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Summary

Several types of tags were tested on the western rock lobster *Panulirus longipes cygnus* George, seeking a multi-purpose tag having high retention through successive moults, low mortality due to tag, and no inhibition of either growth or mobility.

The Western Rock Lobster Tag was developed by combining the most suitable features of the Gundersen Tag and the Sphyrion Tag. Field trials have shown that this tag fulfilled most of the requirements although tag mutilation (owing to gregarious behaviour of this species) has not been eliminated entirely.

INTRODUCTION

Making or tagging of crustacea which undergo regular ecdyses presents problems. Tests leading to the development of a multi-purpose tag, highly effective for the western rock lobster, *Panulirus longipes cygnus* George, are described here. It should be noted that a method satisfactory for one species may be less effective for even a closely related species, due to slight differences in anatomy, behaviour, or habitat.

For short-term identification of individual rock lobsters held in aquaria, numbers painted on the carapace with epoxy-resin ("Vepox" towelling resin) have been used. This epoxy-resin is effective as it can be applied to damp surfaces, adheres well to the rough spiny shell of this species, and hardens underwater so that the rock lobsters can be returned to their tanks immediately after marking. The mark can be re-applied to the new shell a few days after each moult (at the time of measuring for growth studies).

In the field, considerable use has been made of tail punching or clipping appendages (Chittleborough 1970). This is effective when dispersion is minimal and the research team relies on its own efforts to recapture (and identify) marked individuals. A coded series of small holes punched into telson and uropods recorded the carapace length (to the nearest millimetre) at that time, while the clipping of a particular abdominal spine or pleopod identified the time of marking. Such specimens were useful both for short-term growth studies (up to one year) and also for mark-recapture estimates of population density. Even when the

holes in the telson or uropods were healed after two or three moults, the scars could still be recognized through several more moults.

Clipping or punching has limited uses since individuals cannot be distinguished and fishermen cannot be expected to recognize such marks. A tag carrying its own serial number is needed for long-term studies, especially when migration is expected.

Ideally, an effective tag should have the following characteristics:

(a) It should be retained through successive moults for up to three years. Some slight losses might be acceptable but these must be measured if the tag is to be used in quantitative studies.

(b) It should not increase mortality. Losses at the time of tagging should be distinguished from subsequent deaths (e.g. at moulting).

(c) It should not depress the growth rate (either by delaying moulting or by reducing the growth increment at the moult).

(d) It should not impair mobility or behaviour. Any such effect could lower survival (e.g. by increased predation), reduce the likelihood of recapture, or change the pattern of migration or dispersal.

(e) It should be recognized easily by fishermen. Not only is it necessary to have all tagged rock lobsters reported, but also it is important that they be identified at sea (so that locality and depth can be recorded) rather than at the processing plant.

Tags were tested initially in aquaria and if showing promise, field trials were carried out upon readily accessible reefs in a test area. In the earlier tests (1964-68), the closed-circuit seawater system situated some kilometres from the sea did not afford ideal conditions, but the main effects of the tags could be gauged by the use of untagged controls. From 1969, an open-circuit seawater system was available at the new laboratory on the coast.

TAG TESTS

1. Tag cut from rigid plastic sheet

This type of tag (see Figure 1) has been used to some extent in South Africa upon *Jasus lalandii* (Milne-Edwards) by Heydord (personal communication) and also in Cuba upon *Panulirus argus* (Latr.). Samples obtained from South Africa were tested on aquarium held western rock lobsters. Eighteen juveniles were tagged by inserting the barbs into the dorso-lateral muscles between the second and third abdominal segment, and held with eighteen untagged controls.

