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A Commercial Sampling Program for Sandworms, *Nereis virens* Sars, and Bloodworms, *Glycera dibranchiata* Ehlers, Harvested Along the Maine Coast

Edwin P. Creaser, Jr., David A. Clifford,
Michael J. Hogan, and David B. Sampson

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741. Distribution of gammaridean Amphipoda (Crustacea) in the Middle Atlantic Bight region. By John J. Dickinson, Roland L. Wigley, Richard D. Brodeur, and Susan Brown-Leger. October 1980, vi + 46 p., 26 figs., 52 tables.

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A Commercial Sampling Program for Sandworms, *Nereis virens* Sars, and Bloodworms, *Glycera dibranchiata* Ehlers, Harvested Along the Maine Coast

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John V. Byrne, Administrator
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William G. Gordon, Assistant Administrator for Fisheries

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A Commercial Sampling Program for Sandworms, *Nereis virens* Sars, and Bloodworms, *Glycera dibranchiata* Ehlers, Harvested Along the Maine Coast

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ABSTRACT

Brief discussions of the history and development of the marine worm fisheries for bloodworms, *Glycera dibranchiata*, and sandworms, *Nereis virens*, the methods of digging both species, the packing media used in their shipment, and the various marine worm markets, are presented.

The status of the commercial marine worm fishery between April and September 1973–76 was investigated. A sampling program for bloodworms and sandworms revealed that there was no significant difference in the mean size of bloodworms (18.72 ± 0.60–20.83 ± 0.54 cm) and sandworms (25.69 ± 0.42–26.77 ± 0.53 cm) harvested. Marine worm diggers avoid picking up potential spawning sandworms during the months of March, April, and May and bloodworms during the month of May. During August and September, potential sandworm spawners comprise 15.6–38.3% of the commercial catch; during April, potential bloodworm spawners comprise 7.33–13.58% of the commercial catch. Sandworm spawners were found coastwide but bloodworm spawners were never collected east of the Taunton River (Sullivan, Maine). Approximately 8% of the sandworms and 5–7% of the bloodworms had regenerated tails and approximately 19–23% of the sandworms and 12–13% of the bloodworms were broken.

The use of probability sampling expansions has enabled us to estimate that sandworm diggers dug a total of 45,746–66,004 hours/sampling season during a total of 23,402–31,587 tides/sampling season and landed a total catch of 307,426–409,189 pounds. Bloodworm diggers dug a total of 89,691–177,909 hours/sampling season during a total of 30,545–62,339 tides/sampling season and landed a total catch of 109,936–206,577 pounds.

It cannot be conclusively stated that sandworm and bloodworm abundance changed significantly between 1973 and 1976. Ratio estimates of the numbers of marine worms dug/digger tide varied between 1,024 ± 60–1,184 ± 38 (sandworms) and 536 ± 36–662 ± 26 (bloodworms).

The 6-month mean value/tide and value/hour varied between \$27.97–\$40.30 and \$14.34–\$19.15, respectively (sandworms), and \$27.97–\$31.59 and \$10.11–\$11.00, respectively (bloodworms).

A significant difference exists in the length-weight relationships for sandworms and bloodworms from eastern Maine and the Sheepscot River. This observation may result from the fact that bloodworm spawners are rare in eastern Maine and bloodworms may substitute an increase in weight for the production of gametes. No explanation for this observation in sandworms can presently be given.

The numbers of bloodworms and sandworms per pound were calculated from mean length and length-weight data. Although the mean number of bloodworms per pound decreased during the 4-year sampling period, the decrease was not significant at 95% confidence limits (1.96 SE). No significant changes in the mean number of sandworms per pound were recorded during the same period.

The MSY (maximum sustainable yield) for the fishery was obtained with approximately 815 bloodworm diggers, 386 sandworm diggers, and 99 diggers who dug both species. OSY (optimal sustainable yield) was approximately 564–689 bloodworm diggers, 267–327 sandworm diggers, and 69–84 diggers who dug both species. Very rough quotas of 28–33 million bloodworms, and 26–30 million sandworms are associated with these OSY figures.

The overall average frequencies of bloodworm and sandworm digging (expressed as the number of low tide periods occurring since the last low tide dug) were 5.3 and 3.4, respectively. The numbers of years of digging experience recorded for bloodworm and sandworm diggers show that worm digging is frequently a short-lived work experience, 35–51% of the bloodworm diggers and 22–34% of the sandworm diggers have dug between 1 and 4 years. The mean age of bloodworm and sandworm diggers varied between 27.7 and 31.9. The vast majority of both bloodworm and sandworm diggers are male.

INTRODUCTION

Two species of Annelid worms are harvested for bait in Maine: the sandworm or clamworm, *Nereis virens*, and the bloodworm or beak-thrower, *Glycera dibranchiata*. These worms are dug from mud flats by marine worm diggers who are licensed by the State of Maine, Department of Marine Resources (DMR). Worm diggers generally dig only one species or the other and sell their catch to wholesale shippers (dealers) who are also licensed by the State. The wholesale shippers pack and ship their worms to wholesale distributors from whom they have received purchase requests. Wholesale distributors sell their worms to bait shop retailers who divide the shipment into lots of a dozen worms and sell directly to recreational fishermen. The worms are used in recreational fisheries for blackfish, bluefish, fluke, kingfish, pogy, weakfish, sea bass, striped bass, spot, flounder, and smelt on the Atlantic, Gulf, and Pacific

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coasts. Although the fishery grew rapidly during the 30 yr prior to 1976 and developed into one of the top five commercial fisheries (landed value) in Maine, it was not until the advent of the State-Federal aid program (P.L. 88–309) that the State obtained funding to collect detailed catch, effort, and catch per effort data for the fishery.

DISTRIBUTION

The sandworm was first recorded as *Nereis grandis* from the mud flats of Grand Manan Island, New Brunswick, Canada, in the Bay of Fundy by Stimpson (1854). *Nereis grandis* was identified at Eastport, Maine, by Verrill (1871). Webster and Benedict (1887) reported *Nereis virens* as being very common in mud and sandy mud during low water in the vicinity of Eastport. *Nereis virens* has been reported from the western Atlantic along the U.S. coast from Virginia to Maine and in Canada from New Brunswick, Nova Scotia, the Gulf of the St. Lawrence, Newfoundland (Pettibone 1963), and Labrador (Miner 1950). It has been reported from the eastern Atlantic to Iceland and Ireland and in the North Sea to France. It is also found in Norway (Pettibone 1963) and in the White Sea of Russia (Sveshnikov 1955).

The bloodworm was first recorded as *Rhynchobolus dibranchiata* from Eastport, Maine, by Verrill (1874). *Glycera dibranchiata* has been reported from Prince Edward Island (MacPhail 1954), the Gulf of the St. Lawrence, Nova Scotia, and New Brunswick south through Maine, New Hampshire, Massachusetts, Rhode Island, Delaware, Maryland, Virginia, and North Carolina to Florida (Pettibone 1963) and the West Indies (Hartman 1944). In the Gulf of Mexico it is found from Florida to Texas (Pettibone 1963) and on the Pacific coast from Mazatlan, Mexico (Hartman 1950), north including Lower California (Pettibone 1963) to San Mateo County, Calif. (Hartman 1950).

HABITAT (SANDWORMS)

The sandworm is especially common in sheltered flats bordering the mouths of rivers, estuaries, and sounds (Pettibone 1963). Although sandworms can be found throughout the intertidal zone, they are commercially abundant in the coarse and fine muddy sands near the low water mark. Ganaros[4] reported that in the early 1940's, commercial sandworm diggers recalled that they could collect worms of commercial quality and quantity close to shore, thus suggesting that sandworms may have become depleted in the upper intertidal zone. In addition to being found in coarse and fine muddy sand, sandworms are often found under cobbles and large rocks along the shore, jetties, and piers, in marsh thatch, under or near mussel beds, in gravelly sand and clay, in water soaked wood, and among the roots of decaying marsh grass and eelgrass (Pettibone 1963). Crowder (1923) reported that young sandworms have been found in old sea shells and within the fronds of *Ulva*. At certain times of the year, sandworms of all sizes can be found swimming free in the river channels (Dean 1978a; Graham[5]). They have also been dredged to a depth of 154 m (Pettibone 1963).

In soft mud, the sandworm burrows to depths of 7–45 cm with the largest specimens usually found at the greatest depths (Pettibone 1963). Commercial sandworm diggers first remove the top 13 cm of soft mud and then dig down about 25 cm farther to reach these commercial quantities of large worms (Glidden[6]). In certain types of mud, the burrows are well defined on the mud surface and aid the diggers in locating areas of high concentration (Fairservice[7]). The burrows themselves are lined with an adhesive mucus that binds the walls (Crowder 1923). Several burrows often intersect so that any burrow may have several openings. The rhythmic undulations of the sandworm create a current of water through the burrow which supplies the worms' respiratory needs. The current of oxygen-rich water also results in the formation of a visible red iron oxide residue in the sediment immediately adjacent to the burrow (Pedrick[8]).

Brafield[9] has indicated that the water and intertidal salinity encountered by the Southend, England, sandworm population varied between 28 and 32‰ and 27.5 and 31.5‰, respectively, and the water temperature varied between 3.2°C (January) and 22.5°C (August). Gosner (1971) reported that sandworms are capable of withstanding salinity as low as 10‰ and Mazurkiewicz[10] found the lower salinity tolerance of sandworms to be 5‰. During a study of the sandworm population at Wiscasset, Maine (Creaser and Clifford[11]), the surface water salinity varied between 17.3 and 28.9‰ and the surface river temperature varied between -1.4° and 15.3°C. The bottom river salinity varied between 23.8 and 29.3‰ and bottom river temperature varied between -1.2° and 14.3°C. The interstitial mud temperature for this area varied between +0.3° and 15.6°C. The range of temperatures recorded for the sandworm population at Brandy Cove, New Brunswick (Snow 1972), are very similar to those recorded above for the Wiscasset studies. More recent salinity and temperature studies (Creaser et al.[12]) at the site of the Wiscasset sandworm work, have yielded surface and bottom salinities ranging between 9.7 and 30.8‰ and 10.0 and 31.6‰, respectively, and surface and bottom temperatures ranging between -1.3° and 20.1°C and -1.6° and 19.7°C, respectively.

The complete analysis of sediments from coastwide marine worm growing areas is lacking. Pedrick (footnote 8), however, analyzed the sandworm sediment within DMR's closed marine worm conservation area at Wiscasset, Maine, for a number of parameters. The results, presented in Table 1, demonstrate that the sediment in the closed area is primarily a silty clay and the concentrations of the seven heavy metals tested decrease with depth.

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[4]Ganaros, A. 1951. Commercial worm digging. Maine Dep. Sea Shore Fish. Bull., Augusta, 6 p.

[5]J. J. Graham, Marine resources scientist, Maine Department of Marine Resources Research Laboratory, West Boothbay Harbor, ME 04575, pers. commun. June 1974.

[6]Glidden, P. E. 1951. Three commercially important polychaete marine worms from Maine: *Nereis (Neanthas) virens*, *Glycera dibranchiata*, *Glycera americana*. A report to the Maine Department of Sea and Shore Fisheries, Augusta, 4 p.

[7]S. Fairservice, marine worm digger, Wiscasset, ME 04578, pers. commun. March 1977.

[8]R. A. Pedrick, Coordinator, Environmental Impact Statements, Natl. Mar. Fish. Ser., NOAA, Wash., DC 20230, pers. commun. April 1976.

[9]A. E. Brafield, Queen Elizabeth College, London, England, pers. commun. July 1968.

[10]M. Mazurkiewicz, Assistant Professor, University of Maine, Portland, ME 04103, pers. commun. June 1977.

[11]Creaser, E. P., and D. A. Clifford. 1981. Life history studies on the sandworm, *Nereis virens* Sars, in the Sheepscot estuary, Maine. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 81/16, 37 p.

[12]Creaser, E. P., Jr., D. C. Clifford, and M. J. Hogan. 1978. Hydrographic data report Part II. Salinity and temperature data obtained from simultaneous stations at Bluff Head and Long Ledge (Montsweag Bay, Maine) and the Wiscasset Bridge (Wiscasset, Maine) 1970–1976. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 78/12, 167 p.

Table 1.—Size and heavy metals analysis of sediment from the bloodworm and sandworm producing portions of the marine worm conservation area at Wiscasset, Maine.

	Sandworms				Bloodworms			
Subsample depth in core (cm)	0.0–3.0 cm	3.5–15.5	15.5–19.0	19.0–25.5	0.0–4.5	4.5–8.0	12.5–17.0	18.0–23.5
				Sediment size				
Gravel (>2.0 mm) (%)	0.32	0.65	0.31	0.36	0.02	0.06	0.10	0.22
Sand (2.0–0.063 mm) (%)	9.52	11.24	10.72	8.73	9.66	6.54	7.23	6.62
Silt (0.063–0.004 mm) (%)	49.18	54.95	56.30	58.53	75.77	63.60	61.46	59.25
Clay (<0.004 mm)(%)	40.99	33.16	32.67	32.39	14.55	29.79	31.21	33.92
				Heavy metals				
Subsample depth in core (cm)	0.4		12–16			0–4		12–16
Copper (ppm dry weight)	24.5		18.4			17.3		16.9
Zinc (ppm dry weight)	212		169.3			151		138.5
Manganese (ppm dry weight)	347		323.2			266		277.8
Chromium (ppm dry weight)	57.8		43.9			36.7		39.3
Cobalt (ppm dry weight)	18.4		15.4			10.9		14.0
Nickel (ppm dry weight)	37.0		30.7			37.7		30.7
Iron (%)	3.6		3.2			2.9		2.8
Organic carbon (%)	2.27		2.19			2.27		2.1

HABITAT (BLOODWORMS)

The bloodworm is a relatively common inhabitant of intertidal flats bordering brackish waters and tidal estuaries (Pettibone 1963). Bloodworm diggers generally share the opinion that bloodworms are found in greatest abundance around freshwater streams that empty into coves (Ganaros footnote 4). Under many circumstances, areas affected by considerable quantities of freshwater run-off may be occupied by bloodworms and not by sandworms and clams (Dow and Wallace;[13] Pettibone 1963). Although bloodworms are commonly found in soft organically rich muds (Klawe and Dickie 1957), the mud is usually more compact than that found in commercial sandworm digging areas (Ganaros footnote 4). Klawe and Dickie (1957) believed that a relationship exists between soil type and abundance; a continuous increase in abundance exists in the following series of sediment types: sand, hard clay, dark sand, sand and mud, and soft mud. Sanders et al. (1962), on the other hand, reported that in Barnstable Harbor, Mass., the largest numbers of bloodworms were found at sandy stations. Andrews (1892) has recorded bloodworms as inhabiting shoals in the Beaufort, N.C., area. In the same area, Adams and Angelovic (1970) described the bloodworm as one of the dominant species of infauna in estuarine eelgrass beds. At certain times of the year, bloodworms containing immature gametes can be found swimming free in some bays, harbors, and river channels (Graham and Creaser 1978; Dean 1978b). They have also been dredged in water up to approximately 400 m deep on bottoms of sand, mud, mud mixed with gravel, rocks, and particularly in mud rich in detritus (Pettibone 1963).

Bloodworms are dug commercially from the mud at depths up to 25 cm (Pettibone 1963). Commerical bloodworm concentrations are usually not as dense as commercial sandworm concentrations (Ganaros footnote 4).

Worm holes are not characteristic of a bloodworm flat (Ganaros footnote 4). However, evidence for the passage of oxygenated water through the burrows is revealed by the presence of a layer of lighter colored oxidized sediments around each burrow (Mangum;[14] Pedrick 1978).

[13]Dow, R. L., and D. E. Wallace. 1955. Marine worm management and conservation. Maine Dep. Sea Shore Fish., Fish. Circ. 16, 9 p.

[14]C. P. Mangum, Associate Professor, College of William and Mary, Williamsburg, VA 23185, pers. commun. May 1972.

During a study of the bloodworm population at Wiscasset, Maine (Creaser 1973), the surface water salinity varied between 10.4 and 30.2‰ and the surface river temperature varied between −1.2° and 20.3°C. The bottom river salinity varied between 15.1 and 30.5‰ and bottom temperature varied between −0.6° and 19.0°C. The interstitial mud temperature for this same area varied between 0.8° and 16.7°C. The results of more recent salinity and temperature studies from this same area (Creaser et al. footnote 12) have already been reported under sandworm habitat.

Bloodworm sediments within DMR's closed marine worm conservation area at Wiscasset were also analyzed by Pedrick (footnote 8). The results of size and heavy metals analysis of bloodworm sediments are presented in Table 1. The physical properties of the sediment taken approximately halfway between the bloodworm and sandworm producing portions of the flat are recorded in Table 2. A more detailed analysis of marine worm sediment size from Wiscasset and other areas along the Maine coast is available from DMR files.

Table 2.—Physical properties of the sediment taken approximately halfway between the bloodworm and sandworm producing portion of the closed conservation area at Wiscasset, Maine.

	Subsample depth in core (cm)[1]		
Property	0–6.5	6.5–18	18–24
Wet unit weight (g/cm³)	1.42	1.48	1.53
Specific gravity of solids	2.62	2.60	2.62
Water content (% dry weight)	110.10	90.04	78.00
Void ratio	2.883	2.337	2.045
Saturated void ratio	2.883	2.337	2.045
Porosity (%)	74.2	70.0	67.2

[1]Subsampling depths determined by X-ray diffraction techniques.

HISTORY OF THE MARINE WORM FISHERY

It is generally agreed that a small marine baitworm fishery was in operation on Long Island, N.Y., during 1921–22. However, small scale worm transactions between a few individuals may have occurred on Long Island considerably before these dates (Wanser[15]). By the mid-1920's the Long Island fishery had become well

[15]A. Wanser, marine worm dealer, Milbridge, ME 04658, pers. commun. July 1979.

established as the result of a demand for baitworms by party boats fishing for weakfish in Peconic Bay. Initially, clams and mussels had been used for bait in this fishery but when fishermen discovered that marine worms worked as well as or better than these baits, a preference for marine worms developed (Schmal[16]). Although initially sandworms were the most sought after species, it was not long before both sandworms and bloodworms were being dug in areas such as Stony Brook, St. James, Jamaica Bay, Brooklyn, and Staten Island. Throughout Long Island, the worms were dug from sand flats and beaches. Sandworms were short but fat and of excellent quality. Bloodworms were of similar quality to those now obtained in Maine. Exploratory digging was soon extended as far as Fairfield, Conn., and Massachusetts (Sandrof 1946). A fishery that dealt mainly with sandworms was established in the area north of Boston: Winthrop, Revere, Lynn, Swampscot, Marblehead, Salem, Gloucester, and Newburyport by 1929 during the depression (Greely [17]). By 1932, some digging had occurred south of Boston to Chatham on the Cape (Greely footnote 17). Marine worms were probably also being dug commercially in New Hampshire by this time. Yet, despite the exploration for and discovery of commercial marine worm populations prior to 1932, sufficient quantities were still not available to supply the market. This lack of availability has been attributed to: 1) an initial lack of abundance and the complaints of landowners who objected to worm digging in their sandy beaches (Sandrof 1946), 2) overdigging and depletion of the known stocks (Schmal footnote 16; Greely footnote 17), 3) increased demand for marine baitworms in the sportfish fisheries (MacPhail 1954; Dow[18]), 4) a decline due to increased pollution from heated effluent discharge and toxic heavy metal pollutants (Dow footnote 18), and 5) a demise in the fishery resulting from higher than optimal seawater temperatures (Dow footnote 18). Although some worming probably began in the Portland, Maine, area in the early 1920's, the fisheries' slow initial growth in Maine was partly due to a certain skepticism toward the digging of marine worms (Glidden footnote 6). In 1933, an abundant supply of worms was found in the area around Wiscasset (Sandrop 1946) and Boothbay Harbor (Schaml footnote 16; Greely footnote 17). Most of the digging in these areas was directed toward sandworms but some bloodworms were also obtained. By 1937, the industry had become well enough established for the Maine Legislature to instigate "control" legislation (Glidden footnote 6). The municipalities affected by this legislation were mainly located in Cumberland, Sagadahoc, and Lincoln Counties (Dow[19]). Nearly 40 laws were passed between 1937 and 1955 which prohibited nonresidents from digging worms within the political boundaries of numerous municipalities. All these laws were repealed in 1955 after it was established that many of these exclusions were motivated by coastal property owners who desired to prevent trespass rather than conserve marine worm stocks (Dow footnote 19). The fishery in Maine had been extended from Cumberland, Sagadahoc, and Lincoln Counties into Hancock and Washington Counties by the early 1940's (Flye[20]). By 1949, bait dealer inquiries from the United States had stimulated the Canadian Atlantic Biological Stations to initiate a program of exploration for baitworms along the Maritime coast. Stocks of sandworms were found in Charlotte County, New Brunswick, and in 1950 a bait business was established there. This initial endeavor was not successful due to the relatively small size of the worms and the lack of a suitable packing weed (MacPhail 1954). The search for worms was continued in the Maritimes during 1950–51 in New Brunswick, Nova Scotia, and Prince Edward Island. Although some worms were found in practically all the areas examined, commercial quantities of bloodworms were found only in Nova Scotia in certain regions within Annapolis, Digby, Yarmouth, and Shelburne Counties (Flye footnote 20; Klawe and Dickie 1957; MacPhail 1954). Although the size of the worms dug within these areas was smaller than their Maine counterparts, excellent transportation facilities were available and by 1952, three shippers were operating in Yarmouth County, Nova Scotia. In 1953, sandworms were again shipped from Charlotte County, New Brunswick, but the absence of a suitable packing weed prevented large scale development of the industry (MacPhail 1954).

Maine marine worm landings recorded in U.S. Department of Commerce (1946–80) in pounds and converted back into numbers, as well as landed value, are presented in Table 3.

Table 3.—The numbers and value of bloodworms and sandworms landed by licensed marine worm diggers in the State of Maine between 1946 and 1980.

Year	Licensed marine worm diggers	Bloodworms Numbers	Bloodworms Value (dollars)	Sandworms Numbers	Sandworms Value (dollars)
1946	—	2,608,000	57,125	2,335,000	47,188
1947	—	7,200,000	144,530	2,046,000	37,086
1948	449	25,018,000	305,044	3,116,000	57,307
1949	498	17,700,000	297,021	1,356,000	18,910
1950	389	13,718,000	242,081	2,276,000	37,158
1951	324	9,511,000	157,966	5,868,000	88,412
1952	435	9,256,000	178,312	6,288,000	91,109
1953	522	11,198,000	217,966	9,744,000	148,499
1954	625	10,555,000	200,518	11,364,000	167,196
1955	551	8,921,000	167,004	7,176,000	110,283
1956	530	7,493,000	150,748	11,312,000	177,672
1957	640	10,485,000	246,436	11,636,000	214,344
1958	628	13,604,000	309,678	10,764,000	193,853
1959	784	18,837,000	371,832	21,548,000	334,285
1960	643	24,207,000	482,100	24,516,000	365,850
1961	729	26,176,000	515,979	25,720,000	387,066
1962	775	25,674,000	516,362	27,108,000	421,267
1963	921	32,198,000	696,887	32,532,000	506,578
1964	1,041	33,390,000	745,315	30,894,000	450,544
1965	1,015	33,918,000	759,582	29,545,000	447,341
1966	930	31,511,000	731,335	31,848,000	509,018
1967	1,025	32,956,000	834,826	28,257,000	492,384
1968	1,165	36,632,000	1,048,581	27,833,000	533,358
1969	1,168	34,449,000	999,787	26,914,000	523,836
1970	1,194	37,242,000	1,215,772	29,877,000	621,474
1971	1,396	35,603,000	1,381,676	30,115,000	674,296
1972	1,383	31,013,000	1,325,895	27,886,000	625,848
1973	1,451	35,381,000	1,744,832	28,135,000	1,060,402
1974	1,455	31,377,000	1,569,823	32,881,000	949,956
1975	1,267	35,634,000	1,779,266	29,935,000	862,854
1976	1,199	23,454,000	1,255,852	27,915,000	812,318
1977	1,197	17,474,000	1,313,987	29,506,000	1,000,432
1978	1,155	16,202,000	1,164,688	29,937,000	1,075,409
1979	1,105	19,387,000	1,434,258	29,776,000	1,109,292
1980	985	20,338,000	1,404,222	29,002,000	1,094,535

WORM DIGGING

One of the most attractive features associated with digging marine worms is the low initial cost of involvement in the fishery.

[16]D. Schmal, marine worm digger, North Edgecomb, ME 04545, pers. commun. July 1979.

[17]O. Greeley, marine worm dealer, Sullivan, ME 04682, pers. commun. July 1979.

[18]Dow, R. L. 1977. The Maine marine baitworm fishery. Dep. Mar. Resour. statement, Augusta, 7 p.

[19]R. L. Dow, Coordinator, New England Regional Fisheries Management Council, Maine Dep. Mar. Resour., Augusta, ME 04330, pers. commun. July 1979.

[20]I. Flye, marine worm dealer, Newcastle, ME 04553, pers. commun. July 1979.

Based upon 1980 prices, a new digger is prepared to enter the fishery for an outlay of approximately $70–90 (license $10, bloodworm hoe $22 or sandworm hoe $45, boots $30, buckets $4, and perhaps a pair of gloves $4). The new digger can quickly recover his initial outlay with a little experience and two or three tides of digging effort. An experienced digger may desire a 14–16 ft aluminum boat and a 10–25 hp motor.

A good bloodworm digger will start digging high on the mud flat and follow the receding tide out with a trench measuring approximately 1 m in width. When the tide changes, the digger reverses direction and digs ahead of the incoming tide. A bloodworm flat is considered good if the digger can dig one commercial-sized worm for each four or five turns of the hoe. Although a good bloodworm digger may dig as long as 5 h on a low drain tide, 2 to 4 h is the general rule.

The sandworm digger generally waits until the tide is near the low water mark before he begins digging. He spends the entire tide digging parallel to the shore in the region of the low water mark. A sandworm flat is considered good if the digger can dig one commercial-sized worm for each turn of the hoe. Often the digger may be rewarded with three–four worms per hoe turn. Although a good sandworm digger may dig as long as 3–3½ h on a low drain tide, 1½ to 2½ h is the general rule.

MARINE WORM HOES

A commonly used form of the bloodworm hoe (Fig. 1A) is constructed from two small spading forks welded together on a V-shaped brace. The hoe handle is constructed from a portion of the handle of one of the original spading forks. The handle is pounded down onto a short tine that has been welded to the middle of the brace at a relatively sharp angle to the tines. Various important bloodworm hoe measurements from the areas east and west of Penobscot Bay during 1977 are presented in Table 4.

A commonly used form of the sandworm hoe (Fig. 1B) is constructed from parts of three large spading forks. One tine from each of two large 4-tined spading forks is removed. The remaining portions are then welded together to form a 6-tined hoe. Each tine is then lengthened by welding on four additional tines from the third spading fork plus the two tines that were removed from the first two spading forks. The hoe handle, obtained from a portion of one of the original spading fork handles, is attached to the tines in much the same manner described previously for the bloodworm hoe. Various important sandworm hoe measurements from the areas east and west of Penobscot Bay during 1977 are presented in Table 4.

Previous descriptions of Maine marine worm hoes have been presented by Ganaros (footnote 4) and Dow and Creaser (1970).

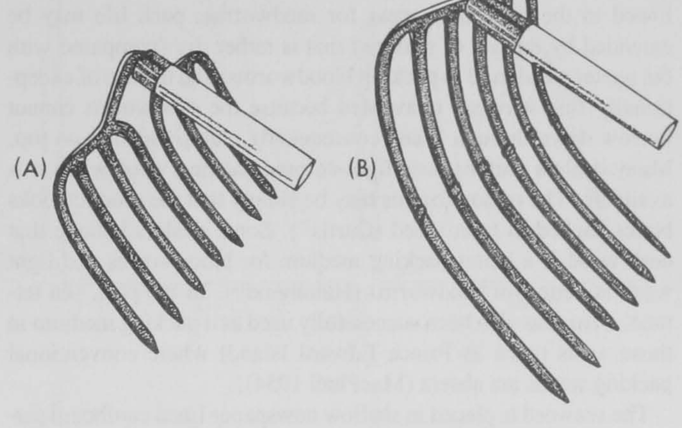


Figure 1.—Marine worm hoes commonly used by commercial diggers: (A) bloodworm hoe, (B) sandworm hoe.

According to the hoe description supplied by Ganaros (footnote 4), the hoe was constructed from a modified garden fork, the handle of which was cut off 9–10 in (22.9–25.4 cm) from the tines. Two additional tines were welded on either side of the fork and all six tines were bent at an angle of approximately 45° with the handle. Each tine was flattened and gently curved inward. The lengths of the tines were approximately 11½ in (29.2 cm) and the overall width obtained was 10½ in (26.7 cm). Although Ganaros (footnote 4) did not state which worm species this hoe was designed for, the tine lengths are midway between those reported for bloodworm and sandworm hoes (Table 4), thus suggesting that it might have been used for both.

The bloodworm and sandworm hoes described by Dow and Creaser (1970) are very similar in dimension to those summarized in Table 4.

Bloodworm hoes used by diggers in the Maritime Provinces were also constructed from garden forks (Klawe and Dickie 1957). The four tines on these hoes were tapered from 0.5 to 0.75 in (1.3–1.9 cm) in width, were 9 to 10.5 in long (22.9–26.7 cm), and were curved slightly inward. No other measurements were recorded.

PACKING AND SHIPPING MEDIUM

Seaweed gatherers collect packing weed for specific use by marine worm dealers. Dealers prefer to pack both species of worms in the young fine textured shoots of *Ascophyllum nodosum* f. *scorpiodes* and *Ascophyllum machaii*, both of which are found growing quite abundantly at the base of *Spartina* in salt and brackish water

Table 4.—A summary of bloodworm (B) and sandworm (S) hoe measurements recorded east and west of Penobscot Bay during 1977.

		Tine measurements (±1 SE)				Hoe measurements (±1 SE)			
Species and area	No. hoes measured	Number	Length (cm)	Flat or round (%)	Width (cm)	Width (cm)	Handle length (cm)	Handle-tine angle (°)	Distance handle tine (cm)
B (east)	50	5.74	22.16	100 F	1.75	25.56	15.96	51.82	14.29
		±0.15	±0.48		±0.08	±0.31	±0.41	±1.07	±0.19
B (west)	55	7.11	21.39	100 F	1.01	27.75	20.91	42.07	18.01
		±0.10	±0.52		±0.01	±0.35	±0.16	±0.68	±0.27
S (east)	48	6	38.84	87.5 F	1.15	27.99	29.89	45.46	24.89
		±0	±0.57	12.5 R	±0.04	±0.33	±0.55	±0.80	±0.41
S (west)	50	5.62	34.74	76.0 F	1.00	25.21	23.17	46.54	23.35
		±0.07	±0.73	24.0 R	±0.05	±0.35	±0.16	±0.77	±0.25

marshes (Vadis;[21] Topinka[22]). Two precautionary measures are followed in the packing process for sandworms; pack life may be extended by the use of seaweed that is rather dry (compared with the wetter weed used in packing bloodworms) and the use of exceptionally fine seaweed is avoided because the sandworms cannot burrow down through it and consequently clump together on top. Many dealers prefer to use light-colored packing weed when it is available. The reason for this may be simply that the product looks better packed in light weed (Curtis[23]). Some dealers believe that dark weed is a better packing medium for bloodworms and light week is better for sandworms (Hammond[24]). In the past, sea lettuce, *Ulva*, has also been successfully used as a packing medium in those areas (such as Prince Edward Island) where conventional packing weeds are absent (MacPhail 1954).

The seaweed is placed in shallow newspaper-lined cardboard cartons with lids. In the recent past, shallow tomato boxes were used for this purpose. Canned milk cartons have also been used successfully for shipping bloodworms (Ganaros footnote 4). Each carton contains 250 bloodworms or 125 sandworms.

The worms are shipped to their destination by refrigerated truck, bus, or air freight. In the past, they were also shipped by railway express and parcel post (Sandrof 1946).

PRESENT MARINE WORM MARKETS

Marine worm dealers presently categorize their U.S. marine worm markets into four general areas of delivery: New York, Boston, the southern market, and California (Peaslee;[25] Wanser;[26] Wright;[27] Crowley;[28] Fairservice[29]). The approximate extent of the season and the worm species associated with each of these markets is described as follows.

The onset of the "New York market," including Connecticut, generally occurs some time between the end of February and the middle of March. This market is concluded between the middle and end of November. Both bloodworms and sandworms are marketed in New York but sandworms prevail in the "Connecticut market."

The "Boston market" is comprised of two divisions: a Boston proper market, including the area just east of Boston, and a market on the Cape Cod peninsula. The onset of the former occurs between the end of February and the end of March and it is concluded between the end of October and the end of November. The onset of the market on the Cape occurs in May, demand is high during June, July, and August, and the market is concluded by the first of September. Both divisions of the Boston market deal primarily with sandworms.

The "southern market" includes New Jersey; Delaware; Maryland; Washington, D.C.; Virginia; and North and South Carolina. The onset of this market occurs between the first of April and the end of May. It is concluded between the first of September and the end of October. Both bloodworms and sandworms are marketed in the northern New Jersey market. Bloodworms prevail in southern New Jersey and the remainder of the southern market.

Several previous references to marine worm markets are available in the literature. Ganaros (footnote 4) reported that bloodworms and sandworms were marketed in New York, New Jersey, Pennsylvania, and Connecticut. MacPhail (1954) and Pettibone (1963) reported on the use of marine worms in a sport fishery that was concentrated about Long Island and extended from Connecticut to Maryland. Dow (1969) stated that both species of marine annelids were marketed from Long Island Sound to Chesapeake Bay.

