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Identification and Distribution of Urophycis (Gill) and Phycis (Artedi) Larvae and Pelagic Juveniles in the Middle Atlantic Bight

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IDENTIFICATION AND DISTRIBUTION OF *UROPHYCIS* (Gill) AND *PHYCIS* (Artedi) LARVAE AND PELAGIC JUVENILES IN THE MIDDLE ATLANTIC BIGHT

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By

Bruce H. Comyns

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ABSTRACT

Analysis of surface and subsurface plankton collections in the Middle Atlantic Bight yielded larvae and juveniles of Phycis chesteri and five species of Urophycis. Identification was based on meristic, osteological and morphometric criteria. Meristic characters included numbers of epibranchial gill rakers, vertebrae (abdominal and caudal), and fin rays (dorsal, caudal and pelvic). Osteological analysis was based on patterns of interdigitation between the pterygiophores supporting the median fins and the neural or haemal spines. Morphometric characters included height of the pelvic fin-base, mandible length, and body depth at the vent.

U. chuss was found in summer and fall collections off the coast of both New Jersey and Virginia, with abundances highest at mid-shelf stations. U. chuss was the only species found during summer, dominating plankton collections at this time of year. U. regia was primarily found in mid shelf areas of the southern sector during fall, but was also a component of the southern fauna found offshore from both Virginia and New Jersey during winter. P. chesteri, also found in fall and winter collections, was restricted to offshore stations. Southern species, found exclusively in offshore winter collections, included U. floridana and U. cirrata. U. earlli, if present, would probably also be found in these collections. U. tenuis was found during spring off Virginia and New Jersey, with highest abundances appearing offshore. U. tenuis accounted for 99% of the Urophycis or Phycis larvae and juveniles taken at this time.

Pelagic Phycis and Urophycis showed patterns of diel vertical migration. U. tenuis was most abundant in surface waters at night, while other species were more abundant in the neuston during early morning or evening hours. This vertical movement in the water column was probably a response to changing light levels and may have been due to diel feeding behavior or to a predator avoidance mechanism, but further research is needed.

IDENTIFICATION AND DISTRIBUTION OF *UROPHYCIS* (Gill) AND *PHYCIS* (Artedi) LARVAE AND PELAGIC JUVENILES IN THE MIDDLE ATLANTIC BIGHT

INTRODUCTION

Urophycis (Gill) and Phycis (Artedi) are both genera of the cod family Gadidae. Fishes of these two genera, commonly referred to as hake, are abundant on the continental shelf and slope of the northwest Atlantic Ocean. Merluccius, a third genus commonly referred to as hake, is in the family Merlucciidae and is not discussed in this thesis. Six species of Urophycis and one species of Phycis are endemic to this area (Svetovidov, 1948; Wenner, 1983): U. tenuis (Mitchill), U. chuss (Walbaum), U. regia (Walbaum), U. floridana (Bean and Dresel), U. earlli (Bean), U. cirrata (Goode and Bean) and P. chesteri (Goode and Bean). Subsequent uses of the term "hake" will refer to these seven species. As with most marine fishes the early life stages of hake are planktonic, but relatively little is known about these larvae because individual species are difficult to identify (Serebryakov, 1978).

Methven (1985) presented a size dependent key to the identification of larval and pelagic juvenile U. chuss, U. tenuis and P. chesteri from the Northwest Atlantic. Identifications were based on body depth, numbers of epibranchial gill rakers (Musick, 1973; Wenner, 1983), and numbers of caudal fin rays (Markle, 1982). Material for

Methven's study came from the Scotian Shelf. He did not consider U. cirrata, U. earlli, U. floridana and U. regia which occur further to the south and rarely, if ever, occur on the Scotian Shelf. Because of overlapping meristics and body depths, Methven's key is of limited use in the Middle Atlantic area where southern forms occur.

Hildebrand and Cable (1938) described larval and pelagic juvenile U. chuss, U. regia and U. floridana. Larvae approximately 3-7 mm in length were identified on the basis of body depth and pelvic fin pigmentation, U. chuss having the most slender-bodied larvae and U. regia having the only larvae without dark pelvic fin pigmentation. However, too much overlap exists with body depth measurements to afford confident identifications, and U. regia does occasionally exhibit pelvic fin pigmentation (this study). Hildebrand and Cable used additional meristic characters to identify larger larvae. They noted that U. chuss has more second dorsal fin rays than U. regia, and can be separated from U. regia at sizes as small as 7 mm by numbers of second dorsal fin fulcra. Hildebrand and Cable also distinguished U. chuss from U. regia and U. floridana by numbers of anal fin rays, but meristic overlap precludes this separation.

Newly hatched U. chuss and U. regia of known parentage were described by Hildebrand and Cable (1938), Miller and Marak (1959), Barans and Barans (1972) and Serebryakov (1978). Although these descriptions provide pigmentation

differences between the two species, this information alone is not sufficient to positively identify field caught larvae because newly hatched larvae of other species have not been described.

Larvae and juveniles of U. tenuis and U. chuss are common on the continental shelf and slope of the Northwest Atlantic in spring and summer months, respectively. These young fish remain pelagic for 2-3 months, at which time juvenile U. chuss become demersal and seek shelter by associating with scallops (Musick, 1969), and U. tenuis juveniles settle to the bottom in nearshore shallows (Markle et al., 1982).

Larvae of U. regia and U. floridana have been frequently collected in offshore winter collections from the South Atlantic Bight (Hildebrand and Cable, 1938; Powles and Stender, 1976). Hildebrand and Cable noted that by early spring juveniles (>40 mm) of both species appear inshore in shallow, muddy bottom areas.

No information is available on the early life history of P. chesteri, U. cirrata or U. earlli. Larvae of the latter two species remain undescribed.

Urophycis larvae and juveniles have dominated plankton collections in the Middle and South Atlantic Bights during summer and winter months, respectively (Powles and Stender, 1976; Kendall and Naplin, 1981). However, the ecological significance of the abundance of these pelagic larvae and juveniles remains unknown.

The economic importance of Urophycis species as a food fish in the United States is increasing, although U. chuss and U. tenuis are the only species currently being commercially harvested. In 1976 9.1 million pounds of U. tenuis were landed in New England, and total U.S. landings of U. chuss in 1978 reached 4.8 million pounds (Gendron, 1980). The optimal yield of U. chuss has been estimated at over 70 million pounds (Regenstein et al., 1980). Consequently there is an abundant resource for development. The ability to identify larval hake will be useful as the exploitation of hake increases since defining the spatial and temporal distribution of young larvae helps locate aggregations of spawning adults, and stock sizes can be estimated from abundances of eggs and larvae.

Both northern and southern species of larval hake are found in the Middle Atlantic Bight, but a paucity of taxonomic information (Dunn and Matarese, 1984) has hindered the identification of Urophycis and Phycis larvae in this area (Kendall and Naplin, 1981; Hermes, 1985).

The objectives of my study were to describe taxonomic characters useful in delimiting larval Urophycis and Phycis, and to examine the spatial and temporal distribution of these larvae in the Middle Atlantic Bight.

MATERIALS AND METHODS

In October 1975 the Virginia Institute of Marine Science initiated a field sampling program in the continental shelf waters of the Middle Atlantic Bight to collect biological, physical and chemical data. This program, funded by the Bureau of Land Management, was designed to furnish baseline data to help determine the impact of oil and gas exploration along the outer continental shelf. In the course of this two year study surface and subsurface plankton collections were taken during eight quarterly cruises.

Sampling Locations and Shipboard Procedure

Sampling was conducted during a two year period at six stations along a transect of the continental shelf off Atlantic City, New Jersey. The stations (C1, D1, N3, E3, F2, J1) extended seaward from a nearshore station in 17 meters of water to an offshore slope station located in approximately 400 meters of water. These stations were sampled quarterly in October 1975 and February, June and August-September 1976. During the second year sampling was expanded by adding a transect of four stations off the

Virginia coast (L1, L2, L4, L6) and two northerly stations (B5, A2) off New Jersey. The twelve stations (Fig.1) were occupied quarterly in November 1976 and February-March, May and August 1977. Table 1 lists water depth, surface temperature, and surface salinity at each station during the eight cruises.

Neuston samples were collected with a sampler developed at Woods Hole Oceanographic Institution (Bartlett and Haedrich, 1968; Craddock, 1969). This sampler is constructed from two streamlined foam-filled floats connected by an endless fiberglass band, and a one-meter plankton net constructed with 505 um mesh Nitex. The net opening is 1 meter wide, and fishes to a depth of 12 cm in calm seas. Tows were of 20 minutes duration at a ship speed of approximately 2 knots. The net was deployed from a boom and the towing course followed a widely circular track to prevent sampling in the ship's wake. A single neuston tow was made at three hour intervals over a 24 h period at each station resulting in 8 samples per station per quarter. Twenty-four hour sampling was not conducted at three stations (D1, N3, F2) off Atlantic City, N.J. during the second year.

Two oblique tows between near-surface and bottom were made at all stations with 60 cm opening-closing bongo systems (McGowan and Brown, 1966), the first with paired 202 um Nitex nets and the second with paired 505 um nets. To prevent surface contamination all nets were closed

during passage through the surface layer (upper meter).

Both bongo and neuston nets were equipped with flow meters (General Oceanics,Inc.). Samples were washed into buckets, concentrated with a 110 um sieve, and preserved in glass jars with 5-8% buffered formalin in sea water and returned to the laboratory for sorting and identification.

Laboratory Procedure

Large and relatively infrequent taxa such as fish larvae were sorted from whole collections. Larvae were initially sorted to the lowest possible taxon and, in the case of the Gadidae, to the generic level. Fourteen of the 58 collections of larval hake collected during August-September 1976 (n = >16,000) were subsampled to streamline identification efforts. Half or quarter subsamples were taken from collections containing over 400 or 1000 specimens, respectively. Subsamples were obtained by using a 9x12 inch sorting tray, the bottom of which was marked into quadrants. Specimens were evenly distributed in the tray and either one or two quadrants were randomly selected depending on whether a quarter or half split was to be taken. A specimen positioned on a quadrant line was included in a subsample if the head of the larva crossed into the chosen quadrant. Specimens of Urophycis and Phycis were cleared and stained (Dingerkus and Uhler, 1977; Potthoff, 1984; and Taylor and Van Dyke, 1985) to

facilitate identification. Table 2 lists additional material examined (x-rayed).

Hake larvae that had developed adult meristic complements were initially sorted into groups based on published and unpublished meristic data (Table 3). The taxonomic significance of some of these data was previously unrecognized because meristic ranges overlap, comparisons between all species had not been made, and in general characters had been examined on an individual basis as opposed to being viewed as part of a suite of characters. Meristic analysis in this study is based on numbers of epibranchial gill rakers, vertebrae (abdominal and caudal) and fin rays (dorsal, caudal and pelvic). All counts were made with the use of a stereomicroscope. Meristic data compiled from both my cleared and stained material and radiographs of juvenile and adult museum specimens (Appendix Tables A-1 to A-7) enabled me to verify published ranges and obtain percent frequencies of meristic numbers.

As meristic data accumulated the confidence of identifications increased, but problems still existed with the identification of larvae that had not yet developed adult meristic complements. The identification of these smaller larvae was facilitated by defining developmental times of fin rays, vertebrae and gill rakers. The sizes at which adult meristic complements are attained are also listed in Appendix Tables A-1 to A-7. In addition, identification improved with the development of

morphometric criteria and patterns of interdigitation between pterygiophores supporting the median fins and the neural or haemal spines. Morphometric criteria used in the analysis are defined below:

Body depth at vent- vertical distance from anterior end of anal fin base to dorsal surface immediately above.

Height of pelvic fin- distance from base of pelvic fin to ventral edge of body.

Mandible length- distance from anterior tip of dentary bone to posterior ventral tip of angular bone.

Loss of pigmentation caused by formalin preservation and subsequent clearing and staining curtailed the use of pigmentation as a possible taxonomic aid.

Standard or notochord lengths of fish were measured to 0.1 mm. Measurements were taken from the tip of the snout to the end of the notochord in pre-flexion larvae and from the tip of the snout to the end of the urostyle or hypural plate (whichever was more distal) in flexion or post-flexion larvae. Fish smaller than 12 mm were measured with an ocular micrometer, while lengths of larger specimens were taken with a dial caliper ruler. Specimens less than 18 mm SL are arbitrarily referred to as larvae, whereas fish equal to or longer than 18 mm are referred to as juveniles. The size, abundance and location of hake larvae collected during the eight BLM cruises are listed in Appendix Table A-8.

Figure 1. Ichthyoplankton sampling locations off New Jersey and Virginia.

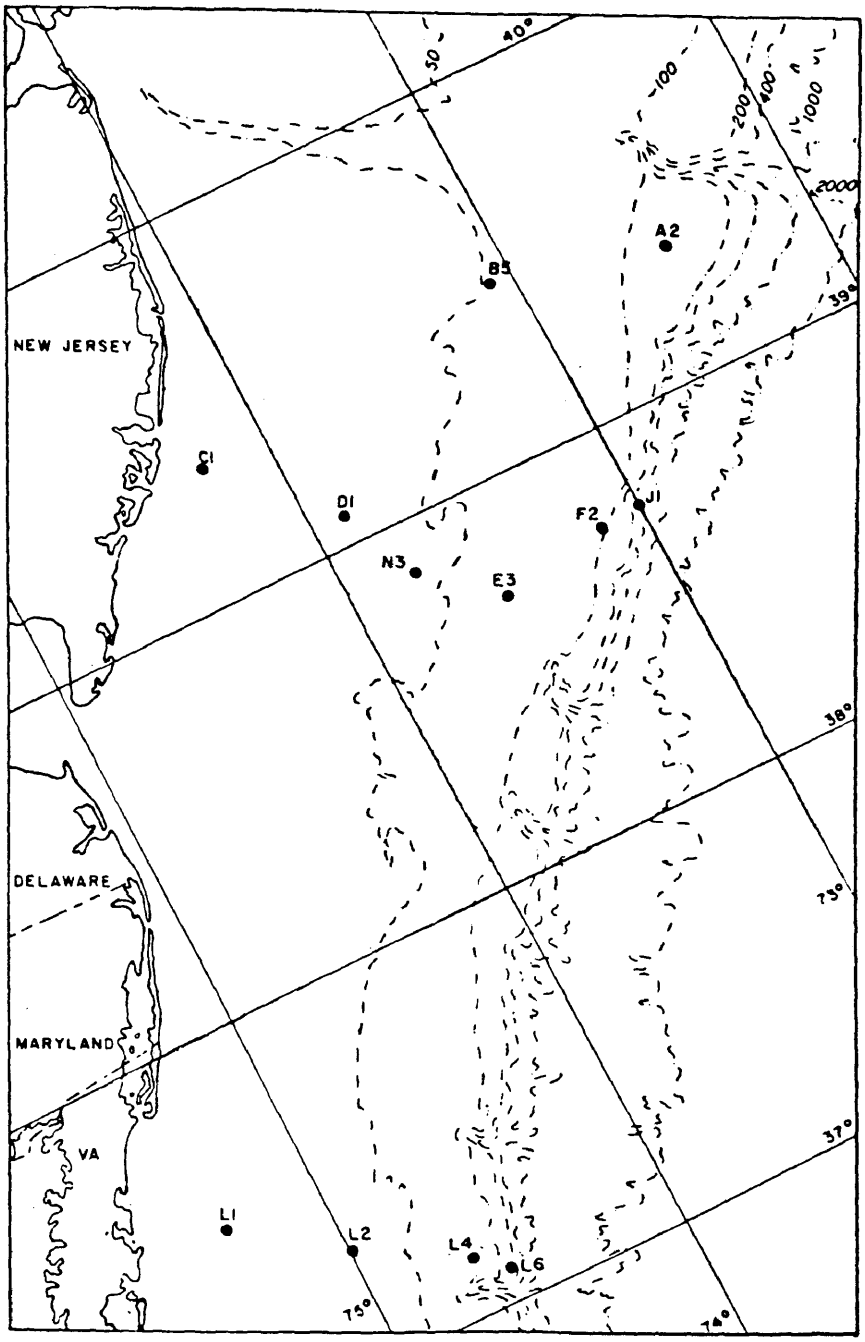

40°
50
100
200
400
1000
2000
A2
B5
39°
NEW JERSEY
C1
D1
F2
J1
N3
E3
38°
DELAWARE
75°
MARYLAND
VA
37°
L1
L2
L4
L6
75°
74°

Table 1. Summary of hydrographic data for cruises BLM 01W-BLM 08W.

CRUISE	STATION	DEPTH(m)	SURFACE TEMP(C°)	SURFACE SAL‰
BLM 01W	C1	12	17-18	30-31
(Oct. 75')	D1	38-40	17	32
	N3	46	16-17	33-34
	E3	62	16-17	33
	F2	107	16-17	34
	J1	250-300	19-21	34-35
BLM 02W	C1	17-20	2-3	30-31
(Feb. 76')	D1	31-38	4	31-33
	N3	43-48	6-7	32-33
	E3	65-71	8-9	32-34
	F2	110-123	9-10	34-35
	J1	300-800	10	34-35
BLM 03W	C1	16	16-18	32
(June 76')	D1	40	17	32
	N3	41-45	16	32
	E3	60	16	32
	F2	75-77	15-16	32-33
	J1	370	15-16	33-34
BLM 04W	C1	14-16	20-21	32
(Aug-Sep 76')	D1	40-42	22-23	32
	N3	37-49	20-22	32
	E3	62-66	21-22	33-35
	F2	107-119	20-23	33-35
	J1	300-1250	21-23	33-35
BLM 05W	L1	24-27	15-16	33
(Nov 76')	L2	41-43	12-13	34
	L4	97	14	35
	L6	106-658	13-14	34-35
	C1	20-31	9-10	32-33
	D1	40	11	34
	N3	46	10	34
	E3	53	11	--
	F2	100	14	--
	J1	330	12	35
	B5	55-60	10-12	33-34
	A2	125-132	12-13	34-35

Table 1 continued.

CRUISE	STATION	DEPTH(m)	SURFACE TEMP(C°)	SURFACE SAL‰
BLM 06W (Feb-Mar77')	L1	18	2-3	34-35
	L2	41	4-5	34-35
	L4	94	11-12	36
	L6	274-382	11-13	35-36
	C1	15	2-4	33
	D1	38	3	34
	N3	40-43	4	34
	E3	49-58	9-10	35-36
	F2	91-107	12	35
	J1	340	10-12	35-36
	B5	63	6-7	34-35
	A2	136	8-10	34-35
BLM 07W (May77')	L1	23	14-16	33
	L2	40	14-16	33
	L4	86	17-18	36
	L6	350	18-20	36
	C1	16	15-17	32
	D1	32-50	17	33
	N3	47	18	34
	E3	60	16-20	34
	F2	106	18-19	34
	J1	381	16-20	34-36
	B5	60-68	15-17	33
	A2	138-140	13-17	34
BLM 08W (Aug77')	L1	23	22-24	32
	L2	42	25-26	32
	L4	95-97	25-26	35
	L6	197-320	25-27	34-35
	C1	16	21-22	32
	D1	39-46	24	33
	N3	43-46	24	--
	E3	64-65	23-24	32
	F2	--	--	--
	J1	341	23-24	32-33
	B5	61-67	22-24	32
	A2	128	23-24	34

Table 2. Sources of material, collection data and lengths of hakes used in radipgraphic analysis of meristics and pterygiophore interdigitation. Standard acronyms for resource collections follow Leviton et al. (1985).

SPECIES	COLL.#	LOCATION	# SPECIMENS	SL(mm)
U. earlli	VIMS 06557	Gulf of Mexico	1	195
	USNM 025295	N. Carolina	1	124
	USNM 155746	32°34'N,79°05'W	1	55
	USNM 155747	Wilmington,N.C.	2	50-60
	USNM 226521	32°29'N,79°42'W	3	88-129
	USNM 226522	32°29'N,79°41'W	3	91-122
	USNM 226523	32°29'N,79°41'W	1	113
	USNM 226524	33°14'N,78°24'W	1	130
	USNM 226525	34°14'N,78°24'W	1	82
	USNM 226526	32°28'N,79°42'W	4	91-132
	USNM 226530	32°29'N,79°40'W	4	96-157
	USNM 226531	32°29'N,79°41'W	5	138-166
	USNM 226543	28°48'N,80°38'W	1	74
U. floridana	VIMS 03756	Silver Bay	1	165
	VIMS 04142	Brunswick Snd.,Ga.	5	78-113
	VIMS 04152	Silver Bay	4	52-85
	VIMS 04192	Pensacola, Fl.	2	81,109
	VIMS 04193	Cumberland Id.,Ga.	2	129,184
	VIMS 04194	N.Cumberland R.,Ga.	2	133,157
	VIMS 04195	Santa Rosa Snd.,Fl.	1	66
	VIMS 04196	Oregon S646	1	185
	USNM 073010	Key West,Fl.	1	63
	USNM 116729	Beaufort,N.C.	16	35-49
	USNM 131586	26°18'N,83°09'W	1	59
	USNM 155738	Texas	1	77
	USNM 155782	Cape Canaveral,Fl.	1	86
	USNM 155783	St. Aug.,Fl.	1	67
	USNM 156146	Pelican-Sta. 120-5	1	94
	USNM 214118	Brickhill Crk.,Ga.	5	64-75
U. cirrata	USNM 115686	22°23'N,91°45'W	1	141
	USNM 116929	Tortugas,Fl.	1	140
	USNM 155642	29°04'N,88°44'W	1	114
	USNM 218169	29°18'N,88°51'W	1	108
	USNM 218192	28°58'N,84°44'W	1	109
	USNM uncata	24°32'N,83°36'W	1	197
	USNM uncata	28°59'N,88°48'W	1	198
	USNM uncata	28°35'N,91°12'W	2	186-220

Table 2 continued.

SPECIES	COLL.#	LOCATION	# SPECIMENS	SL(mm)
P. chesteri	VIMS 05238	36°43'N,74°39'W	4	67-150
	USNM 025903	Newport,R.I.	17	73-98
	USNM 026081	Marthas Vineyard,Ma.	5	68-83
	USNM 026097	No data	1	79
	USNM 028732	No data	9	58-76
	USNM 083821	Ga.,S.C.	12	54-65
	USNM 092695	No data	1	63
	USNM uncata	Atlantic Arctus Expd.	6	105-147

Table 3. Ranges of meristic characters in adults of Phycis chesteri and six species of Urophycis.

	U. tenuis	U. chuss	U. regia	U. floridana	U. earlli	U. cirrata	P. chesteri
caudal fin rays	33-39*	28-34	28-32	28-32*	27-30*	28-33	28-35*
1st dorsal fin rays	9-10*	9-11*	8-10	10-13	8-11	9-11*	8-11*
2nd dorsal fin rays	50-59*	53-64*	43-52	54-63	57-63*	54-68	50-63
anal fin rays	41-52*	45-56*	41-50*	45-54*	49-56*	46-58	43-53*
vertebrae (total)	47-50*	45-50*	44-47*	44-50*	45-47*	47-52*	45-52
caudal vertebrae	34-35*	33-36	30-33*	30-34*	31-33*	32-37	31-37
abdominal vertebrae	13-17	14-17	13-15	14-17	14-15	15-17	13-16
pelvic fin rays	3	3	3	3	3	3	3
epibranchial gill rakers (1st arch)	2*	3*	3*	2	2	3	4-5
source of data (see below)	1,3,6, 8,11	1,2,4,5, 6,8,11	1,2,3, 4,5,8	1,7,12	1,5,12	1,12	1,10,11, 12

Data sources are: (1)Svetovidov, 1948; (2)Hildebrand and Cable, 1937; (3)Bigelow and Schroeder, 1953; (4)Leim and Scott, 1966; (5)Miller and Jorgenson, 1973; (6)Musick, 1973; (7)Hoese and Moore, 1977; (8)Markle, 1982; (9)Fahay, 1983; (10)Wenner, 1983; (11)Methven, 1985; (12)Cohen and Musick, pers.comm.

Ranges marked by asterisk have been extended by this study. See appendix Tables A-1 to A-7.

RESULTS

SECTION I. MORPHOLOGY OF PHYCIS AND UROPHYCIS LARVAE

Three types of characters (meristics, pterygiophore interdigitation and morphometrics) were used to identify larval hake of the genera Urophycis and Phycis. Meristic characters included numbers of epibranchial gill rakers, vertebrae and fin rays (dorsal, caudal and pelvic). Morphometric characters included body depth at vent, mandibular length, and height of the pelvic fin base. In addition, the position of anal and dorsal fin pterygiophores relative to haemal or neural spines helped delimit certain hake species.

MERISTICS

Epibranchial gill rakers:

The number of gill rakers supported by the epibranchial bone of the first gill arch (Fig.2) delimited Urophycis and Phycis larvae above 13 and 18 mm,

respectively (Table 4). In general, U. floridana, U. earlli and U. tenuis had two, U. chuss, U. regia and U. cirrata had three, and P. chesteri had four or five epibranchial gill rakers. Some overlap was observed, however. Approximately 3% of U. chuss and U. regia possessed two or four epibranchial gill rakers (n = 1263) and 11% of U. tenuis possessed a 3rd gill raker (n = 57). In addition, the 3rd gill raker in U. cirrata is sometimes difficult to see (Cohen and Musick, pers. comm.).

In U. chuss, U. regia and U. tenuis, the adult complement of epibranchial gill rakers was attained by 11-13 mm. Although undocumented due to a lack of material, the other three species of Urophycis probably develop at a similar rate. P. chesteri does not attain the adult complement until 16-18 mm (Methven, 1985), but by 13 mm the third epibranchial gill raker has developed and serves to delimit this species from U. tenuis, U. earlli and U. floridana.

Figure 2. Epibranchial gill rakers on first gill arch of U. chuss (12.2 mm).

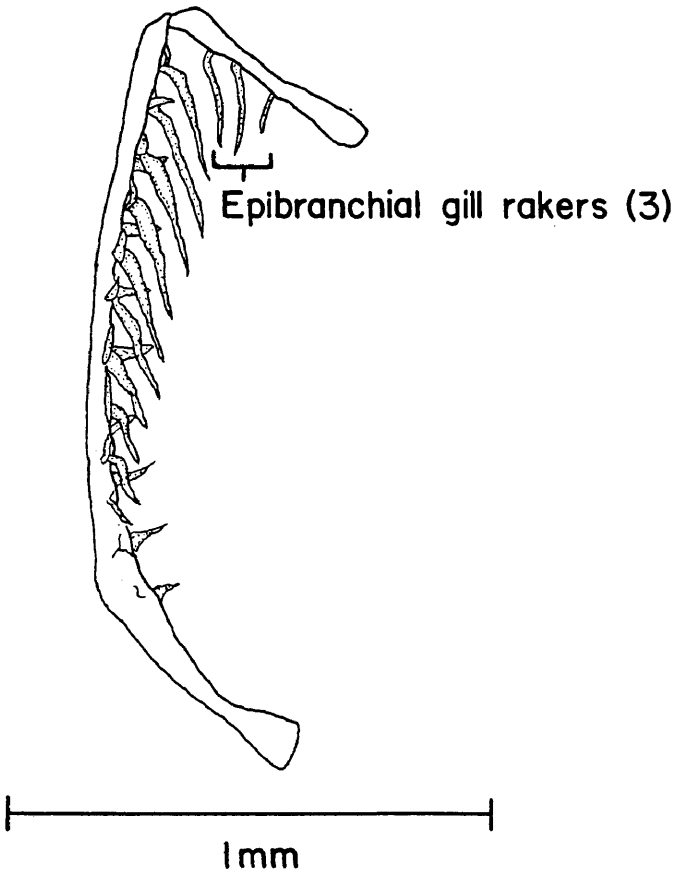

Epibranchial gill rakers (3)
1mm

Table 4. Percent frequency of the number of gill rakers on the epibranchial bone of the left first gill arch in Phycis chesteri and six species of Urophycis. Slash indicates counts of gill rakers on both right and left sides.