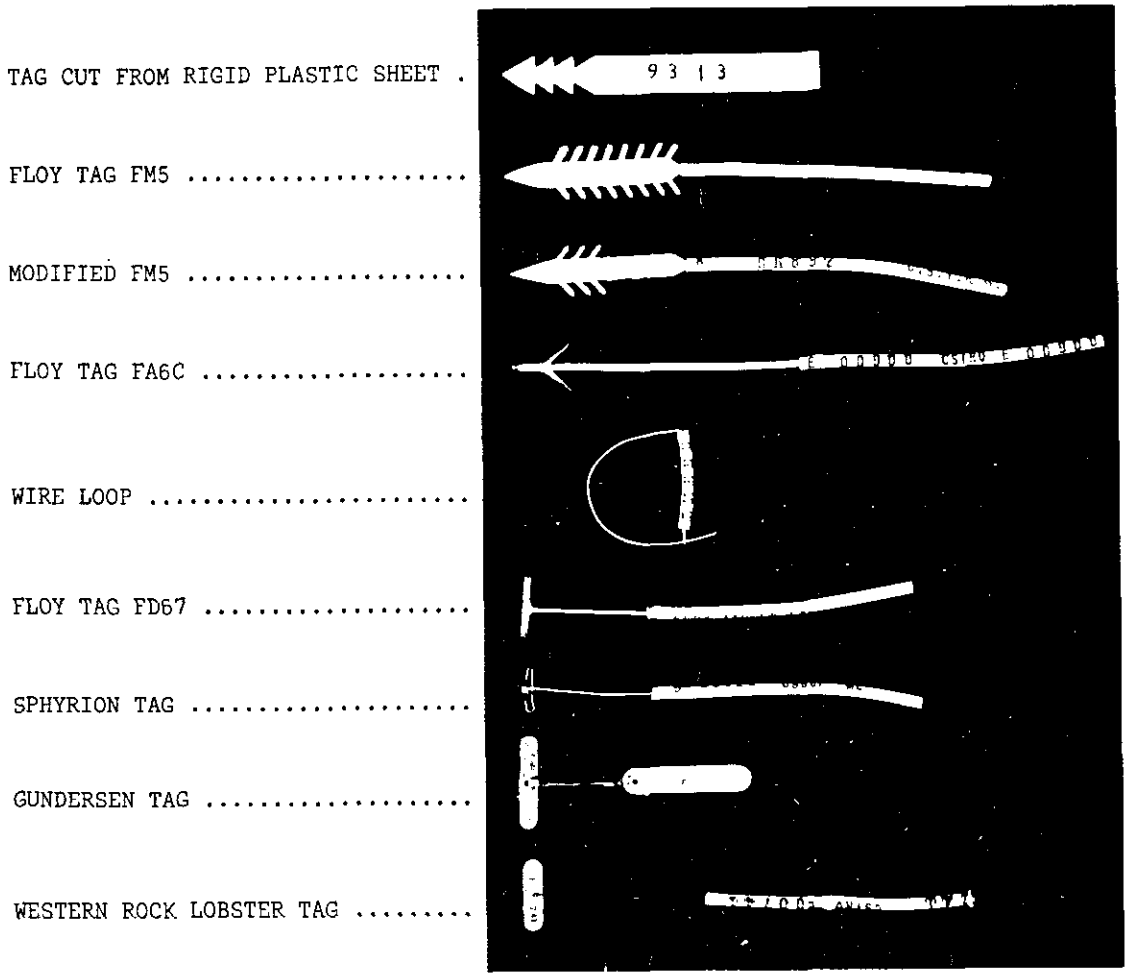

Fig. 1. Some of the tags tested for use on the western rock lobster (actual size).

There was much bleeding as the tags were inserted and the area around the tag often became severely infected, although only one specimen died as a result. The rigidity of this tag was a disadvantage, rock lobsters backing rapidly in a fright reaction often striking the protruding end of the tag on a rock or the tank wall. This tended to re-open the wound, and in two cases, broke the tag leaving the barbed head in the muscles. Only three of the tagged rock lobsters moulted during the three months of this test. Tags were held in each case but the growth increments (1.0, 1.4, 1.7 mm) were much less than those of controls (3.0 - 4.7 mm).

Rock lobsters carrying this tag did not extend the tail as often or as fully as the controls. There appeared to be some loss of mobility which would be undesirable in the field as migration might be restricted and both survival and recapture of tagged individuals diminished.

2. Floy Tag FM5

This was one of a series of tags made by Floy Tag and Manufacturing Inc., 4616 Union Bay Place NE, Seattle, Washington 98105, U.S.A. This tag (Figure 1) has been used in Hawaii on *P. japonicus* von Siebold by Morris (personal communication) apparently with some success (recoveries up to 17 per cent).

Eighteen juvenile western rock lobsters were tagged with this tag and held with the 18 untagged controls. There was extensive bleeding as the tags were inserted. Six tagged animals died from four to nine days after tagging, the muscle around the tag being dark and necrotic. During the next few weeks, the numbered plastic tubing broke away from the head of three of the tags, making these ineffective.

When the test was terminated after 137 days, the remaining nine tagged rock lobsters had moulted once, seven shedding the tag (and one animal dying after moulting), so that only two of the original 18 tagged rock lobsters succeeded in carrying the tag through a moult. During the same period the controls all moulted successfully.

Once again, the tagged rock lobsters appeared to have difficulty in straightening the tail, a slight hump being evident at the point of insertion of the tag, even at the end of the test period.

3. Modified FM5

In an attempt to make the multibarb tag more effective, the last five pairs of barbs were removed, in the expectation that the wound would heal better behind the front three barbs. Thirty rock lobsters were tagged, half being first treated with antiseptic on the surface of the site of tagging.

Neither the removal of barbs nor the treatment with antiseptic made any improvement. Seven animals died three to four days after tagging, nine tags lost the numbered plastic tubing, seven tags were

shed during the first moult, three held the tag through the moult but died within 48 hours, leaving four from the original 30 surviving with the tag intact after one moult. The growth increment at moulting of the tagged specimens was less than that of the untagged controls.

4. Floy Tag FA6C

This single barb tag has a long shaft specified by Olsen (personal communication) for use on the southern rock lobster *Janus novaehollandiae* Holthius. In a test of this tag, 18 juvenile rock lobsters were tagged and held with untagged controls of the same size range. Two tagged animals died after tagging (at four and eight days), the muscle around the tag being severely infected. By the 105th day after tagging, the remaining 16 tagged rock lobsters had all moulted but 13 had either shed the whole tag or lost the numbered plastic tubing. Three retained the tag through the moult, but two died within a few days, apparently as a result of infection through the re-opened tagging wound. Thus only one of the 18 survived a moult with tag intact. The untagged controls moulted without any deaths.

