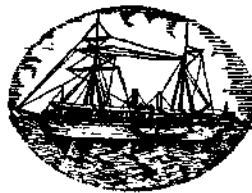


SYMPOSIUM ON CRUSTACEA

PART IV



MARINE BIOLOGICAL ASSOCIATION OF INDIA

MARINE FISHERIES P.O., MANDAPAM CAMP

INDIA

PROCEEDINGS
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PART IV



SYMPOSIUM SERIES 2

MARINE BIOLOGICAL ASSOCIATION OF INDIA
MARINE FISHERIES P.O., MANDAPAM CAMP
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MARK-RECOVERY EXPERIMENTS IN CRUSTACEANS*

M. J. GEORGE**

Central Marine Fisheries Research Institute, Mandapam Camp, India

ABSTRACT

Mark recovery experiments employing different techniques in marking, like tagging and staining is an important tool in the study of migration and movements in the economically important crustaceans such as shrimps, lobsters and crabs. The various methods used in these marking studies in the case of the penaeid prawns, spiny lobsters, craw fishes and crabs along the Gulf of Mexico, the Atlantic coasts and the Indo-Pacific region are described. The typical movements elucidated so far are also described.

INTRODUCTION

THE mark-recovery technique has proved a very valuable tool in many areas of fishery research. Devised just prior to the turn of the century, it was initially used to determine movements of anadromous fishes and to assist in estimating abundance of marine bottomfishes. Today its utility seems limitless. One of the major implements of the inland fishery researcher for measuring population size, the mark-recovery experiment is also being widely employed by marine biologists to determine migration, dispersal and growth patterns of a variety of ocean fishes and invertebrates.

Properly designed and implemented, mark-recovery experiments can provide information on: (1) migration and dispersal, (2) growth, (3) rate of exploitation in fish and shellfish populations and (4) estimation of population sizes. Such information, often supplemented by that obtained by other techniques, represents the foundation upon which resource management programmes are erected. These are of interest to commercial fishermen since any management programme's aim is to protect their interests by ensuring on a continuing basis, the availability of the greatest quantity of a specified resource supportable under any combination of natural and artificial factors.

In essence, the mark-recovery technique consists of capturing, marking for future identification, releasing and recapturing samples of fish or shellfish populations. Such samples are, in effect, experimental populations whose characteristics are known, and which are expected to behave like the parent populations from which they are drawn and into which they are reintroduced. In fact the over-all usefulness of information gained through this method hinges entirely upon how well the experimental or sample population reflects the whole population whose maintenance is of concern. The success of any mark-recovery experiment also depends critically upon the number of marked specimens subsequently recaptured or recovered. It is appropriate to point out here that marking and recapturing phases of such experiments go hand in hand. Unless equal, if not added, effort is extended towards the latter phase any mark-recovery experiment can be counted a failure.

Many kinds of devices each having its advantages and disadvantages have been used in mark-recapture experiments in fishes as well as Crustaceans. In the case of the latter the frequent ecdysis taking place in the animals render it all the more difficult to devise a suitable tag or mark to stay through these moultings. Numbered tags of corrosion-resistant metal and plastic have proved useful, being widely used in a variety of freshwater and marine fishes and shellfishes. The tags may

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** Present Address; C.M.F.R. Sub-station, Ernakulam, India.

be regular or irregular in shape and attached directly to the body with non-corrosive wire or nylon. Another method of marking is by mutilating body parts like fins and appendages. Although quite suited for determining migration patterns this method does not lend itself to growth studies because once released each individual involved loses its identity. To be useful for the latter purpose individuals making up population marked in this manner must be reasonably uniform in size, a requirement not easily met. The same can be said for the third means of marking, *i.e.*, injection with biological dyes. One other decided disadvantage in both the mutilation and staining methods is the facility with which specimens so marked go undetected in commercial landings. This is particularly serious in the case of Crustaceans where stained specimens must be recovered through close scrutiny of voluminous landings, a tedious and difficult task. The best that persons responsible for carrying out these mark-recovery experiments can do is widely publicise such experiments, encourage and reward the alertness and co-operation of fishermen, processors and other interested parties, and if in fact marked specimens are present hope for their detection.