		EPIBRANCHIAL GILL RAKERS					
		2	3/2	3	4/3	4	5
U. chuss	(n=614)	--	1	97	1	1	--
U. regia	(n=649)	--	1	97	1	1	--
* U. cirrata	(n=13)	--	--	100	--	--	--
U. tenuis	(n=57)	89	9	2	--	--	--
* U. floridana	(n=44)	100	--	--	--	--	--
* U. earlli	(n=32)	100	--	--	--	--	--
* P. chesteri	(n=32)	--	--	--	--	75	25

Note: Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Caudal fin rays:

Methven (1985) reported that numbers of caudal fin rays separate U. tenuis and U. chuss. In my sample, 99% of U. tenuis possessed 35 or more caudal fin rays (Table 5), while all other species of Urophycis had less than 35 rays. Although ranges in U. tenuis and P. chesteri overlapped, over half of the U. tenuis examined possessed 37 or more caudal fin rays, while P. chesteri has never been recorded with more than 36 rays.

Over half of the P. chesteri examined possessed more than 33 caudal fin rays, while no U. earlli or U. cirrata, and only 1% of U. regia, 4% of U. floridana and 6% of U. chuss had this many rays.

U. earlli has never been recorded with more than 31 caudal fin rays, while U. floridana commonly has more than 31 rays (Fig.3).

U. chuss and U. regia had attained the adult complement of caudal fin rays by 8-9 mm. U. tenuis from the Scotian Shelf is reported to attain the adult complement of caudal fin rays by 7-8 mm (Methven, 1985), but development in the Middle Atlantic Bight was not complete until 11 mm (Fig.4).

Fahay and Markle (1984) reported that U. regia has six vertebrae supporting the caudal fin (Fig.5)., while U. chuss and U. tenuis are reported to have seven and eight supporting vertebrae respectively. I found 7 to 8

vertebrae support the caudal fin in U. regia, while 6 to 8 and 7 to 9 supporting vertebrae were found in U. chuss and U. tenuis, respectively (Table 6). This character does not aid in the identification of Urophycis or Phycis larvae from the Middle Atlantic Bight because of overlapping ranges.

Table 5. Number of caudal fin rays in *Phycis chesteri* and six species of *Urophycis*.

	NUMBER OF CAUDAL FIN RAYS											
	29	30	31	32	33	34	35	36	37	38	39	40
U. tenuis (n=195)	--	--	--	--	--	2	28	56	65	34	9	1
* *P. chesteri* (n=56)	--	--	1	8	15	19	10	3	--	--	--	--
U. regia (n=71)	--	1	19	34	16	1	--	--	--	--	--	--
U. chuss (n=50)	1	1	22	13	10	3	--	--	--	--	--	--
* *U. cirrata* (n=13)	--	--	3	8	2	--	--	--	--	--	--	--
* *U. floridana* (n=55)	-	5	13	21	14	2	--	--	--	--	--	--
* *U. earlli* (n=31)	12	13	6	--	--	--	--	--	--	--	--	--

Note: As few as 28 caudal fin rays have been reported in *P. chesteri* (Wenner, 1983) and *U. cirrata* (Cohen and Musick, pers. comm.). This may be because some of the small procurrent rays are not easily seen in larger fish.

Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Table 6. Percent frequency distribution of the number of vertebrae supporting the caudal fin in Phycis chesteri and six species of Urophycis.

		NUMBER OF SUPPORTING VERTEBRAE			
		6	7	8	9
	U. regia (n=66)	-	73	27	-
	U. chuss (n=50)	8	82	10	-
	U. tenuis (n=48)	-	6	75	19
*	U. floridana (n=53)	-	87	13	-
*	U. earlli (n=31)	16	84	-	-
*	U. cirrata (n=10)	10	70	20	-
*	P. chesteri (n=57)	-	54	42	4

Note: Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Figure 3. Bar graphs showing number of caudal fin rays in Phycis chesteri and six species of Urophycis. White boxes = 1 standard deviation to each side of mean; black boxes = 2 standard errors to each side of mean; horizontal lines = ranges. Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

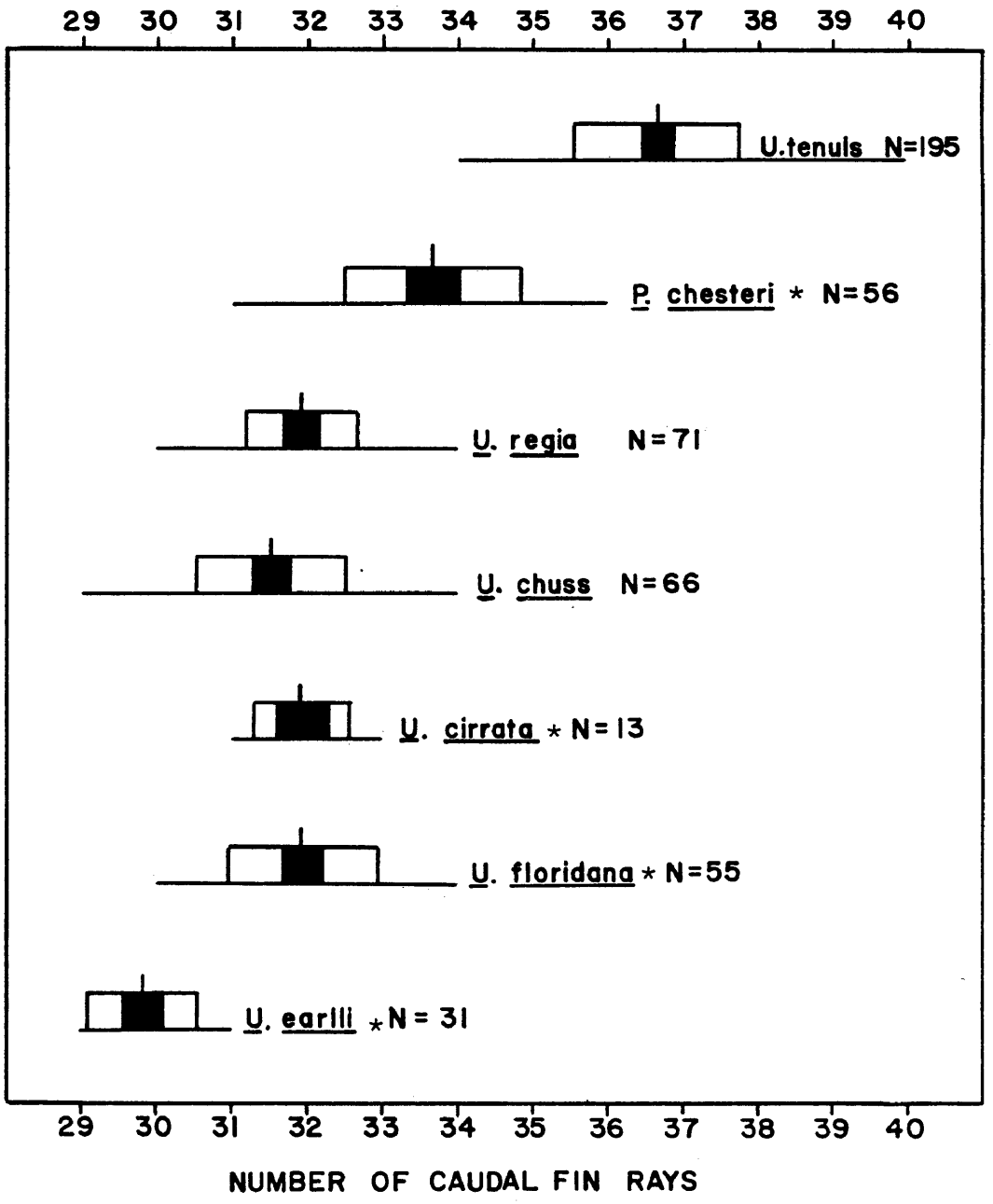

29 30 31 32 33 34 35 36 37 38 39 40
U.tenuis N=195
P. chesteri * N=56
U. regia N=71
U. chuss N=66
U. cirrata * N=13
U. floridana * N=55
U. earlii *N=31
29 30 31 32 33 34 35 36 37 38 39 40
NUMBER OF CAUDAL FIN RAYS

Figure 4. Scatter plot of the development of adult complement of caudal fin rays in U. chuss, U. regia and U. tenuis.

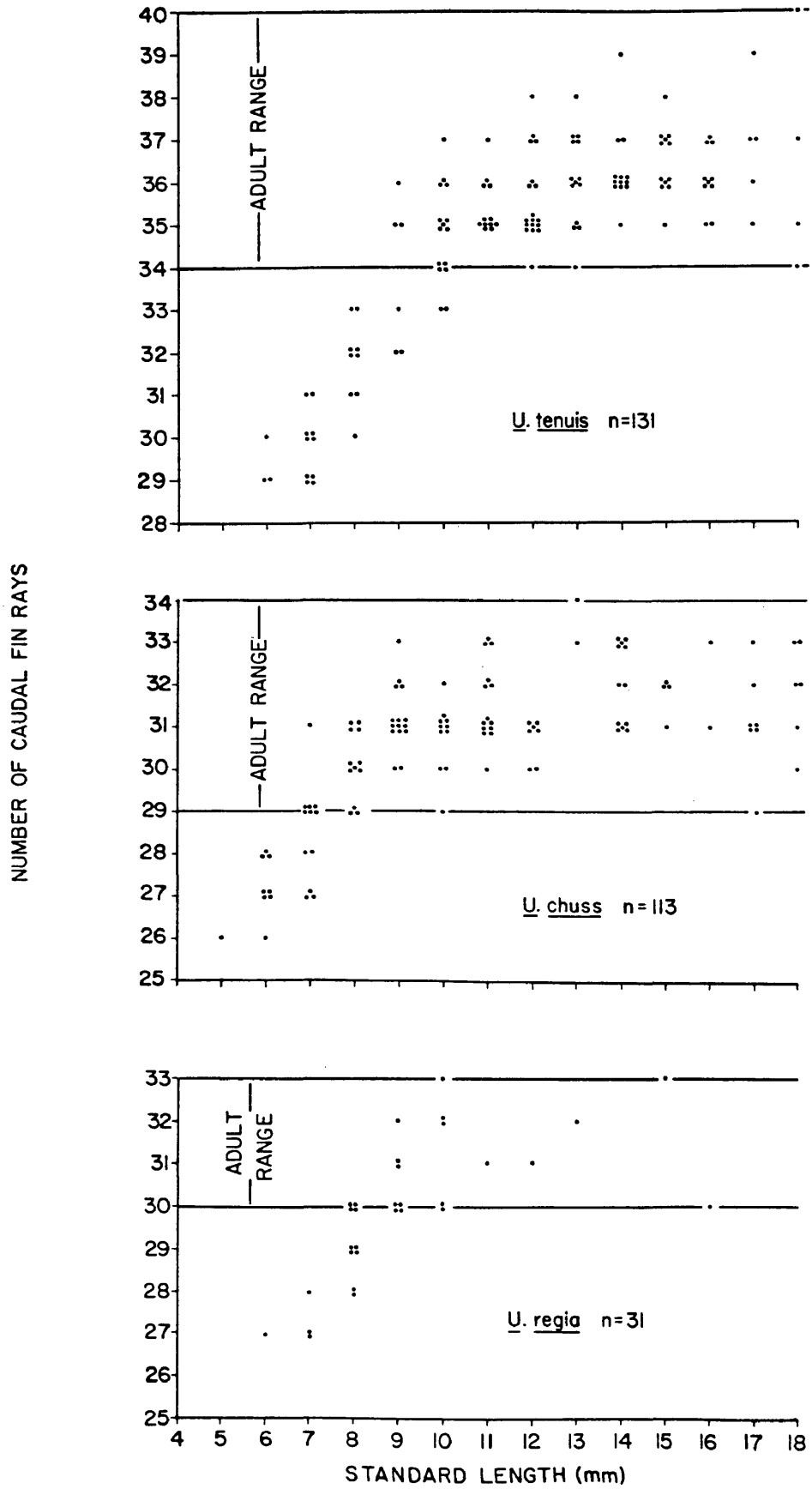
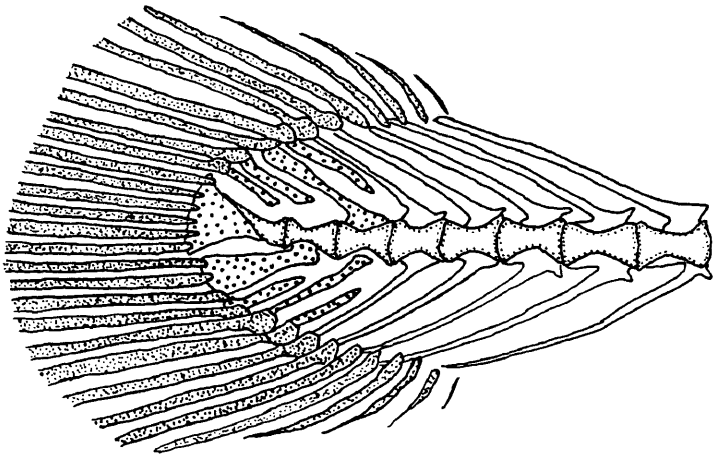

NUMBER OF CAUDAL FIN RAYS
ADULT RANGE
U. tenuis n=131
ADULT RANGE
U. chuss n=113
ADULT RANGE
U. regia n=31
STANDARD LENGTH (mm)

Figure 5. Caudal fin of U. regia (15.3 mm).



1 mm

Second dorsal fin rays:

Hildebrand and Cable (1938) noted that U. regia had fewer second dorsal fin rays than U. chuss or U. floridana, and that by 7 mm U. chuss had developed more second dorsal fin fulcra than U. regia. In my material numbers of second dorsal fin pterygiophores developed prior to the rays that they support and separated U. regia and U. chuss at sizes as small as 6 mm (Fig.6). The relatively low number of second dorsal fin rays in U. regia delimited this species from P. chesteri and other Urophycis species with very little overlap (Table 7). U. regia has always been found with less than 53 second dorsal fin rays, while in this study only 1% of U. chuss (n = 106) and 7% of U. tenuis (n = 56) possessed so few rays.

Although ranges overlapped, U. cirrata had more second dorsal fin rays than P. chesteri and other species of Urophycis (except U. earlli). These ranges were exceeded by all five specimens of U. cirrata collected in this study.

U. chuss, U. tenuis and U. regia from the Middle Atlantic Bight attained the adult complement of second dorsal fin rays by 14 mm (Fig.7). It should be noted that U. chuss and U. tenuis from the Scotian Shelf were reported to attain the adult complement of these rays at 9.6 and 11.4 mm, respectively (Methven, 1985).

Figure 6. Scatter plot of the development of the number of second dorsal fin pterygiophores in U. chuss and U. regia.

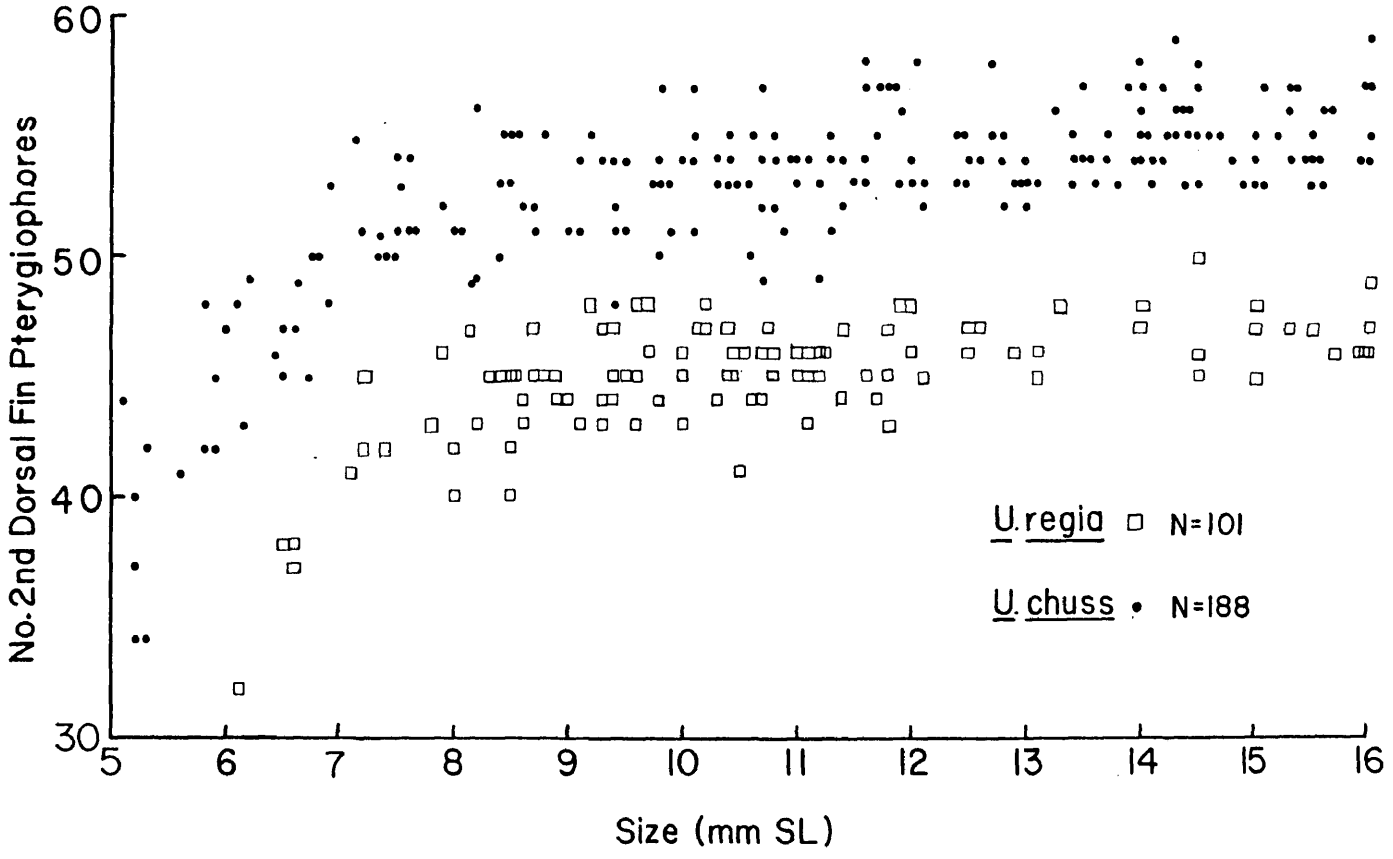
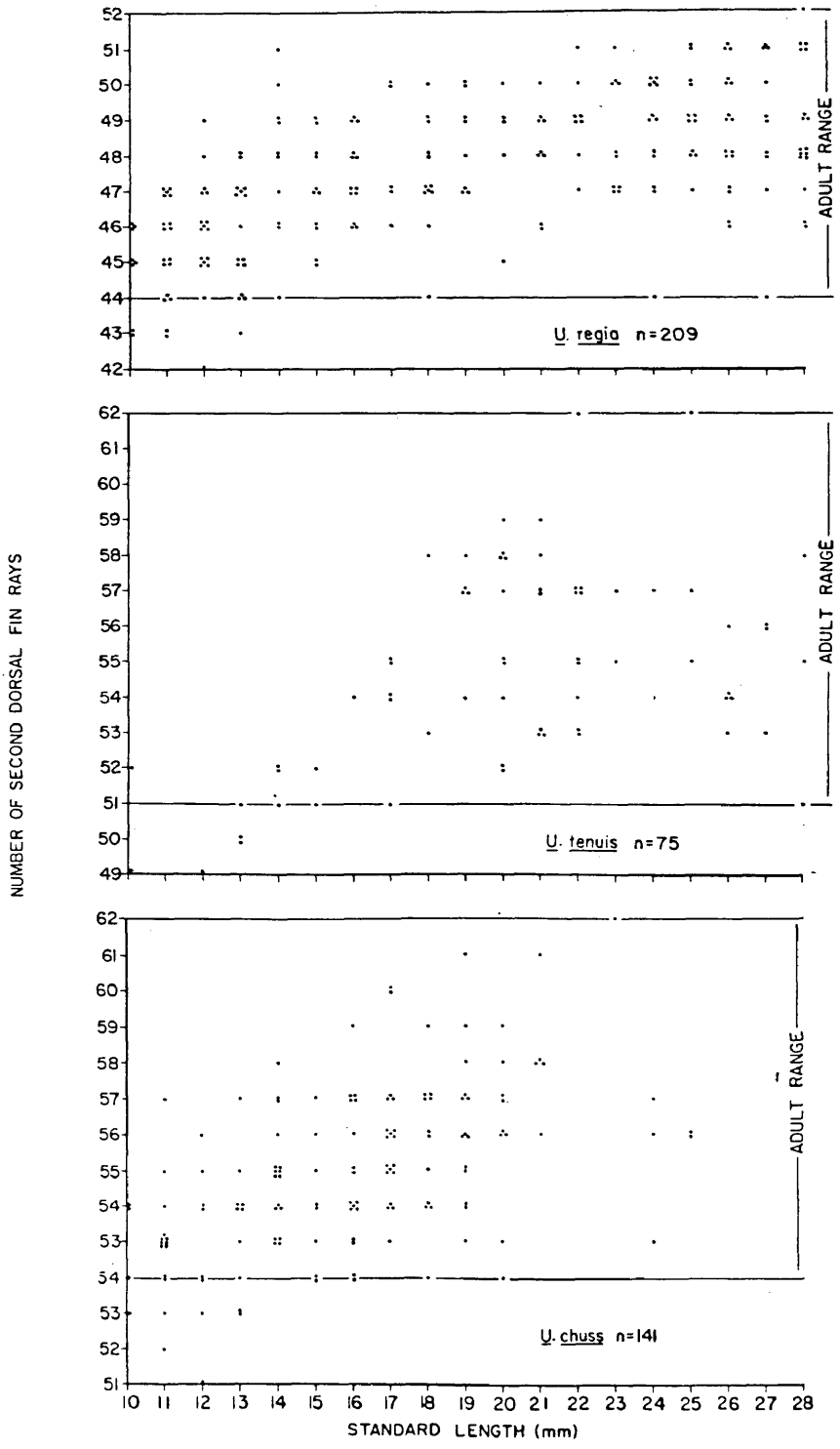

60
50
40
30
5
6
7
8
9
10
11
12
13
14
15
16
No. 2nd Dorsal Fin Pterygiophores
Size (mm SL)
U. regia □ N=101
U. chuss • N=188

Table 7. Percent frequency distribution of the number of second dorsal fin rays in Phycis chesteri and six species of Urophycis.

		NUMBER OF SECOND DORSAL FIN RAYS																								
		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
U. regia	(n=153)	1	1	10	14	20	24	19	10	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
U. tenuis	(n=56)	--	--	--	--	--	--	--	2	5	16	13	14	5	21	9	7	2	2	4	--	--	--	--	--	--
U. chuss	(n=107)	--	--	--	--	--	--	--	--	1	7	12	12	20	21	10	8	7	1	--	--	--	--	--	--	--
*P. chesteri	(n=58)	--	--	--	--	--	--	--	--	--	5	14	9	24	22	9	9	5	2	--	2	--	--	--	--	--
*U. earlli	(n=32)	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	6	25	25	9	22	3	3	--	3
*U. cirrata	(n=13)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8	--	8	8	8	15	15	38	--	--

Note: Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Figure 7. Scatter plot of the development of adult complement of second dorsal fin rays in U. chuss, U. regia and U. tenuis.


NUMBER OF SECOND DORSAL FIN RAYS
U. regia n=209
ADULT RANGE
U. tenuis n=75
ADULT RANGE
U. chuss n=141
ADULT RANGE
STANDARD LENGTH (mm)

First dorsal fin rays:

Despite overlapping ranges, numbers of first dorsal fin rays helped distinguish U. floridana from other species of hake. U. regia and U. earlli have never been found with more than 10 and 11 first dorsal rays, respectively, while over 80% of U. floridana (n = 45) possessed more than 11 rays (Table 8). One third of U. floridana examined possessed 13 first dorsal rays, but in no other species of hake are these rays this numerous.

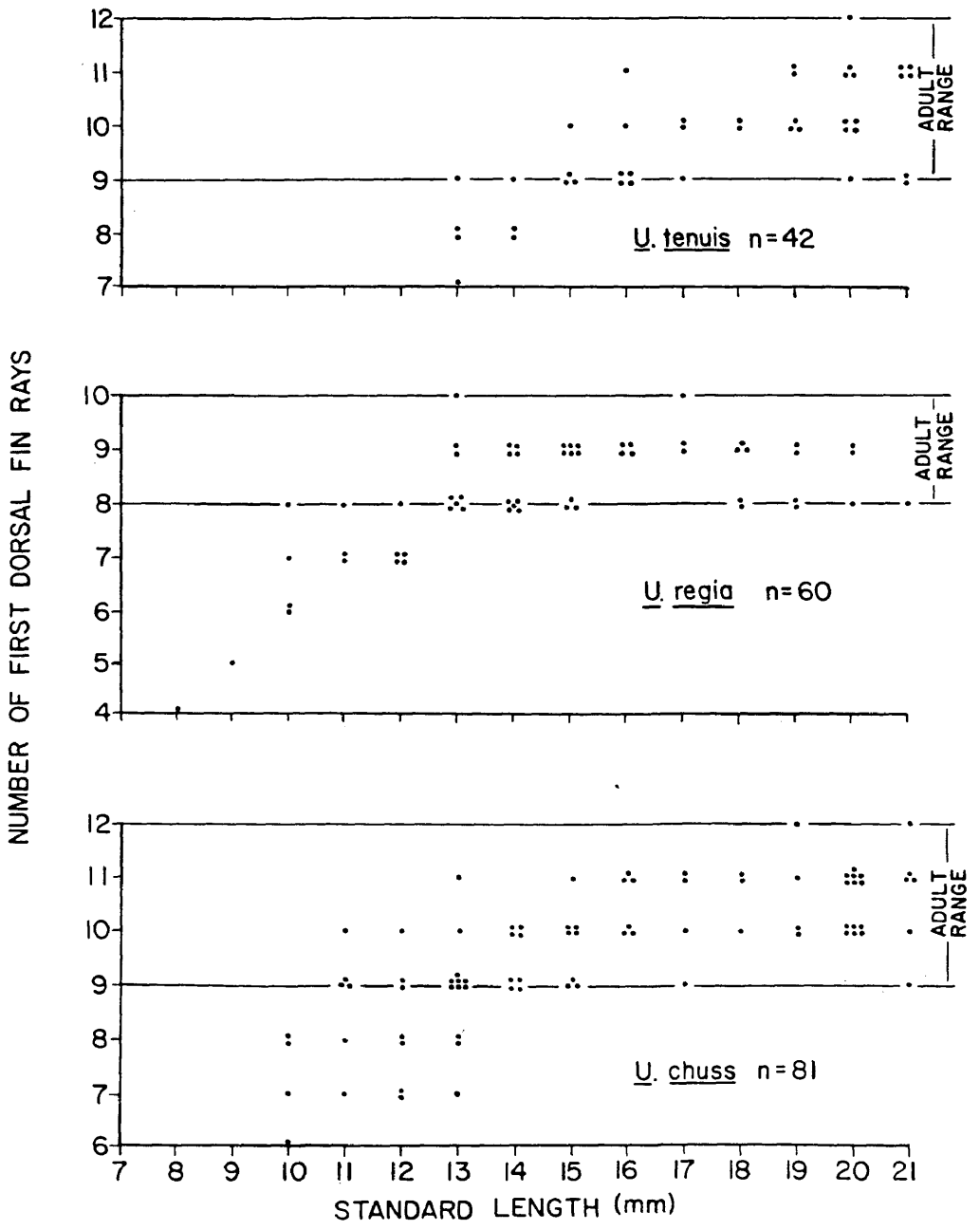
U. regia, U. chuss and U. tenuis had developed the adult complement of first dorsal fin rays by 13, 14 and 15 mm, respectively (Fig.8). Fin development in U. floridana was not examined because of a lack of small specimens.

