in Fig. 1A and B (*6*). In the adapting pattern the upper square is a further disparity of 2 minutes of arc (three-element shift) in front and the lower square is the same disparity behind the fixation point. In the test pattern the squares are at the same depth as the fixation bar. We found these conditions to be optimum for inducing the aftereffect. Although we did not explore systematically the conditions for an optimum aftereffect, we observed that differences in disparity larger or smaller than 2 minutes of arc yielded less effective adaptation stimuli.

A number of observers tried the experiment informally. A small proportion had difficulty in fusing random-dot stereograms, but all those who could fuse the stereograms experienced a distinct aftereffect.

Adapting for as short a time as 5 seconds produces a perceptible aftereffect but it lasts much longer if adaptation is prolonged. An observer held a stopwatch and simply estimated how long the two squares in the test pattern appeared to be misaligned (Fig. 2). Despite the difficulty of this judgment results were similar in different subjects. It is evident that the aftereffect is lengthened by prolonged adaptation.

To measure the strength of the effect we used test stereograms with very small disparities for the upper and lower squares and in the same direction as those in the adapting pattern. Adaptation to the most efficient pattern with a disparity of ± 2 minutes of arc would just flatten out a test pattern with a disparity of ± 30 seconds of arc, which made the two squares momentarily seem aligned in depth. Thus, the strength of the aftereffect is in the order of a change of 30 seconds of arc in disparity, well above the limit of stereo acuity. This value was obtained for 2-minute adaptation time. Further increase of adaptation time did not markedly influence the strength of the aftereffect.

The finding that the duration of the aftereffect is markedly influenced by the adaptation time, but not its strength (provided the adaptation time exceeds about 2 minutes), is interesting, but not restricted to this aftereffect alone. Among the recently discovered aftereffects (*7*), those of Blakemore and Campbell and Blakemore and Sutton have this same property.

The finding that random-dot stereograms produce an aftereffect in depth has several implications. First, it shows that textures without large monocular contours (except for small edges at the boundaries of the granules) can evoke a three-dimensional aftereffect. But, more importantly, the fact that the stimuli for adaptation only exist at a site where global stereopsis is processed demonstrates that the neural mechanisms responsible for this aftereffect are central. Random-dot stereograms are uniquely suited to this kind of tracing of information flow in the visual system (*8*).

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16 September 1970; revised 21 October 1970 ■

Migrations and Growth of Deep-Sea Lobsters, Homarus americanus

Abstract. *In distinct contrast to the restricted movements of coastal stocks of lobsters* (Homarus americanus), *those inhabiting the outer continental shelf undertake extensive seasonal migrations. Of 5710 tagged lobsters released on the outer continental shelf off New England from April 1968 to June 1969, 400 had been recaptured by April 1970. The distribution of the recoveries demonstrated shoalward migration in spring and summer and a return to the edge of the shelf in fall and winter. Deep-sea lobsters have a faster rate of growth than coastal lobsters; growth increments at molting and the frequency of molting are greater.*

Commercial concentrations of northern lobsters, *Homarus americanus*, occur to depths of 700 m along the edge of the North American continental shelf and slope from Georges Bank, off Massachusetts, southward to the latitude of North Carolina (*1*). Over the past decade these stocks have become an increasingly important part of the valuable lobster fishery of the United States. Landings by offshore trawlers have averaged over 5 million pounds (1 pound = 0.453 kg) annually for the past 5 years and now constitute over 15 percent of the total U.S. lobster landings. The migration of these lobsters is being studied by the U.S. Bureau of Commercial Fisheries Laboratory, Boothbay Harbor, Maine, to establish the degree of interaction with endemic populations of the coast of New England. Other approaches to the problem of stock identification include biochemical studies, parasitological studies, and morphometric comparisons. This report describes the seasonal migration of deep-sea lobsters, based on recapture of tagged specimens.

Table 1. Summary statistics of lobster releases and recoveries.

