RELATIVE ABUNDANCE, BEHAVIOR, AND FOOD HABITS OF THE AMERICAN SAND LANCE, *AMMODYTES AMERICANUS*, FROM THE GULF OF MAINE

THOMAS L. MEYER, RICHARD A. COOPER, AND RICHARD W. LANGTON[1]

ABSTRACT

Meristic characteristics of sand lance taken from Stellwagen Bank indicated the species to be the American sand lance, *Ammodytes americanus*. Bottom trawl data, ichthyoplankton surveys, and diver and submersible observations demonstrated a significant increase in relative abundance of sand lance since about 1975 on Stellwagen Bank; this trend was typical of the Northwest Atlantic from Cape Hatteras, N.C., to the Gulf of Maine. School shapes were constant in appearance, vertically compressed, tightly compacted, and bluntly linear from a dorsal and ventral view. School strengths varied from about 100 to tens of thousands of individuals with the nearest-neighbor distance ranging from ¼ to 1½ body lengths. The swimming motion is sinusoidal in form and eellike in appearance. Swimming speeds varied from 15 to over 120 cm/s. Copepods were the most important food source, constituting 41% of the total weight of food consumed; sand lance feed in school formation between midwater and the surface. Sand lance bury themselves totally or partially in clean sandy substrates when not schooling.

In the Northwest Atlantic, sand lance range from Cape Hatteras, N.C., to Hudson Bay. They occur over sand and fine gravel bottoms and play an important role as a trophic link between zooplankton and commercially important fish such as Atlantic cod, haddock, silver hake, and yellowtail flounder (Scott 1968, 1973; Bowman and Langton 1978). Several species of sportfish (e.g., striped bass and bluefish) also utilize the sand lance as a food source (Bigelow and Schroeder 1953).

Studies of the eggs, larvae, and postlarvae of the American sand lance, *Ammodytes americanus*, have been reported by Covill (1959), Richards (1959, 1965, 1976), Norcross et al. (1961), Williams et al. (1964), and Richards and Kendall (1973). Investigations on the adult sand lance include taxonomic studies by Backus (1957), Richards et al. (1963), Leim and Scott (1966), Reay (1970), Winters (1970), Scott (1972), and Pellegrini[2] and studies on mortality and growth by Graham (1956) and Pellegrini (see footnote 2). Despite these investigations, little is known about the relative abundance, biology, behavior, and food habits of the adult American sand lance.

For the last 10 yr, information has been collected on sand lance during fishery cruises and undersea research programs conducted by the Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Woods Hole, Mass. The purpose of this paper is to describe some aspects of the abundance, behavior, and food habits of the American sand lance based on bottom trawl (groundfish) survey data, observations by scuba divers and from research submersibles with photographic records, and a food-habit study.

MATERIALS AND METHODS

Study Area

The majority of the observations on sand lance were made on Stellwagen Bank, a submarine ridge that rises to within 18 m of the ocean surface on the eastern boundary of Massachusetts Bay (Figure 1). The length of the bank is 39 km (north-south axis) and its greatest width is 13 km (at the southern end). Depths range from 18 to 77 m. Substrate characteristics by depth interval recorded during submersible operations are: 18-43 m—sandy; 43-55 m—sandy bottom with crushed shells; 55-77 m—gravel, rocky with boulders; and below 77 m—mud/silt. Approximately 95% of the bank has a sandy bottom.

Additional observations on sand lance were

[1]Northeast Fisheries Center Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543.

[2]Pellegrini, R. 1976. Aspects of the biology of the American sand lance, *Ammodytes americanus*, from the lower Merrimack River estuary, Massachusetts. Master's problem, Univ. Massachusetts, Amherst, 44 p.

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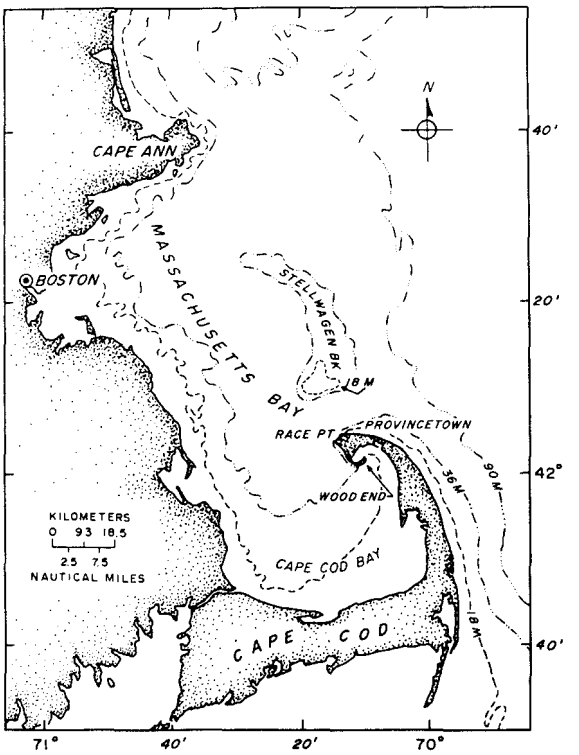

FIGURE 1.—Study area of sand lance observations, Gulf of Maine.

made on the Provincetown slope from Race Point to Wood End (Figure 1). Depths over the Provincetown slope range from 0 to 46 m, with a medium-coarse sandy substrate throughout the range. Slope gradients by depth interval are: 0-9 m—5°-15°; 9-46 m—30°-45°. The relatively steep slope begins between 90 and 250 m offshore.