The "California market" is a relatively new market. Although marine worms are shipped to this market throughout the year, the greatest quantities are shipped during two specific periods. The first period begins in February and lasts through May or June. Few worms are shipped during the summer because of mortalities associated with overheating during delayed air transport. Market demand increases again during September, October, and November. Both bloodworms and sandworms are desired by the northern California market, whereas a preference for bloodworms prevails in the southern California market.

The most recent market to develop is the French market. The demand for worms increases around the end of May, remains good during the summer, and slows down during November. A small but continuous demand exists throughout the winter. Although both species are desired by the French market, 90% of the shipments consist of bloodworms (Flye footnote 20).

According to many of the dealers interviewed during the course of this research, the weather plays an important role in determining the extent of a given market's season; good weather will result in a market's beginning earlier and ending later than normal.

MATERIAL AND METHODS

Marine Worm Sampling Program

We developed a multistage sampling plan with monthly stratification that would yield information on: 1) Size and length frequency of the catch, 2) probability sampling expansions for total catch in numbers, total number of digger hours dug, total value of catch, total number of digger tides dug, total catch in pounds, and 3) ratio estimates (catch/effort data) for catch in numbers/hour, catch in numbers/tide, catch in pounds/hour, and catch in pounds/tide.

Selection of Commercial Sampling Period

A survey of the marine worm industry conducted in 1972 showed that the initial increased demand for marine worms occurred during March, peak demand occurred during June, July, and August, and by the end of November the demand had substantially subsided. This trend is also evident from the monthly bloodworm and sandworm landings obtained from U.S. Department of Commerce (1946–80), converted from pounds into numbers of worms, and presented in Figure 2. On the basis of the information above, we initially sampled commercial marine worm landings between 1 April and 31 October. However, the sampling period was shortened to 1 April–30 September after the first year's sampling (1973) when

[21]R. L. Vadis, Professor, University of Maine, Orono, ME 04473, pers. commun. July 1979.

[22]J. Topinka, Principal investigator, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, ME 04575, pers. commun. July 1979.

[23]C. Curtis, marine worm digger, Wiscasset, ME 04578, pers. commun. July 1979.

[24]F. H. Hammond, marine worm dealer, Wiscasset, ME 04578, pers. commun. 1979.

[25]F. E. Peaslee, marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

[26]R. Wanser, marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

[27]W. A. Wright, marine worm dealer, Addison, ME 04604, pers. commun. August 1979.

[28]K. A. Crowley, marine worm dealer, Addison, ME 04604, pers. commun. August 1979.

[29]S. H. Fairservice, Sr., marine worm dealer, Wiscasset, ME 04578, pers. commun. August 1979.

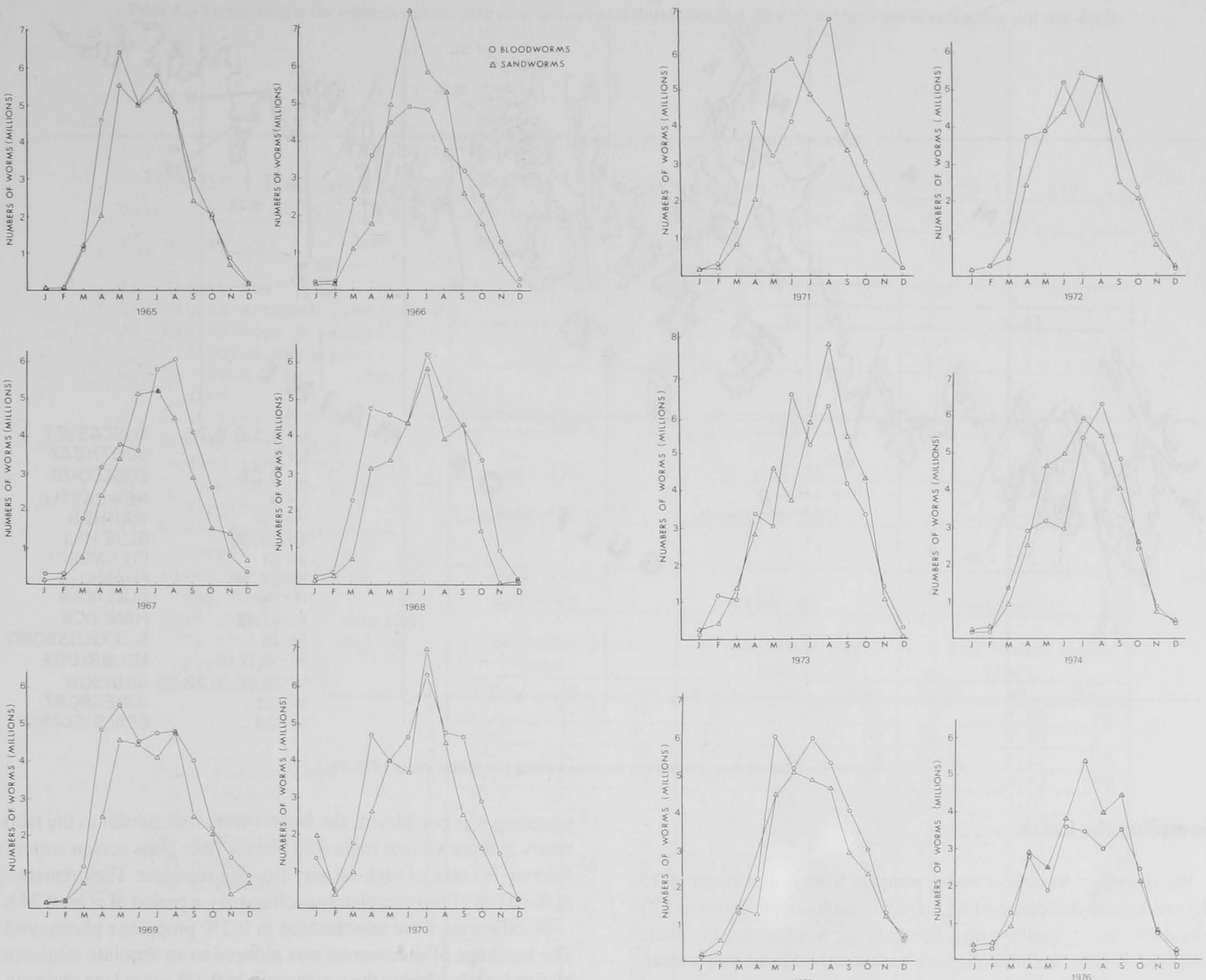


Figure 2.—Bloodworm and sandworm landings in numbers reported monthly for the period 1965–76.

it became evident that few dealers were purchasing large quantities of worms in October and the majority of our sampling trips during that month yielded no information at all.

Primary Sampling Unit

All daylight low tide periods occurring between one-half hour before sunrise and sunset during the months of April through September were listed and designated as the primary sampling unit. The time of sunrise and sunset at lat. 44°16′N, long. 68°38′W (a point near Blue Hill, Maine, that is halfway between the extreme dealer sampling locations of Wiscasset and Jonesport) was obtained from the Nautical Almanac Office of the U.S. Naval Observatory in Washington, D.C. Low tide periods were recorded for Portland, Maine (U.S. Department of Commerce 1973–76). Six randomly selected daylight low tide periods were chosen for sampling during any one month.

Secondary Sampling Units

All marine worm dealers who purchase their worms continually from 5 or more diggers during any given month were listed and designated as the secondary sampling units. A restriction of at least 5 diggers/dealer was necessary in order to eliminate a number of worm dealers (6 during 1976) in the western portion of the state who operated bait and tackle shops or who supplied marine worms to party boats and purchased their worms occasionally from 1 to 3 diggers. Marginal dealers, who might be buying continually from 4 diggers one month and 5 diggers the following month, were contacted monthly during the sampling period to determine whether or not they should be included as secondary sampling units. A dealer code number consisting of a county and number was assigned to each qualified dealer (Fig. 3).

Digger Interview

Marine worm diggers were interviewed as they delivered their catches to the dealer. It was often necessary to fractionally interview and sample the diggers (sample every 2nd, 3rd, 4th, or 5th digger) instead of sampling every digger that approached the dealer buying location because of the large numbers of diggers involved, and their grouped arrivals during one or two predominant periods after low water (an early arrival period for sandworm diggers and a later arrival period for bloodworm diggers).

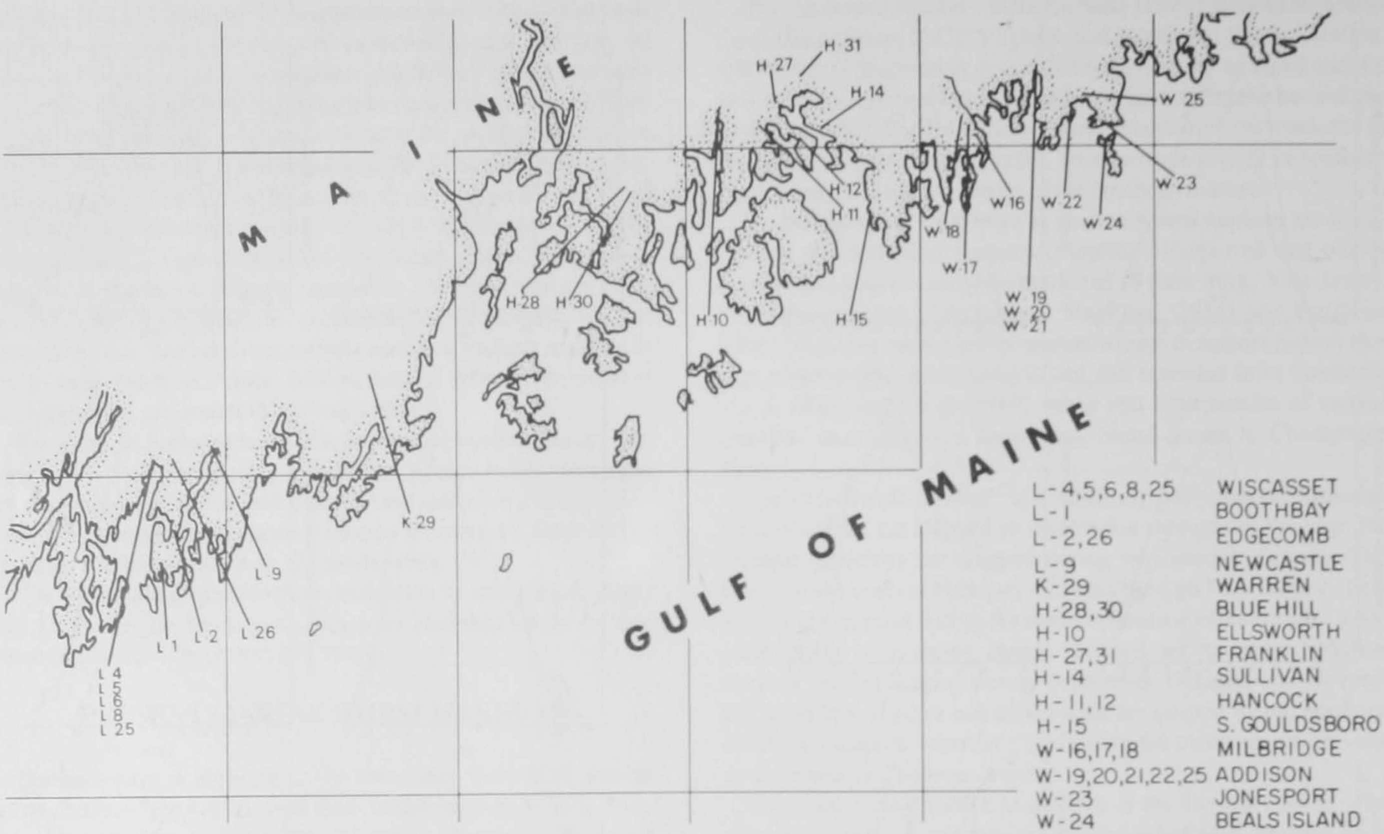


Figure 3.—Marine worm sampling locations along the Maine coast 1973–76.

Sampling the Catch

We attempted to collect worm samples from a maximum of 15 diggers at each dealer sampling location. Each sample contained 25 bloodworms or sandworms. Samples of marine worms were obtained directly from the digger's bucket or hod prior to his entering the worm cellar and therefore contained worms of commercial value as well as culls.

Bloodworm diggers virtually always transported their worms to the buying locations in plastic or stainless steel buckets. The contents of each bucket sample were stirred with a small paddle and while the water and worms were in motion, a fine meshed tropical fish net was used to obtain a sample from the bucket. Sandworm diggers transported their worms to the buying locations in round 5 gal plastic pails or in rectangular wooden hods. Usually, these containers held great quantities of worms in as little water as possible. It was not possible to stir the contents of these containers with a paddle without breaking the sandworms. Therefore the contents were mixed by reaching into the bottom of the container with both hands and gently drawing the bottom worms upward. After doing this three or four times in one area of the container, the sample was withdrawn with cupped hands. Samples of bloodworms and sandworms obtained in the above manner were deposited into a narrow wooden tray from which a random cluster of 25 bloodworms or sandworms was counted out. The remaining worms were returned to the digger.

Processing the Samples

The 25-worm samples of bloodworms or sandworms were immediately placed into containers of high salinity water (31–33‰) after being collected at the sampling location. When sampling was completed, the worms were transported to the laboratory and placed into trays with porous fiber glass screen bottoms floating in tanks of high-salinity flowing seawater. They remained in these trays until completely acclimated—a period of at least 24 h.

Bloodworms were anesthetized in 0.2% propylene phenoxytol. The breakage of sandworms was reduced to an absolute minimum by first briefly placing the sandworms in 0.1% propylene phenoxytol to quiet them down and then the 0.1% mixture was replaced with 0.2%. When completely anesthetized, the worms were measured in a V-shaped measuring trough while submerged in anesthetic. Their weight, sex, and condition (broken, punctured, regenerated) were also recorded.

Sex was determined during April and May for bloodworms and during August and September for sandworms. Sex was distinguished from a sample of the coelomic fluid withdrawn with a capillary pipette and examined under a microscope.

Unanesthetized length measurements in the natural state were derived from a photograph taken while the worms were immersed in a seawater bath containing a 15 cm rule.

Compilation of Interview and Cluster Sampling Information

The information compiled by digger from the interviews and cluster samples is presented in Table 5. The information recorded in Table 5A was then summarized for each dealer daylight low-tide period sampled and recorded in the form shown in Table 6.

Statistics

All formulas used to calculate: 1) Individual, monthly, and 6-mo means, variances, and standard errors, 2) monthly and 6-mo proba-

Table 5.—Forms used in the collection of (A) interview and sample information and (B) the total landings of acceptable and cull worms.

(A)

Commercial Catch - Sandworms - ~~Bloodworms~~

Dealer (Code No.) L-5 Limit No Yes No. 750 Sampling fraction 1:1 (1:2) 1:3 1:4

Date 9/10/74 No. low tides on sample day 1 Sampler D.C. M.H. E.P.C.

Price/worm .04

	S or ~~B~~	S or ~~B~~	S or ~~B~~
1) Digger No.	1	3	4
2) Digger arrival time	1215	1247	1247
3) Digger age, # years digging experience	34 25	39 20	39 27
4) Is catch 1 or 2 tides dig?	1	1	1
6) What time stop dig?	1203	1141	1141
5) Low tide at 1141 What time start dig?	1045	1100	1100
7) OR How long on flats digging?	1.30 hrs. ~~1 hr. 18 min.~~	0.68 hrs. ~~0 hr. 41 min.~~	0.68 hrs. ~~0 hr. 41 min.~~
8) Worms from 1 area or more?	1	1	1
9) River or area worms dug from?	Back River Boothbay	Waldoboro	Waldoboro
10) Last tide dug - morning or afternoon, day or night?	2 low tides prev. (day)	2 low tides prev. (day)	2 low tides prev. (day)

11) Worm sample

R = regenerated
B = broken
P = punctured
NS = nonspawner
M = male
F = female
FI = female (immature)

	Lgth.	Wt.	Sex	Lgth.	Wt.	Sex	Lgth.	Wt.	Sex
1	B	4.42	NS	B	9.55	NS	R	4.82	NS
2	27.4	7.89	F	32.1	7.90	NS	32.1	9.20	F
3	24.7	4.20	NS	30.8	6.63	NS	28.6	5.52	NS
4	24.2	4.58	NS	28.7	7.13	M	R	3.97	NS
5	38.4	11.40	F	43.0	14.83	M	22.8	3.00	NS
6	34.0	8.40	NS	29.8	6.15	NS	25.4	3.63	NS
7	27.9	5.13	NS	B	5.03	M	28.3	6.00	NS
8	37.7	12.46	NS	31.3	7.40	NS	B	4.50	NS
9	B	8.00	M	28.5	5.45	NS	B	6.87	NS
10	B	4.52	NS	B	4.30	F	28.7	6.40	M
11	B	6.53	F	B	8.23	NS	31.2	7.88	NS
12	25.0	4.56	NS	33.3	8.91	NS	30.6	8.00	F
13	B	4.30	NS	35.2	8.22	NS	25.8	3.62	NS
14	23.4	3.97	NS	28.1	6.00	NS	30.1	6.00	NS
15	29.1	6.22	NS	B	3.97	NS	R	2.90	NS
16	R	4.09	NS	B	3.87	NS	R	6.00	F
17	R	5.40	NS	24.1	3.80	NS	33.1	7.66	M
18	19.3	2.63	NS	28.5	4.74	NS	34.8	9.99	F
19	B	2.03	NS	25.3	4.00	NS	36.4	8.73	NS
20	R	6.91	F	B	4.38	NS	25.5	4.69	M
21	23.0	3.22	NS	35.7	9.50	F	29.0	6.23	NS
22	B	5.45	NS	B	5.27	NS	23.0	3.32	NS
23	B	7.82	M	27.6	5.89	M	R	3.20	NS
24	30.7	6.70	M	25.8	5.10	NS	R	5.21	F
25	R	3.24	NS	B	2.80	NS	29.5	5.70	NS

12) Total no. worms dug (include estimates of #'s of culls, if any)	13 25 364.8 134.07 775+8 = 783	16 25 487.8 159.05 775+5 - 780	17 25 494.9 143.04 775+3 = 778

Weather: Wind velocity 1 Wind direction E Air Temp. 21°C Barometric Press. -

Cloud cover 7/8 clouds - rain clouds - no rain

Tide: Low tide (ft.) - tide table +1.00 Low tide (ft.) - actual +.75

Table 5.—*Continued.*

(B)

Dealer L-5 Mo. Sept. Day 10 Year 1974

M. R. No. (if any)	No. Worms Dug	Bloods (B) or Sands (S)	Culls	Other	Total, Including Culls
1	775	S	8	-	783
-	750	S	10	-	760
3	775	S	5	-	780
-	750	S	5	-	755
4	775	S	3	90B	778
-	750	S	0	35B	750
5	775	S	10	-	785
-	750	S	10	-	760
					Note - add 125 B to bloodworm form (L-5, 9/10/74)
	Total Dug 6100		Total Culls 51		Total Time 4.66 hrs
	Total From Diggers Sampled 3100		Culls from diggers sampled 26		

bility expansion and ratio estimates, 3) time efficiency values, 4) optimum and proportional allocation, and 5) length-weight relationships, are presented in Appendix A.

Verification of Sampling Procedures and Responses to Interview Questions

The methodology employed in several of the marine worm sampling and processing procedures was closely scrutinized. Since we anesthetize and measure the worm's length immediately prior to weighing them, studies were performed to determine what effect the anesthetic might have on the worm's weight. In these studies, worm weights were compared before and after anesthetization with 0.2% propylene phenoxytol.

Another problem associated with length measurements on soft-bodied Annelids involved a determination whether the measurements were reproducible. This was investigated by repetitious measurements, reviving of individuals of both species between measurements, and a comparison of the results.

Other experiments were performed to compare length differences resulting from relaxing and measuring the same assorted bloodworms in two different anesthetics. One group of bloodworms was first acclimated to high salinity water, anesthetized in 0.2% propylene phenoxytol, and then measured. These worms were then revived in high salinity water and the following day they were anesthetized and measured in 7.5% $MgCl_2$. The entire experiment was then reversed using another group of assorted worms and the results of both experiments were compared.

Experiments were performed to determine if the manner in which a 25-worm sample was obtained from the digger produced a mean length and weight estimate that was truly representative of the mean length and weight of all the worms present in the bucket (bloodworms) or hod (sandworms). All worms used in these experiments were obtained from two commercial diggers. A bucket con-

Table 6.—The summary sheet for catch statistics data collected during each dealer daylight low tide period sampled.

CATCH STATISTICS

bloodworms ~~sandworms~~

Dealer ______ L-4 ______ Day __ 4 __ Month __ June __ Year __ 1976

1. Value/worm ______ $ 0.055
2. Number of diggers sampled ______ 18
3. Accepted catch in numbers from diggers sampled ______ 15,532
4. Catch in grams from diggers sampled 27216.52 lbs. (x.002205) 60.01
   (numbers from diggers sampled (3) x mean wt./worm)
5. Number of worms taken in DMR samples ______ 450
6. Number of mature males in DMR samples ______ -
7. Number of mature females in DMR samples ______ -
8. Number of digger tides dug from diggers sampled ______ 18
9. Number of digger hours dug from diggers sampled ______ 63.42
10. Mean length of worms in DMR samples ______ 16.77
    (from unbiased estimates of weighted means)
11. Mean weight of worms in DMR samples ______ 1.75
    (from unbiased estimates of weighted means)
12. Catch in numbers/digger tide dug ______ 862.89
    (catch in numbers from diggers sampled (3) / (number of digger tides dug (8)
13. Catch in grams/digger tide dug ______ 1512.03
    (catch in gms. from diggers sampled (4) / (number of digger tides dug)(8)
14. Catch in lbs./digger tide dug ______ 3.33
    (convert grams (13) to lbs. by multi. gms. x .002205)
15. Catch in numbers/digger hour dug ______ 244.91
    (catch in numbers from diggers sampled (3) / (number of digger hours dug from diggers sampled (9)
16. Catch in grams/digger hour dug ______ 429.15
    (catch in grams from diggers sampled (4) / (number of digger hours dug (9)
17. Catch in lbs./digger hour dug ______ .95
    (convert grams (16) to lbs. by multi. gms. x .002205)
18. Value/digger tide dug ______ $47.46
    (derive from (12) by multi. numbers x value/worm)
19. Value/digger hour dug ______ $13.47
    (derive from (15) by multi. numbers x value/worm)
20. Value/gram ______ $0.03139
    (catch in numbers from diggers sampled (3) x value/worm) / (catch in grams from diggers sampled (4)
21. Value/lb. ______ $14.24
    (convert value/gm. to value/lb. by multi. (20) x 453.59)
22. Total number of diggers that dug 37 men 36 women 1
23. Total number of digger tides dug for all diggers ______ 37
24. Total accepted catch in numbers for all diggers entering cellar ______ 26,107 (+ others)
25. Total estimated number of digger hours dug for all of accepted catch 130.36
    (estimate by interpolatation using (9)/(2) x x)/(22)
26. Total catch in grams ______ 45749.91 (+ others)
    (total accepted catch in numbers (24) x mean weight (11)
27. Total catch in lbs. ______ 100.88 (+ others)
    (total catch in grams (26) x .002205)
28. Total value of catch ______ $1435.89 (+ others)
    (total accepted catch in numbers (24) x value/worm)
29. Total number of culls in catch for all diggers entering cellar 622(% of total catcn)2.33%
30. Total number of daylight low tides/month ______ 42
31. Low tide magnitude - actual -.27 calculated -.2
32. Weather 1 K from E, air temp. 20.1°C, clear and sunny with scattered clouds

taining 581 bloodworms and a hod containing 1,041 sandworms were sampled as previously reported. The worms obtained in the sampling process were anesthetized, measured, weighed, and then returned to the original bucket or hod. After the worms had revived, the procedure was repeated a total of 10 times. The results obtained from these length and weight measurements on bloodworm and sandworm samples were then compared with the mean length of all measurable (461) and weighable (581) bloodworms in the bucket, and all measurable (779) and weighable (1,041) sandworms in the hod.

The digger responses to several questions asked during the sampling interview were routinely checked for accuracy. The total worm count dug and reported to the sampler by the digger was checked against the number reported on the dealer's record sheet (the number of worms the digger was actually paid for). The digger's response to questions dealing with the time digging began and ended on a given tide was compared with the actual digging time observed and recorded by the sampler for that digger from a concealed position along the shore.

Yield-Effort Curves

License and landings data used in bloodworm and sandworm yield-effort curves were obtained from DMR license records and U.S. Department of Commerce (1946–80) (for the appropriate years). Landings data reported in pounds in U.S. Department of Commerce (1946–80) were converted back into numbers using the appropriate conversion factors.

RESULTS AND DISCUSSION

Digger Interview

The proper use of a sampling fraction, in both the digger interview and the commercial sampling, requires that the diggers are approaching the cellar in random fashion. This requirement is probably met when one considers that some diggers dig for long periods and other dig for short periods, regardless of the distance between the digging site and the dealer buying locations. The use of a randomly selected choice of diggers has one advantage in that if the diggers were approaching the cellar in some sort of order, the order would in no way affect the selection of a random sample. For reasons of simplicity, the use of a sampling fraction was also the only logical choice; the act of interviewing different fractions of bloodworm and sandworm diggers as they were both entering and leaving the worm cellar simultaneously, was already complicated enough.

Sampling the Catch

We attempted to limit ourselves to collecting marine worm samples from a maximum of 15 diggers (at 25 worms/digger) per dealer buying location because of the time involved in processing 375 worms for length, weight, and sex. Occasionally, when the larger dealers were sampled, we were unable to determine how many bloodworm or sandworm diggers would be arriving at the cellar with worms during the sampling period and we had to estimate, on the basis of past experience, what sampling fraction to use for both species without exceeding a total of 15 samples. In some cases we were successful and approximately 15 samples were obtained. At other times, our estimates were erroneous and either more or fewer than 15 samples were obtained.

We chose to sample the diggers just prior to entering the dealer buying locations for several reasons. First, we did not desire to interfere with the dealer's handling practices and procedures. Second, the inclusion of cull worms in the sampling procedure is desirable because the vast majority of the culls were never returned to the flats alive; they were either discarded in the "discard" bucket, along the road side, or they were dumped on the flats or in the water where they were rapidly consumed by sea gulls and fish. Our commercial sampling therefore reveals what is lost from the natural population through commercial digging and it includes both commercially acceptable worms and a small percentage of cull worms that will be discarded and wasted. Our commercial sampling results indicate that bloodworm culls comprise 3.0–4.6% and sandworm culls comprise 2.6–5.1% of the worm catch brought into the cellar. The net result is that the mean lengths recorded from our samplings of the catch are actually slightly smaller (they contain length measurements for cull worms that would be discarded and wasted during the normal handling procedure in the cellar) than the mean size of worms shipped out of state.

Processing the Samples

Acclimation of all worm samples to high salinity water prior to anesthetization and measurement was necessary because the length and weight of marine worms vary with salinity. Preliminary investigations revealed that some marine worms had either been dug from varying salinity conditions or had been exposed to additional dilution by the diggers for varying periods of time prior to our obtaining them (Table 7). This practice of "watering down" the worms is prevalent among bloodworm diggers and rare among sandworm diggers. Although salinities as low as 10‰ have rarely been recorded from bloodworm bucket water, it is highly unlikely that the worms themselves are dug very often from mud of this salinity because salinity tolerance experiments conducted previously (Creaser[30]) showed that bloodworms are stressed after exposure to 10‰ for 24 h. Experiments designed to measure the time required for bloodworms to acclimate to a standard lab line salinity of 31–33‰ from a lower salinity were initiated at a salinity of approximately 16‰ because we did not wish to stress the bloodworms. Although sandworm diggers rarely "water down" their worms, an initial starting salinity of 16‰ was also used in similar sandworm experiments. The results of these acclimation experiments on bloodworms and sandworms are presented in Figure 4. The results in Figure 4 show that bloodworms required as much as 10 h and sandworms required as much as 16–18 h to completely acclimate to high salinity after being dug and transported under the conditions reported. In view of the facts that: 1) The experiments in

[30]Creaser, E. P., Jr. 1971. Biological, environmental and technological research on marine worms. Project 3-16-R Completion Report covering the period 1966–1971. Dep. Sea Shore Fish., State House Annex, Capitol Shopping Center, Augusta, ME 04333, 224 p.

Table 7.—The salinity content of water obtained from the hods and buckets of marine worm diggers and used in transporting bloodworms and sandworms from the flats to the dealer.

Dealer code	Date (1972)	Number of samples	Bloods (B) or sands (S)	Mean salinity (‰)	1 standard error (‰)
L-4	4/24	19	B and S	16.09	±1.02
L-5	4/24	7	B and S	21.33	±2.26
L-6	5/07	13	S	26.61	±0.87
L-6	5/07	5	B	20.06	±3.77
W-18	5/02	14	B and S	20.29	±0.81

Figure 4 were conducted in the fall at temperatures of 4°–5°C when the acclimation time would be slower, 2) no changes in weight were noted after 18–20 h during repetitious weighings of a few randomly selected bloodworms and sandworms collected periodically during commercial sampling, and 3) commercial samples collected on one day were never processed until at least 24 h later, it is highly probable that all length and weight measurements were made on commercial samples only after all worms had been fully acclimated to standard high salinity conditions.

The length measurement of a marine worm in its natural state is a difficult if not impossible undertaking; the soft-bodied Annelid can coil, undulate, expand, and contract. To avoid these problems, we anesthetized the worms before measuring them. The relationships of natural lengths to anesthetized lengths for bloodworms and sandworms collected from the Sheepscot River are shown in Figure 5. These results demonstrate that the difference between anesthetized length and natural length is greater for bloodworms than for sandworms; a bloodworm of 20 cm anesthetized length is equivalent to approximately 13 cm natural length, whereas a sandworm of 20 cm anesthetized length is equivalent to approximately 17 cm natural length.

Bloodworm samples collected during April and May were sexed because in the region of Wiscasset, Maine, spawning occurs in June (Creaser 1973). Sandworm samples were sexed during August and September after spawning in April and May (Creaser and Clifford footnote 11).

Verification of Sampling Procedures and Interview Responses

Studies preformed to determine what effect the anesthetic might have on the worm's weight indicated that it had little effect.

Studies performed to determine if length measurements upon bloodworms and sandworms are true and reproducible indicated that bloodworm lengths, over the range of sizes tested (15.7–36.6 cm), are reproducible within ± 0.2 to ± 1.0 cm (at 95% confidence limits or 1.96 SE) and sandworm lengths, over the range of sizes tested (12.1–64.3 cm), are reproducible within ± 0.4 to ± 2.4 cm (at 95% confidence limits or 1.96 SE).

Studies in which lengths were obtained on individual worms after being relaxed in two different anesthetics (0.2% propylene phenoxytol and 7.5% $MgCl_2$) demonstrate that when bloodworms were first relaxed and measured in 0.2% propylene phenoxytol and then relaxed and measured in 7.5% $MgCl_2$, the lengths recorded in the $MgCl_2$ were usually smaller (23 out of 24 cases). The reduction in size varied between 0.8 and 23.4%. When bloodworms were first relaxed and measured in 7.5% $MgCl_2$ and then relaxed and measured in 0.2% propylene phenoxytol, the lengths recorded in the propylene phenoxytol were usually greater (16 out of 21 cases). Increased lengths varied between 1.0 and 12.0% and decreases varied between 1.5 and 13.0%. These results suggest that caution should be used when comparing the findings in this manuscript (where 0.2% propylene phenoxytol was used as as anesthetic) with the results in other publications (where other anesthetics were used).

More detailed information on the results of the studies above, which were performed to verify various sampling procedures, is reported in Creaser et al.[31]

The results of studies to determine if the 25 worm samples were truly representative of the entire contents of the bloodworm buckets and sandworm hods are presented in Table 8. It is evident from these results that on 10 out of 10 tries the range of bloodworm mean lengths and weights (± 1.96 SE) overlapped the actual mean length and weight of the entire "bucket" population. On 9 out of 10 tries the range of sandworm mean lengths (± 1.96 SE), and 8 out of 10 tries the range of sandworm mean weights (± 1.96 SE), overlapped the actual mean length and weight of the entire "hod" population. There were few problems inherent in our method of selecting 25 bloodworms for measurement and most of the time the same holds true for sandworms.

Few errors were observed when comparing the total landings we recorded during the digger interview with the total the dealer recorded and paid the digger for. In only a few instances during a 4-yr period were intentional errors made by diggers. Occasionally, a digger failed to report to the dealer that we had collected 25 of his worms and his recorded landings with the dealer were therefore 25 worms short.

The results of our efforts to check the accuracy of the diggers' estimates of their digging time are shown in Table 9. This study was necessary because certain industry factions shared the opinion that diggers were reporting false information regarding their estimates of beginning and ending time. The results in Table 9 demonstrate that there is less than a 2% discrepancy between the time estimates of groups of diggers and their actual digging time recorded by observation from concealed positions. However, when time estimates for individual diggers are obtained through digger interviews on the flat, these estimates are probably more accurate than the estimates they would have made had they been interviewed at the worm cellar some distance away. Because of manpower limitations we were not able to follow individual diggers back to their respective cellars to obtain estimates of their digging time. We can only state that had we been able to do this the discrepancy might have been greater than 2%, but probably still within very acceptable limits. These data were analyzed to determine if the ratio of two variables (actual vs. reported time) was significantly different from a 1:1 ratio at 95% confidence limits (2 $SE_{\bar{R}}$). The results indicate that the relationship between actual and reported time is not significantly different from a 1:1 ratio (1.01764 ± 0.02819 or 0.98945–1.04583). In other words, the mean estimate of digging time, as reported to the sampling crew, is quite accurate. As far as individual groups of diggers are concerned, some estimate a little high, some estimate a little low, and some estimate precisely. Verification of the accuracy of both reported landings and digging time estimates enables us to conclude that the estimates of catch/hour, one of the simplest indices of marine worm abundance, are probably quite accurate.

