MARKING FISH AND INVERTEBRATES

UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF COMMERCIAL FISHERIES

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ABSTRACT

Reasons for marking fish and invertebrates are explained. The use and characteristics of various types of marks are discussed. The more successful tags in current use are illustrated, and the attributes of each explained, including methods of attachment and recovery, and how to select the most suitable mark for a specific species or experiment.

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WHY FISH ARE MARKED

Fish are marked and released for a variety of reasons. Of course, the primary reason for marking is the need for distinguishing single individuals or a small group of individuals from the remainder of the population so that when they are recaptured, biologists may arrive at certain inferences concerning them.

There are instances in which a group of fish may bear a natural mark by which they can be distinguished from other fish of the same stock. Thus, the very abundant 1904 year class of Norwegian herring was distinguished by an extra large initial growth band on its scales. Similarly, salmon sometimes have scales with characteristic growth bands that serve to distinguish fish of the same species, even from different tributaries of the same river. The difference in the species of their parasites, or in the degree they are parasitized, has also been used to distinguish fish of the same species but of different origin.

However, occurrence of natural marks is too uncertain, and the marks are usually too difficult of interpretation to serve in more than a few special cases. Therefore, we must normally mark and release fish ourselves if we wish to obtain from the recaptures several types of information needed for adequate conservation measures.

What are these facts or attributes that can be inferred from the recapture of marked fish?

1. *Species distinction.* One of the earliest uses of tagging was the marking of immature salmon and sea trout in Britain to discover whether the young, which were difficult to distinguish, always returned in the adult form as the same species identified in the immature stage.

2. *Frequency of spawning.* The first really successful tagging was of salmon in the Penobscot River in 1873 by Charles G. Atkins. He discovered by marking kelts (spawned out adult Atlantic salmon) that the majority only spawned every second year.

3. *Race distinction.* Marking is employed to determine whether groups of fish marked in different localities intermingle to any degree or whether subpopulations or races exist in different areas.

4. *Geographical distribution.* Marking and recapture of fish reveals the geographical distribution of any group of fish (provided fishing provides adequate opportunity for recapture over the whole area). When young stages can be marked and recaptures continue over a considerable period of time, one may also determine the areas occupied by fish of successively greater size or age. This is often of importance in determining which areas suitable for

young fish are contributing to specific offshore fisheries.

5. *Age and growth.* Recapture of marked fish over a long time may show the increased size at successive ages. For some species, such as shrimp, which periodically shed their exoskeletons, or fish in tropical waters which may not form definite annuli on their scales, this is an extremely valuable method of age assessment. Where sufficiently large numbers of carefully measured fish are liberated, growth rates may be determined. Even for species with decipherable annuli on their scales, the corroborative evidence from recaptured fish may be very useful in scale interpretation.

6. *Spawning migrations.* Many fishes make long spawning migrations which are difficult to understand without this useful tool. Thus, tagging experiments have shown that many of the king salmon taken as far north as Southeastern Alaska enter and ascend the Columbia River to spawn. Similarly, mature halibut from as far away as the Aleutian Islands migrate to the Gulf of Alaska off Yakutat to spawn (Thompson and Herrington, 1930).

7. *Migration routes.* Marking is especially valuable here. For example, in Southeastern Alaska pink salmon can enter the myriad waterways of the Alexander Archipelago through several straits on their way to their natal streams to spawn. To assure adequate seeding of each stream intelligent conservation requires knowledge of which routes are used by salmon spawning in different streams. Continuous marking at the entrances of these straits during the migration period has shown the routes used. In some cases the early and late salmon runs to the same stream use different routes.

8. *Speed of migration.* The speed of migration is important in certain circumstances. Thus, in determining the effect of barriers in delaying the upstream migration of salmon, it becomes vital to know the rate of progress, for the salmon must reach its spawning beds before exhausting its supply of stored fuel.

9. *Mortality rates.* The most useful and necessary information concerning any population is knowledge of the rates of mortality. For humans, these mortality rates are very accurately calculated by insurance actuaries. Without the birth and death certificates, and occupational and geographical data available to the actuary, the fishery biologist does the next best thing; he marks individual members of the population. Circumstances may warrant the making of certain assumptions; such as, the representativeness of the sample marked, its even distribution through the population (or at least all of the population being equally vulnerable to the gear fished), and the tagged individuals acting and being acted upon as wholly normal individuals. It is then often possible to calculate from the rate of recapture of the tagged individuals relative to the untagged portion of the population at the time of tagging, the rates of fishing and natural mortality.