Relative Abundance

Divers using scuba, or observers in submersibles,[3] made in situ observations during various manned undersea research projects from 1968 through 1977 (Table 1, Figure 2). Camera systems aboard the submersible were: 1) a 35-mm Nikon[4] camera using a 55-mm micro lens and an externally mounted MK 150 Subsea stroboscopic light, and 2) a Sony AD 3400 Monochrome video camera and recorder.

[3]Research submersibles were chartered by NOAA's Manned Undersea Science and Technology Program, Rockville, Md.

[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Dive locations on Stellwagen Bank and Cape Cod (Provincetown, Mass.) with observations[1] on presence (+) or absence (0) of American sand lance. Observations were made using scuba and submersible (sub).

Dates of observations	Dive sites: Provincetown Scuba	Provincetown Sub	Stellwagen Bank Scuba	Stellwagen Bank Sub
1968	1 - 0			
12-16 July - scuba	2 - 0			
1969	1 - 0			
21-25 July - scuba	2 - 0			
	3 - 0			
1970	1 - 0		5 - 0	
06-09 July - scuba	2 - 0		6 - 0	
	3 - 0			
1971	1 - 0	8 - 0	4 - 0	1 - 0
23-25 June - scuba	2 - 0	9 - 0		2 - 0
22 Sept. - sub	3 - 0	10 - 0		3 - 0
				4 - 0
				5 - 0
				6 - 0
				7 - 0
1972	1 - 0		4 - 0	
18-21 July - scuba	2 - 0		5 - 0	
24-31 Oct. - scuba	3 - 0		6 - 0	
1973	1 - 0		7 - 0	1 - 0
05-10 Oct. - scuba	2 - 0		8 - 0	2 - 0
05-09 Oct. - sub	3 - 0		9 - 0	3 - 0
			10 - 0	4 - 0
			11 - 0	5 - 0
			12 - 0	6 - 0
				7 - 0
				8 - 0
				9 - 0
				10 - 0
1974	1 - 0			
06-11 July - scuba	2 - 0			
	3 - 0			
1976	1 - ++	1 - ++		3 - +
16-18 June - scuba	2 - ++	2 - +		
15-18 June - sub	3 - ++			
1977	1 - +++		4 - ++	
08-11 Aug. - scuba	2 - +++		5 - ++	
	3 - +++			

[1]Estimates of relative abundance are noted as 0 for no sightings, + for a few sand lance observed, ++ for small schools (several hundred individuals per school) with infrequent sightings, and +++ for large schools (thousands per school) and schools observed almost continuously.

Stellwagen Bank is included in one of the sampling strata covered by the spring and fall bottom trawl surveys since 1963 (Grosslein 1969). This stratum encompasses the Massachusetts Bay area, extending from Provincetown to Cape Ann and ranges in depth up to 110 m (Figure 1). Stations were selected randomly within the stratum for each survey and the number of stations actually occupied on Stellwagen Bank on each survey ranged from 0 to 6. Trawl survey results are presented only for 1967-77, the period during which diver and submersible observations were made.

Behavior

Photographic and video records of sand lance behavior were made by scuba divers during a hydroacoustic experiment from RV *Albatross IV*,

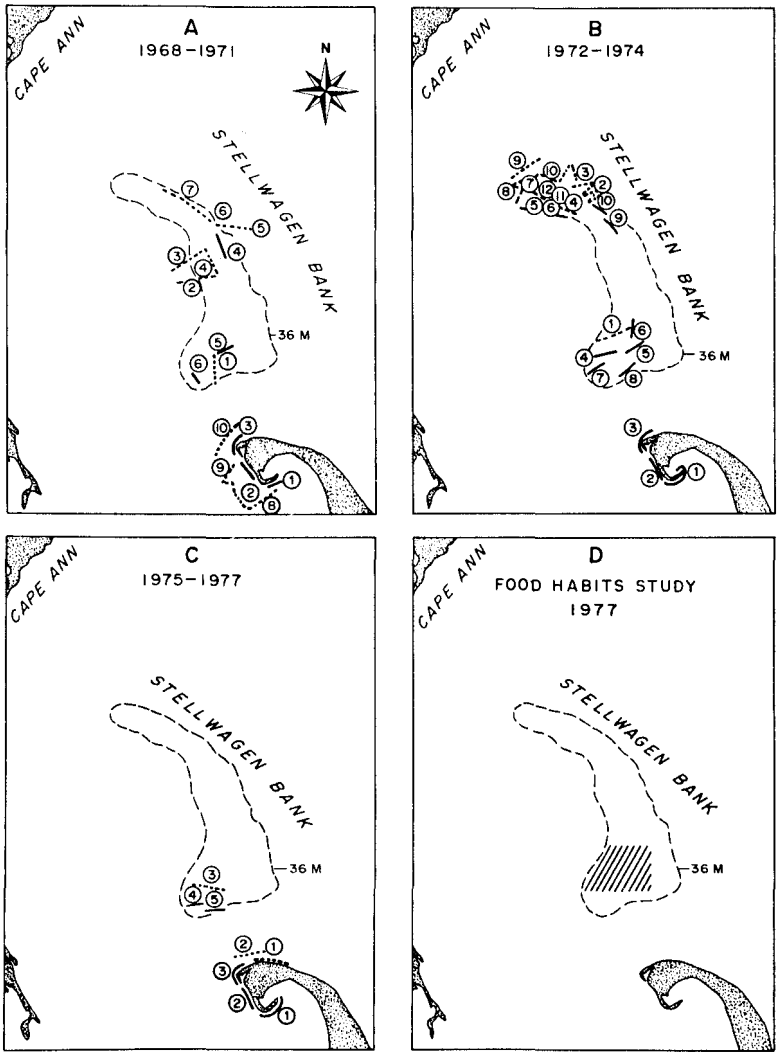

FIGURE 2.—Dive sites and location of 1977 food habits study on Stellwagen Bank and Cape Cod (Provincetown) from 1968 to 1977. Scuba (lines), submersible (dotted lines), 1977 bottom trawl (hatching) sampling areas. See Table 1 for key.