Release location	Releases			Recoveries			
	No. tagged	Females (%)	Mean carapace length (mm)	No. and percent recaptured	Females (%)	Mean carapace length at tagging (mm)	Mean radius of dispersion (km)
Georges Bank	46	50.0	128.7	6 (13.0)	50.0	129.0	28.0
Corsair Canyon	975	65.2	141.1	68 (7.0)	62.8	140.2	65.2
Lydonia Canyon	223	61.9	116.5	21 (9.4)	42.9	118.5	58.1
Southwest Georges	521	41.8	105.9	38 (7.3)	28.9	100.1	59.2
Veatch Canyon	2412	47.9	84.8	154 (6.4)	45.2	82.7	48.3
Atlantis Canyon	530	67.2	91.0	52 (8.8)	71.1	90.1	43.9
Block Canyon	857	53.2	92.6	53 (6.2)	64.1	88.7	76.9
Hudson Canyon	146	53.4	80.2	8 (5.5)	75.0	80.9	77.9

Studies of the movements of inshore lobsters in the coastal areas of New Brunswick, Nova Scotia, and Prince Edward Island (*2*) and in the Gulf of Maine (*3*) have demonstrated that coastal lobsters are, in general, nonmigratory. Wilder (*2*) reported the average straight line distance between release and recapture points of lobsters that were free for 10 to 12 months in the Gulf of St. Lawrence to be 13.5 km, and Cooper (*3*) reported 4.6 km for lobsters free 13 to 19 months in the Gulf of Maine. Bergeron (*4*) concluded that lobsters in the Magdalen Islands area of Quebec undertake a seasonal movement of 10 to 16 km.

The ability of offshore lobsters to undertake extensive migrations was first demonstrated by Saila and Flowers (*5*), who transplanted 1260 egg-bearing females from Veatch Canyon to Narragansett Bay, Rhode Island (218 km northwest of the canyon). Saila concluded that displaced, tagged, female lobsters tended to remain in shoal waters in suitable spawning habitat until they had shed their eggs or molted, or both; afterward there was a pronounced directional tendency in the movements of the displaced animals toward Veatch Canyon. Within 1 year, three of the tagged lobsters had migrated back to Veatch Canyon.

In our study 5710 tagged lobsters were released at eight general locations along or near the edge of the continental shelf from Hudson Canyon to Corsair Canyon between April 1968 and June 1969. These lobsters were taken with otter trawls at depths of 70 to 400 m, then tagged and released within a day after capture—all within 5 km of the capture site at depths of 60 to 200 m.

The tagging technique has been described previously by Cooper (*3*). The tag consists of coded polyvinyl chloride tubing with a polyethylene monofilament leader and a stainless steel anchor that is implanted in the right or left dorsal extensor muscle below the carapace. The anchor is inserted with a hypodermic needle through the connecting membrane between the carapace and the first abdominal segment. This membrane breaks down at ecdysis to permit withdrawal of the lobster, and the implanted tag is retained through successive molts.

Sex, carapace length, and tag number were recorded and referenced to a specific release locality. The tagged lobsters had a carapace length of 55 to 215 mm (average, 99.5 mm). The market value of the lobster plus $1 reward was paid for the return of each tagged lobster, along with information on date and location of recapture. By 1 April 1970, 400 tagged lobsters were reported, of which 80 percent were documented as to location and date of recapture. For convenience in analysis and discussion, all recaptures were grouped in the nearest of eight tagging centers to provide a "radius of dispersion" from each area (Fig. 1). Dispersion was calculated as the mean of straight line distances from point of release to point of recapture.

Percentage recovery of tagged lobsters from the eight locations ranged from 5.5 to 13.0, with an average of 8.0 percent (Table 1). The percentage of females among the releases ranged from 41.8 (Southwest Georges) to 67.2 (Atlantis Canyon). The sex ratios of the releases and recoveries, grouped by area of release, were tested by chi-square and found to be similar, with the exception of lobsters released at Block Canyon. Mean carapace lengths of lobsters released and of those recovered, back calculated to the time of release, were similar. These comparisons suggest that catchability was unchanged. Cooper (*3*) demonstrated that there was no measurable effect of tagging on behavior or survival of lobsters at Monhegan Island, Maine.