Table 8. Percent frequency distribution of the number of first dorsal fin rays in *Phycis chesteri* and six species of *Urophycis*.

		NUMBER OF FIRST DORSAL FIN RAYS					
		8	9	10	11	12	13
U. regia	(n=82)	17	74	9	--	--	--
* *P. chesteri*	(n=73)	1	26	52	18	3	--
* *U. earlli*	(n=32)	--	19	66	16	--	--
U. tenuis	(n=63)	--	16	38	41	5	--
U. chuss	(n=95)	--	2	35	54	9	--
* *U. cirrata*	(n=13)	--	--	15	62	23	--
* *U. floridana*	(n=45)	--	--	--	18	49	33

Note: Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Figure 8. Scatter plot of the development of adult complement of first dorsal fin rays in U. chuss, U. regia and U. tenuis.


NUMBER OF FIRST DORSAL FIN RAYS
STANDARD LENGTH (mm)
U. tenuis n=42
U. regia n=60
U. chuss n=81
ADULT RANGE
ADULT RANGE
ADULT RANGE

Abdominal vertebrae:

Although numbers of total vertebrae cannot be used to identify larval hake because of overlapping ranges, abdominal vertebral counts are taxonomically useful. The precocious development of abdominal vertebrae aids in the identification of larvae as small as 4 mm.

In my material U. chuss (n = 448) possessed 14 to 16 abdominal vertebrae, but over 85% of the specimens had 15 (Table 8). In all other species of Urophycis examined the count of 15 occurred in less than 20% of the specimens, and although ranges of U. chuss and P. chesteri were similar, P. chesteri commonly had 14 or 16 abdominal vertebrae. Consequently, in summer collections that have been found to contain only U. chuss, a check for species other than U. chuss need only be performed on those specimens that do not have 15 abdominal vertebrae. If other species are found, however, this time saving method of identification is not valid because larvae with 15 abdominal vertebrae may be misidentified.

U. regia spawns from September until February, with peak spawning activity in October (Barans and Barans, 1972). Fall ichthyoplankton collections consequently contained larvae of both U. chuss and U. regia.

U. regia had 13-15 abdominal vertebrae, but only eight specimens (n = 698) had 15, and seven of these specimens

had an anomolous 15th abdominal vertebra. This anomolous vertebra had an incompletely formed haemal arch (Fig.9). Because 99.9% of U. regia examined had less than 15 normal abdominal vertebrae, it can be assumed that specimens with 15 or more abdominal vertebrae are not U. regia. This is useful when identifying larvae smaller than 6 or 7 mm when numbers of second dorsal fin rays cannot be used to separate these two species.

Numbers of abdominal vertebrae helped identify U. tenuis larvae smaller than 10 mm, the size below which numbers of caudal fin rays no longer afforded confident identifications. In my material ninety percent of U. tenuis (n = 205) had 16 or more abdominal vertebrae, whereas only 6% of P. chesteri, 2% of U. chuss and no U. regia possessed this many vertebrae (Fig.10). No U. tenuis had fewer than 15 abdominal vertebrae, while counts this low were found in P. chesteri, U. chuss and U. regia.

U. tenuis larvae were found in the Middle Atlantic Bight only in the spring, accounting for 99% of the Urophycis collected at this time (U. regia juveniles accounted for the other 1%). Urophycis larvae under 10 mm that were present in spring collections yielded abdominal vertebral counts consistent with those of U. tenuis. Eighty-eight percent of the 154 specimens had at least 16 abdominal vertebrae, and no specimens were found with fewer than 15. It is unlikely that any of these small larvae were

U. floridana or U. cirrata. These two southern species were present only in winter collections and were longer than 10 mm when collected.

Larvae of U. earlli remain undescribed. Numbers of abdominal vertebrae may help separate this species from U. floridana and U. cirrata, the other two southern species of Urophycis. Over 80% of U. floridana and U. cirrata possessed 16 or 17 abdominal vertebrae, but U. earlli has never been recorded with this many.

Table 9. Percent frequency distribution of the number of abdominal vertebrae in Phycis chesteri and six species of Urophycis.

		NUMBER OF ABDOMINAL VERTEBRAE				
		13	14	15	16	17
U. tenuis	(n=205)	--	--	10	88	2
* U. cirrata	(n=13)	--	--	15	77	8
* U. floridana	(n=49)	--	2	14	78	6
U. chuss	(n=448)	--	11	87	3	--
* P. chesteri	(n=69)	--	12	83	5	--
* U. earlli	(n=31)	--	87	13	--	--
U. regia	(n=698)	9	89	1	--	--

Note: Although 8 specimens of U. regia had 15 abdominal vertebrae, in only one of these specimens (0.1%) was the 15th vertebra normally developed (Fig.7).

Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.

Figure 9. Anomalous 15th abdominal vertebra (U. regia, 9.7mm).

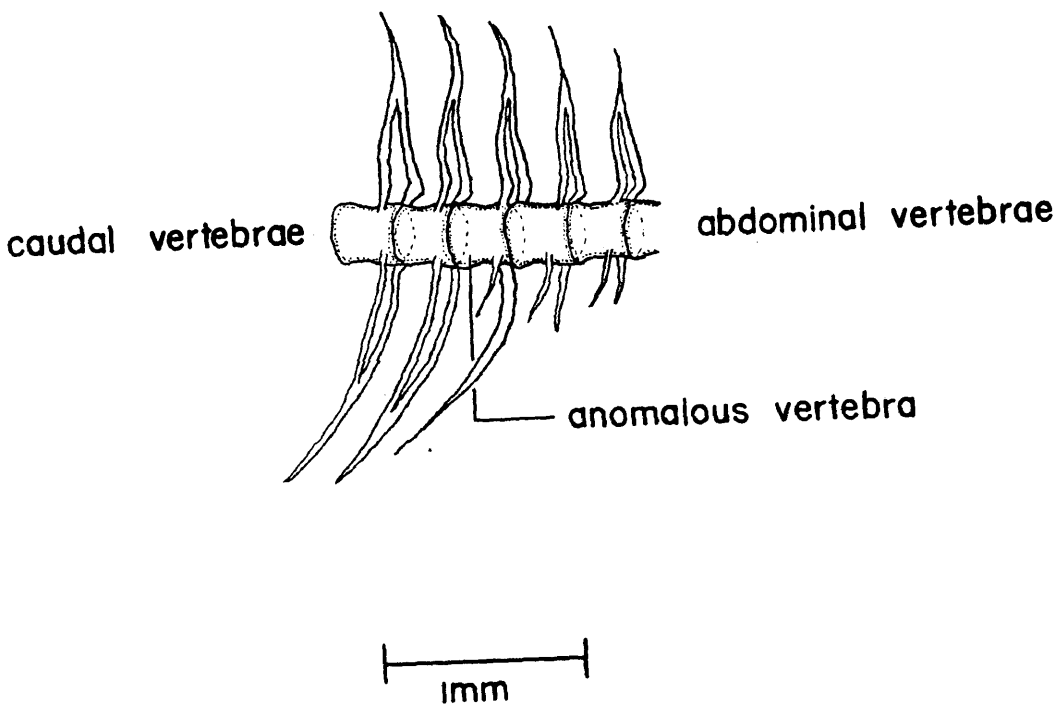
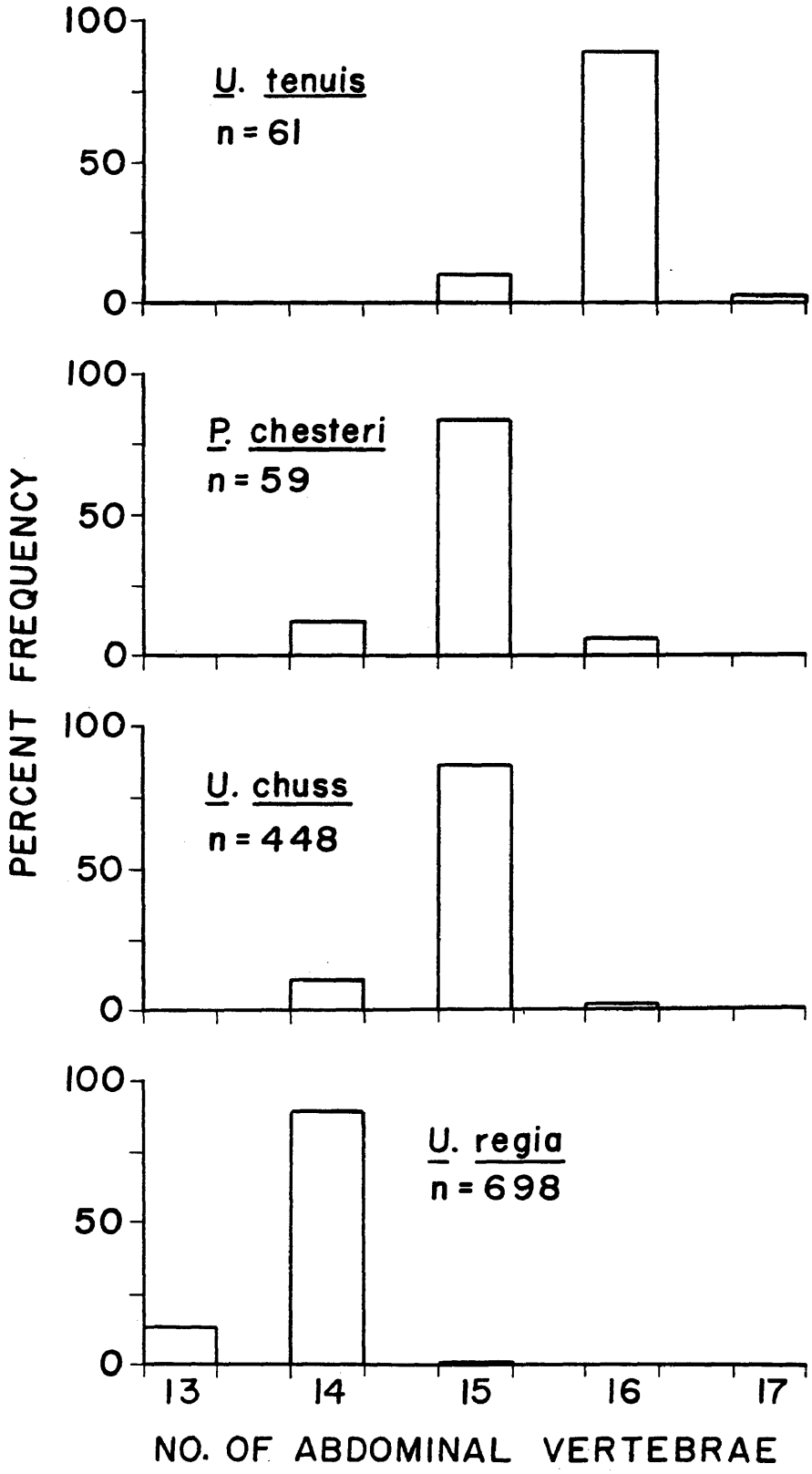

caudal vertebrae
abdominal vertebrae
anomalous vertebra
1mm

Figure 10. Percent frequency distribution of abdominal vertebrae in P. chesteri, U. chuss, U. regia and U. tenuis. Data from juvenile and adult specimens of P. chesteri are included.


100
50
0
U. tenuis
n = 61
P. chesteri
n = 59
U. chuss
n = 448
U. regia
n = 698
PERCENT FREQUENCY
13
14
15
16
17
NO. OF ABDOMINAL VERTEBRAE

PTERYGIOPHORE INTERDIGITATION

Anal fin pterygiophores:

The number of anal fin pterygiophores positioned anterior to the first haemal spine (Fig.11) helped distinguish *P. chesteri*, *U. cirrata* and *U. tenuis* from *U. earlli*, *U. floridana*, *U. regia* and *U. chuss* (Fig.12). In my material less than 2% of *U. tenuis* and no *U. cirrata* or *P. chesteri* had seven or more anal fin pterygiophores positioned anterior to the first haemal spine, while 45% of *U. chuss* and over half of *U. earlli*, *U. floridana* and *U. regia* had at least seven of these pterygiophores. More than 60% of *U. tenuis*, *U. cirrata* and *P. chesteri* had fewer than six anterior anal fin pterygiophores, whereas less than 2% of *U. regia* and no *U. earlli* or *U. floridana* had this few. The adult complement of these anal fin pterygiophores was acquired by 8-9 mm.

Figure 11. Anal fin pterygiophores lying anterior to the first haemal spine (U. chuss, 12.9mm).

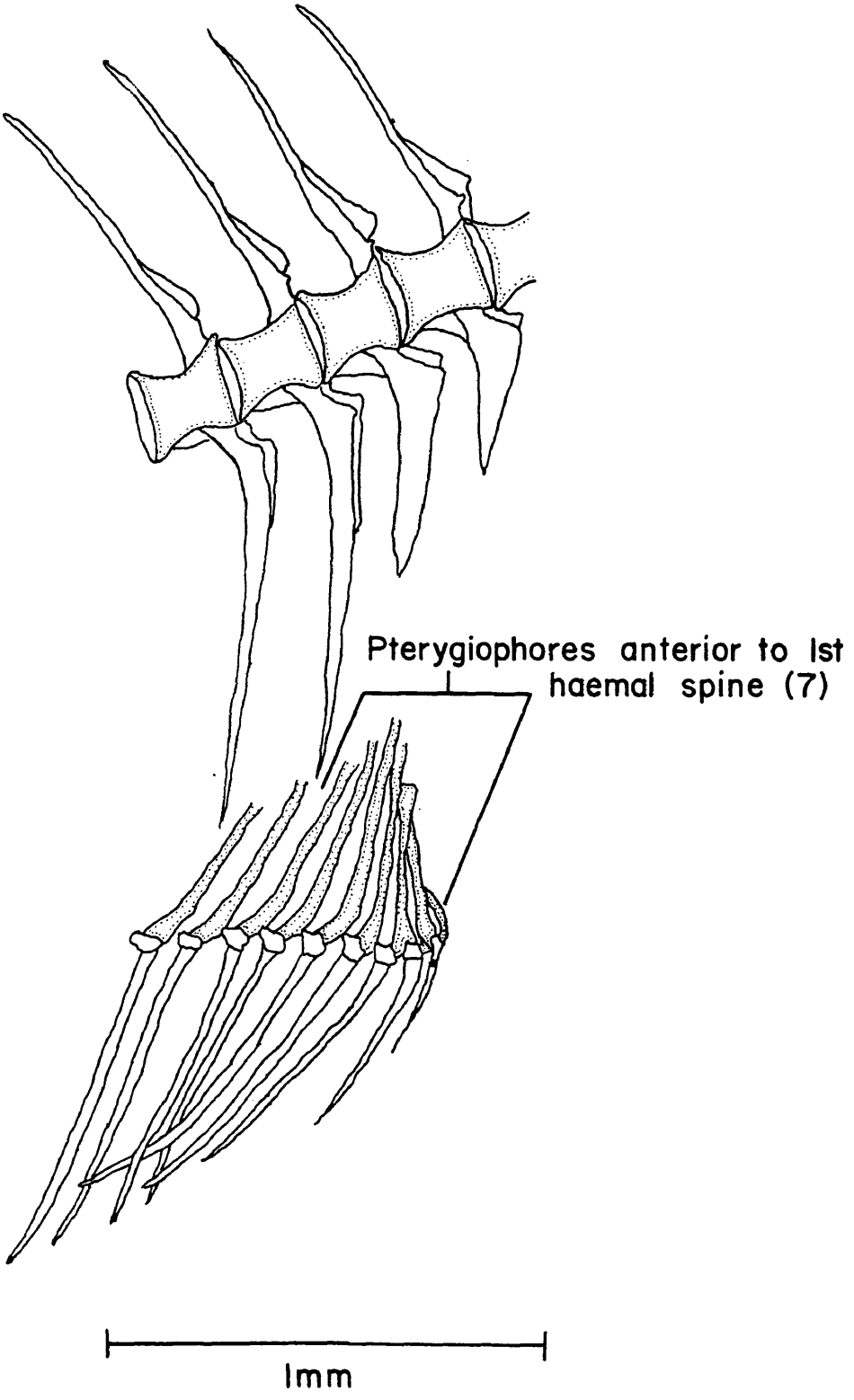
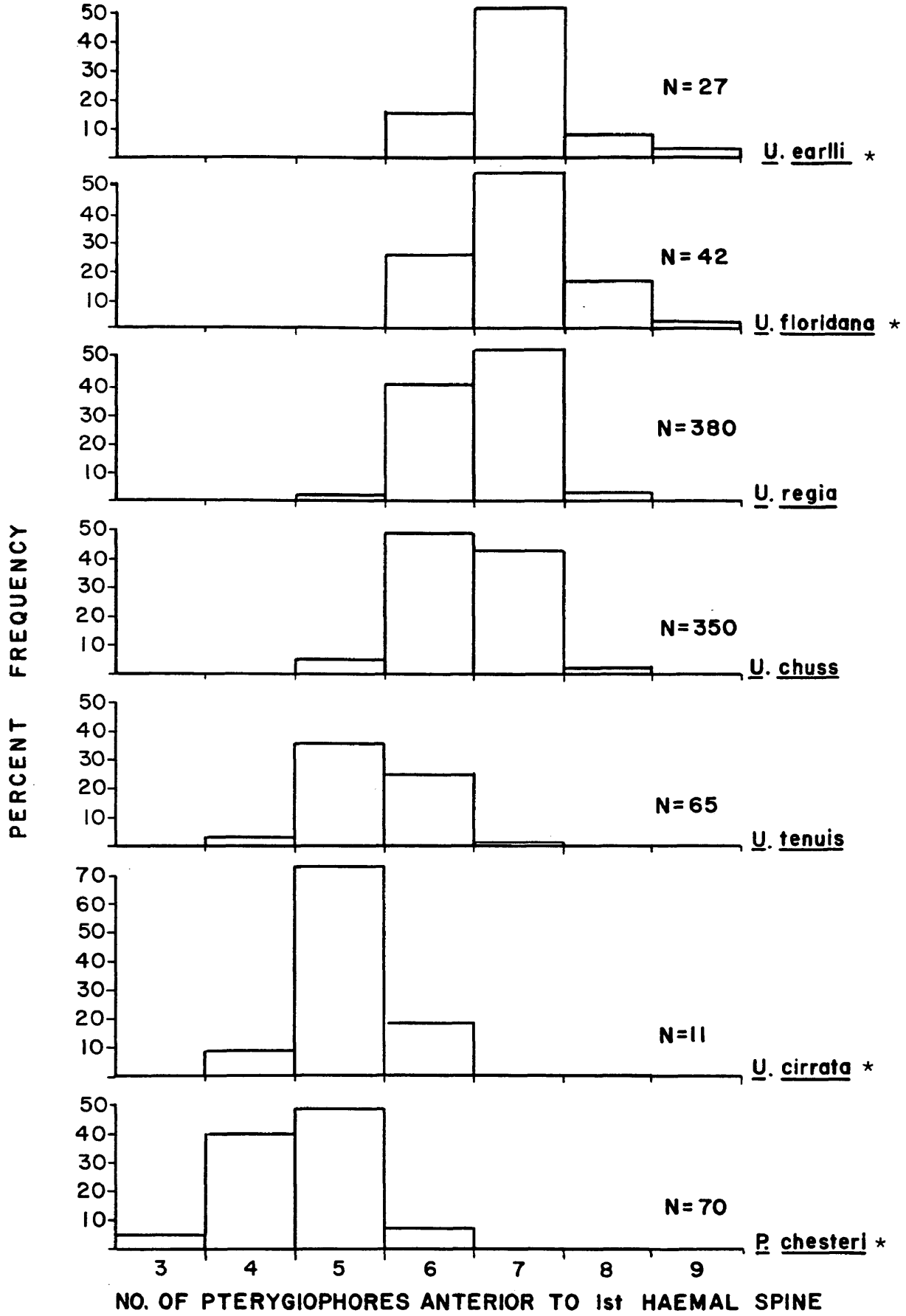

Pterygiophores anterior to 1st haemal spine (7)
1mm

Figure 12. Percent frequency distribution of number of pterygiophores anterior to first haemal spine in Phycis chesteri and six species of Urophycis. Asterisk denotes data from juvenile and adult specimens are included. All larvae had attained the adult meristic complement.


PERCENT FREQUENCY
N=27
U. earlli *
N=42
U. floridana *
N=380
U. regia
N=350
U. chuss
N=65
U. tenuis
N=11
U. cirrata *
N=70
P. chesteri *
3
4
5
6
7
8
9
NO. OF PTERYGIOPHORES ANTERIOR TO 1st HAEMAL SPINE

Pterygiophore interdigitation of second dorsal fin:

The position of the first pterygiophore of the second dorsal fin (as indicated by interneural space number) (Fig.13) is a character that helped separate U. chuss from U. regia, and U. floridana from U. earlli.

Numbers of second dorsal fin rays clearly separate U. chuss and U. regia, but larvae were frequently found with small "bite sized" sections of fin bases missing. This mutilation, perhaps due to predation, obviated counts of fin rays in these specimens. In these cases, pterygiophore interdigitation patterns helped separate these two species. Occasionally, the proximal tip of the dorsal pterygiophore was aligned with the distal tip of its associated neural spine. In these instances, the position of the pterygiophore was difficult to determine but was recorded in the more posterior interneural space. Over half of U. chuss examined (n = 431) had this insertion posterior to the 8th interneural space, whereas U. regia (n = 182) have always shown the insertion to be anterior to this point (Table 9). Over 75% of U. regia had this insertion anterior to the 8th interneural space, while less than 1% of U. chuss showed this pattern.

In over 70% of U. floridana (n = 42), the first pterygiophore of the second dorsal fin was positioned posterior to the 8th interneural space, whereas all juvenile and adult U. earlli (n = 27) were found with the

pterygiophore anterior to this point. In over half of U. earlli examined the first pterygiophore of the second dorsal fin projected into the 7th interneural space, while only 2% of U. floridana had the insertion this far forward.

U. chuss and U. regia developed this pattern of pterygiophore interdigitation by 12 mm. In larvae smaller than 12 mm the position of the proximal tip of the pterygiophore relative to the neural spines had not stabilized. The size at which this criterion can be used to identify U. earlli and U. floridana was not determined due to a lack of material. It is probable that this character cannot be used to identify larvae smaller than 12 mm.

Figure 13. First pterygiophore of the second dorsal fin projecting into the 9th interneural space (U. chuss, 12.9mm).

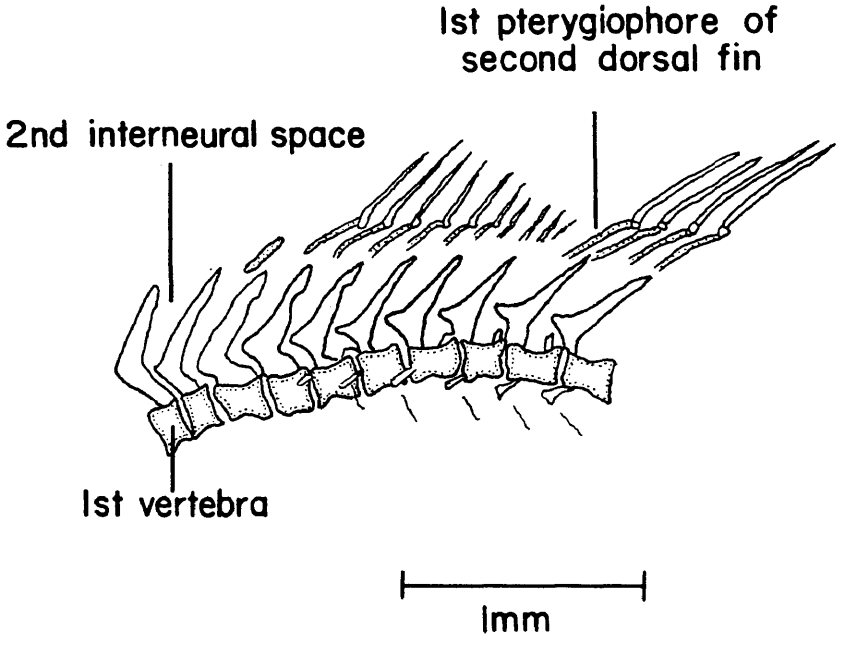

1st pterygiophore of
second dorsal fin
2nd interneural space
1st vertebra
1mm

Table 10. Position (as indicated by interneural space number) of the pterygiophore supporting the first ray of the second dorsal fin.

			INTERNEURAL SPACE			
			7	8	9	10
			(percent frequency)			
	U. tenuis	(n=66)	0	12	79	9
*	*U. floridana*	(n=42)	2	24	59	14
*	*P. chesteri*	(n=55)	6	56	36	2
	U. chuss	(n=431)	1	47	51	1
	U. regia	(n=182)	77	23	0	0
*	*U. earlli*	(n=27)	56	44	0	0

Note: If the pterygiophore is aligned with the tip of a neural spine, it is arbitrarily recorded as pointing into the space posterior to the spine in question.