During 1964, B.K. Bowen (personal communication) carried out a field trial of this tag (FA6C) at the Abrolhos Islands. A total of 1199 western rock lobsters were tagged and also marked with an arrow-shaped tail punch, while 912 received a heart-shaped punch mark on the telson but were not tagged. Comparison of recovery rates from the two groups (within the same reed area) indicated that in two months at least 64 per cent of the tagged rock lobsters had either died or lost their tags. Mutilation of tags was higher in the field than in aquarium tests. In one series of 90 tags recaptured approximately two months after tagging, the plastic tubing of 32 was so bitten that the tag number could not be identified.

5. Wire loop

This was modified from the Suture Tag of Edwards (1965). In a preliminary trial (carried out in the closed-circuit system during 1965), a loop of suture wire 0.2 mm diameter was inserted through the dorsal muscles between the carapace and the first abdominal segment using a curved needle. A short length of plastic tubing over the exposed portion of the loop carried the number identification. The splitting of the membrane immediately behind the carapace at ecdysis was expected to favour retention of this type of tag.

Ten juvenile rock lobsters tagged in September all survived the initial tagging and moulted during the following eight weeks. Only two tags were shed at the moult. Growth increments may have been depressed but loss of controls prevented a proper comparison. The preliminary trial was sufficiently encouraging to warrant further tests.

Early in 1966, a further test of the wire loop tag was commenced, the stainless steel wire being 0.6 mm in diameter, rigid enough to be inserted without using a needle yet soft enough for the free end to

close the loop easily (Figure 1). Fifteen juvenile rock lobsters were tagged immediately behind the carapace as before and held in the closed-circuit aquarium. Little bleeding occurred during tagging and little infection occurred subsequently.

One rock lobster died four days after tagging and the tag was torn from another specimen within one month of tagging (not having moulted). The remaining 13 held the loop tag through the first moult but three animals died soon after moulting. At least one of these deaths was due to a temporary failure in water circulation (moulting rock lobsters being highly sensitive to a decreased oxygen supply). The remaining ten tagged specimens all survived a second moult, only one shedding the tag. Growth increments (mean 2.80±0.34 mm at first moult, 2.35±0.76 mm at second moult) were not particularly good, but comparisons could not be made owing to circulation problems in different tanks. However, the relatively good retention of the loop tag led to a field trial on one of the test reefs.

In February 1967, a total of 146 juvenile rock lobsters were tagged with loop tags and returned to a small section of reed in the test area at Garden Island ($32^{o}10'S.$, $115^{o}39.5'E.$). Other juveniles were tail punched and pleopod clipped on adjacent segments of reef for growth and census measurements.

During September, 301 rock lobsters were trapped on the section of reef where the tagging had been carried out. Of these, 38 carried loop tags and four more carried scars or remnants of wire showing that they had been tagged. Many other rock lobsters (1329 animals) were trapped on adjacent segments of reef during September and October, none of these carried loop tags, showing that there had been practically no dispersal of tagged individuals away from original reef site during that period.

The total population of rock lobsters inhabiting the tagging site in September was estimated to be 382±78 animals. This was calculated by the single census method, marking (pleopod clipping) independently of the loop tags. Assuming that 38/301 of this reef population carried loop tags, the total numbers of tagged rock lobsters surviving to that date would be 48. The natural mortality coefficient of juvenile rock lobsters in this area, measured as described by Chittleborough (1970), on an adjacent segment of reef between January and September 1967, was .026 per week. Then in the 29 weeks between tagging and recapture, the group of tagged rock lobsters would have been expected to decrease from 146 to 69 by natural mortality. The number calculated to have survived was 48 tagged rock lobsters, so that the estimated tagging mortality was 21/69 or 30.4 per cent over the period of 29 weeks.

From the condition of tags and tagging scars at the time of recapture, loss of tags could be expected to continue, and also further deaths would occur as tearing during moulting had resulted in some tag sites becoming re-infected. The rigidity of the wire had caused distortion of the posterior margin of the carapace during moulting of some specimens, the buckling sometimes interfering with the precise measurement of carapace length.

Growth (increase in carapace length) of 24 rock lobsters which carried the loop tag intact for the 29 weeks ranged from 0 to 4 mm with a mean of 2.2 mm. This represented poorer growth than that of 108 rock lobsters recaptured at the same time, after tail punching at the beginning of the year. In these, growth ranged from 1 to 11 mm with a mean of 6.6 mm.

Despite some initial promise, the wire loop tag did not prove to be sufficiently good to warrant further development.

6. Floy Tag FD67

This type of tag has been used to tag teleost fish (Lenanton, personal communication) and also prawns (Lucas, Young and Brundritt, 1972; Penn, personal communication).

Twelve juvenile rock lobsters were tagged in February, 1968. The anchor bar of the tag was injected into the dorso-lateral muscles between the carapace and the first abdominal segment. No deaths occurred immediately after tagging, but four died when the circulation failed five weeks later. Dissection of the dead specimens showed that two of the tags would have been lost shortly. Of the surviving eight tagged rock lobsters, one lost the tag without moulting, six shed the tag during the first moult, while the last remaining animal held the tag through the moult but died next day when the water circulation failed.

This type of tag appeared quite unsuitable for the western rock lobster.

7. Gundersen Tag

This was first used by Gundersen (1962) on the crab *Cancer pangurus* (L.) and later on the lobster *Homarus vulgaris* (L.). Mohamed and George (1968) have also used this tag on *Panulirus homarus* (L.) with some success.

