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MARKING STUDIES ON THE RED CRAB, *Geryon quinquedens* Smith, OFF SOUTHERN NEW ENGLAND

by

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ABSTRACT

During red crab tagging studies in upper continental slope waters off southern New England in May-June 1974, in depths of 275-1,100 m, 7,822 trap-caught red crabs (81-154 mm carapace width) were tagged with tags of vinyl tubing tied around the carapace. This type of tag is lost at molting. Through June 1981 a total of 593 recaptures were reported, mostly by red crab trap fishermen. Three recaptures were made as late as early 1981. The principal indicated movements were along the slope, with maximum distances moved of 90 km in easterly directions and 55 km towards the west. Most of the crabs moved little, however, and the majority of recaptures were within 20 km or less of release positions. Short movements up and down slope of up to about 6 km, and with depth changes of up to 500 m, also were noted. No migration pattern was apparent in any of the movements.

The tagged crabs apparently grew slowly since the intermolt period of those recaptured in 1980-81 was six to seven years or more, indicating that the harvested segment of the population (i.e., male crabs $\geq$114 mm carapace width) consists of old individuals. Some ovigerous tagged crabs were caught throughout the period of recaptures, possibly indicating that sperm stored from mating at the time of the last pre-tagging molt fertilized new masses of eggs for several years. A Peterson estimate of the fishing rate from tag returns suggested that a small number of fishing vessels could exert a significant mortality on market-sized crabs.

INTRODUCTION

The red crab, Geryon quinquedens, occurs on continental shelf and upper continental slope areas from south of Nova Scotia to Brazil (Rathbun, 1937). While some individuals are found in Gulf of Maine waters as shoal as 40 m, the bulk of the population resides in deeper areas of the outer shelf and upper slope. The presence of an extensive, concentrated, and potentially exploitable red crab population on the upper slope at depths of about 275-1,000 m from Georges Bank to off Cape Hatteras has been recognized since the late 1950's (Schroeder, 1959; McRae, 1961).

Information on this resource led to the development in 1973 of a small commercial trap fishery for the species on slope areas off southern New England, following a decline there in the catch of lobsters, Homarus americanus (Gerrior, 1981). In 1980 the red crab catch from this fishery was 2,500 metric tons. A small amount of red crab effort also began in slope waters off Delaware, Maryland, and Virginia in 1976. Reported red crab landings there in 1980 were 65 metric tons, although this likely is an underestimate of actual catch.

When the New England fishery began some efforts were undertaken to gather data on the size and extent of the red crab resource and its population characteristics (Meade and Gray, 1973; Haefner and Musick, 1974; Wigley et al. 1975). As a part of this effort 7,822 red crabs were tagged in the late spring of 1974 to obtain data on migrations, growth, and removals by the fishery. The tagging was funded by the New England Fisheries Development Program, a cooperative program of the National Marine Fisheries Service (NMFS) and the fishing industry for aiding the development of fisheries for underutilized species (Rathjen, 1974).

In addition to the NMFS (Northeast Fisheries Center, Woods Hole, MA), the state divisions of marine fisheries in Rhode Island and Massachusetts took part in the tagging. The Rhode Island division, under contract to the New England Fisheries Development Program, assembled a report covering the first year of tag returns (Ganz and Herrmann).[4/] The present report summarizes the results of the tagging through June 1981.

TAGGING METHODS

When the tagging was planned, red crabs were being fished only on upper slope grounds between Hudson and Block Canyons, south of New England (Figures 1 and 2). Since directed fishing was necessary for the recovery of tagged crabs, this was the area chosen for tagging.

The tagging was done during three trips in May and early June 1974 aboard a chartered commercial red crab fishing vessel. The tagging trips were to some extent commercial ones also, for under the charter agreement the vessel crew was permitted to catch and sell crabs surplus to tagging requirements. The method of fishing during these trips was the same as that used in the commercial fishery. The crabs were caught in rectangular lobster-style traps set in trawls of about 50 traps each.

The tagging was conducted around the clock by six taggers working in shifts of three men each. No attempt was made to select crabs for size or sex: when a trap was pulled for tagging all lively individuals in it were

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4/ Ganz, A. R., and J. F. Herrmann. 1975. Investigations into the Southern New England red crab fishery. Unpublished report Rhode Island Dept. Nat. Res., Marine Fish. Sec., 78 p.

tagged. The maximum carapace width in millimeters, measuring from tip to tip of the fifth lateral spines, and the sex of each tagged crab were recorded. Information on crab condition, such as injuries or missing legs and claws, was routinely obtained. In addition, notes on some of the ovigerous crabs were made.

The tags were of yellow vinyl tubing 1.7 mm dia (Watson, 1970). These were individually numbered and bore return instructions. The tags were attached to the crabs by simply tying them loosely around the carapace (Figure 3). Since this type of tag is lost at molting, tag returns were only from crabs that had not molted between tagging and recapture.

The crabs were caught and tagged in an area bounded by $39^{o}40'$ - $40^{o}00'$N and $71^{o}30'$ - $72^{o}00'$W (Figure 2). The first tagging trip was carried out May 16-18, 1974; the second trip, May 25-27; and the third trip, June 3-5. The crabs tagged during trips one and three were caught and released in depths of 290-365 m; those from trip two were caught and released in depths of 275-1,100 m.

Posters bearing tagging information and instructions to tag finders were posted in ports of landing. A reward of $2.00 was paid for a tag with the crab and $1.00, for a tag only. Since the landed value of a market-sized crab averaged about a half a dollar, there was some monetary incentive for returning crabs as well as tags.

Tag recoveries were mostly from commercial red crab fishing vessels, the number of which varied from one to four in New England waters in 1973-81. In addition, some tags were obtained by lobster fishermen who trap lobsters in upper slope areas a little shallower than those generally fished for red crabs.

For the most part, the returned tags and crabs were turned in to NMFS port agents who collect data on the catch. They recorded recovery location, depth, recovery date, and other available data on tag return forms and forwarded these to the NMFS laboratory in Woods Hole. A few additional tags were mailed in. In cases where the crab as well as the tag was returned, the crab was measured and sex and shell condition were noted. Except as indicated later here, the females were checked for eggs.

An attempt was made to get recovery locations for all recaptures. For many tags, however, the general vicinity fished during the particular trip was the best information available. Since vessels commonly covered a strip of slope 10 miles long or more in the course of a trip, these tag returns were of limited use for measuring crab movement.

Male red crabs are larger than females and also are heavier for a given carapace width (Haefner, 1978); fishermen therefore land only males and primarily those 114 mm (4.5 inches) carapace width or larger, which are the sizes preferred by the market. Females and undersized males are discarded at sea. During the culling process the entire catch is handled; therefore, the discards receive about the same level of scrutiny for tags as the kept catch.

The carapace measurements used throughout this report, including those for tag recaptures, are those from the tagging records. These all were made with calipers and are reasonably accurate.