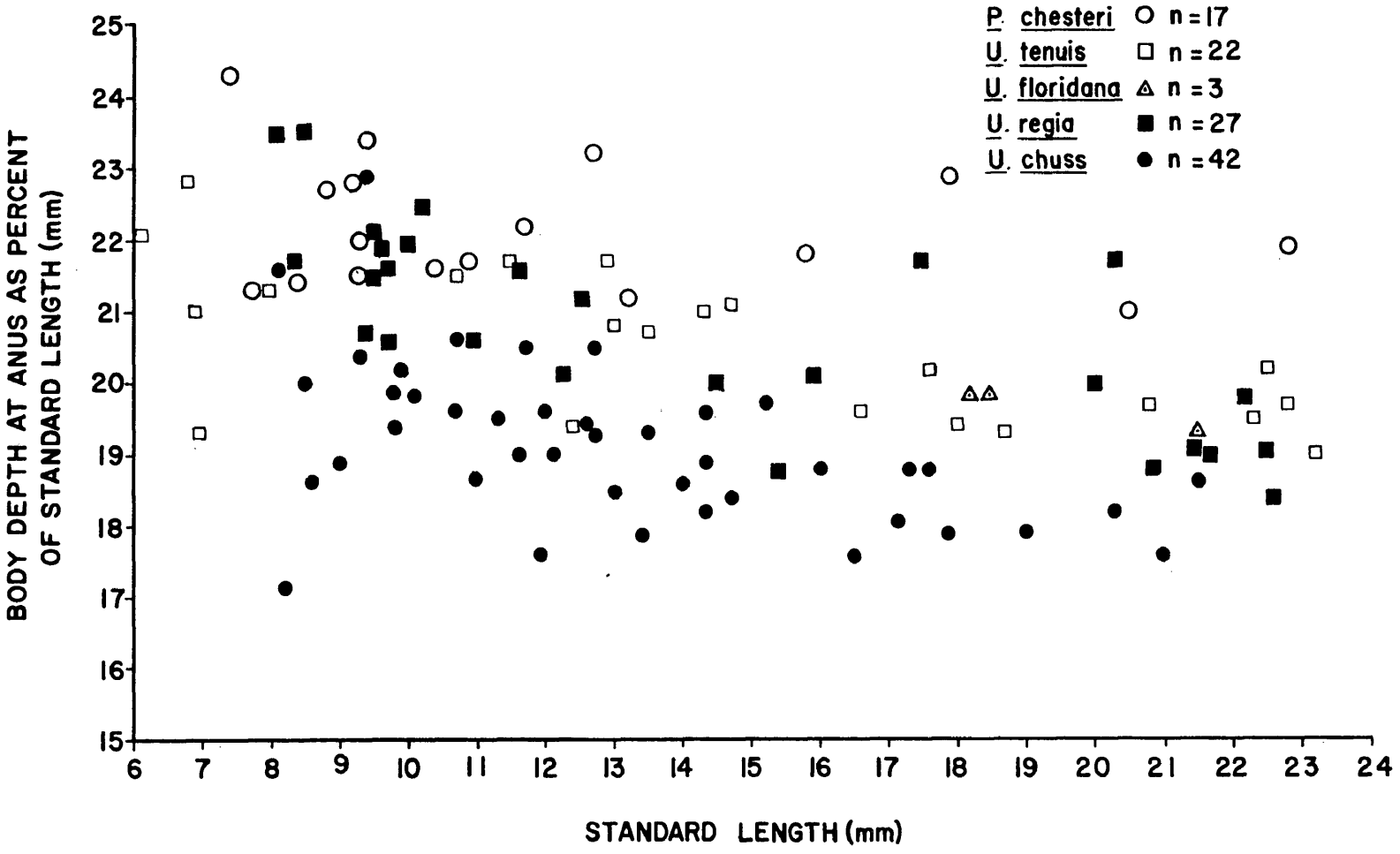
Asterisk denotes data from juvenile and adult specimens are included.

MORPHOMETRICS

Body depth at vent:

Body depth at the vent separated some species of larval hake at sizes larger than 12-13 mm (Fig.14). Methven (1985) showed *P. chesteri* to be deeper-bodied than *U. tenuis*, which in turn was deeper-bodied than *U. chuss*. My results concurred with these findings and showed little overlap among these three species. Ranges of body depth as percent of standard length for *P. chesteri*, *U. tenuis* and *U. chuss* were 21.0-23.4, 19.0-21.1, and 17.6-19.7, respectively. Body depth of *U. floridana*, however, was found to overlap ranges of *U. tenuis* and *U. regia*, while *U. regia* exhibited the greatest variation in this character, overlapping the ranges of *P. chesteri* and all other species of *Urophycis* studied.

Figure 14. Scatter plot of body depth at anus VS standard length for larval and juvenile Phycis chesteri and four species of Urophycis.


P. chesteri n = 17
U. tenuis n = 22
U. floridana n = 3
U. regia n = 27
U. chuss n = 42
BODY DEPTH AT ANUS AS PERCENT OF STANDARD LENGTH (mm)
STANDARD LENGTH (mm)
25
24
23
22
21
20
19
18
17
16
15
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

Mandible length and height of pelvic fin base:

In P. chesteri the pelvic fin base was located higher on the body than in species of Urophycis. Although this criterion tended to separate these two genera, the difference was accentuated by dividing this measurement by the mandible length because the lower jaw tended to be shorter in P. chesteri than in the other larval hake. Ranges of pelvic fin-base height as percent of mandible length delimited larval P. chesteri from other hake at sizes between approximately 6 and 3 mm (Fig.15). At sizes larger than 35 mm P. chesteri was similar to Urophycis with respect to this character, primarily because P. chesteri became more slender bodied and the pelvic fin originated closer to the ventral edge of the body. Table 11 lists ranges of these percentages for six species of larval hake.

Figure 15. Scatter plot of pelvic fin-base height VS mandible length for larval and juvenile Phycis chesteri and six species of Urophycis.

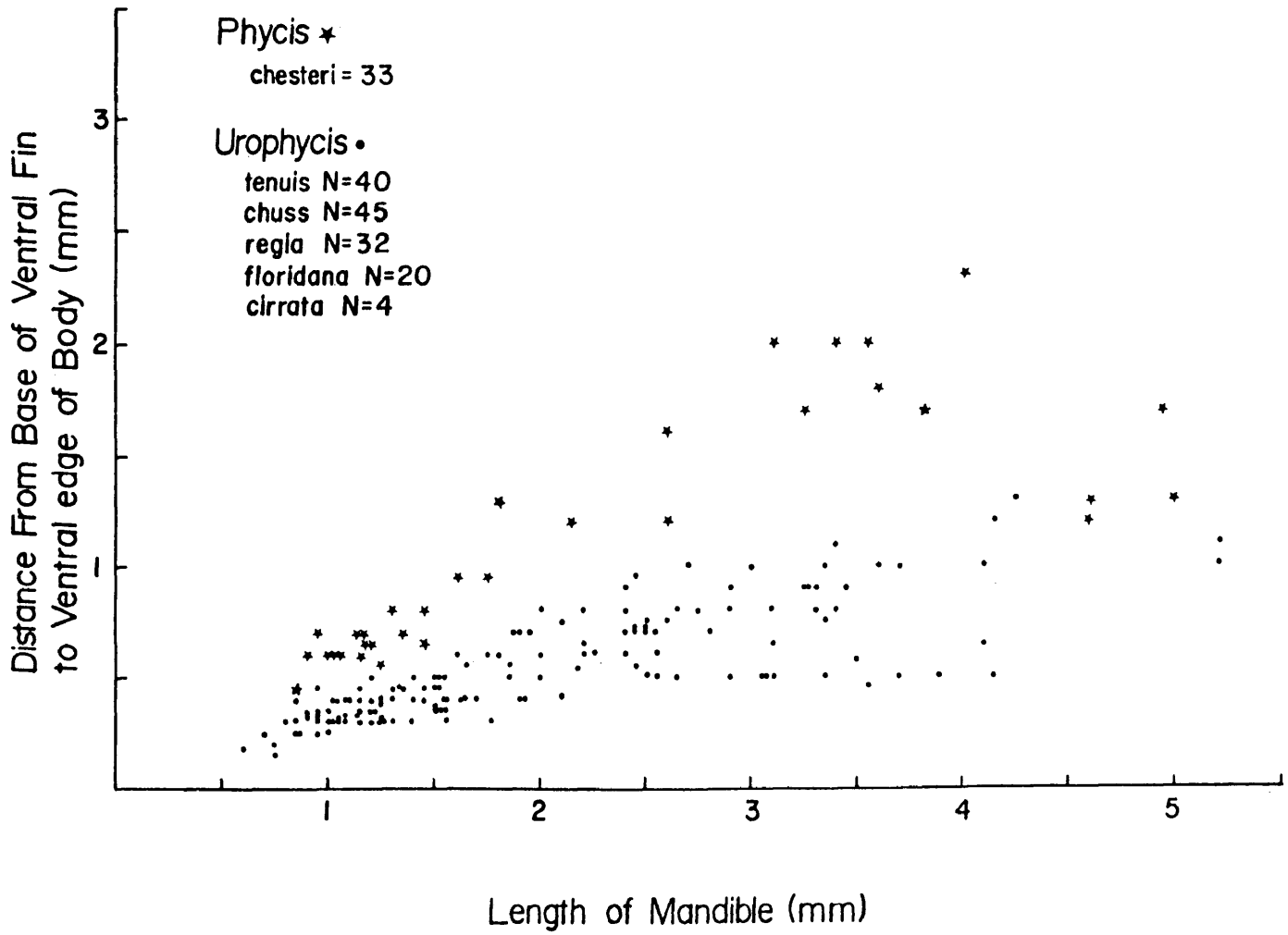

Phycis *
chesteri = 33
Urophycis •
tenuis N=40
chuss N=45
regia N=32
floridana N=20
cirrata N=4
Distance From Base of Ventral Fin to Ventral edge of Body (mm)
1
2
3
1
2
3
4
5
Length of Mandible (mm)

Table 11. Ranges of pelvic fin-base height as percent of mandible length for Phycis chesteri and five species of Urophycis. Ranges of values are given for different size intervals of larvae. Abbreviation N.D. denotes no data.

	SIZE INTERVAL (mm)						
	5-9	10-14	15-19	20-24	25-29	30-34	35-45
U. regia (n=31)	21-30	19-33	19-25	16-28	12-17	N.D.	N.D.
U. floridana (n=19)	N.D.	N.D.	29-36	23-37	23-28	24-29	N.D.
U. chuss (n=38)	20-39	23-33	24-36	19-22	15-16	16	16
U. cirrata (n=4)	N.D.	N.D.	N.D.	39	31	N.D.	19-31
P. chesteri (n=29)	44-74	52-61	54-61	46-61	52-64	50-59	26-57
U. tenuis (n=39)	28-42	24-42	33-40	29-37	26-30	32	N.D.

PIGMENTATION

Faded pigmentation caused by specimen storage in formalin and subsequent clearing and staining prevented descriptions of larval pigmentation.

Miller and Marak (1959) described pigment development of U. chuss aged 3-86 hrs (2.1-2.2 mm NL). A single large chromatophore was located on the nape and an overlying dorso-ventral pair was found halfway back on the tail. This pigmentation was observed in some early larval stages of U. chuss. When present, the dorso-ventral pair of chromatophores were located over the same myomeres. Serebryakov (1978) and Barans and Barans (1972) reported that U. regia also has a dorso-ventral pair of chromatophores, but that the dorsal chromatophore of U. regia lies just anterior to the ventral chromatophore.

U. regia is the only species of Urophycis reported to lack pelvic fin pigmentation (Hildebrand and Cable, 1938; Fahay, 1983). However, some specimens of U. regia collected in the Middle Atlantic Bight did possess this pigment.

Methven (1985) described pigmentation of larval U. chuss and U. tenuis. Comments on these descriptions are found in the discussion section.

DISCUSSION

Previously it has not been possible to identify larval hake collected in the Middle Atlantic Bight because of the overlapping meristic characters and spawning seasons of the several species. No single character separates all species of hake. Identifications in this study were based on suites of characters comprised of meristic, morphometric, and pterygiophore interdigitation data.

Meristic analysis was the most powerful method for identification of larval hake. Substantial meristic data for P. chesteri and all species of Urophycis exist in the literature, but because of overlapping meristic ranges, a lack of knowledge concerning developmental osteology and the tendency to compare meristic characters separately, significant taxonomic information has been overlooked.

Larvae of P. chesteri and Urophycis are similar to those of Enchelyopus cimbrius and Gaidropsaurus ensis , but can be separated by numbers of pelvic fin rays (Cohen and Russo, 1979; Markle, 1982). Planktonic P. chesteri and Urophycis have developed the full complement of three pelvic fin rays by 3 mm, whereas E. cimbrius and G. ensis have already developed four pelvic fin rays by 2 and 4 mm, respectively (Markle, 1982). The third pelvic fin ray in

P. chesteri and Urophycis becomes rudimentary in demersal juveniles and adults, whereas E. cimbrius and G. ensis develop an adult complement of up to six and nine pelvic fin rays, respectively.

The best character used to separate species of hake larvae was the number of gill rakers attached to the epibranchial bone of the first gill arch. Musick (1973) first demonstrated the significance of these structures by showing that U. tenuis and U. chuss have 2 and 3 epibranchial gill rakers, respectively. In general, U. floridana, U. earlli and U. tenuis had two, U. chuss, U. regia and U. cirrata had three, and P. chesteri had four or five epibranchial gill rakers. U. tenuis should not be confused with other hake that have two epibranchial gill rakers because this species only co-occurs with U. chuss and U. regia.

Although numbers of total vertebrae cannot be used to identify larval hake because of overlapping ranges, counts of abdominal vertebrae were taxonomically useful. Musick (1973) showed that most U. tenuis have 16 abdominal vertebrae, while U. chuss usually has 15, and noted that this character may be valuable in identifying collections of postlarval and juvenile hakes when the mean number of abdominal vertebrae for an entire sample is known.

Abdominal vertebrae developed precociously and aided in the identification of larvae as small as 4 mm. This meristic character was also important for the following

reasons: it facilitated the identification of numerous U. chuss in summer collections; it helped separate small U. regia from U. chuss in fall collections; it aided in the identification of U. tenuis at sizes below which numbers of caudal fin rays no longer afford confident identifications, and it helped separate U. floridana and U. cirrata from U. earlli, a southern species whose larvae remain undescribed. Hildebrand and Cable (1938) noted that U. floridana had 16 abdominal vertebrae while U. regia only had 14. Only two specimens were examined, however, and the significance of these meristics was not fully realized.

Numbers of caudal fin rays were shown by Methven (1985) to separate U. tenuis from U. chuss. This character also separates U. tenuis from other species of Urophycis at sizes larger than about 10 mm, and although the ranges of U. tenuis and P. chesteri overlap, over 50% of U. tenuis examined possessed 37 or more caudal fin rays, while P. chesteri has never been recorded with more than 36 rays.

Fahay and Markle (1984) reported that U. regia has 6 vertebrae supporting the caudal fin, while U. chuss and U. tenuis were reported to have 7 and 8 supporting vertebrae, respectively. This study found 7 to 8 vertebrae supported the caudal fin in U. regia, while 6 to 8 and 7 to 9 supporting vertebrae were found in U. chuss and U. tenuis, respectively. This character does not aid in the identification of larval hake from the Middle Atlantic Bight because of overlapping ranges.

Numbers of second dorsal fin rays, developed in U. chuss, U. regia and U. tenuis by 14 mm SL, delimited U. regia from other species of hake and helped identify specimens of U. cirrata that possessed high numbers of rays.

Hildebrand and Cable (1938) found U. regia to have low numbers of second dorsal fin rays, and noted that by 7 mm U. chuss had developed more second dorsal fin fulcra than U. regia. Similarly, I found that second dorsal fin pterygiophores developed prior to the rays that they support, and delimited U. regia from U. chuss at sizes as small as 6 mm. Low numbers of second dorsal fin rays also separated U. regia from other species of hake.

Although ranges overlapped, U. cirrata had more second dorsal fin rays than P. chesteri and other species of Urophycis (except U. earlli). These ranges were exceeded by all five specimens of U. cirrata examined in this study.

Despite overlapping ranges, numbers of first dorsal fin rays helped distinguish U. floridana from other species of hake. Over 30% of U. floridana examined (n = 45) possessed 13 first dorsal rays, but in no other species of hake were these rays this numerous.

The taxonomic importance of the location of certain elements in relation to neural spines was first recognized in Morone by Woolcott (1957). Potthoff (1974, 1975) used the position of anal and dorsal fin pterygiophores in relation to vertebrae as a character to delimit larval

scombrids. It is therefore not surprising that these characters aided in the identification of larval hake.

U. tenuis, U. cirrata and P. chesteri tended to have fewer anal fin pterygiophores positioned anterior to the first haemal spine than other hake. In over 60% of our material these species had fewer than six anterior anal fin pterygiophores, while less than 2% of U. regia and no U. earlli or U. floridana had this few. At the upper end of this range less than 2% of our U. tenuis and no U. cirrata or P. chesteri had more than six pterygiophores anterior to the first haemal spine, while 45% of U. chuss and over half of U. earlli, U. floridana and U. regia had at least seven of these pterygiophores. This character can be used to identify larvae larger than 8-9 mm.

The relative position of the second dorsal fin in relation to neural spines helped separate U. chuss from U. regia, and U. floridana from U. earlli. Although numbers of second dorsal fin rays clearly separated U. chuss and U. regia, larvae in fall collections were frequently found with fin-base sections missing (perhaps due to predation), and consequently fin ray counts could not be obtained. However, the majority of U. chuss and U. regia could be separated by the position of the pterygiophore supporting the first ray of the second dorsal fin. In over 75% of U. regia (n = 182) this pterygiophore was positioned anterior to the 8th interneural space, while less than 1% of U. chuss (n = 431) had this pterygiophore positioned so far

forward. In addition, over half of U. chuss examined had the insertion of this pterygiophore posterior to the 8th interneural space, while U. regia always showed the insertion to be anterior to this point.

This pattern of pterygiophore interdigitation also helped separate U. floridana from U. earlli. These two species probably co-occur (Hildebrand and Cable, 1938), but larvae of U. earlli are rare and remain undescribed. In over 70% of U. floridana (n = 42) the first pterygiophore of the second dorsal fin was positioned posterior to the 8th interneural space, whereas in all U. earlli examined (n = 27) this pterygiophore was positioned anterior to this point. In over half of U. earlli (n= 27) this pterygiophore projected into the 7th interneural space, while only 2% of U. floridana had the insertion this far forward.

Two diagnostic morphometric characters used in this study were body depth, and a ratio of the distance between the pelvic fin-base and the vental edge of the body to the lower jaw length.

Methven (1985) showed P. chesteri to be deeper bodied than U. tenuis, which in turn was deeper bodied than U. chuss. Body depth differences were most distinct at the vent, and were presented as a percent of body length. My data from cleared and stained larvae concurred with these findings, but I found that body depth in U. floridana overlapped ranges of U. tenuis and U. regia, while U. regia showed most variation, overlapping the ranges of P.

chesteri and all other species of Urophycis studied. Therefore body depth should not be used to identify larvae smaller than 12-13 mm SL because of overlapping ranges.

The origin of the pelvic fin-base was located higher on the body in P. chesteri than in other species of larval hake, while the lower jaw length in P. chesteri tended to be shorter. A ratio of these two measurements delimited larval P. chesteri from other hake at sizes between approximately 6 and 35 mm. Values for P. chesteri ranged from 0.44 to 0.61, while the highest value for this ratio in 5 species of Urophycis examined was 0.42 (U. tenuis). At sizes larger than about 35 mm P. chesteri became more slender bodied and the pelvic fin-base was located closer to the ventral edge of the body.

Faded pigmentation caused by specimen storage in formalin and subsequent clearing and staining prevented descriptions of larval pigmentation. Previous workers have shown several pigment characters to delimit U. chuss from U. regia and U. tenuis at specific sizes. Miller and Marak (1959) showed that U. chuss (2.1-2.2 mm NL) is characterized by having a single large chromatophore on the nape and an overlying dorso-ventral pair of chromatophores halfway back on the tail. This pigmentation was found in some of my specimens. U. regia is also reported to have a dorso-ventral pair of chromatophores, but supposedly the dorsal chromatophore of U. regia lies just anterior to the ventral chromatophore (Barans and Barans, 1972;

Serebryakov, 1978).

Although U. regia is reported to lack pelvic fin pigmentation (Hildebrand and Cable, 1938; Fahay, 1983), some specimens collected in the Middle Atlantic Bight did possess this pigment.

Methven (1985) described several pigment characters that aid in the separation of U. chuss and U. tenuis. Although some overlap was found in all characters , a pigment spot at the base of the pectoral fin was found in U. tenuis as small as 4 mm, but this pigmentation did not develop in U. chuss until 8-10 mm.

A summary of key characters to delimit Phycis chesteri and six species of Urophycis is presented in Table 12.

Table 12. A summary of key meristic, morphometric and pterygiophore interdigitation characters to delimit Phycis chesteri and six species of Urophycis. The length at which characters are attained and explanatory notes are presented for each species (see key to Table for further explanation). Percentages indicate proportion of sample possessing a particular character.

	EPIBRANCHIAL GILL RAKERS	CAUDAL FIN RAYS	2nd DORSAL FIN RAYS	1st DORSAL FIN RAYS	ABDOMINAL VERTEBRAE	ANAL FIN PTERYGIOPHORES ANTERIOR TO FIRST HAEMAL SPINE	INTERDIGITATION OF SECOND DORSAL FIN PTERYGIOPHORE (J)	BODY DEPTH AT VENT AS PERCENT STANDARD LENGTH	HEIGHT OF PELVIC FIN-BASE AS PERCENT OF MANDIBLE LENGTH	
	11-13mm	11mm	14mm	15mm	4mm	8-9mm		12mm	6-19mm	20-34mm
U. tenuis	2 (89%)	≥35 (99%)	≥53 (93%)	≤12	≥15 (F)	>6 (2%) <6 (60%)	≥9 (88%)	19.0-21.1 (K)	24-42 (L)	26-37
	11-13mm	8-9mm	14-15mm	14mm	4mm	8-9mm	12mm	12mm	6-19mm	20-34mm
U. chuss	3 (97%)	<35	≥53 (99%) (C)	≤12	≥15 (87%) (G)	>6 (45%) <6 (5%)	≥9 (52%)	17.6-19.7	20-39	15-22
	11-13mm	8-9mm	14-16mm	13mm	4mm	8-9mm	12mm	12mm	6-19mm	20-34mm
U. regia	3 (97%)	<35	≤52 (C)	<12 (E)	≤14 (H)	>6 (57%) <6 (2%)	<9	18.4-21.7	19-33	12-28
U. floridana	2	<35	≥53	13 (33%)	≥15 (98%) (I)	>6 (74%) <6 (0%)	≥9 (73%)	12mm 17.7-19.8	15-19mm 29-36	20-34mm 23-37
U. earlii	2	<35	>53	<12 (E)	≤14 (87%) (I)	>6 (85%) <6 (0%)	<9			
U. cirrata	3	<35	>53 (D)	≤12	≥15 (I)	>6 (0%) <6 (82%)				20-34mm 31-39
	16-18mm							12mm	6-19mm	20-34mm
P. chesteri	4-5 (A)	<35 (77%) (B)	≥53	≤12	≥15 (88%)	>6 (0%) <6 (93%)	≥9 (38%)	21.0-23.4	44-74 (M)	46-61

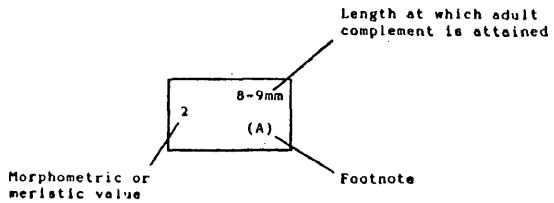


Table 12 continued.

FOOTNOTES

(A) Three epibranchial gill rakers had developed by 13 mm SL.

(B) Although ranges in U. tenuis and P. chesteri overlapped, over half of the U. tenuis examined possessed 37 or more caudal fin rays, while P. chesteri has never been recorded with more than 36 rays.

(C) Numbers of second dorsal fin pterygiophores separated U. regia from U. chuss at sizes as small as 6 mm SL.

(D) Although ranges overlapped, U. cirrata had more second dorsal fin rays than P. chesteri and other species of Urophycis (except U. earlli).

(E) U. regia and U. earlli have never been found with more than 10 and 11 first dorsal rays, respectively, while over 80% of U. floridana (n = 45) possessed more than 11 rays.

(F) Numbers of abdominal vertebrae helped identify U. tenuis larvae smaller than 10 mm, the size below which numbers of caudal fin rays no longer afford confident identifications. Musick (1973) showed that most U. tenuis have 16 abdominal vertebrae, while U. chuss usually has 15, and noted that this character may be valuable in identifying collections of postlarval and juvenile hakes when the mean number of abdominal vertebrae for an entire sample is known.

(G) U. chuss (n = 448) possessed 14 to 16 abdominal vertebrae, but over 85% of the specimens had 15. In all other species of Urophycis examined the count of 15 occurred in less than 20% of the specimens, and although ranges of U. chuss and P. chesteri are similar, P. chesteri commonly had 14 or 16 abdominal vertebrae. Consequently, in summer collections that have only been found to contain U. chuss, a check for species other than U. chuss need only be performed on those specimens that do not have 15 abdominal vertebrae.

Table 12 continued.

(H) Only seven specimens of U. regia from the Middle Atlantic Bight (n = 698) had 15 abdominal vertebrae, and seven of these specimens had an anomalous 15th vertebra.

(I) U. floridana and U. cirrata commonly possessed 16 or 17 abdominal vertebrae, but U. earlli has never been recorded with this many.

(J) Numbers refer to the interneural space into which projects the pterygiophore supporting the first ray of the second dorsal fin.

(K) Specimens of all species were cleared and stained.

(L) Size ranges do not define size when character first became useful, but bracket the size range over which particular morphometric values were found.

(M) At sizes larger than 35 mm SL P. chesteri was similar to Urophycis with respect to this character.

SECTION II. DISTRIBUTION AND ABUNDANCE OF *UROPHYCIS* AND *PHYCIS* LARVAE AND PELAGIC JUVENILES IN THE MIDDLE ATLANTIC BIGHT

Larvae of *Phycis chesteri* and all six species of *Urophycis* endemic to the continental shelf and slope of the northwest Atlantic Ocean may be found in the Middle Atlantic Bight. *U. earlli*, the only species not identified in this study, was probably absent from collections because of its rare occurrence. All species of larval hake showed distinct patterns of spatial and temporal distribution.

Urophycis chuss

Distribution and abundance:

Larval and pelagic juvenile red hake, *Urophycis chuss*, were found in the Middle Atlantic Bight off Virginia and New Jersey from August until November, but were most abundant in summer when surface water temperatures ranged from 20° to 26° C (Fig.16). Ninety seven percent (n = 39,395) of *U. chuss* were collected in August and September, while only 3% (n = 1355) were found in October and November when surface water temperatures ranged from 9° to 18° C.

Latitudinal variation in larval abundance was most apparent in summer collections. In August 1977 densities off the coast of New Jersey (stations C1-J1) were up to two orders of magnitude higher than abundances found off the Virginia coast (stations L1-L6). Neuston densities as high as 7547 larvae per 1000 m^3 were found off New Jersey, while the highest density found in August off Virginia was only 69 larvae per 1000 m^3. This latitudinal variation in larval abundance was not well defined in the fall. In November 1976 larval densities off Virginia were slightly higher than densities found in the central sector of the Middle Atlantic Bight off New Jersey.

Densities of larval U. chuss were also found to vary with water depth. Larvae were found across the entire continental shelf in summer, but densities tended to be lowest inshore and highest in mid-shelf regions. Over 35,000 U. chuss larvae were collected in August 1977 and August-September 1976 off central New Jersey (stations C1, D1, N3, E3, F2, J1), but only 5.0 of the specimens were found at inshore station C1 in 16 meters of water (Fig.16). Abundances were highest in the central region of the shelf in water ranging in depth from 40 m to 120 m. Neuston abundances appear more variable in August 1977 than in August-September 1976, but this is probably because in August 1977 only one neuston cast was made at stations D1, N3 and F2.