Commercial Sampling for Length, Weight, Sex, and Condition

Table 10 shows that the 6-mo mean lengths (± 1 SE) for bloodworms were 18.72 ± 0.60 cm (1973), 19.84 ± 0.38 cm (1974), 20.74 ± 0.59 cm (1975), and 20.83 ± 0.54 cm (1976). These means are not significantly different from one another at 95% confidence limits (± 1.96 SE). On the basis of this commercial sampling information, no significant differences occurred in the size of bloodworms harvested between 1973 and 1976.

It is also apparent from Table 10 that during April and May potential spawners comprise between 7.33–13.58% and 0.50–1.63%, respectively, of the commercial catch. Apparently, the diggers

[31]Creaser, E. P., D. A. Clifford, M. J. Hogan, and D. B. Sampson. 1980. An analysis of the commercial baitworm fishery for sandworms *Nereis virens* Sars and bloodworms *Glycera dibranchiata* Ehlers in Maine. Maine Dep. Mar. Res. Lab. Res. Ref. Doc. 80/18, 180 p.

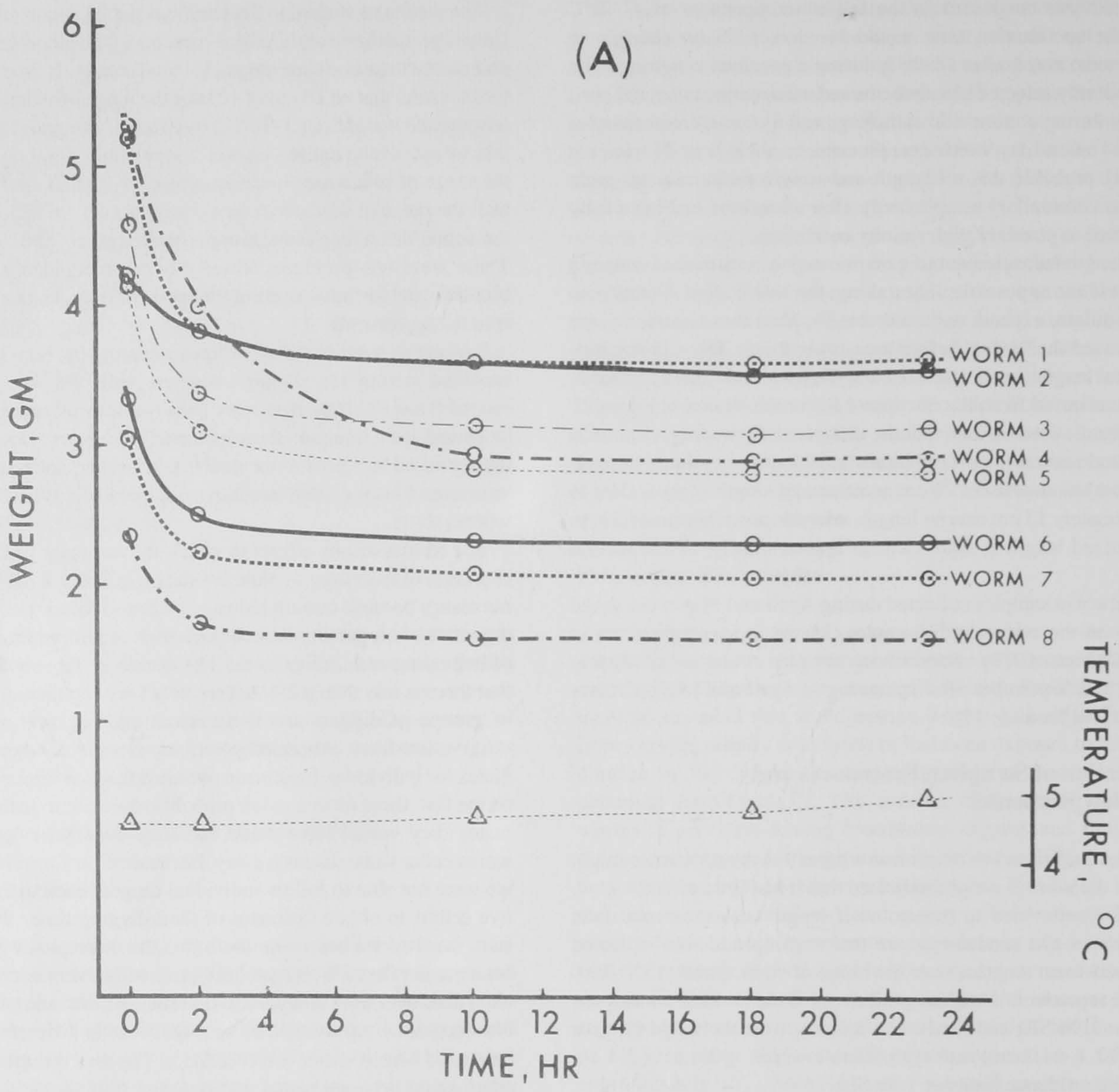


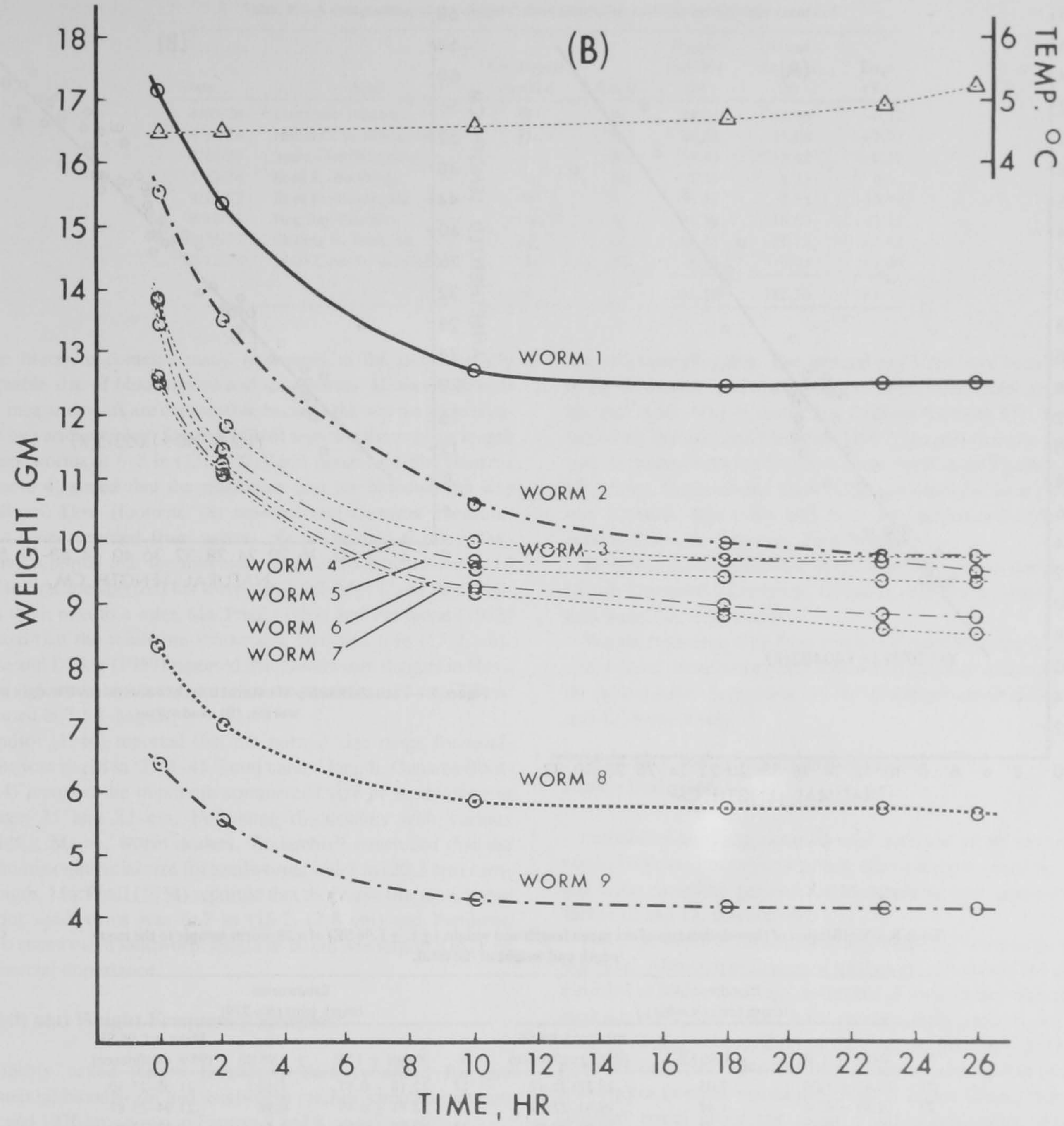
Figure 4.—The time required for assorted sizes of bloodworms and sandworms to acclimate to 32‰. (A) Bloodworms dug from an interstitial salinity of 19.52‰, transported to the laboratory in 16.09‰, and acclimated to 32‰. (B) Sandworms dug from an interstitial salinity of 22.00‰, transported to the laboratory in 16.49‰, and acclimated to 32‰.

avoid harvesting the fragile bloodworms that are approaching spawning condition in May. Diggers harvest slightly more female bloodworms than males. Potential bloodworm spawners are not evenly distributed along the coast; they were never collected east of the Taunton River (Sullivan, Maine) during 4 yr of commercial sampling. There are four possible sources of bloodworms recruited into the commercial fishery in eastern Maine. Trochophores (or juveniles) produced from the excellent spawning stocks in Nova Scotia (Klawe and Dickie 1957), may be carried on counterclockwise currents across the Bay of Fundy to eastern Maine. Evidence for these currents in the spring and summer is presented by Graham (1970) and also by Bumpus and Lauzier (1965). It is also possible that close inshore currents move clockwise and transport trochophores (or juveniles) from the abundant spawning stocks in the Taunton River and Sullivan Harbor to eastern Maine. Recruitment may occur from unknown subtidal or intertidal spawning communities in eastern Maine. However, since the worm digger is a hunter, it is unlikely that any large intertidal digging areas containing spawners could exist without the diggers' knowledge of them. An unlikely possibility is that the survival rate of the bloodworm trochophores produced by the rare spawners reportedly found by diggers in eastern Maine is exceptional and accounts for the excellent sporadic worm sets reported for numerous areas.

The 6-mo means reported in Table 10 show that approximately 5–7% of the catch consists of bloodworms with regenerated tails. Broken bloodworms comprised approximately 12–13% of the catch.

Table 11 shows that the 6-mo mean lengths (± 1 SE) for sandworms were 26.11 ± 0.98 cm (1973), 26.22 ± 0.68 cm (1974), 26.77 ± 0.53 cm (1975), and 25.69 ± 0.42 cm (1976). These means are also not significantly different from one another at 95% confidence limits (± 1.96 SE).

Sandworms spawn during March, April, and May and sandworm diggers also avoid picking up spawning worms. We waited until



August and September before attempting to sex sandworms obtained from the commercial catch. During these months potential spawners comprised between 15.6 and 38.3% of the commercial catch. Diggers usually harvested more female sandworms than males. Potential sandworm spawners were found all along the coast of Maine.

The 6-mo mean shows that approximately 8% of the catch consists of sandworms with regenerated tails. Broken worms comprised approximately 19–23% of the catch.

Variations in the mean size of bloodworms and sandworms harvested between dealers listed in Tables 10 and 11 can be explained by: 1) Dealer preference, 2) tidal amplitude, and 3) the length characteristics of the local worm populations being harvested on the days commercial samples were obtained.

Some previous information exists regarding the commercially acceptable size of bloodworms and sandworms harvested in western Maine. During March 1966, four dealers were asked to cull two bloodworm lots and two sandworm lots into commercial and noncommercial size groups. The results are shown in Figure 6.

Although the commercial length results presented in Figure 6 cannot be directly compared with the 6-mo mean lengths recorded for bloodworms and sandworms in Tables 10 and 11 (7.5% $MgCl_2$ was used to anesthetize the former, 0.2% propylene phenoxytol the latter), the results suggest that, had the 1966 bloodworm and sandworm samples been anesthetized in 0.2% propylene phenoxytol, their mean sizes would probably have been slightly larger than the 6-mo mean lengths reported for bloodworms and sandworms during the 1973–76 sampling program. These data suggest that there may have been a slight decrease in the acceptable size of commercial bloodworms and sandworms harvested between 1966 and 1973.

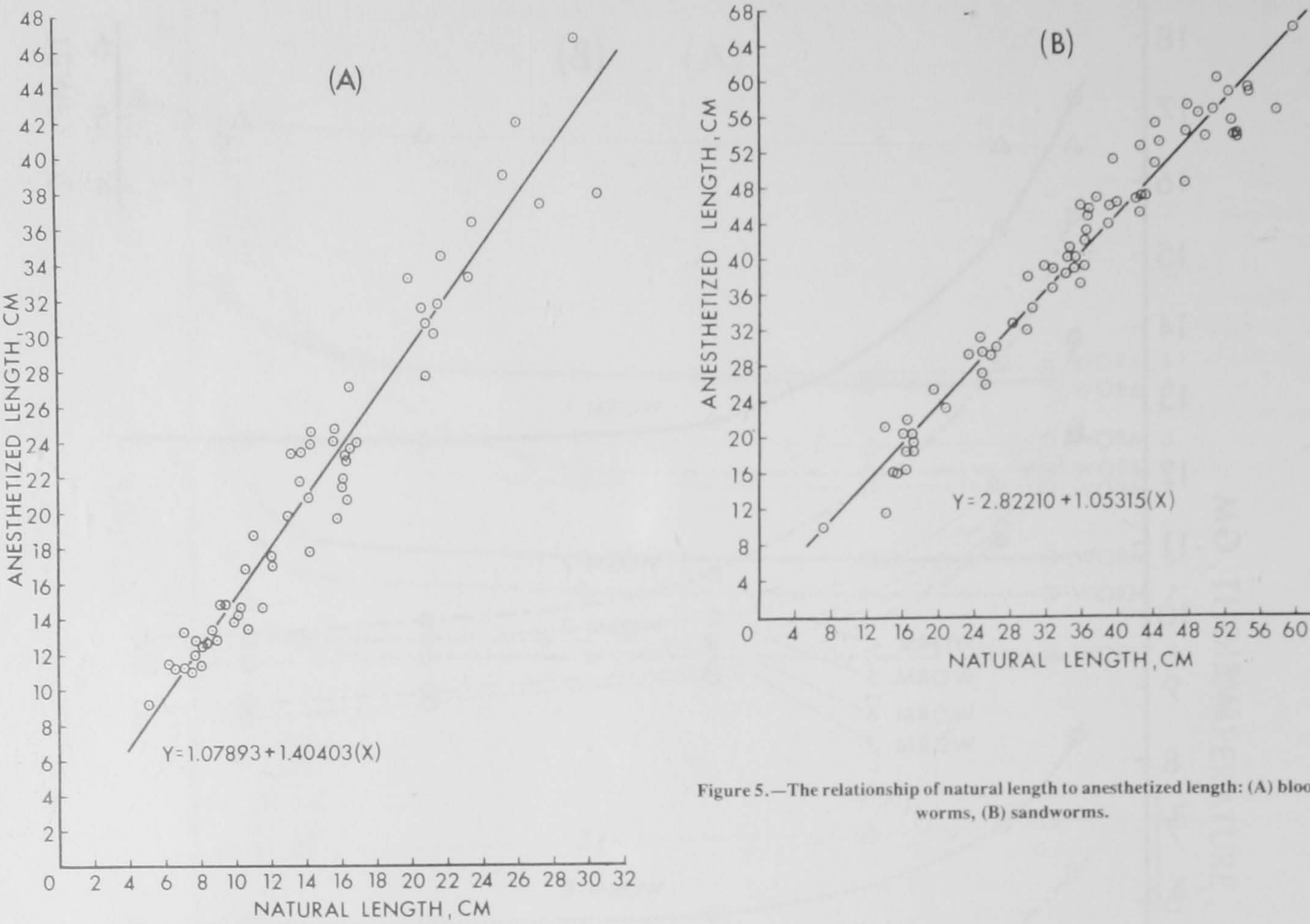


Figure 5.—The relationship of natural length to anesthetized length: (A) bloodworms, (B) sandworms.

Table 8.—Verification of the relationship of the mean length and weight (±1, ±1.96 SE) of a 25-worm sample to the mean length and weight of the total.

Bloodworms length (cm) (N=461)				Sandworms length (cm) (N=779)			
N	$\bar{X}$(cm) ± 1 SE	± 1.96 SE	Mean ± 1.96 SE (95% confidence)	N	$\bar{X}$(cm) ± 1 SE	± 1.96 SE	Mean ± 1.96 SE (95% confidence)
21	20.42 ± 1.05	2.05	18.38–22.47	17	22.18 ± 0.57	1.12	21.05–23.30
23	20.89 ± 0.76	1.48	19.41–22.38	17	22.91 ± 0.49	0.96	21.94–23.87
20	19.44 ± 0.73	1.43	18.01–20.86	22	22.88 ± 0.82	1.61	21.27–24.49
20	19.93 ± 0.75	1.47	18.46–21.39	20	23.14 ± 1.10	2.15	20.99–25.28
19	20.78 ± 0.97	1.91	18.88–22.69	22	22.79 ± 0.71	1.39	21.40–24.18
19	19.78 ± 0.76	1.50	18.28–21.28	22	25.13 ± 0.62	1.21	23.92–26.34
15	18.35 ± 0.90	1.77	16.58–20.13	18	23.27 ± 0.87	1.71	21.56–24.99
24	19.22 ± 0.76	1.50	17.72–20.71	18	23.21 ± 0.65	1.27	21.94–24.48
22	20.39 ± 0.69	1.36	19.03–21.75	18	22.84 ± 0.62	1.21	21.63–24.05
22	20.55 ± 0.81	1.59	18.96–22.13	21	21.98 ± 0.60	1.18	20.80–23.16
461	19.94			779	22.49		
weight (g) (N=581)				weight (g) (N=1,041)			
25	2.33 ± 0.28	0.54	1.78–2.87	25	3.58 ± 0.17	0.33	3.25–3.91
25	2.19 ± 0.19	0.37	1.81–2.56	25	3.90 ± 0.24	0.48	3.43–4.38
25	1.91 ± 0.22	0.42	1.48–2.33	25	3.98 ± 0.30	0.60	3.38–4.58
25	1.96 ± 0.19	0.38	1.58–2.34	25	4.15 ± 0.49	0.96	3.19–5.10
25	2.31 ± 0.27	0.54	1.77–2.85	25	4.09 ± 0.35	0.69	3.40–4.78
25	1.95 ± 0.17	0.33	1.63–2.28	25	4.55 ± 0.28	0.55	4.00–5.10
25	1.79 ± 0.20	0.39	1.40–2.18	25	3.94 ± 0.30	0.59	3.35–4.53
25	1.77 ± 0.17	0.33	1.40–2.10	25	4.56 ± 0.32	0.62	3.93–5.18
25	2.07 ± 0.21	0.41	1.67–2.47	25	3.66 ± 0.22	0.42	3.24–4.08
25	2.29 ± 0.22	0.43	1.86–2.71	25	3.76 ± 0.25	0.48	3.28–4.25
581	2.07			1,041	3.43		

Table 9.—A comparison of the diggers' time estimates with the actual time recorded.

Date	Area	No. diggers checked	S or B	Diggers estimate (h)	Actual recorded (h)	Error (%)
4/03/74	Cod Cove-Wiscasset	19	B	48.22	48.30	-0.17
4/12/74	Hilton Cove-Wiscasset	15	B	46.33	45.08	+2.77
4/14/74	Yacht Club-Wiscasset	6	B	18.45	18.42	+0.16
5/13/74	Back R.-Boothbay	6	S	8.33	8.33	0
8/17/77	Rays Pt.-Harrington	6	S	6.58	7.65	-13.99
8/18/77	Hog Bay-Franklin	8	B	18.50	16.50	+12.12
8/23/77	Skilling R.-Hancock	12	B	30.25	29.25	+3.42
10/12/77	Jones Cove-W. Gouldsboro	6	S	9.12	9.03	+1.00
		78		185.78	182.56	+1.77

The literature contains many references to the commercially acceptable size of bloodworms and sandworms. However, few of these measurements are comparable because the worms were measured by various means. Sandrof (1946) reported the average length of bloodworms at 6–8 in (15.2–20.3 cm) natural length. Ganaros (footnote 4) stated that the minimum size for bloodworms was 18–20 cm. Dow (footnote 18) reported that Ganaros' measurements were recorded from worms placed next to a ruler. Taxiarchis[32] reported that the minimum size for bloodworms was 16 cm. He first anesthetized his worms in 7.5% $MgCl_2$ and then measured them next to a ruler. MacPhail (1954) and Pettibone (1963) reported that the minimum marketable size was 6 in (15.2 cm). Klawe and Dickie (1957) reported that bloodworm diggers in Nova Scotia ordinarily harvest worms that are more than 20 cm (7.9 in) measured in 7.5% $MgCl_2$.

Sandrof (1946) reported that the normal size range for sandworms was 10–18 in (25.4–45.7 cm) natural length. Ganaros (footnote 4) reported the minimum commercial size of sandworms at between 21 and 22 cm. Following discussions with various Boothbay, Maine, worm dealers, Taxiarchis[33] concluded that the minimum commercial size for sandworms was 8 in (20.3 cm) natural length. MacPhail (1954) reported that the minimum marketable size for sandworms was 6–7 in (15.2–17.8 cm) and Pettibone (1963) stated that a sandworm length of 20 cm was required to be of commercial importance.

Length and Weight Frequency Samples

Monthly sexed length frequency data recorded for the commercial bloodworm and sandworm catches sampled between 1973 and 1976 are shown in Figures 7 and 8, respectively.

In Figure 7, the complete lack of maturing spawners during April 1975 may be attributed to the small sample size ($N=44$) and the fact that the random samples were only collected in the eastern portion of the state where bloodworm spawners were lacking from commercial samples.

The commercial sandworm samples for 1974, 1975, and 1976 (Fig. 8) show that during August and September individual female sandworms contained eggs of either one of two size ranges. This happens because spawning occurs annually in sandworm populations but the period of egg development in the coelom is longer than 12 mo. Therefore, worms containing larger eggs will spawn the following March–May, whereas those containing small eggs will spawn a year after that. Two general egg sizes have been recorded in the Wiscasset sandworm population between October–November and April–May (Creaser and Clifford footnote 11). Data presented by Brafield and Chapman (1967) suggest that two egg sizes may be present between September and April in the Thames estuary (Southend, England) and Snow (1972) reported the same phenomenon between September and June for sandworms collected at Brandy Cove, St. Andrews, New Brunswick.

Bloodworm and sandworm sexed length frequency data for 6 mo (April–September) combined sampling data are presented in Figures 9 and 10, respectively.

Weight frequency data from combined monthly samplings of the commercial bloodworm and sandworm catches collected during the period April–September (1974–76) are presented in Figures 11 and 12, respectively.

Probability Sampling Expansions and Ratios Estimates

Probability sampling expansions of catch and effort and ratios of two variables estimates (catch/unit effort) are presented by month and 6-mo sampling periods for bloodworms and sandworms in Tables 12 and 13, respectively.

The importance of these probability sampling expansions is considerable. Although estimates of total catch in numbers are already recorded in Maine Landings, estimates of some of the other parameters are either nonexistent (total number of digger tides dug, total number of digger hours dug) or they are reported in U.S. Department of Commerce (1946–80) in gross error (total catch in pounds). It is evident from the results presented in Tables 12 and 13 that the standard errors about the mean monthly probability sampling expansions are greater than those reported for the 6-mo expansions. Standard errors reported for the 6 mo combined data are 19.7–26.2% of the mean for bloodworm expansions and 19.2–31.9% of the mean for sandworm expansions. Although greater accuracy (smaller standard errors) of the expansions could be obtained by randomly selecting more than six daylight low tides per month, this could not be accomplished because of time and manpower limitations.

Based upon the results of the four 6-mo ratio estimates for bloodworm and sandworm catch in numbers/digger hour, it cannot be conclusively stated that bloodworm and sandworm abundance changed significantly between 1973 and 1976. The only indication of a decline in abundance of bloodworms occurred during 1976 when the catch in numbers/digger hour was significantly different (at ± 1.96 SE or 95% confidence levels) from the same recorded during 1974 and 1975. However, there was no significant difference between the 1973 and 1976 bloodworm data for catch in numbers/digger hour at 95% confidence levels.

[32]Taxiarchis, L. N. 1954. Field notes on marine worms. Dep. Sea Shore Fish., Augusta, 36 p.

[33]Taxiarchis, L. N. 1953. Survey of the littoral zone of York County, Maine with respect to commercial productivity. Dep. Sea Shore Fish. Gen. Bull. 2, 13 p.

Table 10.—A summary of bloodworm mean length (cm) and weight (g) data, and the percentages of males, females, regenerated, broken, and punctured individuals by dealer code, including monthly and combined 6-mo means (±1 SE) for the period April–September 1973–76.

April

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	L-25	16	18.18	2.25	8.21	8.31	5.81	7.77	4.45
	W-22	2	19.58	2.30	.00	.00	8.00	6.41	.00
	H-10	11	20.52	2.70	5.70	8.61	6.42	9.15	2.58
	L-6	8	24.06	4.00	6.18	17.31	4.38	8.23	6.47
	L-5	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	37	20.59	2.81	5.02	8.56	6.15	7.89	3.37
	Standard Error		±1.25	±.41	±1.76	±3.53	±.75	±.57	±1.38
1974	H-12	11	19.77	2.45	4.49	5.26	3.59	6.52	1.95
	L-8	16	17.91	2.06	5.35	4.74	7.70	9.44	3.14
	H-14	10	17.18	1.72	1.46	7.60	5.84	8.38	4.53
	H-11	3	16.43	1.50	3.49	1.16	1.10	13.12	2.33
	W-23	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	40	17.82	1.93	3.70	4.69	7.02	9.37	2.98
	Standard Error		±.72	±.21	±.84	±1.33	±1.56	±1.39	±.57
1975	W-19	2	19.15	2.25	.00	.00	5.01	5.01	2.99
	W-18	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	L-8	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	2	19.15	2.25	.00	.00	5.01	5.01	2.99
	Standard Error		-	-	-	-	-	-	-
1976	W-23	3	18.21	2.62	1.57	.00	1.78	13.37	4.85
	H-12	18	19.00	2.33	4.26	8.82	7.87	16.60	5.31
	W-17	-	-	-	-	-	-	-	-
	L-2	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	21	18.60	2.48	2.92	4.41	4.82	14.99	5.08
	Standard Error		±.40	±.15	±1.34	±4.41	±3.05	±1.61	±.23

May

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-18	9	21.76	2.99	.00	.00	5.96	13.25	.55
	W-23	1	24.24	3.80	.00	.00	4.00	.00	4.00
	H-12	7	18.66	1.89	.00	.00	3.84	17.87	3.84
	L-8	14	18.58	2.26	.37	2.55	1.89	10.11	4.81
	L-1	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	31	20.81	2.73	.09	.64	3.92	10.31	3.30
	Standard Error		±1.36	±.42	±.09	±.64	±.83	±3.79	±.94
1974	L-8	14	18.58	2.01	.00	1.63	3.96	11.96	5.54
	H-27	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	14	18.58	2.01	.00	1.63	3.96	11.96	5.54
	Standard Error		-	-	-	-	-	-	-
1975	L-6	5	20.97	2.72	.00	.83	7.00	10.98	9.13
	H-14	6	19.51	2.57	.00	.68	4.77	22.83	5.05
	W-19	3	19.42	2.75	.00	.00	7.38	26.97	8.00
	L-2	-	-	-	-	-	-	-	-
	W-18	-	-	-	-	-	-	-	-
	W-31	-	-	-	-	-	-	-	-
	Monthly Mean	14	19.97	2.68	.00	.50	6.38	20.26	7.40
	Standard Error		±.50	±.05	-	±.26	±.81	±4.79	±1.22
1976	W-19	9	21.98	2.94	.00	.00	9.52	9.20	3.33
	L-2	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	L-5	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	Monthly Mean	9	21.98	2.94	.00	.00	9.52	9.20	3.33
	Standard Error		-	-	-	-	-	-	-

June

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-22	2	20.36	2.55	-	-	4.00	12.00	5.22
	L-4	10	17.22	1.79	-	-	5.65	18.01	4.19
	H-14	14	17.20	1.72	-	-	5.95	9.01	2.46
	L-1	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	26	18.26	2.02	-	-	5.20	13.01	3.96
	Standard Error		±1.05	±.27	-	-	±.61	±2.64	±.81
1974	L-5	6	19.80	2.43	-	-	4.80	11.80	4.81
	H-14	13	18.40	2.34	-	-	5.93	12.95	2.14
	W-22	1	23.44	4.83	-	-	.00	16.00	4.00
	L-8	14	19.85	2.28	-	-	5.28	9.98	5.19
	W-19	11	17.92	2.24	-	-	8.98	11.69	4.99
	W-23	-	-	-	-	-	-	-	-
	Monthly Mean	45	19.88	2.82	-	-	5.00	12.48	4.23
	Standard Error		±.97	±.50	-	-	±1.45	±1.00	±.56
1975	L-8	2	16.31	1.82	-	-	4.45	7.10	4.00
	H-15	9	22.27	3.16	-	-	9.73	11.52	2.92
	L-4	9	19.74	2.32	-	-	2.57	12.63	7.21
	W-21	9	19.72	2.98	-	-	7.02	7.48	3.41
	W-24	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-
	Monthly Mean	29	19.51	2.57	-	-	5.94	9.68	4.38
	Standard Error		±1.22	±.31	-	-	±1.56	±1.40	±.97
1976	L-4	18	16.77	1.75	-	-	6.84	17.69	8.51
	W-18	12	20.38	3.15	-	-	8.36	11.24	6.23
	H-28	-	-	-	-	-	-	-	-
	W-23	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	30	18.57	2.45	-	-	7.60	14.46	7.37
	Standard Error		±1.81	±.70	-	-	±.76	±3.22	±1.14

July

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	L-4	11	16.69	1.63	-	-	18.16	11.61	2.81
	W-17	2	22.46	3.31	-	-	.00	8.92	2.46
	W-18	13	16.12	1.60	-	-	2.05	6.41	1.17
	W-19	10	17.38	2.05	-	-	4.58	14.70	1.93
	W-24	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	Monthly Mean	36	18.16	2.15	-	-	6.20	10.41	2.09
	Standard Error		±1.46	±.40	-	-	±4.10	±1.78	±.36
1974	H-12	10	20.97	2.60	-	-	5.32	14.92	2.46
	L-8	10	21.77	3.06	-	-	3.55	15.66	5.56
	L-9	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	20	21.37	2.93	-	-	4.44	15.29	4.01
	Standard Error		±.40	±.23	-	-	±.89	±.37	±1.55
1975	H-12	12	19.56	2.88	-	-	12.06	18.37	1.69
	W-17	1	26.28	6.90	-	-	.00	12.00	12.00
	W-19	3	19.81	3.03	-	-	4.05	13.27	10.41
	W-23	3	18.46	2.41	-	-	9.53	12.20	9.56
	W-20	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	19	21.03	3.81	-	-	6.41	13.96	8.42
	Standard Error		±1.77	±1.04	-	-	±2.71	±1.50	±2.30
1976	W-19	11	19.91	2.90	-	-	6.73	17.95	.90
	W-21	8	19.79	3.09	-	-	9.49	22.03	4.46
	H-11	6	20.10	2.88	-	-	9.62	8.72	2.35
	L-6	3	20.41	3.18	-	-	2.36	4.99	11.48
	L-2	1	28.79	5.34	-	-	4.00	12.00	8.00
	W-23	-	-	-	-	-	-	-	-
	Monthly Mean	29	21.80	3.48	-	-	6.44	13.14	5.44
	Standard Error		±1.75	±.47	-	-	±1.45	±3.08	±1.93

Table 10.—*Continued.*

August

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate.	Broken	Punctured
1973	L-26	6	15.24	1.36	-	-	1.33	15.83	.00
	W-19	4	14.46	1.12	-	-	1.06	13.93	1.67
	H-10	14	16.01	1.41	-	-	5.40	18.37	.78
	W-24	1	25.35	4.13	-	-	.00	20.00	8.00
	K-29	7	13.88	1.05	-	-	3.30	17.29	1.05
	L-1		-	-	-	-	-	-	-
	Monthly Mean	32	16.99	1.81	-	-	2.22	17.08	2.30
	Standard Error		±2.12	±.58	-	-	±.96	±1.04	±1.45
1974	K-29	3	18.59	1.94	-	-	8.65	16.78	8.63
	W-21	12	19.23	2.81	-	-	5.40	11.80	3.28
	L-2	1	16.23	1.35	-	-	36.00	4.00	4.00
	L-6	5	24.48	4.00	-	-	7.33	7.34	3.73
	H-27	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	Monthly Mean	21	19.63	2.52	-	-	14.34	9.98	4.91
	Standard Error		±1.74	±.58	-	-	±7.25	±2.77	±1.25
1975	H-14	6	22.38	3.29	-	-	5.74	12.06	4.21
	L-4	10	22.10	3.00	-	-	5.89	13.22	17.11
	H-15	8	21.95	4.00	-	-	9.43	18.06	3.03
	L-1	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	Monthly Mean	24	22.14	3.43	-	-	7.02	14.45	8.12
	Standard Error		±.13	±.30	-	-	±1.21	±1.84	±4.51
1976	H-14	8	22.10	3.72	-	-	4.38	7.98	3.64
	W-21	3	22.60	3.47	-	-	12.74	9.42	5.42
	L-5	7	24.23	4.12	-	-	6.18	11.86	4.52
	L-9	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	18	22.98	3.77	-	-	7.76	9.75	4.53
	Standard Error		±.64	±.19	-	-	±2.54	±1.13	±.51

September

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate.	Broken	Punctured
1973	H-12	3	14.66	1.14	-	-	7.99	17.60	1.10
	H-11	4	17.17	2.14	-	-	4.11	14.16	2.72
	W-18	8	17.43	2.57	-	-	3.96	8.73	1.19
	H-14	4	20.41	2.37	-	-	6.66	12.27	.99
	W-23	-	-	-	-	-	-	-	-
	W-16	-	-	-	-	-	-	-	-
	Monthly Mean	19	17.42	2.06	-	-	5.68	13.19	1.50
	Standard Error		±1.18	±.32	-	-	±.99	±1.85	±.41
1974	L-5	10	20.64	2.73	-	-	1.44	10.23	6.25
	W-17	6	23.33	4.45	-	-	5.55	18.89	4.32
	L-25	7	21.66	3.00	-	-	13.50	10.86	7.29
	H-11	5	23.34	3.19	-	-	13.13	11.32	3.29
	W-21	6	19.42	3.20	-	-	10.26	8.70	3.90
	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	34	21.68	3.31	-	-	8.77	12.00	5.01
	Standard Error		±.76	±.30	-	-	±2.32	±1.78	±.76
1975	W-17	8	26.19	5.10	-	-	4.46	11.25	6.50
	H-11	11	20.01	2.47	-	-	8.03	17.03	4.70
	L-1	-	-	-	-	-	-	-	-
	L-2	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	Monthly Mean	19	23.10	3.78	-	-	6.25	14.14	5.60
	Standard Error		±3.09	±1.31	-	-	±1.78	±2.89	±.90
1976	W-21	6	20.83	2.88	-	-	8.74	9.78	1.84
	H-11	5	18.68	2.56	-	-	4.64	10.43	4.14
	L-4	11	19.19	2.11	-	-	5.08	13.98	3.51
	W-17	3	27.25	6.92	-	-	6.10	10.13	4.87
	H-14	6	20.37	3.17	-	-	6.59	16.49	2.46
	L-6	5	22.07	2.97	-	-	5.02	9.68	8.92
	Monthly Mean	36	21.40	3.44	-	-	6.03	11.75	4.29
	Standard Error		±1.27	±.71	-	-	±.62	±1.15	±1.03

Six Month Estimates

Year	Mean: Length	Weight	Percent: Male	Female	Regenerate.	Broken	Punctured
1973							
Mean	18.72				4.87	11.98	2.78
Standard Error	±.60				±.82	±.94	±.40
1974							
Mean	19.84	2.57			7.19	11.92	4.45
Standard Error	±.36	±.15			±1.34	±.61	±.39
1975							
Mean	20.74	3.07			6.17	12.95	6.19
Standard Error	±.59	±.27			±.65	±1.05	±.90
1976							
Mean	20.83	3.11			6.88	12.44	5.16
Standard Error	±.54	±.20			±.77	±.93	±.48

Table 11.—A summary of sandworm mean length (cm) and weight (g) data, and the percentages of males, females, regenerated, broken, and punctured individuals by dealer code, including monthly and combined 6-mo means (±1 SE) for the period April–September 1973–76.