8-11 August 1977, on Stellwagen Bank (scuba dive locations 4, 5) and along the Provincetown slope (scuba dive locations 1-3) (Figure 2C).

Divers, using a Hydro-Products Model 125 television system with a 250-W thallium-iodide light source, filmed sand lance behavior on and near the bottom. The angles and speed at which sand lance entered the bottom substrate and exited from it were estimated from slow-motion video playback.

Schooling behavior was observed and photographed using a Nikonos II underwater camera with a 28- or 35-mm lens and a Subsea MK 150 or 225 electronic strobe. School strength, shape, nearest-neighbor distance, and individual fish size were estimated using in situ observations, photographs, or bottom trawl data. School swimming speeds were estimated at approximately 1 kn by divers swimming parallel to several schools for short distances. A speed of 1 kn is the approximate short-term sustained swimming speed of a diver. All in situ observations by diver scientists were made in daylight between 0900 and 1600 h.

Food Habits

A series of nine tows were conducted from *Albatross IV* on the southwestern edge of Stellwagen Bank over one 24-h period beginning at 1800 h on 9 August 1977 (Figure 2D). The tows were of 5-15 min duration at 3-h intervals and were made with

a Yankee #36 trawl (Grosslein[5]). The cod end and upper belly of the net were lined with 13-mm mesh netting, knot to knot. Only three species of fish were caught in any quantity: spiny dogfish, *Squalus acanthias*; silver hake, *Merluccius bilinearis*; and American sand lance. Sand lance were taken at random from the catch and preserved whole in 10% Formalin for stomach-content analysis.

In the laboratory, the stomachs were dissected out for stomach-content analysis. Ten fish from each of the nine tows were randomly selected from the preserved specimens for analysis. After the stomach was removed from each fish, the contents were examined and washed onto a fine-mesh screen. If the stomach appeared empty or had trace amounts (<1.0 mg) of food in it, it was rinsed out with seawater directly into a Petri dish. When there was a weighable quantity of prey present, the excess water was drawn off by pressing an absorbent tissue paper to the underside of the screen; the contents were weighed and then washed into a Petri dish. Using a dissecting microscope, the prey of each fish were identified to the lowest possible taxonomic grouping, and the percentage composition of each of the identified groups estimated. The percentage composition and total stomach-content weight were used to calculate the percentage weight for each prey category. The data were also expressed in terms of the percentage occurrence of each prey group in the stomachs.

RESULTS AND DISCUSSION

In the taxonomic studies listed above, morphometric and meristic characteristics were used to distinguish between "inshore sand lance" (*Ammodytes americanus* - *Ammodytes hexapterus*) and "offshore sand lance" (*Ammodytes dubius*), although Bigelow and Schroeder (1953) questioned whether such a distinction could be made.

Because of the question regarding the taxonomic status of *A. americanus* and *A. dubius*, several meristic characteristics were evaluated on sand lance caught on Stellwagen Bank (Figure 2D). Dorsal and anal fin ray counts were made directly on 10 randomly chosen fish ranging from 17.9 to 22.2 cm fork length (FL) and averaging 20.0 cm, SD = 1.24. The anal fin ray count ranged from 30 to 31 with a mean of 30.7, SD = 0.48. The dorsal fin ray count ranged from 60 to 63 with a mean of 61.1, SD = 0.99. The vertebral count, based on radiographs of 20 fish and excluding the hypural complex, ranged from 67 to 72 and averaged 69.25, SD = 1.21. The mean values reported here fell into the *A. americanus* category given by Reay (1970). For the purpose of this paper, the classification of Reay (1970) is accepted.

Relative Abundance

Examination of spring and fall survey data for the past 10 yr, excluding 1967, 1969, 1971, and 1973 for spring and 1971 and 1977 for fall (Stellwagen Bank stations were not sampled), indicates a substantial increase in sand lance abundance on Stellwagen Bank (Figure 3). The relative abundance increased during spring cruises from virtually 0 for the 1967-75 period to 50/tow in 1976 and 10,729/tow in 1977, while increasing during fall cruises from 0 for the 1967-74 period to 4,238/tow in 1975 with a decrease to 5/tow in 1976. Spring cruises (March-May) may give a better indication of sand lance abundance since fall cruises are conducted from October to December, a period of lesser sand lance activity before spawning (Winslade 1974). In the Gulf of Maine, all bottom trawl survey catches <75 sand lance/tow occurred on or along the edge of Stellwagen Bank. The catch rate

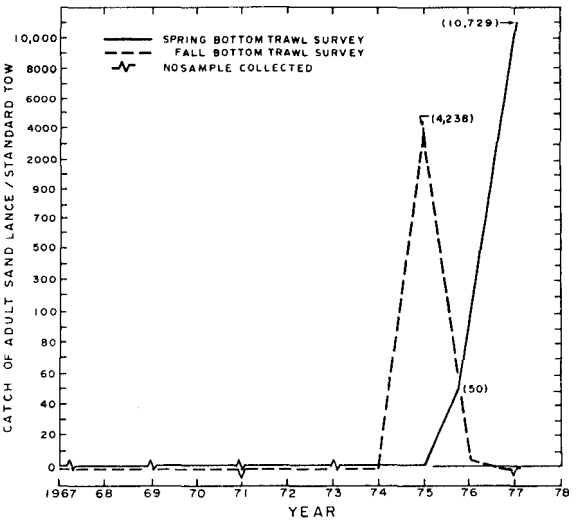

FIGURE 3.—Catch of adult sand lance per standard tow on Stellwagen Bank during the NMFS spring and fall bottom trawl stratified sampling surveys for 1967-77.