Collections off northern New Jersey and Virginia in August 1977 again showed U. chuss larvae to be more abundant in the central shelf region. Off northern New Jersey larvae were twice as abundant at mid-shelf station B5 (60-70 m) than at offshore station A2 (128 m), and off Virginia larvae were three times more abundant in neuston collections at mid-shelf station L2 (42 m) than either inshore or offshore. No larvae were taken in bongo collections at stations L2 or L1, but this is probably because larvae were larger at these stations and were able to avoid bongo nets.

Variation of larval density with depth was not as well defined in fall collections. In October 1975 off central New Jersey neustonic larvae were most abundant at inshore station C1 and densities decreased progressing offshore. In November 1976, however, larval densities were highest at offshore station J1.

Geographic variation in larval abundance in fall collections off northern New Jersey and Virginia was similar to that observed in summer collections with the exception that off Virginia highest abundances were found further offshore at station L4 and no larvae were collected at inshore station L1.

Except for station B5 in November 1976, the mean size of larval U. chuss in bongo collections was smaller than in neuston collections at all stations in the four cruises in which U. chuss were found (Fig.17). In August 1977 the

mean size of U. chuss larvae in bongo and neuston collections was 4 and 8 mm, respectively. In August-September 1976 the mean size of neustonic larvae increased to 11 mm, but the mean size of larvae caught in bongo nets remained at 4 mm.

The mean size of neustonic U. chuss tended to increase from summer until fall. In August 1977 the mean size of neustonic U. chuss at stations off New Jersey and Virginia ranged from 4 to 13 mm, while in November 1976 the range in mean size at these stations increased to 12-40 mm. As larval sizes increased in fall collections, the number of larvae collected with bongo nets decreased greatly. Although 1330 specimens of U. chuss were collected in October 1975 and November 1976, only 25 of the larvae were collected with bongo gear.

No clear patterns of onshore-offshore variation in larval size were apparent in August 1977 when mean larval sizes were smallest. However, in October 1975, August-September 1976 and November 1976, larvae tended to be larger inshore than offshore (Fig.17).

Figure 16. Mean abundance of Urophycis chuss in neuston and bongo collections at stations off Virginia and New Jersey, October 1975-August 1977. n refers to actual number of larvae collected. NS means no samples taken.

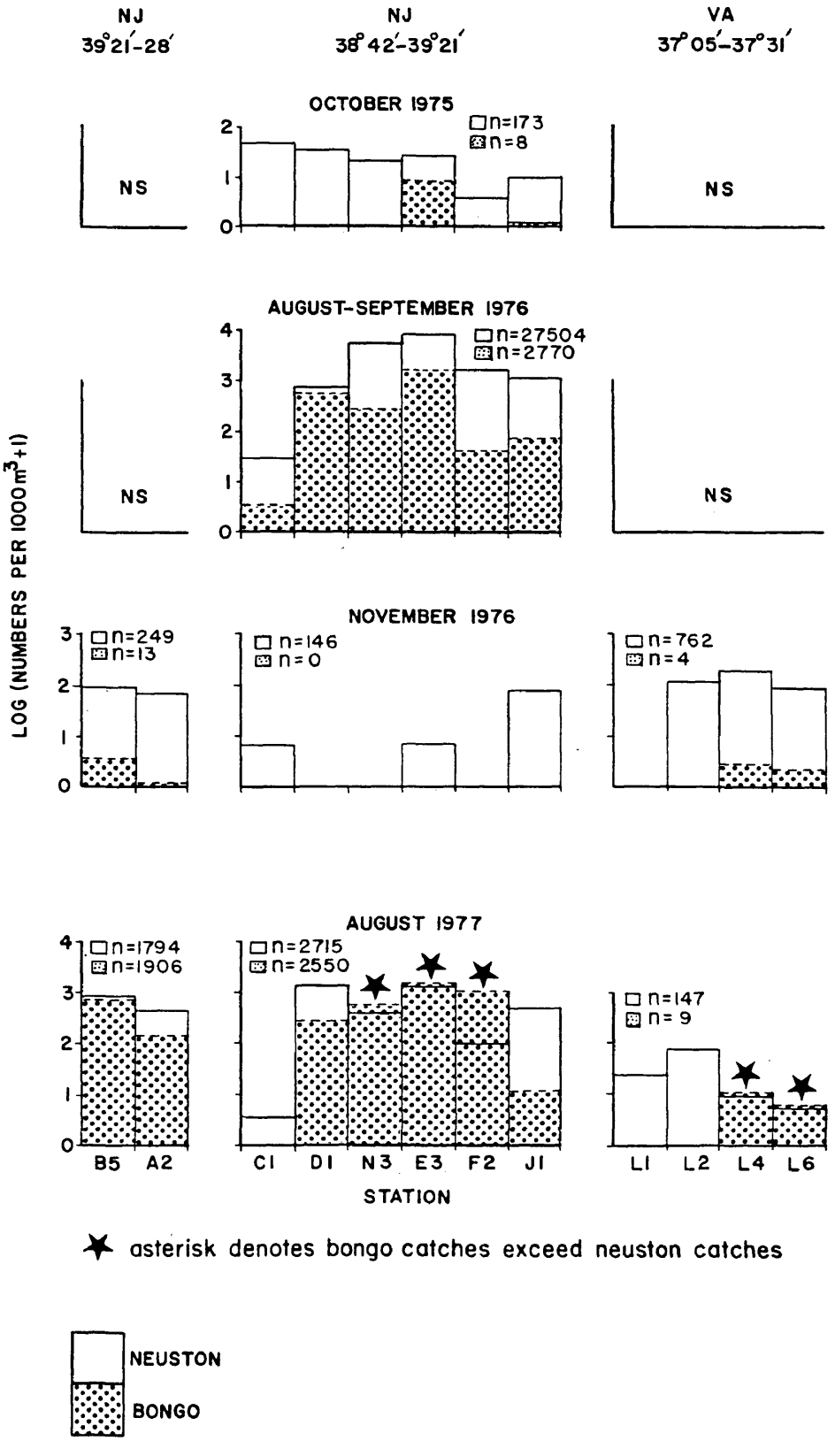
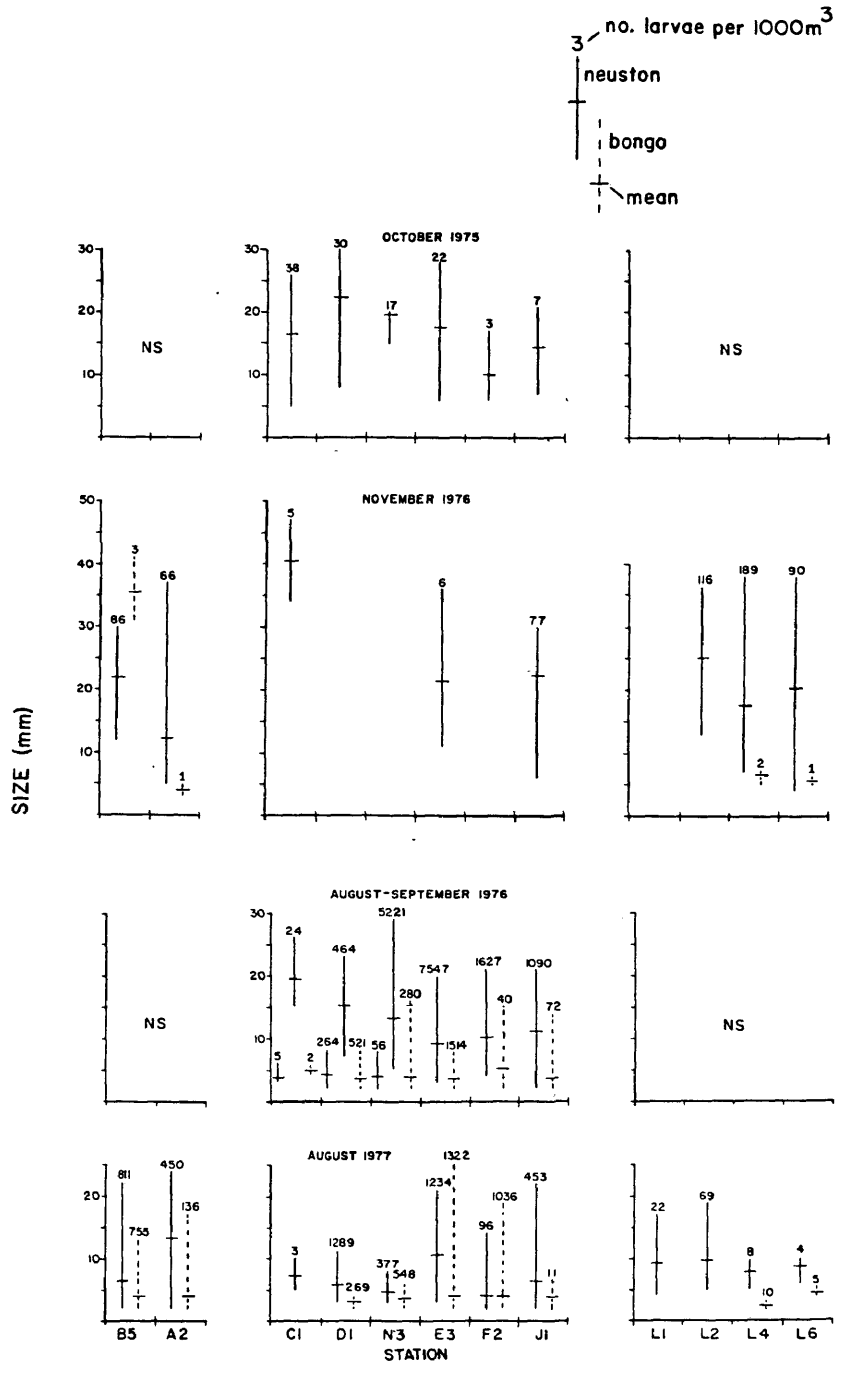

NJ
39°21′-28′
NJ
38°42′-39°21′
VA
37°05′-37°31′
OCTOBER 1975
n=173
n=8
NS
NS
AUGUST-SEPTEMBER 1976
n=27504
n=2770
NS
NS
NOVEMBER 1976
n=249
n=13
n=146
n=0
n=762
n=4
AUGUST 1977
n=1794
n=1906
n=2715
n=2550
n=147
n=9
LOG (NUMBERS PER 1000m³+1)
B5 A2
C1 D1 N3 E3 F2 J1
L1 L2 L4 L6
STATION
asterisk denotes bongo catches exceed neuston catches
NEUSTON
BONGO

Figure 17. Range and mean size of Urophycis chuss in neuston and bongo collections at stations off Virginia and New Jersey, October 1975-August 1977. NS means no samples taken.



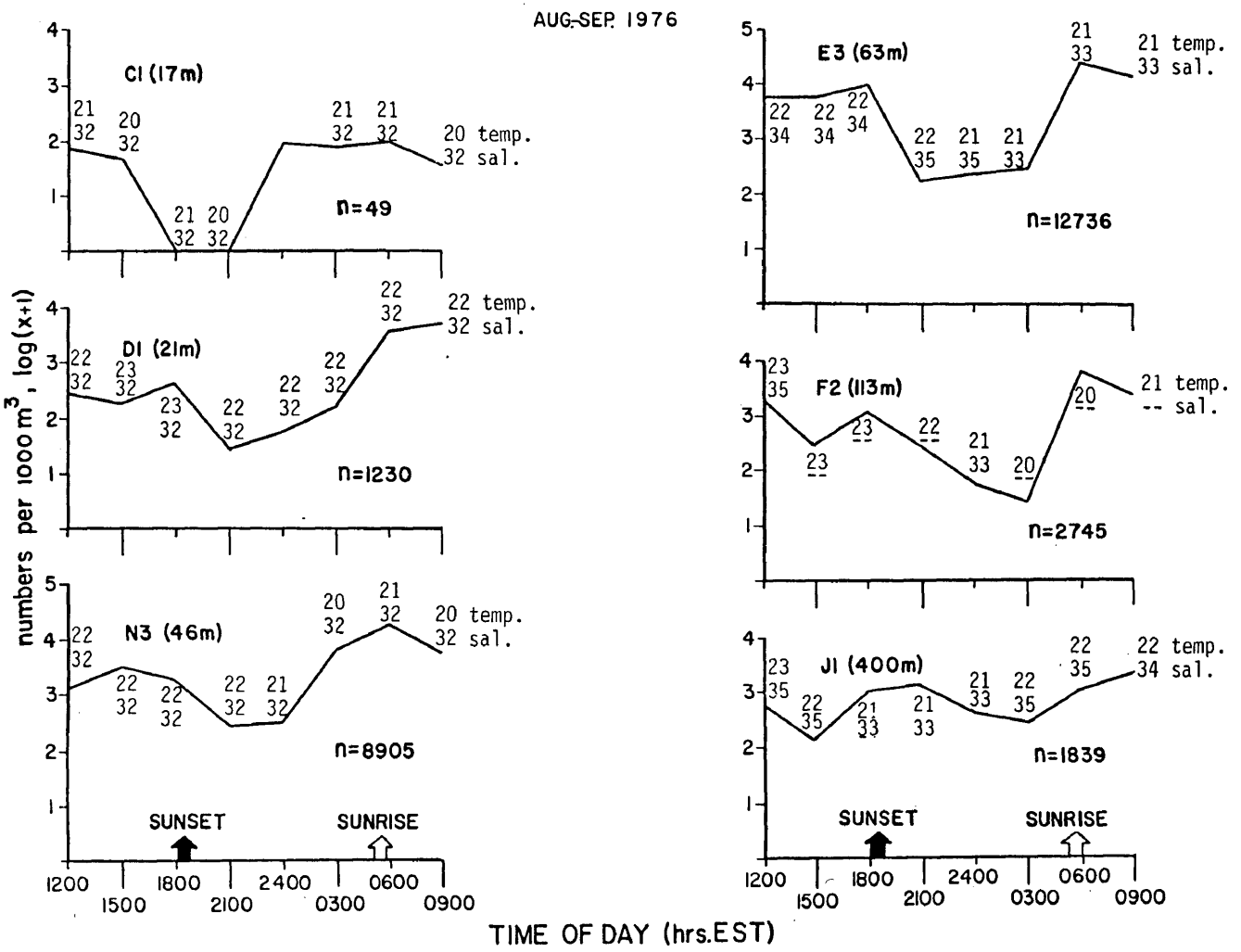
note : two neuston ranges are shown if more than one size class is present.

Diel variation in surface abundance:

Forty-eight neuston casts made off the New Jersey coast in the summer of 1976 yielded over 28,000 neustonic U. chuss larvae and juveniles. Collections, made every three hours at each of the six sampling locations, showed that U. chuss tended to exhibit patterns of diel variability in surface abundance (Fig.18). Except for inshore station C1, peaks in abundance occurred during crepuscular periods and lowest abundances generally occurred at night. At station C1 a total of only 49 larvae were collected in 8 neuston casts. This sample size may be too small to show trends in the variability of surface abundance. While 43% of U. chuss larvae (n = 11,827) were collected at dawn, only 3% of the specimens were collected at night at 2100 hrs and 2400 hrs. Temperature and salinity data (Fig.18) showed no indication that abundance variation was correlated with changes in water masses.

Figure 18. Diel variation in temperature, salinity and abundance of Urophycis chuss in surface waters off New Jersey, August-September 1976. Data points represent single density estimates made at three hour intervals.

U. chuss


AUG-SEP. 1976
C1 (17m)
n=49
20 temp.
32 sal.
D1 (21m)
n=1230
22 temp.
32 sal.
N3 (46m)
n=8905
20 temp.
32 sal.
E3 (63m)
n=12736
21 temp.
33 sal.
F2 (113m)
n=2745
21 temp.
-- sal.
J1 (400m)
n=1839
22 temp.
34 sal.
SUNSET
SUNRISE
numbers per 1000 m3, log(x+1)
TIME OF DAY (hrs.EST)
1200
1500
1800
2100
2400
0300
0600
0900

Urophycis regia

Distribution and abundance:

Larval and pelagic juvenile U. regia were collected in the Middle Atlantic Bight in October 1975, February 1976, November 1976, February-March 1977 and May 1977, with peak abundance occurring during a fall cruise off the Virginia coast (Fig.19). U. regia appeared off the New Jersey coast in October when surface water temperatures ranged from 16° to 21° C (no sampling was conducted off Virginia that year). In November 1976 larvae were found off New Jersey and Virginia when surface water temperatures ranged from 9° to 13° C, and 12° to 16° C, respectively. Abundance in November 1976 off the Virginia coast was two orders of magnitude higher than that off the coast of New Jersey, with density estimates exceeding 4500 larvae per 1000 m^3 at Virginia station L2. The highest density recorded off New Jersey (station B5) was only 67 larvae per 1000 m^3. Abundance off central New Jersey (stations C1-J1) during this November cruise was lower than off northern New Jersey (stations B5, A2). The more abundant larvae off northern New Jersey were significantly smaller ($\bar{x}$ = 12 mm) than fish collected off central New Jersey ($\bar{x}$ = 20 mm) (Fig.20).

Although the variation in larval density between the southern and central sectors of the Middle Atlantic Bight

diminished in winter collections, highest abundance was still found off Virginia. In February-March 1977 larvae were at least six times more abundant off the Virginia coast than off New Jersey. The single neuston tow at station F2 yielded no larvae, resulting in an anomalous appearance in distribution. High densities were obtained at the bracketing stations E3 and J1 where neuston sampling effort was eight times greater. Surface water temperatures at this time of year ranged from 2° to 13° C off both Virginia and New Jersey. The scarcity of U. regia in May 1977 (n = 7) precluded comparisons of latitudinal variation in larval density.

The abundance of larvae not only varied with latitude, but also with depth. In November 1976 densities of U. regia off the Virginia coast were two orders of magnitude higher at mid-shelf station L2 (41-43 m) than at offshore stations, and densities at this station were one order of magnitude higher than at inshore station L1 (24-27 m). Only 1% of the specimens were collected in water deeper than 43 m (n= 8031).

Onshore-offshore variance in larval density was not as well defined during November 1976 off the southern coast of New Jersey (stations C1-J1). This is probably because the sample size at this transect was small (n = 25) and the average larval size was relatively large (20.1 mm). These older fish would tend to be more dispersed than younger fish, and consequently patterns of larval distribution

predetermined by the distribution of spawning adults would diminish. In October 1975, however, variations in larval density at these stations were found. 80% of the specimens (n = 110) were collected at inshore station C1 (12 m). These larvae were smaller ($\bar{x}$ = 9.1 mm) than those collected in 1976, and were probably located closer to the area from which they originated. All but three of the remaining specimens (n = 23) were found at offshore station J1. These larvae were either spawned in offshore waters, or resulted from more southerly spawning activity and were carried into the Middle Atlantic Bight by northward flowing currents.

Larval and pelagic juvenile U. regia remained in surface waters during winter months with highest abundances being consistently found at offshore stations. In February 1976 87% of U. regia (n = 106) were collected at offshore stations F2 and J1, and in February-March 1977 all U. regia (n = 827) collected off Virginia and New Jersey were found in offshore waters. U. regia found in offshore winter collections tended to be relatively large (Fig.20), averaging 24 mm and 21 mm in 1976 and 1977, respectively.

By May neustonic U. regia were scarce in the Middle Atlantic Bight. In May 1977 two small juveniles ($\bar{x}$ = 25 mm) were collected off Virginia at offshore stations L4 and L6, and five juveniles ($\bar{x}$ = 20 mm) were found at offshore stations B5 and A2 in the central sector of the Middle Atlantic Bight. U. regia found in offshore winter and

spring collections were probably transported from more southerly areas by the Gulf Stream.

Bongo nets were generally ineffective at catching U. regia (Fig.19), probably because of gear avoidance by larger larvae. U. regia were collected with bongo gear in only two of the five cruises in which this species was found. The mean size of U. regia in bongo collections was only 6 mm, while fish in neuston collections averaged 15 mm.

Figure 19. Mean abundance of Urophycis regia in neuston and bongo collections at stations off Virginia and New Jersey, October 1975-May 1977. n refers to actual number of larvae collected. NS means no samples taken.

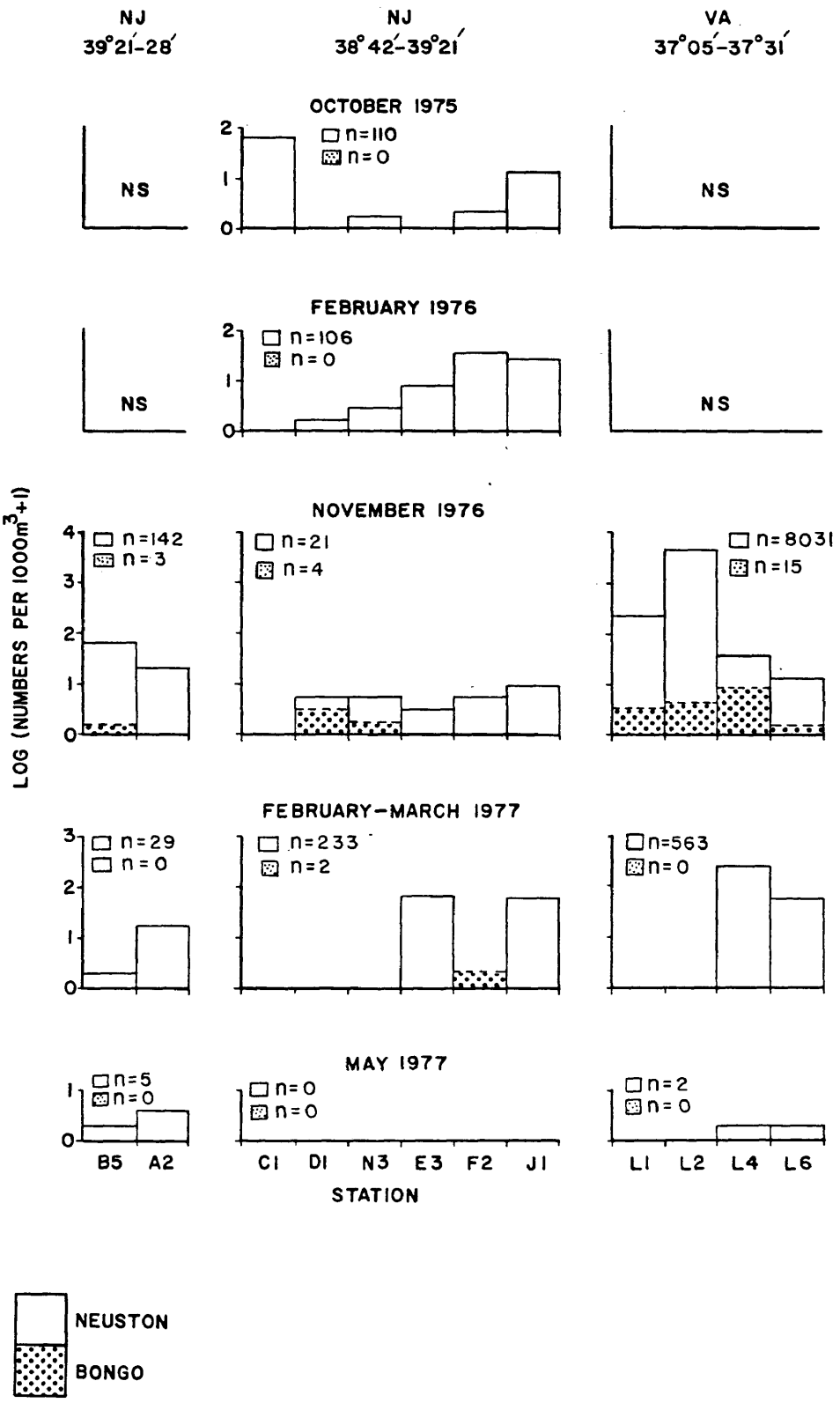
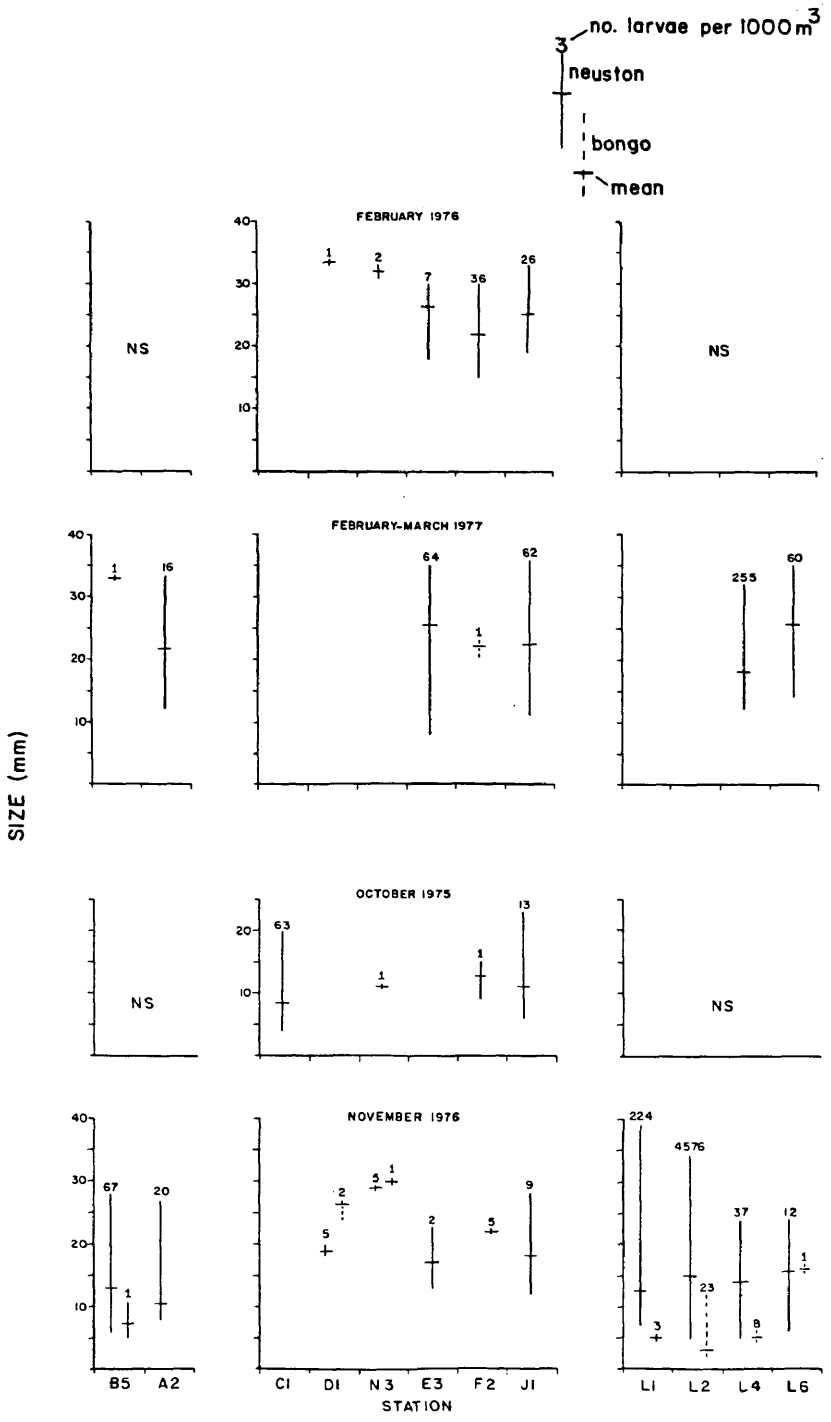

NJ
39°21'-28'
NJ
38°42'-39°21'
VA
37°05'-37°31'
OCTOBER 1975
n=110
n=0
NS
NS
FEBRUARY 1976
n=106
n=0
NS
NS
NOVEMBER 1976
n=142
n=3
n=21
n=4
n=8031
n=15
FEBRUARY-MARCH 1977
n=29
n=0
n=233
n=2
n=563
n=0
MAY 1977
n=5
n=0
n=0
n=0
n=2
n=0
LOG (NUMBERS PER 1000m3+1)
B5 A2
C1 D1 N3 E3 F2 J1
L1 L2 L4 L6
STATION
NEUSTON
BONGO

Figure 20. Range and mean size of Urophycis regia in neuston and bongo collections at stations off Virginia and New Jersey, October 1975-February/March 1977. NS means no samples taken.