RESULTS AND DISCUSSION

1. Sizes of tagged and recaptured red crabs.

In the three 1974 tagging trips combined, 7,822 red crabs were tagged. The percentage size frequencies of those tagged in each of these trips are presented in Figure 4. The range in carapace width of the males was 81-154 mm and of the females, 85-139 mm (Table 1). The first and third tagging trips were conducted in depths of 290-365 m and over the areas more frequently fished by commercial red crab vessels. The crabs from these trips therefore were similar in size composition to commercial catches before culling of discards. On the second tagging trip most of the crabs were caught in about 530-1,000 m depths (Figure 2), which is deeper than normally is fished commercially, and these crabs were smaller than those from the other two trips (Figure 4, Table 1). The mean carapace width of males in trips one and three combined was 124.7 mm, and that of females, 110.4 mm, while in trip two the mean sizes were 118.4 mm for males and 104.6 mm for females. This decreasing size with increasing depth agrees with the general finding that there are more smaller red crabs in deeper water (Wigley et al. 1975).

The absence of crabs less than 81 mm carapace width among those tagged appears to be due to these smaller sizes seldom entering traps, at least in the areas of tagging. Red crabs much smaller than 81 mm have been caught on the slope areas in otter trawls (Haefner and Musick, 1974; Wigley et al. 1975).

For trips one and three the ratio of males to females was similar at 1.44 and 1.51, respectively (Table 1). In trip two, however, the

males outnumbered the females by more than eight to one. Few female red crabs were caught beyond depths of about 650 m, a distribution pattern which agrees with the findings of Ganz and Herrmann[4/], Wigley et al. (1975), and Haefner (1978).

Through June 1981 there were 593 recaptures of tagged crabs reported, 7.58% of those released. The percentage of males recaptured was 8.14%, and that of females, 6.62% (Table 2). The numbers of tagged crabs recaptured varied greatly from year to year, depending on level of fishing effort in the general vicinity of tagging. In 1976 and 1978, for example, there was little fishing effort in the release areas and consequently there were few tag recoveries (Table 2), for, as is shown here later, few tagged crabs moved out of the general area where they had been released.

Since some of the tagged crabs had not molted for nearly seven years it is evident that molt frequency was low. If it is assumed that tagged crabs molted with the same frequency as untagged ones a slow growth rate is indicated. Further information on this is provided by the mean sizes of recaptures in each year (Table 2). These data show that there was little difference in mean size at recapture with the passage of time. For example, the mean carapace width of all male crabs tagged was 123.6 mm (Table 1), while that of the 10 males recaptured in 1980 was 129.6 mm, not a great deal larger than at tagging. For the females the situation was similar: those tagged had a mean carapace width of 110.1 mm and the seven recaptures in 1980 had a mean width of 112.0 mm (Tables 1 and 2). These figures indicate that some of the smaller tagged crabs, of both sexes, also had a low molt frequency.

Additional data on the size of recaptured crabs compared with size at tagging is provided by size frequencies of recaptures in 1974, 1975, and 1977 from releases of tagging trips one and three, the trips from which most of the returns were obtained (Figure 5). These data show that the size composition of recaptured crabs of both sexes in these years did not differ greatly from that of the tagged population, further indicating long intermolt periods. There was, however, a general lack of the smallest sizes among the recaptures, leaving the possibility that many of these had molted before they could be recaught.

The comparative rates of tag returns by sex in 1974-81 provide some indication that the tagged females may have molted sooner than the males (Table 2). The rate of return was similar for both sexes in 1974-76, with the average ratio of males to females among returns running about 1.55. In 1977, however, this ratio was 5.71, suggesting that by this later year there was a greater loss of tags to molts among the females. In 1980-81 the sex ratio shifted back toward the females again, although the total number of returns in these years was small (Table 2). In view of this and of the patchy nature of red crab distribution by sex (Wigley et al. 1975; Haefner, 1978), the observed sex ratio variations may be of rather limited use for estimating frequency of molt.

In Gulf of St. Lawrence tagging studies of male snow crabs, Chionoecetes opilio, with a tag like that used for red crabs, Watson (1970) reported that recaptures were obtained for up to three years after tagging, thus indicating a relatively long intermolt period in this species also. The snow crab lives in water temperatures of about -1° to $2^{o}C$

(Imbeault, 1969), which is colder than the southern New England red crab environment where upper slope bottom temperatures run from about 4° to $8^{o}C$ (Schroeder, 1959; Wigley et al. 1975; Haefner, 1978).

2. Tagging Mortality.

Information on tagging mortality is useful for interpreting results in tagging studies. While the extent of this is unknown for the tagged red crabs, two pieces of tag return information suggested to us that it was not great. The first of these relates to tag recoveries immediately following tagging. During the three tagging trips a total of 118 of the tagged crabs were recaught, some within a day of being tagged and released. Since the crabs had to move into baited traps to be recaught, these recaptures soon after tagging indicated that recovery from being caught and tagged was rapid and that tagging shock was small. Of the 118 tagged crabs recaught during tagging operations, 112 were in good enough condition to be returned to the water. The percentage of these subsequently caught by fishermen, 6.6%, was similar to, though somewhat lower than, the overall tag recapture rate of 7.58%, further suggesting that there was a rather low mortality from catching and handling.

The other source of information on tagging mortality is from observations of injured crabs that were tagged. Data from the tagging logs indicated that many of the crabs caught for tagging had one or more appendages (claws or walking legs) missing. It is likely that in most cases these were lost during catching and tagging operations since the crabs, crowded in traps, frequently closed their claws on each other, and the resulting injuries sometimes caused autotomy of affected appendages. Of the 7,822 crabs tagged and released, 1,658 (21.2%) were recorded as having

appendages missing. Most of these had lost only one or two appendages, but some had lost three or four.

The return rate of tagged crabs with missing appendages was examined for two periods: 1974-76 and 1977-80. In 1974-76 there were 396 tagged crabs returned, 19% of which had had missing appendages at tagging. This figure is only slightly lower than that for all crabs tagged. Somewhat higher mortality among the injured crabs is a possible explanation for their lower rate of recapture. Reduced mobility because of limb loss perhaps also had an effect. The conclusion from this, however, is that in 1974-76 there was no markedly greater mortality in injured crabs, indicating a low mortality from being caught and tagged.

For the 194 tagged crabs returned in 1977-80, only 8.8% had had missing appendages at tagging, a sharp difference from the 21.2% with missing appendages of all releases. Causes for this marked change, while unknown, may be related to earlier molt, and therefore accelerated tag loss, among the crabs with lost appendages. However, a delayed tagging mortality among injured crabs cannot be ruled out.

3. Movements of tagged crabs.

Of the 593 tagged crabs recaptured through June 1981, 547 (92.2%) were caught by red crab trap effort and 44 (7.4%), by offshore lobster trap fishermen. The other two recaptures (0.3%) were by a research vessel otter trawl.

Red crab fishing effort in the years following tagging, based on interviews with crab fishermen, covered the upper slope area in depths

of about 290-750 m from just southwest of Hudson Canyon to off southern Georges Bank. As indicated below, the effort and area of operations varied considerably from year to year. In addition to New England effort, from 1976 on there also was a small amount of red crab fishing on grounds off Delaware to Virginia, about 220 km to the southwest of the tagging area.

In the first few years of the fishery New England red crab vessels changed fishing areas with some frequency. The principal reason given was that the catch of market-sized crabs declined after a period of fishing. Fishermen moved to another area when this occurred, or sometimes before it did. In more recent years fishermen have routinely moved their gear each trip, minimizing this problem (Gerrior, 1981). These patterns of fishing, plus the intermittent nature of the fishery in early years, have contributed to the irregular distribution of red crab effort, which is reflected in the tag return rates from year to year.