The distribution of tag returns over a 24-month period indicates that continental shelf lobsters move into shoal water in late spring and early summer and return to the deep waters at the edge of the shelf and slope in late fall and early winter (Fig. 2). The relatively large confidence limits about the mean depths of recapture from December through May can be attributed to concentration of lobsters in the high gradient zone of the continental slope where small horizontal excursions result in large variations in depth. The magnitude of variation in depth at recapture suggests that the migration toward shoal water and return is not a response of the total population, nor is it likely a well-coordinated one; hence, we hypothesize that some lobsters migrate early, some late, and some not at all. The net movement, however, is clearly cyclical.

This migratory behavior appears to be motivated by temperature, as the seasonal distribution of tagged lobsters according to depth is well correlated with bottom temperature. We have partitioned the data on the location at recapture by months and plotted these data against mean monthly bottom isotherms derived by Walford and Wicklund (*6*); results show that, with few exceptions, recaptured lobsters were distributed within a temperature regime

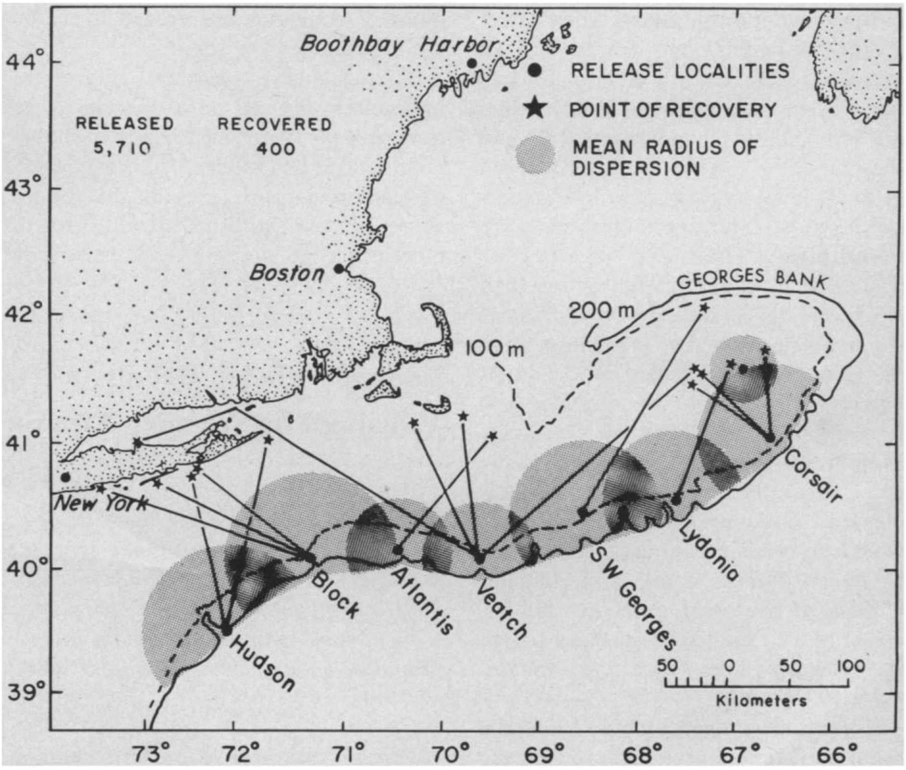

Fig. 1. Mean dispersion of tagged lobsters and examples of the longest shoalward migrations.

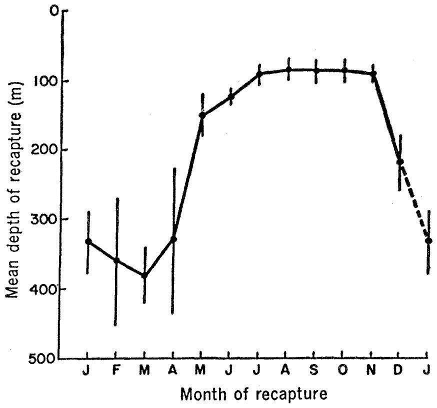

Fig. 2. Mean depth of recapture and 95 percent confidence limits. by months.

of 10° to 17.5°C. It is evident, therefore, that offshore lobsters actively orient to optimum temperature according to season, in contrast to coastal populations that remain localized and subject to wider seasonal extremes and a lower annual mean temperature.