April

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-22	9	26.64	7.26	-	-	8.21	21.28	1.85
	L-6	2	36.08	17.12	-	-	4.53	23.47	3.47
	L-5	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-10	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	Monthly Mean	11	31.36	12.19	-	-	6.37	22.37	2.66
	Standard Error		±4.72	±4.93	-	-	±1.84	±1.10	±.81
1974	L-8	5	20.82	4.61	-	-	6.51	28.41	.83
	H-11	2	24.42	5.39	-	-	3.15	20.00	7.15
	W-24	9	29.28	7.71	-	-	8.63	20.90	9.44
	W-23	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	16	24.84	5.90	-	-	6.10	23.10	5.80
	Standard Error		±2.45	±.93	-	-	±1.59	±2.67	±2.57
1975	W-19	6	33.22	9.37	-	-	4.28	30.90	8.95
	L-1	5	31.43	10.32	-	-	6.75	17.67	4.60
	W-18	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	L-8	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	11	32.32	9.85	-	-	5.52	24.28	6.77
	Standard Error		±.90	±.47	-	-	±1.24	±6.61	±2.18
1976	L-2	6	24.58	6.12	-	-	8.22	17.29	2.39
	W-17	-	-	-	-	-	-	-	-
	W-23	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	6	24.58	6.12	-	-	8.22	17.29	2.39
	Standard Error		-	-	-	-	-	-	-

May

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-18	5	27.32	7.73	-	-	6.65	23.98	.59
	L-1	4	30.49	10.08	-	-	3.14	12.57	1.71
	W-23	7	28.93	8.97	-	-	2.35	20.43	6.14
	L-8	1	22.24	4.73	-	-	12.00	16.00	12.00
	W-24	8	27.93	8.19	-	-	7.42	24.08	4.80
	H-12	-	-	-	-	-	-	-	-
	Monthly Mean	25	27.39	7.94	-	-	6.31	19.41	5.05
	Standard Error		±1.39	±.89	-	-	±1.72	±2.26	±2.01
1974	L-8	6	27.29	6.35	-	-	9.05	18.37	1.26
	H-27	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	W-20	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	W-24	-	-	-	-	-	-	-	-
	Monthly Mean	6	27.29	6.35	-	-	9.05	18.37	1.26
	Standard Error		-	-	-	-	-	-	-
1975	L-2	4	25.60	5.79	-	-	7.96	20.48	.59
	L-6	10	24.56	5.70	-	-	1.47	29.59	.61
	W-25	2	24.18	6.03	-	-	5.70	47.53	.00
	W-19	6	25.61	5.81	-	-	3.09	29.19	1.93
	W-18	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	22	24.99	5.83	-	-	4.55	31.70	.78
	Standard Error		±.36	±.07	-	-	±1.43	±5.68	±.41
1976	L-2	5	25.18	7.50	-	-	2.26	25.13	3.63
	W-19	12	28.63	6.61	-	-	1.80	25.52	6.10
	H-30	4	29.62	7.71	-	-	2.37	16.32	5.16
	L-5	7	26.39	5.79	-	-	3.28	20.60	3.79
	H-11	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	Monthly Mean	28	27.45	6.90	-	-	2.43	21.89	4.67
	Standard Error		±1.01	±.44	-	-	±.31	±2.17	±.59

June

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-22	7	25.29	6.53	-	-	4.00	26.22	.00
	L-1	5	29.68	9.55	-	-	5.21	18.17	.00
	W-24	6	26.44	7.18	-	-	8.84	13.60	1.62
	L-4	5	28.59	8.53	-	-	1.20	27.86	2.69
	W-21	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	23	27.50	7.95	-	-	4.81	21.46	1.08
	Standard Error		±1.00	±.68	-	-	±1.58	±3.37	±.66
1974	W-22	6	27.88	7.14	-	-	6.09	30.73	2.69
	L-8	7	26.08	6.04	-	-	8.70	22.64	1.83
	W-19	16	26.01	6.03	-	-	5.49	17.89	2.61
	W-23	-	-	-	-	-	-	-	-
	L-5	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	24	26.66	6.40	-	-	6.76	23.75	2.38
	Standard Error		±.61	±.37	-	-	±.98	±3.75	±.27
1975	L-8	5	24.57	5.21	-	-	8.26	9.86	4.82
	W-21	7	26.51	5.52	-	-	12.52	18.72	6.21
	W-24	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-
	L-4	-	-	-	-	-	-	-	-
	Monthly Mean	12	25.54	5.36	-	-	10.39	14.29	5.51
	Standard Error		±.97	±.15	-	-	±2.13	±4.43	±.69
1976	W-23	7	25.68	6.81	-	-	1.93	40.52	7.33
	W-18	2	26.44	5.12	-	-	24.70	14.17	4.35
	H-28	-	-	-	-	-	-	-	-
	L-4	-	-	-	-	-	-	-	-
	L-1	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	9	26.06	5.97	-	-	13.31	27.35	5.84
	Standard Error		±.38	±.85	-	-	±11.38	±13.17	±1.49

July

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-17	3	20.77	4.34	-	-	7.79	28.67	5.05
	W-24	1	23.90	5.51	-	-	8.00	8.00	.00
	H-28	3	25.60	6.72	-	-	11.04	28.03	.00
	W-18	2	22.91	5.23	-	-	12.17	32.00	.00
	W-19	4	23.73	5.56	-	-	7.26	29.56	1.18
	L-4	-	-	-	-	-	-	-	-
	Monthly Mean	13	23.38	5.47	-	-	9.25	25.25	1.25
	Standard Error		±.79	±.38	-	-	±.98	±4.37	±.98
1974	L-8	8	21.87	3.95	-	-	5.07	14.87	.51
	W-24	9	26.62	6.20	-	-	8.35	18.98	2.10
	L-9	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	H-12	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	17	24.25	5.07	-	-	6.71	16.92	1.30
	Standard Error		±2.38	±1.13	-	-	±1.64	±2.06	±.80
1975	W-17	3	22.94	4.63	-	-	20.42	21.41	2.26
	W-20	5	25.80	5.35	-	-	9.72	17.48	.00
	W-23	12	24.17	4.66	-	-	4.35	17.83	2.82
	H-12	-	-	-	-	-	-	-	-
	W-19	-	-	-	-	-	-	-	-
	H-30	-	-	-	-	-	-	-	-
	Monthly Mean	20	24.31	4.88	-	-	11.50	18.91	1.69
	Standard Error		±.83	±.24	-	-	±4.72	±1.26	±.86
1976	W-19	7	26.12	6.21	-	-	8.87	22.13	3.52
	W-21	9	25.15	5.44	-	-	20.75	17.81	1.44
	L-6	9	24.50	5.26	-	-	3.62	14.95	4.19
	L-2	7	26.63	5.79	-	-	3.80	17.08	2.23
	H-11	-	-	-	-	-	-	-	-
	W-23	-	-	-	-	-	-	-	-
	Monthly Mean	32	25.60	5.67	-	-	9.26	17.99	2.84
	Standard Error		±.48	±.21	-	-	±4.02	±1.60	±.62

Table 11.—*Continued.*

August

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	L-1	3	31.93	11.41	1.07	10.93	5.07	20.44	5.07
	W-19	13	22.69	5.12	1.05	18.59	11.71	23.68	5.83
	W-24	7	22.84	5.17	4.50	10.74	15.95	21.42	.81
	L-26	-	-	-	-	-	-	-	-
	H-10	-	-	-	-	-	-	-	-
	K-29	-	-	-	-	-	-	-	-
	Monthly Mean	23	25.82	7.23	2.21	13.42	10.91	21.85	3.90
	Standard Error		±3.05	±2.09	±1.15	±2.59	±3.16	±.96	±1.56
1974	W-21	5	25.55	5.22	1.62	7.14(2.37)	11.72	17.47	2.13
	L-2	10	26.17	5.13	8.43	22.16(7.47)	4.22	16.84	1.06
	L-6	3	29.68	6.19	13.66	28.64(.00)	10.98	11.51	2.46
	L-1	10	31.26	9.17	6.68	25.88(.00)	6.18	12.42	1.57
	H-27	-	-	-	-	-	-	-	-
	K-29	-	-	-	-	-	-	-	-
	Monthly Mean	28	28.16	6.43	7.60	20.96(2.46)	8.27	14.56	1.81
	Standard Error		±1.38	±.95	±2.48	±4.79(1.76)	±1.83	±1.52	±.31
1975	L-1	9	25.43	5.53	11.02	19.08(3.82)	2.24	20.84	1.73
	L-9	5	27.58	6.21	25.43	20.54(5.26)	8.75	11.59	2.95
	H-28	4	24.73	4.77	14.61	24.20(5.87)	9.80	18.52	.35
	H-14	-	-	-	-	-	-	-	-
	L-4	-	-	-	-	-	-	-	-
	H-15	-	-	-	-	-	-	-	-
	Monthly Mean	18	25.91	5.50	17.02	21.27(4.98)	6.93	16.98	1.68
	Standard Error		±.86	±.42	±4.33	±1.52(±.61)	±2.37	±2.78	±.75
1976	L-5	8	25.23	5.53	7.89	18.44(3.68)	6.69	12.20	1.78
	H-30	6	28.88	7.58	13.48	21.24(4.06)	4.23	11.79	1.23
	H-14	-	-	-	-	-	-	-	-
	L-9	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	H-28	-	-	-	-	-	-	-	-
	Monthly Mean	14	27.06	6.56	10.68	19.84(3.87)	5.46	11.99	1.51
	Standard Error		±1.83	±1.03	±2.80	±1.40(±.19)	±1.23	±.20	±.27

September

Year	Dealer Code	No. Samples	Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	W-23	7	19.08	3.43	9.21	12.25	3.44	34.95	.79
	W-18	2	22.93	5.26	14.97	17.49	13.94	26.06	1.49
	H-12	-	-	-	-	-	-	-	-
	W-16	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	9	21.00	4.34	12.09	14.87	8.69	30.50	1.14
	Standard Error		±1.93	±.92	±2.88	±2.62	±5.25	±4.45	±.35
1974	L-5	4	29.14	5.94	13.99	13.00(3.01)	11.99	24.01	.00
	W-17	4	23.21	3.95	7.51	4.64(1.03)	7.60	7.03	1.41
	W-21	5	25.79	4.84	6.47	3.08(3.78)	11.68	17.70	.00
	W-20	-	-	-	-	-	-	-	-
	L-25	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	13	26.05	4.91	9.33	6.90(2.61)	10.42	16.25	.47
	Standard Error		±1.72	±.58	±2.35	±3.08(±.82)	±1.41	±4.95	-
1975	L-1	9	31.27	8.77	19.30	16.95(8.75)	7.49	14.53	2.49
	W-17	2	25.26	4.97	5.69	16.63(13.06)	4.00	16.63	2.31
	L-2	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	W-21	-	-	-	-	-	-	-	-
	H-11	-	-	-	-	-	-	-	-
	Monthly Mean	11	28.26	6.87	12.49	16.79(10.90)	5.75	15.58	2.40
	Standard Error		±3.01	±1.90	±6.80	±.16(±2.16)	±1.75	±1.05	±.09
1976	W-21	6	26.16	6.42	10.36	18.76(5.28)	8.72	14.90	.66
	L-4	7	21.81	3.26	16.18	20.18(3.92)	7.83	16.25	3.69
	L-6	7	23.26	4.14	17.49	15.48(2.56)	6.02	20.10	.97
	H-11	-	-	-	-	-	-	-	-
	W-17	-	-	-	-	-	-	-	-
	H-14	-	-	-	-	-	-	-	-
	Monthly Mean	20	23.74	4.61	14.68	18.14(3.92)	7.52	17.08	1.78
	Standard Error		±1.28	±.94	±2.19	±1.39(±.78)	±.79	±1.56	±.96

Six Month Estimates

Year		Mean: Length	Weight	Percent: Male	Female	Regenerate	Broken	Punctured
1973	Mean	26.11				7.71	23.26	2.54
	Standard Error	±.98				±1.05	±1.27	±.51
1974	Mean	26.22	5.86			7.85	18.81	2.14
	Standard Error	±.68	±.31			±.56	±1.16	±.43
1975	Mean	26.77	6.32			7.54	20.40	3.25
	Standard Error	±.53	±.29			±1.07	±1.75	±.45
1976	Mean	25.69	5.93			8.07	18.82	3.12
	Standard Error	±.42	±.29			±2.23	±2.44	±.35

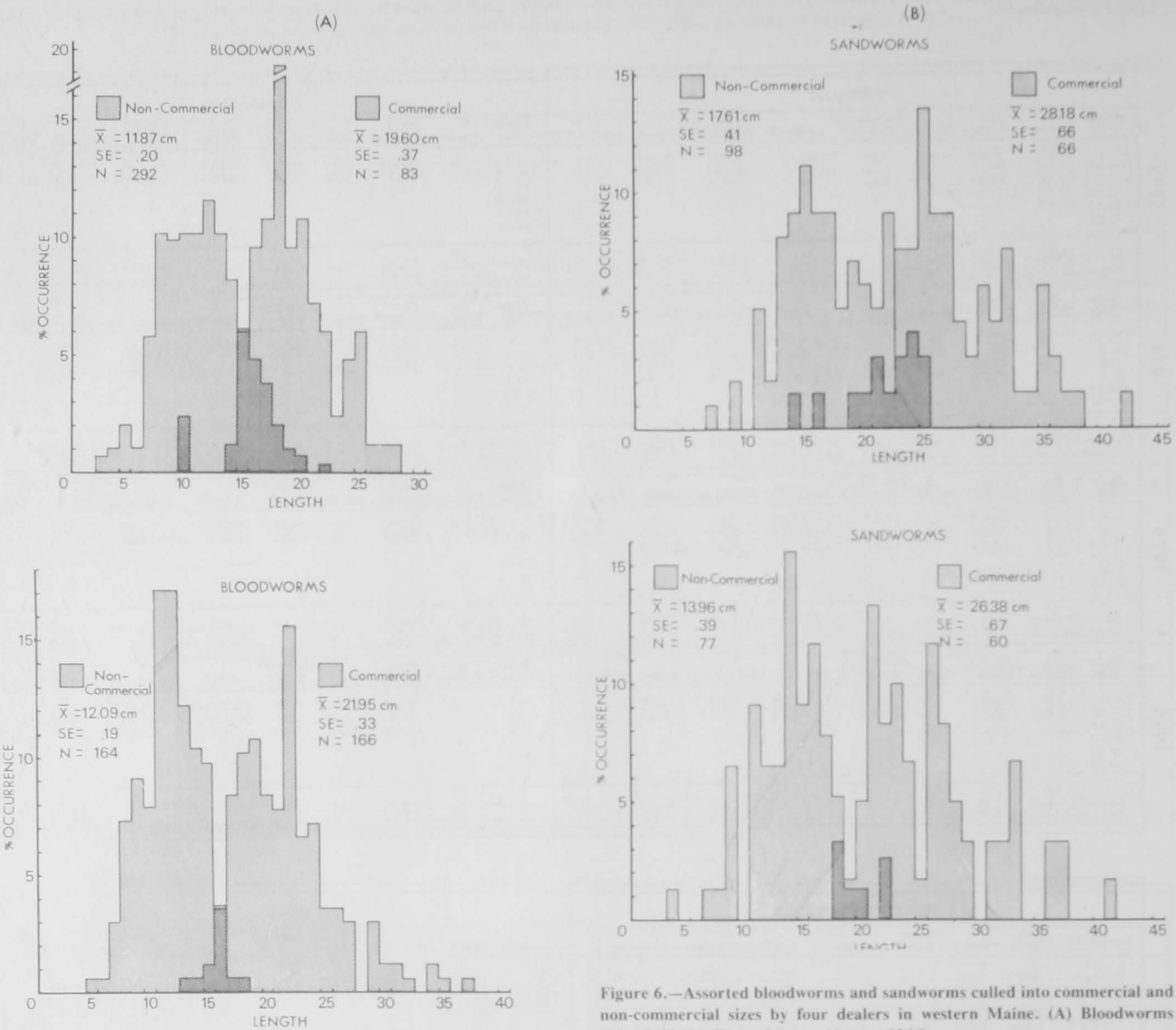
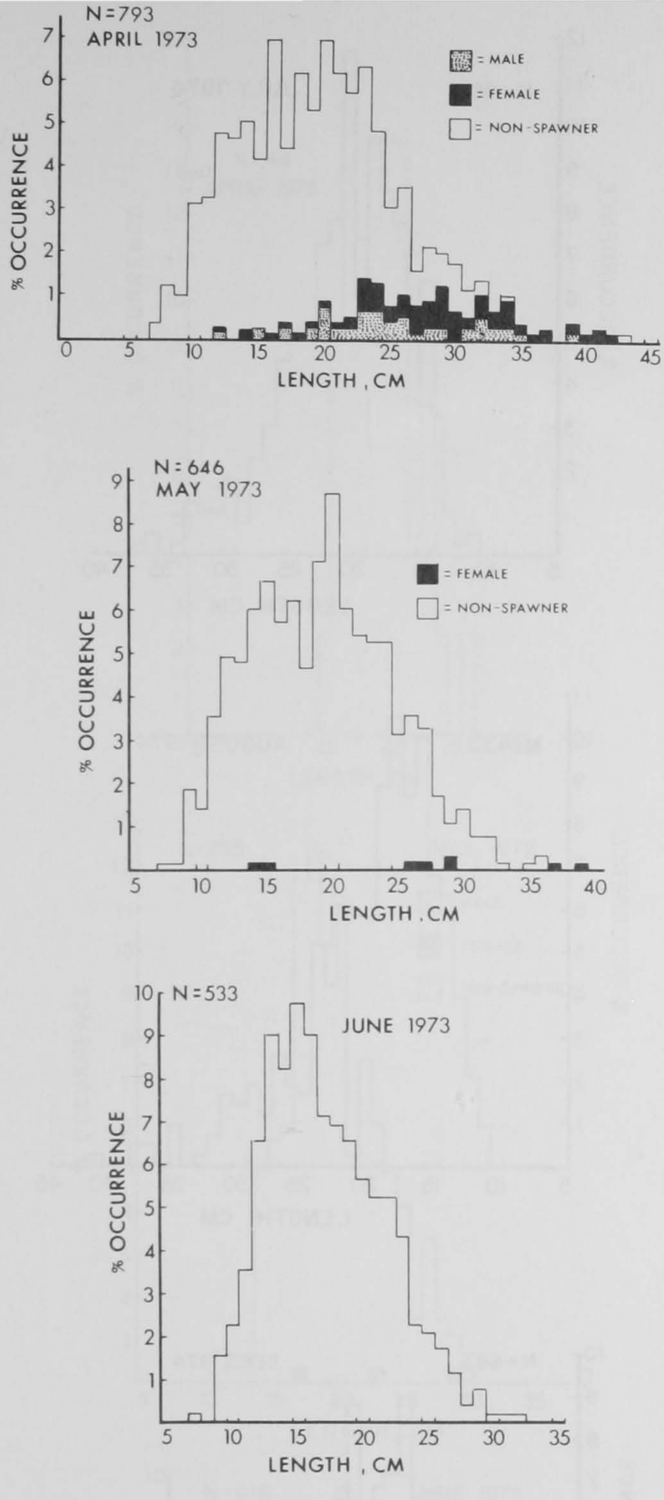


Figure 6.—Assorted bloodworms and sandworms culled into commercial and non-commercial sizes by four dealers in western Maine. (A) Bloodworms (March 1966), (B) sandworms (August 1966)

Monthly and combined 6-mo values for catch in numbers/digger tide and catch in numbers/digger hour recorded in Tables 12 and 13 are mean values derived from samples collected during all low tide amplitudes. It is generally known by marine worm diggers and dealers that the number of worms dug/tide fluctuates with variations in low tide amplitudes. During the early 1950's, marine biologists in Maine observed that a +1.0 ft low tide reduced the take of marine worms an average of 30% compared with a 0.0 low tide (Dow 1969).

The catch in numbers/digger hour for 6 mo combined bloodworm data (Table 12) varied between 193 ± 6 and 233 ± 6. Ganaros (footnote 4) reported that the catch/hour of commercial-sized bloodworms varied between 150 and 200. It is quite possible, however, that these lower catch/effort figures reported by Ganaros (footnote 4) resulted from the fact that larger bloodworms were demanded by the commercial market during 1951. Estimates of commercial bloodworm catch/hour have also been reported from the Marsh River (118–293 bloodworms/h) and Montsweag Bay (10–450 bloodworms/h) in the vicinity of Wiscasset, Maine, by Dean and Ewart.[34] The catch in numbers/digger tide for 6 mo combined bloodworm data (Table 12) varied between 536 ± 36 and 662 ± 26. Sandrof (1946) reported that bloodworm diggers dug approximately 350 commercial-sized bloodworms/tide. This reduction in catch/effort is also probably the result of larger worms being commercially harvested at that time. Sandrof (1946) reported that the average natural length of commercial-sized bloodworms was 6–8 in (15.2–20.3 cm), which is equivalent to approximately 22–29 cm relaxed length (Fig. 5A). It is also possible that this reduction in catch/effort may have resulted from frequent "limits" imposed upon bloodworm diggers.

[34]Dean, D., and J. Ewart. 1978. Final report, environmental surveillance and studies at the Maine Yankee nuclear generating station 1969–1977. Section 10 Benthos (commercially important invertebrates). Maine Yankee Atomic Power Company, 830 p.



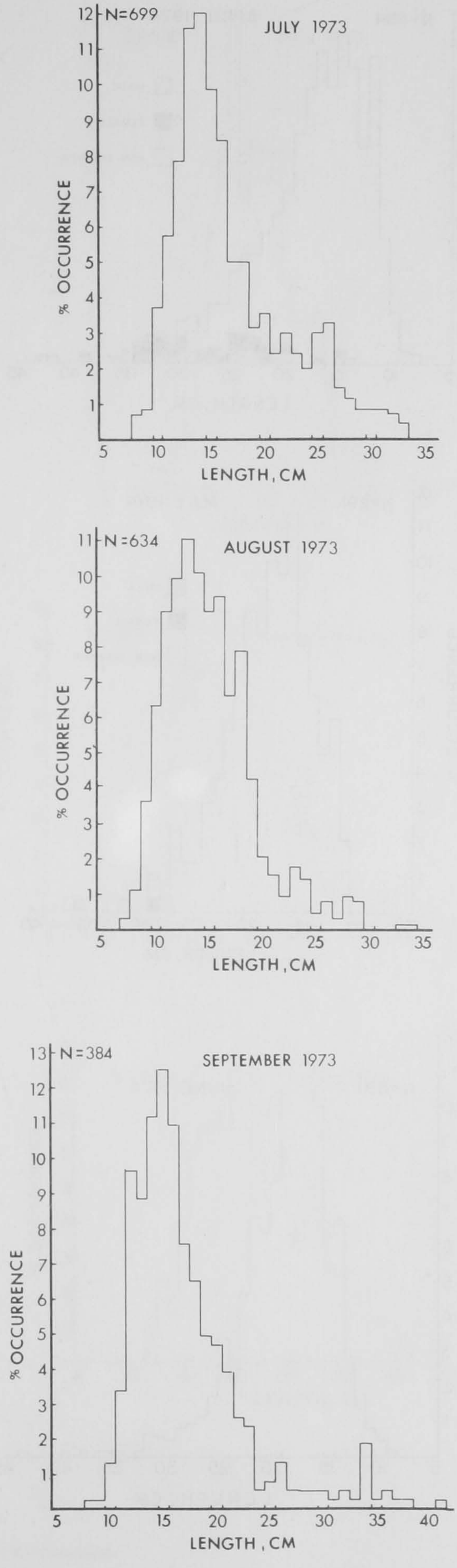


Figure 7.—Sexed length frequency data obtained from monthly samplings of the commercial bloodworm catch: (A) 1973, (B) 1974, (C) 1975, (D) 1976.

