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1. Introduction

A yield assessment of lobster (*Homarus gammarus* (L.)) stocks requires a knowledge of growth and mortality rates, and an understanding of possible migration patterns. Mark-recapture techniques enable the estimation of the necessary parameters. Growth of large decapods such as the lobster is by ecdysis, which precludes the use of tags attached to the exoskeleton.In a study of growth and long-term migration patterns a persistent tag is essential. In recent years a number of specialised persistent tags have been developed for crustaceans, enabling long-term mark-recapture experiments to be carried out. The over exploitation of lobster stocks in both Europe and North America has resulted in an intensified search for a suitable persistent tagging technique (Gundersen, 1964, 1973; Scarratt and Elson, 1965; Cooper, 1970). The International Council for the Exploration of the Sea (ICES) Working Group on *Homarus* stocks stressed the need to develop a suitable tag which allows recognition of individual lobsters and which is retained after moulting (ICES, 1978).

As part of the Ministry of Agriculture, Fisheries and Food's expanded lobster research programme for England and Wales, a number of tagging and marking techniques were tried, both in the laboratory and in the sea. These trials led to the development of the persistent Burnham lobster tag which has subsequently been used in an extensive lobster tagging programme covering the main fisheries in England and Wales (Bennett *et al.*, 1977, 1978). This report details the trials and the development of the Burnham lobster tag, and makes an assessment of the impact of tagging technique on lobster vitality, growth, and mobility.

2. First laboratory trial

Laboratory testing of three tagging methods was started in June 1974. Lobsters obtained from Selsey, Sussex were held individually in 50ℓ tanks containing approximately 25ℓ of sea water which was continuously aerated and slowly exchanged by a continual inflow of about 60ℓ d^{-1}. The lobsters were fed with live slipper limpets (*Crepidula fornicata* (L.)) and live or frozen shrimp (*Crangon crangon* (L.)) about twice a week. The aquaria were initially kept in an unheated tank-room at ambient air temperature ranging from 12 to 21°C, but from 25 January 1975 onwards the ambient air temperature was maintained at 22°C.

Thirty-two lobsters were used, all of approximately the same size, sixteen of them male and sixteen female. Four lobsters were assigned to each of four groups of males and four groups of females, those in each group being selected to ensure that the groups had approximately the same mean size (70.1-72.4 mm carapace length).

One of four different treatments was randomly allotted to each of the four groups of males and to each of the four groups of females. The four treatments were:

(1) Control. No tags, no branding.

(2) Sphyrion tag (Figure 1a). This tag was developed by Scarratt and Elson (1965) for use on salmon and lobsters (*Homarus americanus* Milne-Edwards). It consists of an anchor of stainless steel wire, joined by a strand of monofilament polypropylene to a length of vinyl tubing with a reference number printed on it. The anchor is inserted between the carapace and the first abdominal segment, where the shell splits to allow the lobster to crawl out when moulting, leaving the rest of the tag visible externally. In these trials insertion of the anchor was made to one side of the mid-line to avoid the heart: bleeding often occurred, but the lobsters were quickly returned to water to aid blood clotting at the wound.

(3) Toggle tag (Figure 1b). This tag was first used by Gundersen (1964) on the lobster *H. gammarus.* It consists of a flat, rectangular, stainless steel toggle anchor attached by a double piece of nylon monofilament to an external, flat, rectangular, plastic tag. Both the toggle and the external tag may be numbered. The toggle is inserted between the carapace and abdomen as is the sphyrion anchor. The trial of this tag started 70 days after the other methods, due to difficulties in obtaining the toggles from Norway.

(4) Branding. A hot butane gas soldering iron was applied to the exoskeleton of the abdomen, to make red marks in a coded sequence. The underlying pigment was destroyed leaving marks which were visible on the new shell. This technique was first used on the crayfish, *Astacus astacus* Linne, by Abrahamson (1965), and was used by Dybern (1965) and Gundersen (1973) on *H. gammarus.*

During the first six months after tagging only three lobsters moulted. After the tank room was heated in January 1975, 59% of the lobsters moulted within two months and the last lobster moulted at the end of June 1975. Within the year after tagging only one lobster died. Some of the 32 lobsters were retained after the first year to observe long-term tag retention. Second and third moults occurred during the next two years, and a few moulted four times.