Fishing effort by offshore lobster trap vessels in 1974-80 was distributed over the entire outer shelf area from southern Georges Bank to off Virginia. These vessels fished out to depths of about 310 m, which is the upper fringe of red crab distribution in this area. There was some lobster effort on these grounds in all years following tagging, although the intensity of it from place to place has varied widely.

Only those tag returns with accurate return positions were plotted on charts showing recapture locations of tagged red crabs (Figure 6-8). A discussion of tag recaptures by year follows.

In 1974 a total of 269 tags were returned; 236 of these were from red crab vessels, 31 from lobster vessels, and 2 from a research vessel. These tagged crabs all were recaught in the general area of tagging, which is where all 1974 post-tagging crab effort took place (Figure 6). Some of the crabs moved in both easterly and westerly directions along the slope from the release points, with little indication of a directed movement. While the maximum apparent distance moved was about 40 km, most of the crabs showed little or no movement.

All 1974 recaptures were made in August and September, the only post-tagging period of 1974 in which red crab fishing took place. Most of the tag returns in this year were not plotted in Figure 6 because of imprecise recapture locations. However, since all 1974 post-tagging effort was in the general tagging area, the recaptures not plotted were caught in the same vicinity as those shown in Figure 6.

In 1975 there were 118 tagged crabs returned: 116 from crab vessels and 2 from lobster vessels; in 1976 only 9 tagged red crabs were recaptured, 1 from a crab vessel and 8 from lobster vessels (Figure 7). The 1975 recaptures, again, were mostly from the tagging area; however, there was a considerable scattering of crabs to the eastward, with a maximum indicated movement of about 65 km. Fishing for red crabs in this year covered the eastern part of the tagging area (Figure 2) and slope areas to about 130 km to the east of this.

All of the 1975 tag recaptures by red crab vessels were in October-December, when there was an active fishery in the eastern part of the release area. The two returns from lobster vessels were caught in March within a few kilometers of points of release.

In 1976 the red crab effort was entirely to the east of 71°10'W, and of the total of nine tagged crabs recaptured, eight were caught by lobster trap vessels, in March to July, in the general area of the 1974 releases (Figure 7). The ninth was caught by a red crab vessel in June about 85 km to the east of where it had been released.

In 1977 there were 161 tagged crabs returned, 159 from red crab vessels and 2 from lobster trap vessels. In 1978 there was only one recapture, while in 1979 and 1980 there were 15 and 17 recoveries, respectively; all of the 1978-80 recaptures were by red crab vessels.

Most of the recaptures in 1977 were from within a few kilometers of the tagging locations; however, there was some movement of tagged crabs both east and west, along the slope, from the release points (Figure 8). Recoveries were made throughout the year, but most were caught in April-June. In 1978 the single tagged crab recaptured was caught in January along the east side of Hudson Canyon, about 45 km to the west of the point of release (Figure 8).

In 1979 most of the returns were from the general vicinity of tagging; one crab, however, was recaught about 90 km to the east of where released and another was recaptured 55 km west of the release point (Figure 8). Four returns were caught in April, three in July, seven in September, and one in December.

In 1980 the pattern of return locations of the ten recaptures for which there were accurate return positions was similar to that for 1979, with recaptures dispersed over the entire area between 71°00'W and 72°00'W (Figure 8). Nine of the 1980 returns were caught in January-March, five in June, and three in November.

Fishing effort for red crabs in 1977 extended over the entire vicinity of tagging as well as slope areas to about 150 km to the east, and 35 km to the southwest of it. Considerable effort was expended in the Block Canyon region, where many of the 1977 recaptures were obtained (Figure 8). In 1978 the crab effort covered slope grounds to the southwest of the tagging area (from about 72°00'W to 72°40'W) and from 120-425 km to the east of it (about 65°50'W to 70°00'W). There was no directed effort within the vicinity of tagging, and only one tagged crab was recovered (Figure 8). The 1979 crab effort covered the tagging area, grounds to about 55 km to the southwest of it (near Hudson Canyon), and grounds as far as 185 km to the east of it (about 68°40'W). In 1980 the effort was from Hudson Canyon to slope areas about 220 km to the north and east of this, with most of it falling within the eastern part of the tagging area, just to the southwest of Block Canyon.

There were three tag recaptures in 1981, through June (Table 2). While the recovery locations for these are not shown in Figure 8, all were caught on slope areas within 30 km of release positions. One, in March, was caught in a lobster trap; the other two, in April, were taken in red crab traps. Red crab effort in the first half of 1981 was mainly east and west of the tagging area; however, there was a small amount of effort within the tagging area in April.

The number of tag recaptures in relation to the estimated red crab catch within the tagging area has declined greatly over the years. Losses of tags to molts, natural mortality, and tag detachment, as well as fishing mortality, all have worked to reduce the tagged population. In view of this we expect few tag recaptures from these experiments in the future.

The pattern of recapture locations for all years indicated that most tagged crabs were recaught within about 20 km or less of where they had been released. Maximum movements were about 90 km to the east, and 55 km to the southwest of points where they were tagged. None of the tagged crabs were recaptured on the southwest side of Hudson Canyon. The movement of crabs seemed more a dispersal along the slope, away from points of release, than a directed movement. It appears that movement may have been greatest in an easterly direction; however, the heaviest concentration of red crab fishing effort also was on the eastern side of centers of tag releases.

In addition to the movements along the slope, some tag returns indicated that movements of about 1 to 6 km up or down the slope had occurred resulting in depth changes of up to 500 m. While such movements may be related to the red crab spawning cycle, there was no detectable seasonal migration pattern in these observations.

In the tagging study of snow crabs in the Gulf of St. Lawrence, Watson (1970) found that most of the tagged crabs had moved only a few kilometers in the first two years at liberty, and then in the third year movements of up to 52 km were recorded. It appeared that, as in red crabs, the movement was random rather than directed. Fishing takes place in this gulf only from May to November, however, because of winter ice cover, and there could have been seasonal movements that went undetected because of this.

4. Cycle of egg production based on tagging and recapture data.

Information from studies aboard commercial red crab vessels by Ganz and Herrmann[4/] indicated that some ovigerous crabs occurred year-round and that, in general, they had early stage eggs in summer and fall, middle stage in winter, and late stage in spring, thus suggesting spring hatching and summer and fall egg extrusion. This is similar to patterns tentatively proposed by Wigley et al. (1975) and Haefner (1978) who suggested, on the basis of research vessel collections of ovigerous red crabs, that a high incidence of hatching occurred between January and June. Haefner (1978) found few ovigerous crabs in June and many in November and January.

We found evidence of a pattern similar to those described above in the data from the May-June 1974 tagging trips, in which 27 ovigerous crabs were reported among those tagged. While it is likely that other ovigerous crabs were overlooked at tagging, the log notes on these 27 were of interest. The eggs of 21 of them were recorded as being "black" and/or "eyed," and they probably were late stage. Of the other six, one was recorded as having early stage eggs, two were classified as having some early and some late eggs, and three had no notes on egg stage. These records indicated that hatching was approaching for many of the crabs.

Further information on spawning stage and the reproductive cycle was obtained from recaptured tagged crabs. The eggs of these, where present, were classed as early, middle, or late stages of development. In 1974 this was done on the basis of egg color and the presence or absence of embryonic eyes. Since color is not completely reliable for determining stage (Haefner, 1978), in 1977-81 we also used a microscope to examine the eggs, in some cases removing the embryos from them.