Despite the many shortcomings of the methods, the recapture of commercial shrimps, crabs and lobsters marked with various tags and dyes has resulted in acquiring information about the shrimps of the Gulf of Mexico and South Atlantic, King crabs of Alaskan waters, the swimming crabs of the Scottish coast as well as both Atlantic and Pacific American coasts, and lobsters and crayfishes of the Japanese, North Sea, Australian, South African and American waters, which could be obtained in no other way. Among the various authors who contributed substantially to these studies may be mentioned Lindner and Anderson (1956), Dawson (1957), Ráček (1959), Costello and Allen (1960), Iversen and Jones (1961), Kutkuhn (1962), Allen and Costello (1963) and Costello (1964) in penaeid prawns, Cronin (1949), Mason (1962), Weber *et al.* (1962), Fischler and Walburg (1962), Hayes and Montgomery (1963) and Powell (1964) in the case of crabs, and Allen (1916), Templeman (1935 and 1947), Wilder (1947), Von Bonde (1935), Sheard (1949 and 1962), Dawson and Idyll (1951), Thomas (1955) and Smith (1958) in spiny lobsters and crayfishes. Though limited these studies have provided important clues as to which coastal estuaries are utilised by maturing shrimps spawned from parent stocks inhabiting off-shore fishing grounds and frequency of moults and inshore off-shore movements of crabs and lobsters. Such information is valuable in that it permits, with reservation, to define ranges of populations or stocks, an obvious first step in setting up an effective management programme.

PENAEID PRAWNS

Tags and Tagging Methods

In the study of the migration pattern of penaeid prawns the only method used extensively since 1934 and before 1957 was tagging with numbered plastic or celluloid discs known as Petersen discs. The method of this tagging is quite simple. The materials needed are two small celluloid discs, preferably of different colours and with perforations in the centre, and one sharp nickel pin of about 2 inches in length (Fig. 3). One of the discs is numbered consecutively and the other bore instructions for returning the shrimp. The discs are of opaque celluloid or plastic, usually about ten-one-thousandths of an inch thick. The diameter of the discs vary from 8-10 mm. according to the size of the shrimp marked. Usually the tagging is done on board a boat where there are facilities for keeping the shrimps alive in tanks with circulating water. The pins are kept in readiness for tagging by pinning them with one of the discs mounted according to serial numbers on some sponge or cork panel. When attaching the tags on the animal the pin with the numbered disc mounted is thrust through the side of the first abdominal somite about midway between the dorsal and ventral surfaces, the other disc is slipped over the end of the pin protruding from the other side of the shrimp, and a loop made in the pin with surgical forceps in order to prevent the disc from slipping off. In making this loop approximately $\frac{1}{4}$ th to $\frac{1}{2}$ th inch ply should be left between the sides of the shrimp and each disc to allow for growth. While inserting the pin care should be taken not to penetrate any of the vital organs. Measurements are also recorded of the tagged specimens. As far as possible both measuring and tagging are done under water. As the shrimps are measured and tagged they are placed in tubs of fresh running sea-water and releases are made in batches of 25 or 50 after

examination and substitution for all that appear to be in poor condition due to the effect of tagging. Records are maintained of the date, time and place of capture, tag number, sex and length of each shrimp, and the date, time and place of release. Several hundreds of specimens are tagged like this and released at different spots. By the recovery of these specimens their movements and growth are studied. There are several drawbacks for this method and opinions differ as to the suitability of the method of study. It is doubted whether these discs on the sides of the small animals might affect their swimming, and whether they might have an adverse effect on the moulting frequency, etc. However some valuable results have been obtained by employing this method.

The U.S. Fish and Wildlife Service initiated tests in 1954 to find a more suitable method for marking shrimp because of the severe limitations in the mechanical tags. As a result Charles Dawson in 1957 reported successful use of biological stains as marking agents in penaeid shrimps. This method of staining slowly replaced the tagging method and now it is used extensively in different parts of the Gulf of Mexico for all mark-recovery experiments on shrimps. Dawson experimented with different dyes and found some of the stains like fast green and trypan blue most suitable. But his work was confined to laboratory experimentation. The problem remained to adapt his technique for field use and to determine whether these stains would remain fast and recognisable under natural conditions. Since 1957 extensive field studies have been conducted by the different federal and state agencies of U.S.A. and the use of this technique for conducting mark-recovery experiments to determine migration and growth of the Gulf shrimp has been established.

For marking shrimps with stains three methods could be made use of, immersion, injection and feeding. In the immersion method the animals are placed in an aerated stain solution like 0.1% Nile Blue Sulphate in sea-water for about 3 minutes and then transferred through changes of fresh sea-water in order to remove excess stain adhering to the exterior or trapped within the branchial chamber, as done by Racek (1959). In the injection method the technique is to inject a dilute solution of these dyes on the animal. After a few hours the stain collects in the gill area and remain coloured (Fig. 1). The feeding method is to feed the shrimps with food previously stained by these dyes for a certain period. Among these three methods the injection method gave very good results and was proved to be quite suitable for extensive field studies.