[5]Grosslein, M. D. 1969. Groundfish survey methods, NMFS, Woods Hole, Massachusetts. Lab. Ref. No. 69-02, 34 p.

declined drastically, to <1 sand lance/tow, when not fishing on the bank. In the southwest North Sea, fishermen have also noticed that better catches occur along the edges of larger banks and on the tops of smaller ones (Popp Madsen 1963).

In the last 10 yr, sand lance have shown evidence of a population increase along the Atlantic coast from Cape Hatteras, N.C., to and including the Gulf of Maine. Northeast Fisheries Center spring and fall bottom trawl survey results from 1968 to 1977 show large annual fluctuations in sand lance abundance since 1968 with a definite upward trend beginning in 1975 (Figure 4). The magnitude of this increase is considerably less than that recorded on Stellwagen Bank for the same period, but the yearly trends are similar.

One area of concern in attempting quantitative sampling is net avoidance. Livingstone (1962) documented on film that adult sand lance were able to escape in <2.5 s from the cod end of a Yankee Modified #41 trawl net with a cod end mesh of 114 mm, knot to knot, and a 38-mm cotton webbing covering. These films also showed the ease with which individuals and small schools were able to avoid the trawl net. In areas where abundance is high, the ability to avoid trawl nets may be less effective. Scott (1973) found it unusual to catch adult sand lance in nets except in areas where they were very abundant.

Relative abundance of sand lance on Stellwagen Bank and Provincetown slope, based on diver and submersible observations, has increased significantly since 1976 (Table 1). Although numerous diving programs have been carried out over the study area since 1968, it was not until the spring of 1976 that schools of sand lance were first observed. However, it is very likely that relatively small numbers of sand lance were present in the study area prior to 1976 but not noticed by the divers. This increase in sightings coincides with an increase in number of sand lance caught per tow during the bottom trawl survey cruises.

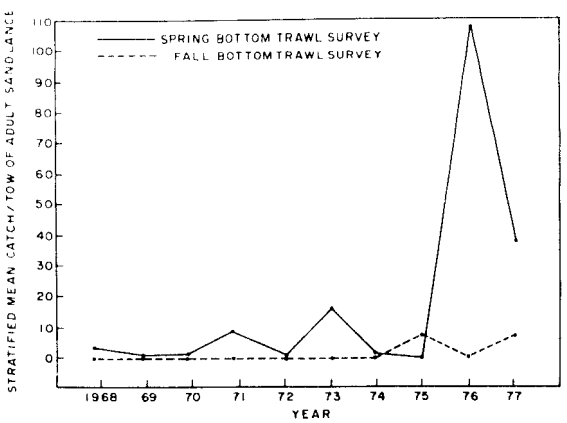

FIGURE 4.—Changes in the relative abundance of adult *Ammodytes* spp. in the Northeast Fisheries Center spring and fall bottom trawl surveys from 1968 to 1977 in the area extending from Cape Hatteras northward. (Data from Grosslein et al. in press, table 3.2.)

Sand lance larvae studies, conducted by the Boston Edison Company[6] showed sand lance larvae were among the most abundant fish larvae occurring in ichthyoplankton sampling surveys conducted in Cape Cod Bay, Mass., during 1974-77. They were more abundant in the eastern portion of the bay and were considerably more abundant in 1976 than in the previous 2 yr. This increase in sand lance larvae was also observed during the Northeast Fisheries Center spring ichthyoplankton surveys conducted in the area from Cape Hatteras to the Gulf of Maine for the past 4 yr (Figure 5). For example, the mean sand lance catch/10 m^2 area in spring 1977 was 9 times greater than in spring 1974.

Bottom trawl survey results, diver and submersible observations, and ichthyoplankton survey results all indicate that there is a relatively large concentration of sand lance inhabiting a small section of the Gulf of Maine, i.e., Stellwagen Bank and outer Cape Cod (Provincetown slope), and that this population has increased considerably since 1975; this increase in population is typical of the Northwest Atlantic from Cape Hatteras to the Gulf of Maine.

Behavior

School Structure

Schools of sand lance observed on the Provincetown slope were relatively small in numbers of fish, ranging from about 100 to several thousand individuals and were usually found in depths ranging from 6 to 20 m. From photographs it was calculated that individual fish on Provincetown slope ranged from approximately 12 to 17 cm long, with a mean of 15 cm. Sand lance schools observed on Stellwagen Bank were relatively large in numbers, ranging from about 500 to tens of thousands

[6]Boston Edison Company. 1974-77. Marine ecology studies related to operation of Pilgrim Station. Boston Edison Co., 800 Boylston Street, Boston, MA 02199.