There were 16 ovigerous crabs among the 1974 recaptures. One of these carried late stage eggs when tagged May 25 and was ovigerous also at recapture August 25, although egg stage then was unrecorded. The other 15 ovigerous crabs were recaught in August to early September, and none of these were reported as ovigerous when tagged in May-June. Thirteen had eggs of early stage, 1 of middle stage, and for 1 the egg stage was unrecorded.

In 1975 there were 45 tagged female crabs recaptured; however, the spawning condition was not obtained at recapture. One of them was recorded as ovigerous when tagged. In 1976 only three tagged females, all non-ovigerous, were recaptured in March.

In 1977 there were 24 tagged females recaptured, none of which were recorded as ovigerous at tagging. Ten were ovigerous at recapture. One of these was caught in April and had eggs of middle to late stage. Five were caught in May and had late stage eggs. Some of the eggs of one of the latter had hatched, since there were empty egg cases and zoeal stages in the egg mass. The other four ovigerous crabs were recaught in September-November, and all had early stage eggs.

In 1978 no tagged females were recaptured. In 1979 there were two, neither of which was recorded as ovigerous at tagging. One of these, recaught in late April, was non-ovigerous; the other, recaught in mid-September, was ovigerous with early stage eggs.

In 1980 seven tagged females were recaptured: one in February, two in March, and four in June. None of these were reported as ovigerous at tagging, and we found none ovigerous at recapture. Through June 1981 two tagged females were recaught, one each in March and April. Neither

was reported ovigerous at tagging. We did not see the crab from the March recapture; the April one, however, had a small cluster of residual eggs of late stage. There also were empty egg cases in the cluster, indicating that some hatching had occurred not long before.

The above observations, while they do not cover the entire year, indicate that red crab hatching occurred primarily in spring and egg laying in summer and fall, coinciding reasonably well with findings of Ganz and Herrmann,[4/] Wigley et al. (1975), and Haefner (1978). Whether or not inseminated females may lay fertile eggs in every year for several years after mating is unknown. The data show, however, that eggs may be laid some years after a molt, and, assuming that mating occurs only right after a molt, that stored sperm remains viable for several years.

With respect to crab mating, Watson (1972) found that some of the immature female snow crabs from the Gulf of St. Lawrence held in aquaria mated within minutes after molting to maturity and then laid fertile eggs within 24 hours. In the same study a number of ovigerous females with late stage eggs hatched their eggs in aquaria and then, without molting or contact with a male, laid new fertile eggs within about two weeks. A similar pattern may occur in red crabs, with immature females mating after the molt that brings them to maturity and mature females mating only after a subsequent molt.

No direct information on red crab mating was obtained from the tagging study. However, there have been some underwater observations in relation to this. During dives in Veatch Canyon (approximate position $39^{o}53'$-$40^{o}00'$N,

69°36'-69°38'W, 275-1,255 m depth) June 24-29, 1975 with the Research Submarine Alvin numerous paired red crabs were observed, photographed, and videotaped by NMFS scientists.[5/] In these cases the male apparently was holding the female in a pre- or post-molting embrace, as is common in brachyurans. It seems likely that these red crab females molted just before mating took place, although hard-shelled mating also occurs in some crabs (Hartnoll, 1969). These observations, although they do not define the entire season of mating, indicate that there was considerable mating activity in June in this area. This information is in agreement with the proposed spawning cycles mentioned above.

5. Fishing mortality.

As indicated earlier here, fishermen have reported drops in the catch of market-sized male red crabs in an area following a period of fishing, indicating that exploitation can rather rapidly exert a significant mortality on the marketable segment of the population. If such a fished area is left unfished for a time the proportion of large males again rises, presumably through growth and, possibly, immigration, and more profitable fishing may be resumed. While it would be of value to use the long-term tag return data to estimate this fishing mortality rate, the scattered and sporadic nature of red crab effort in the years following tagging makes this impractical. A further complicating factor is that the tagged population was continuously being reduced an unknown amount through molts and the consequent loss of tags.

In view of these problems, the best means for getting any measure of fishing mortality in the tagging area appeared to be from early recaptures, before large tag losses had occurred. We therefore used the recaptures in late 1974 for estimating the rate of exploitation at that time.

5/ Personal communication from J. R. Uzmann, National Marine Fisheries Service, NOAA, Northeast Fisheries Center, Woods Hole, MA 02543.

The post-tagging fishing effort in 1974 did not begin until mid-August, or more than two months after tagging, which gave the tagged crabs time to become dispersed in the general tagging area. This fishing effort consisted only of 3.25 red crab trips by a single vessel (the fractional trip resulting from low market demand) between August 17 and September 23, 1974. The catch from these trips amounted to approximately 117,000 market males landed and about 107,000 females and undersized males that were discarded for a total catch of 224,000 crabs.[6/]

A total of 230 tagged crabs were recaptured during these trips from the 7,822 released for a return rate of 2.9%. If all red crabs caught were landed this would represent a Peterson estimate of the fishing rate for these trips, in that area. Since only about 52% of the catch is saved and most of the discarded part, it is assumed, survives, the estimated fishing rate on marketable crabs was (0.52) (2.9%) or 1.51%. It is possible for a fishing vessel of this size to make about 50 red crab trips per year, and at the 1974 level of efficiency it could exert an estimated mortality on market-sized male crabs of (50/3.25) (1.51) or 23.2%. Since there likely was some small mortality among discards, and also some small tagging mortality and loss of tags to molts between tagging and recapture, this may underestimate total fishing mortality. Nonrandom distribution of the

6/ Live weight of red crab landings was obtained by multiplying the weight of butchered crab sections, the landed form, by 1.76, the NMFS butchered to live conversion factor. The estimated number of market crabs was obtained by dividing landed live weight in kilograms by 0.64 kg, the average weight of a market male red crab in tagging trips one and three, which were in areas commercially fished; average weight was determined from average caparace width, using a carapace size to weight relationship from Haefner (1978). The estimated numbers of discards are based on the proportion of market to discard crabs in the catches of tagging trips one and three.

tagged crabs, however, could overestimate it.

The above calculation is for the situation where fishing takes place in the same general area for the entire year. In the actual case fishermen routinely change areas. Despite the obvious shortcomings of this estimate it is of interest for projecting what the fishing rate on male crabs might be in relation to the stock abundance, estimated by Wigley et al. (1975), as the effort in the fishery increases.

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Table 1.--Numbers of male and female red crabs tagged, mean carapace width, range of carapace width, and sex ratio for each tagging trip and all trips combined, May-June, 1974.

Trip number	Males			Females			Sex ratio
	Number of crabs	Carapace width (mm) Mean	Carapace width (mm) Range	Number of crabs	Carapace width (mm) Mean	Carapace width (mm) Range	male/female
1	1,784	124.9	90-149	1,242	109.2	85-133	1.44
2	879	118.4	81-154	108	104.6	87-122	8.14
3	2,290	124.5	92-150	1,519	111.3	86-139	1.51
All trips	4,953	123.6	81-154	2,869	110.1	85-139	1.73

Table 2.--Numbers of tag recoveries, mean carapace widths in millimeters, percentages recaptured,[1/] and sex ratios for each year 1974-81 for tagged male and female red crabs in 1974 releases.