In the injection method of staining shrimps three stains have been proved to be quite useful for mark-recovery experiments, namely, fast green, trypan blue and trypan red. The first two give distinct easily recognisable markings. Trypan red also gives a distinct colour but tends to blend with the natural colour of the shrimp and also it is subject to more fading when compared to the others. Sterile, nonelectrolytic distilled water should be used as a base for all staining solutions. There is no advantage in aging solution and in fact aging of the solution was found to render it more toxic. So the stain solutions in distilled water are prepared just before use. 0.5% solution of the dyes gives best results. Before using for injection the solution is shaken well and filtered once through a sheet of Whatman No. 1 filter-paper. Unfiltered solutions are not found satisfactory. The injection is best done with a $\frac{1}{2}$ c.c. tuberculin syringe equipped with No. 25 or 27 by $\frac{1}{2}$ or $\frac{3}{4}$ inch hypodermic needle. For smaller shrimps 30 gauge needle can be used with advantage. Holding the syringe in the right hand, a shrimp is held with the left so that its head is pointed towards the left wrist and its abdomen held in a flexed position by the left thumb and forefinger. The needle is then introduced through the articular membrane of the 6th abdominal joint slightly to the left of the mid-dorsal line and at an angle approximating 45 degrees. For very small shrimps (12 mm. carapace length) injection laterally through exoskeleton of the 1st abdominal segment joint is preferable. The needle is inserted to a depth of from 2 to 4 mm. until stain is visibly entering the blood vascular system through the dorsal abdominal artery. Care must be taken not to puncture the hindgut when the needle is inserted through the articular membrane. Volume of individual injections generally range from 0.1-0.05 c.c. with optimum at about 0.03 c.c. Injection of greater volumes frequently result in rapid death and does not produce more vivid or durable staining. During the process of staining care must be taken to avoid air bubbles in the syringe and also to minimise handling of the specimens as much as possible (Ref. Costello, 1964).

As in the case of tagging with Petersen discs in the staining experiments also the stained specimens are kept in tanks with circulating sea-water for a few hours before they are released in batches of hundreds, after substituting for all those which appear to be in poor condition. Stained shrimp should not be released during the first four hours following injection for they might easily fall prey to predators. The staining can best be done in the field on board small boats equipped with staining tables and tanks for holding the shrimps both before and after staining with facilities for running sea-water in the tanks. The main disadvantage in the staining method of marking is that for growth studies growth information secured through recovery of stained shrimps must depend upon the releases whose components are practically uniform in size, which is not a problem in tagging programmes, where in each specimen carries an identifying number.

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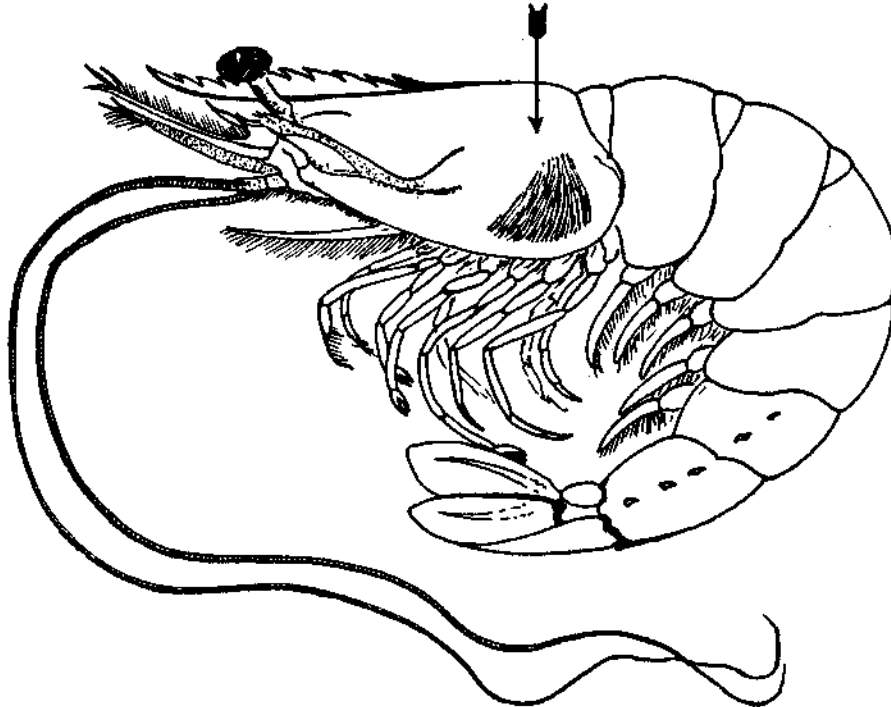


FIG. 1. Panaeid prawn showing the colour marking on the gills.

