,500	2,800	1,500	3,700	19,300
No.of recaptured squid		58	151	121	201	183	23	164	921
Days elapsed	0 - 10	9	73	54	64	56	2	85	343
	11 - 20	16	33	27	54	41	3	10	184
	21 - 30	17	21	13	32	42	3	22	150
	31 - 40	8	9	12	16	18	2	33	101
	41 - 50	4	8	8	24	10	3	3	62
	51 - 60	2	2	3	5	4	1	7	26
	61 - 70	1	5	0	1	11	5	0	27
	71 - 80	0	0	2	3	1	3	0	15
	81 - 90	1	0	0	2	0	1	2	9
	91 - 100	0	0	2	0	0	0	2	4

BEVERTON AND HOLT's method

Reg. coefficient A	3.016	4.053	3.884	4.371	4.323	0.984	3.850	5.879
Total mortality Z (F + M)	0.436	0.522	0.519	0.510	0.505	0.041	0.448	0.470
Mortality rate	0.353	0.407	0.405	0.400	0.396	0.040	0.361	0.375
Fishing mortality F	0.036	0.024	0.042	0.018	0.034	0.002	0.016	0.023
Exploitation rate	0.029	0.019	0.033	0.014	0.027	0.002	0.013	0.019
Natural mortality M	0.400	0.497	0.477	0.492	0.470	0.039	0.433	0.447
Other-loss coefficient	0.324	0.388	0.372	0.385	0.369	0.038	0.349	0.356

TANAKA's method

Average days elapsed until recapture $\bar{t}$	27.966	16.669	20.180	22.159	22.590	45.391	19.673	22.575
Total mortality $Z\ (F + M) = (1/\bar{t}) \times 10$	0.358	0.600	0.496	0.451	0.443	0.220	0.508	0.443
Fishing mortality $F = (m/So) \times (F + M)$	0.030	0.030	0.041	0.016	0.029	0.003	0.023	0.021
Natural mortality $M = (F + M) - F$	0.327	0.570	0.455	0.435	0.414	0.217	0.486	0.422
Exploitation rate $E = F/(F + M)$	0.084	0.050	0.082	0.037	0.065	0.015	0.045	0.048

Values of parameters Z, F, M and E were calculated in 10 days intervals. Natural mortality coefficient M involves all other factors except F.

The obtained values seem reasonable, however, M is supposed to be too large while F is too small, in view of the present state of the squid fisheries along with the size of the specimens considered. Therefore, further work is needed, in order to give more acceptable values for these parameters.

4. CONCLUSION

A tagging experiment should always be designed with a specific objective in mind. If the objective is to investigate large-scale migration such as in the cases of large-sized mackerel, yellowtail, tuna and squid, it is important that the method of recovery is one likely to provide reliable information on the position. A good choice would be an attractively colored external tag, easily detected at the time of recapture.

For investigating mortality there are two liberation procedures:

i) All the tagged fish should be released together at the same time. It is also important to know when each fish is recovered;

ii) An alternative procedure is to release tagged individuals in groups at fixed intervals. For example, if groups of tagged animals are released at annual intervals, it may be sufficient to know in which year a fish is recaptured.

Both methods require records of the fishing effort on the recaptures in each period, preferably broken down by areas.

A number of factors can bias mortality estimates based on tagging experiments. In particular, there is likely to be some additional mortality of tagged fish, either initially or subsequently, due to the presence of the tag on the fish. Loss of tags, non-reporting of tags, emigration of tagged individuals away from the recapture area, can also bias the results. These factors all lead to overestimates of the mortality rate of the untagged individuals.

For estimating population size, it is important that the distribution of tagged and untagged individuals be the same. If tagged individuals are liberated together, they should be given time to disperse and mix with the whole untagged population before taking account of any recaptures. In a situation where the recovery of tags depends on reporting by fishermen, however, it may be better to liberate the fish in small batches over the whole area occupied by the untagged population.

5. REFERENCES

Beverton, R.J.H. and S.J. Holt, (1954). On the Dynamics of Exploited Fish Populations. Fish. Invest. Minist. Agric. Fish. Food G.B., Series II, Vol.19: 533 pp.