	Males			Females			Sex ratio
Year	Number	Mean width	% recaptured	Number	Mean width	% recaptured	Male/female
1974	160	127.3	3.23	107	110.7	3.72	1.50
1975	75	128.2	1.51	45	109.2	1.57	1.67
1976	6	127.0	0.12	3	105.0	0.10	2.00
1977	137	125.5	2.77	24	111.2	0.84	5.71
1978	1	133.0	0.02	0	-	-	-
1979	13	129.8	0.26	2	97.5	0.07	6.50
1980	10	129.6	0.20	7	112.0	0.24	1.43
1981 [2/]	1	140.0	0.02	2	111.5	0.06	0.50
All years	403	127.0	8.14	190	110.2	6.62	2.12

1/ Percentage of original number tagged.

2/ January-June 1981.

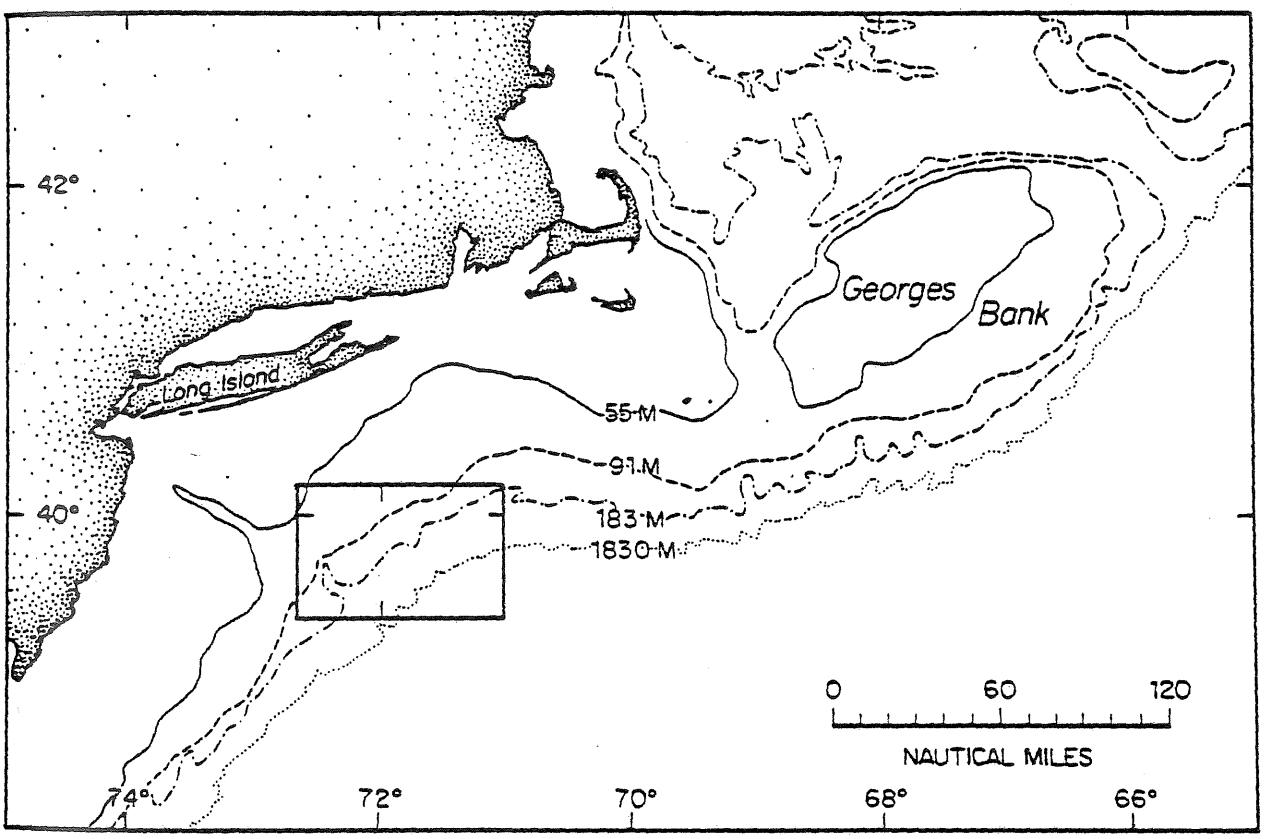

Figure 1.—Bathymetric chart of grounds off southern New England including the general area (outlined) where red crabs were tagged in 1974.

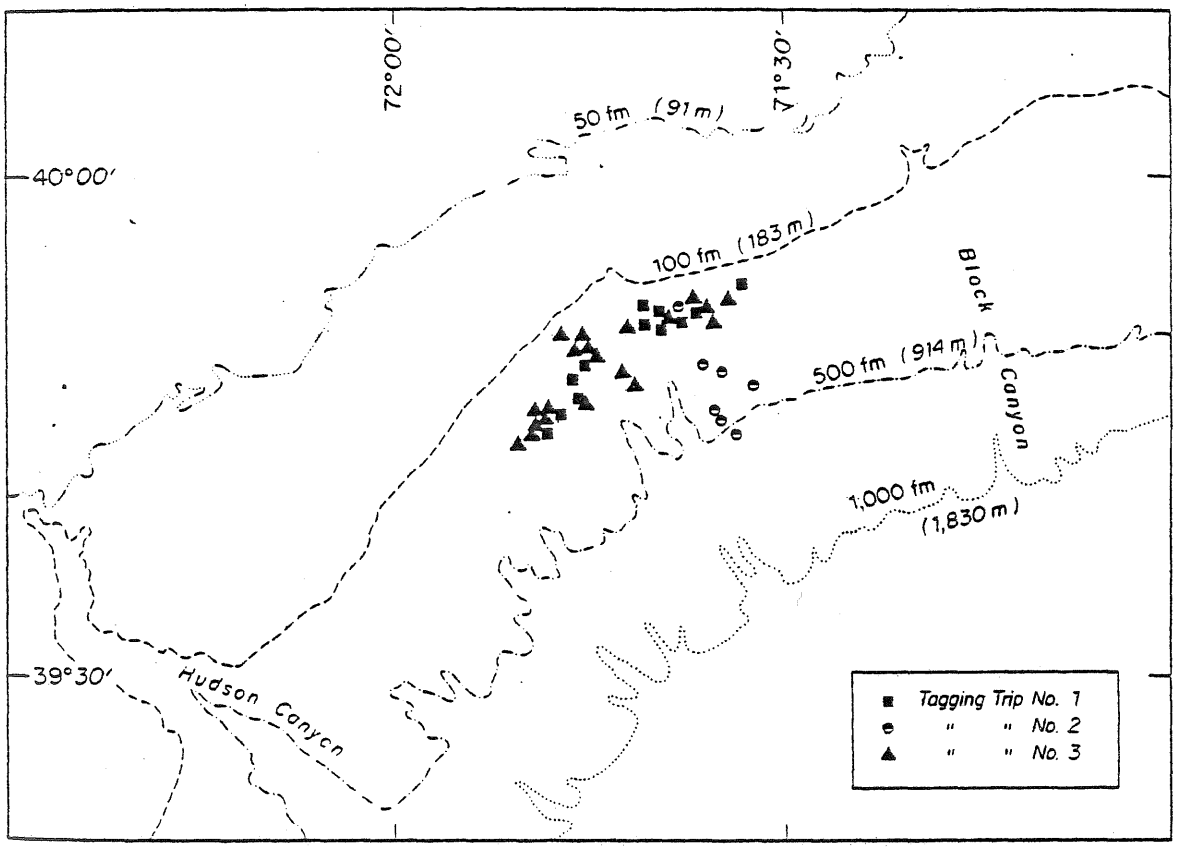

Figure 2.--Chart showing the general area where red crabs were tagged in 1974 (see Figure 1) and the specific locations where groups of tagged crabs were released, shown by symbols, during each of the three tagging trips.