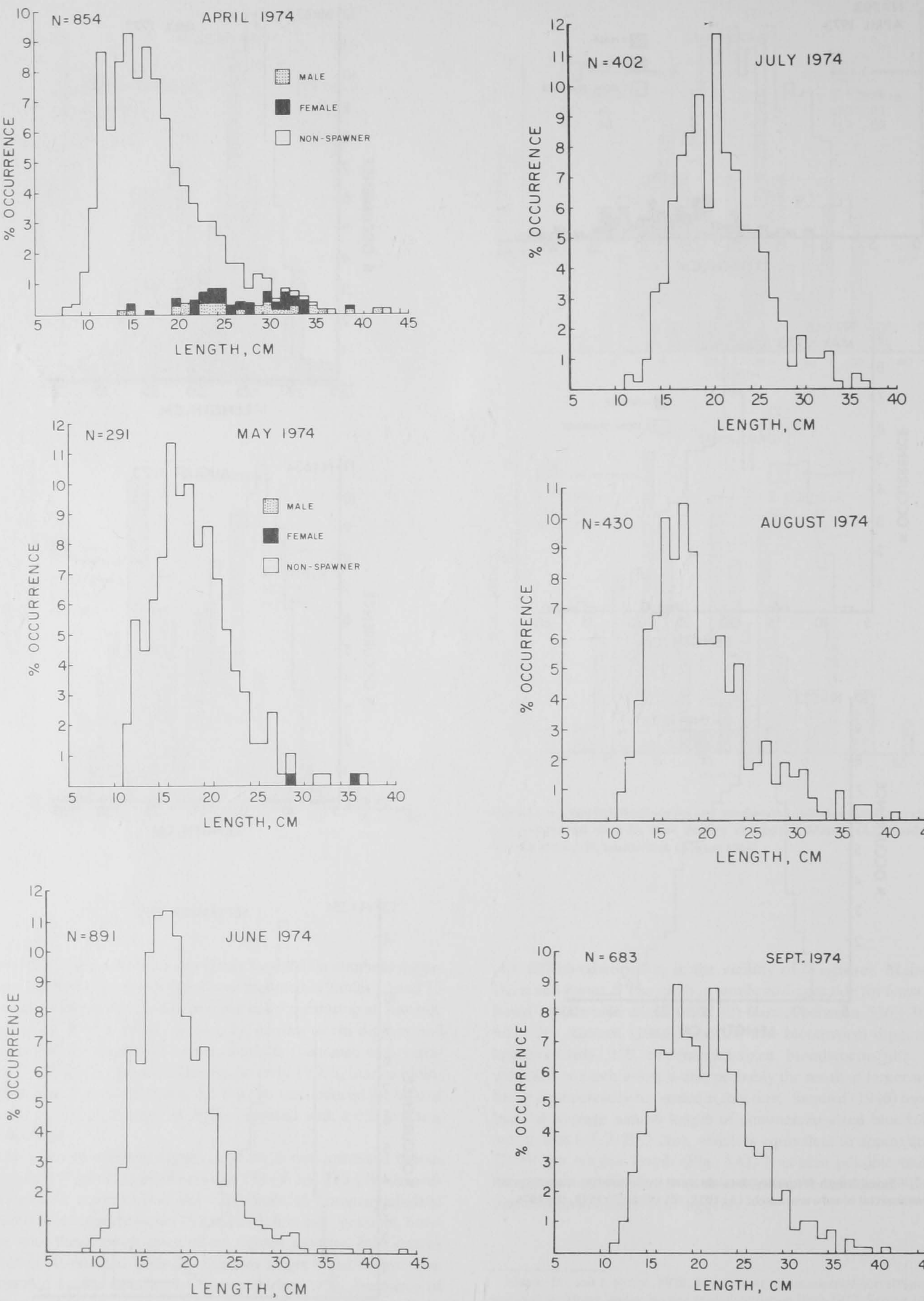


Figure 7.—*Continued.*

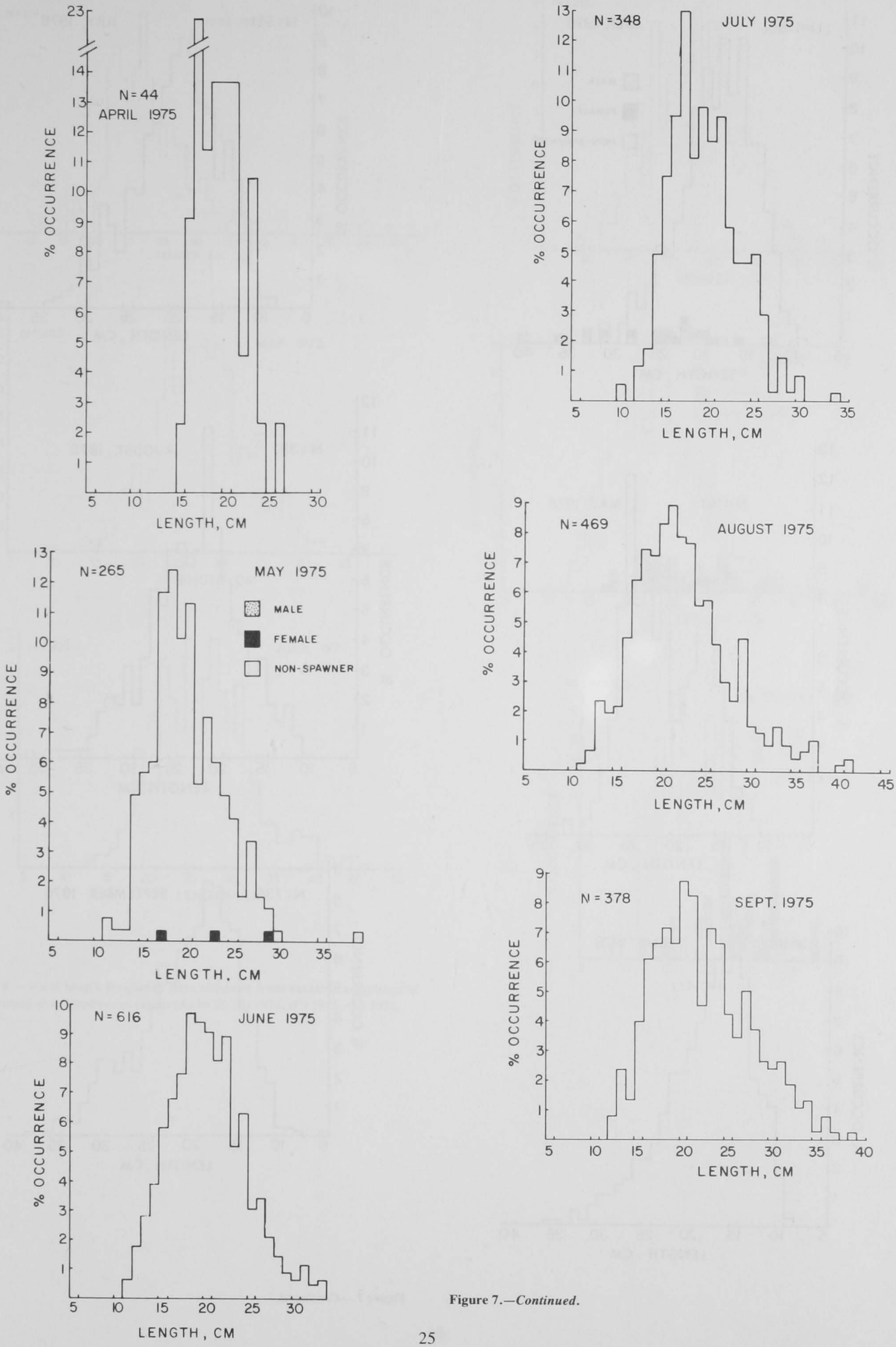


Figure 7.—*Continued.*

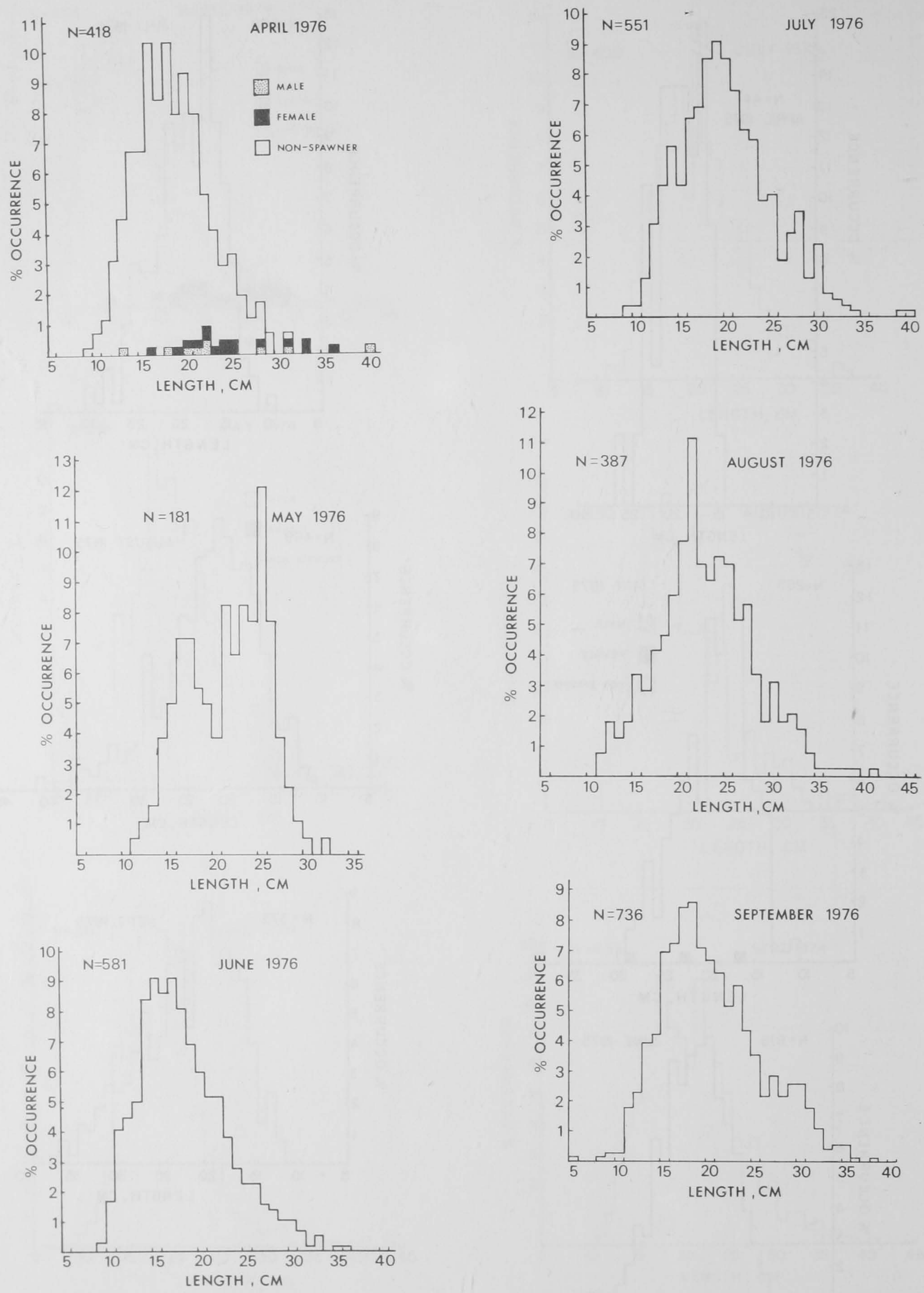


Figure 7.—*Continued.*

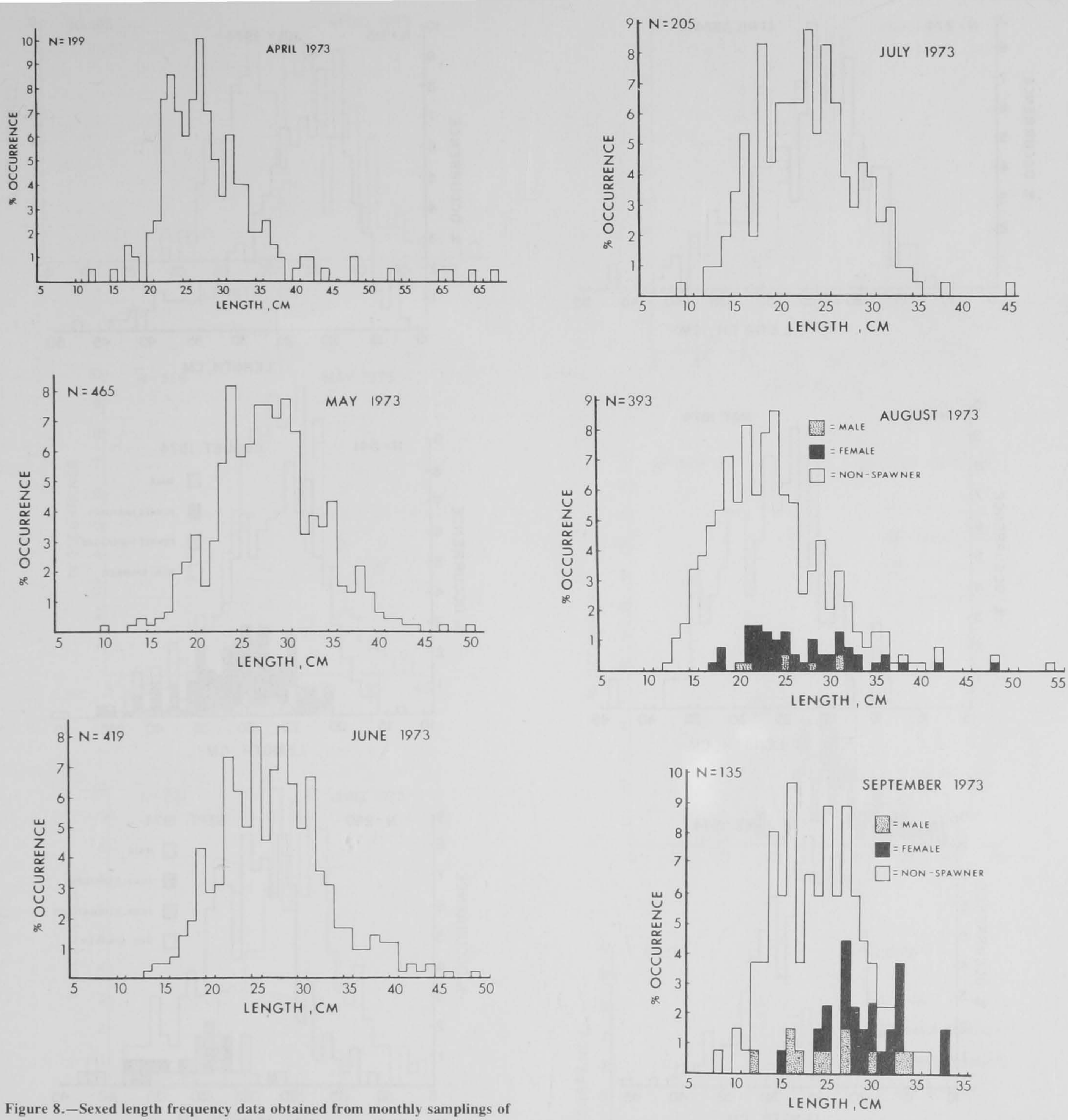


Figure 8.—Sexed length frequency data obtained from monthly samplings of the commercial sandworm catch: (A) 1973, (B) 1974, (C) 1975, (D) 1976.

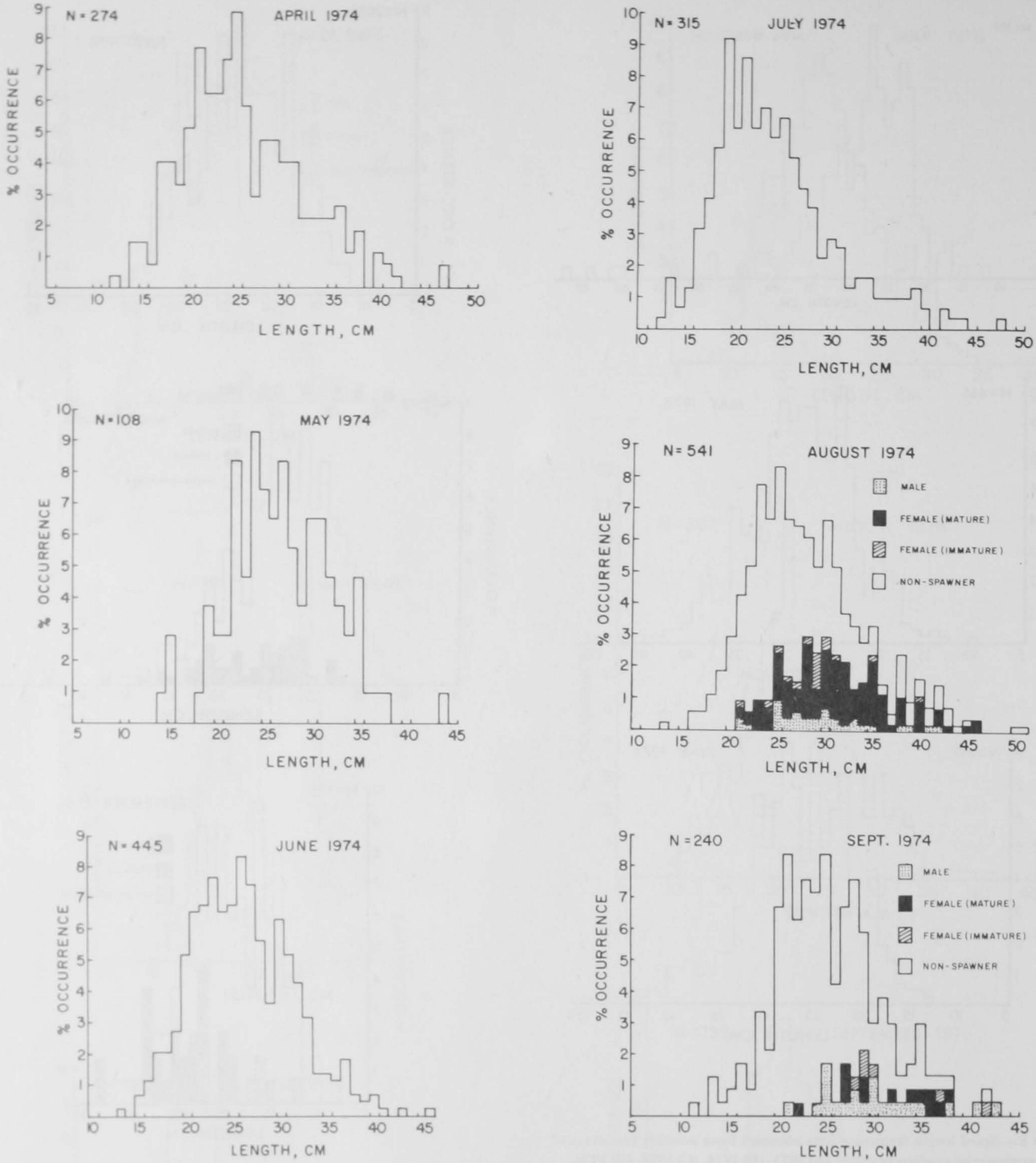


Figure 8.—*Continued.*

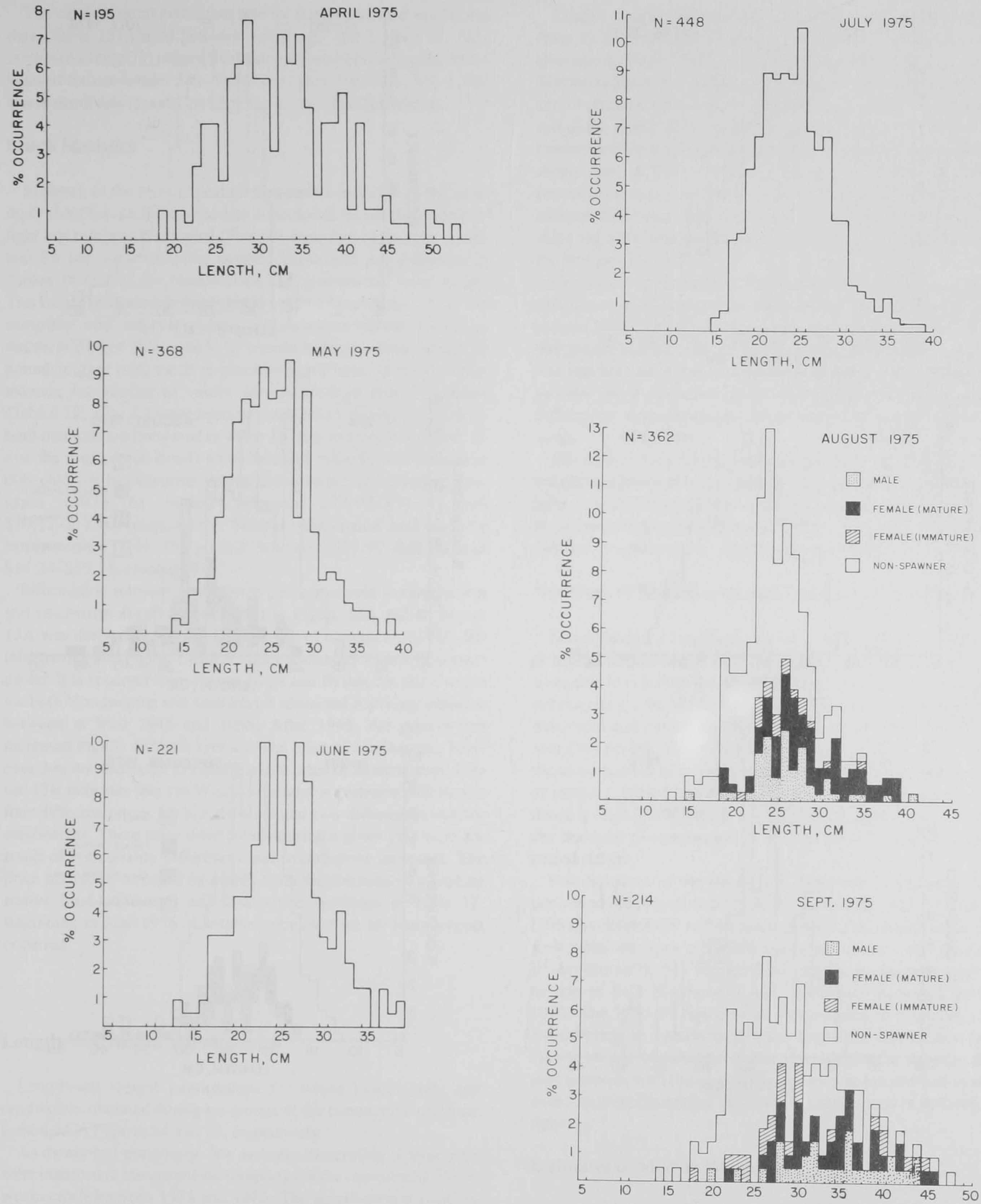


Figure 8.—*Continued.*

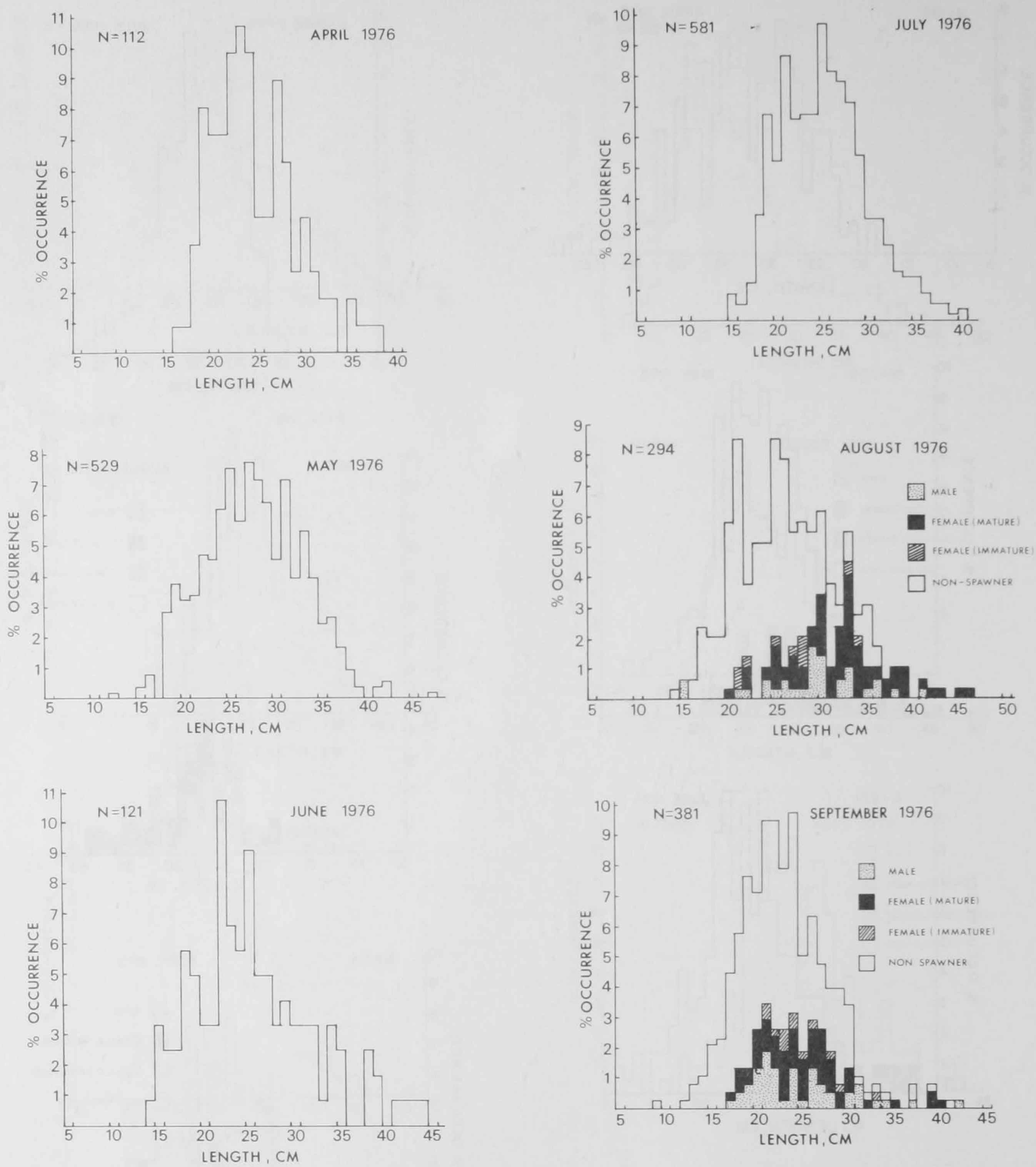


Figure 8.—*Continued.*

The catch in numbers/digger tide for 6 mo combined sandworm data (Table 13) varied between $1,028 \pm 60$ and $1,184 \pm 38$. Taxiarchis (footnote 33) judged the quality of sandworm digging on the basis of the catch/tide: 500–700 sandworms/tide (fair), 700–1,000 sandworms/tide (good), and 1,000 and over/tide (excellent).

Catch Statistics

Eighteen of the most important parameters included on the summary sheet for catch statistics data collected during each dealer daylight low tide period sampled (Table 6) were summarized by month and for the 6-mo sampling period. These data are presented in Tables 14 and 15 for bloodworms and sandworms, respectively. The values presented in these tables were derived directly from the sampling and interview data. Catch/effort values (catch in numbers/digger tide, catch in numbers/digger hour, catch in pounds/digger tide, catch in pounds/digger hour) derived in this manner, are similar to values derived through ratios estimates (Tables 12, 13). A comparison of catch/effort results obtained by both methods are presented in Table 16. It is evident from Table 14 that the 6-mo mean (total) value/tide and value/hour information collected for bloodworms during the commercial sampling program (1973–76) varied between \$27.97–\$31.59 and \$10.11–\$11.00, respectively. Similar information collected for sandworms (Table 15) varied between \$27.97–\$40.30 and \$14.34–\$19.15, respectively.

Information relevant to the price per worm paid to bloodworm and sandworm diggers is presented in Figure 13A and B. Figure 13A was derived from U.S. Department of Commerce (1946–80) information and Figure 13B was obtained directly from a Wiscasset dealer. It is apparent from Figure 13 (A and B) that the price/worm for both bloodworms and sandworms remained relatively constant between at least 1945 and 1965. After 1965, the price/worm increased rapidly for both species. The price of sandworms, however, has not increased as rapidly as the price of bloodworms. Figure 13B indicates that the Wiscasset dealer sometimes paid two to four different prices for bloodworms and two different prices for sandworms. These price differentials during a given year were the result of both quality differences and overall price increases. The price per worm recorded by month from the commercial sampling results for bloodworms and sandworms is shown in Table 17. Beginning in June 1976, a notable price increase for bloodworms occurred.

Length-Wet Weight Relationships

Length-wet weight relationships for whole bloodworms and sandworms obtained during samplings of the commercial catch are presented in Figures 14 and 15, respectively.

As mentioned previously, few sexually discernible bloodworms were obtained in our coastwide samplings of the commercial bloodworm catch between 1974 and 1976. The length-weight relationships for those few male and female sandworms obtained coastwide between 1974 and 1976 are presented in Figure 15A. A comparison of the slopes of the length-weight curves for males and females of each species (Table 18) shows that, at 95% confidence limits (± 1.96 SE) overlap occurs in the upper and lower ranges of the b values. No significant differences therefore exist in the length-weight relationships for male and female bloodworms and sandworms.

Length-weight relationships for bloodworms and sandworms from 1) all areas and all sexes combined, and 2) eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington) and the Sheepscot River (excluding Montsweag Bay), are displayed in Figure 14 (B and C) and Figure 15 (B and C), respectively. A comparison of the slopes of the length-weight curves for bloodworms and sandworms from eastern Maine and the Sheepscot River (Table 18) shows that, at 95% confidence limits (± 1.96 SE), no overlap occurs in the upper and lower range of b values for these data. Significant differences therefore exist in the length-weight relationships for both bloodworms and sandworms in eastern Maine and the Sheepscot River.

One possible explanation for the existence of these significant differences in length-weight relationships for bloodworms from eastern Maine and the Sheepscot River may be related to the fact that mature bloodworms are rare in eastern Maine. Bloodworms in this area may substitute an increase in weight for the production of gametes. No explanation can presently be given for the significant differences in length-weight relationships for sandworms in both areas.

The authors were unable to locate any other bloodworm length-weight relationships in the literature to compare with data presented here. A scatter diagram for sandworm length-weight relationships is presented in Snow and Marsden (1974), but a comparison is difficult because their results are not fully analyzed.

Numbers of Bloodworms and Sandworms Per Pound

Given the mean length data ($\pm$ SE) and length-wet weight relationships obtained from the commercial sampling program, we were able to calculate the numbers of bloodworms and sandworms per pound (± 1.96 SE) for each 6-mo sampling period as well as the maximum and minimum values for individual months within that sampling period. These data are presented in Table 19. Although the mean number of bloodworms per pound decreased during the 4-yr sampling period, the decrease was not significant at 95% confidence levels (± 1.96 SE). No significant changes were recorded in the numbers of sandworms per pound during the 4-yr sampling period either.

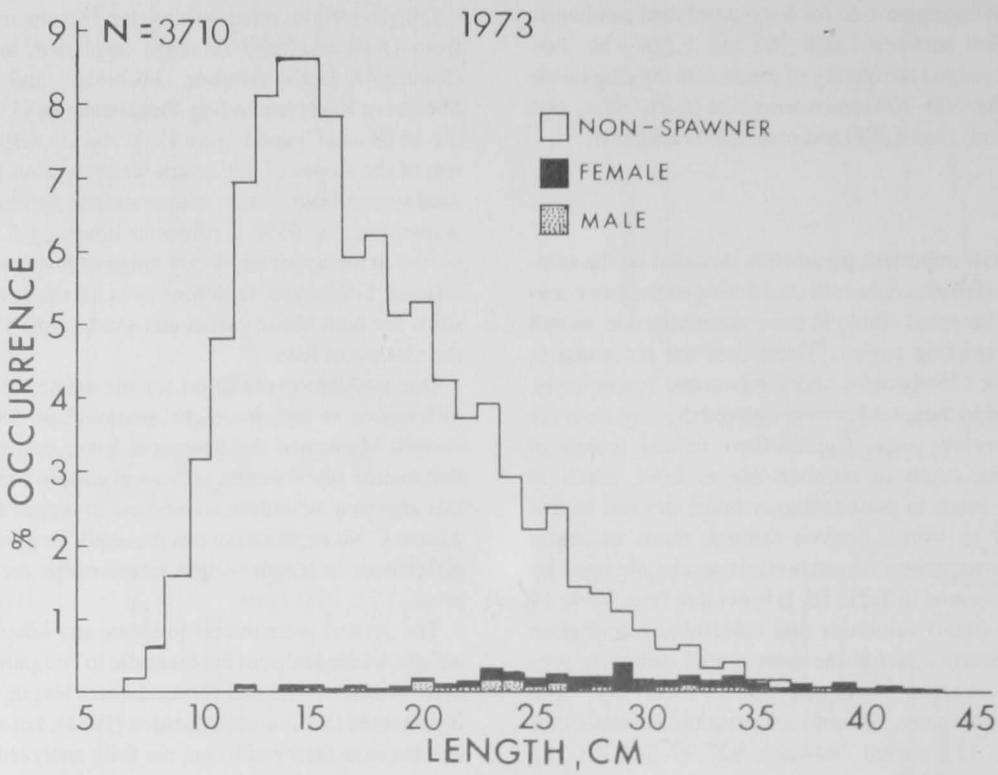
Past estimates of the numbers of bloodworms and sandworms per pound are presented in Table 20. Although some of these data (106 bloodworms/lb and 63 sandworms/lb) are biased in that they were obtained from a specific geographical area, the Sheepscot River (Walton[35]), they suggest that a progressive decrease occurred in size of both bloodworms and sandworms harvested prior to 1970. The 1950–52 figure of 44 bloodworms/lb (Cates and McKown[36]) may be questioned to some degree because a recent interview with one bloodworm dealer revealed that he supplied these port samplers with the largest bloodworms in his possession when asked for a representative bloodworm sample used in deriving this figure.

Estimates of Marine Worm Age

One of the most difficult problems encountered in our studies of the commercial baitworm fishery was the analysis of commercial

[35]C. J. Walton, Marine resources scientist, Maine Dep. Sea Shore Fish., West Boothbay Harbor, ME 04575, pers. commun. 1966, 1968.

[36]L. B. Cates, Port sampler, Maine Dep. Sea Shore Fish., Augusta, ME 04330, pers. commun. and D. A. McKown, Port sampler, National Marine Fisheries Service, NOAA, Rockland, ME 04841, pers. commun.



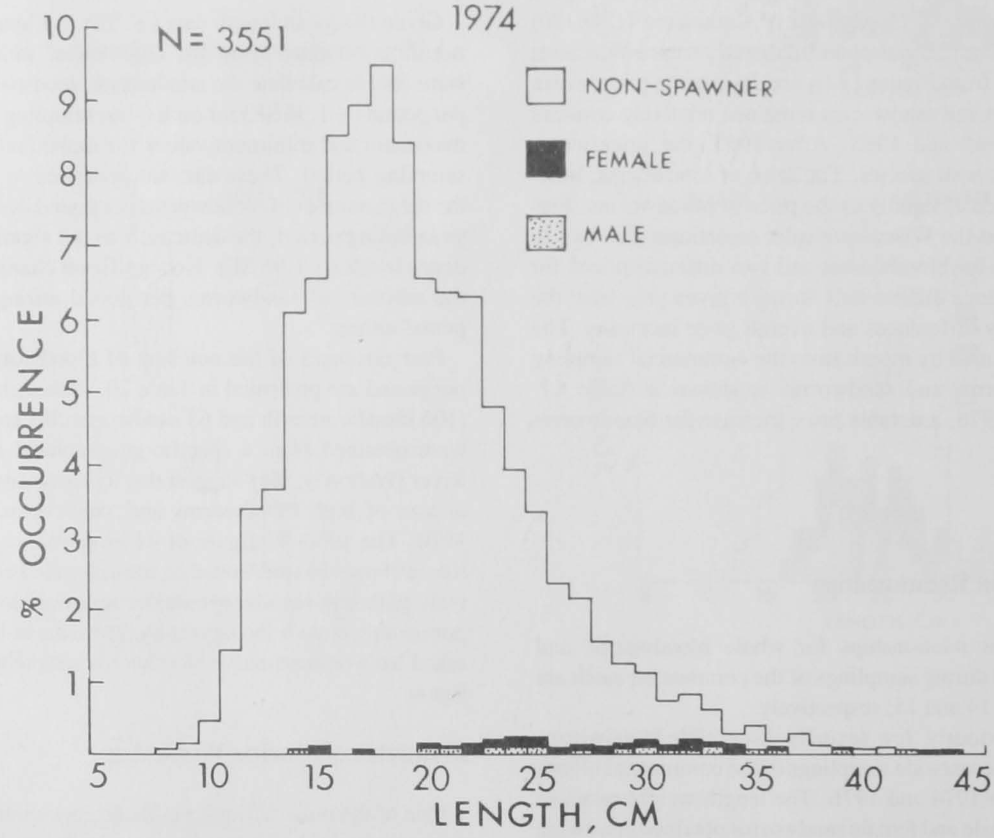
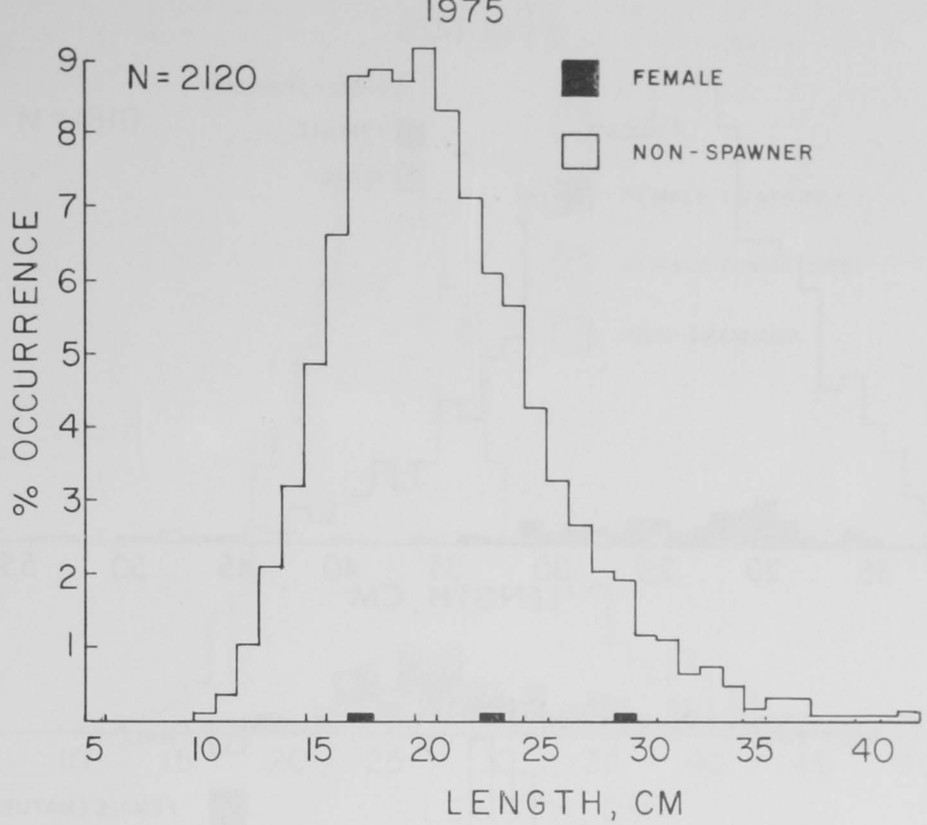
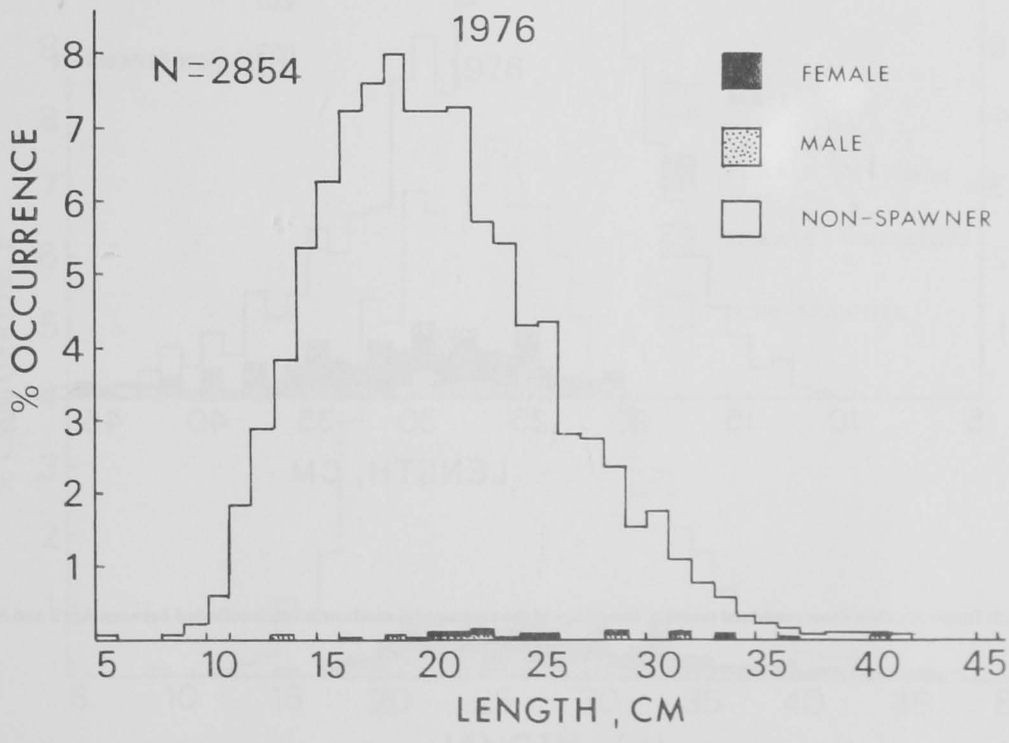


Figure 9.—Sexed length frequency data from combined monthly samplings of the commercial bloodworm catch collected between April and September of each year (1973–76).