Beverton, R.J.H. (1963). In "North Atlantic Fish Marking Symposium". Spec. Publ. ICNAF, (4): 5-6.

Beverton, R.J.H. and B.C. Bedford, (1963). On the Effect of "Holding: Tagged Fish for various periods before Release. Spec. Publ. ICNAF, (4): 348-358.

Chullasorn, S. (1984). Review of the mackerels fishery (Rastrelliger spp.) in the west coast of Thailand (unpublished)

Conand, C. (1983). Methods of Studying Growth in Holothurian. (Beche-de-Mer), and Preliminary Results from a Beche-de-Mer Tagging Experiment in New Caledonia. South Pacific Commisson, Fish. Newsletter No.26, July-September 1983: 31-38.

Farmer, A.S.D. (1981). A review of Crustacean marking methods with particular reference to Penaeid shrimp. Kuwait Bulletin of Marine Science 1981, (2): 167-183.

Garcia, S., P. Petit and A. Fonteneau. (1972). Biologie de Penaeus duorarum en Côte d'Ivoire. Partie 3. Etude des variations quotidiennes des rendements et de leur relation avec Hydroclimat. Essai de generalisation au Golfe de Guinée. Doc. Sci. Cent. Rech. Oceanogr. Abidjan ORSTOM, 4(2): 71-104

Garcia, S. and L. Le Reste, (1981). Life Cycles, Dynamics, Exploitation and Management of Coastal Penaeid Shrimp Stocks. FAO Fisheries Technical paper No.203, 215 pp.

Hartt, A.C. (1963). Problems in Tagging Salmon at Sea. Spec. Publ. ICNAF, (4): 144-155.

Jakobsson, J. (1970). On Fish Tags and Tagging. Oceanogr. Mar. Biol., 8: 457-499.

Jones, R. (1979). Materials and Methods used in Marking Experiments in Fishery Research. FAO Fisheries Technical Paper No.190, 134 pp.

Jones, R. (1981). Mathematical methods for use with mark-recapture studies. Kuwait Bulletin of Marine Science 1981, (2): 249-263.

Jones, R. and N.P. van Zalinge, (1981). Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bulletin of Marine Science 1981, (2): 273-288.

Ketchen, K.S. (1953). The use of catch effort and tagging data in estimating a flatfish population. J. Fish. Res. Board Can. 10(8): 459-485.

Klima, E.F. (1965). Evaluation of Biological Stains, inks and fluorescent pigments as marks for shrimp. Spec. Sci. Rep. USFWS (Fish.), 511: 8 pp.

Kotthaus, A. (1963). Tagging experiments with the North Sea sole (Solea solea) in 1959 and 1960. Spec. Publ. ICNAF, (4): 123-129.

Kurogane, K. (1963). On the Tagging Experiments for Fisheries Research in Japan. Bull. Japan Soc. Sci. Fish., 29(5): 482-496.

Lindner, M.J. and W.W. Anderson, (1956). Growth, Migration, Spawning and Size Distribution of Shrimp, Penaeus setiferus. Fish. Bull. U.S. Fish Wildl. Serv., 56(106): 553-645.

Machinaka, S., M. Miyashita, H. Miyajima and S. Kasahara, (1980). Tagging experiments for the common squid (Todarodes pacificus) in the off-shore areas of the Japan Sea with estimation of parameters in dynamics of squid population. Bull. Ishikawa Pref. Fish. Exp. Station, (3): 37-52.

Marullo, F., (1976). A vinyl streamer tag for shrimp (Penaeus spp.) Trans. Am. Fish. Soc., 105(6): 658-663.

Nakai, Z. and S. Hattori, (1952). Tokaiku Tohokukaiku Iwashi Shigen Chosa Seiseki Yoho (Prelim. Rept. Iwashi Resce Survey, Pacific Coast), 1951, Tokai RFR Lab.

Neal, R.A. (1969). Methods of Marking Shrimp. FAO Fish. Rep., (57): Vol. 3: 1149-1165.

Okada, K. (1966). On the Distribution and Movement of the Sea Bream in the Yellow Sea Ascertained by Tagging Experiments in 1964. Bull. Japan. Soc. Sci. Fish., 32(9): 679-704.

