# MIGRATIONS OF THE HORSESHOE CRAB *LIMULUS POLYPHEMUS* IN PLUM ISLAND SOUND, MASS.



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United States Department of the Interior, Fred A. Seaton, Secretary
U.S. Fish and Wildlife Service

# MIGRATIONS OF THE HORSESHOE CRAB, LIMULUS POLYPHEMUS, IN PLUM ISLAND SOUND, MASSACHUSETTS

By

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## ABSTRACT

During the years 1952, 1953, and 1954 a total of 1,780 horseshoe crabs (Limulus polyphemus) were tagged and released in or near Plum Island Sound, Mass. Recovery of tagged crabs indicated an onshore migration that began early in March and reached a peak in June. The largest numbers of crabs were present in the Sound during June, July, and August, after which an offshore migration resulted in a reduction of their numbers on the flats. Low recoveries of crabs during the year they were tagged indicated that individual crabs may spend a fairly short time in the Sound each summer. A population of horseshoe crabs that is probably local for Plum Island Sound and nearby estuaries was indicated by the tag recoveries. Five tagged crabs were recovered almost 4 years after tagging.

CONTENTS

# MIGRATIONS OF THE HORSESHOE CRAB, LIMULUS POLYPHEMUS, IN PLUM ISLAND SOUND, MASSACHUSETTS

## INTRODUCTION

The predation on soft-clam (Mya arenaria) by the horseshoe crab (Limulus polyphermus) is of major significance in the soft-clam producing areas of Massachusetts (Turner, Ayers, and Wheeler, 1948; Shuster, 1950; Smith and Chin, 1951). The migratory habits of the horseshoe crab in Plum Island Sound, Mass., were investigated as a part of studies to develop methods for control of this predator.

Observations on the distribution, abundance, and migration of Limulus were made in the sound from 1949 to 1955. Preliminary observations indicated a seasonal pattern of abundance within the sound during the summer months. During 1951 a program of marking the crabs by cutting off half of the tail and certain abdominal spines was started. This system gave some returns, but many were not definite enough to be useful because it soon became evident that some individuals had lost a tail or spines before we marked them.

A program of tagging with Petersen-disk tags was initiated in 1951 and continued through 1954. A total of 1,639 horseshoe crabs was tagged and released from flats within Plum Island Sound during these years. An additional 141 horseshoe crabs were released from areas outside Plum Island Sound making a total of nearly 1,800 Limulus tagged in or near Plum Island Sound.

The authors were assisted in the recovery of tagged crabs and the collection of untagged crabs by Lionel Sheppard, Clam Commissioner, Charles Bayley, Deputy Clam Commissioner, of Ipswich, Mass., and by Daniel Pierce, Conservation Officer, Massachusetts Department of Marine Fisheries.

## METHODS

Most of the horseshoe crabs tagged were captured and released in the intertidal zone of Plum Island Sound. A few, encountered while searching for previously tagged individuals, were tagged in the Annisquam River near Gloucester, Mass., and in Hampton Harbor, N.H.

Subtidal collections were made with a 30-inch-wide scallop dredge or beam trawl hauled by a 16-foot outboard motorboat. The warp was made fast in the boat, but by holding on to it one could feel whether the dredge was scraping the bottom. Although the dredge did not catch large numbers of crabs, it did provide some observations in the subtidal zone.

Intertidal collections were made while crabs were moving to and from the flats during a flooding tide or sometimes an ebbing tide. We observed that fairly large numbers of horseshoe crabs began their movements onto the flats almost as soon as did the tide and would stay until just before the flats became exposed at low tide. Crabs that had buried themselves in the flat during some previous tide, rose out of the soil and moved about as the tide flooded the flat. Several hundred of these crabs could be harvested by three men during one tide. Best results were obtained at the narrow entrance to a channel. By wading in water 2 to 3 feet deep the three of us picked the crabs off the bottom and placed them in the boat which was towed behind or anchored nearby. Of the techniques used, this one yielded the largest number of crabs.

During low tide, the presence of Limulus was indicated by depression that liberally pockmarked the flats. These depressions, which were circular, 6 to 8 inches wide and 2 to 3 inches deep, were made by crabs in search of food or in preparation for laying eggs. By digging with a clam hoe in or at the edge of fresh pits we often uncovered a crab or a mating pair, but this method was not nearly as productive as collections made during a flooding tide.

Petersen tags were attached to the crabs through a hole pierced by an awl at the right rear point of the prosoma or "head". The

numbered white disk was placed on a nickel pin and this pushed through the hole so that this disk was under the prosoma. The red disk with a notice of reward and address for mailing was placed on the upper side. The width of the crab was measured at its widest point and the sex noted. This information was recorded with the serial number of the tag.

Usually a day's catch could be tagged, measured and released the same day it was caught, but some large collections were held overnight in the boat or laboratory. This apparently did the crabs no harm as they were lively when released and some of the highest returns came from crabs so held. A case in point is a collection of 38 made on June 26, 1952, which was brought to the laboratory, kept out of water overnight, tagged and released the next day. Seven have been recovered; 4 in 1953, 1 in 1954, and 2 in 1955. Also, 92 collected on August 14, 1952 and released the next day, have yielded 14 recoveries; 4 in 1952, 2 in 1953, 5 in 1954, and 3 in 1955.

The recovery of tags may be roughly divided into three groups, according to who found them: (1) recoveries made throughout the year by our staff while collecting crabs for tagging and other data; (2) recoveries by "alerted" persons who knew of our tagging program and were deliberately searching for tagged crabs within Plum Island Sound, either for the reward or to help us; and (3) purely accidental recoveries by visitors to the seashore. This last group includes many people from inland towns and the general surprise and curiosity is quite evident from the letters. These may be considered chance or random recoveries, which might be expected from any popular beach or shoreside area. The first two groups, those found by the staff and "alerted" persons, are not random in geographical distribution because most of the searching was done within Plum Island Sound.

