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Identification and Development of Larval and Juvenile *Urophycis chuss*, *U. tenuis* and *Phycis chesteri* (Pisces, Gadidae) from the Northwest Atlantic

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Abstract

Pelagic stages of *Urophycis chuss*, *Urophycis tenuis* and *Phycis chesteri* from the Northwest Atlantic were identified by differences in caudal fin-ray and epibranchial gillraker counts, body depth and pigmentation. The adult complement of caudal fin rays in *U. chuss* (28-34, mean 31.5) and *U. tenuis* (33-39, mean 36.5) distinguished larvae greater than 7-8 mm SL (standard length). Caudal fin-ray counts in *P. chesteri* (32-35, mean 33.3) overlapped those of the two *Urophycis* species. The adult complement of epibranchial gillrakers in *U. chuss* (3), *U. tenuis* (2) and *P. chesteri* (4-5) developed at 12-14 mm in *Urophycis* and at 16-18 mm in *P. chesteri*. *Phycis chesteri* was deeper-bodied (24.4% SL) than *U. tenuis* (21.3% SL) which in turn was deeper-bodied than *U. chuss* (19.3% SL). Pelagic larvae and juveniles of the three species had 3 pelvic fin rays. A size-dependent key to pelagic stages of these species is presented.

Black pigment on pelvic fins of pelagic *Urophycis* and *Phycis* was absent in newly-demersal specimens. Differences in pigmentation on the midline, pectoral fin base, dorso-lateral trunk and caudal peduncle helped to separate 5-10 mm *Urophycis* larvae. Ossification generally occurred at a smaller size in *U. chuss* than in either *U. tenuis* or *P. chesteri* for most of the structures examined. The mandibular arch, dentary, premaxilla, precaudal vertebrae, branchiostegals, cleithra and parasphenoid ossified first. Pelvic fins were the first fins to develop. The first dorsal fin and the pectoral fins developed last.

Introduction

Hakes of the genera *Phycis* Rose 1793 and *Urophycis* Gill 1863 are common gadid fishes on the continental shelf and slope of the Northwest Atlantic. *Phycis* is represented there by one species, the longfin hake (*Phycis chesteri* Goode and Bean 1878) (Svetovidov, 1948). *Urophycis* is represented by seven species which are endemic to the western Atlantic, two of which are the red or squirrel hake, *Urophycis chuss* (Walbaum 1792), and the white or common hake, *U. tenuis* (Mitchill 1815). The larvae and juveniles of these two species remain pelagic for 2-3 months. Juvenile *U. chuss* become demersal at 25-30 mm in length and associate with scallops, whereas *U. tenuis* juveniles remain pelagic until they are about 50-60 mm in length (sometimes 80 mm) and settle to the bottom nearshore (Markle *et al.*, 1982).

Musick (1973) and Wenner (1983) have shown how adult *U. chuss*, *U. tenuis* and *P. chesteri* may be identified, but the larvae of *U. tenuis* and *P. chesteri* have not been previously described (Fahay, 1983). The larvae are similar to those of the fourbeard rockling (*Enchelyopus cimbrius*), the threebeard rockling (*Gaidropsarus ensis*) and several other *Urophycis* species (Hildebrand and Cable, 1938; Cohen and Russo, 1979; Kendall and Naplin, 1981; Markle, 1982; Markle *et al.*, 1982; Fahay, 1983). Although *U. chuss* eggs, newly-hatched 2 mm larvae and 7-15 mm larvae have been described (Hildebrand and Cable, 1938; Miller and Marak, 1959; Fahay, 1983), misidentification of these larvae was possible because unidentified larvae of several *Urophycis* species co-occur with *U. chuss*.

Previous attempts to identify *Urophycis* larvae (Merriman and Sclar, 1952; Bigelow and Schroeder, 1953) were unsuccessful (Musick, MS 1969; Kendall and Naplin, 1981). Nichols and Breder (1927) noted that the pelvic fins were shorter, the body deeper and the head longer in juvenile *Phycis tenuis* (=*Urophycis tenuis*) than in *Phycis chuss* (=*Urophycis chuss*). They also noted that this species might be confused with *Phycis chuss* because the pelvic fins reached the origin of the anal fin (Bigelow and Welsh, 1925).

The only *Phycis* larvae that have been described were from the Northeast Atlantic (D'Ancona, 1933; Russell, 1976). Although these larvae and *P. chesteri* have overlapping dorsal and anal fin-ray counts, elongated pigmented pelvic fin rays, and 3+6 hypural caudal fin rays, they differ from *P. chesteri* and *Urophycis* larvae in having an initial number of four pelvic fin rays instead of three and by the presence of two temporal spines (Russell, 1976). Further studies may indicate that *P. chesteri* actually belongs to the genus *Urophycis*. In this paper, descriptive information on the pelagic stages of *U. chuss*, *U. tenuis* and *P. chesteri* is presented and early development of these species is compared.

Materials and Methods

All specimens in the collections of *U. chuss*, *U. tenuis* and *P. chesteri* from various areas of the Northwest Atlantic (Table 1) were preserved in 5-10% formalin. Upon examination in the laboratory, length measurements were recorded as standard length (SL)

TABLE 1. Collections of larval and juvenile *U. chuss*, *U. tenuis* and *P. chesteri* from the Northwest Atlantic.