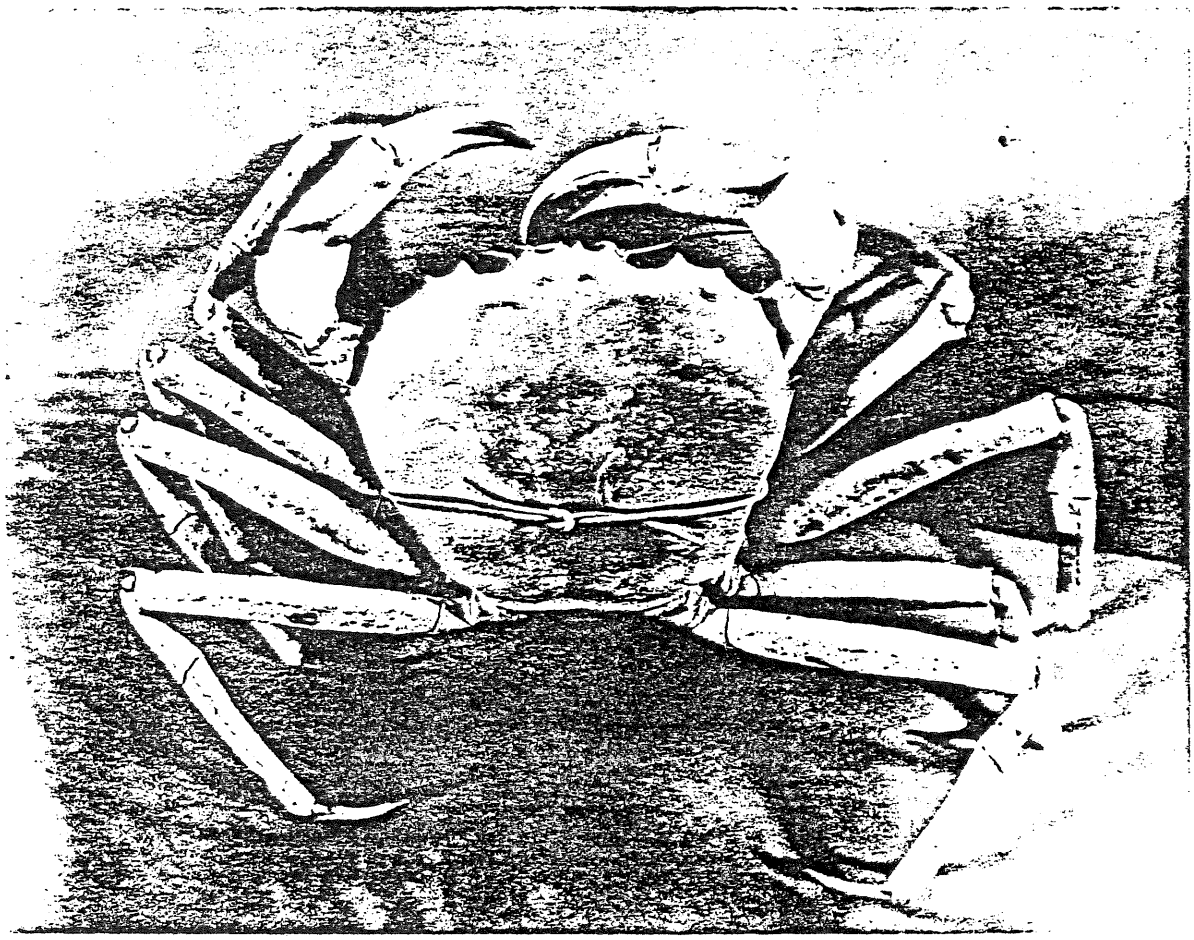

Figure 3.--Red crab with vinyl tag in place around carapace.

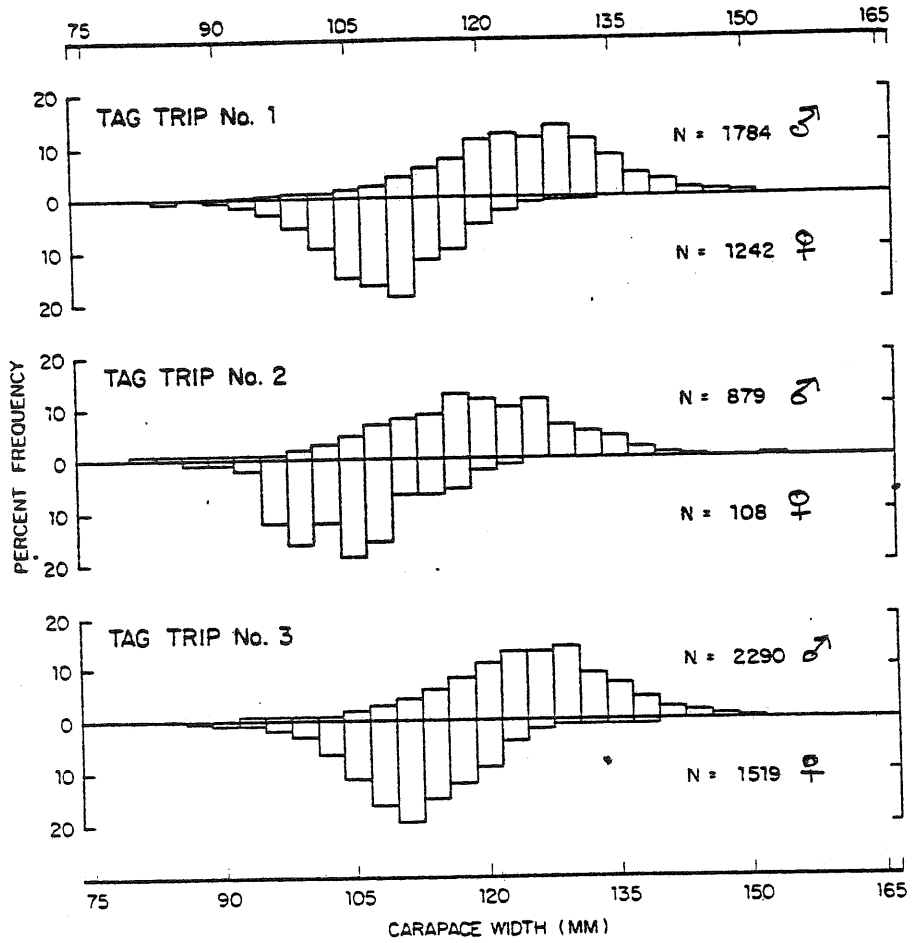

Figure 4.--Percentage size frequencies of male and female red crabs tagged during each of the three 1974 tagging trips.