## RESULTS

Results are tabulated in tables 1 to 7 and shown in figures 1 to 3.

Table 1.--Summary of intertidal collections of horseshoe crabs in upper and lower parts of Plum Island Sound, Mass., 1951 through 1954

| Month | Number of collections | | Total number of crabs | | Average number of crabs per collection | |
|---|---|---|---|---|---|---|
| | Upper | Lower | Upper | Lower | Upper | Lower |
| April | 1 | 0 | 20 | | 20.0 | |
| May | 10 | 2 | 282 | 25 | 28.2 | 12.5 |
| June | 22 | 4 | 537 | 705 | 24.4 | 176.3 |
| July | 12 | 7 | 271 | 1,171 | 22.6 | 167.3 |
| August | 5 | 9 | 251 | 798 | 50.2 | 88.7 |
| September | 1 | 5 | 2 | 100 | 2.0 | 20.0 |
| October | 1 | 1 | 1 | 17 | 1.0 | 17.0 |
| Total | 52 | 28 | 1,364 | 2,816 | 26.2 | 100.6 |

Table 2.--Summary of subtidal collections of horseshoe crabs in upper and lower parts of Plum Island Sound, Mass., 1951 through 1955

| Month | Number of collections | | Total number of crabs | | Average number of crabs per collection | |
|---|---|---|---|---|---|---|
| | Upper | Lower | Upper | Lower | Upper | Lower |
| March | 2 | 3 | 5 | 2 | 2.5 | 0.7 |
| April | 4 | 4 | 15 | 39 | 3.8 | 9.8 |
| May | 4 | 5 | 46 | 74 | 11.5 | 14.8 |
| June | 2 | 2 | 7 | 2 | 3.5 | 1.0 |
| July | 1 | 1 | 4 | 10 | 4.0 | 10.0 |
| August | 1 | 2 | 14 | 15 | 14.0 | 7.5 |
| September | 3 | 6 | 16 | 48 | 5.3 | 8.0 |
| October | 6 | 5 | 8 | 19 | 1.3 | 3.8 |
| November | 3 | 4 | 3 | 1 | 1.0 | 0.3 |
| December | 4 | 1 | 0 | 1 | 0.0 | 1.0 |
| Total | 30 | 33 | 118 | 211 | 3.9 | 6.4 |

Table 3.--Release of tagged horseshoe crabs from areas within Plum Island Sound, Mass., and their recovery during 1951 through 1955.

| Released | | | | | | Recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mature | | Immat- | | | | Sear- | Sex and Size | |
| Date | Place | M | F | ure | Total | Date | Place | cher(4) | | mm. |
| 8/14/51 | Doles Island | | | | 2 | | | | | |
| 5/29/52 | Roger Island R. | 14 | 6 | 9 | 29 | | | | | |
| 6/16/52 | Hales Cove | 13 | 7 | | 20 | 7/17/52 | Cranes B. | N | F | 171 |
| | | | | | | 6/20/54 | Sargents B., Gloucester | N | M | ? |
| 6/27/52 | Nelsons Island | 25 | 9 | 4 | 38 | 5/10/53 | Beach, mo. Essex R. | N | F | 160 |
| | | | | | | 5/16/53 | Wingaersheek B. | N | F | 163 |
| | | | | | | 8/ 8/53 | 1/2 mile mo. Essex R. | N | M | 117 |
| | | | | | | 12/ -/53 | Ipswich(1 and2) | N | M | 120 |
| | | | | | | 8/11/54 | Cranes B. | N | F | 157 |
| | | | | | | 8/12/54 | Cranes B. (No letter) | N | M | 111 |
| | | | | | | 4/ 8/55 | Cranes B. | N | M | 121 |
| | | | | | | 9/ 5/55 | Eagle Hill R. | A | F | 147 |
| 7/1/52 | Hales Cove | 1 | | | 1 | | | | | |
| 7/14/52 | Hales Cove | 6 | 2 | | 8 | 8/ 3/52 | Ipswich Bay(1) | N | M | 112 |
| 8/ 1/52 | Hales Cove | 1 | | | 1 | | | | | |
| 8/11/52 | Nighways Creek | 4 | 10 | | 14 | 7/20/53 | Point Peter(3) | S | F | 155 |
| 8/11/52 | Lufkins Flat | 22 | 11 | 3 | 36 | 8/13/52 | Lufkins Flat(3) | S | M | 107 |
| | | | | | | 8/14/52 | Cranes B. | N | M | 117 |