2.1 Tag retention

The frequency of retention of tags by lobsters after each moult in this first laboratory trial and in two of the subsequent trials is given in Table 1.

Branding did not appear to be very successful. After moulting the brands were either so indistinct that it was not possible to determine the coded number, even on very close examination, or, if the code could be read, the marks left on the new shell were so inconspicuous as to be unlikely to attract the attention of fishermen. At the second and third moults the brands virtually disappeared altogether; on a few lobsters, smooth areas of exoskeleton were discernable, but only because the observer knew there might be some visible mark.

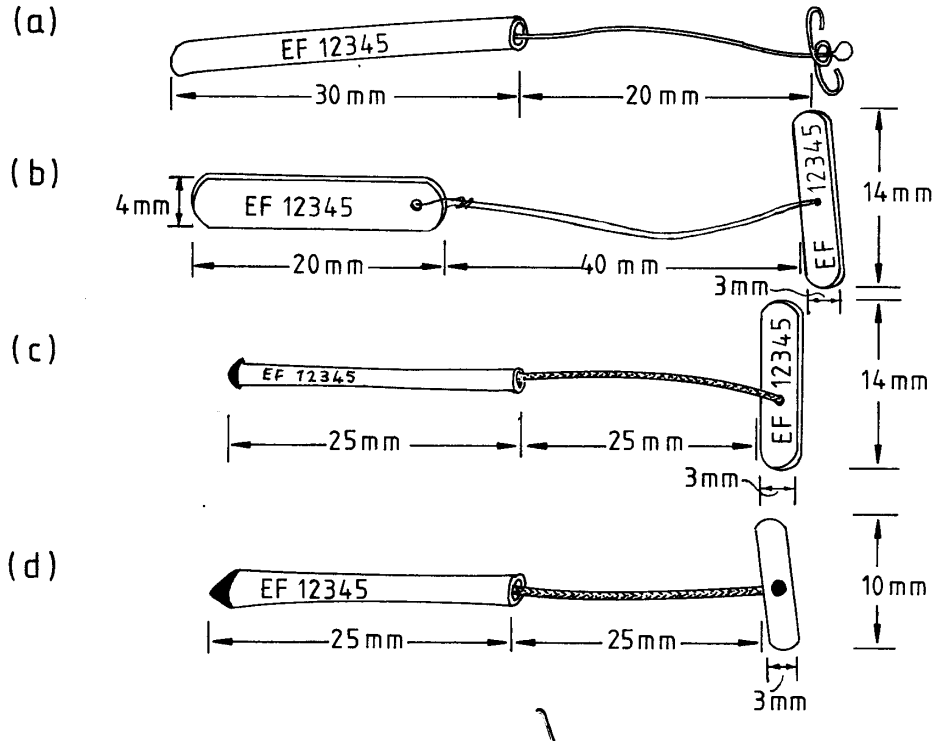

Figure 1 (a) Sphyrion tag; (b) Toggle tag; (c) Modified toggle tag; (d) Burnham lobster tag.

Table 1 Percentage of lobsters retaining tags after moulting. The number of lobsters is given in parentheses.

	Moult 1	Moult 2	Moult 3	Moult 4
First laboratory trial				
Sphyrion tag	100 (8)	100 (7)	100 (6)	67 (3)
Toggle tag	100 (8)	100 (7)	100 (4)	100 (2)
Brand	75 (8)	0 (3)	0 (3)	0 (2)
Second field trial (sample held in laboratory)				
Modified toggle tag	100 (10)*	88 (8)	100 (2)	–
Laboratory trials of the Burnham tag				
Burnham tag	100 (29)	100 (24)	100 (2)	–

* 7 of these moults occurred in the sea

Table 2 **The effects of the sphyrion tag, toggle tag, and branding on the moult increment and timing of the moulting of *Homarus gammarus*.**

	Mean premoult carapace length (mm ± SE)	Mean % increment (% ± SE)	Mean time to moult (days ± SE)
Males			
Control	71.5 ± 2.7	9.9 ± 0.7	234 ± 49
Sphyrion	72.3 ± 2.0	8.8 ± 1.3	204 ± 21
Toggle	71.1 ± 1.1	9.7 ± 1.0	(150 ± 4)*
Brand	72.4 ± 2.9	8.5 ± 1.0	223 ± 10
Females			
Control	71.0 ± 2.4	9.6 ± 1.2	261 ± 23
Sphyrion	70.7 ± 1.1	9.3 ± 0.5	275 ± 14
Toggle	71.5 ± 1.4	10.2 ± 0.7	(213 ± 8)*
Brand	70.1 ± 2.4	9.5 ± 0.2	228 ± 52

* Toggle tags applied 70 days after other methods.