Distribution of tagged lobsters that were recaptured is considered representative of the distribution of the lobster population. Fishermen search for commercial quantities of lobsters throughout the year at depths of from 20 to 700 m, which is a considerably greater range than the 70- to 400-m depth interval from which lobsters for tagging were initially captured.

Twenty-one percent of the recaptured lobsters had moved distances less than 16 km, 58 percent between 16 and 80 km, and 21 percent in excess of 80 km. Ten lobsters had migrated farther than 160 km and one had moved 338 km. The apparent speed of travel ranged up to 10 km/day. Lobsters demonstrating the most extensive migrations were predominantly females. Of the 61 lobsters that had migrated more than 80 km, 41 (67.2 percent) were females —a significantly higher percentage than the 53.6 percent females released. Of the 47 lobsters that had migrated onshore more than 80 km, 37 (78.7 percent) were females—also significantly higher than the percentage of females released. Distance of travel was not related to size; mean carapace length of males (103.9 mm) and females (95.0 mm) that had exceeded 80 km was similar to the mean carapace length of all tagged males (99.3 mm) and females (99.7 mm).

Migration of tagged lobsters into the inshore fishing grounds from the Hudson, Block, Atlantis, and Veatch Canyon areas was generally confined to areas south and west of Cape Cod and included several intrusions into the trap fishery of southern Long Island and one into inner Long Island Sound. Lobsters from Lydonia Canyon, Southwest Georges, and Corsair Canyon shoaled onto Georges Bank. No recoveries were made north of Cape Cod in the Gulf of Maine proper, which suggests little, if any, mixing with coastal stocks in the Gulf of Maine.

The growth rate of lobsters depends on the increase in size at molting and the frequency of molting. The increase in carapace length at molting, for the lobsters that were measured at recapture, averaged 18.7 percent for 53 males and 16.7 percent for 51 females. These growth increments are significantly greater than the 12.5 percent increase for males and females from the inshore Gulf of Maine population reported by Cooper (*3*).

Frequency of molting for offshore lobsters was obtained from 65 recoveries that had been at large for approximately 1 or 2 years. Approximately 97 percent of the lobsters (sexes combined) in the group 60 to 80 mm in size molted annually, 88 percent in the group 80 to 100 mm, and 51 percent in the group 100 to 120 mm. These rates of molting are significantly greater than those reported by Cooper (*3*) for lobsters of similar sizes in the inshore Gulf of Maine population. Additional recoveries are needed to define molt frequency by sex.

The extensive seasonal migrations undertaken by offshore lobsters contrast sharply with the localized movements of coastal stocks. Rate of growth of offshore lobsters exceeds that of inshore lobsters, in terms of both growth increments at molting and frequency of molting. Whether the offshore stocks are genetically distinct from their coastal counterparts has not been firmly established, but it is evident that the shelf edge and slope is a permanent habitat from which small and large-scale excursions are made with seasonal regularity. We hypothesize that the continental slope habitat lacks sufficiently high temperatures during the summer to permit the extrusion and hatching of eggs and the molting and subsequent mating, and that the deficiency is compensated by seasonal shoalward migration to warmer water.

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9 October 1970

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Internal Cellular Details of Euglena gracilis Visualized by Scanning Electron Microscopy

Abstract. *Simple washing of live* Euglena gracilis *cleans the pellicle of external coating material. When these cleaned cells are viewed with a scanning electron microscope, organelle outlines can be seen through the thinned pellicle. To view organelles directly, fixed* Euglena *cells are gently broken first or first frozen and then broken as part of their preparation for scanning electron microscopy. Subsequent viewing at magnifications of × 5,000 to × 21,000 reveals organelles, storage granules, endoplasmic reticulum, and nuclear pores, while retaining great depth of focus.*

During the last 5 years scanning electron microscopy has begun to be exploited for the study of soft as well as mineralized biological material (*1*). These studies have revealed many external details of multicellular and uni-