Twelve juvenile western rock lobsters were tagged by inserting the anchoring toggle into the muscle dorso-laterally between the carapace and first abdominal segment. This test was commenced during February 1968, in the closed-circuit seawater system using tags obtained from Norway. Two animals died without having moulted. The remaining ten all retained the tag successfully through the first moult. Seven moulted again before the test was terminated, each retaining the tag. The untagged controls were lost due to a circuit fialure early in the test, but the mean growth increment per moult of the tagged animals (3.04 mm) compared favourably with that of controls from tests in previous years in the same seawater system.

Early in 1969, another test of this type of tag was commenced (in the new open-circuit seawater system). On this occasion, the tags were made locally so that the test was partly to check the effectiveness of the sheet plastic from which the tags were made.

Twelve juvenile western rock lobsters (carapace lengths ranging from 42-52 mm in an attempt to use a single age group) were tagged as before, and held with twelve untagged controls of similar size. Because they were also part of another experiment on feeding rates, both groups were fed three times a week. This has some bearing on the interpretation of the results.

During the 44 weeks of this test, all the rock lobsters moulted, most moulting twice, some three times. The twelve tagged animals underwent a total of 25 moults without any deaths occurring. Only one tag was shed (at that individual's second moult). The twelve controls also achieved a total of 25 moults with no deaths occurring. Tagging did not depress the frequency of moulting. The growth increment per moult of the tagged rock lobsters (range 0.1 - 5.3 mm, mean 2.7 mm) did not differ significantly from that of the controls (0.0 - 4.9 mm; 2.7 mm). However, in both groups, the moult increments were less than in other rock lobsters which had been fed daily.

The aquarium tests were sufficiently encouraging to warrant a field trial of this type of tag. In January, 1970, a total of 207 juveniles (carapace lengths ranging from 40-80 mm) were tagged and released in one segment of reef in the test area at Garden Island. Each was given a secondary mark by clipping one of the abdominal spines. On an adjacent reef, marking (by clipping another spine) was carried out in order to compare mortality on the two reefs and tail punching was also carried our to compare growth rates.

Recaptures after four weeks showed the tags to be holding well and in good condition but this was to be expected as most animals had not yet moulted since tagging. One defect was that on some tags, the printing was lifting from the plastic. This was more serious after twelve weeks (Table 1), but by that time, a much greater problem was becoming evident. The external portions of many of the tags apparently had been chewed by other rock lobsters, obliterating the printing and even cutting off the plastic plate completely. This problem increased with time so that after 42 weeks, less than 8 per cent of the recaptured tagged animals could be identified. However, Table 1 shows that the field trial confirms the low losses by shedding of the whole tag (mainly at moulting), already indicated in the aquarium tests.

This test underlines the need for field trials of tags, rather than to rely completely on aquarium tests. In the aquarium tests, tagged rock lobsters were held in small groups furnished with individual shelters so that mutilation of the tags was not a serious problem. However, in wild populations, the gregarious behaviour of these rock lobsters led to much more mutilation of tags by biting and chewing. This appeared to increase further under stress conditions when a group was confined in a trap.

At the first moult after the trial commenced, the mean growth increment of the tagged rock lobsters did not differ significantly from that of the tail punched animals.

The natural mortality coefficient measured (as described by Chittleborough, 1970) during 1970 on a reef adjacent to that of tagging was 0.09×10^{-2} per week. Then at 34 weeks after tagging, natural losses would have reduced the tagged group from 207 to 200 individuals. The total stock on the tagging reef at 34 weeks (measured by single census method not using the tags) was estimated to be 410±48 rock lobsters. As 71/192 of these had been tagged (Table 1), the total number of the tagged group surviving after 34 weeks was 152 animals. Thus, of 55 deaths occurring in the tagged group over the 34 week period, 48 were caused by the tag. This represents a tagging mortality of 24.0 per cent.

The most serious defect in using the Gundersen Tag on western rock lobsters was the mutilation of the external segment of the tag. In an attempt to overcome this, the flat plate was replaced with plastic tubing carrying the identification number. Tests of these modified Gundersen Tags were carried out at the same time as the field trial of the Sphyrion Tag reported below.

8. Sphyrion Tag

This tag was developed by Scarratt and Elson (1965) for use on salmon and lobsters and later applied in research upon *Homarus americanus* (Cooper 1970, Scarratt 1970). It was used by Little (1972) on *Panulirus argus* though recaptures in this species were low and did not extend over a long period.

After the high loss rate of Floy Tag FD67 from western rock lobster, it was thought unlikely that the Sphyrion Tag would be satisfactory for this species as the anchoring toggle was no larger than that of Floy Tag FD67. A relatively small test was set up in constant temperature aquaria (at 26°C), eight juvenile rock lobsters being tagged dorso-laterally immediately behind the carapace using the Sphyrion Tag. Three animals died a few days later, but this was apparently due to oxygen deficiency because of poor circulation of water, rather than from infection at the site of tagging. The remaining five tagged animals achieved a total of ten moults without shedding a tag, a better result than had been anticipated.

Accordingly, a field trial was set up, in which the effectiveness of the Sphyrion Tag was compared with a modified Gundersen Tag (toggle of flat plastic, 14 x 3 x 0.6 mm, as before, but external flat section replaced with plastic tubing carrying identifying number). The anchoring ability of the Gundersen Tag had been verified, but the modification was aimed at lessening mutilation of the external portion by other rock lobsters.