Recently, Allen and Costello (1963) after laboratory experiments extending to over three or four months reported on the possible use of a modified Atkins-type of tags for use in mark-recapture experiments on shrimps as an improvement on the Petersen disc tags. This tag is composed of a small oblong strip of cellulose acetate, 0.8 mm. thick and inscribed with printed information, secured to short length of monofilament nylon line which has a loop in the free end. The tag is attached to a shrimp by means of a surgical needle with the eye cut open on one side. The nylon loop is hooked by the needle eye and the needle then inserted laterally through the muscle tissue of the first abdominal somite of the shrimp, taking care not to injure any of the vital organs. After the nylon line is drawn through, the plastic strip is passed through the nylon loop twice, securing the tag in position. Although indications are that this Atkins tag which is light weight and flexible is an improvement over the Petersen tag the advantages are yet to be proved by large-scale field experiments.

RESULTS

The Petersen disc tagging as well as the stain injection method has been used extensively in the mark-recovery experiments on commercial shrimps of the Gulf of Mexico and South Atlantic by several agencies, the former in earlier years and the latter in the past 4 or 5 years and much valuable data on migration of these shrimps have been obtained. Petersen disc tagging was first used in the field for shrimp studies in the Gulf of Mexico in 1935 and resulted in recoveries of almost 25 per cent. The typical inshore off-shore movements and the migration of juveniles from the inside waters like inland bays and bayous to off-shore waters in the various regions of the South Atlantic and Gulf of Mexico coast in the case of the white shrimp *Penaeus setiferus* was elucidated by recoveries of Petersen disc tagged shrimps by Lindner and Andersen (1956). The growth of the shrimp also has been traced to a certain extent as a result of these recoveries. The largest time between release and recapture recorded by them is that of a shrimp marked at Cape Canaveral in January and recaptured off the Georgia coast 257 days later. In the case of the pink shrimp *Penaeus duorarum* recoveries of marked shrimps using both Petersen disc method and staining method have proved that the Florida bay estuaries are the nursery grounds for the heavily exploited Tortugas pink shrimp fishery (Iversen and Idyll, 1960 and Costello and Allen, 1960). Iversen and Idyll (*op. cit.*) obtained recovery after 123 days during which time the shrimp moved 60 miles. Costello and Allen (*op. cit.*) obtained recoveries of stained shrimps which moved a maximum of 90 miles in 85 days. Subsequent mark-recovery experiments using stains have conclusively proved that juvenile shrimp make extensive movements in migrating from estuaries to off-shore waters. Much valued data on growth of the shrimps have also been accumulated as a result of these studies. Experiments conducted on the brown shrimp, *Penaeus aztecus*, also have given results regarding the movements and growth of the species along Louisiana and Texas coast as evidenced by the various reports from the biological laboratories engaged in these studies.

A start in this kind of study has already been made in the Central Marine Fisheries Research Institute in 1963-64 and preliminary experiments using the three stains fast green, trypan blue and trypan red have been conducted at Ernakulam in order to determine the suitability of stains and also to select the proper species in which future studies could be conducted. It has been found as a result of this that for the smaller species like *Metapenaeus dobsoni* the staining method is not suited and that in the bigger species *Penaeus indicus* the method could be used with advantage.

CRABS

Mark-recapture experiments using different types of tags have been conducted in several edible crabs in different regions. Among these are the studies on the blue crab *Callinectes sapidus* of America, the swimming crab of the Scottish coast, *Cancer pagurus*, the dungeness crab, *Cancer magister*, the king crab of the Alaskan waters, *Paralithodes camtschatica*, and the predator horse-shoe crab, *Limulus polyphemus*.

Tags and Tagging Methods

Several types of tags have been used in the crab tagging experiments. One of the earliest tag used in tagging studies on the blue crab in Chesapeake Bay (Fiedler, 1925) is one similar to the fish body cavity tag. It consists of a strip of silver $1" \times \frac{1}{4}"$ size stamped with serial number and other information and two pieces of silver wire one on each side (Fig. 2). The silver strip is attached on the dorsal surface of carapace of the crab by looping the silver wires around the lateral spines.

Nesbit type of fish belly tags is another tag used on these crabs later. The material for the tag is only a strip of red plastic bearing serial numbers and other details regarding date of release, etc. This tag has been used in tagging experiments in three different ways: (1) Inserted into the branchial chamber of the crab through the inhalent aperture above base of cheliped. (2) Inserted into the branchial chamber through a slit cut into the carapace. (3) Attached on the carapace with both

ends inserted into slots cut into the same. The same plastic tag has been used in another way also by attaching by means of pieces of wires on each side looped around the lateral spines so that the plastic tag remains on the dorsal surface across the carapace like in the method of Fiedler (Cronin, 1949).