Table 3.--Continued

| Released | | | | | | Recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mature | | Immat- | Total | | | Sear- | Sex and Size | |
| Date | Place | M | F | ure | | Date | Place | cher(4) | | mm. |
| 8/11/52 | Lufkins Flat (cont'd.) | | | | | 8/ 5/53 | Third Cr. | A | F | 146 |
| | | | | | | 8/ 6/53 | Middleground | A | M | 110 |
| | | | | | | 9/26/54 | Cranes B. | N | M | 127 |
| 8/12/52 | Ipswich Yacht Club | 28 | 3 | | 31 | 9/ 3/55 | Eagle Hill R. | A | M | 108 |
| 8/13/52 | Lufkins Flat | 11 | 8 | 2 | 21 | | | | | |
| 8/14/52 | Lufkins Flat | 126 | 48 | 4 | 178 | 8/ -/52 | Cranes B. | N | M | 136 |
| | | | | | | 9/ 2/52 | Lufkins Flat(1) | N | M | 120 |
| | | | | | | 11/ 1/52 | Roger Island R. | A | F | 150 |
| | | | | | | 12/29/52 | Plum Island B.(1) | N | F | 154 |
| | | | | | | 6/23/53 | Richards Ground | A | F | 143 |
| | | | | | | 7/20/53 | Point Peter (3) | S | M | 115 |
| | | | | | | 5/ 1/54 | Plum Island Shore | N | M | 119 |
| | | | | | | 7/ 5/54 | Richards Ground | A | M | 123 |
| | | | | | | 7/24/54 | Gloucester Harbor | N | M | 102 |
| | | | | | | 8/ 5/54 | Richards Ground | A | M | 123 |
| | | | | | | 8/ 8/54 | The Nobbs | N | F | 141 |
| | | | | | | 6/ 1/55 | 1 mile S.Cranes B. | N | F | 159 |
| | | | | | | 6/15/55 | Cranes B. | N | M | 112 |
| | | | | | | 7/ 4/55 | Ipswich River mo. | N | F | 152 |
| 8/15/52 | Hales Cove | 43 | 43 | 6 | 92 | 9/ 2/52 | Sandy Point (1) | N | M | 115 |
| | | | | | | 7/20/53 | Point Peter (3) | S | M | 124 |
| | | | | | | 8/ 6/53 | Middleground | A | F | 159 |
| | | | | | | 9/ 2/53 | S. end Plum Is.(1) | N | F | 160 |
| | | | | | | 9/ 7/55 | Point Peter | A | F | 140 |
| 8/21/52 | Hales Cove | 35 | 51 | 4 | 90 | 6/11/53 | Hampton Beach, N.H. | N | F | 164 |
| | | | | | | 6/18/53 | The Nobbs | N | F | 168 |
| | | | | | | 6/21/53 | The Nobbs | N | M | 131 |
| | | | | | | 8/ 6/53 | Middleground | A | F | 153 |
| | | | | | | 6/ 4/54 | Hales Cove (3) | A | F | 160 |
| | | | | | | 7/ 4/55 | Grape Island | N | F | 161 |
| 8/22/52 | North of Rowley Middleground | 31 | 50 | 3 | 84 | 3/29/53 | Horseshoe Flat | N | F | 149 |
| | | | | | | 6/19/53 | Mo.Ipswich R. | N | M | 130 |
| | | | | | | 7/ 5/53 | The Nobbs | N | M | 119 |
| | | | | | | 7/20/53 | Point Peter (3) | S | F | 154 |
| | | | | | | 9/ 4/54 | Ipswich (1 and 2) | N | M | 114 |
| | | | | | | 6/11/55 | Parker River | N | F | 145 |
| | | | | | | 7/ 7/55 | Lufkins Flat | A | F | 152 |
| | | | | | | 7/ 7/55 | Davis Pt., Gloucester | N | M | 119 |
| | | | | | | 7/17/55 | Third Creek | A | F | 146 |
| | | | | | | 8/ 2/55 | Nighways Creek | A | F | 163 |
| 8/25/52 | Point Peter | 81 | 104 | 7 | 192 | 6/23/53 | Richards Ground | A | F | 149 |

Table 3.--Continued

| Released | | | | | | Recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mature | | Immat- | | | | Sear- | Sex and Size | |
| Date | Place | M | F | ure | Total | Date | Place | cher(4) | | mm. |
| 8/25/52 | Point Peter (cont'd.) | | | | | 6/24/53 | Richards Ground | A | F | 159 |
| | | | | | | 7/22/53 | Third Creek (See 2nd. Recovery) (3) | S | F | 159 |
| | | | | | | 8/26/53 | Plum Island Sound(2) | N | F | 142 |
| | | | | | | 9/ 1/53 | Lanesville, Gloucester | N | M | 126 |
| | | | | | | 9/21/53 | Ipswich B. (2) | N | M | 137 |
| | | | | | | 6/10/54 | Eagle Hill R. Cove | A | F | 166 |
| | | | | | | 6/10/54 | Cranes B. | N | F | 165 |
| | | | | | | 6/ -/54 | Richards Ground | A | M | 125 |
| | | | | | | 6/ -/54 | Eagle Hill R. | A | F | 142 |
| | | | | | | 7/ 3/54 | Richards Ground | A | F | 148 |
| | | | | | | 7/ 6/54 | Cranes B. | N | M | 123 |
| | | | | | | 7/ 8/54 | Plum Island B. | N | F | 155 |
| | | | | | | 8/21/54 | Eagle Hill R. | A | F | 183 |
| | | | | | | 8/23/54 | Plum Island B. | N | F | 156 |
| | | | | | | 5/21/55 | Plum Island (2nd. recovery) | N | F | 159 |
| | | | | | | 8/ 1/55 | Lufkins Flat | A | M | 133 |
| | | | | | | 8/ 4/55 | Nighways Creek | A | F | 153 |
| 8/27/52 | Nelsons Island | 34 | 28 | 4 | 66 | 8/31/52 | Rowley Shore of Plum Island R. | N | M | 111 |
| | | | | | | 5/30/53 | Between Great and Little Neck | N | F | 153 |
| | | | | | | 6/25/53 | Annisquam R. | N | F | 152 |
| | | | | | | 7/20/53 | Point Peter (3) | S | F | 150 |
| | | | | | | 6/ 4/54 | Hales Cove (3) | A | M | 122 |
| | | | | | | 8/28/54 | Ipswich Bay (2) | N | F | 149 |
| | | | | | | 6/17/55 | Cranes B. | N | M | 116 |
| 8/28/52 | Horseshoe Flat | 43 | 33 | 3 | 79 | 7/20/53 | Point Peter (3) | S | M | 106 |
| | | | | | | 7/ 3/54 | Sandy Point | N | M | 129 |
| | | | | | | 8/23/54 | Great Neck | A | F | 172 |
| Total released in 1952 | | 517 | 414 | 49 | 980 | | | | | |
| Total recovered of this group | | 36 | 43 | 2 | 81 | | | | | |
| 7/20/53 | Point Peter | 21 | 20 | 1 | 42 | 7/ 5/54 | Richards Ground | A | M | 120 |
| 7/20/53 | Parker River | 9 | | | 9 | | | | | |
| 7/21/53 | Nelsons Island | 22 | 17 | | 39 | 8/2/54 | S.end Plum Island(1) | N | F | 149 |
| | | | | | | 5/29/55 | Plum Island B. | N | F | 155 |
| 7/31/53 | Point Peter | 32 | 44 | | 76 | 8/20/53 | Cranes B. | N | F | 169 |
| | | | | | | 8/30/53 | Lufkins Flat | A | M | 114 |
| | | | | | | 5/31/54 | Eagle Hill R. | N | F | ? |
| | | | | | | 6/ 4/54 | Hales Cove (3) | A | M | 124 |
| | | | | | | 6/ 4/54 | Hales Cove | A | F | 159 |
| | | | | | | 7/ 5/53 | Wingaersheek B. | N | F | 139 |