During January, 1971, in the test area at Garden Island, 195 juvenile rock lobsters were tagged with the Sphyrion Tag and 183 others with the modified Gundersen Tag. During the same month, 314 juveniles were tagged on a test reef at Seven Mile Beach (29°08'S., 114°53'E.) using the modified Gundersen Tag. As a means of checking on tag loss,

TABLE 1

TRIAL OF GUNDERSEN TAG ON TEST REEF AT GARDEN ISLAND. RECAPTURES SUBSEQUENT TO TAGGING 207 JUVENILE WESTERN ROCK LOBSTERS IN JANUARY 1970.

Weeks since tagged	Total catch	Total tagged recap'd	Tags still intact	Tags shed	Tags illegible	
					Printing lifted	Chewed
4	139	65	60	0	4	1
12	131	54	28	0	10	16
34	192	71	7	3	2	59
38	202	73	8	0	2	63
42	160	53	4	0	0	49

TABLE 2

COMPARISON OF RECAPTURES FROM TWO TYPES OF TAGS TESTED ON REEF C AT GARDEN ISLAND DURING 1971

Tag type	Numbers Tagged Initially	Time lapse to recapture									
		5 weeks		13 weeks		31 weeks		35 weeks		39 weeks	
		No.	%	No.	%	No.	%	No.	%	No.	%
Sphyrion Tag	96	27	28.1	37	38.5	38	39.6	20	20.8	20	20.8
Modified Gundersen Tag	93	27	29.0	33	35.5	34	36.6	19	20.4	18	19.4

TABLE 3

LOSSES FROM TWO TAG TYPES AT SUCCESSIVE INTERVALS DURING FIELD TRIALS ON JUVENILE WESTERN ROCK LOBSTERS

Tag - recapture interval (weeks)	Test at Garden Island						At Seven Mile Beach		
	Sphyrion Tag			Mod. Gundersen Tag			Mod. Gundersen Tag		
	Total recap.	Tag lost		Total recap.	Tag lost		Total recap.	Tag lost	
		No.	%		No.	%		No.	%
5	67	1	1.5	57	0	0	76	0	0
13	99	12	12.1	57	6	10.5	61	1	1.6
31	80	12	15.0	67	5	7.5	117	2	1.7
35	38	8	21.0	41	4	9.8	42	0	0
39	33	6	18.2	31	3	9.7	59	0	0
52	56	15	26.8	62	8	12.9	71	4	5.6

TABLE 4

PROPORTIONS OF RECAPTURED TAGS WHOSE EXTERNAL PLASTIC TUBING HAD BEEN MUTILATED BEYOND RECOGNITION OF TAG NUMBER

Tag - Recapture interval (weeks)	Garden Island			Seven Mile Beach		
	Total tags recap.	Chewed beyond identification		Total tags recap.	Chewed beyond identification	
		No.	%		No.	%
5	123	0	0	76	1	1.3
13	138	2	1.4	60	0	0
31	130	11	8.5	115	7	6.1
35	67	9	13.4	42	2	4.8
39	55	5	9.1	59	6	10.2
52	95	13	13.7	67	12	17.9

each individual tagged was given a secondary mark by clipping a spine, distinguishing the type of tag used and reef upon which released.

Mortality due to tag: In this case, it is only possible to compare the recaptures of the two types of tags and assume that the mortality generated by the modified Gundersen Tag was the same as that recorded in the previous section for the Gundersen Tag. Table 2 shows that very similar proportions of the rock lobsters originally tagged with the two different types of tags were recaptured each time re-trapping was carried out. Intense fishing over the whole test area twelve months after tagging resulted in the recapture of 28.7 per cent of those originally tagged with Sphyrion Tags and 33.9 per cent of those originally tagged with modified Gundersen Tags. This shows that the mortality generated on this species by the Sphyrion Tag was practically the same as that generated by the Gundersen Tag. (For this comparison, the retention or condition of the tag at the time of recapture was not considered.)

Tag loss: From the marked animals recaptured throughout the year following tagging, the proportion which had shed the entire tag was recorded (Table 3). After five weeks of freedom, very few tags had been lost because few of the rock lobsters had moulted in that time. After 13 weeks, when all of the juvenile rock lobsters had moulted once, 12.1 per cent of the Sphyrion Tags had been shed. This is the same loss per moult as recorded by Cooper (1970) from *Homarus americanus* tagged with the Sphyrion Tag. Losses of Sphyrion Tags continued at subsequent moults though at a slightly lower rate (7-8 per cent per moult) so that at the end of a year (during which these juveniles would have had an average of close to three moults each), 27 per cent of the Sphyrion Tags had been lost.

Losses of the modified Gundersen Tag also occurred during the first moult after tagging, but few were shed throughout the rest of the year (Table 3). This type of tag then has a distinct advantage over the Sphyrion Tag for use on the western rock lobster.

Table 3 shows that there was a clear difference in the loss rate of modified Gundersen Tags between the two reef areas in which it was tested. The same research staff applied the same tagging technique to juveniles of similar size in the two areas. There are differences between the two localities, both in habitat and in population density. If either of these cause the loss rate of tags to vary significantly, it will not be possible to apply a single measurement of loss rate to all localities.