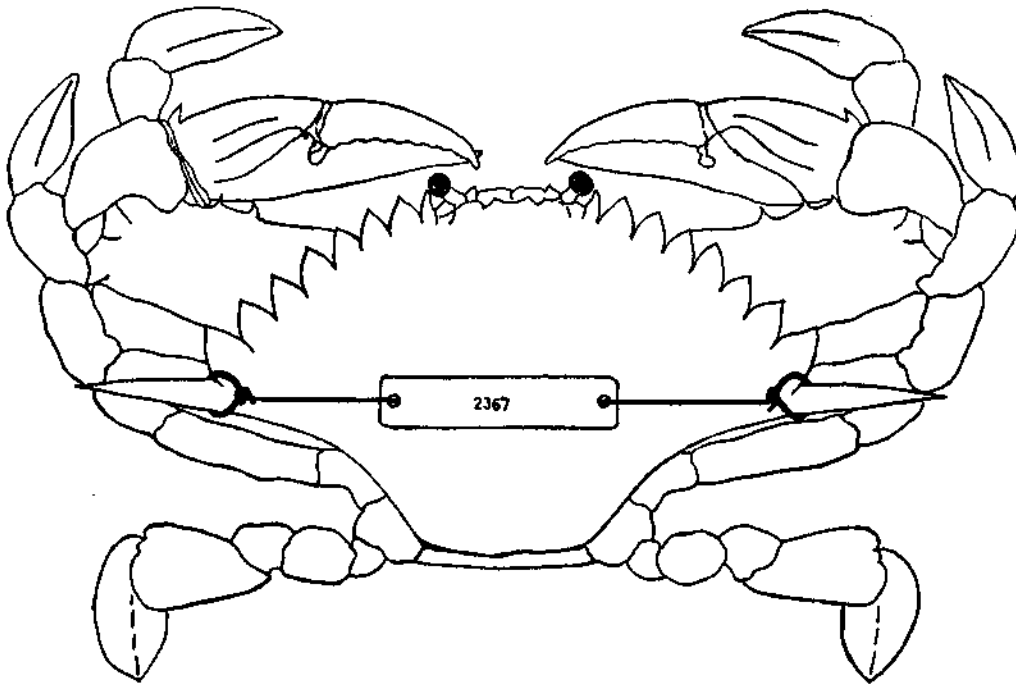


FIG. 2. Swimming crab showing the carapace tag attached.

Cronin (*op. cit.*) used a Petersen type tag also for the blue crab tagging experiments, the material for the tag consisting of 2 discs and a nickel pin. The discs are attached by pinning through at the base of the lateral spine of the carapace. But this method gave less returns when compared with the other methods. From the results obtained in these experiments it is evident that a bright tag of the Nesbit type attached on the carapace by the Fiedler method, *i.e.*, by looping wires on the lateral spines, is the best suitable and this was in use in the blue crab studies for several years from 1943 onwards. The Alaskan king crabs were tagged with Petersen disc-type tags on a leg or through the carapace from the initiation of these crab tagging studies in 1954.

In the blue crab movement studies in coastal South Carolina in 1955-59 a carapace tag which is more or less similar to the Nesbit type of tag with the Fiedler method of attachment was made use of by Fischler and Walburg (1962). This tag consists of a strip of celluloid in bright colour bearing the serial number, name and address of the tagging agency, etc., and a piece of stainless steel wire. The tag is attached to the dorsal surface of the carapace by the wire going round the body of the animal. The main disadvantage of these tags is that they can be made use of only in mark recapture experiments to study short range movements since the tag is shed off during moulting of the crab. However some of these methods were used in the crab tagging studies on the Scottish coast also.

A tagging method that permits tag retention through successive moults is essential to study growth and long range movements. The location of an insertion point along the splitting line of the crab shell during moulting which makes retention of the tag through several successive sheddings

possible came as a major breakthrough in the study of migration, distribution and growth rates of crabs by tagging recapture experiments. This insertion point for the tag was located on the isthmus at the base of the last pereopod of the crab in tagging program on the dungeness crab *Cancer magister* of the Oregon Fish Commission. Ever since the location of this site for tagging most of the experiments on the dungeness crab, the blue crab and the king crab are being conducted by using this method. Two types of tags are being used in these studies, namely, the spaghetti type loop tag and the dart tag. These tags are inserted through the muscular isthmus between the postero dorsal portion of the cephalothorax and the abdomen. Here the isthmus is covered with a parchment-like chitinous membrane which is one of the first parts of the exoskeleton to slough away during ecdysis. The moulting crab exsheaths through a posterior split between the abdomen and the carapace along this isthmus by means of a series of alternate body shifts. Since the tag is attached to the arthral muscle in the isthmus it is freed at the time of this split and does not appear to hinder moulting.

The spaghetti type loop tag is made from a 12-inch length of polyvinyl chloride plastic tubing with an oval plastic button bearing identification, number, etc. In attaching the tag the abdomen is spread from the carapace to expose the isthmus and the tag is then threaded through the muscular part of the same with a curved stainless steel needle, taking care to avoid the large blood sinus anterior to the muscular part. After threading through, the two ends of the plastic tubing are brought together and tied. The trailing ends of the 'spaghetti' provide conspicuous identification of tagged crabs even at a distance.