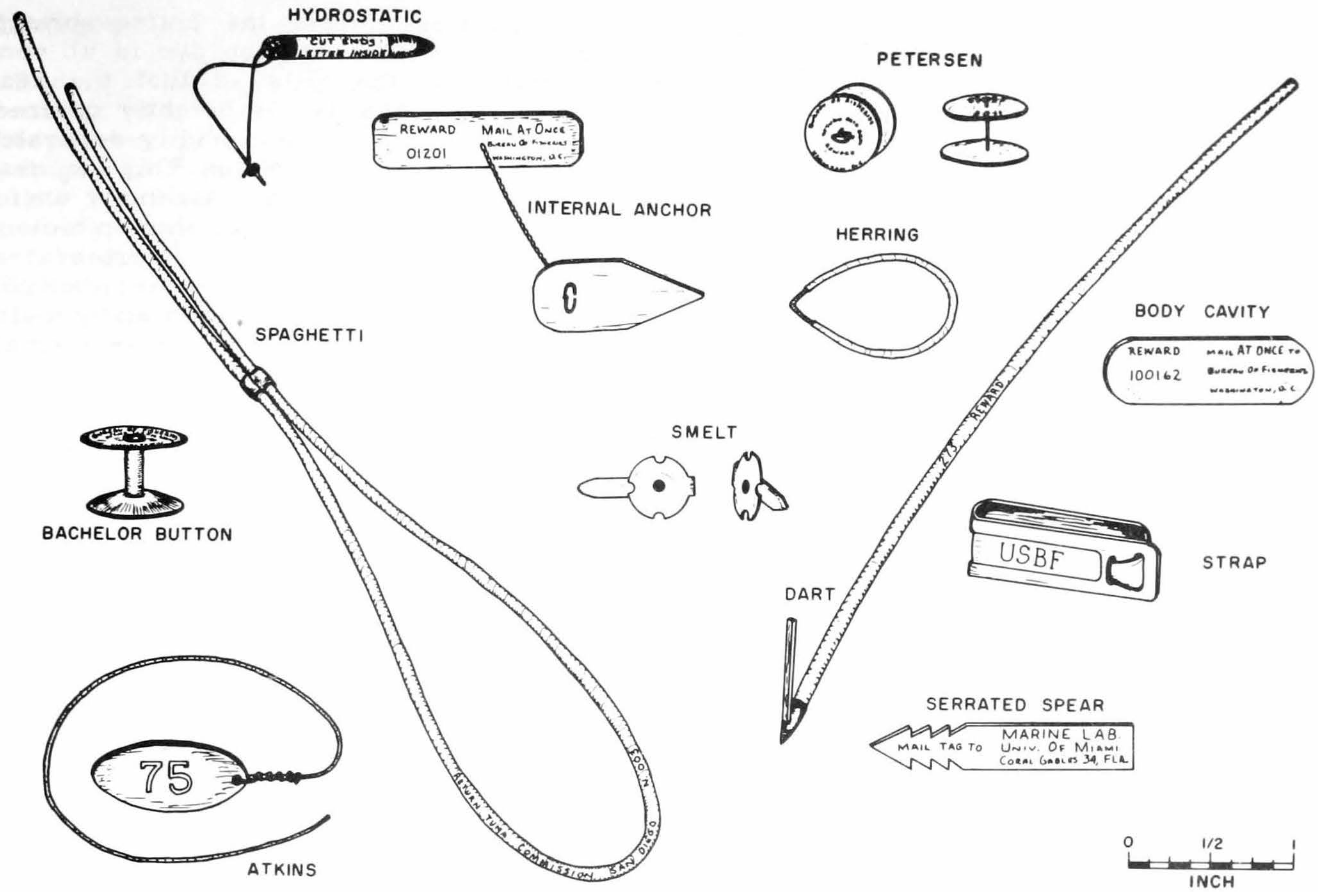
10. *Rearing methods.* Marking has been widely used to check the success of various methods of rearing fish, especially the salmonids. Thus, fast growth of young fish in the hatchery up to the time of release may appear desirable, but on the other hand, growth alone is not always a sufficient criterion of future survival. By marking and releasing numbers of fish reared under different conditions of feeding, handling, and temporal and spatial methods of release, it is possible through comparison of the recaptures to evaluate methods to improve hatchery efficiency in terms of adult fish.