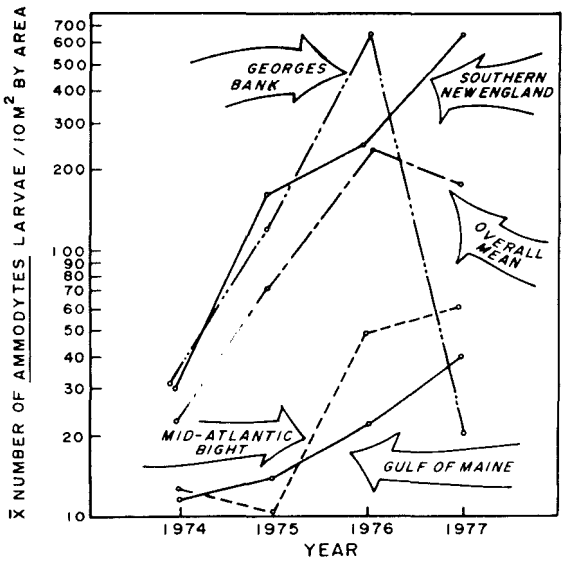

FIGURE 5.—Changes in the relative abundance of larval *Ammodytes* spp. in the Northeast Fisheries Center spring ichthyoplankton surveys from 1974 to 1977 in the area extending from Cape Hatteras northward. Data from Smith, W. G., and L. Sullivan. 1978. Annual changes in the distribution and abundance of sand lance, *Ammodytes* spp., on the northeastern continental shelf of the U.S. from the Gulf of Maine to Cape Hatteras. Northeast Fish. Cent., Sandy Hook Lab., Sandy Hook, NJ 07732. Lab. Ref. No. SHL 78-22.

of individuals. Individuals varied from 7.4 to 24.0 cm FL (measurements from bottom-trawl catches), with a mean length of 18.2 cm. Sand lance within a given school were of similar size; slightly larger fish were observed in positions at the head or central "core" of the school, with the smaller individuals occurring at the periphery. This distribution by size within the school was observed in both study areas. Schools were observed on the surface, at mid-depth, and near the bottom.

Inshore school strengths described by Kühlmann and Karst (1967) for European sand lance species *Hyperoplus lanceolatus* and *Ammodytes lancea* were commonly 30-100 or 200-300 individuals. These smaller schools joined up to form schools of from 500 to >1,000 fish and headed offshore for deeper water in the early morning. We observed schools of this size primarily in the Provincetown slope area. However, because the individual size of the fish and school strengths on Stellwagen Bank were larger, it is unlikely that these schools formed in the Provincetown slope area and moved out to the bank.

School Shape

The shape of sand lance schools, where individuals were not engaged in feeding, was constant in appearance. As a school moved undisturbed through the water it appeared vertically compressed, tightly compacted, and bluntly linear from the lateral view (Figure 6). Provincetown slope schools were 1-5 m wide, 0.5-1.5 m high, and 3-20 m long; these measurements depended on school strength. This school form, where the height-width-length ratio was approximately 1:3:10 (having more individuals situated ahead, alongside, and behind than above or below), is called a stratified school (Wahlert and Wahlert 1963). This school formation was, in general, independent of school strength. The "nearest-neighbor" distance between fish was approximately ½-¾ body length (BL) (Figure 6). This distance became greater along the school's flanks. The "nearest-neighbor" distance decreased to ¼ BL when the school exhibited a fright reaction to divers. The fishes leading the school and ones along the flanks usually swam the deepest. School shapes described by Kühlmann and Karst (1967) were similar to the measurements reported in this study, but a significant difference appeared in the school height and length measurements. Kühlmann and Karst (1967) listed their school height as 15-50 cm, and their school length as ≥40 m. Sand lance schools encountered in our study were more than double the height and shorter in length. The European study took place in water depths of 1-6 m, and in this relatively shallow water, there may be a tendency for a school to flatten out and increase its length.

Movement

The swimming motion of sand lance is sinusoidal in form and eellike in appearance from the dorsal and ventral views. Sidewise undulations begin at the head and run along the body toward the tail (Figure 7). Schools swimming undisturbed, and not engaged in feeding, maintain an estimated speed of 30-50 cm/s. Schools exhibiting feeding behavior usually swim at about half the speed of undisturbed schools, or about 15-25 cm/s, and spread out to a little over double the normal schooling distances so that the nearest neighbor is approximately 1-1½ BL away. Smaller schooling groups were observed to swim faster than larger schools. When approached by divers, schools ac-