Table 3 **Significance of differences between the mean % moult increments and the mean times to moult of various pairs of tagging methods.**

	Mean % moult increment				Mean time to moult			
	Male		Female		Male		Female	
Methods compared	t	P	t	P	t	P	t	P
Control/sphyrion	0.77	0.5	0.21	0.9	0.56	0.6	0.53	0.7
Control/toggle	0.16	0.9	0.46	0.7	*		*	
Control/brand	1.16	0.3	0.02	>0.9	0.22	0.9	0.58	0.6
Sphyrion/toggle	0.56	0.6	1.05	0.4	*		*	
Sphyrion/brand	0.19	0.9	0.48	0.7	0.81	0.5	0.88	0.4
Toggle/brand	0.85	0.5	0.88	0.5	*		*	

* Comparison not possible as toggle tags applied 70 days after other methods.

All of the eight sphyrion tags were retained after the first moult. One of the anchors was only partly embedded in the muscle between the carapace and abdomen and the external portion of the tag was missing; two anchors were visible at the scar around the entry point of the monofilament; the rest appeared to be well embedded. The sphyrion anchors which were still well embedded after the first moult remained well attached and were retained after three or even four moults. Where the anchors were near the surface the tag was still retained, although the anchor in one case was only just hooked into the membrane between the carapace and abdomen and that tag was eventually lost.

All eight toggle tags were retained after the first moult, although one of the toggles was visible near the surface of the musculature, and all were retained through subsequent moults. It was noticed about the toggle tag that during moulting the membrane between the old carapace and abdomen was generally torn by the rectangular part of the tag passing through, and that a portion of the old membrane remained attached to the tag for some time after moulting. While no difficulties were observed, it was felt that this necessity to tear the membrane might result in some problems during the actual moult. Dissection of dead lobsters 14-16 months after tagging showed that several of the stainless steel toggles were connected to the hepatopancreas and were encapsulated within a lump of discoloured hard tissue.

2.2 Growth

An analysis of the growth observations is given in Table 2. Table 3 lists the results of t-tests on the differences in moult increments and mean times to moult. No significant differences ($P > 0.3$) were found between the mean percentage moult increments in carapace length of the controls, sphyrion tagged, toggle tagged and branded lobsters. There were no significant differences ($P > 0.4$) between the sexes within each treatment. There were no significant differences ($P > 0.1$) between the mean times to moult of three of the treatments (toggle-tagged lobsters had to be omitted from this comparison because they were tagged 70 days later).

3. First field trial

In a field trial 299 lobsters, each with a sphyrion tag and coded brand marks, were released a few miles off Selsey Bill, Sussex in June 1974. Fishermen were asked to bring ashore any tagged or branded lobsters caught, and these were then held alive in commercial storage tanks at Selsey until laboratory staff could examine them. The market value plus a reward was paid for each marked lobster and information about its time and place of recapture.

3.1 Tag retention

Over half (52%) of the 299 lobsters released were recaptured in 1974. Most were re-released and some were subsequently recaptured again, a few up to five times. Observations on the brands indicated that they tended to fade and some perforated the exoskeleton. The sphyrion tag appeared to remain well anchored in the lobsters which had not moulted. During the 1974 fishing season (i.e., the four months or so immediately after release) only 9 of the recaptured lobsters had moulted; all of which had retained the sphyrion tags but the brands had faded on the new shell.

The majority (78%) of the 23 lobsters recaptured during the 1975 fishing season had moulted and their brand marks were very faint. Amongst those few which had not moulted, where a hole had formed in the exoskeleton, erosion of the shell was taking place. On moulted lobsters such holes had left marks on the new shell which were identifiable, but still would be unlikely to attract attention even though most lobsters are handled individually by fishermen and merchants. Most of the lobsters which had moulted had retained their sphyrion tags well, although a few had the anchor near the surface or visible in the entry wound. It was originally hoped that by both branding and tagging each lobster it would be possible to detect the loss of a sphyrion tag because the brand marks would persist. However, this was not so, because fishermen would not have noticed a lobster which had lost the sphyrion tag and bore only the faint brand marks.