Table 3.--Continued

| Released | | | | | | Recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mature | | Immat- | | | | Sear- | Sex and Size | |
| Date | Place | M | F | ure | Total | Date | Place | cher(4) | | mm. |
| 9/1/53 | Point Peter | 28 | 41 | | 69 | 6/29/54 | Point Peter(3) | S | F | 156 |
| | | | | | | 6/29/54 | Point Peter(3) | S | F | 156 |
| | | | | | | 7/21/55 | Middleground | A | F | 151 |
| | | | | | | 8/15/55 | Eagle Hill R. | A | M | 115 |
| 9/10/53 | Broad Sound | 5 | 1 | 2 | 8 | | | | | |
| 9/16/53 | Point Peter | 4 | 1 | | 5 | 6/10/54 | Cranes B. | N | M | 124 |
| 9/17/53 | Buoy 4 to Eagle Hill R. | 2 | | 2 | 4 | | | | | |
| 9/17/53 | Third Creek | 4 | 9 | 1 | 14 | 7/4/54 | Richards Ground | A | F | 152 |
| 9/29/53 | Point Peter | | 1 | | 1 | | | | | |
| 10/2/53 | Bluff Creek | 7 | 5 | 3 | 15 | | | | | |
| Total released in 1953 | | 134 | 139 | 9 | 282 | | | | | |
| Total recovered of this group | | 5 | 10 | 0 | 15 | | | | | |
| 6/17/54 | Doles Island | 11 | 9 | | 20 | 7/11/54 | Mo.Ipswich R. | N | M | 120 |
| | | | | | | 7/ 8/55 | Lufkins Flat | A | F | 156 |
| | | | | | | 8/17/55 | Point Peter | A | M | 113 |
| 6/29/54 | Point Peter | 99 | 240 | 6 | 345 | 7/ 5/54 | Sandy Point | N | F | 160 |
| | | | | | | 8/ 3/54 | Eagle Hill R. | A | F | 151 |
| | | | | | | 8/ 7/54 | Little Neck | A | F | 153 |
| | | | | | | 6/ 7/55 | Cranes B. | A | F | 162 |
| | | | | | | 6/16/55 | Eagle Hill R. | N | M | 114 |
| | | | | | | 6/25/55 | Cranes B. | N | F | 159 |
| | | | | | | 7/26/55 | Ipswich Bay(2) | N | F | 159 |
| | | | | | | 7/30/55 | Middleground | A | M | 140 |
| | | | | | | 7/31/55 | Lufkins Flat | A | F | 149 |
| | | | | | | 8/ 2/55 | Lufkins Flat | A | M | 142 |
| | | | | | | 8/ 4/55 | Cranes B. | N | F | 154 |
| | | | | | | 8/ 9/55 | Staceys Creek | A | F | 168 |
| | | | | | | 8/11/55 | Ipswich Bay (1 and 2) | N | F | 160 |
| | | | | | | 8/14/55 | Sandy Point | N | F | 165 |
| | | | | | | 9/ 3/55 | Eagle Hill R. | A | F | 152 |
| 7/27/54 | Plum Island Bridge | 1 | 9 | | 10 | | | | | |
| Total release in 1954 | | 111 | 258 | 6 | 375 | | | | | |
| Total recovered in this group | | 5 | 13 | 0 | 18 | | | | | |
| Grand total released | | 762 | 811 | 64 | 1639 | | | | | |
| Grand total recovered | | 46 | 66 | 2 | 114 | | | | | |

Table 3.--Continued

(1) Indicates letter or postmark date was used; actual date of recovery not supplied by searcher.
(2) Indicates poor location of recovery was supplied by searcher.
(3) Indicates these crabs were re-released by the staff.
(4) Symbols used in table: Searcher - N = non-alerted, A = alerted, S = staff.
(5) Includes 2 released in 1951 for which sex was not recorded.