Tag mutilation: As the numbered plastic tubing of the external portion of the Sphyrion and modified Gundersen Tags were the same, recoveries of the two types were pooled when considering mutilation (biting or chewing) by other rock lobsters. Marked animals which had shed the whole tag were not included for consideration here.

Table 4 shows that loss of identity of tags increased throughout the year, the problem being of similar magnitude at both localities.

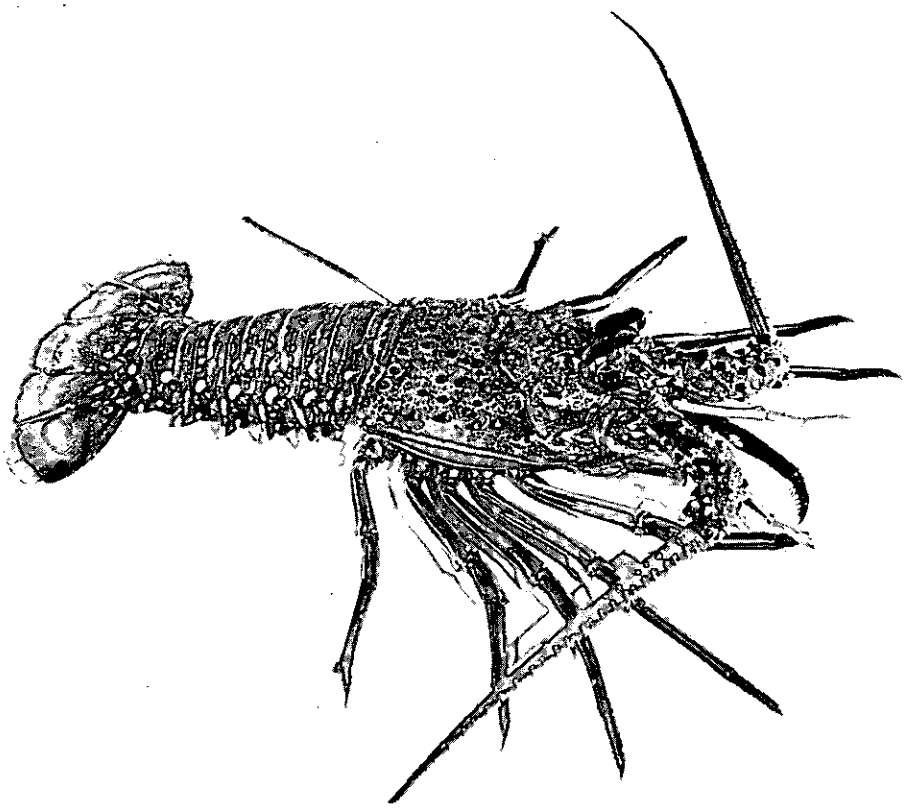

Fig. 2. Tagged juvenile western rock lobster.

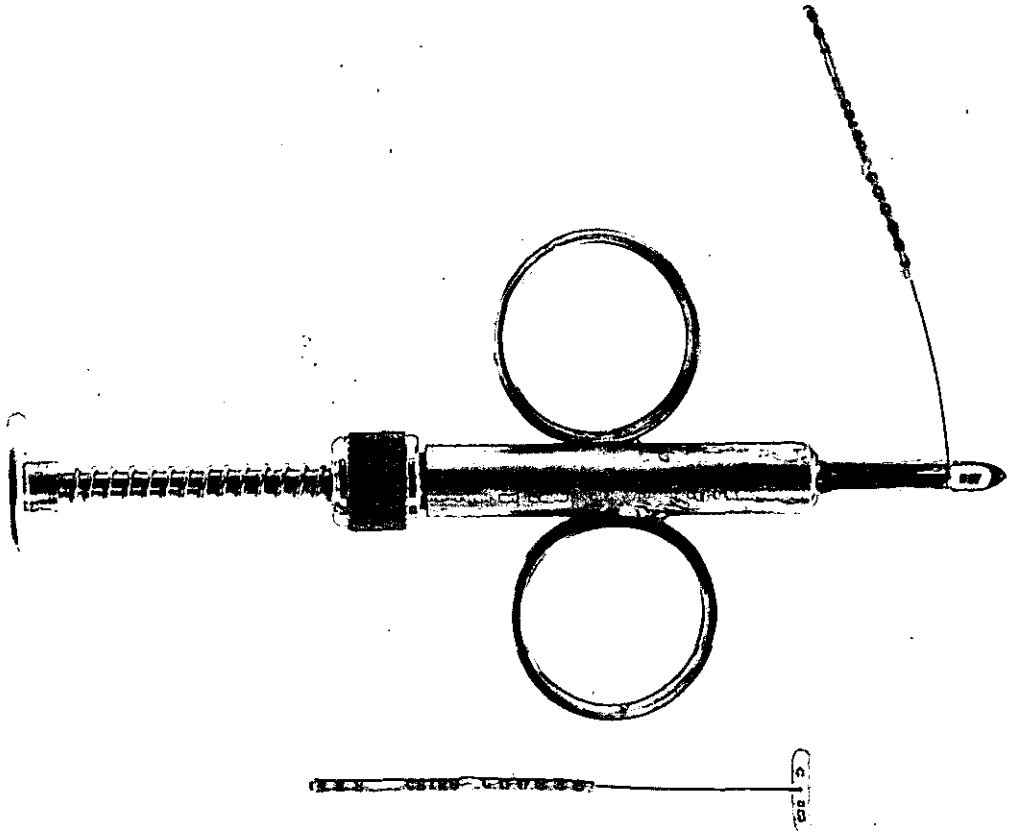

Fig. 3. Western rock lobster tags and applicator.