Table 4 Comparison of the effects of various tagging methods on the growth of *Homarus gammarus*, sexes combined, under laboratory and/or field conditions.

	1st lab trial	1st field trial	1st field trial	2nd field trial	1st lab trial	Final lab trial	1st field trial
Size group	All	< 80 mm	> 80 mm	> 80 mm	All	< 80 mm	< 80 mm
Tag type	Sphyrion + Branded	Sphyrion & Brands	Sphyrion & Brands	Modified toggle	Controls	Burnham	Sphyrion & Brands
Number	16	11	17	11	8	22	11
Mean premoult carapace length (mm)	71.4	75.1	83.6	82.9	71.2	73.8	75.1
± SE	1.0	1.1	0.7	0.7	1.7	0.9	1.1
Mean % moult increment	9.0	12.2	9.8	10.1	9.7	9.6	12.2
± SE	0.4	0.7	0.5	0.8	0.7	0.6	0.7
P value for t-test	< 0.001		< 0.08		> 0.9	< 0.02	

3.2 Growth

The growth of sphyrion-tagged and branded lobsters released in the sea was compared with that of the similarly tagged and branded laboratory-held lobsters. Only those released lobsters of a premoult size less than 80 mm carapace length were considered, in order that their mean size should be as similar as possible tc the 71.4 mm of the laboratory-held lobsters. The mean premoult size of the 11 lobsters which moulted in the field trial was 75.1 mm carapace length, and the mean percentage moult increment was 12.2%, which was significantly ($P < 0.001$) greater than the 9.0% for laboratory-held lobsters (Table 4).

4. Conclusions from the first laboratory and field trials

The small-scale laboratory tests alone of the three marking methods (sphyrion tag, toggle tag and branding) suggested that none of the methods affected the growth of *H. gammarus*. However, comparison with the field growth results showed that growth in the laboratory was less than at sea, suggesting that the laboratory conditions rather than the tagging had reduced the moult increment.

The persistence of brand marks after moulting was not sufficient for fishermen to recognise them. Observations on the position of the internal anchor after moulting suggested that the larger and smoother stainless steel toggle was more effectively retained beneath the musculature than was the sphyrion anchor. It appeared that the small sphyrion anchor with its sharp edges at the cut ends of the wire gradually worked its way to the surface of the muscles just beneath the soft membrane between the carapace and first abdominal segment. An anchor in this position is likely to be cast off with the old shell at moulting. Gundersen (1973) found that the recapture rate of toggle-tagged lobsters was higher than that of sphyrion-tagged lobsters, which indicated a higher tag loss rate or higher tagging mortality for sphyrion tags.

The results of these first laboratory and field trials led logically to the development of a tag which combined the internal anchor of the toggle tag with the external vinyl tubing of the sphyrion tag. It was anticipated that this design would combine the apparently superior persistence of the internal toggle with the advantages of the neater and smaller external vinyl tubing. The latter offers less resistance than the larger, rectangular, external part of the toggle tag when it is pulled through the membrane between the carapace and first abdominal segment during moulting.

5. Second field trial

During May 1975 each of 203 lobsters released off Selsey, Sussex was both branded and tagged with a modified toggle tag. This consisted of the 14 x 3 x 0.5 mm stainless steel internal toggle attached by approximately 25 mm of braided terylene thread to a 25 mm length of numbered vinyl tubing, as used on the sphyrion tag (Figure 1c).

5.1 Tag retention

Although it was obvious by the end of the 1975 fishing season that after moulting brand marks were difficult to see, the staff at the lobster storage tanks had been trained to find the brands. No examples were recorded of lobsters being recognised from the brands after losing the modified toggle tag. Examination of the recaptured lobsters indicated that the toggle was well embedded in the musculature, even after moulting. Some 'infection' of the wound in lobsters which had not moulted was seen as a black, possibly necrotic discoloration, but moulted lobsters had a 'clean' wound. In a few lobsters the wound became quite large with the stainless steel toggle easily visible, although still well embedded. Some of the lobsters were recaptured more than two years after release, most of them having moulted two or three times and having retained the tag.