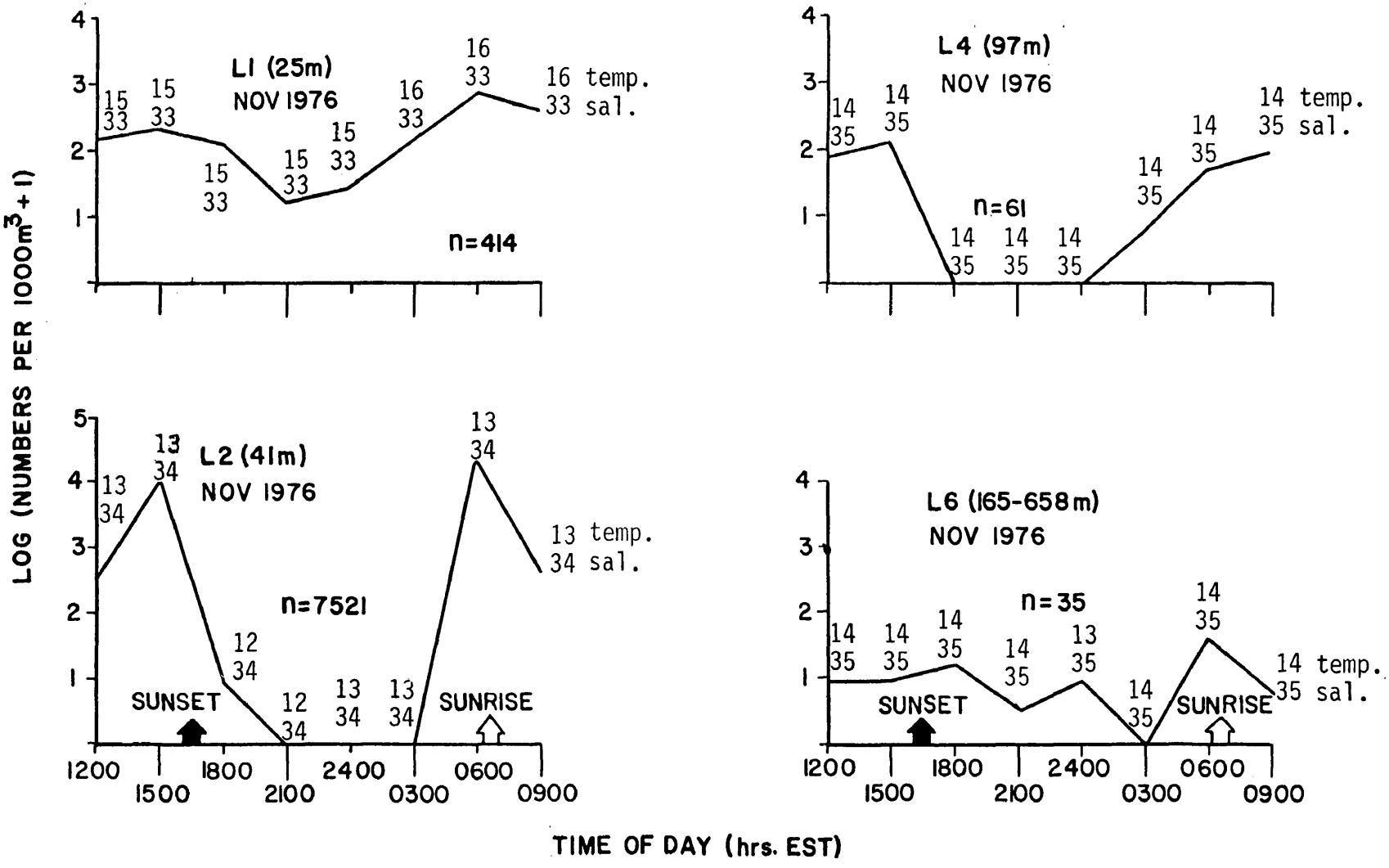
note: two neuston ranges are shown if more than one size class is present.

Diel variation in surface abundance:

Thirty-nine neuston tows made off the Virginia coast in November 1976 resulted in the collection of 8049 U. regia. U. regia larvae exhibited strong patterns of diel variation in surface abundance, with most pronounced variation occurring at mid-shelf station L2 and L4 (Fig.21). Peaks in neuston abundance occurred at dawn and late afternoon, while lowest abundances were found at night. A total of 7521 U. regia were collected at station L2. While no larvae were taken in neuston collections at 2100, 2400 or 0300 hrs., 4997 larvae were captured at 0600 hrs. and 2355 larvae were collected at 1500 hrs.(98%). Sampling at 1800 hrs. was just after dark and U. regia larvae might have already migrated beneath surface waters at this time (only two larvae were collected at 1800 hrs.).

Figure 21. Diel variation in temperature, salinity and abundance of Urophycis regia in surface waters off Virginia in November 1976. Data points represent single density estimates made at three hour intervals.

U. regia


LOG (NUMBERS PER 1000m³+1)
L1 (25m)
NOV 1976
n=414
16 temp.
33 sal.
L4 (97m)
NOV 1976
n=61
14 temp.
35 sal.
L2 (41m)
NOV 1976
n=7521
13 temp.
34 sal.
L6 (165-658m)
NOV 1976
n=35
14 temp.
35 sal.
SUNSET
SUNRISE
1200
1500
1800
2100
2400
0300
0600
0900
TIME OF DAY (hrs. EST)

Urophycis tenuis

Distribution and abundance:

Young U. tenuis were taken in Middle Atlantic Bight bongo and neuston collections in May 1977 and June 1976 when surface water temperatures ranged from 14° to 20° C (Fig.22).

Abundance of U. tenuis in May 1977 was up to one order of magnitude higher than abundances in June 1976. Larvae were collected at all but inshore stations off both Virginia and New Jersey, but were most abundant at offshore stations where mean densities approached 200 larvae per 1000 m^3. U. tenuis ranged in size from 3 to 53 mm, but larval size was smallest at offshore stations and increased as collections proceeded inshore (Fig.23).

Early summer densities of U. tenuis (June 1976, Fig.22) were low, never exceeding 19 fish per 1000 m^3. The average size of neustonic U. tenuis was larger in June 1976 ($\bar{x}$ = 29 mm) than in May 1977 ($\bar{x}$ = 16 mm), but the trend of increasing densities and decreasing larval size as collections proceeded offshore was still evident. Mean size and abundance (neuston) at near-shore station D1 was 47 mm and three juveniles per 1000 m^3, respectively, while at offshore station J1 mean larval/juvenile size decreased to 23 mm and densities increased to 19 fish per 1000 m^3.

As with U. chuss and U. regia, bongo nets caught fewer and smaller larvae. Neuston collections contained U. tenuis ranging in length from 4 to 53 mm SL, but the largest larva collected with bongo gear was only 7 mm.

Figure 22. Mean abundance of Urophycis tenuis in neuston and bongo collections at stations off Virginia and New Jersey, June 1976 and May 1977. n refers to actual number of larvae collected. NS means no samples taken.

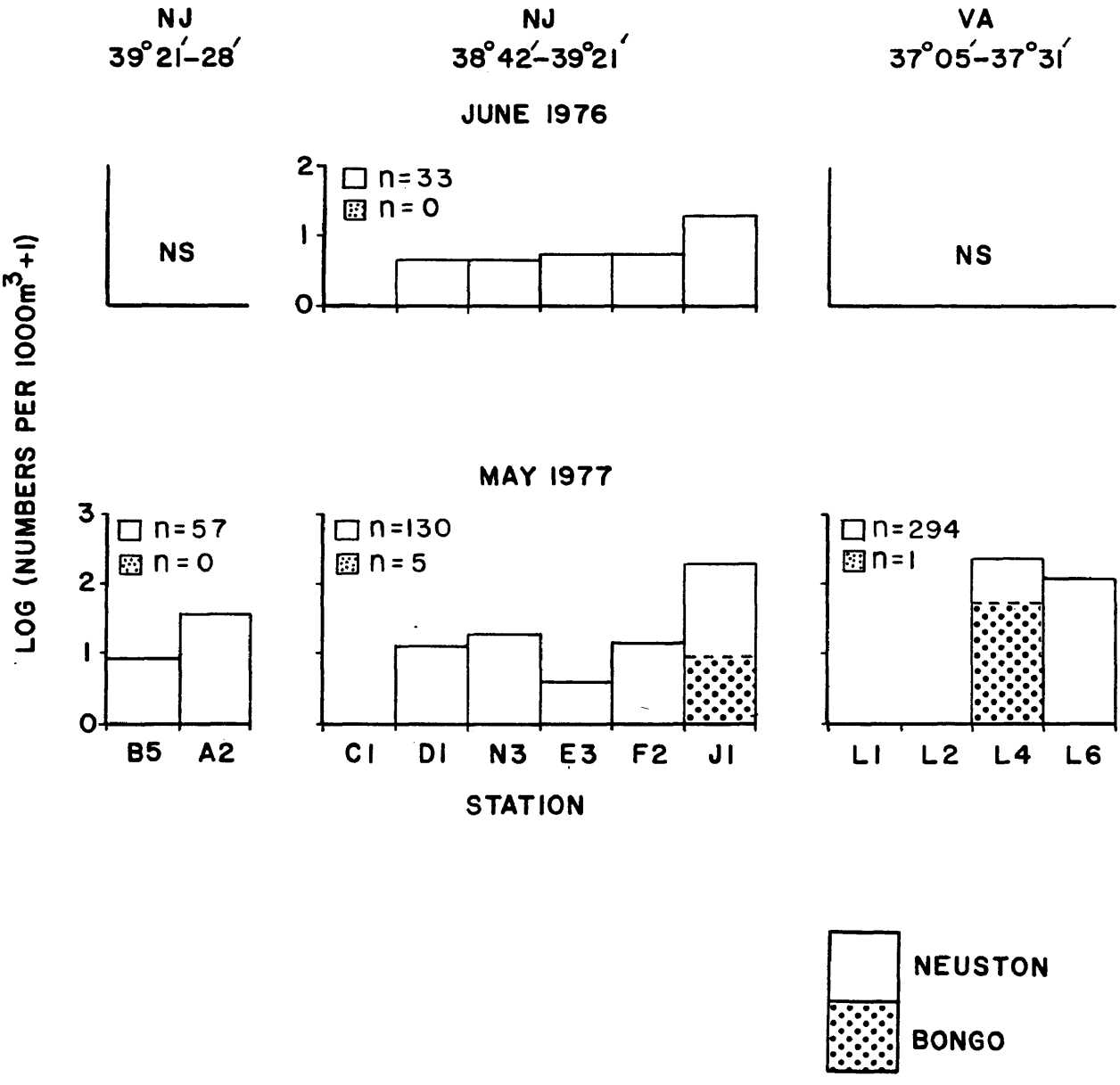
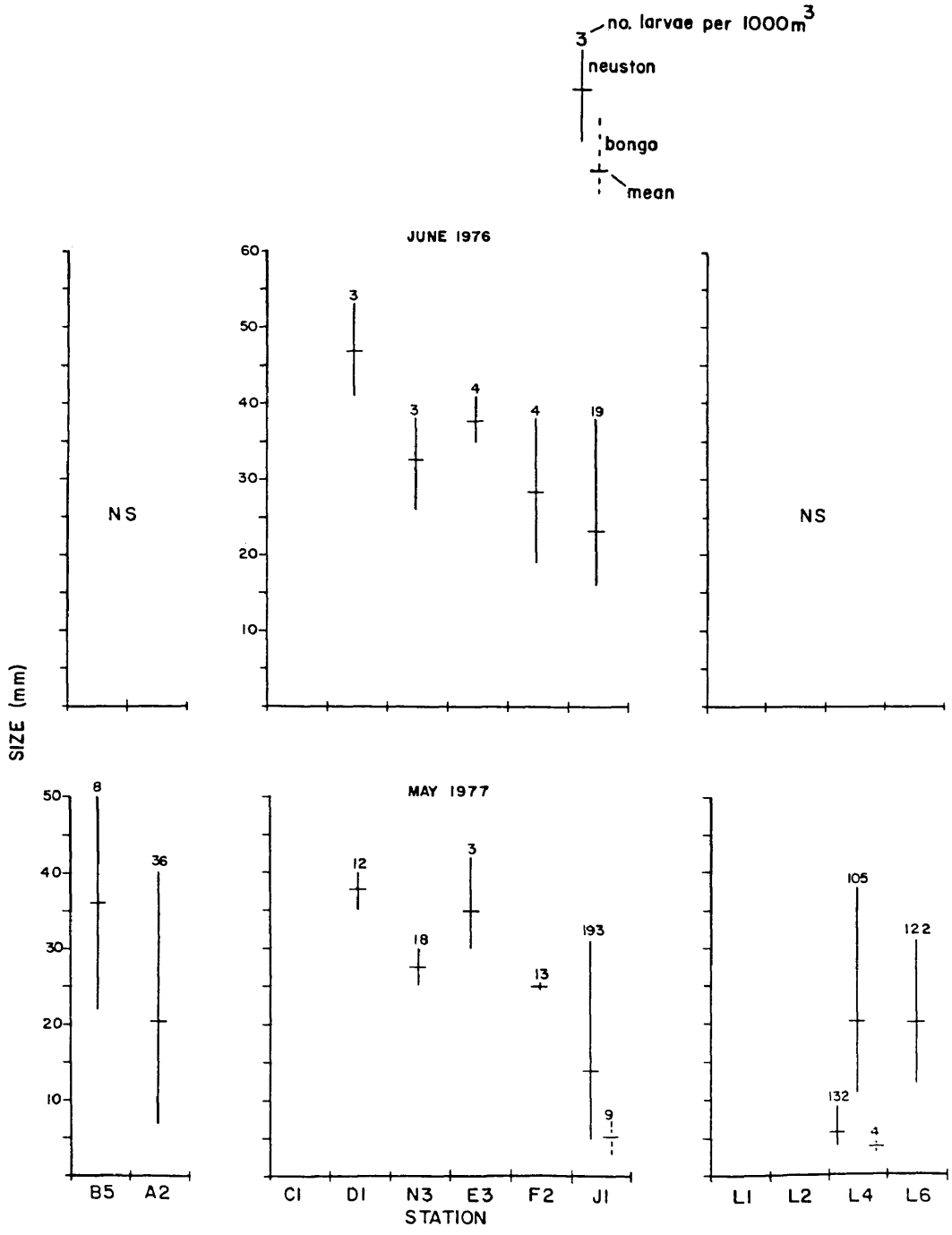

NJ
39°21′-28′
NJ
38°42′-39°21′
VA
37°05′-37°31′
JUNE 1976
NS
n=33
n=0
NS
MAY 1977
n=57
n=0
n=130
n=5
n=294
n=1
LOG (NUMBERS PER 1000m3+1)
B5
A2
C1
D1
N3
E3
F2
J1
L1
L2
L4
L6
STATION
NEUSTON
BONGO

Figure 23. Range and mean size of Urophycis tenuis in neuston and bongo collections at stations off Virginia and New Jersey, June 1976 and May 1977. NS means no samples taken.

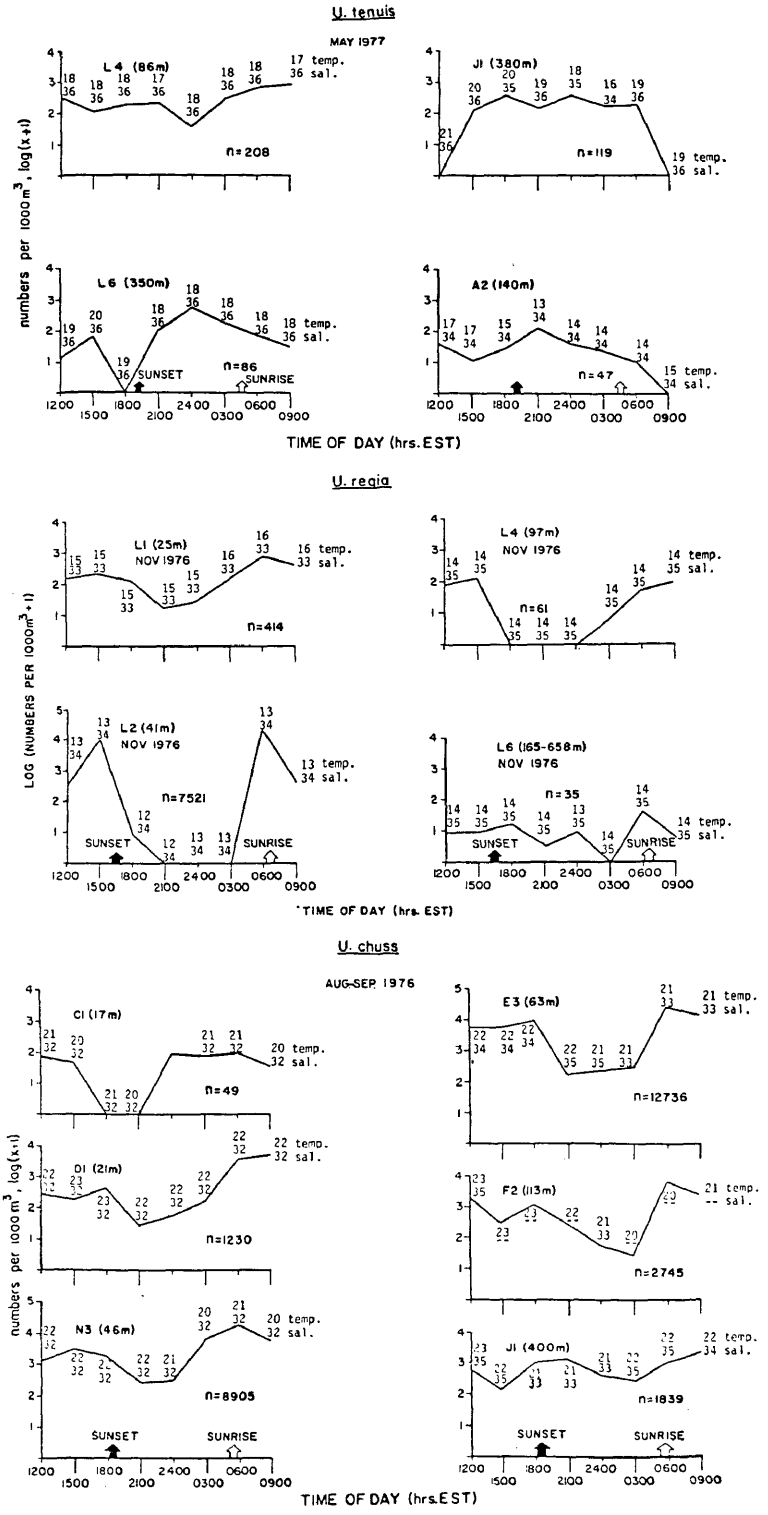


note: two neuston ranges are shown if more than one size class is present.

Diel variation in surface abundance:

U. tenuis was the only species of Urophycis that tended to be more abundant in surface waters at night than during the day. Figure 24 compares catches of U. tenuis over 24 hr periods with catches of U. chuss and U. regia, two species of Urophycis that showed opposite trends. In May 1977 surface abundances of U. tenuis were highest during the night at three of the four stations examined. At station L4 abundances over time were quite variable.

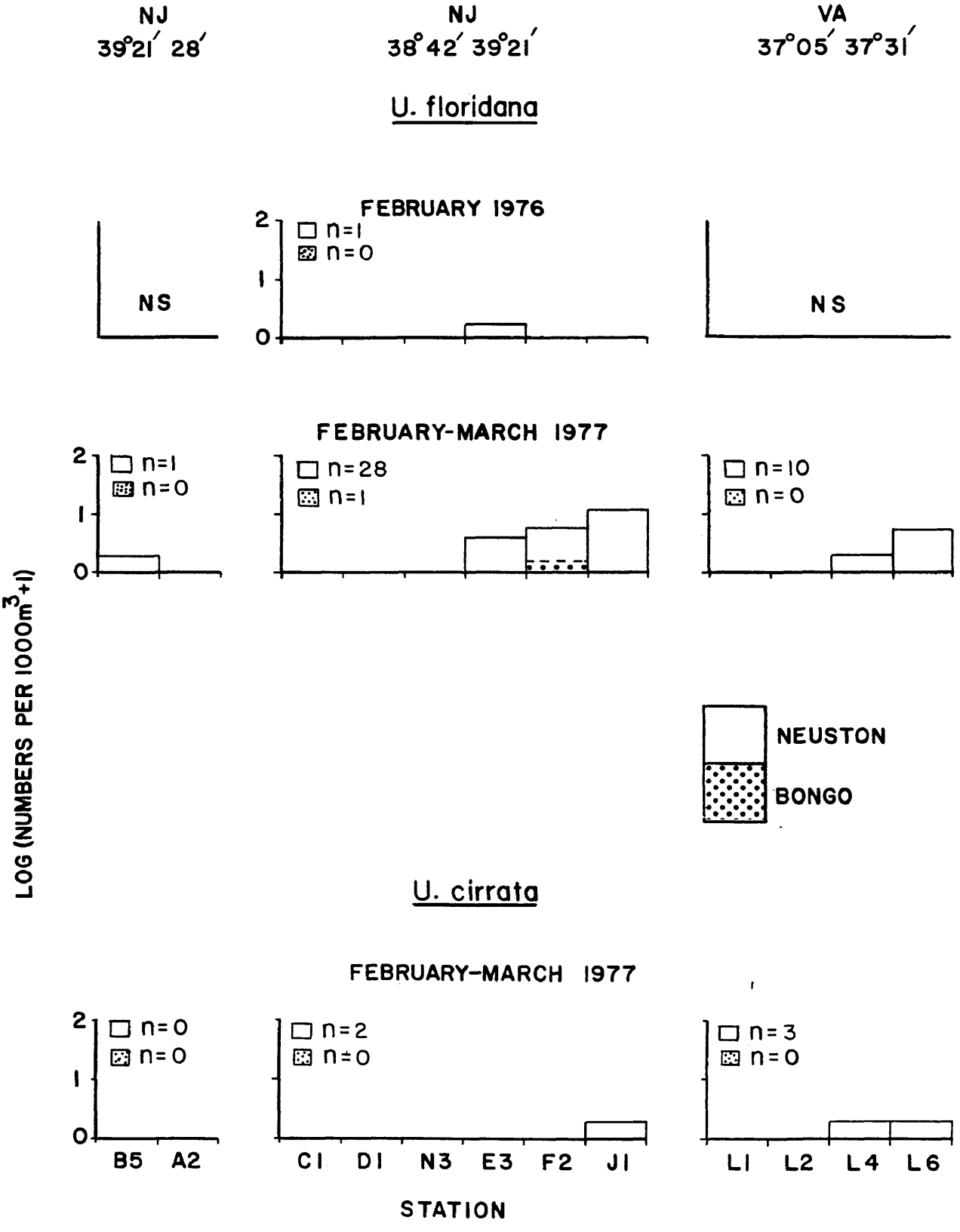
Figure 24. Diel variation in temperature, salinity and abundance of *Urophycis tenuis* in surface waters off Virginia and New Jersey, May 1977. Data points represent single density estimates made at three hour intervals. *U. chuss* and *U. regia* data is included for comparison.


U. tenuis
MAY 1977
L4 (86m)
17 temp.
36 sal.
n=208
JI (380m)
19 temp.
36 sal.
n=119
L6 (350m)
18 temp.
36 sal.
SUNSET
SUNRISE
n=86
A2 (140m)
15 temp.
34 sal.
n=47
numbers per 1000 m3, log(x+1)
1200 1500 1800 2100 2400 0300 0600 0900
TIME OF DAY (hrs. EST)
U. regia
LI (25m)
NOV 1976
16 temp.
33 sal.
n=414
L4 (97m)
NOV 1976
14 temp.
35 sal.
n=61
L2 (41m)
NOV 1976
13 temp.
34 sal.
n=7521
SUNSET
SUNRISE
L6 (165-658m)
NOV 1976
14 temp.
35 sal.
n=35
LOG (NUMBERS PER 1000m3+1)
TIME OF DAY (hrs. EST)
U. chuss
AUG-SEP 1976
CI (17m)
20 temp.
32 sal.
n=49
E3 (63m)
21 temp.
33 sal.
n=12736
DI (21m)
22 temp.
32 sal.
n=1230
F2 (113m)
21 temp.
-- sal.
n=2745
N3 (46m)
20 temp.
32 sal.
n=8905
SUNSET
SUNRISE
JI (400m)
22 temp.
34 sal.
n=1839
numbers per 1000 m3, log(x+1)
TIME OF DAY (hrs. EST)

Urophycis floridana and *U. cirrata*

Young *U. floridana* (n = 41, 13-32 mm SL) and *U. cirrata* (n = 5, 20-42 mm SL) appeared in collections only during February-March 1976-77 when surface water temperatures ranged from 2° to 13° C. Larvae were found off Virginia and New Jersey at offshore stations E3, F2, J1, L4 and L6. Density estimates generally increased with increasing distance from shore (Fig.25). The surface temperature and salinity at these stations ranged from 9° to 13° C and 35-36‰, while at stations further inshore temperatures and salinities were lower, ranging from 2° to 5° C and 33-35‰. With the exception of a single juvenile *U. floridana* (23.0 mm SL) captured in a bongo cast at station J1, all specimens appeared in surface waters.

Figure 25. Mean abundance of larval and neustonic juvenile Urophycis floridana and U. cirrata in neuston and bongo collections at stations off Virginia and New Jersey, February 1976-March 1977. n refers to actual number of larvae collected. NS means no samples taken.