However, comparison of Tables 1 and 4 shows that the plastic tubing suffered far less mutilation than the flat plastic of the original type of Gundersen Tag.

Tagging and Growth: If tagging depressed growth, the effect is likely to be more pronounced at the first moult than at subsequent moults. Table 5 shows that the growth increment at first moult after inserting the Sphyrion Tag was slightly less than that after applying the modified Gundersen Tag, but this difference was not significant ($P>0.05$). Tail punching was not carried out at Garden Island during 1971, but the growth increments at first moult after tagging were only slightly less than those tail punched in previous years. However, direct comparisons are difficult owing to variation in moult increments from one year to another. These variations will be considered in detail in a separate study.

9. Western Rock Lobster Tag

The tag now in use for research on the western rock lobster (Figure 2) was developed from the tests described above. Because it was thought that the relatively long anchoring toggle (14x3x0.6 mm) might contribute to the mortality due to tagging (see Section 7 above), the toggle length was reduced from 14 mm to 11 mm. In order to overcome (at least partially) the problem of loss of tag identity due to mutilation of the external plastic tubing, the number was printed on the internal toggle as well as on the plastic tubing.

The flat toggle piece was made and numbered by Howitt Plastics Co. (Molalla, Oregon, U.S.A.), the numbered plastic tubing obtained from Floy Tag & Manufacturing (Seattle, Washington, U.S.A.), and the tags assembled at this laboratory. Polypropylene filament (dia. 0.3 mm) was selected to join the two sections as polypropylene melts back from a heat source to give a locking mass at the end of the filament without loss of strength. In assembling a tag, a double knot was first tied in the polypropylene filament and this knot pulled down inside the plastic tubing to the mid-point. This knot helped to lock the filament into the plastic tubing. The free end of the thread away from the numbered end of the plastic tubing was then cut leaving 2 mm of filament extending beyond the tubing. This free end was then held close to a heat source unitl the polypropylene melted back to form a lump just inside the tubing. The end of the plastic tubing also became swollen from the heat. This could be an advantage, making it more difficult for other rock lobsters to pass the free end of a tag between their mandibles. The filament was then cut 30 mm from the plastic tubing, and inserted through the central hole of the toggle section. By applying heat to the free end of the filament, a locking lump melted back, leaving the filament between the two numbered sections at approximately 27 mm.

These tags were inserted using an applicator (Figure 3) having a hollow, sharpened blade. The toggle was injected into the muscle to one side of the mid-dorsal line, between the carapace and the first abdominal segment. The plunger then ejected the toggle from the applicator. In practice, it was not found necessary to insert the toggle very deeply into the muscles.

TABLE 5

INCREASE IN CARAPACE LENGTH (mm) OF JUVENILE ROCK LOBSTERS AT FIRST MOULT AFTER TAGGING AT GARDEN ISLAND IN JANUARY, 1971

Tag type	Males				Females			
	No.	Range	Mean	s.d.	No.	Range	Mean	s.d.
Sphyrion Tag	31	2.6-6.5	4.25	0.95	50	0.5-5.5	3.62	1.08
Mod. Gundersen Tag	22	2.0-6.6	4.43	1.19	26	2.0-5.9	3.87	1.11

TABLE 6

INCREASE IN CARAPACE LENGTH (mm) OF JUVENILE ROCK LOBSTERS AFTER TAGGING AND TAIL PUNCHING AT GARDEN ISLAND IN JANUARY 1972

A. Growth increment at next moult

	Males				Females			
	No.	Range	Mean	s.d.	No.	Range	Mean	s.d.
Tail punch	21	2-7	5.52	1.33	19	1-7	4.42	1.57
W. rock lobster tag	11	2.6-7.7	5.29	1.44	15	0.8-6.1	4.14	1.45

B. Growth over 12 months

	No.	Range	Mean	s.d.	No.	Range	Mean	s.d.
Tail punch	14	5-17	10.07	3.29	9	6-15	10.22	3.67
W. rock lobster tag	11	4.3-18.7	10.28	5.19	17	5.5-14.5	9.73	2.83

During January, 1972, tags of this type were inserted into 157 juvenile rock lobsters on a test reef at Garden Island. Another 135 juveniles on the same reef were marked by tail punching. Because of a residue of previous marking and tagging trials in the test area, it proved difficult in this instance to separate mortality due to the tag, shedding of tags (at moult), and those whose numbered plastic tubing had been chewed beyond recognition. However, an estimate could be made of the survival of tagged rock lobsters through all three forms of losses by comparing the ratio of those tagged and tail punched in January (157:135), with the corresponding ratio in the catch taken in October, 39 weeks later (36 intact tags:40 punched). Had there been no deaths due to tagging, loss of tags at moulting, or chewing of numbered plastic tubing, 47 tagged animals should have been recaptured in October to maintain the original ratio. This represents an overall tag loss of 23 per cent over the period of 39 weeks. Corresponding tag loss of the modified Gundersen Tag over a period of 34 weeks was estimated to have been 41 per cent (24 per cent dying as a result of tagging, approximately 10 per cent of the survivors shedding the tag and some 11 per cent of the remaining tags mutilated). On this basis, the western rock lobster tag represents an improvement on the modified Gundersen Tag.