Park, J.S. and J.Y. Lim, (1967). On the Results of the Tagging Experiments on Squids in the Korean Waters. Rep. Fish. Resour. Busan, (7): 29-40.

Penn, J.W. (1981). A review of mark-recapture and recruitment studies on Australian Penaeid Shrimp. Kuwait Bulletin of Marine Science 1981, (2): 227-247.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish population. Bull. Fish. Res. Board Can., 191: 382 pp.

Rodriquez, L.M. (1976). A Simple Method of Tagging Prawns. Natur. Appl. Sci. Bull., 28: 303-308.

Rounsefell, G.A. and J.K. Kask, (1943). How to mark fish. Trans Amer. Fish. Soc., 73: 320-363.

Ruello, N.V. (1977). Migration and stock studies on the Australian school prawn, Metapenaeus macleayi. Mar. Biol., 41: 185-190.

Sandeman, E.J. and E.I.S. Rees, (1963). Some Notes on the Tagging of Redfish, Sehastes marinus (L.) from Deep water. Spec. Publ. ICNAF, (4): 300-305.

Somjaiwong, D., S. Chullasorn and S. Supongpun, (1970). Progress Report of the Tagging of Indo-Pacific Mackerel (Rastrelliger neglectus Van Kampen). 1967 - Rearing Experiments. A paper submitted to the 1st Symposium on Marine Fisheries organized by Mar. Fish. Lab., Bangkok, 23 pp.

Somjaiwong, D. and S. Chullasorn, (1974). Tagging Experiment on the Indo-Pacific Mackerel Rastrelliger neglectus (Van Kampen) in the Gulf of Thailand (1960-1965). Proc. IPFC, 15(3): 287-96.

Somjaiwong, D. (1980). Tagging Experiments in Chub Mackerel (R. neglectus) in the Gulf of Thailand. Contribution Paper No.13, Marine Fish. Div., 57 pp.

Takagi, K. (1972). Migration of the Tagged Spiny Lobster, Panulirus japonicus, on the Southern Boso Peninsula, Chiba prefecture: A continuous Experiment, 1951- 1968. Extrait de La mer. Tome 10, N°3 pp. 95 a 112.

Tanaka, S. (1966). In "Mojako saiho no buri shigeon ni oyobosu eikyo ni kansuru kenkyu (in Japanese)". Bull. Tokai Reg. Fish. Res. Lab. : 99 pp.

Tanaka, S. (1972). Migration of Yellowtails along the Pacific Coast of Japan Observed by Tagging Experiments-I. Results from Release and Recapture Data. Bull. Japan. Soc. Sci. Fish., 38(1): 29-32.

Tanaka, S. (1975). Migration of Yellowtails along the Pacific Coast of Japan Observed by Tagging Experiments-IV: Movement in and around the Sagami Bay. Bull. Japan. Soc. Fish., 41(4): 423-427.

Tanaka, S. (1979). Migration Model and Population Dynamics of Large-sized Yellowtails in the Pacific Ocean along the Japanese Coast Inferred from Tagging Experiments-I. Bull. Japan. Soc. Sci. Fish., 45(3): 297-303.

Thomson, J.M. (1963). The Tagging and Marking of Marine Animals in Australia. Spec. Publ. ICNAF, (4): 50-58.

Usami, S and Y. Matsushita, (1974). The Movements of the Pacific Subpopulation Adult Mackerel: Characteristics of Their Movements as Viewed from Tagging Experiments during 1950-1968. Bull. Japan. Soc. Sci. Fish., 40(11): 1083-1097.

Voss, G.L. (1973). Cephalopod Resources of the World. FAO Fisheries Circular. No.149, 75 pp.

Watanabe, K. (1979). Distribution and Migration of Yellowtail in the Tsushima Warm Current Waters based on Recapture of Fish Tagged in Spring and Summer. Bull. Jap. Sea. Reg. Fish. Res. Lab, (30): 131-164.

Yonemori, T., J. Uktolseja and G.S. Merta, (1984). Progress report on tuna tagging in eastern Indonesian waters. A paper submitted to the fourth Session of SCORRAD, 23-29 August 1984, Jakarta, Indonesia.