Table 4.--Release of tagged horseshoe crabs from areas outside Plum Island Sound, Mass., and their recovery 1952 through 1955.

| Released | | | | | | Recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Place | Mature M | Mature F | Immature | Total | Date | Place | Searcher(1) | Sex | Size mm. |
| 8/12/52 | Haskells Landing, Essex, Mass. | 25 | 14 | | 39 | 6/14/53 | Wingaersheek B. | N | F | 180 |
| | | | | | | 7/20/53 | Ferris Landing, Conomo Pt., Essex, Mass. | N | F | 150 |
| | | | | | | 4/10/55 | Wingaersheek B. | N | M | 114 |
| | | | | | | 8/ -/55 | Essex River | N | M | 101 |
| 6/10/54 | Black Water Cr., N.H. | 2 | 3 | | 5 | | | | | |
| 6/25/54 | Conomo Pt., Essex, Mass. | 47 | 27 | 3 | 77 | | | | | |
| 7/15/54 | Hampton River, N.H. | | 1 | | 1 | | | | | |
| 8/ 2/54 | Black Water Cr., N.H. | 2 | 1 | | 3 | | | | | |
| 8/17/54 | Annisquam R., Mass. | 10 | 6 | | 16 | | | | | |
| Total released in these areas | | 86 | 52 | 3 | 141 | | | | | |
| Total recovered of this group | | 2 | 2 | | 4 | | | | | |

(1) Searcher - N = nonalerted

Table 5.--Number of horseshoe crabs recovered by three groups of searchers 1952 through 1955, listed by areas and months

| Month | Upper Plum Island Sound | | | | | | | Lower Plum Island Sound | | | | | | | | Outside Plum Island Sound | | | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year recovered | | | | Total No. | Searcher (1) | | Year recovered | | | | Total No. | Searcher | | | Year recovered | | | | Total No.(2) | |
| | '52 | '53 | '54 | '55 | | Non | Al | '52 | '53 | '54 | '55 | | Non | Al | S | '52 | '53 | '54 | '55 | | |
| Jan. | | | | | | | | | | | | | | | | | | | | | |
| Feb. | | | | | | | | | | | | | | | | | | | | | |
| Mar. | | 1 | | | 1 | 1 | | | | | | | | | | | | | | | 1 |
| Apr. | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 |
| May | | | | | | | | | 1 | 1 | | 2 | 2 | | | | 2 | 1 | 2 | 5 | 7 |
| June | | | 4 | 1 | 5 | 1 | 4 | | 6 | 5 | 1 | 12 | 4 | 6 | 2 | | 2 | 3 | 5 | 10 | 27 |
| July | | | | | | | | | 8 | 8 | 8 | 24 | 7 | 10 | 7 | 1 | | 4 | 1 | 6 | 31(3) |
| Aug. | 1 | | | | 1 | 1 | | 3 | 7 | 6 | 8 | 24 | 6 | 17 | 1 | 2 | 2 | 2 | 1 | 7 | 37(4) |
| Sept. | | | | | | | | | | | 4 | 4 | | 4 | | | 1 | 1 | | 2 | 7(5) |
| Oct. | | | | | | | | | | | | | | | | | | | | | |
| Nov. | | | | | | | | 1 | | | | 1 | | 1 | | | | | | | 1 |
| Dec. | | | | | | | | | | | | | | | | 1 | | | | 1 | 2(6) |
| Total | 1 | 1 | 4 | 1 | 7 | 3 | 4 | 4 | 22 | 20 | 21 | 67 | 19 | 38 | 10 | 4 | 7 | 11 | 10 | 32 | 114 |

(1) Symbols for searcher groups: Non = non-alerted, Al = alerted, S = staff.
(2) All recovered by non-alerted searchers.
(3) Includes 1 for which area was in doubt.
(4) " 5 " " " " " "
(5) " 1 " " " " " "
(6) " 1 " " " " " "

Table 6.--Number and percentage of tagged horseshoe crabs recovered 1952 through 1955

| Recovered | Number tags out [5] tagged in '52 | '53 | '54 | Number tags recovered tagged in '52 | '53 | '54 | Percentage recovery tagged in '52 | '53 | '54 |
|---|---|---|---|---|---|---|---|---|---|
| 1952 | 980 | | | 10[1] | | | 1.02 | | |
| 1953 | 971 | 282 | | 30[2] | 2 | | 3.09 | 0.71 | |
| 1954 | 948 | 280 | 375 | 24[3] | 10[4] | 4 | 2.53 | 3.57 | 1.07 |
| 1955 | 926 | 273 | 371 | 16 | 4 | 14 | 1.73 | 1.47 | 3.77 |
| 1956 | 910 | 269 | 357 | | | | | | |

1/ 1 of these re-released
2/ 7 " " "
3/ 2 " " "
4/ 3 " " "
5/ Neglecting natural mortality.

Table 7.--Mean carapace width of adult male and female horseshoe crabs collected in Plum Island Sound, Mass., 1952 through 1954

| Year | Males Number | Mean width | Standard deviation | Females Number | Mean width | Standard deviation |
|---|---|---|---|---|---|---|
| 1952 | 608 | 118.1 | 9.08 | 491 | 156.1 | 10.82 |
| 1953 | 655 | 118.6 | 8.30 | 601 | 155.1 | 11.27 |
| 1954 | 204 | 116.7 | 9.82 | 295 | 155.5 | 10.75 |
| Total | 1,467 | 118.1 | 8.95 | 1,387 | 155.5 | 11.04 |

## DISCUSSION

Horseshoe crabs were encountered in Plum Island Sound every month of the year except January and February (table 2). As no dredging was done during these months, it is possible that some may have been present in the subtidal zone. Dredgings made during the month of March indicated that some may be active at this time.

Although crabs were present in channels of the sound all or nearly all year, they did not appear on the clam flats until April. Even at this time their numbers were very low and pits made by the crabs were not in evidence. In May there was an obvious and abrupt increase, both in the numbers of crabs that could be picked up, and in the numbers of pits on the flats. The numbers of crabs present during the following months increased even more abruptly, and reached a peak during July and August. The total numbers collected per month (1,442 and 1,049) and the average number per collection (75.9 and 74.9) were highest for these 2 months.