TYPES OF MARKS

The choice of one of several general types of marks depends on many factors; such as, size of the organism to be marked, speed of marking, degree of permanency desired, ease of handling the fish, manner of recovery, etc. The chief types are as follows:

Mutilation

This method is used chiefly for making large numbers of very small fish, especially when recovery may be a long time hence, when the fish are much larger. Consequently, a mark with great permanency is desired. This method has been used on several species but chiefly on salmonids. Here, because the young are very small in comparison to the adult, few tags are suitable for marking the young. Thus, pink salmon fry $1\frac{1}{2}$ inches long have been successfully marked by excising fins



The chief tags in current use listed in table 1.

and the adults recaptured a year and a half later when they returned from the sea to spawn.

Because of the natural occurrence of fish with one fin missing, it is usual to excise two fins. The fins excised can include the dorsal, adipose, anal, left and right ventral (pelvic), and left and right pectoral. It has been shown by Barnaby (1944) that fewer sockeye salmon smolts survive to return as adults with a pectoral fin excised than with other fins removed; therefore, excision of the pectoral is not recommended. This leaves but 10 two-fin combinations. Some biologists have attempted to increase the number of combinations by use of a half-dorsal or a half-anal mark, clipping off half of the fin at the base. As reported by Slater (1949) fins not cut off at the very base tend to regenerate. My personal experience would suggest that these latter two marks are fraught with uncertainty since only extremely careful and slow marking of fairly large fingerlings can guarantee against portions of fins regenerating. These partially regenerated fins cause little difficulty in recognition in the normal two-fin combination. However, the distinction between a partially regenerated dorsal fin and one supposedly half excised can be tenuous.

In addition to fin removal there have been attempts to mark some of the more bony fishes by clipping notches in the edges of the opercle or maxillary.

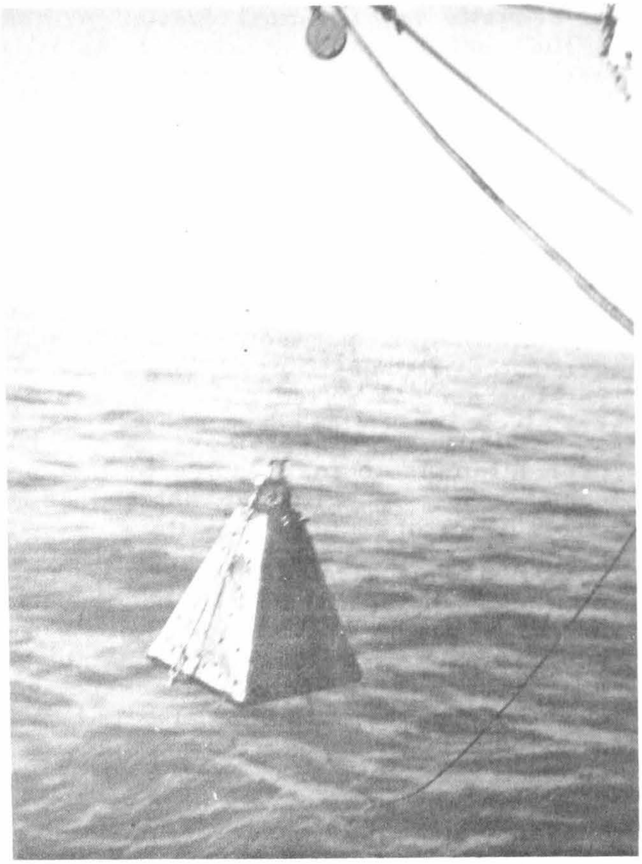
Fish are occasionally marked by punching holes in the fin membrane or cutting the tip off a fin. LeCren and Kipling (1961) punched 4-mm. holes in fin membranes of char for a temporary mark not good for over 6 weeks. Lobsters also are sometimes marked temporarily by punching or notching the telson or uropods.

Clams and other hard-shelled mollusks are sometimes marked by notching or etching the shell with a file or drill.