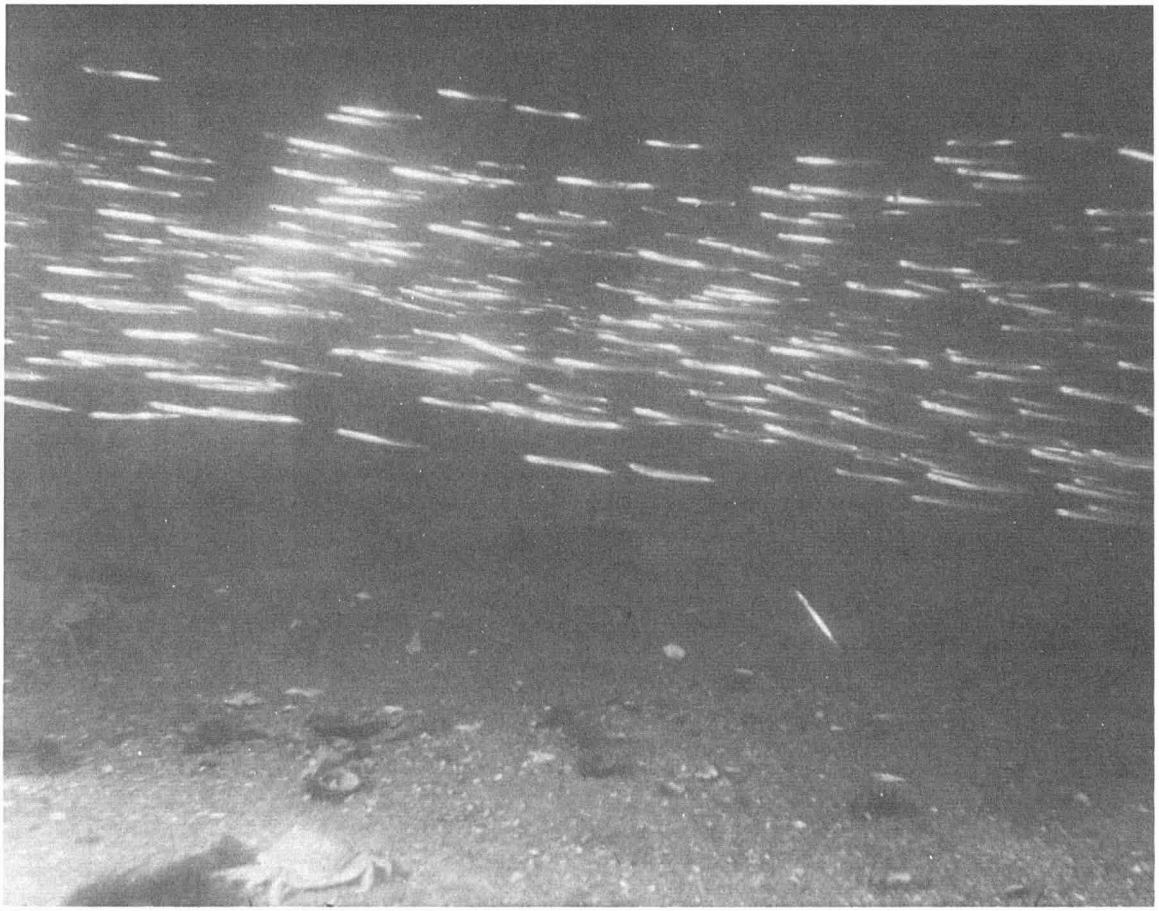

FIGURE 6.—School of sand lance encountered on Provincetown slope. Note lateral view of sand lance leaving the bottom to join school above.

celerated to one side or split to avoid the divers at the part of the school closest to the divers. The forward portion of the school continued on in its original direction, while the rear portion generally reversed direction. These avoidance maneuvers were made at about 70-120 cm/s, over double the original undisturbed speed, and lasted for only a few seconds before the divided sections regrouped and slowed down to their original speed. Feeding schools were observed in midwater and near the surface, but not on the bottom.

Kühlmann and Karst (1967) recorded the escape speed of larger sand lance to be 300-500 cm/s for at least a few seconds. During our study, there were many occasions when the swimming speed appeared to be >120 cm/s, but the actual speed was not calculated.

Behavior Within and Near the Ocean Floor

Sand lance were found in substrates conducive to burrowing, such as clean sandy bottoms, sand bottoms with crushed shells, and fine-graveled bottoms. Substrates of mud, mud/silt, medium to coarse gravel, and rock/boulder were avoided. This preference for loose porous substrate facilitates entry and exit and may relate to a sufficient supply of dissolved oxygen within at least the first few centimeters of interstitial water. Oxygen is continually replenished by tidal currents of 32-47 cm/s (0.62-0.91 kn) measured at 1 m above the bottom on Stellwagen Bank (Padan 1977).

Sand lance usually disappear into the bottom in small groups. The initial penetrating angle was estimated as 60°-75° from the horizontal and con-