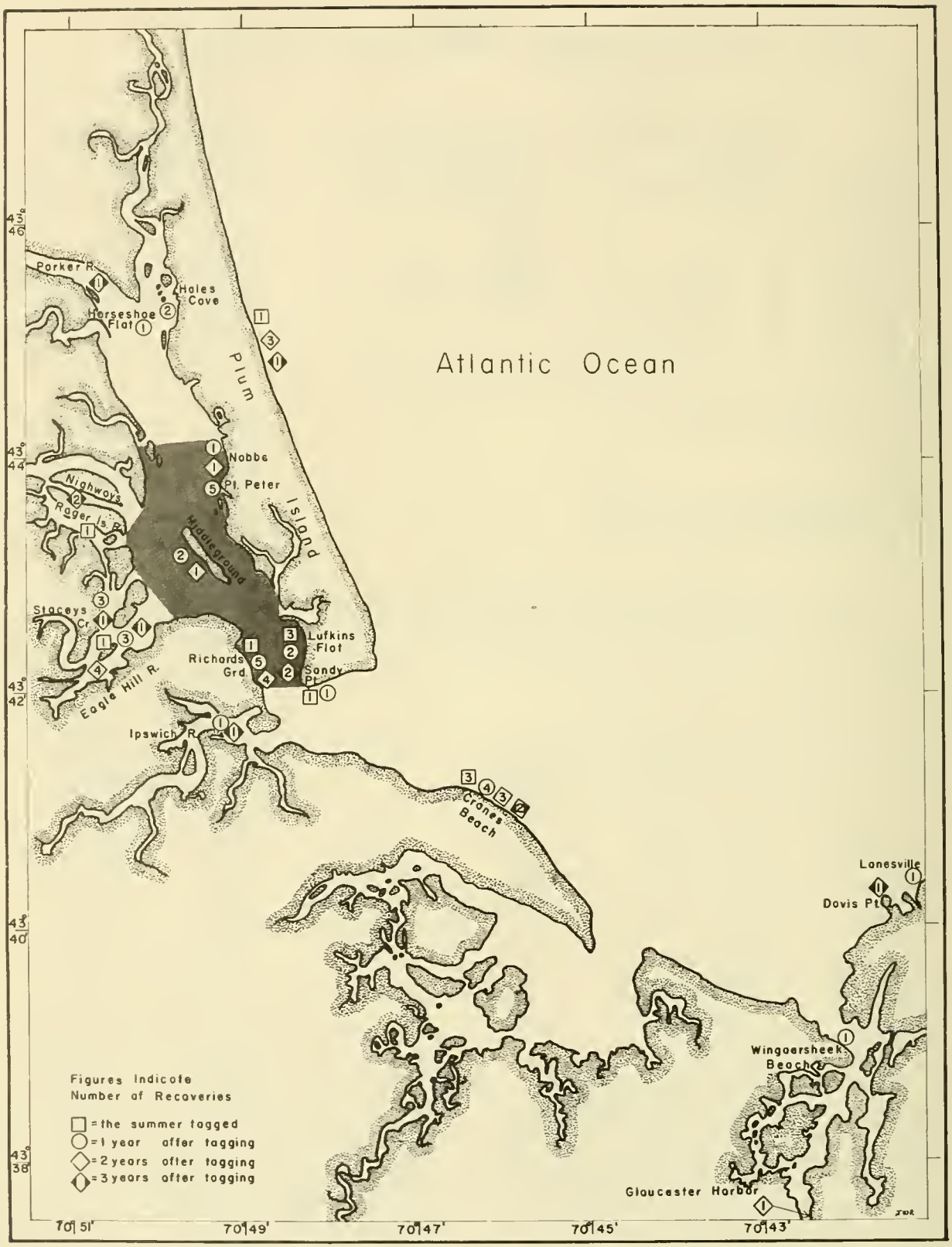


Figure 1.--Release of 1,135 tagged horseshoe crabs from the lower part of Plum Island Sound, Mass., during 1952, 1953, and 1954, and their recovery.