1975
N = 2120
FEMALE
NON-SPAWNER
% OCCURRENCE
LENGTH, CM



1976
N=2854
FEMALE
MALE
NON-SPAWNER
% OCCURRENCE
LENGTH , CM

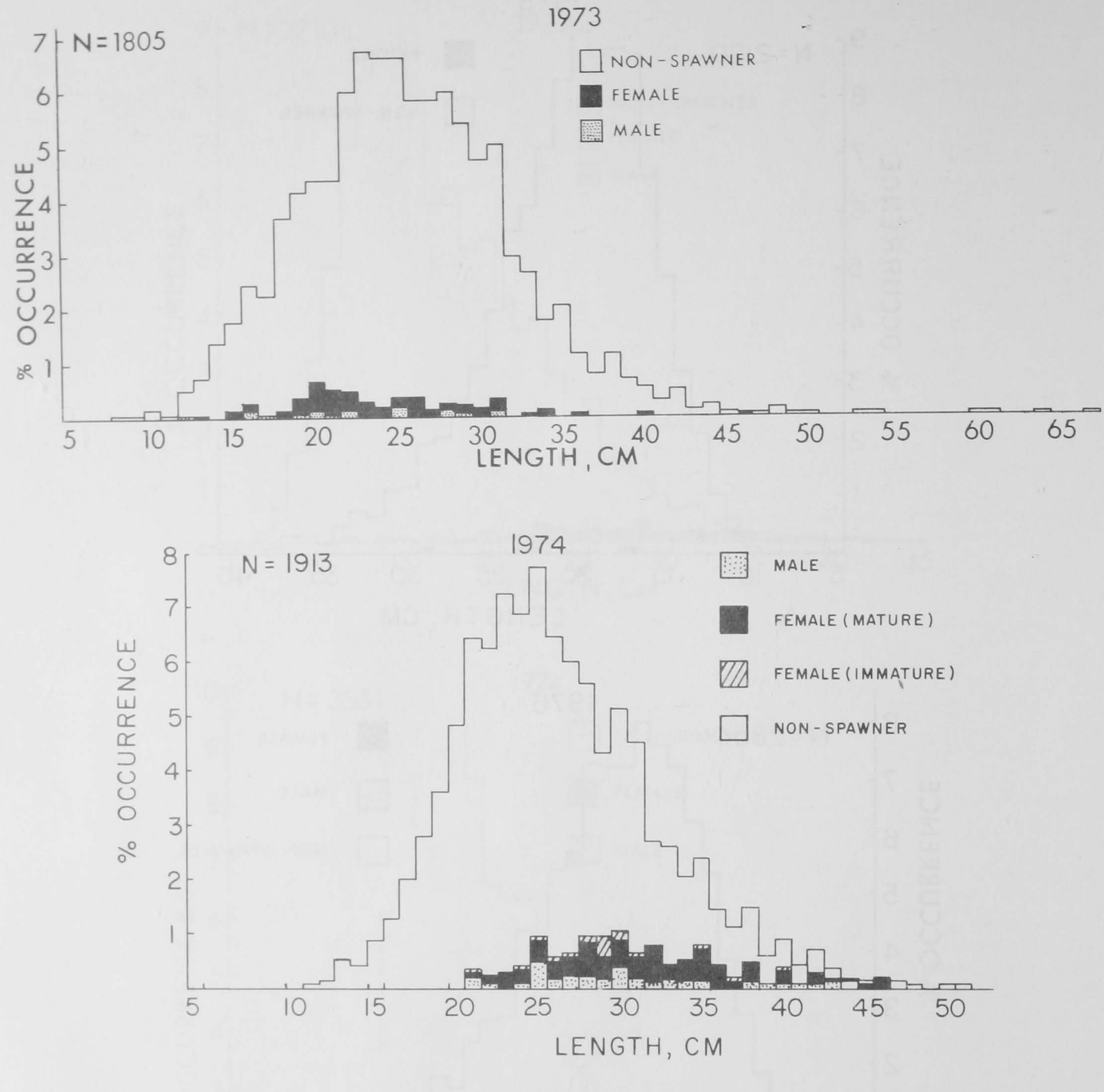
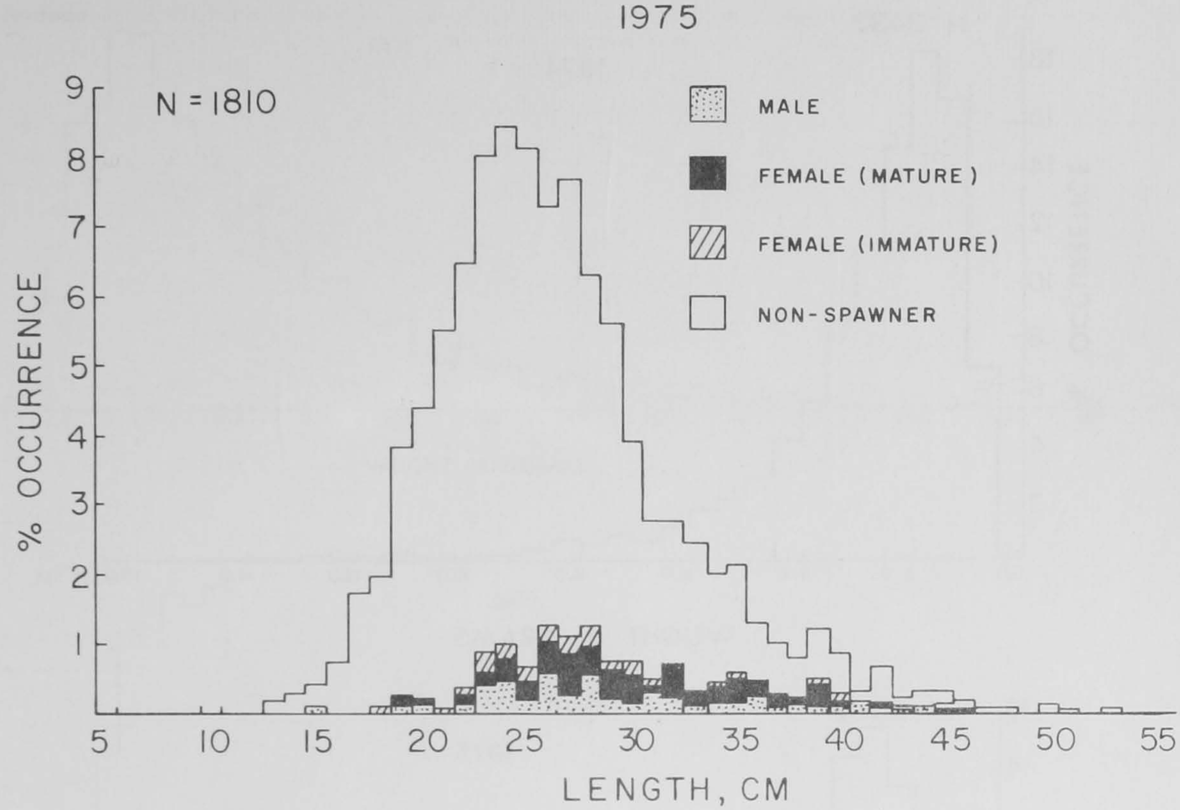
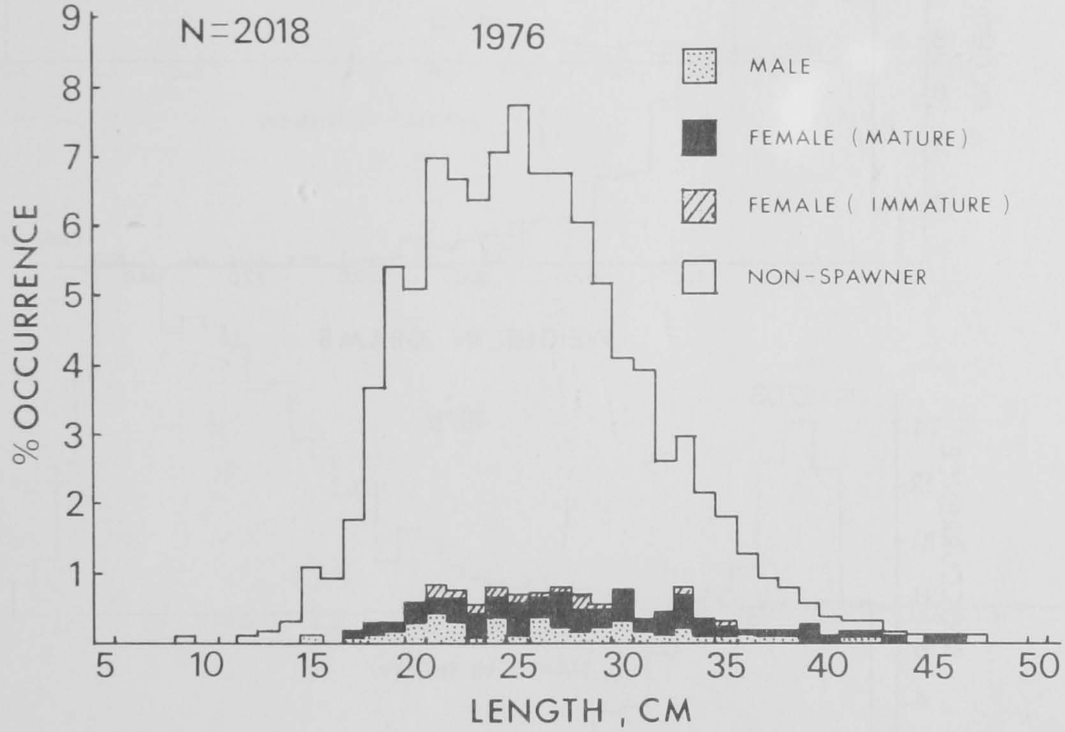


Figure 10.—Sexed length frequency data from combined monthly samplings of the commercial sandworm catch collected between April and September of each year (1973–76).


1975
N = 1810
MALE
FEMALE (MATURE)
FEMALE (IMMATURE)
NON-SPAWNER
% OCCURRENCE
LENGTH, CM


N=2018
1976
MALE
FEMALE (MATURE)
FEMALE (IMMATURE)
NON-SPAWNER
% OCCURRENCE
LENGTH , CM

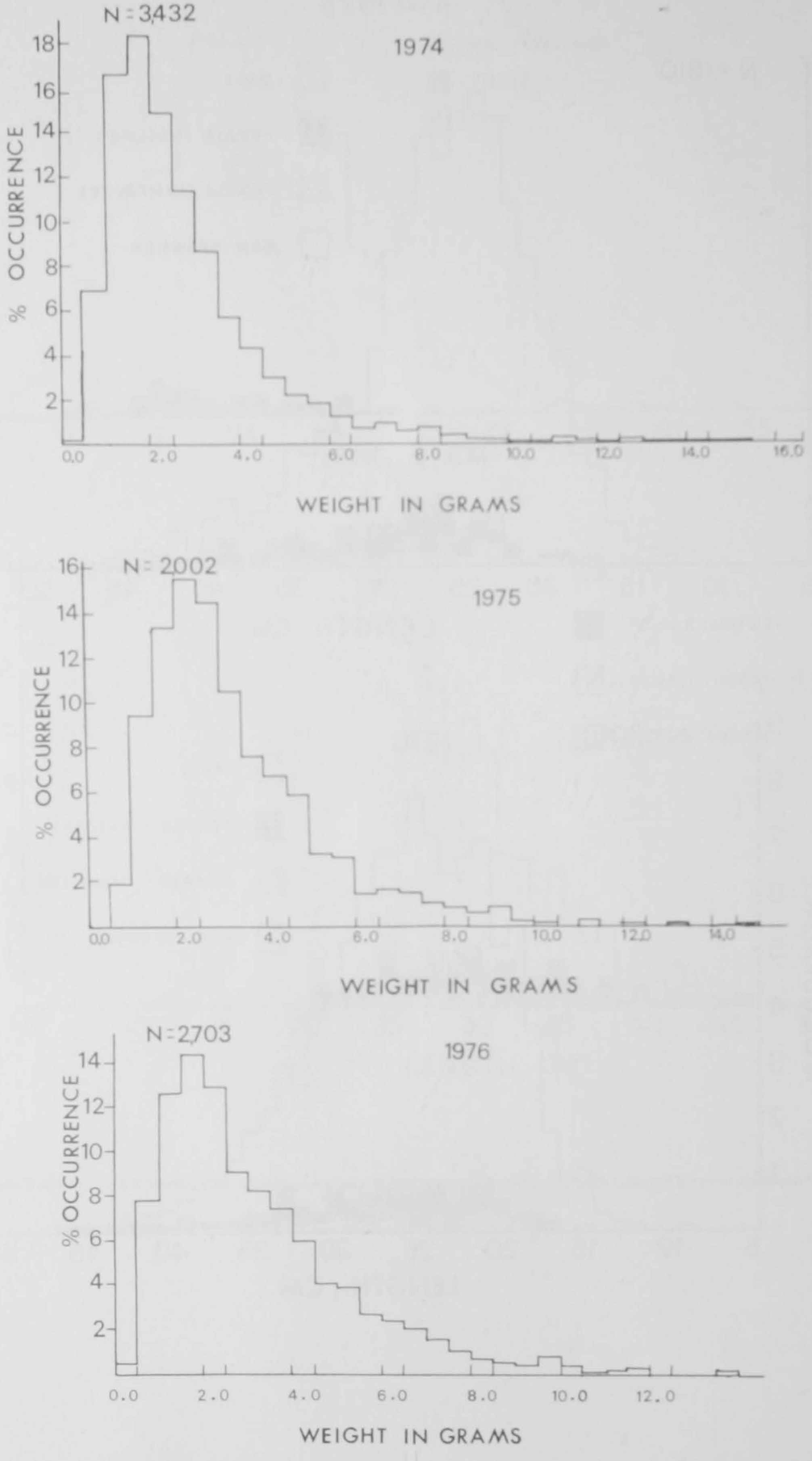


Figure 11.—Weight frequency data from combined monthly samplings of the commercial bloodworm catch collected during the period April–September of each year (1974–76).

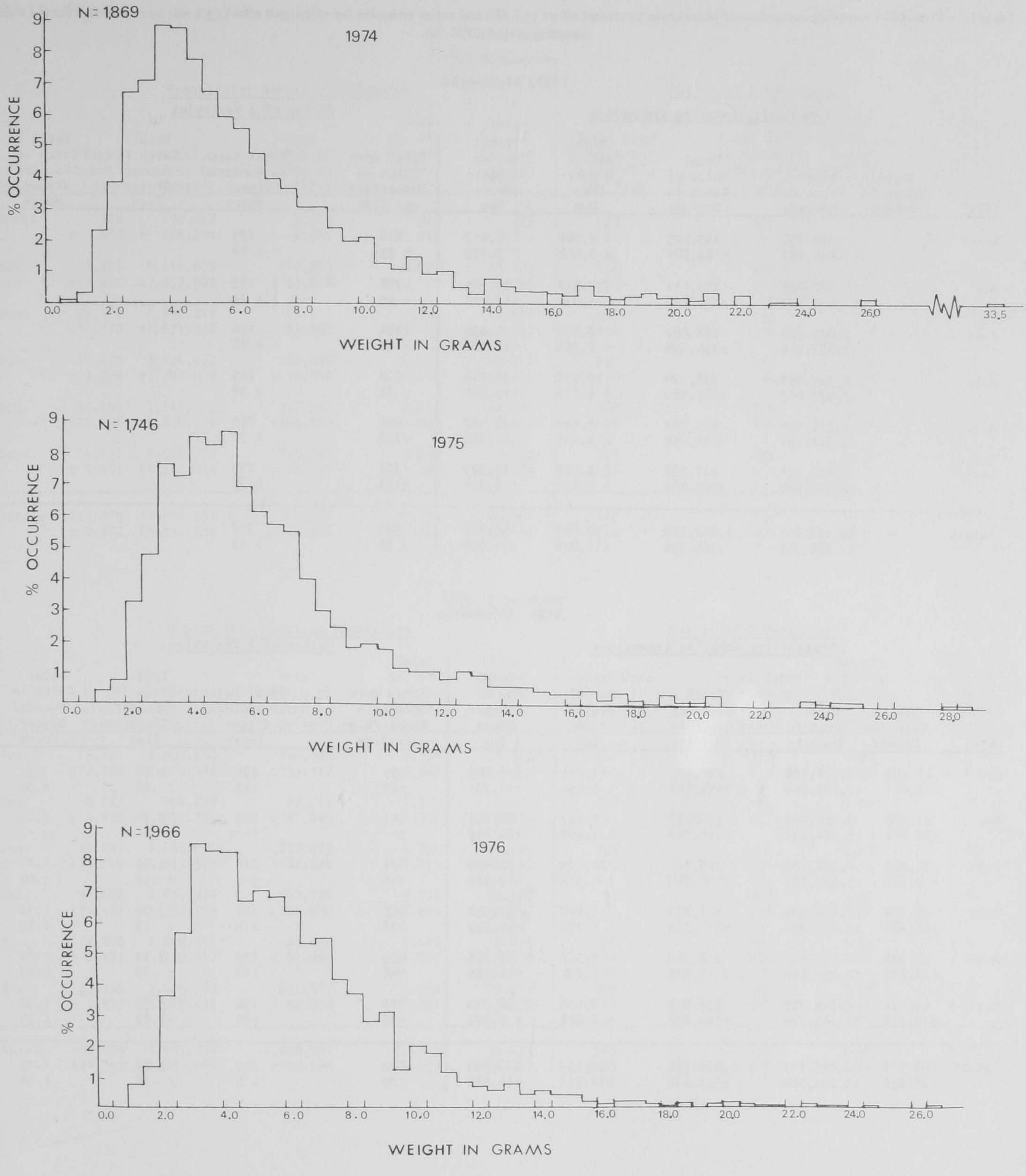


Figure 12.—Weight frequency data from combined monthly samplings of the commercial sandworm catch collected during the period April–September of each year (1974–76).

Table 12.—Probability sampling expansions of bloodworm catch and effort (±1 SE) and ratios estimates for catch/unit effort (±1 SE) by month and for the 6-mo sampling period (1973–76).

1973 Bloodworms

1973	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
	Probability Sampling Expansions					Ratios of 2 Variables			
April	-	3,034,896 ±1,335,169	145,073 ± 64,674	6,900 ± 2,958	16,617 ± 7,739	418 ± 23	173 ± 19	-	-
May	-	5,888,974 ±2,609,582	293,411 ±130,875	13,832 ± 5,870	39,385 ±17,295	388 ± 55	139 ± 21	-	-
June	-	5,800,704 ±3,883,544	288,597 ±194,539	10,374 ± 6,756	26,638 ±17,028	524 ± 48	196 ± 18	-	-
July	-	6,766,569 ±3,079,667	338,328 ±153,983	13,537 ± 5,219	31,710 ±12,540	516 ± 82	215 ± 38	-	-
Aug.	-	7,515,040 ±3,827,157	375,752 ±191,358	9,440 ± 4,141	23,320 ±11,384	666 ±128	251 ± 32	-	-
Sept.	-	4,431,768 ±2,039,640	221,588 ±101,982	5,808 ± 2,472	12,309 ± 5,574	737 ±153	299 ± 33	-	-
Totals	-	33,437,951 ±7,208,753	1,662,750 ±360,396	59,891 ±11,804	149,978 ±31,094	536 ± 36	210 ± 12	-	-

1974 Bloodworms

1974	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
	Probability Sampling Expansions					Ratios of 2 Variables			
April	26,303 ±12,841	5,778,108 ±2,693,900	288,905 ±134,695	11,214 ± 5,656	28,869 ±14,701	539 ±40	206 ±19	2.38 ± .08	.91 ±.03
May	27,388 ±25,251	6,165,533 ±5,684,341	308,277 ±284,217	8,127 ± 7,492	26,951 ±24,848	841 ±-	254 ±-	3.74 ± -	1.13 ± -
June	37,253 ±19,527	7,338,112 ±3,903,567	368,969 ±194,748	11,473 ± 5,378	32,439 ±17,320	571 ±40	216 ± 7	2.93 ± .19	1.11 ±.04
July	48,139 ±28,485	8,056,594 ±4,667,030	402,830 ±233,352	13,468 ± 8,158	37,550 ±22,942	605 ±28	218 ± 4	3.76 ± .13	1.36 ±.09
Aug.	27,323 ±14,675	4,362,800 ±2,250,516	218,140 ±112,526	9,360 ± 5,062	27,385 ±16,326	509 ±48	170 ±10	3.17 ± .30	1.06 ±.07
Sept.	40,171 ±10,725	5,744,270 ±1,745,874	309,865 ±104,836	8,698 ± 2,814	24,714 ± 9,372	718 ±98	256 ±20	5.32 ±1.23	1.90 ±.34
Totals	206,577 ±48,224	37,445,417 ±9,203,300	1,896,986 ±463,632	62,339 ±14,735	177,909 ±44,880	630 ±20	219 ± 5	3.53 ± .20	1.23 ±.06

Table 12.—*Continued.*

1975 Bloodworms

1975	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	926 ± 850	290,162 ± 266,271	9,313 ± 8,546	323 ± 296	775 ± 711	573 ± -	239 ±-	2.85 ± -	1.19 ±-
May	24,771 ±11,031	4,219,618 ±1,857,563	210,981 ± 92,878	5,023 ±2,197	15,773 ± 6,755	846 ± 59	259 ±17	4.95 ± .24	1.51 ±.07
June	23,377 ±11,577	3,692,213 ±1,671,937	184,611 ± 83,597	7,406 ±3,034	21,687 ± 9,702	508 ±100	179 ±26	3.07 ± .70	1.08 ±.14
July	24,879 ±17,089	3,824,562 ±2,704,017	188,430 ±135,840	6,027 ±4,318	17,728 ±12,475	607 ± 50	215 ±13	4.13 ± .50	1.46 ±.13
Aug.	37,491 ±20,104	5,141,273 ±2,880,779	257,064 ±144,039	8,736 ±5,004	25,538 ±14,475	689 ± 58	229 ±10	5.19 ± .66	1.73 ±.16
Sept.	16,171 ± 9,461	2,338,710 ±1,561,634	116,883 ± 78,075	3,031 ±1,978	8,190 ± 5,488	771 ± 51	290 ± 1	5.93 ±1.73	2.23 ±.79
Totals	127,615 ±32,282	19,506,537 ±4,936,204	967,281 ±246,948	30,545 ±7,865	89,691 ±23,142	662 ± 26	233 ± 6	4.30 ± .31	1.51 ±.12

1976 Bloodworms

1976	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	15,151 ±13,252	2,937,600 ±2,586,339	146,880 ±129,317	4,774 ±3,887	14,422 ±12,702	631 ±103	215 ± 1	3.26 ±.49	1.11 ±.02
May	6,127 ± 5,420	954,270 ± 832,799	47,714 ± 41,640	1,573 ±1,392	5,217 ± 4,615	548 ± -	181 ±-	3.56 ±-	1.17 ±-
June	21,217 ±13,218	4,685,850 ±3,313,372	257,429 ±182,326	6,880 ±4,710	23,052 ±16,547	759 ±125	234 ±14	3.68 ±.41	1.13 ±.24
July	31,656 ±12,647	4,831,974 ±1,992,739	267,706 ±108,930	9,828 ±3,686	27,030 ±10,837	455 ± 51	167 ±18	3.02 ±.28	1.11 ±.11
Aug.	12,010 ± 6,171	1,466,724 ± 748,547	83,035 ± 41,951	3,648 ±1,697	9,875 ± 4,838	458 ± 88	169 ±15	3.84 ±.64	1.41 ±.09
Sept.	23,775 ± 3,847	3,809,360 ±1,045,432	215,477 ± 60,033	6,347 ±1,721	19,634 ± 5,295	554 ± 41	189 ±14	3.74 ±.76	1.27 ±.26
Totals	109,936 ±24,343	18,685,778 ±4,897,488	1,018,241 ±262,544	33,049 ±7,659	99,230 ±25,007	567 ± 35	193 ± 6	3.50 ±.21	1.20 ±.07

Table 13.—Probability sampling expansions of sandworm catch and effort (±1 SE) and ratios estimates for catch/unit effort (±1 SE) by month and for the 6-mo sampling period (1973–76).

1973 Sandworms

1973	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	-	3,536,940	72,111	2,760	5,749	1,137	542	-	-
		±3,032,880	± 60,486	±2,231	±4,602	±173	± 97		
May	-	10,140,130	280,531	8,372	17,184	1,165	577	-	-
		±4,240,642	±116,073	±3,430	±7,216	±198	±120		
June	-	9,597,224	276,118	10,010	21,742	875	412	-	-
		±3,810,652	±111,477	±3,071	±7,162	±245	± 85		
July	-	4,516,131	124,195	3,241	5,545	1,482	863	-	-
		±1,266,239	± 34,822	±1,210	±2,056	±273	±112		
Aug.	-	4,590,400	126,600	4,960	9,517	930	506	-	-
		±2,574,932	± 70,722	±2,518	±5,125	±215	±131		
Sept.	-	2,565,420	78,271	2,244	6,267	1,102	404	-	-
		±1,971,590	± 54,344	±1,638	±5,003	± 67	± 48		
Totals	-	34,946,245	957,825	31,587	66,004	1,120	559	-	-
		±7,336,435	±196,789	±6,055	±13,418	± 88	± 43		

1974 Sandworms

1974	Probability Sampling Expansions					Ratios of 2 Variables			
	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
April	36,001	2,678,760	76,915	2,772	5,661	942	459	13.93	6.79
	±20,352	±1,441,976	±41,638	±1,411	±3,013	±139	±31	±4.14	±1.55
May	30,212	2,158,167	64,745	1,840	3,910	1,401	659	19.61	9.23
	±27,853	±1,989,731	±59,692	±1,696	±3,605	± -	±-	± -	± -
June	74,357	5,410,463	156,294	4,872	8,891	1,076	611	14.91	8.47
	±36,140	±2,704,834	±80,433	±2,186	±4,026	±262	±96	±3.75	±1.03
July	55,577	5,146,778	148,976	6,188	12,778	803	391	9.00	4.38
	±32,657	±3,068,389	±89,771	±3,623	±7,527	± 39	±16	±1.56	±1.15
Aug.	80,531	5,583,067	162,855	6,413	12,821	929	433	14.04	6.55
	±30,471	±1,877,012	±54,101	±2,328	±4,413	± 85	±59	±3.48	±1.78
Sept.	30,749	2,795,450	86,217	2,695	4,480	1,020	592	10.91	6.33
	±15,601	±1,416,962	±41,646	±1,217	±2,091	±167	±85	±1.82	±1.37
Totals	307,426	23,772,684	696,003	24,781	48,542	1,028	523	13.75	6.96
	±68,807	±5,319,814	±156,482	±5,448	±10,899	± 60	±24	±1.16	± .52

Table 13.—*Continued.*

1975 Sandworms

1975	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
	Probability Sampling Expansions					Ratios of 2 Variables			
April	22,126 ±13,695	1,036,292 ± 653,061	29,346 ± 18,193	1,830 ±1,190	2,441 ± 1,506	587 ± 39	421 ± 29	12.73 ±1.45	9.14 ± .19
May	153,137 ±83,385	12,051,848 ±6,578,737	346,453 ±189,807	9,471 ±4,702	19,222 ±10,568	1,279 ±335	692 ± 71	16.25 ±4.16	8.79 ± .90
June	50,171 ±32,697	4,198,075 ±2,704,852	118,728 ± 75,205	2,898 ±1,932	5,445 ± 3,384	1,506 ± 32	761 ±119	17.88 ± .12	9.03 ±1.66
July	64,853 ±46,772	6,227,183 ±4,554,999	171,249 ±125,262	5,597 ±3,955	11,332 ± 8,690	1,053 ± 89	545 ± 50	11.06 ± .64	5.73 ± .66
Aug.	26,593 ±11,237	2,251,568 ± 940,503	65,935 ± 27,781	2,457 ±1,134	4,903 ± 2,144	916 ±155	459 ± 45	11.18 ±1.99	5.60 ± .36
Sept.	18,194 ±14,700	1,007,903 ± 756,806	29,851 ± 22,714	1,150 ± 834	2,404 ± 1,847	877 ± 51	419 ± 16	15.83 ±2.82	7.57 ± .62
Totals	335,075 ±103,633	26,772,867 ±8,557,325	761,562 ±242,882	23,402 ±6,699	45,746 ±14,455	1,051 ± 67	558 ± 28	14.16 ± .93	7.65 ± .37

1976 Sandworms

1976	Total Catch in Pounds	Total Catch in Numbers	Total Value of Catch in Dollars	Total No. of Digger-Tides Dug	Total No. of Digger-Hours Dug	Total Worm Catch in Number/Digger Tide	Total Catch in Numbers/Digger Hours	Total Catch in Pounds/Digger Tide	Total Catch in Pounds/Digger Hours
	Probability Sampling Expansions					Ratios of 2 Variables			
April	8,315 ± 7,716	615,672 ± 571,319	18,470 ± 17,140	734 ± 681	1,102 ±1,022	838 ± -	559 ± -	11.32 ± -	7.55 ± -
May	61,223 ±31,447	4,167,900 ±2,168,487	116,970 ± 59,382	3,600 ±1,674	7,161 ±2,714	1,126 ±153	533 ±109	16.60 ±2.39	7.85 ±1.52
June	65,004 ±54,839	4,441,554 ±3,634,273	135,375 ±110,857	3,229 ±2,699	5,654 ±4,651	1,469 ± 75	822 ± 2	20.72 ± .99	11.59 ±1.17
July	192,101 ±77,777	15,169,140 ±5,933,135	474,884 ±180,290	10,458 ±3,949	23,247 ±8,611	1,384 ± 95	614 ± 68	17.13 ±1.03	7.61 ± .87
Aug.	20,577 ±12,158	1,423,860 ± 826,382	46,276 ± 26,863	1,596 ± 940	3,819 ±2,253	881 ±136	368 ± 59	12.76 ±3.96	5.33 ±1.69
Sept.	61,970 ±25,811	6,318,333 ±2,613,942	194,715 ± 80,676	4,533 ±1,869	9,834 ±4,127	1,356 ± 41	626 ± 40	13.56 ±2.87	6.26 ±1.67
Totals	409,189 ±104,494	32,136,459 ±7,807,329	986,690 ±236,314	24,151 ±5,525	50,817 ±11,239	1,184 ± 38	592 ± 22	15.40 ± .92	7.73 ± .52

Table 14.—A monthly and 6 mo combined summary of bloodworm catch statistics data collected between 1973 and 1976.