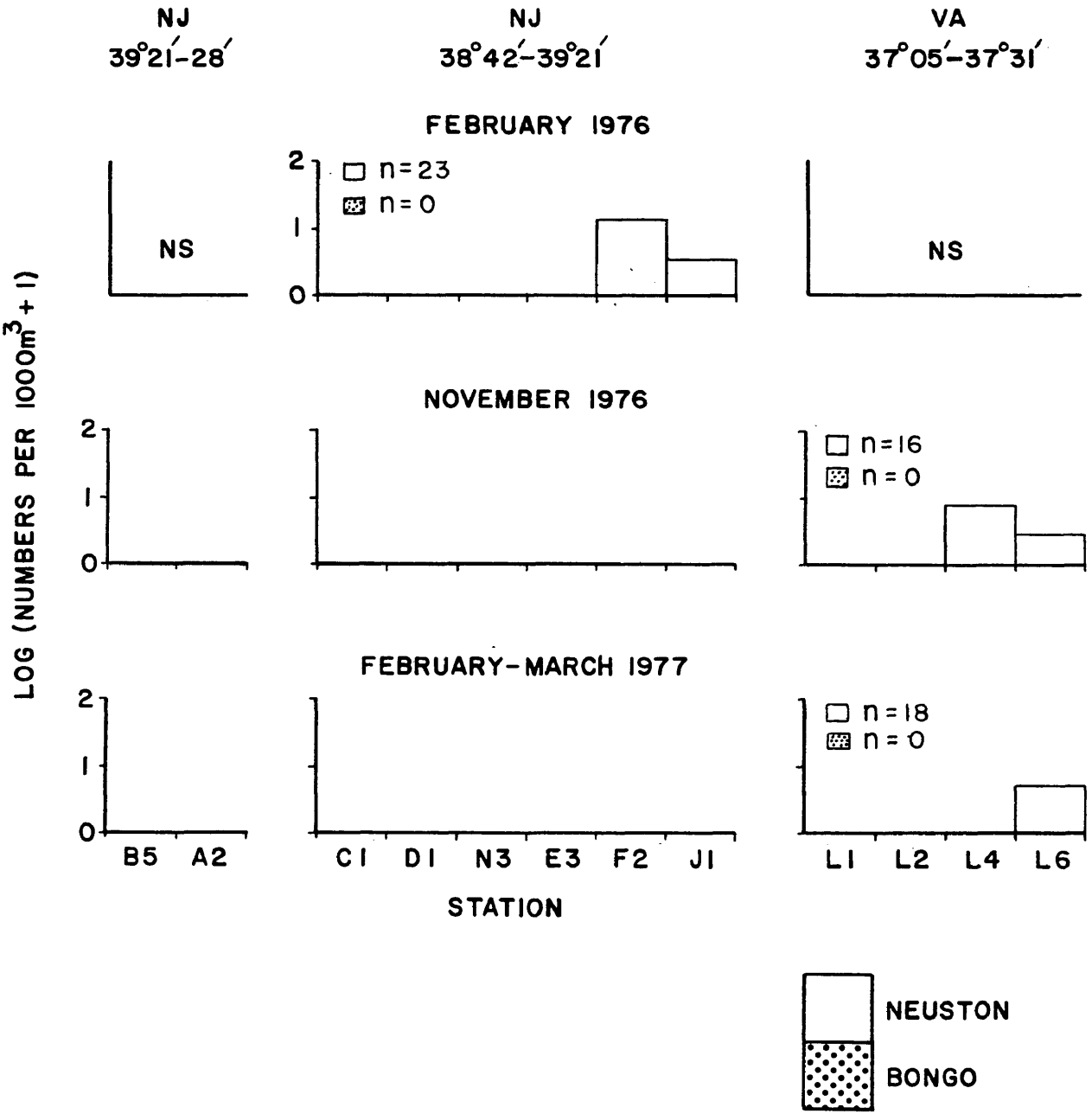

NJ
39°21′ 28′
NJ
38°42′ 39°21′
VA
37°05′ 37°31′
U. floridana
FEBRUARY 1976
n=1
n=0
NS
NS
FEBRUARY-MARCH 1977
n=1
n=0
n=28
n=1
n=10
n=0
NEUSTON
BONGO
LOG (NUMBERS PER 1000m3+1)
U. cirrata
FEBRUARY-MARCH 1977
n=0
n=0
n=2
n=0
n=3
n=0
B5 A2
C1 D1 N3 E3 F2 J1
L1 L2 L4 L6
STATION

Phycis chesteri

Distribution and abundance:

P. chesteri larvae appeared in fall and winter collections in February 1976, November 1976 and February-March 1977 (Fig.26). All specimens (n= 47) were found at depths greater than about 100 m at offshore stations F2, J1, L4 and L6, where surface water temperatures off Virginia and New Jersey ranged from 11° to 14° C and 9° to 10° C, respectively. P. chesteri ranged in length from 5 to 36 mm SL, but the small sample size precluded comparisons of larval size between stations and at different times of the year.

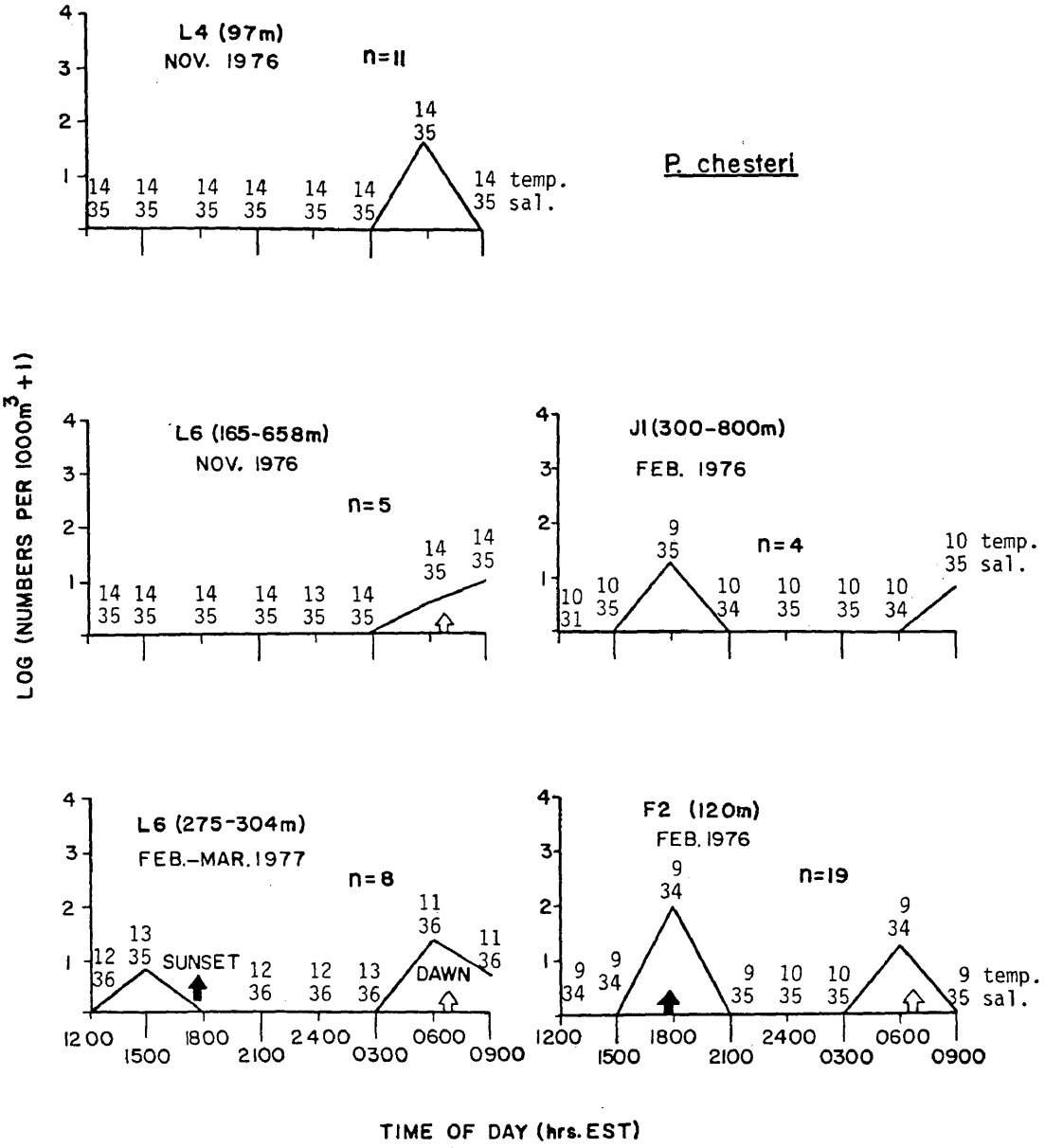
Figure 26. Mean abundance of larval and neustonic juvenile Phycis chesteri in neuston and bongo collections at stations off Virginia and New Jersey, February 1976-March 1977. n refers to actual number of larvae collected. NS means no samples taken.


NJ
39°21′-28′
NJ
38°42′-39°21′
VA
37°05′-37°31′
FEBRUARY 1976
NS
n=23
n=0
NS
NOVEMBER 1976
n=16
n=0
FEBRUARY-MARCH 1977
n=18
n=0
LOG (NUMBERS PER 1000m3+1)
0
1
2
B5
A2
C1
D1
N3
E3
F2
J1
L1
L2
L4
L6
STATION
NEUSTON
BONGO

Diel variation in surface abundance:

During the fall of 1976 and winter of 1976-77, a total of forty-six P. chesteri larvae and neustonic juveniles were collected in offshore waters off the coast of Virginia and New Jersey. Neuston collections, taken every three hours at each station, showed that P. chesteri tended to be crepuscular with respect to diel patterns of surface abundance (Fig.27). Forty of the specimens were captured in surface waters at dusk or dawn (1800 hrs, 0600 hrs), and the remaining 6 larvae were collected within three hours of these times.

Figure 27. Diel variation in temperature, salinity and abundance of Phycis chesteri in surface waters off Virginia and New Jersey, November 1976-March 1977. Data points represent single density estimates made at three hour intervals.


L4 (97m)
NOV. 1976
n=11
14 35
14 14 14 14 14 14 35 35 35 35 35 35
14 temp.
35 sal.
P. chesteri
L6 (165-658m)
NOV. 1976
n=5
14 14 14 14 13 14 14 14
35 35 35 35 35 35 35 35
J1 (300-800m)
FEB. 1976
n=4
9 35
10 10 10 10 10 10 10
31 35 34 35 35 34
10 temp.
35 sal.
L6 (275-304m)
FEB.-MAR. 1977
n=8
13 35
12 36
SUNSET
12 36
12 36
13 36
11 36
DAWN
11 36
F2 (120m)
FEB. 1976
n=19
9 34
9 34
9 35
10 35
10 35
9 34
9 35
9 temp.
35 sal.
LOG (NUMBERS PER 1000m3 +1)
1200 1500 1800 2100 2400 0300 0600 0900
TIME OF DAY (hrs. EST)

DISCUSSION

Pelagic larval and juvenile Urophycis or Phycis were present in the Middle Atlantic Bight throughout the year and dominated ichthyoplankton collections during summer months. However, because of overlapping meristic characters and spawning seasons, it has not previously been possible to determine the species composition of pelagic hake collections in this area (Kendall and Naplin, 1981; Hermes, 1985). Serebryakov (1978) stated that the eggs and larvae of four species of Urophycis may be found in ichthyoplankton collections from the east coast of North America. In actuality larvae from six species of Urophycis may be found in this area. Five species were identified from the Middle Atlantic Bight in the present study, and the sixth species (U. earlli) was probably absent from collections because of its rare occurrence. The spatial and temporal distribution of each species was consistent during both years of study.

U. tenuis is most common on the Scotian Shelf, in the Gulf of St. Lawrence and on the Grand Banks, but strays as far south as Florida in deep water (Musick, 1974). Ichthyoplankton collections taken during this study confirmed that U. tenuis is found south of the Grand Banks.

U. tenuis larvae and pelagic juveniles were found in June 1976 and May 1977 in both central (New Jersey) and southern (Virginia) sectors of the Middle Atlantic Bight when surface water temperatures ranged from 14° to 20° C. Highest abundances were found offshore.

Reported spawning times of U. tenuis in Canadian and New England waters are variable, ranging from winter till late summer (Markle, 1982). Musick (1969) noted that off New England and Nova Scotia a small percentage of ripe U. tenuis are found almost year-round. However, U. tenuis spawning activity that produced larvae found in the Middle Atlantic Bight occurred over a limited time period because U. tenuis larvae were collected only in May and June.

In May 1977 U. tenuis larvae as small as 3-4 mm were found over the continental break and slope off both New Jersey (station J1) and Virginia (stations L4, L6). The presence of small larvae indicates that spawning had occurred recently in these offshore waters. U. tenuis collected in June 1976 were larger, ranging in length at offshore stations from 16-38 mm. Based on crude growth rates of 10-22 mm/month (Markle, 1982) and demersal juvenile growth rates of ≃40 mm/month (Methven, 1983) these fish were probably spawned in April and May.

The size of U. tenuis increased shoreward, with neustonic juveniles (35-53 mm) being captured in water as shallow as 32 m off the coast of New Jersey (station D1). These specimens would have originated from waters to the

northeast of the capture location because the mean along shelf flow of surface water in the Middle Atlantic Bight is toward the southwest (Beardsley and Winant, 1979; Beardsley et al., 1976). Bishop and Overland (1977) estimated the currents in the Middle Atlantic Bight set southwestward on the order of 5 to 15 cm s^{-1}, and consequently a 50 mm neustonic juvenile may have been transported 250-500 miles during one or two months spent in surface waters. Occasional southerly winds and low river run off may cause short-term reversals in the direction of nearshore current flow (Bumpus, 1969), but even during these periods most of the surface water in the Middle Atlantic Bight flows in a southerly direction. It should also be noted that gyre-like patterns of flow exist along the inner shelf of the Middle Atlantic Bight (Epifanio et al., 1984), but these phenomena do not negate the general north-south movement of water over the continental shelf.

Markle et al. (1982) found neuston catches of juvenile U. tenuis to be influenced by time of day, with most individuals being caught at night. This study found neuston catches at night to be higher in three of four stations examined. No trend was seen at station L4, and although the reason for this is unclear it should be noted that the salp Thalia democratica was abundant at this station and consequent net clogging was a problem. The size of fish at this station was not a factor, and temperature and salinity data indicated that all samples at

this station were taken in the same water mass.

In some instances higher neuston catches at night could be the result of gear avoidance by fish during daylight, but because neuston catches of other species of Urophycis have been higher during daylight hours, the increased catches of U. tenuis at night probably reflected actual increases in surface abundance. It is likely that this variation in surface abundance was due to patterns of diel vertical migration. This vertical movement in the water column was probably a response to light levels and may have been due to diel feeding behavior or to a predator avoidance mechanism, but further research is needed.

U. chuss, the only species collected during summer months, was by far the dominant species of larval hake found in the Middle Atlantic Bight and accounted for 80% of all Urophycis and Phycis (N = 50,625). 97% of U. chuss (N = 39,395) were taken in summer collections (Aug-Sep), while only 3% were collected in the fall (Oct-Nov).

The abundance of pelagic U. chuss was higher in the central sector of the Middle Atlantic Bight than in the southern section. Neuston abundances off the coast of New Jersey reached 7547 fish per 1000 m^3, while the highest abundance recorded off the Virginia coast was only 69 fish per 1000 m^3. Highest abundances in both sectors occurred in areas where water depth ranged from 40-60 m. Musick (1974) found U. chuss to be a summer spawner with major spawning concentrations east of Block Island and on the

southwest part of Georges Bank at depths of less than 60 fm. The present study also found U. chuss to be a summer shelf spawner, but significant spawning also occurred in the central sector of the Middle Atlantic Bight.

Musick (1969) showed that juvenile U. chuss are commonly found within the mantle cavities of sea scallops Placopecten magellanicus. Although P. magellanicus is most common in northern waters, this species ranges from Labrador to North Carolina, and consequently it is probable that juvenile postneustonic U. chuss in the Middle Atlantic Bight also engage in this symbiotic relationship. Steiner et al. (1982) showed that this is at least the case off the coast of northern New Jersey.

Unlike U. tenuis, U. chuss were most abundant in surface waters at dawn and late afternoon-dusk, while lowest abundances occurred at night. Hermes (1985), sampling in November on Georges Bank, Nantucket Shoals and in the Gulf of Maine, also found the abundance of Urophycis spp. to be lowest in surface waters at night. This pattern of diel migration indicated that the Urophycis spp. referred to by Hermes was probably U. chuss because U. tenuis is most abundant in the neuston at night. These findings are not consistent with those of Kendall and Naplin (1981) who took discrete depth plankton collections during the summer in the Middle Atlantic Bight and found more Urophycis spp. in 0 and 4 m nets (20 cm bongo) at night than during the day. The Urophycis spp. referred to

in Kendall's study were almost certainly U. chuss, the most abundant taxa found in their summer ichthyoplankton collections. Bongo nets (20 cm) fished at the surface may not effectively catch neustonic hake during daylight because of gear avoidance.

U. regia is found in coastal waters from Nova Scotia and the vicinity of Sable Island to Texas, but is rare north of southern New England (Hardy, 1978). Larval and pelagic juvenile density gradients showed that U. regia was more abundant in the southern sector of the Middle Atlantic Bight than in central or northern sectors. Abundances of U. regia were up to two orders of magnitude higher off the coast of Virginia than off New Jersey.

U. regia in the Middle Atlantic Bight is reported to spawn from late September through November, and possibly to February, with peak activity in October (Barans and Barans, 1972). Most U. regia in the present study were collected in November, but some larvae or neustonic juveniles were collected from October to May.

Ninety four percent of U. regia caught in November 1976 off Virginia (n = 8046) were collected at station L2 (41-43 m). Sizes ranged from 2 to 34 mm, and although some of the larger specimens may have drifted from deeper water, small larvae would have been spawned in the shallower mid-shelf area. Evidence of U. regia spawning inshore was also found in October 1975 off New Jersey at station C1 where larvae as small as 4 mm were found in water as shallow as

12 m. However, not all specimens off New Jersey originated in shallow water, as a second group of larvae ranging in length from 6 to 23 mm was found at offshore station J1.

The offshore distribution of U. regia became quite distinct in winter collections, with abundances being greater at offshore stations in February 1976, February-March 1977 and May 1977. These fish were probably either spawned in offshore waters of the Middle Atlantic Bight or spawned in offshore waters of the South Atlantic Bight and carried northward by the Gulf Stream. Wenner et al. (1979) found adult U. regia to be abundant in offshore waters of the South Atlantic Bight in fall otter trawl collections, and Hildebrand and Cable (1938) noted that U. regia spawns during winter months in offshore waters off North Carolina.

U. regia was similar to U. chuss with respect to patterns of diel variation in surface abundance. Peaks in neuston abundance occurred at dawn and late afternoon, while lowest abundances were found at night. Patterns of diel variation in surface abundance were particularly pronounced at mid-shelf stations, but the reason for this is unclear. It is doubtful that larval size at different stations affected this variation in surface abundance because mean larval size at the four Virginia stations differed by no more than 3 mm. Temperature and salinity data showed no indication that abundance variation was correlated with changes in water masses.

U. floridana and U. cirrata, two southern species, were found off New Jersey and Virginia only in offshore winter collections. The large size and offshore distribution observed for both species suggests that winter spawning did not occur in the study area. Instead, as with U. regia in offshore winter collections, larvae likely resulted from more southerly spawning activity and were carried into offshore waters of the Middle Atlantic Bight by northward flowing currents. Examination of surface temperature and salinity records across the shelf supported this conclusion. In winter offshore Gulf Stream water has a higher temperature and salinity than inshore shelf water, and U. floridana and U. cirrata were found in water that had a relatively high temperature and salinity. In February-March 1977 all specimens off Virginia and central New Jersey were found at offshore stations E3, F2, J1, L4 and L6. The surface temperature and salinity at these stations ranged from 9° to 13° C and 35-36‰, while at stations further inshore temperatures and salinities were lower, ranging from 2° to 5° C and 33-35‰.

Although no evidence of Gulf Stream rings was found at winter station locations, anticyclonic eddies formed from shoreward meanders of the Gulf Stream (Saunders, 1971) were probably responsible for the impingement of southern species onto the continental slope and shelf off northern Virginia and New Jersey. Katz et al. (1983) concluded it

is unlikely that egg or larval transport occurs between the Middle Atlantic and South Atlantic Bights based on the Gulf Stream position north of Cape Hatteras and the difference between northern and southern continental shelf water masses. Katz et al. conceded that anticyclonic eddies could provide a mechanism for transporting larvae from the Gulf Stream to Middle Atlantic Bight waters, but they concluded that this phenomenon would be uncommon. My data suggest that this type of transportation is quite common.

P. chesteri larvae and pelagic juveniles appeared at offshore stations in fall and winter off Virginia and New Jersey. Although specimens were found in the same collections as southern species of hake, P. chesteri was probably not transported northward into the Middle Atlantic Bight with U. floridana and U. cirrata. Instead, P. chesteri larvae were probably spawned in offshore waters in the general vicinity of the capture location. Wenner (1983) found P. chesteri generally at depths greater than 183 m on the continental slope from 36° N to 47° N in the western North Atlantic, and noted that spawning off Virginia took place between late September and April, with peak spawning occurring in December and January.

U. floridana, U. cirrata and P. chesteri tended to be crepuscular, with highest surface abundances occurring around dawn and dusk. As with other species of hake the reason for this behavior is uncertain, but is probably a response to light levels and may be due to diel feeding

patterns or predator avoidance behavior.

Although small hake larvae were captured with neuston gear, neuston collections consistently contained larger fish than were found in bongo collections. When small larvae were absent in the sampling area, as was the case with southern forms at offshore winter stations, all specimens were captured with neuston gear. Comparisons of bongo and neuston catches indicated that the rare occurrence of larger larvae and juveniles in bongo collections was probably due to gear avoidance. For example, U. chuss and U. regia showed distinct patterns of diel vertical migration with lowest neuston catches occurring at night. If the fish tended to move downward in the water column at night they should have been available to the bongo gear, but larger larvae and juveniles were seldom found in night bongo collections.

SUMMARY

The specific identification of larval and pelagic juvenile hake has not previously been possible in the Middle Atlantic Bight because of overlapping spawning seasons and similarities between these fishes. Larval fish are most frequently identified with pigmentation and morphometric criteria, but these characters are seldom sufficient to identify larval and juvenile hake. Consequently, osteological analysis, preceeded by clearing and staining of specimens, is necessary. Osteological analysis is more commonly used to identify larger fish in which development of the adult complement of skeletal components is complete. However, when developmental osteology is understood, pterygiophore interdigitation and meristic analysis of larvae and small juveniles may be taxonomically useful.

Larval and juvenile hake in this study were identified on the basis of pterygiophore interdigitation, meristic and morphometric criteria. Meristic characters included numbers of epibranchial gill rakers, vertebrae and fin rays (dorsal, caudal and pelvic). Morphometric criteria included body depth at vent, mandibular length, and height of the pelvic fin base. In addition, the position of anal and dorsal fin pterygiophores relative to haemal or neural

spines helped delimit certain species of hake.

The spatial and temporal distribution of pelagic Urophycis and Phycis remained consistent during both years of this study. Hake were present in the Middle Atlantic Bight throughout the year and dominated summer plankton collections.

Urophycis chuss was the only species present during summer and was found across the entire continental shelf with highest abundances located in mid-shelf areas (Fig.28). Densities off the coast of New Jersey were up to two orders of magnitude higher than abundances found off Virginia.

Fall collections of pelagic hake were comprised of U. chuss, U. regia and P. chesteri (Fig.29). U. chuss was again found off Virginia and New Jersey, but densities were lower and mean larval/juvenile size tended to be larger in fall than in summer. Onshore-offshore size variation of U. chuss was evident in fall, with larger fish found inshore. U. regia was found across the entire continental shelf, with densities in the southern sector of the Middle Atlantic Bight being an order of magnitude greater than in the central sector. U. regia accounted for over 90% of the pelagic hake in fall collections off Virginia, with most of these fish being found at midshelf station L2. P. chesteri was scarce in fall plankton collections. The few specimens collected were found in offshore waters off Virginia.

Winter collections of larval and juvenile hake were

comprised of U. floridana, U. regia, U. cirrata and P. chesteri (Fig.30). These four species were found off both Virginia and New Jersey and were restricted to offshore waters. Larval U. earlli are rare and remain undescribed, but this species is also expected to occasionally occur in offshore waters during winter. P. chesteri larvae were probably spawned in offshore waters of the Middle Atlantic Bight, but U. floridana, U. regia and U. cirrata likely resulted from more southerly spawning activity and were carried northward by the Gulf Stream. Anticyclonic eddies formed from shoreward meanders of the Gulf Stream were probably responsible for the impingement of these southern species onto the continental slope and shelf off Virginia and New Jersey.

Apart from an occasional U. regia juvenile found at offshore stations, U. tenuis was the only species of hake present in spring plankton collections off Virginia and New Jersey (Fig.31). U. tenuis larvae and pelagic juveniles were most abundant at shelf-break and slope stations, but were found at all but inshore stations L1 and C1.

Zaitsev began studying ichthyoplankton of the Black Sea in the 1950's, and, in his doctoral thesis (Zaitsev 1964, cited in Zaitsev 1970), stressed the importance of the neuston layer in the economy of the sea. This neuston layer was certainly utilized by larval and pelagic juvenile hake, particularly at certain times of day or night. Phycis chesteri and all species of Urophycis were common

in neuston collections, but showed evidence of diel vertical migration. U. tenuis was most abundant in surface waters at night, while P. chesteri and other species of Urophycis were least abundant in surface waters at night, and most abundant in the neuston at dawn and dusk. This vertical movement in the water column was probably a response to changing light levels and may have been due to diel feeding behavior or to a predator avoidance mechanism, but further research is needed.

Figure 28. Distribution and abundance of larval and pelagic juvenile hake in summer plankton collections from the Middle Atlantic Bight.

SUMMER

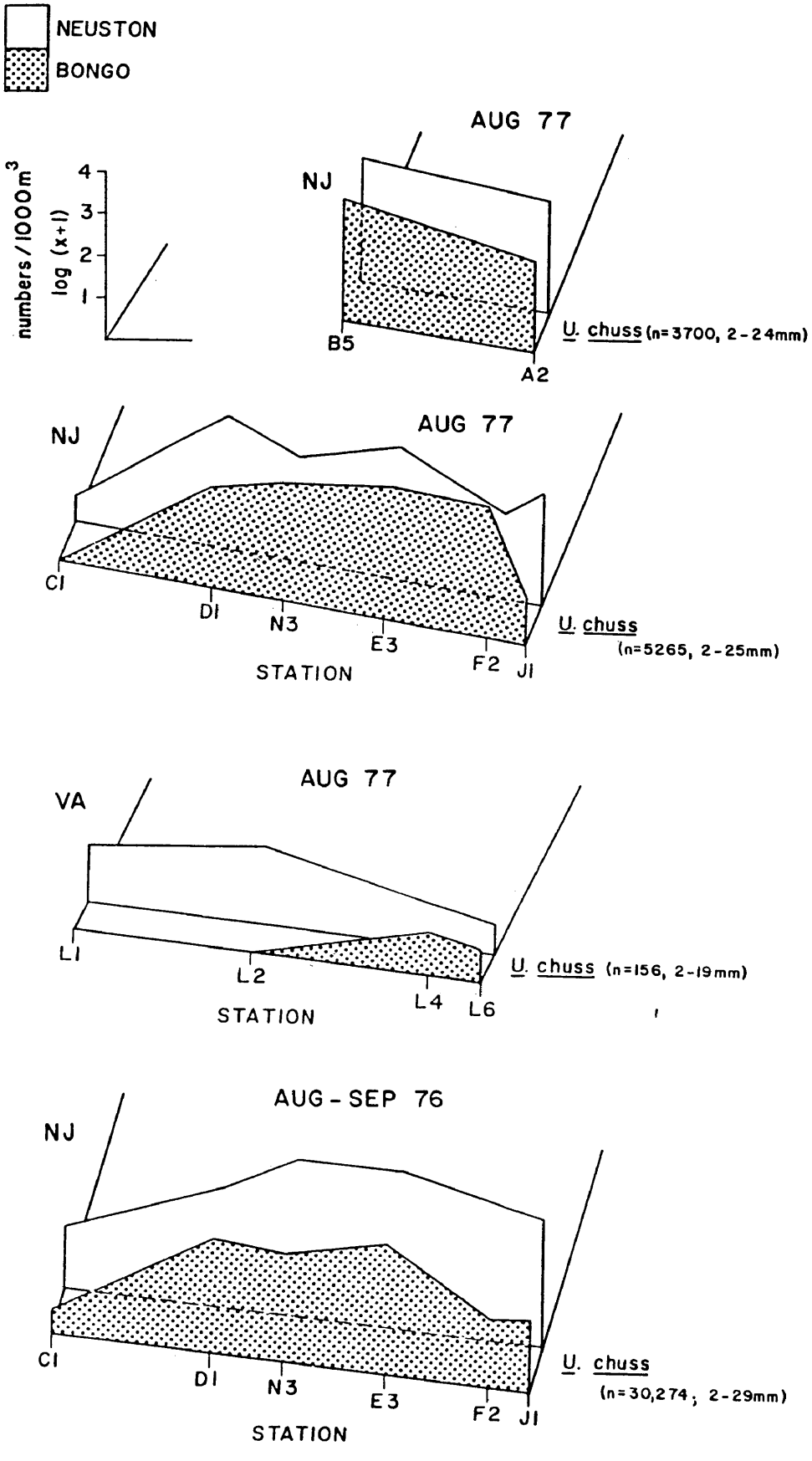

NEUSTON
BONGO
AUG 77
numbers / 1000 m³
log (x+1)
4
3
2
1
NJ
B5
A2
U. chuss (n=3700, 2-24mm)
AUG 77
NJ
C1
D1
N3
E3
F2
J1
STATION
U. chuss
(n=5265, 2-25mm)
AUG 77
VA
L1
L2
L4
L6
STATION
U. chuss (n=156, 2-19mm)
AUG - SEP 76
NJ
C1
D1
N3
E3
F2
J1
STATION
U. chuss
(n=30,274; 2-29mm)

Figure 29. Distribution and abundance of larval and pelagic juvenile hake in fall plankton collections from the Middle Atlantic Bight.