Another form of mutilation is by branding. Robert A. Nesbit (unpublished) tried both hot and cold branding in the late 1920's, but the marks tended to become illegible as the fish grew. Sea herring were branded by Watson (1961) by burning through scales and skin with several resistance wires heated with electricity from a 12-volt battery. The marks of the individual wires were not distinguishable for more than 2 to 3 days. The mark might be useful for very short-term experiments.

Vital Stains

The use of vital stains to mark fish and shellfish has only recently been employed on a large scale. Early experiments involved staining starfish by immersion in a weak solution of stain. Others have tried staining salmonids and invertebrates by mixing stains in their feed. More recently, shrimp are being marked in the Gulf of Mexico by hypodermic injection of small amounts of dye dissolved in distilled water.



Messenger-actuated box in which live stained shrimp are lowered to the sea bottom and there released. This method prevents heavy predation on the newly marked shrimp which burrow into the bottom immediately after leaving the box.

The dye first colors the entire shrimp, but in about 24 hours the dye is all concentrated in the gills so that the head (actually the thorax) is brightly colored, and the shrimp can be readily separated from its nondyed companions. This successful technique is proving extremely useful in studying many aspects of shrimp biology and can be used for other invertebrates. The chief advantages over earlier methods are that the mark is not affected by molting and that it can be used on very small individuals.

For experiments involving only a very short period of time, immersion staining still has its uses. For instance, pink salmon fry are marked by immersion and returned to a stream. Within a few hours or days some of them are recaptured as they migrate downstream to the sea, and the proportions of colored fry to the noncolored fry in the samples captured permits an estimate of the total number leaving the stream. The use of stain by immersion is particularly suitable for temporary marking of larval forms both because they are too delicate to permit handling and because it permits the staining of the vast number that must be marked to obtain sufficient recaptures.

Injecting biological stain into a shrimp with a hypodermic syringe. Left thumb is raised to show position of shrimp.

Fluorescent and Phosphorescent dyes

Recently biologists have been experimenting with the use of fluorescent or phosphorescent dyes for marking. An advantage of this technique would be the ability to discriminate between experimentally dyed specimens and organisms merely discolored or naturally possessing color that may cause confusion. Very minute quantities of different fluorescent dyes can be separated with a fluorometer by their difference in wave length.

Tattooing

Strictly speaking, tattooing consists of forcing small quantities of inert material beneath the skin by means of needles. A single area may be marked, using different colors for different experiments, a letter or number may be inscribed, or a combination of different colors may be used. Kask (1936) marked a number of halibut on the white side, injecting India ink with a hypodermic syringe but found the marks became unidentifiable after 3 months. More recently, colored latex injections at the base of the dorsal fin have been successful over a period of a few months.

Tattooing by use of electric tattooing needles is currently employed, because of its rapidity to mark large numbers of small salmonids when a temporary mark suffices.

Tags

The most prevalent marking method is to attach to the exterior or place inside an organism some readily identifiable foreign object spoken of as a tag. Tags can be variously classified according to several criteria, including material used, method of attachment, place where attached, and method of recovery. A general system of classification by Rounsefell and Kask (1945) lists 18 types; Rounsefell and Everhart (1953) list 21. Some of these types were never used extensively or have become obsolete as new and more efficient tags have been developed; the obsolete types will not be mentioned here.

Materials used.--With the development of new materials, especially plastics, many of the materials formerly used (see Rounsefell and Everhart, 1953) have been abandoned. Materials presently in vogue include various plastics, nickel, monel metal, silver, aluminum, stainless steel, titanium and tantalum wire, and magnetic steel.

The choice of material depends upon several factors.

1. *Time before recovery.* For short-term experiments one may use material, such as aluminum, that although tough and having the great advantage of light weight, is subject to corrosion, especially if not of high purity. Aluminum, therefore, cannot be recommended for experiments in which recoveries are expected over many months or even years.

Calhoun, Fry, and Hughes (1951) found both vinylite and cellulose acetate disks for Petersen tags inferior to cellulose nitrate, because the first two tended to become brittle and crack. Cellulose nitrate disks, however, also become brittle if held a few years in storage. They also discovered that nickel, monel metal, and silver used for pins or wire were inferior to stainless steel or tantalum.

2. *Place of attachment.* For external attachment noncorrosive material is imperative for any long-term experiments. For body cavity tags, loose within the body cavity, nonstainless steel can be used.

3. *Method of recovery.* The material used is somewhat dependent upon the method of recovery. For recovery of tags by electromagnets from fish meal, obviously only metals with magnetic properties are useable.