After tagging the crabs are immediately returned to holding boxes containing salt-water which promotes blood clotting and consequent prevention of excessive bleeding and released after some time. Instead of the spaghetti loop tag dart tag also is used in which case a dart tag is inserted in the isthmus, leaving a portion of the tip projecting outside.

Recently Allen and Costello (1963) experimented with stain injection method for marking the blue crab *Callinectes sapidus*. Trypan blue and fast green stains were tried. Injections were made in the ventral surface of the swimming legs at the articulation of the coxa and the basis. In laboratory experiments crabs marked with fast green were found to retain the colour in sufficiently detectable quantity in the gill filaments after 40 days. Since the exoskeleton of the crab is opaque it is difficult to detect the stained gill filaments without lifting the carapace and that is one of the main disadvantages of the method. However the authors are of opinion that the results indicate that the stain injection techniques of marking crabs could be made use of in limited studies of local populations where captures could be examined by trained observers.

RESULTS

Tagging recapture studies by Cronin and others in Chesapeake Bay using Nesbit type of tags yielded valuable results of the movements and growth of the blue crab *Callinectes sapidus*. Recoveries upto 23% were obtained in these experiments. The movements of adult blue crabs in the estuaries and adjacent coastal waters of South Carolina were elucidated by Fischler and Walburg (1962) by using a carapace tag. During this study a female crab released in January 1958 in South Carolina was recovered in May 1958 from Florida, 145 miles away from the site of release. In the crab tagging experiments of the Oregon Fish Commission considerable results have been obtained in *Cancer magister* by using the nylon spaghetti type and plastic dart type tags. Out of the 10% recoveries made till 1962 one recovered crab was tagged in July 1961 and recaptured in June 1962. This crab measuring 4.5 inches across the carapace when released grew to 6.5 inches and regenerated a claw which was missing when tagged. Movements upto 20 miles have been noticed in these crabs. Much valuable results on the movements, growth and moulting periodicity of the King crab *Paralithodes camschatica* in Alaskan waters have been obtained by using spaghetti loop type tags in mark-recapture experiments. By measuring tagged crabs at release and recovery Weber and Miyahara (1962) arrived at a growth per moult of approximately 16 mm. for male crabs more than 110 mm. in length. Hayes and Montgomery (1963) conducted extensive tagging studies on the same crab using the same tag from 1957 through 1962. They observed migrations of the crab

ranging from 35 miles to 110 miles. Two crabs were recovered after moving 110 miles from the site of release in 200 days and 1 year respectively. Their tagging recoveries also indicated a growth of nearly 17 mm. per moult in large-sized crabs and also biennial as well as triennial moult periods in the case of large crabs. On January 28, 1964, a tagged crab was caught near the Shumagin Islands in Alaska, which had been released within 10 miles of the area six and one-half years earlier. This is the longest period between release and recapture recorded to date. During the time the crab shows a growth from 4.1-7.6 inches in carapace width.

Results obtained by tagging the commercial crab *Cancer magister* with the suture tag in Canadian waters indicate that sub-legal size male crabs move about as much and in some cases more than those of commercial sizes and growth of the male crabs also has been traced (Butler, 1957). The suture method of tagging used on the edible crab *Cancer pagurus* in Norwegian waters have yielded valuable results on growth and movement. Tagged crabs recaptured in 1962 showed a mean increase in breadth of carapace of 27 mm. during 1 year. Tagging recapture experiments on *Cancer pagurus* on the Scottish coast also has yielded encouraging results.

LOBSTERS

Tagging and recapture experiments on the crayfishes and spiny lobsters of commercial importance have been conducted in various regions of the world resulting in very valuable results on their movements and intermoult growth. Among others may be mentioned the studies by Allen (1916) on *Panulirus interruptus* in California waters, Templeman (1935 and 1940) on the American lobster *Homarus americanus* in New Foundland waters, Von Bonde *et al.* (1935) on *Jasus lalandii* from South Africa, Wilder (1947) in Canadian waters, Sheard (1949 and 1962) on the Australian crayfish *Panulirus longipes* in Western Australia, Dawson and Idyll (1951) and Smith (1958) on the spiny lobster *Panulirus argus* of Florida, Thomas (1955) on *Homarus vulgaris* of the Scottish coast and Gundersen (1964) on *Homarus vulgaris* in Norwegian waters.