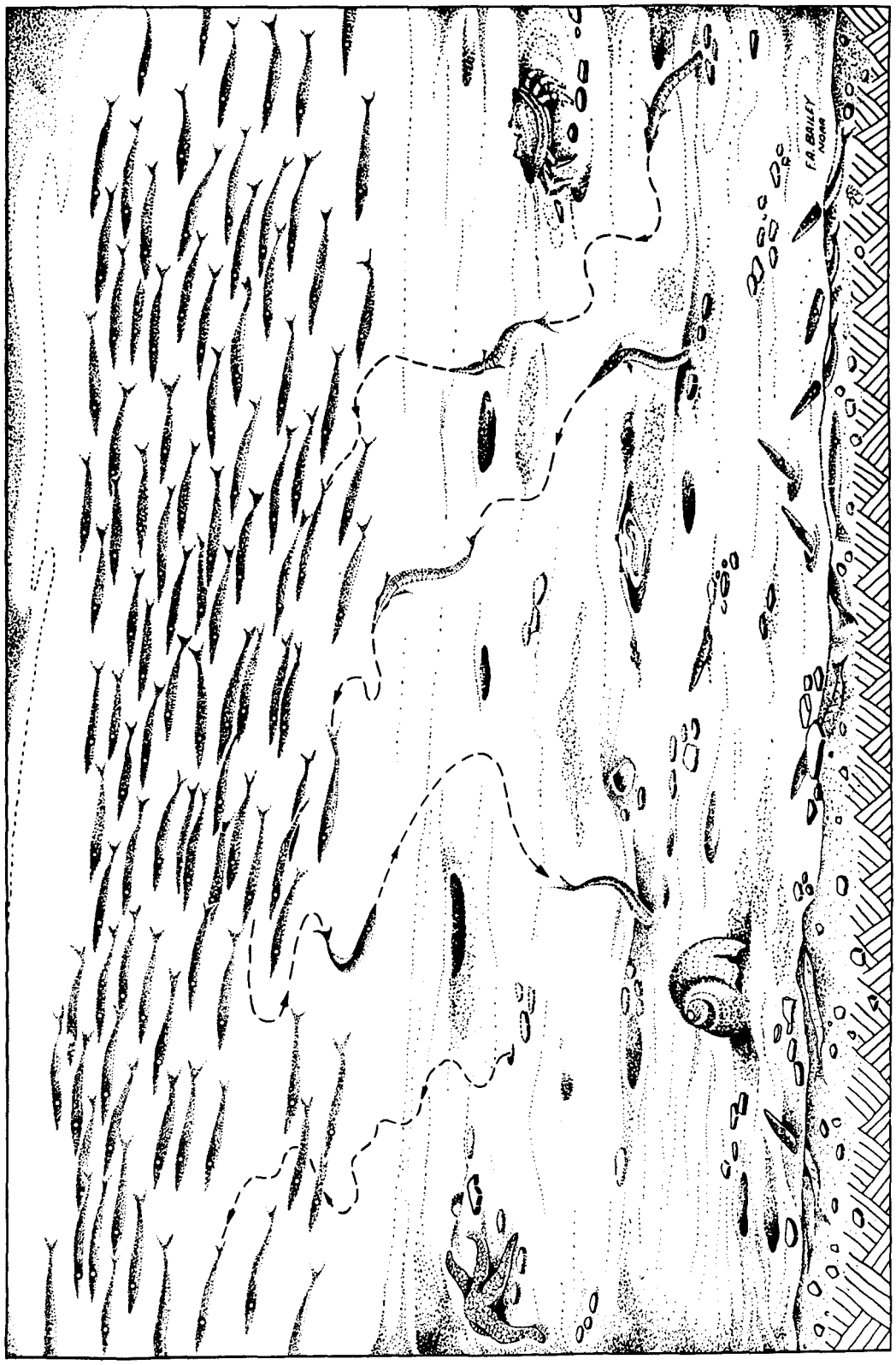

FIGURE 7.—Artist's rendition of sand lance behavior within and near the ocean floor.

sisted of a continuance of their sinuous movement until one-quarter of the body was buried, at which point the remaining three-quarters of the body was brought to a 20°-40° angle to allow the animal to settle into its normal resting position (Figure 7). Once in a resting position, the sand lance would partially emerge headfirst if disturbed (Figure 7). Sand lance on Stellwagen Bank, exhibiting this partial-emergence behavior, would retract back into the bottom when further disturbed. In contrast, sand lance encountered along Provincetown would usually leave the substrate. Kühlmann and Karst (1967) observed similar behavior and noted on several occasions that, after pulling back into the bottom, sand lance could turn, move laterally through the substrate, and emerge some distance away. This behavior was not observed in our study area.

Sand lance leaving the bottom exited at an angle between 20° and 60° with an initial speed of 50-80 cm/s, which increased up to 120 cm/s within the first 1.5 m from the bottom (Figure 7). As divers proceeded along the bottom, sand lance would exit from the substrate and either school or swim to the end of the diver's visual range.

Food Habits

The results of the stomach-content analysis for *A. americanus* collected on Stellwagen Bank are given in Table 2. The data are presented as both the percentage occurrence of prey in the stomachs and as the percentage weight of the total prey consumed. It is evident that copepods were the most important prey, occurring in 37.8% of the stomachs examined and making up 41.4% of the total weight of the prey. The other identifiable prey groups, such as hyperiid amphipods, mysids, euphausiids, chaetognaths, salps, and animal eggs, were much less important, usually occurring in only 1-2% of the stomachs. Of these groups only the chaetognath *Sagitta* contributed significantly to the diet on a percentage weight basis (39.9%). This was because the stomach of one fish was quite distended with chaetognaths. "Animal remains," which are unidentifiable prey, were the most frequently occurring prey category; however, on a weight basis they were much less significant.

The food habits of a number of different species of sand lance have been studied in Atlantic and Pacific waters. In general the diets are all very similar, with copepods being the major prey in almost every instance (Reay 1970). Around Japan, for example, both Senta (1965) and Sekiguchi (1977) have shown that *A. personatus* is a plankton feeder relying heavily on copepods. In the North Sea, Roessingh[7] found that copepods were the major prey of *A. marinus* and occurred in roughly the same proportions in the stomachs as they did in the plankton. Macer (1966) examined the stomach contents of five species of sand lance from the North Sea. In all cases the sand lance were found to be plankton feeders, with copepods being the dominant prey for at least three of the five species. Only for *A. lanceolatus* was it conclusively shown that copepods were less significant as prey, being replaced by fish eggs, larvae, or small fish, particularly small *Ammodytes*. Two species of sand lance are reported to occur along the Atlantic coast of North America, and only a small amount of information is available on their food habits. Richards (1963) examined the stomachs of 290 *A. americanus* in Long Island Sound; as for most other species of sand lance, copepods were the major prey. *Centropages* were preyed upon by 80% of the fish, *Acartia* by 55%, and *Temora* by 42%. Other prey included barnacle cyprids, fish eggs, dinoflagellates and diatoms, mysids, and sand lance larvae. Scott (1973) studied the food habits of

TABLE 2.—Stomach contents of American sand lance collected on Stellwagen Bank, August 1977. The data are expressed as both the percentage frequency of occurrence of prey and as the percentage weight of the total quantity of prey consumed.