Methods of recovery.--Because divergent types of tags have been developed to suit the manner in which they can best be recovered by the fishery, we shall first list the recovery methods.

1. *By sight.* The use of tags that are visible is most common. Detecting tags on live fish is restricted to special experiments, such as identifying bass on their nests or observing live salmon on their shallow spawning beds. These external tags must be conspicuously colored and of large size. Oversize Petersen disc tags with a sharply contrasting colored spot in the center have been used successfully.

The recovery of tags from fish in catches requires tags that can be easily spotted by the fisherman while sorting or handling his catch. It is essential to take into account the exact manner in which the fishermen in a particular locality handle their catch in order to insure placing a tag where it is not easily overlooked. For instance, it may be vital to successful recovery that an opercle tag be placed on the left or right cheek of a fish according to how the fish are held in cleaning. If fish of a certain species are customarily cleaned individually on the fishing vessel soon after catching, an internal (body cavity) tag may be used.

2. *By transmittal of underwater sound.* Tags have been developed that emit low-frequency sound from a small battery-powered transducer for several hours. These permit following the individual fish from a boat. Such tags have been most useful in determining the movements of anadromous fishes in finding and passing through fishways and the quiet forebays above large dams.

3. *By electromagnet or electronic director.* This method of detection finds greatest use in small species taken in enormous quantities and processed without individual scrutiny or handling. Tags with magnetic properties are used, usually in the body cavity. During the processing an electromagnet separates the tags from the fish meal. The use of the electronic detector, placed in a conveying line prior to processing, is a superior method for determining the exact locality of capture and has the added advantage of separating out the whole fish for examination. It is more expensive than magnetic recovery, however, and, like most electronic equipment, is difficult to keep in operation.

4. *By radioactivity.* Tags have been developed with a very low level of radioactivity, much like the radium dial of a wrist watch. These tags can be detected with an instrument that measures radioactivity near the conveying line on which the fish are moved from the vessel into the processing plant.

Methods of attachment.--No one tag serves all purposes, not only because of the above-mentioned differences in methods of recovery and of aims to be achieved, but also because of differences in sizes of fish to be marked, in expected size increases before recovery, and most importantly, in great differences in the structure of the various species to be marked. This is reflected in the methods of tag attachment, which are:

1. To muscles by a filament that enters and leaves the muscle tissues. Filament may be rigid, as a shaft or pin, or flexible, as a wire, thread, or plastic tube. This method of attachment is the most widely used. Tags include the Atkins, Petersen, hydrostatic, spaghetti, etc.

2. To bone by one or two shafts or pins that pierce the bone. They include bachelor button, Archer, strap, smelt, and Petersen (also attached to muscles) tags.

3. To fin membranes by one or two shafts. These include the Archer tag (also attached to bone).

4. Anchored in muscles by projections on the tag which enters the muscles but does not pass through. They include barb, harpoon, and hook tags.

5. Encircling tags that depend upon their shape for attachment. They include collar, jaw, and some carapace tags.

6. Internal tags that are placed inside the body cavity, whence the name body cavity tags.

7. Anchored by material within the body cavity with a filament piercing the body wall for external visibility. This is the internal anchor tag.

8. Tags which depend for attachment on the continued elasticity of the material. These include rubber collar tags and some carapace tags.

Obviously, some of these methods of attachment are superior to others, and some are best adapted to specific situations. For example, method 8, which depends upon continued elasticity of the material is not useful for long-term experiments. For a collar tag, it is poor as the fish cannot expand in girth.

Tags in current use.--Many types of tags have been tried; only a score can be rated as really successful. Rather than confuse by including the long list of unproven or unsatisfactory tags I show in table 1 only those tags which currently are proving most successful under the qualifications as to species, size of organism, etc., that are given.

SELECTION OF MARKS FOR SPECIFIC EXPERIMENTS

A marking experiment should always be designed to answer some specific question. By first posing a question you can decide on what type and quantity of evidence will be sufficient to yield an answer within definable limits of accuracy. Once you have decided on the minimum evidence required, you are ready to select the method of marking. As a first approach, table 2 shows the advantages and disadvantages of several general methods of marking. Mutilation by fin clipping, for instance, can be used on very small fish, and when properly done is quite permanent. However, the individuality of the mark is very low, since only a few marks are available. Recovery of marks is also rather difficult, requiring either intensive canvassing of the fishery, or carefully scheduled representative sampling of the catches.