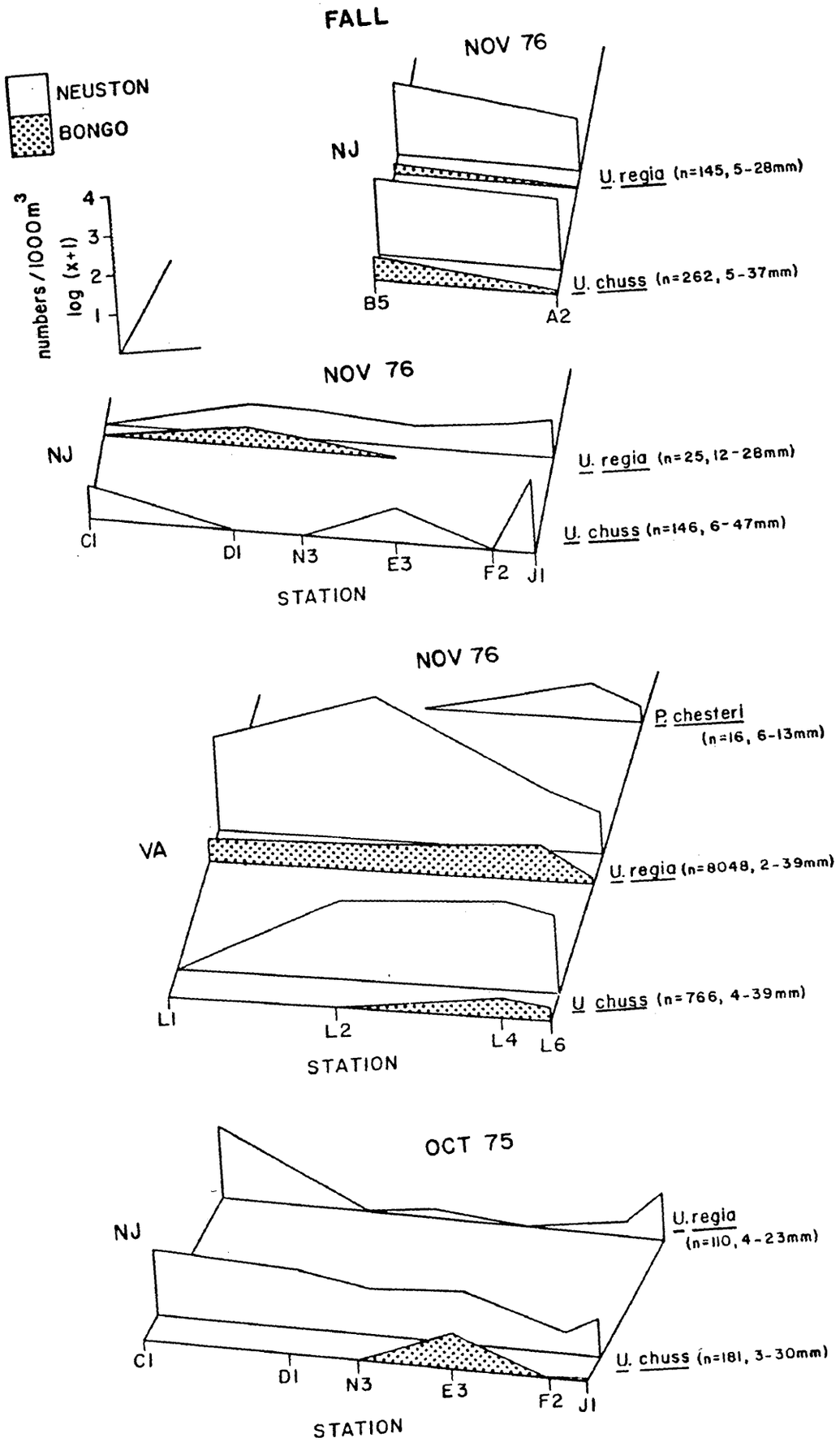
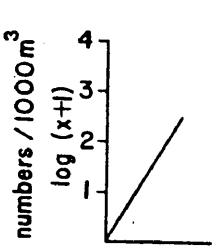
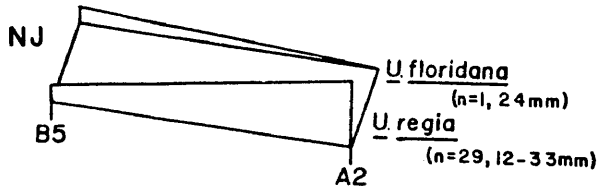

FALL
NOV 76
NEUSTON
BONGO
NJ
U. regia (n=145, 5-28mm)
U. chuss (n=262, 5-37mm)
numbers / 1000m³
log (x+1)
4
3
2
1
B5
A2
NOV 76
NJ
U. regia (n=25, 12-28mm)
U. chuss (n=146, 6-47mm)
C1
D1
N3
E3
F2
J1
STATION
NOV 76
P. chesteri (n=16, 6-13mm)
VA
U. regia (n=8048, 2-39mm)
U. chuss (n=766, 4-39mm)
L1
L2
L4
L6
STATION
OCT 75
NJ
U. regia (n=110, 4-23mm)
U. chuss (n=181, 3-30mm)
C1
D1
N3
E3
F2
J1
STATION

Figure 30. Distribution and abundance of larval and pelagic juvenile hake in winter plankton collections from the Middle Atlantic Bight.

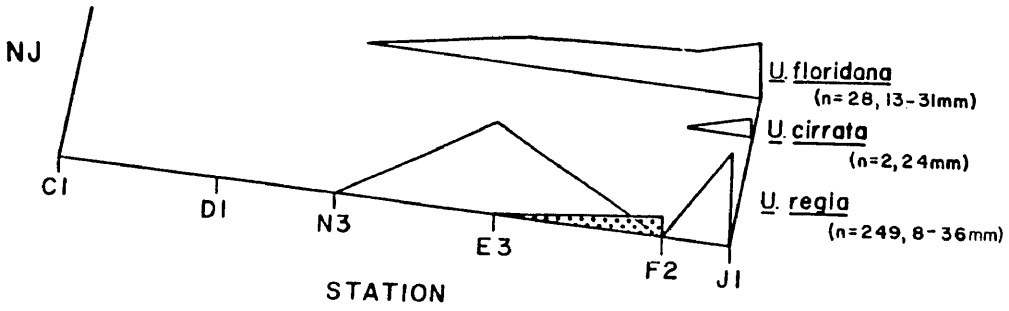
WINTER



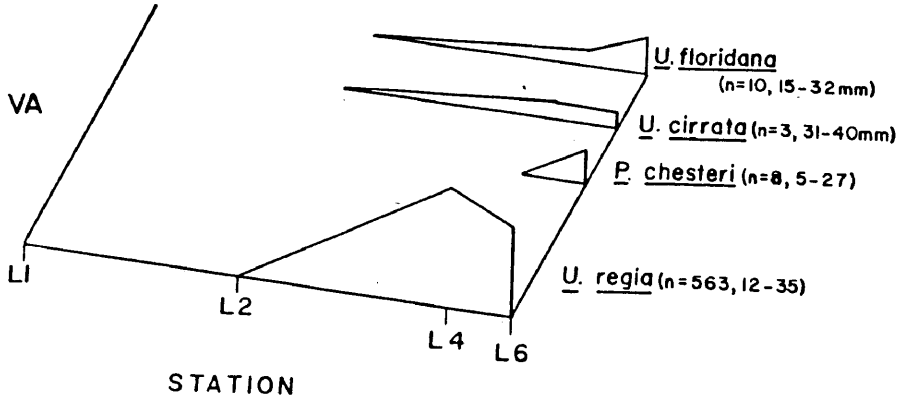
FEB-MARCH 77



FEB-MARCH 77



FEB-MARCH 77



FEB 76

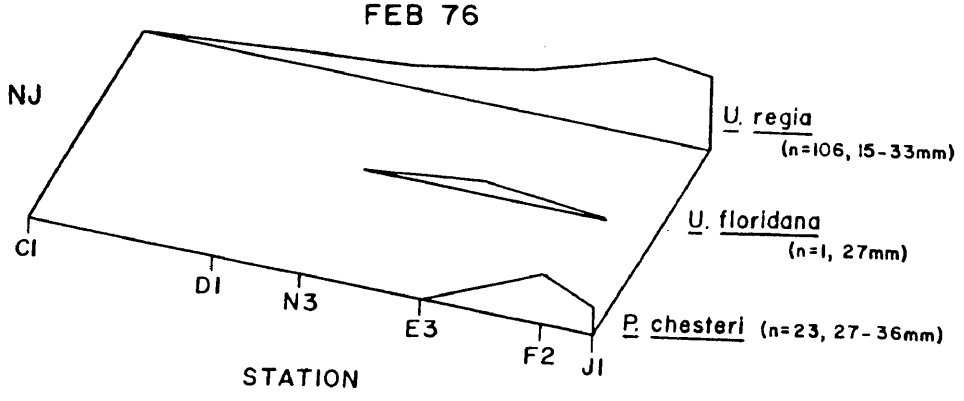
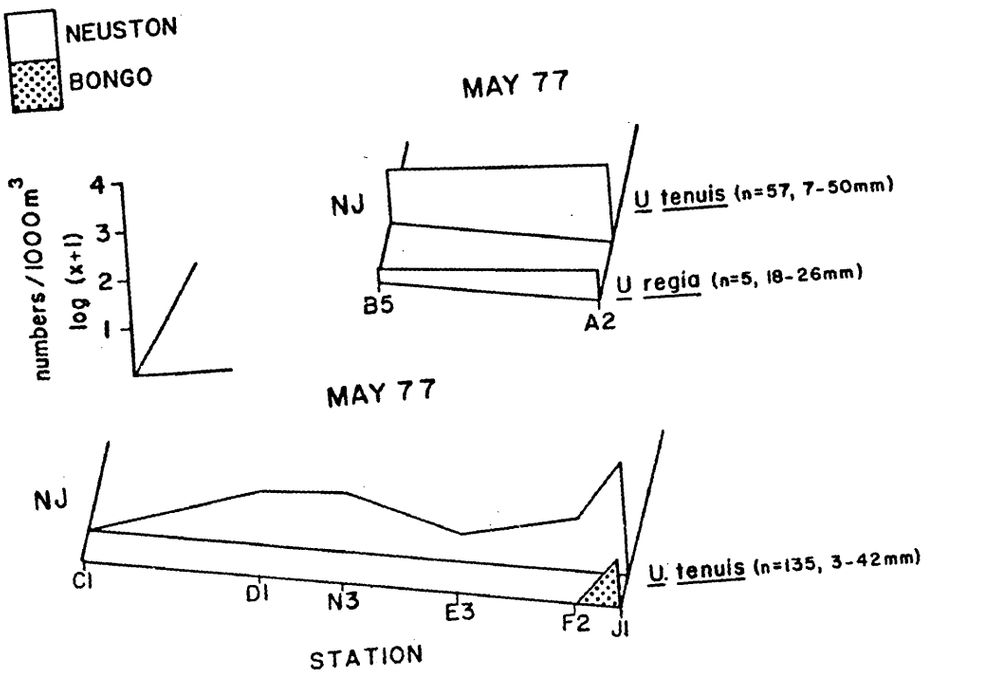


Figure 31. Distribution and abundance of larval and pelagic juvenile hake in spring plankton collections from the Middle Atlantic Bight.

SPRING


NEUSTON
BONGO
MAY 77
numbers / 1000 m³
log (x+1)
4
3
2
1
NJ
U tenuis (n=57, 7-50mm)
U regia (n=5, 18-26mm)
B5
A2
MAY 77
NJ
U. tenuis (n=135, 3-42mm)
C1
D1
N3
E3
F2
J1
STATION
MAY 77
VA
U. regia (n=2, 21-30mm)
U. tenuis (n=295, 4-38mm)
L1
L2
L4
L6
STATION
JUNE 76
NJ
U. tenuis (n=33, 16-53mm)
C1
D1
N3
E3
F2
J1
STATION

APPENDIX TABLES

Table A-1. Meristic characteristics for U. chuss determined from cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N= sample size; size refers to size at which adult complement is attained.

U. chuss

	Mean	LCL	UCL	RANGE	Size	N
caudal fin rays	31.5	31.3	31.7	29-34	8mm SL	66
1st dorsal fin rays	10.7	10.6	10.8	9-12	14mm SL	96
2nd dorsal fin rays	57.9	57.7	58.1	52-63	14-15mm SL	106
anal fin rays	53.4	53.2	53.7	48-57	15-16mm SL	82
vertebrae (total)	49.0	49.0	49.1	47-51	4-5mm NL	214
caudal vertebrae	34.1	34.0	34.2	33-36	4-5mm NL	214
abdominal vertebrae	14.9	14.9	14.9	14-16	4mm NL	448
pelvic fin rays	3.0	3.0	3.0	3-3	3mm NL	200
epibranchial gill rakers (1st arch)	3.0	3.0	3.0	2-4	11-13mm NL	614

Table A-2. Meristic characteristics for U. regia determined from cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N= sample size; size refers to size at which adult complement is attained.

U. regia

	Mean	LCL	UCL	Range	Size	N
caudal fin rays	31.9	31.7	32.1	30-34	9mm SL	71
1st dorsal fin rays	8.9	8.8	9.0	8-10	13mm SL	102
2nd dorsal fin rays	48.6	48.3	48.8	44-52	14-16mm SL	153
anal fin rays	46.6	46.1	47.0	41-51	14-15mm SL	82
vertebrae (total)	46.7	46.6	46.8	45-48	4-5mm NL	179
caudal vertebrae	32.8	32.7	32.9	31-34	4-5mm NL	179
abdominal vertebrae	13.9	13.9	14.0	13-15	4mm NL	179
pelvic fin rays	3.0	3.0	3.0	3-3	3mm NL	200
epibranchial gill rakers (1st arch)	3.0	3.0	3.0	2-4	11-13mm SL	641

Table A-3. Meristic characteristics for U. tenuis determined from cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N = sample size; Size refers to size at which adult complement is attained.

U. tenuis

	Mean	LCL	UCL	Range	Size	N
caudal fin rays	36.7	36.5	36.8	34-40	11mm SL	195
1st dorsal fin rays	10.3	10.2	10.5	9-12	15mm SL	63
2nd dorsal fin rays	55.8	55.1	56.5	51-62	14mm SL	56
anal fin rays	48.7	48.0	49.3	45-53	15mm SL	46
vertebrae (total)	49.7	49.6	49.8	48-51	4-5mm NL	77
caudal vertebrae	33.8	33.6	33.9	32-35	4-5mm NL	77
abdominal vertebrae	15.9	15.9	16.0	15-17	4mm NL	205
pelvic fin rays	3.0	3.0	3.0	3-3	3mm NL	100
epibranchial gill rakers (1st arch)	2.1	2.0	2.2	2-3	11-12mm SL	57

Table A-4. Meristic characteristics for *U. floridana* determined from x-rayed and cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N = sample size.

U. floridana

	Mean	LCL	UCL	RANGE	N
caudal fin rays	31.9	31.6	32.2	30-34	55
1st dorsal fin rays	12.2	11.9	12.4	11-13	45
2nd dorsal fin rays	58.0	57.4	58.6	55-62	45
anal fin rays	50.7	50.2	51.3	48-55	42
vertebrae (total)	49.3	49.1	49.6	46-51	49
caudal vertebrae	33.5	33.2	33.7	32-35	51
abdominal vertebrae	15.9	15.7	16.0	14-17	49
pelvic fin rays	3.0	3.0	3.0	3-3	24
epibranchial gill rakers (1st arch)	2.0	2.0	2.0	2-2	44

Table A-5. Meristic characteristics for *U. cirrata* determined from x-rayed and cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N = sample size.

U. cirrata

	Mean	LCL	UCL	RANGE	N
caudal fin rays	31.9	31.5	32.3	31-33	13
1st dorsal fin rays	11.1	10.7	11.5	10-12	13
2nd dorsal fin rays	64.1	62.7	65.4	59-66	13
anal fin rays	54.9	53.6	56.2	51-57	11
vertebrae (total)	51.5	50.9	52.2	49-53	13
caudal vertebrae	35.6	35.2	36.0	34-36	13
abdominal vertebrae	15.9	15.6	16.2	15-17	13
pelvic fin rays	3.0	3.0	3.0	3-3	5
epibranchial gill rakers (1st arch)	3.0	3.0	3.0	3-3	13

Table A-6. Meristic characteristics for U. earlli determined from x-rayed specimens. LCL and UCL = lower and upper 95% confidence limits; N = sample size.

U. earlli

	Mean	LCL	UCL	RANGE	N
caudal fin rays	29.8	29.5	30.1	29-31	31
1st dorsal fin rays	10.0	9.8	10.2	9-11	32
2nd dorsal fin rays	62.4	61.7	63.1	57-68	32
anal fin rays	55.3	54.8	55.9	52-60	32
vertebrae (total)	46.9	46.7	47.2	45-48	32
caudal vertebrae	32.8	32.5	33.0	31-34	32
abdominal vertebrae	14.1	14.0	14.3	14-15	31
*pelvic fin rays	2.0	2.0	2.0	2-2	32
epibranchial gill rakers (1st arch)	2.0	2.0	2.0	2-2	32

*third ray lost during ontogenetic development

Table A-7. Meristic characteristics for P. chesteri determined from x-rayed and cleared and stained specimens. LCL and UCL = lower and upper 95% confidence limits; N = sample size.

P. chesteri

	Mean	LCL	UCL	RANGE	N
caudal fin rays	33.7	33.4	34.0	31-36	56
1st dorsal fin rays	9.9	9.8	10.1	8-12	73
2nd dorsal fin rays	56.6	56.0	57.1	53-63	58
anal fin rays	49.4	48.8	5.0	45-54	43
vertebrae (total)	49.6	49.3	49.7	48-51	51
caudal vertebrae	34.6	34.4	34.8	33-36	52
abdominal vertebrae	14.9	14.8	15.0	14-16	69
pelvic fin rays	3.0	3.0	3.0	3-3	13
epibranchial gill rakers (1st arch)	4.3	4.1	4.4	4-5	32

Table A-8 Abundance, size and station location of Urophycis and Phycis larvae and neustonic juveniles caught during BLM cruises 01W-08W. Abbrviations used are: n= neuston catches; b= bongo catches; $\bar{X}$= mean length (mm); R= length range (mm) and D= density of fish (#/1000 m^3)

CRUISE BLM 01W (Oct.1975)

		U. regia			U. chuss		
STATION		$\bar{X}$	R	D	$\bar{X}$	R	D
C1	(n)	8.5	4-20	63	16.5	5-26	38
D1	(n)	--	--	--	22.4	8-30	30
N3	(n)	11.2	--	1	19.8	15-20	17
E3	(n)	--	--	--	17.6	6-28	22
	(b)	--	--	--	3.4	3-4	7
F2	(n)	12.7	9-15	1	10.1	6-17	3
J1	(n)	11.2	6-23	13	14.6	7-21	7
	(b)	--	--	--	18.0		<1

CRUISE BLM 02W (FEB.1976)

		U. regia			U. floridana			P. chesteri		
STATION		$\bar{X}$	R	D	$\bar{X}$	R	D	$\bar{X}$	R	D
C1	(n)	--	--	--	--	--	--	--	--	--
D1	(n)	33.8	--	1	--	--	--	--	--	--
N3	(n)	32.2	31-33	2	--	--	--	--	--	--
E3	(n)	26.5	18-30	7	27.4	--	1	--	--	--
F2	(n)	22.3	15-30	36	--	--	--	33.0	31-33	13
J1	(n)	25.2	19-33	26	--	--	--	31.7	27-36	3

CRUISE BLM 03W (JUNE1976)

		U. tenuis		
STATION		$\bar{X}$	R	D
C1	(n)	--	--	--
D1	(n)	46.7	41-53	3
N3	(n)	32.6	26-38	3
E3	(n)	37.7	35-41	4
F2	(n)	28.3	19-38	4
J1	(n)	23.1	16-38	19

Table A-8 continued.

CRUISE BLM 04W (AUG-SEP.1976)

U. chuss

STATION		$\bar{X}$	R	D
C1	(n)	3.7	3-6	5
	(n)	19.6	15-26	24
	(b)	5.2	--	2
D1	(n)	4.2	2-8	264
	(n)	15.1	7-23	464
	(b)	3.7	2-8	521
N3	(n)	4.0	2-8	56
	(n)	13.2	5-29	5221
	(b)	4.0	2-16	280
E3	(n)	9.2	3-20	7547
	(b)	3.8	2-8	1514
F2	(n)	10.2	4-21	1627
	(b)	5.3	2-15	40
J1	(n)	11.2	2-21	1090
	(b)	3.9	2-14	72

CRUISE BLM 05W (Nov.1976)

		U. regia			U. chuss			P. chesteri		
STATION		$\bar{X}$	R	D	$\bar{X}$	R	D	$\bar{X}$	R	D
L1	(n)	12.9	7-39	224	--	--	--	--	--	--
	(b)	5.0	--	3	--	--	--	--	--	--
L2	(n)	15.0	5-34	4576	25.1	13-39	116	--	--	--
	(b)	3.3	2-12	23	--	--	--	--	--	--
L4	(n)	14.5	5-24	37	18.6	7-38	189	8.9	6-11	7
	(b)	5.1	--	8	6.5	5-7	2	--	--	--
L6	(n)	15.8	6-24	12	20.3	4-38	90	10.8	9-13	2
	(b)	16.0	--	1	5.6	--	1	--	--	--
C1	(n)	--	--	--	40.5	34-47	5	--	--	--
D1	(n)	19.0	--	5	--	--	--	--	--	--
	(b)	26.3	24-27	2	--	--	--	--	--	--
N3	(n)	29.0	--	5	--	--	--	--	--	--
	(b)	30.0	--	1	--	--	--	--	--	--
E3	(n)	17.3	13-23	2	21.5	11-36	6	--	--	--
F2	(n)	22.0	22-22	5	--	--	--	--	--	--
J1	(n)	18.1	12-28	9	22.4	6-30	77	--	--	--
B5	(n)	13.0	6-28	67	21.9	12-30	86	--	--	--
	(b)	7.3	5-11	1	35.5	31-41	3	--	--	--
A2	(n)	10.7	8-27	20	12.3	5-37	66	--	--	--
	(b)	--	--	--	4.3	--	1	--	--	--

Note: Two neuston values are recorded at a station if more than one size class of a species is present.

Table A-8 continued.

CRUISE BLM 06W (Feb-Mar.1977)

			U. regia			U. cirrata			U. floridana		
STATION			$\bar{X}$	R	D	$\bar{X}$	R	D	$\bar{X}$	R	D
L1			--	--	--	--	--	--	--	--	--
L2			--	--	--	--	--	--	--	--	--
L4	(n)		18.1	12-32	255	42.2		1	23.5	23-23	1
* L6	(n)		25.6	14-35	60	35.8	31-40	1	20.2	15-32	5
C1			--	--	--	--	--	--	--	--	--
D1			--	--	--	--	--	--	--	--	--
N3			--	--	--	--	--	--	--	--	--
E3	(n)		25.3	8-35	64	--	--	--	24.8	22-31	3
F2	(n)		--	--	--	--	--	--	16.0		5
	(b)		22.0	21-23	1	--	--	--	23.2	--	1
J1	(n)		22.5	11-36	62	24.4		1	21.0	13-28	11
B5	(n)		33.0	--	1	--	--	--	24.0		1
A2	(n)		21.9	12-33	16	--	--	--	--	--	--

* Phycis chesteri collected at station L6: X=14.7, R=5-27, N=4

CRUISE BLM 07W (May 1977)

		U. tenuis			U. regia		
STATION		$\bar{X}$	R	D	$\bar{X}$	R	D
L1		--	--	--	--	--	--
L2		--	--	--	--	--	--
L4	(n)	5.9	4-9	132	--	--	--
	(n)	20.1	11-38	105	21.2		1
	(b)	3.8		4	--	--	--
L6	(n)	20.1	12-31	122	30.0		1
C1		--	--	--	--	--	--
D1	(n)	38.0	35-40	12	--	--	--
N3	(n)	27.7	25-30	18	--	--	--
E3	(n)	35.0	30-42	3	--	--	--
F2	(n)	25.0	24-25	13	--	--	--
J1	(n)	13.7	5-31	193	--	--	--
	(b)	5.4	3-7	9	--	--	--
B5	(n)	36.2	22-50	8	26.3		1
A2	(n)	20.3	7-40	36	18.0		3

Table A-8 continued.

CRUISE BLM 08W (Aug.1977)

U. chuss

STATION		$\bar{X}$	R	D
L1	(n)	9.3	4-17	22
L2	(n)	9.9	5-19	69
L4	(n)	8.0	5-10	8
	(b)	2.8	2-3	10
L6	(n)	8.8	6-10	4
	(b)	4.7	--	5
C1	(n)	7.3	5-10	3
D1	(n)	5.9	3-11	1289
	(b)	3.2	2-4	269
N3	(n)	4.9	3-8	377
	(b)	3.9	2-6	548
E3	(n)	10.6	3-21	1234
	(b)	4.3	2-25	1322
F2	(n)	4.2	2-14	96
	(b)	4.2	2-19	1036
J1	(n)	12.8	2-22	453
	(b)	4.0	2-7	11
B5	(n)	6.6	2-22	811
	(b)	3.9	2-13	755
A2	(n)	13.4	2-24	450
	(b)	4.2	2-17	136

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