This field trial enabled the effect of the western rock lobster tag on growth rate to be checked. At the first moult, the mean increments of the tagged males and females were both slightly below those of the tail punched controls (Table 6), but the differences were not significant ($P>0.05$). After one year of freedom on the test reef, the total growth of those tagged and tail punched (Table 6) again did not differ significantly. Thus the western rock lobster tag can be used reliably for studies of growth in this species.

It is of interest to note that the mean growth increments per moult recorded in Table 6 are higher than those of Table 5. In some cases, for example, the Sphyrion Tag test of 1971 vs. those tail punched in 1972, the differences were significant (for males, $P<0.001$; for females $0.01<P<0.05$). However, it is not clear whether such differences can be attributed to improvements in marking technique or to real differences in growth of rock lobsters at Garden Island from 1971 to 1972. This underlines the need for uniform controls in all such trials.

DISCUSSION

Most of the tags tested on the western rock lobster failed to meet one or more of the requirements listed in Section I.

In the development of an efficient tag for use in research upon this species, it soon became clear that the abdominal tergites of this species fitted too closely together to permit tagging between them. The dorso-lateral muscles immediately behind the carapace afford a suitable tagging site, but in this species, a relatively large anchoring toggle is required.

The shaft of the tag needs to be thin and flexible, otherwise the rear edge of the carapace becomes buckled at ecdysis.

The western rock lobster is highly gregarious, and individuals apparently clean off raised epiphytes growing on the exoskeletons of their fellows, leading to a problem of mutilation of tags by chewing. Tags having flat external sections are more vulnerable than those having plastic tubing; flexible shafts to the tags may also keep the external section down against the body, and thus less likely to be chewed by other rock lobsters.

Colour preferences were not tested in the tagging trials. Most of the tags tested were orange in colour. It may have been coincidence that the worst chewed tags were white (locally made Gundersen Tags).

The tag described here as the Western Rock Lobster Tag is the most effective available at present for this species. It has a high reliability for studies upon growth and movements of rock lobsters. For quantitative studies (mark-recapture estimations of population density), some further calibration of tagging mortality and loss rate at moulting is desirable. This would entail tagging (with a secondary mark such as spine or pleopod clipping) on a reef and a set of untagged controls distinctively marked (by another clipping or tail punch). This should be set up at the beginning of a year and comparative survival rates followed through successive re-trapping (releasing again after examination).

Because of possible differences in loss rates from one locality to another (Table 3), quantitative tests could well be carried out in several localities. When using the Western Rock Lobster Tag on breeding females at Abrolhos Islands, G. Morgan (personal communication) observed that tag losses were apparently higher than recorded in the tests on juveniles in shallow coastal reefs.

These tags are now being used in studies upon growth and movements of juvenile rock lobsters. Over 2300 juveniles have now been tagged. Owing to the size of the toggle used (11x3 mm) only those rock lobsters having a carapace length of 40 mm or more were tagged. By concentrating the tagging in test areas closed to commercial rock lobster fishing, some individuals have been re-trapped, examined and released up to 13 times since being tagged 31 months previously. Others have travelled up to several kilometres and recaptured by commercial fishermen.

REFERENCES

Chittleborough, R.G. (1970).- Studies on recruitment in the Western Australian rock lobster *Panulirus longipes cygnus* George : Density and natural mortality of juveniles. *Aust. J. mar. Freshwat. Res.* 21 : 131-48.

Cooper, R.A. (1970).- Retention of marks and their effects on growth, behaviour, and migrations of the American lobster, *Homarus americanus*. *Trans. Amer. Fish. Soc.* 1970, (2) : 409-17.

Edwards, E. (1965).- Observations on growth of the edible crab *(Cancer pagurus)*. *Rapp. Cons. Explor. Mer.*, 156 : 62-70.

Gundersen, K.R. (1962).- Undersøkelser av krabbe *(Cancer pagurus* L.) i farvannene ved Bergen i arene 1959-60. *Fisken og Havet*, 2 : 12-17.

Little, E.J. (1972).- Tagging of lobsters *(Panulirus argus)* in the Florida Keys, 1967-1969. *Spec. Scient. Rep. mar. Res Lab. Florida Dept. Nat. Resources*, 31 : 1-23.

Lucas, C., Young, P.C. & Brundritt, J.K. (1972).- Preliminary mortality rates of marked king prawns *Penaeus plebejus*, in laboratory tanks. *Aust. J. mar. Freshwat. Res.* 23 : 143-9.

Mohamed, K.H. & George, M.J. (1968).- Results of the tagging experiments on the Indian spiny lobster, *Panulirus homarus* (Linnaeus) - movement and growth. *Indian J. Fish.* 15 : 15-26.

Scarratt, D.J. (1970).- Laboratory and field tests of modified Sphyrion Tags on lobsters *(Homarus americanus)*. *J. Fish. Res. Bd. Canada.* 27 : 257-64.

Scarratt, D.J. and Elson, P.J. (1964).- Preliminary trials of a tag for salmon and lobsters. *J. Fish. Res. Bd. Canada*, 22 : 421-3.