Ten of the lobsters recaptured in 1975 at Selsey were returned to the laboratory for further observation. Nine of these moulted, seven of which had already moulted once during the field trial. All but one of the modified toggle tags held well (Table 1). Several of these lobsters had quite large wounds, and the one tag lost was due to the toggle coming out through the wound during ecdysis. Examination of the stainless steel toggles after the lobsters had been killed showed that several were considerably encapsulated with hard, discoloured tissue.

5.2 Growth

Of the 86 lobsters recaptured in the 1975 fishing season, 15 had moulted. A further nine were recaptured in 1976 and 1977, all of which had large growth increments indicating two or even three moults. A comparison of returns from the 1974 and 1975 releases, based on lobsters of over 80 mm premoult carapace length which had moulted only once, showed that the respective mean percentage increments of 9.8% and 10.1% were not significantly different ($P < 0.8$) (Table 4).

6. Laboratory trial of the Burnham tag

The first laboratory and field trials indicated where tag and tagging technique improvements might be made. At moulting, extraction of the external portion of the tag through the membrane between carapace and abdomen was much easier with the vinyl tubing than with the flat, rectangular, external part of the toggle tag. The internal toggle was found to be more persistent than the sphyrion anchor but nevertheless still caused problems. To insert the toggle an incision was made with a scalpel, about 1-1.5 cm away from the mid-line, and the toggle carefully inserted using forceps. This did make a quite large wound which resulted in at least one toggle being lost at ecdysis. Also, considerable problems were encountered with encapsulation and possible infection by the stainless steel toggle.