CATCH STATISTICS (SUMMARY) 1973 BLOODWORMS

	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	56244.78	71862.53	56002.77	60927.36	59383.68	67803.83	372224.95
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	20773	32005	31426	35489	46193	33574	199460
3 TOTAL VALUE OF CATCH ($)	1038.65	1612.15	1571.30	1774.45	2309.65	1678.70	9984.90
4 TOTAL No. MALES IN SAMPLES	62	0	-	-	-	-	62
5 TOTAL No. FEMALES IN SAMPLES	89	0	-	-	-	-	89
6 TOTAL No. DIGGER TIDES	50	76	57	71	59	44	357
7 TOTAL No. DIGGER HOURS	124.81	219.13	146.36	166.31	157.89	93.25	907.75
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.71	2.25	1.78	1.72	1.29	2.02	1.87
9 CATCH IN Nos/DIGGER TIDE	415	421	551	500	783	763	559
10 CATCH IN gms/DIGGER TIDE	1124.90	945.56	982.50	858.13	1006.50	1541.00	1042.65
11 CATCH IN LBs/DIGGER TIDE	2.48	2.08	2.17	1.89	2.22	3.40	2.30
12 CATCH IN Nos/DIGGER HOUR	166	146	215	213	293	360	220
13 CATCH IN gms/DIGGER HOUR	450.64	327.94	382.64	366.35	376.11	727.12	410.05
14 CATCH IN LBs/DIGGER HOUR	.99	.73	.84	.81	.83	1.60	.90
15 VALUE/DIGGER TIDE ($)	20.77	21.21	27.57	24.99	39.15	38.15	27.97
16 VALUE/DIGGER HOUR ($)	8.32	7.36	10.74	10.67	14.63	18.00	11.00
17 VALUE/gm ($)	.01847	.02243	.02806	.02912	.03889	.02476	.02682
18 VALUE/LB ($)	8.38	10.18	12.73	13.21	17.64	11.23	12.17

CATCH STATISTICS (SUMMARY) 1974 BLOODWORMS

	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	92664.20	80986.92	106138.27	117692.78	70191.48	145725.60	613399.25
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	44165	40200	42025	42345	24670	46017	239422
3 TOTAL VALUE OF CATCH ($)	2208.25	2010.00	2326.03	2117.25	1233.50	2484.51	12379.54
4 TOTAL No. MALES IN SAMPLES	39	0	-	-	-	-	39
5 TOTAL No. FEMALES IN SAMPLES	53	8	-	-	-	-	61
6 TOTAL No. DIGGER TIDES	89	53	73	74	54	71	414
7 TOTAL No. DIGGER HOURS	229.12	175.77	206.40	206.32	157.99	201.75	1177.35
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.10	2.01	2.53	2.78	2.85	3.17	2.56
9 CATCH IN Nos/DIGGER TIDE	496	758	576	572	457	648	578
10 CATCH IN gms/DIGGER TIDE	1041.17	1528.06	1453.95	1590.44	1299.84	2052.47	1481.64
11 CATCH IN LBs/DIGGER TIDE	2.30	3.37	3.21	3.51	2.87	4.53	3.27
12 CATCH IN Nos/DIGGER HOUR	193	229	204	205	156	228	203
13 CATCH IN gms/DIGGER HOUR	404.44	460.76	514.24	570.44	444.28	722.31	521.00
14 CATCH IN LBs/DIGGER HOUR	.89	1.02	1.13	1.26	.98	1.59	1.15
15 VALUE/DIGGER TIDE ($)	24.81	37.92	31.86	28.61	22.84	34.99	29.90
16 VALUE/DIGGER HOUR ($)	9.64	11.44	11.27	10.26	7.81	12.31	10.51
17 VALUE/gm ($)	.02383	.02482	.02192	.01799	.01757	.01705	.02018
18 VALUE/LB ($)	10.81	11.26	9.94	8.16	7.97	7.73	9.15

Table 14.—*Continued.*

CATCH STATISTICS (SUMMARY) 1975 BLOODWORMS	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	3,900.65	77,739.65	64,811.70	75,920.11	125,309.41	70,181.84	417,863.36
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	1,730	28,815	22,583	25,215	37,665	22,370	138,378
3 TOTAL VALUE OF CATCH ($)	86.50	1,440.75	1,129.15	1,260.75	1,883.25	1,118.50	6,918.90
4 TOTAL No. MALES IN SAMPLES	0	0	-	-	-	-	0
5 TOTAL No. FEMALES IN SAMPLES	0	3	-	-	-	-	3
6 TOTAL No. DIGGER TIDES	3	35	46	42	64	29	219
7 TOTAL No. DIGGER HOURS	7.20	109.92	134.70	123.54	187.09	78.37	640.82
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.25	2.70	2.87	3.01	3.33	3.14	3.02
9 CATCH IN Nos/DIGGER TIDE	577	823	491	600	589	771	632
10 CATCH IN gms/DIGGER TIDE	1,300.22	2,221.13	1,408.95	1,807.62	1,957.96	2,420.06	1,908.05
11 CATCH IN LBs/DIGGER TIDE	2.87	4.90	3.11	3.99	4.32	5.34	4.21
12 CATCH IN Nos/DIGGER HOUR	240	262	168	204	201	285	216
13 CATCH IN gms/DIGGER HOUR	541.76	707.24	481.16	614.54	669.78	895.52	652.08
14 CATCH IN LBs/DIGGER HOUR	1.19	1.56	1.06	1.36	1.48	1.97	1.44
15 VALUE/DIGGER TIDE ($)	28.83	41.16	24.55	30.02	29.43	38.57	31.59
16 VALUE/DIGGER HOUR ($)	12.01	13.11	8.38	10.21	10.07	14.27	10.80
17 VALUE/gm ($)	.02218	.01853	.01742	.01661	.01503	.01594	.01656
18 VALUE/LB ($)	10.06	8.41	7.90	7.53	6.82	7.23	7.51

CATCH STATISTICS (SUMMARY) 1976 BLOODWORMS	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	56,133.81	33,559.78	68,535.90	111,930.92	47,779.81	93,999.79	411,940.01
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	24,000	11,400	33,337	37,727	12,546	33,310	152,320
3 TOTAL VALUE OF CATCH ($)	1,200.00	570.00	1833.54	2088.98	709.18	1,384.58	8286.28
4 TOTAL No. MALES IN SAMPLES	17	0	-	-	-	-	17
5 TOTAL No. FEMALES IN SAMPLES	27	0	-	-	-	-	27
6 TOTAL No. DIGGER TIDES	39	18	49	78	32	56	272
7 TOTAL No. DIGGER HOURS	117.83	63.01	164.19	214.52	86.62	173.23	819.40
8 MEAN WEIGHT OF WORMS IN SAMPLES	2.34	2.94	2.06	2.97	3.81	2.82	2.70
9 CATCH IN Nos/DIGGER TIDE	615	633	680	484	392	595	560
10 CATCH IN gms/DIGGER TIDE	1,439.33	1,864.43	1,398.69	1,435.01	1,493.12	1,678.57	1,514.49
11 CATCH IN LBs/DIGGER TIDE	3.17	4.11	3.08	3.16	3.29	3.70	3.34
12 CATCH IN Nos/DIGGER HOUR	204	181	203	176	145	192	186
13 CATCH IN gms/DIGGER HOUR	476.40	532.61	417.42	521.77	551.60	542.63	502.73
14 CATCH IN LBs/DIGGER HOUR	1.05	1.17	.92	1.15	1.22	1.20	1.11
15 VALUE/DIGGER TIDE ($)	30.77	31.67	37.42	26.78	22.16	33.65	30.46
16 VALUE/DIGGER HOUR ($)	10.18	9.05	11.17	9.74	8.19	10.88	10.11
17 VALUE/gm ($)	.02138	.01698	.02675	.01866	.01484	.02005	.02012
18 VALUE/LB ($)	9.70	7.70	12.13	8.47	6.73	9.09	9.12

Table 15.—A monthly and 6 mo combined summary of sandworm catch statistics data collected between 1973 and 1976.

CATCH STATISTICS (SUMMARY) 1973 SANDWORMS

	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	199029.92	470638.60	413145.72	130278.11	153122.73	71393.75	1437608.83
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	25630	55715	52732	23686	28690	19435	205888
3 TOTAL VALUE OF CATCH ($)	522.54	1541.37	1517.13	651.37	791.25	592.96	5616.62
4 TOTAL No. MALES IN SAMPLES	-	-	-	-	11	24	35
5 TOTAL No. FEMALES IN SAMPLES	-	-	-	-	84	31	115
6 TOTAL No. DIGGER TIDES	20	46	55	17	31	17	186
7 TOTAL No. DIGGER HOURS	41.66	94.42	119.46	29.08	59.48	47.48	391.58
8 MEAN WEIGHT OF WORMS IN SAMPLES	7.77	8.45	7.83	5.50	5.34	3.67	6.98
9 CATCH IN Nos/DIGGER TIDE	1282	1211	959	1393	925	1143	1107
10 CATCH IN gms/DIGGER TIDE	9951.50	10231.27	7511.74	7663.42	4939.44	4199.63	7729.08
11 CATCH IN LBs/DIGGER TIDE	21.94	22.56	16.56	16.90	10.89	9.26	17.04
12 CATCH IN Nos/DIGGER HOUR	615	590	441	815	482	409	526
13 CATCH IN gms/DIGGER HOUR	4777.48	4984.52	3458.44	4479.99	2574.36	1503.66	3671.30
14 CATCH IN LBs/DIGGER HOUR	10.53	10.99	7.63	9.88	5.68	3.32	8.10
15 VALUE/DIGGER TIDE ($)	26.13	33.51	27.58	38.32	25.52	34.88	30.20
16 VALUE/DIGGER HOUR ($)	12.54	16.32	12.70	22.40	13.30	12.49	14.34
17 VALUE/gm ($)	.00263	.00328	.00367	.00500	.00517	.00831	.00391
18 VALUE/LB ($)	1.19	1.49	1.67	2.27	2.34	3.77	1.77

CATCH STATISTICS (SUMMARY) 1974 SANDWORMS

	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	120,939.09	89,356.40	214,561.20	136,734.33	210,701.94	113,838.62	886,131.58
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	19385	14,075	34,425	27,834	32,210	22,820	150,749
3 TOTAL VALUE OF CATCH ($)	554.19	422.25	994.45	805.20	939.55	703.81	4419.45
4 TOTAL No. MALES IN SAMPLES	-	-	-	-	49	21	70
5 TOTAL No. FEMALES IN SAMPLES	-	-	-	-	155 (221)	22 (91)	177 (311)
6 TOTAL No. DIGGER TIDES	22	12	31	34	37	22	158
7 TOTAL No. DIGGER HOURS	44.93	25.50	56.57	70.21	73.97	36.57	307.75
8 MEAN WEIGHT OF WORMS IN SAMPLES	6.24	6.35	6.23	4.91	6.54	4.99	5.88
9 CATCH IN Nos/DIGGER TIDE	881	1,173	1,110	819	871	1,037	954
10 CATCH IN gms/DIGGER TIDE	5,497.23	3,504.17	6,921.33	4,021.60	5,694.65	5,174.48	5,608.43
11 CATCH IN LBs/DIGGER TIDE	12.12	7.73	15.26	8.87	12.56	11.41	12.37
12 CATCH IN Nos/DIGGER HOUR	431	552	609	396	435	624	490
13 CATCH IN gms/DIGGER HOUR	2,691.72	3,504.17	3,792.84	1,947.51	2,848.48	3,112.90	2,879.39
14 CATCH IN LBs/DIGGER HOUR	5.94	7.73	8.36	4.29	6.28	6.86	6.35
15 VALUE/DIGGER TIDE ($)	25.19	35.19	32.08	23.68	25.39	31.99	27.97
16 VALUE/DIGGER HOUR ($)	12.33	16.56	17.58	11.47	12.70	19.25	14.36
17 VALUE/gm ($)	.00458	.00473	.00463	.00589	.00446	.00618	.00499
18 VALUE/LB ($)	2.08	2.14	2.10	2.67	2.02	2.80	2.26

Table 15.—*Continued.*

CATCH STATISTICS (SUMMARY)		1975 SANDWORMS					
	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	93,198.89	483,966.67	141,303.33	204,965.15	90,843.24	78,963.80	1,093,241.08
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	9,625	83,985	26,075	43,395	16,495	9,645	189,220
3 TOTAL VALUE OF CATCH ($)	272.56	2,414.31	737.44	1,193.37	483.04	285.66	5,386.38
4 TOTAL No. MALES IN SAMPLES	-		-	-	66	43	109
5 TOTAL No. FEMALES IN SAMPLES	-	-		-	97 (17 I)	46 (7 I)	143 (24 I)
6 TOTAL No. DIGGER TIDES	17	66	18	39	18	11	169
7 TOTAL No. DIGGER HOURS	22.66	133.95	33.82	78.97	35.92	23.00	328.32
8 MEAN WEIGHT OF WORMS IN SAMPLES	9.68	5.76	5.42	4.72	5.51	8.19	5.78
9 CATCH IN Nos/DIGGER TIDE	566	1,272	1449	1,113	916	877	1,120
10 CATCH IN gms/DIGGER TIDE	5,482.29	7,332.83	7,850.18	5,255.52	5,046.85	7,178.53	6,468.88
11 CATCH IN LBs/DIGGER TIDE	12.09	16.17	17.31	11.59	11.13	15.83	14.26
12 CATCH IN Nos/DIGGER HOUR	425	627	771	550	459	419	576
13 CATCH IN gms/DIGGER HOUR	4,112.93	3,613.04	4,178.10	2,595.48	2,529.04	3,433.21	3,329.80
14 CATCH IN LBs/DIGGER HOUR	9.07	7.97	9.21	5.72	5.58	7.57	7.34
15 VALUE/DIGGER TIDE ($)	16.03	36.58	40.97	30.60	26.84	25.97	31.87
16 VALUE/DIGGER HOUR ($)	12.03	18.02	21.80	15.11	13.45	12.42	16.41
17 VALUE/gm ($)	.00292	.00499	.00522	.00582	.00532	.00362	.00493
18 VALUE/LB ($)	1.33	2.26	2.37	2.64	2.41	1.64	2.23

CATCH STATISTICS (SUMMARY)		1976 SANDWORMS					
	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL
1 TOTAL CATCH IN GRAMS (gms)	30,806.69	308,507.92	209,975.38	691,435.47	81,032.30	247,976.91	1,569,734.67
2 TOTAL ACCEPTED CATCH IN NUMBERS (nos)	5,030	46,310	31,635	120,390	12,340	55,750	271,455
3 TOTAL VALUE OF CATCH ($)	150.90	1,299.67	964.21	3,768.92	400.98	1,718.07	8,302.75
4 TOTAL No. MALES IN SAMPLES	-	-	-	-	34	74	108
5 TOTAL No. FEMALES IN SAMPLES	-	-	-	-	69 (14 I)	91 (20 I)	160 (34 I)
6 TOTAL No. DIGGER TIDES	6	40	23	83	14	40	206
7 TOTAL No. DIGGER HOURS	9.00	79.57	40.27	184.50	33.50	86.77	433.61
8 MEAN WEIGHT OF WORMS IN SAMPLES	6.12	6.66	6.64	5.74	6.57	4.45	5.78
9 CATCH IN Nos/DIGGER TIDE	838	1,158	1,375	1,450	881	1,394	1,318
10 CATCH IN gms/DIGGER TIDE	5,134.45	7,712.70	9,129.36	8,330.55	5,788.02	6,199.42	7,620.07
11 CATCH IN LBs/DIGGER TIDE	11.32	17.01	20.13	18.37	12.76	13.67	16.80
12 CATCH IN Nos/DIGGER HOUR	559	582	786	653	368	643	626
13 CATCH IN gms/DIGGER HOUR	3,422.97	3,877.19	5,214.19	3,747.62	2,418.87	2,857.86	3,620.15
14 CATCH IN LBs/DIGGER HOUR	7.55	8.55	11.50	8.26	5.33	6.30	7.98
15 VALUE/DIGGER TIDE ($)	25.15	32.49	41.92	45.41	28.64	42.95	40.30
16 VALUE/DIGGER HOUR ($)	16.77	16.33	23.94	20.43	11.97	19.80	19.15
17 VALUE/gm ($)	.00490	.00421	.00459	.00545	.00495	.00693	.00529
18 VALUE/LB ($)	2.22	1.91	2.08	2.47	2.24	3.14	2.40

Table 16.—A comparison of catch/effort data obtained directly from the sampling and interview data and from ratio estimates.

	1973		1974		1975		1976	
	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)	Sampling and interview	Ratio estimate (±1 SE)
				Bloodworms				
Catch in no./digger tide	559	536±36	578	630±20	632	662±26	560	567±35
Catch in no./digger hour	220	210±12	203	219±5	216	233±6	186	193± 6
Catch in lb./digger tide	2.30		3.27	3.53±0.20	4.21	4.30±0.31	3.34	3.50±0.21
Catch in lb./digger hour	0.90		1.15	1.23±0.06	1.44	1.51±0.12	1.11	1.20±0.07
				Sandworms				
Catch in no./digger tide	1,107	1,120±88	954	1,028±60	1,120	1,051±67	1,318	1,184±38
Catch in no./digger hour	526	559±43	490	523±24	576	558±28	626	592±22
Catch in lb./digger tide	17.04		12.37	13.75±1.16	14.26	14.16±0.93	16.80	15.40±0.92
Catch in lb./digger hour	8.10		6.35	6.96±0.52	7.34	7.65±0.37	7.98	7.73±0.52

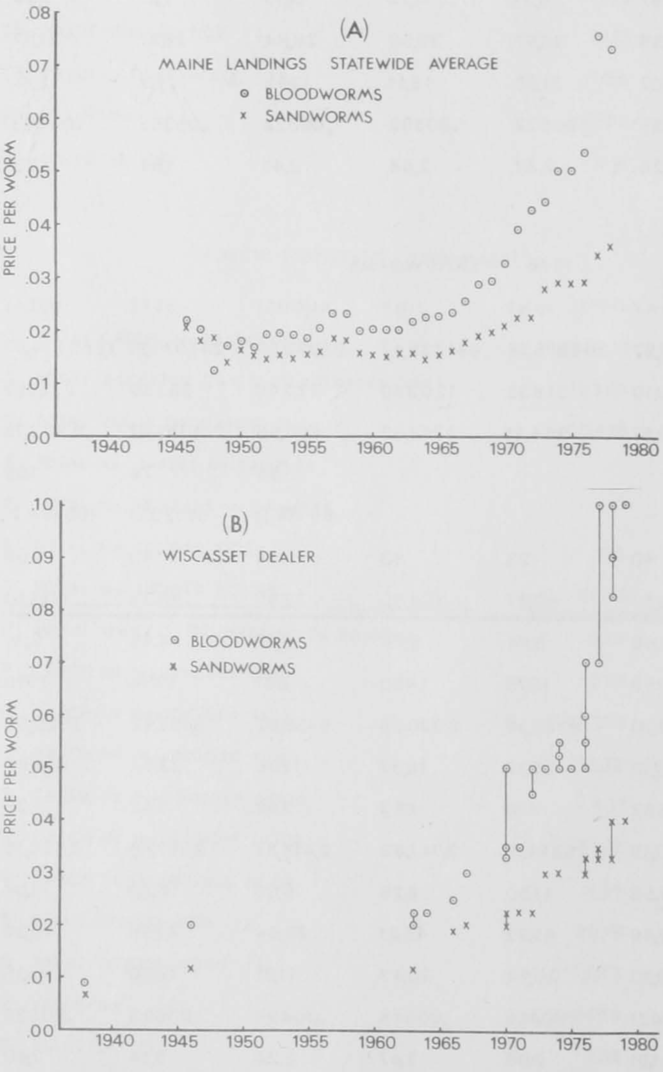


Figure 13.—The price/worm paid to bloodworm and sandworm diggers. (A) Price/worm information derived from Maine Landings estimates of landed value and pounds landed (converted to numbers landed). (B) Price/worm information recorded by a Wiscasset marine worm dealer.

Table 17.—The price/worm recorded by month during the commercial sampling program for bloodworms and sandworms (1973–76).

	1973		1974		1975		1976	
	Bloods	Sands	Bloods	Sands	Bloods	Sands	Bloods	Sands
April	$0.050	$0.024	$0.050	$0.028	$0.050	$0.029	$0.050	$0.030
May	.050	.028	.050	.030	.050	.029	.050	.029
June	.050	.029	.051	.028	.050	.029	.055	.030
July	.050	.028	.050	.029	.050	.028	.060	.032
August	.050	.028	.050	.029	.050	.029	.057	.032
Sept.	.050	.028	.052	.032	.050	.029	.056	.031

sampling data for age. The method of Cassie (1950) was applied in deriving estimates of the number of assumed year-class modes from the length-frequency data presented in Figures 9 and 10, respectively. The results of these analyses have been presented elsewhere (Creaser[37]). However, year-class modes are not obvious in these lumped length-frequency data, probably because worm growth varies between flats, worm growth occurs throughout the 6-mo commercial sampling period, and there is considerable overlap in length at age. The reliability of the age estimates presented in Creaser (footnote 37) are therefore questionable until the data can be verified against other aging techniques. Estimates of natural and fishing mortality, growth, and yield in weight per recruit are not included in this manuscript because of the problems inherent in the age analysis of the length-frequency data from which these estimates are derived.

Yield-Effort Curves

Fisheries can be managed through size restrictions, a reduction in fishing (digging) mortality, or a combination of both methods. Sufficient data presently exist to explore two means of limiting digging mortality: limited entry and quotas.

[37]Creaser, E. P., Jr. 1978. Marine worm research. Completion report. Maine Dep. Mar. Resour., Augusta, 226 p.

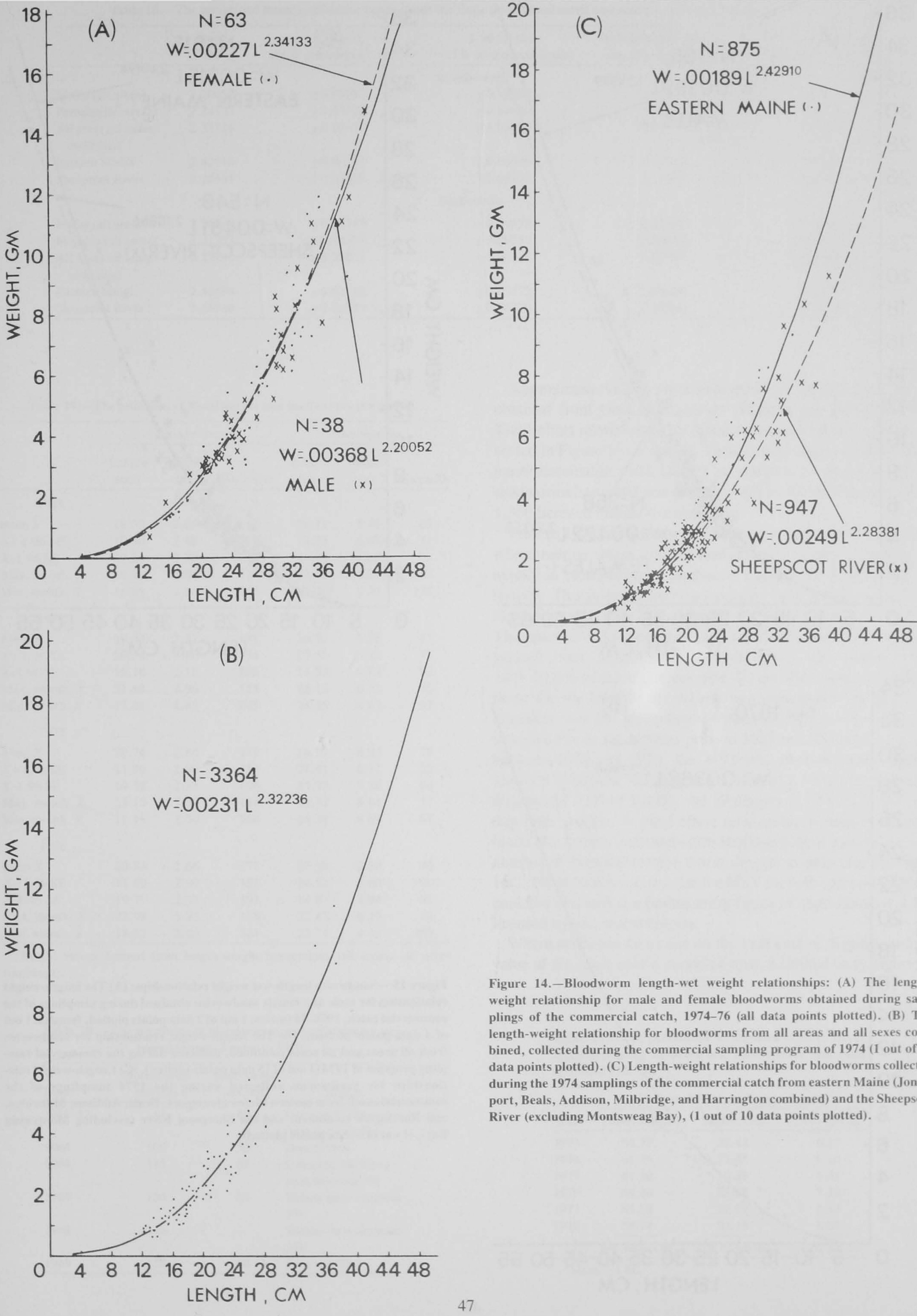
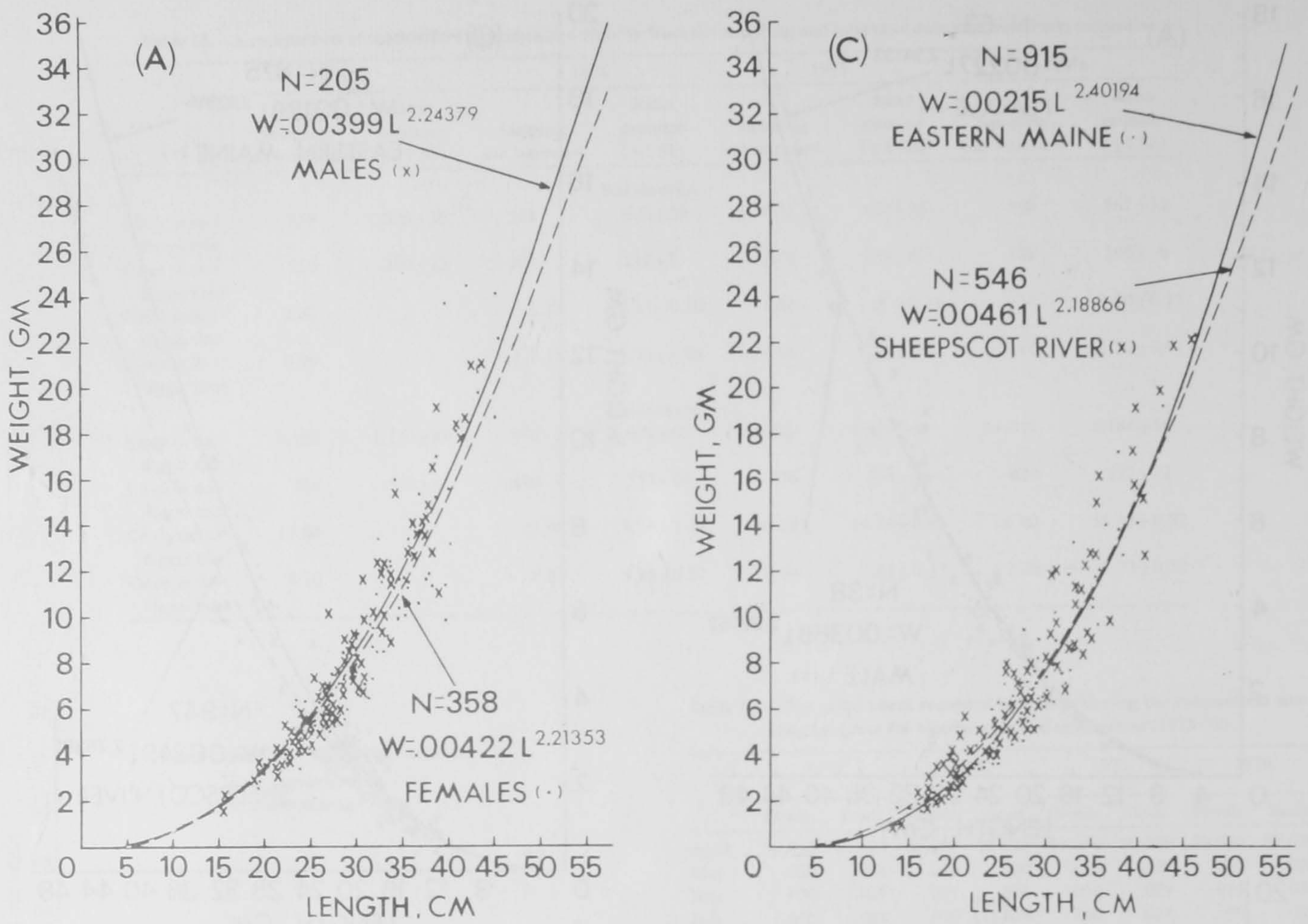


Figure 14.—Bloodworm length-wet weight relationships: (A) The length-weight relationship for male and female bloodworms obtained during samplings of the commercial catch, 1974–76 (all data points plotted). (B) The length-weight relationship for bloodworms from all areas and all sexes combined, collected during the commercial sampling program of 1974 (1 out of 30 data points plotted). (C) Length-weight relationships for bloodworms collected during the 1974 samplings of the commercial catch from eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington combined) and the Sheepscot River (excluding Montsweag Bay), (1 out of 10 data points plotted).



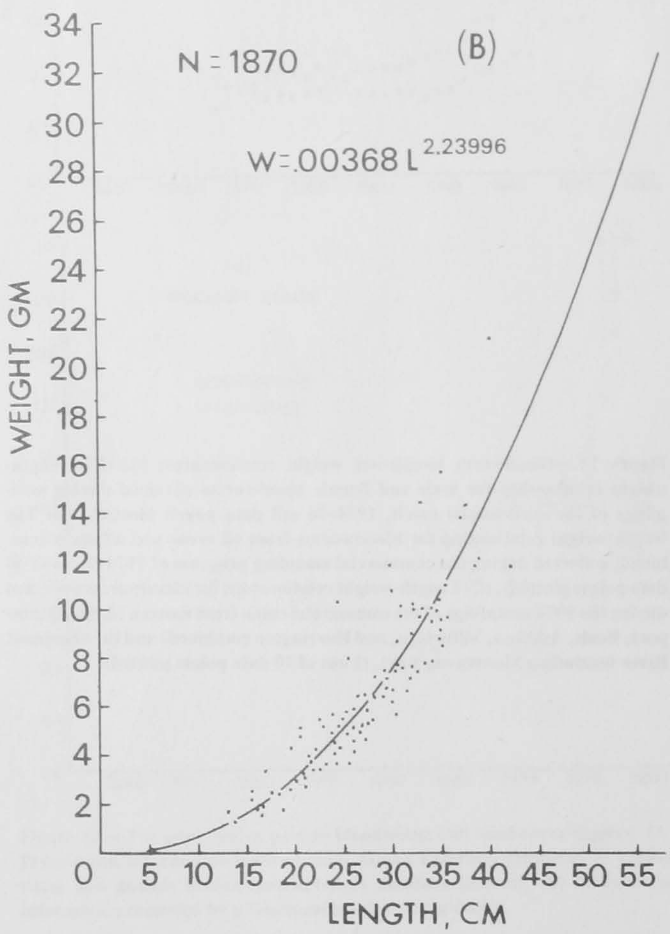


Figure 15.—Sandworm length-wet weight relationships: (A) The length-weight relationship for male and female sandworms obtained during samplings of the commercial catch, 1974–76 (males: 1 out of 2 data points plotted, females: 1 out of 4 data points plotted). (B) The length-weight relationship for sandworms from all areas and all sexes combined, collected during the commercial sampling program of 1974 (1 out of 15 data points plotted). (C) Length-weight relationships for sandworms collected during the 1974 samplings of the commercial catch from eastern Maine (Jonesport, Beals, Addison, Milbridge, and Harrington combined) and the Sheepscot River (excluding Montsweag Bay), (1 out of 5 data points plotted).

Table 18.—The upper and lower confidence limits about the slope (*b*) of bloodworm and sandworm length-weight regressions.

	Slope (*b*)	1 SE of *b* (68% confidence limits)	1.96 SE of *b* (95% confidence limits)	95% confidence limits about *b*-upper range	95% confidence limits about *b*-lower range
			Bloodworms		
Males (all areas)	2.20052	±0.09987	±0.19974	2.40314	1.99789
Females (all areas)	2.34133	±0.07225	±0.14450	2.53256	2.15010
All areas all sexes combined	2.32236	±0.01573	±0.03146	2.35319	2.29153
Eastern Maine	2.42910	±0.03297	±0.06594	2.49373	2.36447
Sheepscot River	2.28381	±0.02636	±0.05272	2.33549	2.23214
			Sandworms		
Males (all areas)	2.24379	±0.04789	±0.09578	2.33766	2.14993
Females (all areas)	2.21353	±0.04627	±0.09254	2.30422	2.12283
All areas all sexes combined	2.23996	±0.02022	±0.04044	2.27960	2.20033
Eastern Maine	2.40194	±0.02786	±0.05572	2.45656	2.34733
Sheepscot River	2.18866	±0.03385	±0.06770	2.25500	2.12231

Table 19.—The numbers of bloodworms and sandworms per pound.