Prey	Occurrence (%)	Weight (%)
Copepods:		
Calanoida	3.3	0.81
Calanus	8.9	9.55
Centropages	10.0	2.57
Pseudocalanus	17.8	6.28
Temora	17.8	8.06
Tortanus	17.8	6.27
Metridia	1.1	1.22
Cyclopoida:		
Oithona	2.2	0.05
Unidentified	28.9	6.62
Copepod subtotal	37.8	41.43
Hyperiid amphipods	1.1	0.09
Mysids	1.1	0.32
Meganyctiphanes norvegica	1.1	0.41
Sagitta elegans	2.2	39.91
Salpidae	1.1	0.04
Animal eggs	1.1	<0.01
Trematodes	3.3	0.01
Animal remains	84.4	17.79
No. stomachs examined	90	
No. stomachs empty or trace	32	
Mean wt of contents/stomach	15.3 mg	
Mean fish length	18.2 cm, SD = 1.8	

[7]Roessingh, M. 1957. Problems arising from the expansion of the industrial fishery for the sand eel, *Ammodytes marinus* Raitt, towards the Dutch coastal area. Near Northern Seas Committee, Int. Counc. Explor. Sea.

A. dubius in the Canadian northwest Atlantic. Again, copepods, especially *Calanus finmarchicus*, were the most important prey. Other prey included crustacean larvae, invertebrate eggs, polychaete larvae, larvaceans, fish eggs, pteropods, and barnacle cyprids. Comparison with plankton tows made at the time the fish were caught showed that *A. dubius* had a definite preference for the larger zooplankton such as copepods. From the data in Table 2, it is clear that the diet of *A. americanus* from Stellwagen Bank is typical for this family of fishes. There are, however, several small differences from other published results which are worth noting. For example, chaetognaths occurred rarely in the stomachs (2.2%) but on a weight basis were only slightly less important than copepods. It would appear that chaetognaths are readily consumed if available. One notable exception to the list of prey is phytoplankton. Both Richards (1963) and Scott (1973), as well as Senta (1965) and Macer (1965), reported finding diatoms or dinoflagellates in the guts of the fish they examined. In our study, no phytoplankton was observed as part of the stomach contents. It is possible that at certain times of the year the occurrence of phytoplankton would be much more apparent in the guts, as might also be expected for other prey such as crustacean larvae, barnacle cyprids, and larval polychaetes.

SUMMARY

1. The meristic counts of sand lance reported are in agreement with published data and fall into the category of *Ammodytes americanus*, the American sand lance.

2. Data on the relative abundance of sand lance from Northeast Fisheries Center spring and fall bottom trawl survey cruises indicate that there has been a substantial increase in sand lance abundance on Stellwagen Bank over the last 10 yr. This trend was also reflected by an increase in the numbers of sand lance larvae occurring in the spring ichthyoplankton results measured in the Gulf of Maine over the last 4 yr. This increasing trend in larval and adult sand lance abundance in the Gulf of Maine was typical of the northwest Atlantic from Cape Hatteras northward.

3. Sand lance encountered within the Provincetown slope area ranged from 12 to 17 cm long (mean = 15 cm), and school strength numbered from about 100 to several thousand individuals. In contrast, individuals on Stellwagen Bank ranged from 7.4 to 24.0 cm FL (mean = 18.2 cm), while school strengths ranged from about 500 to tens of thousands of individuals.

4. School shapes were constant in appearance, vertically compressed, tightly compacted, and bluntly linear from a dorsal and ventral view. Provincetown slope schools were 1-5 m wide, 0.5-1.5 m high, and 3-20 m long depending on school strengths. The nearest-neighbor distance between fish swimming in an undisturbed school was approximately ½-¾ BL; between fish swimming in a school exhibiting a fright or avoidance reaction, ¼ BL; and between fish swimming in a school engaged in feeding, approximately 1-1½ BL.

5. The swimming motion of sand lance is sinusoidal in form and eellike in appearance. Schools swimming undisturbed and not engaged in feeding maintain an estimated swimming speed of 30-50 cm/s; during feeding they maintain an estimated speed of 15-25 cm/s; and during avoidance maneuvers, 70-120 cm/s. Feeding schools were observed in midwater and near the surface, but not on the bottom.

6. Sand lance were found to prefer clean sandy substrates conducive to burrowing. Sand lance usually disappear into the substrate in small groups, initially penetrating at an angle of 60°-75° from the horizontal, and continuing their sinuous movement until one-quarter of the body is buried, at which point the remaining three-quarters of the body is brought to a 20°-40° angle to allow the animal to settle into its resting position. Sand lance encountered on Stellwagen Bank were occasionally observed to partially emerge from the substrate headfirst and retract back into the bottom if approached. In contrast, sand lance along Provincetown slope would exit from the bottom when approached. Sand lance leaving the bottom exited at an angle of between 20° and 60° with an initial speed of 50-80 cm/s and built their speed up to 120 cm/s within the first 1.5 m from the bottom. Individual fish exiting would show schooling behavior if another fish was exiting at the same time.

7. Copepods were the most important prey of *A. americanus*, occurring in 38% of the stomachs examined and making up 41% of the total weight of prey consumed.

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