Tags and Tagging Methods

On the New Foundland lobsters Templeman used barb tags made of celluloid, consisting of a straight shaft that is pushed into the tissues in between the abdominal segments, and depending for holding wholly on one or more barbs. The same type of barb tag was later used in the tagging experiments in Florida waters by Dawson and others and is still being used successfully. These tags are plastic darts 40 mm. long, 6 mm. wide and 0.5 mm. thick (Fig. 3) of white or any other suitable colour. One side of the tag bears the address of the institution to which the tag is to be returned and the obverse side bore serial number and other instructions. The head of the dart is 14 mm. in length and with three serrations on each side. The tags are thrust into the muscles of the crayfish at an angle of approximately 45 degrees between the first and second segments of the abdomen on the dorsal side and to the right of the midline. One-quarter to one-half inch of the tag protrudes and is readily visible against the exoskeleton. This type of tag has the advantage of remaining in position while the animal sheds, at least in many cases, whereas the other types of marks like the carapace tags are lost during the process of moulting.

In the tagging experiments on Cape crawfish *Jasus lalandii* in South Africa marking was done by attaching a small brass label by means of a wire to the basal joints of the antennae. Sheard (1949 and 1962) tested small celluloid and plastic tags used internally with both *Jasus lalandii* in South Australia and *Panulirus longipes* in Western Australia. But he found that suitable punch marks on the tail fan gave better results than the internal tag and he used punch markings in his field studies. This method of marking is quite simple. Using lamb ear-marking pliers with dies of a suitable simple pattern (diamond, heart, bar, circle, oval or star) a punch is made on the tail fan (telson and uropods). It was found by him that the design was readily identifiable upto and including the second moult after marking and in several cases the mark was discernible even after the third moult. Where filled in the design was marked by paler colouring, absence of spines and an

alteration in the direction of the telson ridges and canals. George (1957) also used the punch marking method in his studies on *Panulirus longipes* in Western Australia.

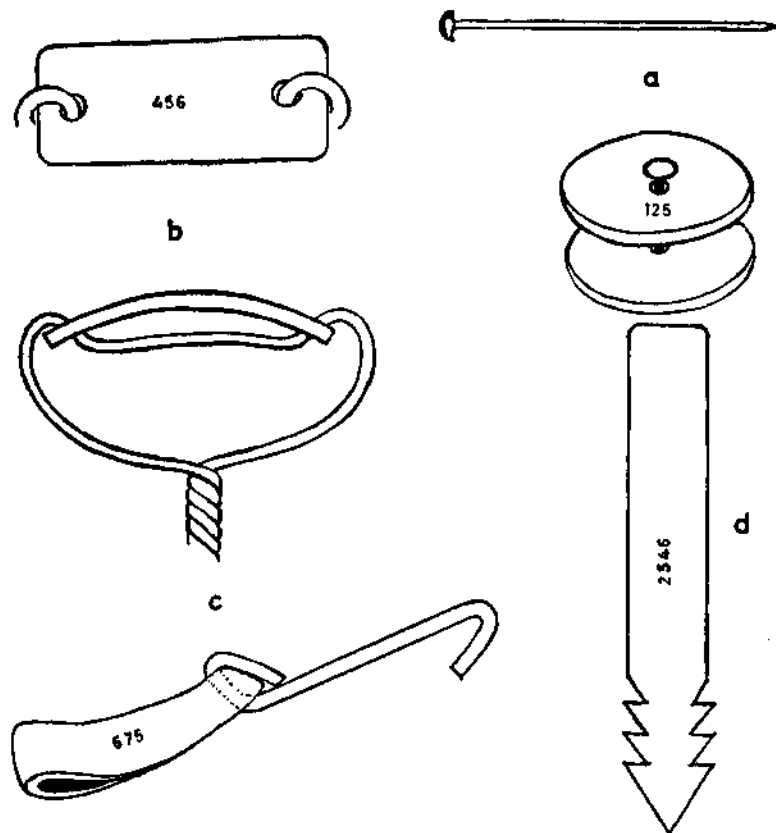


FIG. 3. (a) Petersen disc tag. (b) Celluloid and wire, carapace tag for lobster. (c) Metal and rubber carapace tag for lobster. (d) Dart tag for lobster.

Petersen disc tags and carapace tags were also used in tagging experiments on the American lobster *Homarus americanus* and others. Scattergood used both these methods. Discs of 10 mm. diameter were used in the disc tagging. The carapace tags are typically 2 different types, although there are various other modifications, namely, the metal and rubber tag and the celluloid and wire tag (Fig. 3). In the former the rubber is passed over the rostrum and the metal hook over the posterior end of the telson. In the latter, as explained in the case of crabs, the tag consists of a bright celluloid strip bearing serial number, etc., and a piece of stainless steel wire. It is attached to the dorsal surface of the carapace by the wire going round the body of the animal. All these tags have the disadvantage of being lost when the animal sheds.