	Bloodworms			Sandworms		
	Length (cm)	Weight[1] (g)	Worms/lb	Length (cm)	Weight[1] (g)	Worms/lb
1973						
6-mo $\bar{X}$	18.72	2.07	219	26.11	5.49	83
$\bar{X}$+1.96 SE	19.90	2.40	189	28.03	6.42	71
$\bar{X}$-1.96 SE	17.54	1.78	255	24.19	4.63	98
Max. month. $\bar{X}$	20.81	2.66	171	31.36	8.30	55
Min. month. $\bar{X}$	16.99	1.66	273	21.00	3.37	135
1974						
6-mo $\bar{X}$	19.84	2.37	191	26.22	5.53	82
$\bar{X}$+1.96 SE	20.58	2.60	174	27.55	6.22	73
$\bar{X}$-1.96 SE	19.10	2.18	208	24.89	4.94	92
Max. month. $\bar{X}$	21.68	2.93	155	28.16	6.52	70
Min. month. $\bar{X}$	17.82	1.85	245	24.25	4.67	97
1975						
6-mo $\bar{X}$	20.74	2.63	172	26.77	5.82	78
$\bar{X}$+1.96 SE	21.90	2.99	152	27.81	6.32	72
$\bar{X}$-1.96 SE	19.58	2.31	196	25.73	5.30	86
Max. month. $\bar{X}$	23.10	3.39	134	32.32	8.84	51
Min. month. $\bar{X}$	19.15	2.20	206	24.31	4.67	97
1976						
6-mo $\bar{X}$	20.83	2.66	171	25.69	5.30	86
$\bar{X}$+1.96 SE	21.89	2.99	152	26.51	5.68	80
$\bar{X}$-1.96 SE	19.77	2.37	191	24.87	4.94	92
Max. month. $\bar{X}$	22.98	3.35	135	27.45	6.17	74
Min. month. $\bar{X}$	18.57	2.05	221	23.74	4.42	103

[1]Weight values derived from length-weight conversions (all areas, all sexes combined).

Approximate values for a restriction on limited entry can be obtained from yield-effort curves (Pinhorn and Halliday 1975). Yield-effort relationships for bloodworms and sandworms are presented in Figure 16 (A and B). These results suggest that the maximum sustainable yield (MSY) in numbers of bloodworms and sandworms harvested was obtained with an effort of approximately 1,300 licensed marine worm diggers.

Prior to 1973, no attempt was made to record whether diggers to whom marine worm digging licenses were issued were engaged mainly in bloodworm or sandworm digging, or digging for both species. This information was extracted from licenses issued during the period 1973–78 and the results are presented in Table 21. The assumption has been made in Table 21 that the proportions calculated from completed application forms also apply to that 10.9–20.0% of the applicants who did not file completed applications. On the basis of the information presented in Table 21 and assuming that the percentage of licensed diggers who dug only bloodworms or sandworms prior to 1973 was the same as it was between 1973 and 1978, the MSY was obtained with approximately 815 bloodworm diggers (62.66% of 1,300), 386 sandworm diggers (29.72% of 1,300), and 99 diggers (7.62% of 1,300) who dug both species. A yield-effort relationship consisting of combined bloodworm and sandworm landings plotted against the total number of licensed marine worm diggers is presented in Figure 16C. These results suggest that the MSY for both species combined could be obtained at a limited entry figure of approximately 1,300 licensed marine worm diggers.

Where sufficient data exist on the total cost of digging, and the value of the catch over a period of time, a limited entry figure for

Table 20.—The numbers of bloodworms and sandworms per pound reported prior to 1970.

Date	Bloodworms (no./lb)	Sandworms (no./lb)	Source
1950–52	44	40	Cates and McKown (text footnote 36)
1964	100	50	Dow (1964)
1964	115	57	Cates and McKown (text footnote 36)
1966	106	63	Walton (text footnote 35)
1968	142	—	Walton (text footnote 35)
1969	150	80	Dow (1969)

Table 21.—The percentage of licensed marine worm diggers digging bloodworms, sandworms, and both species (1973–78).

Year	Percent of licensed diggers digging: Bloodworms	Sandworms	Both species
1973	64.77	28.42	6.81
1974	61.39	29.45	9.16
1975	61.36	30.23	8.41
1976	64.80	28.08	7.12
1977	63.88	29.99	6.13
1978	59.78	32.16	8.06
	[1]62.65±0.86	[1]29.72±0.60	[1]7.62±0.46

[1]Mean ±1 SE.

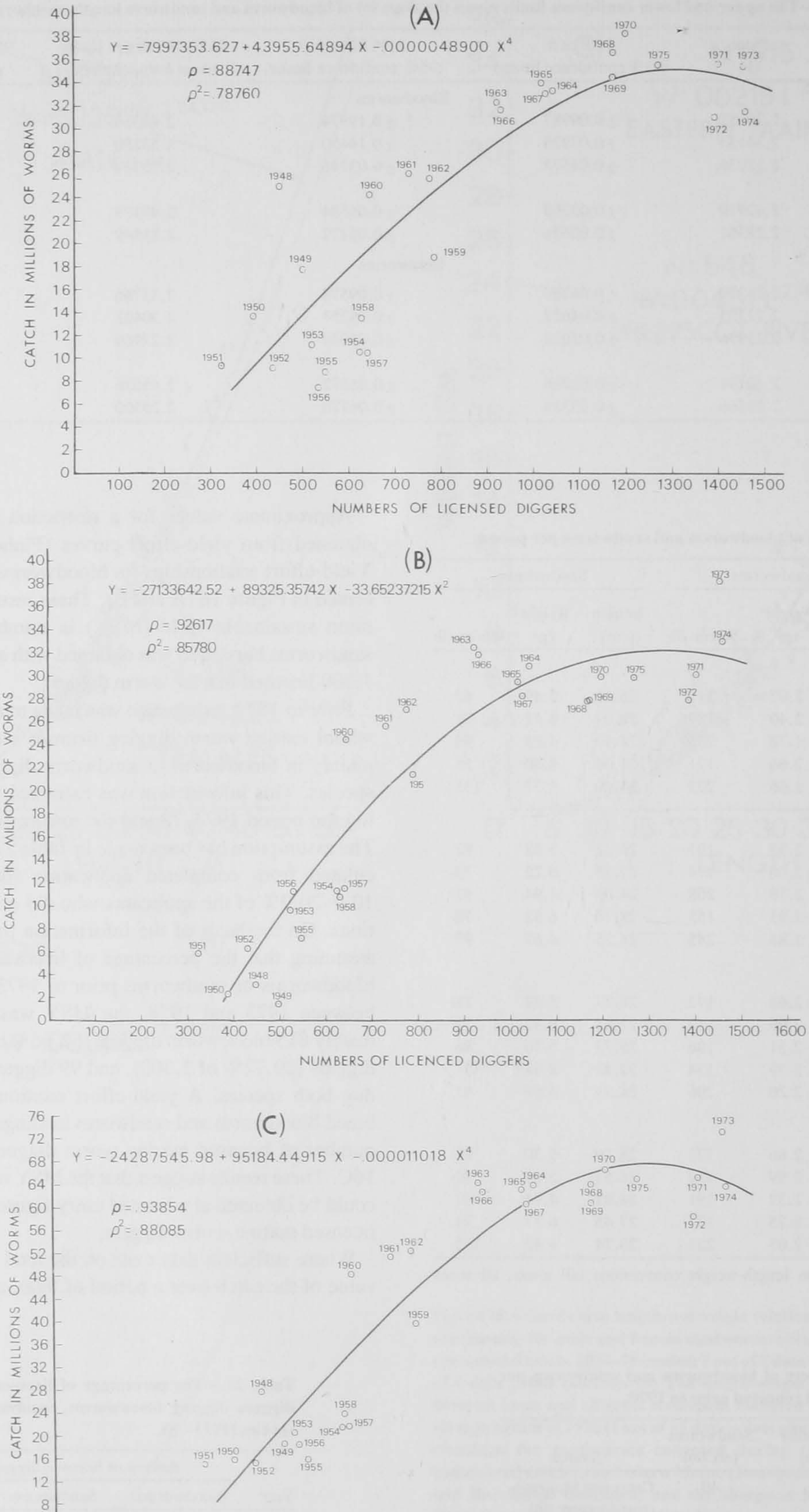


Figure 16.—Yield-effort curves: (A) bloodworms, (B) sandworms, (C) combined.

optimal sustainable yield (OSY) can be approximated by the method of Gulland (1968). In the present case where a portion of this information is lacking, the cost of digging, the OSY can only be very roughly approximated (by inspection of Fig. 16A, B, C) at somewhere between 900–1,100 licensed marine worm diggers. Based upon the proportions presented in Table 21, this would be equivalent to approximately 564–689 bloodworm diggers, 267–327 sandworm diggers, and 69–84 diggers who dig both species.

Assuming that OSY is very roughly approximated at 900–1,100 licensed marine worm diggers, very rough quotas of 28–33 million bloodworms and 26–30 million sandworms can be estimated from the data presented in Figure 16 (A and B).

Miscellaneous Information Obtained from Sampling Interview

Digging Frequency.—One interview question dealt with the frequency of bloodworm and sandworm digging expressed as the number of low tide periods occurring since the last low tide dug. The mean and standard error of the responses of all diggers interviewed during each month of each year (1973–76) are presented in Table 22.

Table 22.—The frequency of bloodworm and sandworm digging expressed as the mean (±1 SE) number of low tide periods occurring since the last low tide period dug.

	Bloodworm diggers			Sandworm diggers		
	No. diggers interviewed	$\bar{X}$	±1 SE	No. diggers interviewed	$\bar{X}$	±1 SE
1973						
A	37	6.5	±0.8	11	6.5	±2.0
M	31	5.6	±2.0	24	5.3	±1.0
J	26	3.3	±0.8	23	2.5	±0.6
J	36	2.1	±0.2	13	2.5	±0.5
A	32	4.0	±1.6	23	2.2	±0.3
S	20	10.1	±5.2	9	5.2	±1.3
	average	5.3		average	4.0	
1974						
A	34	3.0	±0.7	14	2.4	±0.2
M	14	4.4	±1.8	6	5.0	±1.4
J	44	11.2	±4.4	24	3.1	±0.6
J	20	3.2	±0.5	11	4.0	±0.5
A	21	3.0	±0.3	28	2.8	±0.4
S	33	1.9	±0.2	13	2.9	±0.9
	average	4.5		average	3.4	
1975						
A	2	8.0	±8.0	11	5.8	±1.5
M	14	2.1	±0.2	22	2.6	±0.7
J	29	4.1	±1.1	12	1.3	±0.3
J	19	2.0	±0.2	24	5.5	±1.7
A	24	3.8	±1.0	18	6.0	±2.9
S	19	3.3	±1.3	10	1.3	±0.2
	average	3.9		average	3.8	
1976						
A	19	2.2	±0.2	6	2.5	±1.3
M	9	5.3	±0.9	28	4.0	±0.4
J	30	13.1	±4.1	9	1.8	±0.2
J	39	5.7	±1.4	32	2.9	±0.3
A	18	2.3	±0.2	14	2.0	±0.0
S	36	16.9	±7.4	20	2.3	±0.3
	average	7.6		average	2.6	
	Overall average	5.3		Overall average	3.4	

Digging Experience.—The number of years of digging experience was recorded for those bloodworm and sandworm diggers who were interviewed during sampling. These data are expressed as a percent of the total number of diggers categorized in each increment of digging experience by year in Table 23. It is evident from these data that digging for worms is frequently a short-lived work experience; usually, the largest percentage of bloodworm and sandworm diggers interviewed had participated in marine worm digging activity for 4 yr or less.

Table 23.—The percent of the total number of bloodworm and sandworm diggers categorized in each increment of digging experience, 1973–76.

Number of years digging experience	1973	1974	1975	1976
	Bloodworm diggers			
1–4	50.51	37.58	37.73	35.25
5–8	15.82	16.76	23.59	23.02
9–12	15.31	13.87	13.21	9.35
13–16	6.12	17.34	12.26	11.51
17–20	6.63	6.36	7.54	13.67
21–24	2.04	1.73	1.89	1.44
25–28	2.55	5.20	1.89	2.88
29+	1.02	1.16	1.89	2.88
	Sandworm diggers			
1–4	34.23	22.12	23.71	27.52
5–8	16.22	11.54	17.53	13.76
9–12	24.33	13.46	17.53	22.02
13–16	9.01	20.19	11.34	6.43
17–20	11.71	14.42	12.37	16.51
21–24	—	2.88	8.24	3.67
25–28	1.80	10.58	2.06	2.75
29+	2.70	4.81	7.22	7.34

Age of Marine Worm Diggers.—Age-frequency distributions for bloodworm and sandworm diggers interviewed are expressed as a percent of the total number of bloodworm and sandworm diggers interviewed in each age category in Table 24. It is evident from these data that the numbers of diggers in age categories beyond age 40 decline rapidly. The results also show that there are few diggers under age 9 and over age 60. The mean age ±1 SE for all bloodworm and sandworm diggers interviewed during each sampling year is shown in Table 25.

Table 24.—The percent of the total number of bloodworm and sandworm diggers interviewed in each age category (1973–76).

Digger age	1973	1974	1975	1976
	Bloodworm diggers			
≤9	1.09%	0.00%	0.00%	0.00%
10–19	31.87	20.23	24.30	16.77
20–29	26.37	39.88	34.58	34.16
30–39	24.73	23.81	22.43	29.19
40–49	10.44	10.12	14.02	8.70
50–59	3.30	2.98	3.74	7.45
≥60	2.20	2.98	0.93	3.73
	Sandworm diggers			
≤9	0.00%	0.00%	0.00%	0.00%
10–19	21.15	12.38	17.53	21.11
20–29	34.62	35.24	31.96	31.11
30–39	25.00	24.76	22.68	25.56
40–49	9.62	19.05	16.49	17.78
50–59	7.69	8.57	11.34	3.33
≥60	1.92	0.00	0.00	1.11

Table 25.—The mean age ±1 SE of bloodworm and sandworm diggers interviewed during each sampling year (1973–76).

Year	Bloodworm diggers N	$\bar{X}$ age	±1 SE	Sandworm diggers N	$\bar{X}$ age	±1 SE
1973	182	27.7	±0.9	104	29.8	±1.2
1974	168	29.6	±0.9	105	31.9	±1.1
1975	107	29.1	±1.1	97	31.7	±1.2
1976	161	31.2	±1.0	90	30.9	±1.2

Percentage of Day and Nighttime Digging.—The results of one interview question regarding the percentage of bloodworm and sandworm diggers who responded that the last tide dug occurred during daylight (one-half hour before sunrise to one-half hour after sunset) or at night are presented in Table 26. These results indicate that most digging occurs during daylight. A greater percentage of sandworm than bloodworm diggers dig worms at night. Night digging is accomplished with the aid of a miner's light attached to the head.

Table 26.—The percent of bloodworm and sandworm diggers reporting that the last tide dug occurred during daylight or at night (1973–76).

Year	Bloodworms Daylight	Bloodworms Night	Sandworms Daylight	Sandworms Night
1973	94	6	86	14
1974	97	3	92	8
1975	98	2	89	11
1976	97	3	80	20

Percentage of Male and Female Worm Diggers.—The percentage of male and female bloodworm and sandworm diggers recorded during sampling interviews is shown in Table 27. Few women are involved in this occupation.

Table 27.—The percent of male and female bloodworm and sandworm diggers recorded during sampling interviews (1973–76).

Year	Bloodworm diggers Males	Bloodworm diggers Females	Sandworm diggers Males	Sandworm diggers Females
1973	98.4	1.6	99.5	0.5
1974	98.3	1.7	100.0	0.0
1975	99.1	0.9	98.8	1.2
1976	95.3	4.7	100.0	0.0

Decline of Bloodworm Landings After 1975

The bloodworm industry, unlike the sandworm industry, experienced a considerable decrease in production between 1975 and 1979 (Table 28). Many factors probably contributed to this decline.

Table 28.—The percent gain or reduction in bloodworm and sandworm production between 1975 and 1979.

Year	No. of bloodworms	% gain or reduction	No. of sandworms	% gain or reduction
1975	35,634,000		29,935,000	
1976	23,454,000	−34.18	27,915,000	−6.75
1977	17,474,000	−25.50	29,506,000	+5.70
1978	16,202,000	− 7.28	29,937,000	+1.46
1979	19,364,000	+19.52	29,776,000	+0.54

The failure of the Sheepscot River as a major bloodworm producer is probably responsible for a significant portion of the decline in production from western Maine. The exact nature of this continuing failure is unknown but it may be that oil (Page[38]) or toxic chemicals are contributing factors.

Dow (footnote 18) attributes the decline in production to the following causes: 1) Naturally occurring fluctuations in abundance and availability are associated with such environmental factors as seawater temperature. The mean annual sea temperature increased from an optimum of 8.4°C (1972) and 8.8°C (1973) to an above optimum of 9.2°C (1974). 2) A decline was apparent in the numbers of licensed marine worm diggers. Licenses dropped from 1,267 (1975) to 1,105 (1979). The possibility exists, however, that licenses declined as the result of decreased demand and production and not vice versa. 3) Toxic oil spills, heavy metals contamination, and possibly the presence of other pollutants may account for a portion of the decline. 4) A 3-wk strike during 1976 may have reduced production by as many as 3 million worms. 5) Poor market conditions resulted in a decrease in digging effort. Following a series of telephone conversations with marine worm wholesalers and retailers, Walton[39] concluded that the poor market conditions resulted from 1) a reduction in the availability of some sport fish (striped bass, flounder) in the central states (New Jersey, Delaware, Maryland) where bloodworms are used extensively, and 2) either switching from both species of marine worms to alternate and less expensive baits (clam necks, night crawlers) in the northeast (Rhode Island, New York, Massachusetts) or switching from bloodworms to less expensive sandworms.

A decline in fishing activity resulting from the gas shortage and the poor quality (small size) of bloodworms may be other contributing factors.

In many commercial digging areas, diggers and shippers report that overharvesting is a primary cause of the decline in production. However, no research directed toward collecting the catch/effort data necessary to confirm or deny these claims has existed since 1976.

Previous declines in marine worm landings have been attributed to cyclic changes in the environment (Dow;[40] Dow and Wallace footnote 13), gradual changes in soil composition (Klawe and Dickie 1957), expansion of the commercial area dug (Dow and Wallace footnote 13), and changes in tidal exposure because of bridge and highway construction (Ganaros footnote 4).

Suggestions for Improving Future Marine Worm Sampling Programs

It is apparent, from the magnitude of the standard errors about the monthly probability expansion estimates (Table 12), that greater accuracy (smaller standard errors) could be obtained by sampling on more than six daylight low tide periods per month. Although we were not initially optimistic about increasing the accuracy of probability estimates because of project restrictions on time, funding, and manpower, an attempt was made to estimate by optimum and proportional allocation the number of sampling daylight low tides

[38]Page D. S. 1977. A survey of hydrocarbons in bloodworms and accompanying sediments from the Wiscasset, Maine area. Bowdoin College - A report to the Maine Department of Marine Resources, Augusta, 38 p.

[39]C. J. Walton, Marine resources scientist, Maine Dep. Mar. Resour., West Boothbay Harbor, ME 04575, pers. commun. July 1978.

[40]Dow, R. L. 1951. Marine worm report. Maine Dep. Sea Shore Fish., Augusta, 6 p.

required to obtain a minimum desired accuracy of ±15% about the mean expansion estimate (total catch in numbers, total number of digging hours dug, etc.) at the 90% confidence level. The results of these analyses on both bloodworms and sandworms are shown in Tables 29 and 30, respectively. In most cases (using both optimum and proportional allocation), the number of sampling daylight low tides required to obtain the desired accuracy exceeds the number of tides which could reasonably be sampled. Furthermore, to make use of optimal allocation, one must be able to reliably predict the relative variability which occurs in each stratum (month), but the 4 yr of data do not demonstrate consistent monthly variability from year to year. Because of these problems, we chose to sample six daylight low tide periods per month, and accept the large standard errors about the mean estimates for probability expansion estimates.

We applied the combined methodology of Gulland (1966), Pope (1956), and Snedecor and Cochran (1967) to determine whether satisfactory estimates of mean length in a future commercial marine worm sampling program could be obtained with less sampling of worms/digger, diggers/dealer, and dealers/month. The results of this analysis indicate that variability of no more than ±15% of the estimated mean at the 95% confidence level could be obtained for bloodworm lengths by sampling approximately 10 measurable worms/digger, 6 diggers/dealer, and 2 dealers/mo (if only 1 mo was sampled). Similar data could be collected for sandworms by sampling approximately 14 measurable worms/digger, 5 diggers/dealer, and 1 dealer/mo (Creaser footnote 37). Obviously, the desire to obtain a variability of no more than 5 or 10% of the estimated mean at the 95% confidence level would be obtained by increasing the sample size. Since we sampled approximately 20 measurable bloodworms/digger and approximately 7 bloodworm diggers/dealer from an average of 3 bloodworm dealers/mo, and approximately 18 measurable sandworms/digger, and approximately 6 sandworm diggers/dealer from an average of nearly 3 sandworm dealers/mo between 1973 and 1976, we have sampled more than what was required to obtain the minimum desired degree of accuracy. The magnitude of the standard errors about the 6-mo mean lengths (Tables 10, 11) also demonstrates this point.

Considering that 1) probability expansion estimates could be improved (smaller standard errors obtained) by sampling more frequently each month, and 2) satisfactory monthly estimates of marine worm length could be obtained with fewer length samples, it would probably the possible to sample more frequently each month and improve the probability estimates if fewer worms were being obtained for length processing. Although it is not possible to increase sampling to the point at which we could attain the accuracy expressed in Tables 29 and 30, it would probably be possible to increase the amount of sampling to 8 or 10 daylight low tides per month. Sampling could furthermore be stratified so that each of 4 or 5 bloodworm and 4 or 5 sandworm shippers could be randomly sampled each month. Both worm species would be sampled at those shippers selected who purchase both species of worms.

Despite the decreased sampling required to estimate worm length, it might still be desirable to collect some length samples

Table 29.—Calculations of the desired frequency of monthly samplings for bloodworms to obtain a minimum accuracy of ±15% about the mean estimate for 1) total catch in numbers and 2) total number of digger hours dug, at the 90% confidence level.

	1973		1974		1975		1976	
	Total catch in numbers (bloodworms)							
	Optimum allocation							
A	[1](36)	[2]8.72	(36)	15.15	(38)	2.75	(36)	24.20
M	(42)	16.81	(40)	31.65	(41)	19.03	(25)	8.17
J	(42)	25.01	(41)	21.69	(42)	17.09	(39)	30.81
J	(44)	19.76	(42)	25.88	(41)	27.70	(42)	20.47
A	(40)	24.75	(40)	12.53	(39)	29.64	(38)	7.76
S	(33)	13.45	(35)	9.85	(33)	16.34	(34)	10.96
	Proportional allocation							
A	(36)	17.72	(36)	20.21	(38)	22.05	(36)	20.61
M	(42)	20.67	(40)	22.45	(41)	23.79	(25)	13.17
J	(42)	20.67	(41)	23.02	(42)	24.37	(39)	22.33
J	(44)	21.66	(42)	23.58	(41)	23.79	(42)	24.04
A	(40)	19.69	(40)	22.45	(39)	22.63	(38)	21.75
S	(33)	16.24	(35)	19.65	(33)	19.15	(34)	19.46
	Total number of digger hours dug (bloodworms)							
	Optimum allocation							
A	(36)	11.21	(36)	17.87	(38)	1.55	(36)	22.91
M	(42)	24.71	(40)	29.90	(41)	14.59	(25)	8.73
J	(42)	24.33	(41)	20.80	(42)	20.91	(39)	29.67
J	(44)	17.85	(42)	27.49	(41)	26.95	(42)	21.46
A	(40)	16.33	(40)	19.65	(39)	31.40	(38)	9.67
S	(33)	8.15	(35)	11.42	(33)	12.11	(34)	10.70
	Proportional allocation							
A	(36)	16.86	(36)	20.71	(38)	22.34	(36)	19.98
M	(42)	19.67	(40)	23.01	(41)	24.07	(25)	12.77
J	(42)	19.67	(41)	23.59	(42)	24.65	(39)	21.65
J	(44)	20.61	(42)	24.16	(41)	24.07	(42)	23.32
A	(40)	18.73	(40)	23.01	(39)	22.89	(38)	21.10
S	(33)	15.46	(35)	20.14	(33)	19.37	(34)	18.88

[1]( ) = The total number of daylight low tides in the month.

[2]The calculated number of sampling tides required to obtain the desired accuracy.

Table 30.—Calculation of the desired frequency of monthly samplings for sandworms to obtain a minimum accuracy of ±15% about the mean estimate for 1) total catch in numbers and 2) total number of digger hours dug, at the 90% confidence level.

	1973		1974		1975		1976	
	Total catch in numbers (sandworms)							
	Optimum allocation							
A	[1](36)	[2]18.57	(36)	13.30	(38)	4.04	(36)	2.90
M	(42)	25.61	(40)	18.17	(41)	40.46	(25)	11.41
J	(42)	23.01	(41)	24.64	(42)	16.60	(39)	18.32
J	(44)	7.62	(42)	27.90	(41)	28.01	(42)	33.05
A	(40)	15.61	(40)	17.14	(39)	5.81	(38)	4.64
S	(33)	12.19	(35)	13.10	(33)	4.75	(34)	14.86
	Proportional allocation							
A	(36)	17.44	(36)	18.51	(38)	25.77	(36)	19.91
M	(42)	20.35	(40)	20.57	(41)	27.81	(25)	13.83
J	(42)	20.35	(41)	21.08	(42)	28.49	(39)	21.57
J	(44)	21.32	(42)	21.60	(41)	27.81	(42)	23.23
A	(40)	19.38	(40)	20.57	(39)	26.45	(38)	21.02
S	(33)	15.99	(35)	18.00	(33)	22.38	(34)	18.81
	Total number of digger hours dug (sandworms)							
	Optimum allocation							
A	(36)	14.94	(36)	13.17	(38)	5.62	(36)	3.41
M	(42)	23.11	(40)	15.61	(41)	39.20	(25)	9.38
J	(42)	22.93	(41)	17.39	(42)	12.53	(39)	15.40
J	(44)	6.56	(42)	32.45	(41)	32.23	(42)	31.51
A	(40)	16.48	(40)	19.10	(39)	7.99	(38)	8.32
S	(33)	16.40	(35)	9.17	(33)	7.00	(34)	15.40
	Proportional allocation							
A	(36)	16.98	(36)	18.48	(38)	25.62	(36)	18.28
M	(42)	19.81	(40)	20.54	(41)	27.65	(25)	12.69
J	(42)	19.81	(41)	21.05	(42)	28.32	(39)	19.80
J	(44)	20.75	(42)	21.56	(41)	27.65	(42)	21.33
A	(40)	18.86	(40)	20.54	(39)	26.30	(38)	19.30
S	(33)	15.56	(35)	17.97	(33)	22.25	(34)	17.27

[1]( ) = The total number of daylight low tides in the month.

[2]The calculated number of sampling tides required to obtain the desired accuracy.

each month to enable us to determine whether worm size is affected by monthly or seasonal market demands. Monthly sampling would also allow us to accumulate more length, weight, sex, and condition information from assorted growing areas.

Problems inherent in the analysis of lumped commercial length frequency data for age (and the mortality estimates based upon that age structure) have been discussed previously under the section entitled "Estimates of Age." Despite the fact that commercial-length frequency data collected from specific growing areas over short periods of time may be more easily analyzed for age structure than similar data collected from a large geographical area and lumped over a longer period of time, the authors do not recommend the former approach either. Our experience has been that when the former procedure is followed, considerable overlap in the older year classes occurs and the validity of aging results may still be questioned. It would seem more appropriate to develop a means of aging marine worms other than by analyzing length frequency distributions. In this respect, aging by 1) the possible presence of annuli on bloodworm and sandworm mouth parts, and 2) mark and recapture techniques using tagged or dyed worms or worms with mutilated appendages, should be attempted. Age structure determined by these means in three or four commercial growing areas could then be used to determine the numbers of worms at each year class mode required for mortality estimates. Total and natural mortality rates could be estimated from length-frequency data collected from open and closed growing areas situated side by side in each of the three or four study areas. Fishing (digging) mortality (F) could be determined for each study area by $F = Z - M$ where Z = total mortality and M = natural mortality.

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APPENDIX A

The following formulas were used to calculate the means, variances, and standard errors for length and weight data and the percent males, females, broken, regenerated, and punctured individuals collected during each dealer daylight low tide period sampled.

$$\bar{Y}_i = \sum_j N_j \cdot \bar{Y}_j / \sum_j N_j \quad (1)$$

$$\text{var}(\bar{Y}_i) = \sum_j (\bar{Y}_j - \bar{Y}_i)^2 / (m(m-1)) \quad (2)$$

$$\bar{Y}_j = \sum_k Y_{jk} / n_j \quad (3)$$

where $\bar{Y}_i$ = mean for the ith dealer daylight low tide,
$\bar{Y}_j$ = mean for the jth digger sampled,
N_j = number worms landed by the jth digger sampled,
m = number of diggers sampled,
Y_{jk} = measurement for the kth worm from the jth digger sampled,
n_j = number of worms measured from the jth digger sampled.

Formulas used to calculate the monthly means, variances, and standard errors for the same parameters above include the following:

$$\bar{Y}_h = \sum_i \bar{Y}_i / l \quad (4)$$

$$\text{var}(\bar{Y}_h) = \sum_i (\bar{Y}_i - \bar{Y}_h)^2 / (l(l-1)) \quad (5)$$

where $\bar{Y}_h$ = mean for the hth month,
$\bar{Y}_i$ = mean for the ith dealer daylight low tide (Equation (1)),
l = number of dealer daylight low tides sampled.

Formulas used to calculate the 6-mo means and standard errors for the same parameters above include the following:

$$\bar{Y}_{st} = \sum_h N_h \cdot \bar{Y}_h / \sum_h N_h \quad (6)$$

$$\text{var}(\bar{Y}_{st}) = \sum_h (N_h^2 \cdot \text{var}(\bar{Y}_h)) / (\sum_h N_h)^2 \quad (7)$$

where $\bar{Y}_{st}$ = 6-mo stratified mean,
$\bar{Y}_h$ = mean for the hth month (Equation (4)),
N_h = number of daylight low tides in the hth month.

Probability expansions have been calculated for the following marine worm sampling data: total catch in numbers, total number of digger hours dug, total value of the catch, total number of digger tides dug, and total catch in pounds. The formulas used in calculating these expanded estimates, their variances, and standard errors on a monthly basis, conform to the methodology of Gulland (1966) and Snedecor and Cochran (1967) and are presented as follows:

$$\hat{X}_h = N_h \cdot D_h \cdot \bar{X}_h \quad (8)$$

$$\text{var}(\hat{X}_h) = N_h (N_h - n_h) \cdot D_h^2 \cdot \text{var}(\bar{X}_h) \quad (9)$$

where $\hat{X}_h$ = expanded estimate for the hth month,
$\bar{X}_h$ = mean for the hth month (Equation (4)),
N_h = number of daylight low tides in the hth month,
D_h = number of qualified dealer locations open during the hth month,
n_h = number of daylight low tides sampled in the hth month.

Formulas used to calculate probability expansions and their standard errors for the entire 6-mo sampling period include the following:

$$\hat{X}_{st} = \sum_h \hat{X}_h \quad (10)$$

$$\text{var}(\hat{X}_{st}) = \sum_h \text{var}(\hat{X}) \quad (11)$$

where $\hat{X}_{st}$ = 6-mo stratified total,
$\hat{X}_h$ = total for the hth month (Equation (8)).

Ratios of two variables (catch/effort data) have been calculated for the following marine worm sampling data: numbers dug/digger tide, numbers dug/digger hour, pounds dug/digger tide, and pounds dug/digger hour. The formulas used in calculating these ratios of two variables, their variances, and standard errors on a monthly basis, conform to the methodology of Cochran (1963) and are presented as follows:

$$R_h = \sum_i Y_i / \sum_i X_i \quad (12)$$

$$\text{var}(R_h) = n_h \cdot \sum_i (Y_i - R_h \cdot X_i)^2 / ((n_h - 1)(\sum_i X_i)^2) \quad (13)$$

where R_h = ratio estimate for the hth month,
Y_i = some measure of catch sold to the ith dealer daylight low tide sampled,
X_i = some measure of effort for diggers selling to the ith dealer daylight low tide sampled,
n_h = number of dealer daylight low tides sampled.

Formulas used to calculate the ratios of two variables and their standard errors for the entire 6-mo sampling period include the following:

$$R_{st} = \sum_h N_h \cdot R_h / \sum_h N_h \quad (14)$$

$$\text{var}(R_{st}) = \sum_h (N_h^2 \cdot \text{var}(R_h)) / (\sum_h N_h)^2 \quad (15)$$

where R_h = ratio estimate for the hth month (Equation (12)),
N_h = number of daylight low tides in the hth month.

Estimates for the number of dealers that should be sampled each month, the number of diggers that should be sampled per dealer, and the number of worms that should be sampled from each digger, conform to the methodology of Snedecor and Cochran (1967). Information on the use of their methods may be found in Creaser (text footnote 29).

The relationship of worm weight to worm length was calculated using a logarithmic transformation of the basic equation $W = aL^b$.

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