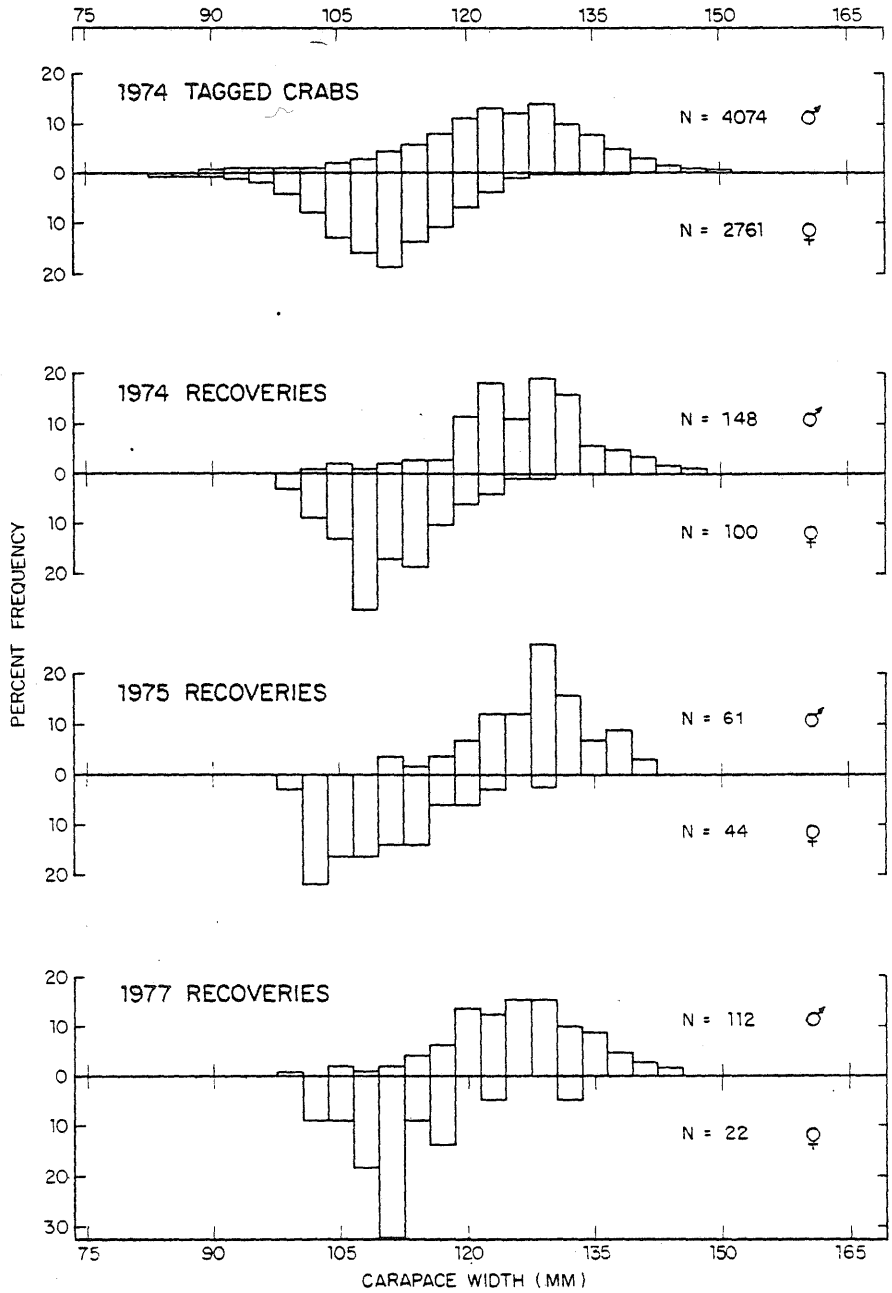

Figure 5.--Percentage size frequencies and total numbers of male and female red crabs tagged in 1974 in tagging trips one and three and of those recaptured in 1974, 1975, and 1977 from these releases.

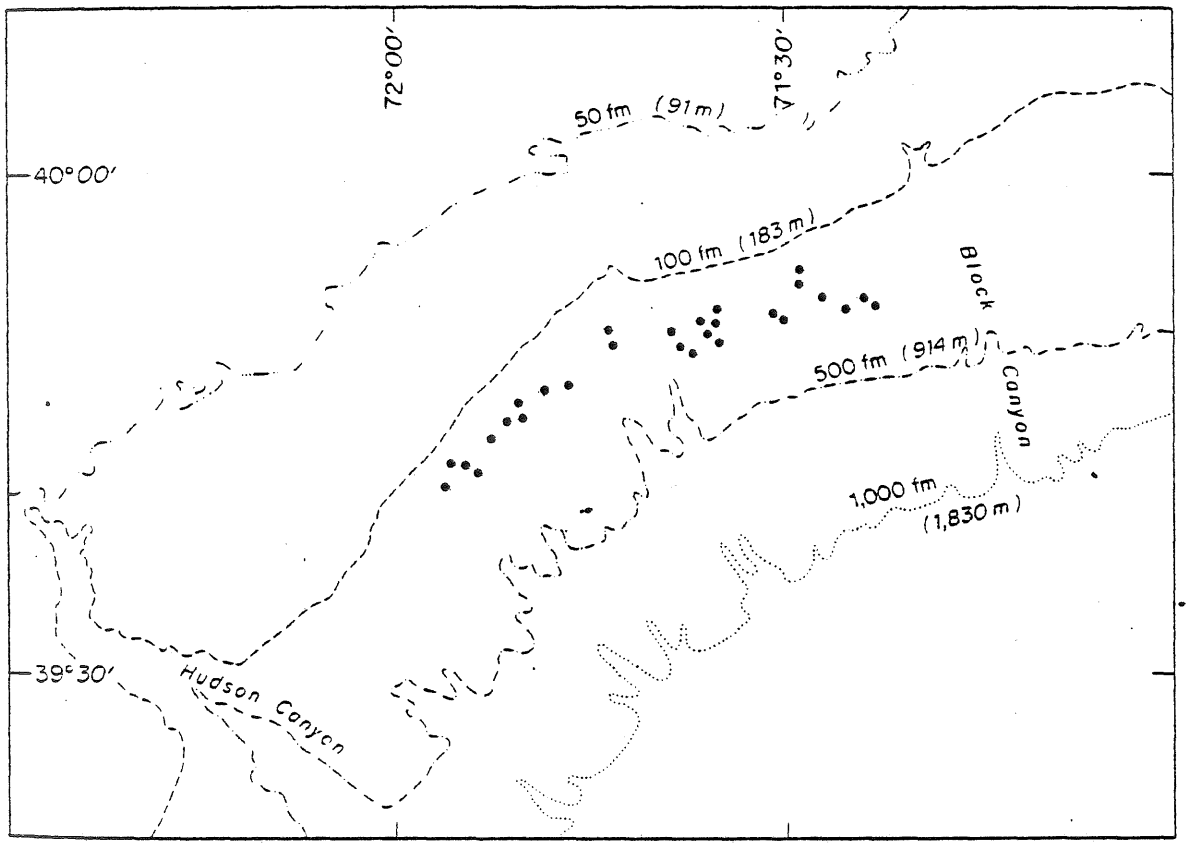

Figure 6.--Recapture locations for tag returns in 1974 from all 1974 releases. (Only returns for which accurate locations were given were plotted.)