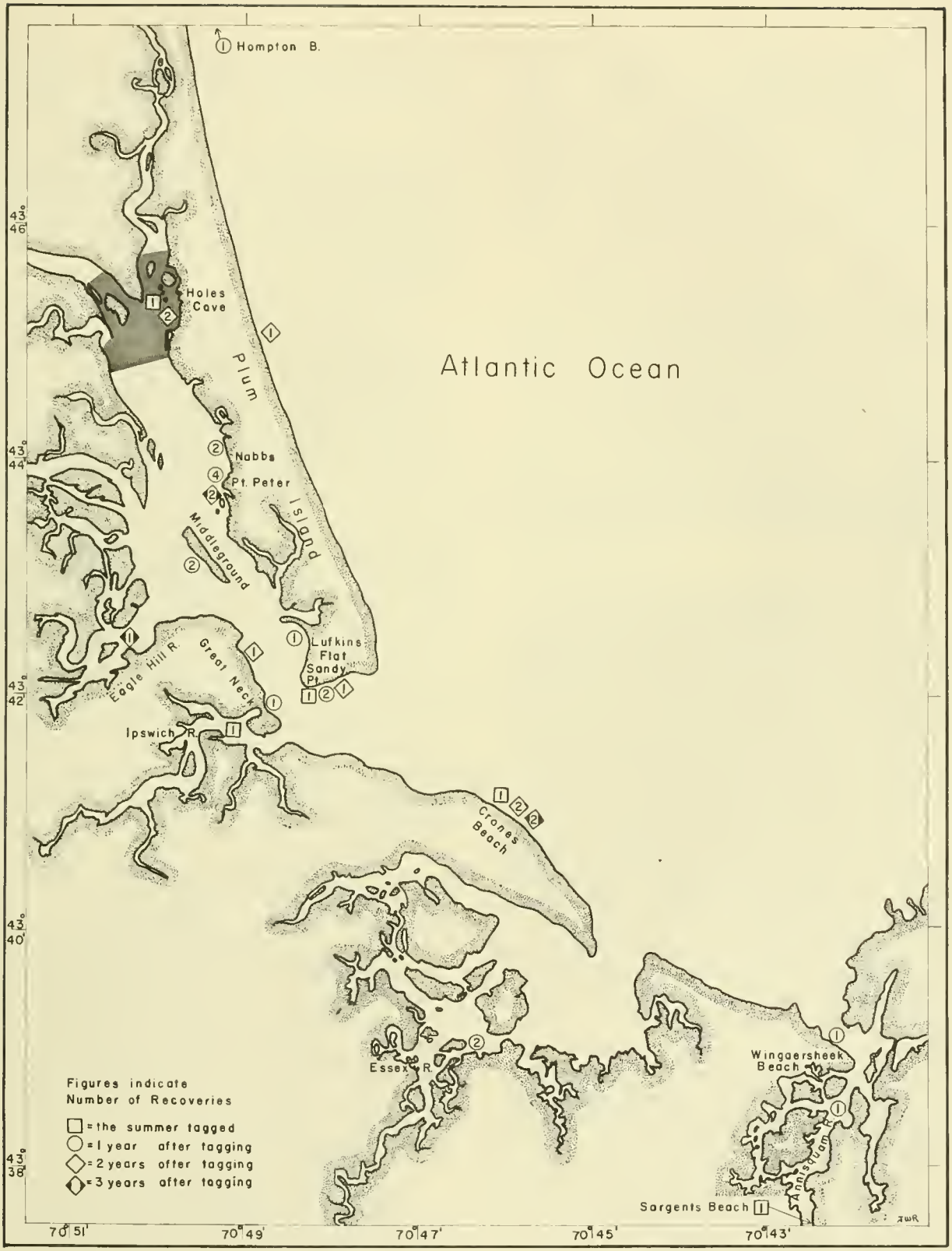


Figure 2.--Release of 504 tagged horseshoe crabs from the upper part of Plum Island Sound, Mass., during 1952, 1953, and 1954 and their recovery.

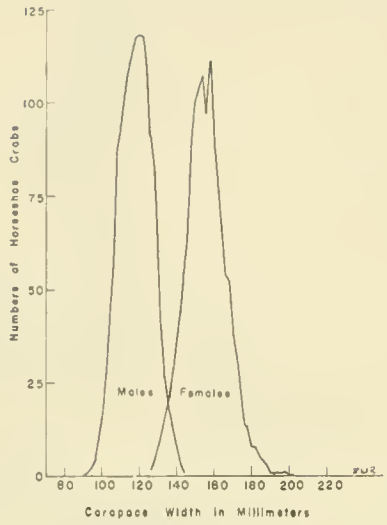


Figure 3.--Length frequency of the carapace width of horseshoe crabs captured and measured in Plum Island Sound, Mass., during 1952 through 1954.

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The peak abundance occurred earlier in the lower part of Plum Island Sound than in the upper. The largest average number per collection in the lower part of the sound, 176.3 crabs, was made in June (table 1). On the flats of the upper part of the sound the largest average number per collection was only 50.2 crabs and this did not occur until the month of August.

From September through December the number of crabs within the sound decreased. This was noticed in September on the flats and later in the channels. After October only lone individuals were uncovered on the flats or dredged up from the channels. As is indicated in tables 1 and 2, this decrease first occurred in the upper part of the sound.

In general the recovery of horseshoe crabs tagged in Plum Island Sound follows the same pattern of seasonal abundance as was described above for untagged crabs encountered in the intertidal zone. The earliest recovery of a tagged crab was made on March 3, 1954 on Horseshoe Flat and only 8 crabs were recovered during April and May (table 5). The recovery of tagged crabs increased to 27 in June and continued high for the months of July and August. Only 10 tagged crabs were recovered in the last 4 months of the year.

Nearly one-third (32) of the recoveries were made in areas outside Plum Island Sound and all of these were found by nonalerted persons. All but 4 of these recoveries were made on beaches facing Ipswich Bay and the open ocean. Cranes Beach and Plum Island Beach, which are just south and north of the entrance to Plum Island Sound, were the sites of recovery for 21 of the 32 tagged crabs recovered outside Plum Island Sound.

Less than one-sixth (7) of the recoveries was made in the upper part of the Sound, even though 504 tagged crabs were released in this area. The poor recovery record for this area may be partly due to the lack of popular beaches which result in fewer searchers on the flats, or the number of crabs venturing into this area may be less whether they be tagged or not. We made nearly twice as many collection trips to this area as to the lower part of Plum Island Sound and utilized this area for other experiments on clams, but failed to recover any tagged crabs.

Eight recoveries were listed as doubtful in table 5 because the nonalerted persons who sent them in did not give a specific location of recovery. In some cases the date of recovery was also omitted. Although the locations given were not specific enough for this study, all were reported to have been found within the nearby Plum Island Sound area.

Recoveries of tagged crabs during the same year they were released were surprisingly low; about 1 percent. During the calendar year after tagging, recoveries in excess of 3 percent were made from all three groups (table 6). Recoveries of tagged crabs out two and more years decreased slightly, but not to the low percentage for the year tagged. Natural mortality has not been considered in arriving at these percentages The percentage recoveries are minimum estimates because the number of tags out would actually be less than the number tagged.