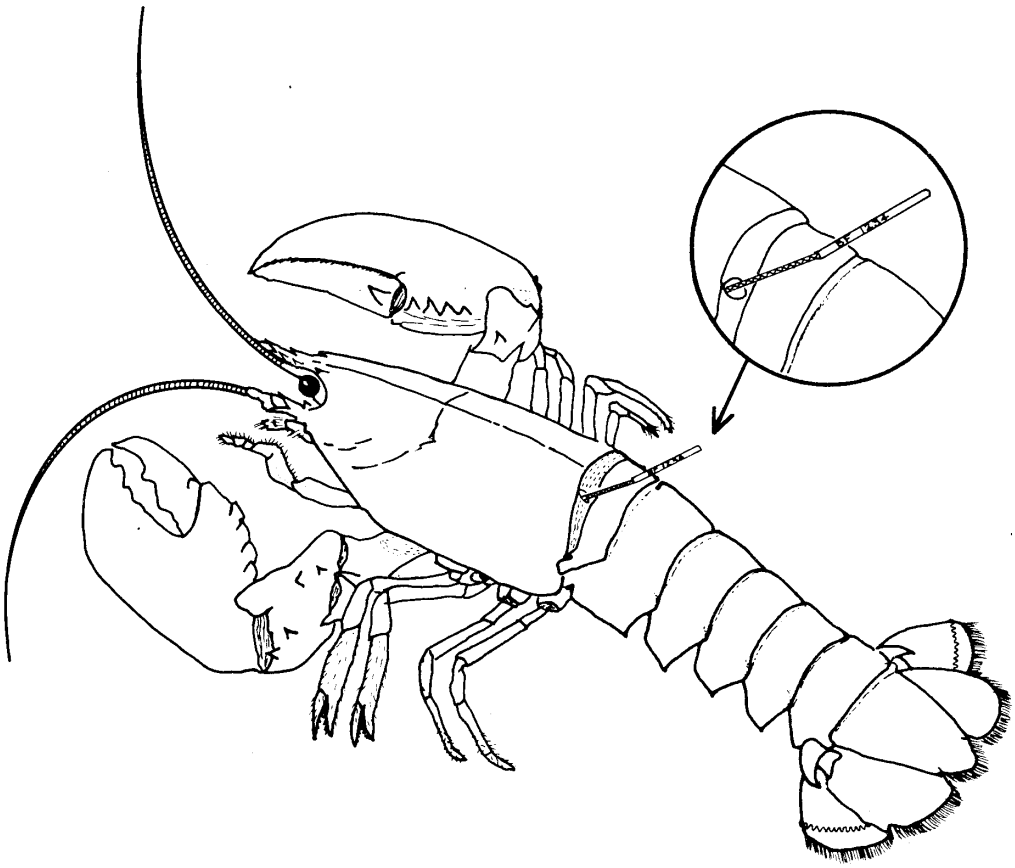

Figure 2 Lobster tagged with Burnham tag

The Burnham lobster tag (Figures 1d and 2) was constructed by threading a 25 mm length of numbered vinyl tubing and a 10 x 3 x 0.8 mm PVC toggle onto a 55 mm length of 0.8 mm diameter braided terylene. Braided terylene was chosen as it was found to be suitable for manual assembly by laboratory staff, and also because, being very pliable, it allowed the tag to lie flat on the lobster's abdomen and did not appear to hinder locomotion. The toggle was attached by heat fusion and the tubing adjusted to give a 25 mm gap between itself and the toggle and then heat fused at the opposite end. PVC was chosen as material for the toggle to reduce the 'allergic' reaction to it. To aid insertion of the toggle, minimise internal damage, and reduce the size of the entry wound, the length of the toggle was reduced from the 14 mm of the toggle tag.

Thirty-two lobsters (equal numbers of each sex) tagged with Burnham tags on 20/21 November 1975 were kept under laboratory conditions identical to those used in the first laboratory trial (see Section 2). Lack of space precluded the setting up of controls, but the main aim, which was to observe tag retention, did not require controls. The tank room was not heated, and ambient air temperature ranged from 11 to 22°C.

6.1 Tag retention

Three of the lobsters died before moulting, 1.5, 4 and 13 months after tagging: the causes of deaths were unknown. All the remaining lobsters moulted two or even three times and all retained the Burnham lobster tag (Table 1).

Dissection of many of these moulted lobsters upon death, or at the end of the experiment more than two years after tagging, showed that the plastic toggle appeared to cause no 'allergic' reaction at all, quite unlike the stainless steel toggle which became encapsulated with scar tissue. Some of the plastic toggles were covered with a thin layer of healthy-looking tissue which anchored the tag into the musculature. There was no evidence of damage to other organs, such as the hepatopancreas or gonads. As a smaller incision was required to insert the 10 mm long plastic toggle, the entry wound was much smaller than for the 14 mm stainless steel toggle, and after moulting was usually quite clean. At moulting no difficulties were observed in pulling the external vinyl tubing through the old membrane between the carapace and abdomen.

6.2 Growth

Comparisons were made between the growth of the lobsters tagged with the Burnham tag, the controls from the first laboratory trial, and the under 80 mm carapace length lobsters from the first field trial. The 22 Burnham tagged lobsters of under 80 mm carapace length had a mean first moult increment of 9.6%. This was not significantly different ($P > 0.9$) from the 9.7% for the controls in the first laboratory trial, but was significantly less ($P < 0.02$) than the 12.1% for tagged and branded lobsters in the first field trial (Table 4), which confirms the earlier conclusion that, while the tagging procedure does not appear to influence the growth rates directly, the laboratory conditions do depress the moult increment.

7. Summary and conclusions

The development of the Burnham lobster tag followed an examination of existing lobster tags and the marriage of the persistent internal toggle with the convenient and unobtrusive external vinyl tubing.

The combination of laboratory tank trials with field trials provided a considerable amount of both qualitative and quantitative information on tag retention, wound condition, tag durability, and the effects of tagging upon growth rates. The first laboratory trial showed that three different tagging techniques, the sphyrion tag, branding and the toggle tag, had no significant effect upon either moult increment or the time taken before moulting occurred. Comparison of moult increments in the laboratory and the field suggested that tank conditions reduce the moult increment. This illustrates the need for a persistent tagging technique which will allow the estimation of growth rates in the field rather than in aquaria under artificial environmental conditions.

No tagging system is ideal, but it is considered that the Burnham tag developed through this series of trials is the most suitable one available at present for long-term studies of lobster growth and migrations. It is interesting to note that quite independently we arrived at the same tag configuration as that developed by Chittleborough (1974) for the western rock lobster *Panulirus longipes cygnus* George.

The Burnham tag has since been used in a series of extensive tagging experiments in England and Wales. A total of 3,910 tagged lobsters were released off east and north-east England and off the Welsh coast in 1976-77. Recaptures from these releases have provided information on growth rates and lobster movements which has been used in a stock assessment model to assist in formulating advice on lobster stock management.

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