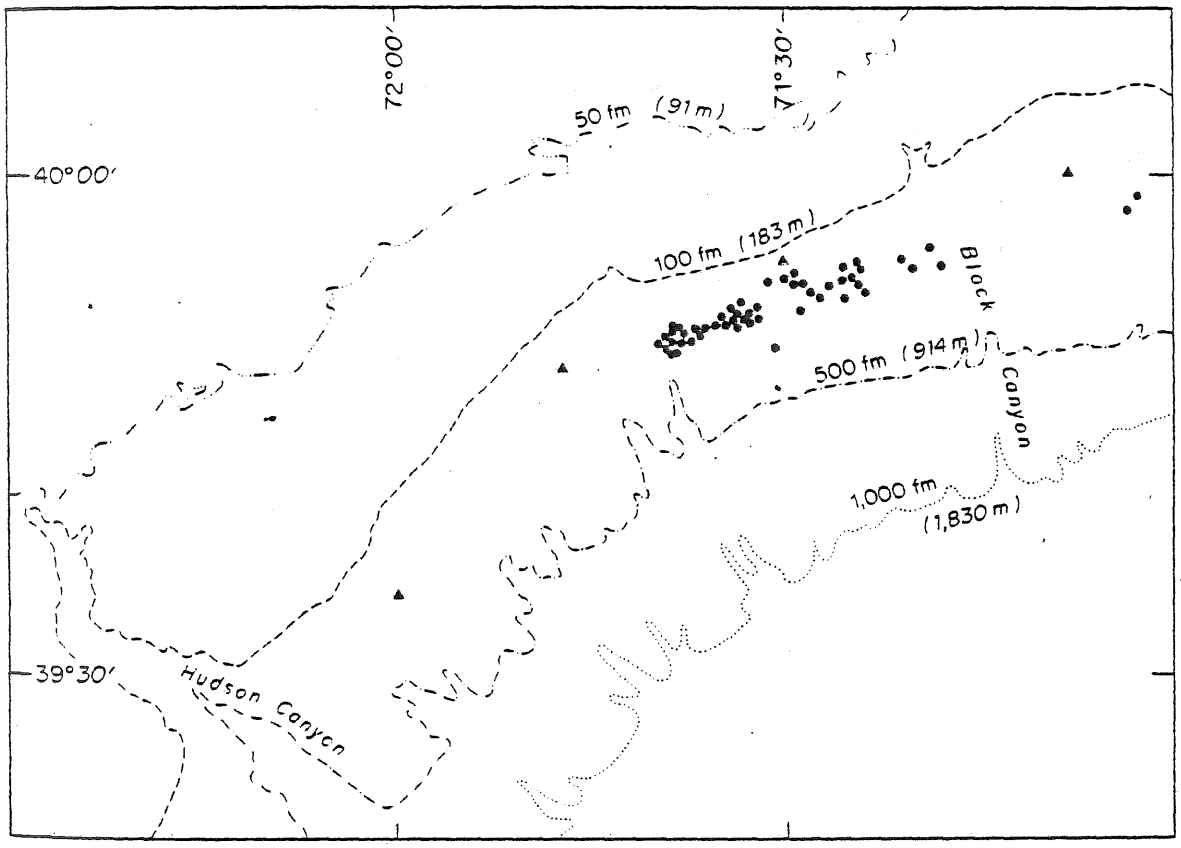

Figure 7.--Recapture locations for red crab tag returns in 1975 (circles) and 1976 (triangles) from all 1974 releases. (Only returns for which accurate locations were given were plotted.)

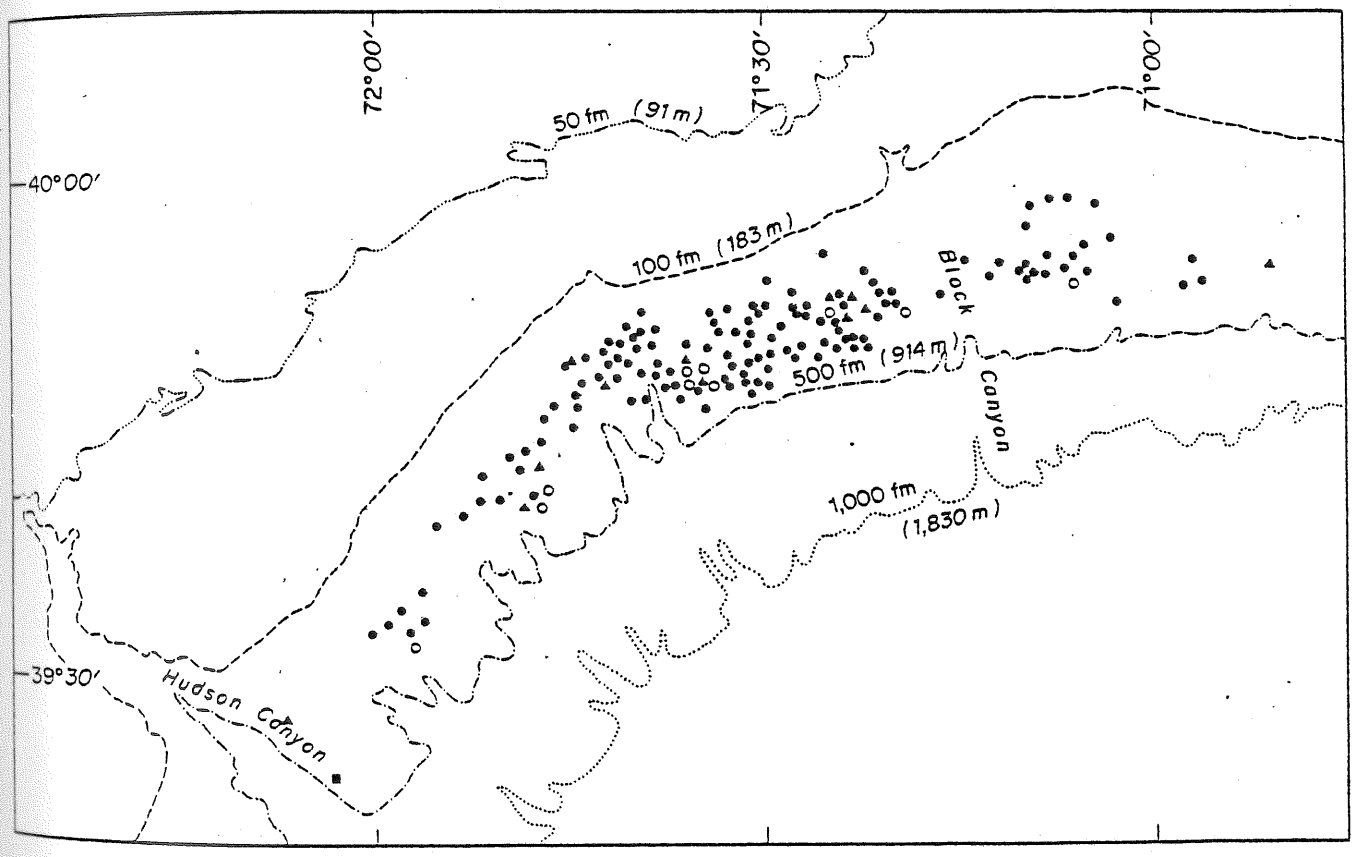

Figure 8.--Recapture locations for red crab tag returns in 1977 (solid circles), 1978 (square), 1979 (triangles), and 1980 (open circles) from all 1974 releases. (Only returns for which accurate locations were given were platted.)