The recoveries of individual crabs (table 3) indicate a fairly rapid oceanward migration throughout the summer. Eleven recoveries during the same year they were tagged were made in areas below or seaward of the place of release. Two other crabs moved across the sound but in an outgoing or downstream direction, while two

others moved upstream from the point of release. One crab was recovered at the place of release.

Some of the tagged crabs moved seaward fairly rapidly. One particular individual, tagged on Lufkins Flat August 11, 1952, was recovered at Cranes Beach, 2 to 3 miles away on August 14, 1952. Thus the sharp increase in recovery of crabs during the next calendar year after tagging and the recovery of crabs from areas in an oceanward direction from the point of release seems to indicate that the individual crabs stay in Plum Island Sound for only a short time each summer. Therefore they might be considered as transient visitors to the seashore which would explain the low rate of recovery during the year a group was tagged.

The apparent migration to and from the Plum Island Sound area indicates that the horseshoe crabs under observation are a local population. The recovery of more crabs during the calendar year after tagging, and recoveries one, two and three years after tagging within an area having a radius less than 13 miles from the point of tagging supports this view.

The crabs tagged in Plum Island Sound do not necessarily return to this area the following year. Ten crabs tagged in Plum Island Sound were recovered in or very near the estuaries south of this area. Exploration of these estuaries showed that horseshoe crabs were abundant and characteristic depressions on the flats were seen and "cast" or molted shells were collected. The recovery of four crabs tagged from these estuaries, although from a very small group of tagged and released crabs, would indicate that these areas are utilized by some horseshoe crabs. No figure has been included for these crabs as so few were released and recovered. Although no collections were made on the southern shores of Cape Ann, one recovery from Gloucester Harbor and another in the Annisquam River indicates that Plum Island Sound crabs may reach this shore by way of the Annisquam River canal.

Exploration of an area north of the sound --Hampton Harbor and Black Water Creek, N.H. --uncovered very few horseshoe crabs, and their characteristic depressions in the flat were rare. In addition, no recoveries of tagged crabs have been made within Hampton Harbor, and only one crab tagged in Plum Island Sound was recovered on beaches outside Hampton Harbor even though the entire shoreline from Cape Ann to Rye Harbor, N.H., is well populated by summer people who might find tagged crabs.

Measurements of adult male and female horseshoe crabs show that the mean carapace width remained nearly constant during the three years, and that there is a definite difference between the sexes, the females averaging 47 mm. wider than the males (table 7 and fig. 3). The observed difference in size between the sexes did not seem to appreciably affect the recovery of tagged crabs. The mean carapace width and standard deviation for recovered tagged males was 120.7 mm. and 9.04, and for females 156.0 mm. and 9.45.

The techniques employed to recover tagged crabs did not permit an accurate estimate of the population. The tagging and recoveries of crabs were extended over such a long period that natural mortality and recruitment might introduce large sources of error. There was also no segment of the tagging program that could be treated separately because of the long time between tagging and recoveries. Even so, rough estimates of the population might be made. On July 20, 1953, the staff recovered 6 tagged crabs on Point Peter while capturing a total of 1,018 untagged crabs. An estimate derived from these figures would yield a figure of 164,000 crabs. On June 4, 1954, an alerted searcher recovered 4 tagged crabs and 495 untagged crabs. An estimate based on these figures would be 151,000 crabs. During the summer of 1955, another alerted searcher recovered 15 tags after capturing and killing 9,541 crabs. An estimate would yield about 1,000,000 crabs. Even with the inaccuracies mentioned, the figures indicate that the population is of considerable magnitude.

## CONCLUSIONS

1. An onshore migration of Plum Island Sound horseshore crabs begins early in March and continues to a peak in June.

2. The largest number of horseshoe

crabs are present in Plum Island Sound during the months of June, July, and August.

3. Individual crabs probably spend a fairly short time in the sound each year.

4. An offshore migration is most evident during September.

5. Tag recoveries indicate that there is a fairly discrete population of horseshoe crabs in Ipswich Bay.

6. The techniques used to recover tagged crabs were not adequate for an accurate estimate of the population size.

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## APPENDIX A

The following data were obtained too late for inclusion in the body of the paper but do not contradict the results discussed.

It is perhaps worthwhile to note that horseshoe crabs tagged in 1952 were still available for recovery in 1956. As the majority of the crabs tagged were mature, this would indicate infrequent, if any, molting of mature horseshoe crabs.

Tag Recoveries During 1956

| Date and location crabs were Released | Date and location crabs were Recovered |
|---|---|
| 8/22/52 - North of Rowley, Middleground | 8/-/55 - Cranes B.<br>N[1/] - F[2/] - 140[3/] mm.<br>(Sent in Sept. 1956) |
| 8/12/52 - Haskell's Landing - Essex | 6/16/56 - Wingaersheek Beach, Ip.<br>N - F - 160 mm. |
| 8/12/52 - Ipswich Yacht Club | 7/15/56 - Plum Island<br>N - M - 111 mm. |
| 8/25/52 - Point Peter | 6/16/56 - Eagle Hill R.<br>A - M - 131 mm. |
| 8/28/52 - Horseshoe Flat | 7/13/56 - Wingaersheek Beach<br>N - F - 160 mm. |
| 7/21/53 - Point Peter | 8/23/56 - Sargents Beach, Gloucester<br>N - F - 154 mm. |
| 9/1/53 - Point Peter | 6/7/56 - Plum Island B.<br>N - M - 125 mm. |

1/ Symbols for search groups: N = Nonalerted; A = alerted

2/ Symbols for sex of crabs: F = female; M = male

3/ Size in mm.

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