For some experiments the marking of very large numbers of small individuals is of such overriding importance that tattooing, for instance, may be in order.

In experiments in which the individual fish must be identifiable there is no good substitute for tagging, as each tag can be given an individual number. A great variety of tags have been devised, and from experimental evidence they are being continually improved. To aid in the first step of selecting the proper tag, table 3 summarizes the chief attributes of the better types currently in use, with the exception of the magnetic and radioactive tags which in essence are body cavity tags that can be recovered nonvisually, but otherwise possess the same attributes.

Even after selection of the specific type of tag, there are certain details that bear watching. The color of an externally visible tag may be very important. Although there is some conflicting evidence, a red-colored external tag appears to be the most attractive to predators according to most investigators. For the herring-type Atkins tag devised by John E. Watson, he reports (personal communication) that with yellow plastic tubing the returns were five times better than with green, and no red-colored tags were recovered.

For attaching Petersen tags, stainless steel pins or wire have been shown to be superior to those made of nickel or silver. The same is true of wire bridles for Atkins tags.

Experiments have shown that the hydrostatic Atkins tag fastened through the dorsal muscles yields better returns when attached by a bridle than by a curved loop. Others have found that a single nylon filament used to attach Atkins tags to the muscles is inferior to the heavier braided nylon.

For tagging the skipjack (striped tuna), Marr (1961) states that the dart tag yielded several times higher recoveries over those obtained using the best spaghetti tag (tubing has a mono-filament core of nylon, and the ends are fastened with a clamp in place of a knot). He attributes this to the ability to hook, tag, and release a skipjack in 4 to 7 seconds using the dart tag, against 20 seconds with the spaghetti tag.

The manner in which fish are recaptured may influence the proportion and the sizes recaptured. Thus, Hartt (1961) found that salmon marked with Petersen tags were more easily held by gill nets. As a result, smaller salmon that would otherwise pass through the nets were retained. Although this fact may tend to yield a larger proportion of recoveries, it may be undesirable from the standpoint of interpretation of the data; since in analyzing the data from a marking experiment, it is important that one be able to assume that marked individuals do not differ from the remainder of the population to any significant degree, including their chances of being captured.

IMPORTANCE OF METHODS OF CAPTURE AND HANDLING OF LIVE FISH

The success of a marking experiment, especially one for the purpose of determining mortality rates, often depends on how the fish are captured and handled. Thus, Iversen and Idyll (1960) obtained 22 percent recoveries of pink shrimp captured in 15- to 20-minute hauls with a small otter trawl (try net) of 15- to 20-foot

TABLE 1.--Some of the more successful tags in current use

Tag type	Tag name	Where usually attached	Material		Expected retention time	Recovery method	Species most used on	Minimum size of species when attached
			Tag	Attachment				
Petersen	Petersen	Dorsal muscle	Plastic	Stainless steel pin or wire	Long	Sight	Salmonids Flatfish	Medium Small
	Petersen	Opercle	do.	do.	Medium	do.	Gadoids	Medium
	do.(small)	Tail	do.	do.	Short	do.	Shrimp	do.
	do.	Shell	do.	do.	Long	do.	Scallops	do.
Barb	Dart	Dorsal muscle	Plastic tube	Nylon barb	Long	Sight	Tunas, Marlin, etc.	Large
	Serrated spear	Dorsal isthmus	Flat plastic	--	Medium	do.	Lobsters, Crabs	do.
	Smelt	Opercle	Bent plastic	--	Short	do.	Smelt	Small
Body cavity	Body cavity	Body cavity	Plastic	--	Very long	Sight	Various	Very small
	Magnetic	do.	Steel	--	do.	Magnetic or electronic detector	Clupeoids Engrauleoids	do.
	Radioactive	do.	Magnetized steel rod	--	Long	Radioactivity detector	do.	do.
Atkins	Hydrostatic	Dorsal muscle	Hollow plastic rod	Stainless steel bridle or plastic filament	Long	Sight	Various	Medium
	Atkins	do.	Flat plastic or metal	do.	Medium	do.	Various	do.
	Spaghetti	do.	Metal clip or knotted	Plastic tube	Long	do.	Tunas, King Crab, Salmon	do.
	Herring	do.	Bent plastic rod	Plastic tube	do.	do.	Clupeoids	Small
Internal anchor	Internal anchor	Body cavity	Hydrostatic	Metal chain to internal flat plastic	Long	Sight	Gadoids, Salmonids, etc.	Very small
	do.	do.	Flat plastic	do.	do.	do.	do.	do.
	do.	do.	Plastic tube	Plastic tube to internal flat plastic	do.	do.	do.	do.
Bachelor button	Bachelor button	Opercle	Plastic disc and metal disc	Metal shaft	Medium	Sight	Gadoids	Medium
Strap	Strap	Opercle	Bent metal strip	Metal shaft	Long	Sight	Halibut	Medium
	Jaw	Jaw	do.	do.	Medium	do.	Various	do.