Recently Gundersen in his experiments on the lobster *Homarus vulgaris* used three methods. In the first method he used the Norwegian suture tag for crabs. The internal tag is put in through a hole made in the dorsal midline of the carapace. In the second method the same tag is used and the internal part is put inside the lobster through the soft skin between the carapace and abdomen on the dorsal side. In the third method an external crab tag is fixed to the lobster by nylon gut. The nylon gut is thread through the lobster by means of a curved needle which is stung through the lobster dorsally from side to side in the soft part between carapace and abdomen.

Allen and Costello (1963) has experimented with biological stain injection for marking the Florida Spiny lobster *Panulirus argus*. Two stains were used, one a 0.25 per cent aqueous solution of trypan blue and the other a 0.5 per cent solution of fast green. Injections are made laterally into the abdomen at the articulation of the fourth and fifth segments where the needle is inserted its full length at an angle of about 45 degrees. Almost immediately after injection the lobsters acquire a general faint bluish or greenish tinge, depending upon the stain used, which could be seen through the more transparent portions of the exoskeleton and disappearing within 2 days. The gill filaments are clearly marked with the stains even after holding in laboratory tanks over 40 days. The colour is also found to be retained after moulting. But as in the case of crabs detection of the stains is difficult without lifting the carapace. Hence this method could be used only where captures could be examined by trained observers.

RESULTS

Allen (1916) tagged *Panulirus interruptus* in California and observed some migratory movements. The largest migration reported by him was 9.6 miles in 28 days and he found that size and sex had no bearing on the direction or extent of the movement. Von Bonde *et al.* (1935) reports experiments carried out by Gilchrist in South Africa on the migration of the cape crawfish or rock lobster *Jasus lalandii*. These experiments revealed that considerable movements do take place but in a haphazard manner. A maximum movement of 13½ miles in 11 days was observed.

Templeman's (1935 and 1940) tagging work gave some very interesting results on the movements of *Homarus americanus* in the Gulf of St. Lawrence and New Foundland waters based on the tagging recoveries of a considerable extent. Sheard (1949) did tagging and punch marking tests on about 10,000 Western Australian crayfishes *Panulirus longipes* and got a maximum of 11.6 per cent recoveries, which gave distinct results about the direction and rate of movement of the crayfish over the Abrolhos fishing grounds in Western Australia, the rate and nature of replacement of the population under fishery conditions, the duration of the intermoult period at different sizes and growth increments. Some crayfishes marked and released in 1947 were recaptured after about 9 months showing an increase in length from 0.7-1.1 inch during the period. George (1958) and Sheard (1962) give valuable results on the mean growth increments over 1 and 2 years in white crayfish.

Dawson and Idyll (1951) give results of extensive tagging experiments conducted on *Panulirus argus* in Florida in 1946 through 1949. 5,345 lobsters were tagged in these 4 years and a total of 251 recoveries were made, *i.e.*, 4.7 per cent. Although most of the recoveries show a movement less than 5 or 6 miles, a few individuals had made extensive migrations over 100 miles. The longest migrations of 119 to 125 miles recorded were accomplished by 4 lobsters in 436, 451, 457 and 472 days respectively. The tagged crayfishes were free on an average of 71.5 days and the average distance travelled was 9.7 miles. They found that as a result of these movements a gradual mixing of the lobster population occurs over the whole area of the fishery. Lobsters which were free for about 6 months after release were found to have increased by a mean length of 1.14-1.22 inches. Tagging experiments by Wilder (1947 and 1953) using punch marking of holes on tail fans and Scattergood have yielded interesting results on the movements of the American lobster *Homarus americanus*. Tagging done by Thomas (1955) has helped in the elucidation of the movement of *Homarus vulgaris* on the Scottish coast.

In the beginning of 1964 experiments in tagging the spiny lobster *Panulirus homarus* have been conducted on the south-west coast of India. Dart tag quite similar to the one used in Florida has been used in these studies. Preliminary experiments with this tag has shown encouraging results regarding the suitability of the tag for field studies and tagging mortality.

CONCLUSION

Among the various types of tags used in crustacean mark-recapture experiments each tag or mark has its own advantage or disadvantage. The suitability of a tag or mark for any tagging

recapture experiment depends upon several factors such as the length of time the tag should remain on the animal, the species, personnel and other facilities available for tagging, methods of capture and handling of the specimens, etc. and all these factors have to be taken into consideration before selecting a suitable tag for a particular study. The problems in crustacean tagging experiments are all the more difficult to be solved because of the frequent shedding of the exoskeleton taking place in these animals. Nevertheless as described in the preceding pages mark-recovery experiments employing the various tags and stain injections for marking has yielded much valuable wealth of information about the movements and growth of commercially important crustaceans in their respective fishing areas which could be obtained in no other way. The success of any mark-recovery experiment, however, will depend largely upon the degree of co-operation received in the detection and disposition of recaptured experimental specimens, for which complete co-operation of the industry is absolutely essential.

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