TABLE 2.--Attributes to consider in selecting general method of marking

	Mutilation by fin clipping or notching	Injection staining	Immersion staining	Tattooing	Tag	
					Nonvisual recovery	Visual recovery
Duration of experiment:						
Few days			x			
Few weeks			?	x		
Few months		x		?		x
Few years		?			x	x
Several years	x				x	x
Individuality of mark:						
Very low			x	x		
Low	x	x			x	
High					x	x
Size of organism at marking:						
Very large						x
Large						x
Medium	x	x		x	x	x
Small	x	x	x	x	x	?
Very small			x			
Recovery method:						
By your own sampling			x	x		
By monitoring machine					x	
By very intensive canvassing	x	x		x		
By less intensive canvassing						x
Numbers to be marked:						
Low						x
Medium						x
High	x	x			x	x
Very high			x	x		
Organism to be marked:						
Crustacea		x	?			x
Bivalve mollusk	x					x
Small schooling fish	x	?			x	x
Juvenile fish	x	?		x		x
Large fish						x

TABLE 3.--Attributes to consider in selecting specific visually recoverable tags

	Petersen	Dart	Atkins: With tag attached	Atkins: Without tag attached	Body cavity	Internal anchor	Bachelor button	Strap	Jaw
Skill required of tagger:									
High	x					x	x		x
Medium	x		x	x	x				
Low		x		x				x	
Amount of handling of fish:									
High	x		x			x	x		x
Medium	x		x	x	x				
Low		x						x	
Structure of fish:									
Bony	x	x	x	x	x	x	x	x	x
Soft, light bones	x	x	x	x	x	x			
Place of attachment:									
Opercle	x						x	x	
Jaw									x
Body cavity					x	x			
Muscles	x	x	x	x					
Hampering of fish:									
High									x
Medium	x		x	x		x	x	x	
Low		x		x	x	x			
Cause of predation:									
High	x		x						
Medium	x		x	x		x	x		
Low		x		x		x		x	x
None					x				
Minimum size markable:									
Large		x					x		
Medium	x	x	x				x		x
Small				x	x	x			
Very small					x	x			
Period of tag retention:									
Short							x	x?	
Medium	x	x	x	x			x		x
Long	x	?	x	x		x	x		x
Very long					x				

spread, while recoveries from shrimp captured in 1-hour hauls of a large commercial otter trawl were only 14 percent.

Fish caught by gill net can sometimes be tagged successfully, but Hartt (1961) found that on the high seas tagging recoveries were consistently poor from salmon taken in gill nets. This is largely because of the need to use long nets to take the scattered fish and the impracticability of hauling the nets from a small boat. Baited longlines gave higher returns than gill nets; however, much the highest proportion were returned when salmon were taken by purse seines.

Equally important as the method of capture is the subsequent handling. Large agile fish easily injure themselves against hard surfaces and should usually be held in some type of padded cradle. For exceptionally large fast-swimming fish the total elapsed time between capture and release may be the most important factor. As mentioned above, Marr (1961) obtained very much better recoveries by marking skipjack tuna with a dart tag which required 7 seconds, than with a spaghetti tag which required 20 seconds for the whole operation.

Many investigators have used various narcotizing solutions to quiet fish prior to marking. Others prefer not to use such means, and opinions remains divided.

For small school fish, such as herring, continuous release of individual fish encourages predation. A number of marked fish should be released as a school.

For releasing marked shrimp. T. J. Costello of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, has successfully used a release box that is lowered to the bottom and opened by messenger. Scuba divers observed the released shrimp quickly digging into the soft bottom, their normal hiding place from predators.

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