Species	Region	Time of capture	Gear	No. of specimens	Standard length (mm)
U. chuss	Scotian Shelf	Aug–Sep 1978	Neuston net	>200	4–32
	Passamaquoddy Bay	May–Sep 1981	Otter trawl & scuba	56	65–228
U. tenuis	Scotian Shelf	Aug–Sep 1978	Neuston net	>200	4–41
	Gulf of St. Lawrence	Sep 1979	Neuston net	>200	4–40
	Passamaquoddy Bay	May–Sep 1981	Otter trawl & beach seine	138	26–176
P. chesteri	Flemish Cap	Mar 1979	Neuston net	5	35–39
	Grand Bank	Jun 1980	IK midwater trawl	3	50–53
	South of Grand Bank	Feb 1981	Engels midwater trawl	5	5–28
	South of Grand Bank	Feb 1982	Engels midwater trawl	1	27
	Scotian Shelf	Mar 1977	Neuston net	3	30–33
	Scotian Shelf	May–Jun 1978	Neuston net	2	32–41
	Scotian Shelf	Jul 1980	Otter trawl	1	49
	Mid-Atlantic Bight	Feb 1975	Bongo plankton sampler	12	16–34
	Mid-Atlantic Bight	Mar 1975	Neuston net	8	24–38

to the nearest 0.1 mm except the smallest *P. chesteri* which was measured as notochord length (NL). Larvae were defined as specimens less than 18 mm and juveniles as fish equal to or greater than 18 mm.

Meristics

Fourteen *U. chuss* (5.3–108.0 mm), 14 *U. tenuis* (5.5–97.8 mm) and 8 *P. chesteri* (4.5–30.2 mm) were cleared and differentially stained with Alizarin Red S and Alcian Blue (Taylor, 1967; Dingerkus and Uhler, 1977). Meristics of these fish were determined with the aid of a stereomicroscope for first and second dorsal fin rays, anal fin rays, caudal fin rays (superior, inferior and hypurals), left and right pectoral and pelvic fin rays, right epibranchial gillrakers, and precaudal and caudal vertebrae. All rudimentary epibranchial gillrakers were included, but gillrakers straddling the angle of the ceratobranchial and epibranchial were not counted (Hubbs and Lagler, 1958). Superior and inferior fin rays were defined as the dorsal-most (superior) and ventral-most (inferior) rays which are separated by rays on hypurals 1–2 and 3–5; otherwise, caudal terminology follows Rosen and Patterson (1969).

Additional caudal and pelvic fin-ray counts were made on 138 *U. tenuis* (26.1–176.1 mm) and 56 *U. chuss* (65.1–228.4 mm) after clearing and staining (Hollister, 1934). Pelvic fins were removed from two *P. chesteri* (178 and 197 mm) and stained by the same method. All elements that were stained by Alizarin Red S (ossified) and Alcian Blue (forming or not ossified) were counted. However, discussion of ossification pertains only to specimens whose structures absorbed the Alizarin Red S stain.

Morphometrics

Measurements of unstained specimens were taken from the left side of 344 *Urophycis* (4.0–40.8 mm) from the Scotian Shelf and Gulf of St. Lawrence and 33 *P. chesteri* (4.5–49.4 mm) with the use of dial calipers and a stereomicroscope. The measurements were defined as follows:

Standard length (SL) — tip of snout to posterior margin of hypurals (for all specimens except notochord length for one *P. chesteri* 4.5 mm NL).

Snout length — tip of snout to anterior margin of orbit.

Head length — tip of snout to posterior margin of operculum.

Preanus length — tip of snout to vent.

D2 fin length — origin of first ray of second dorsal fin to posterior tip of last ray of this fin (specimens $\geqslant$10 mm).

Body depth at D1 — vertical distance from origin of first dorsal fin to ventral surface (specimens $\geqslant$10 mm).

Body depth at D2 — vertical distance from origin of second dorsal fin to ventral surface (specimens $\geqslant$10 mm).

Body depth at vent — vertical distance from vent to dorsal surface.

For analysis and comparison among species, the partial measurements were transformed to percentages of standard length.

Pigmentation

Seven pigment characters (Fig. 1) were examined on 179 *Urophycis* larvae (4.2–15.9 mm). Only pelvic fin pigment was determined for *P. chesteri* because the small sample size (n = 33), with most specimens longer than 15 mm, was inadequate for pigment analysis and comparison with *Urophycis*. With the aid of a stereomicroscope, the left side of each specimen was examined for presence or absence of pigment on the caudal,

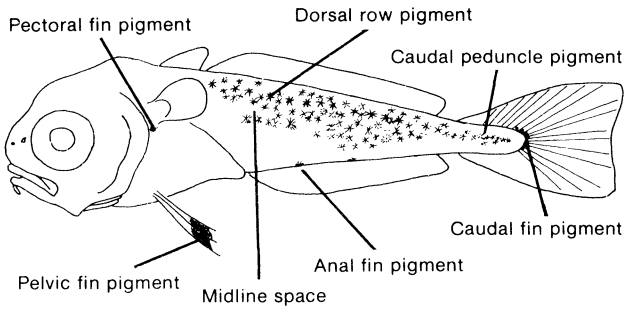

Fig. 1. Locations of seven pigment characters on a generalized illustration of a *Urophycis* larva.

pectoral, pelvic and anal fins. The remaining three pigment characters (dorsal row, caudal peduncle and midline space) had to conform to specific patterns before pigment was considered to be present.

Pectoral fin pigment — usually one melanophore, but sometimes two or three on the ventral portion of the fin base. This external pigment should not be confused with internal gut pigment. The pigment was sometimes covered by the posterior edge of the operculum.

Pelvic fin pigment — on the outer two-thirds of the connecting membrane between the fin rays.

Midline space — an area, lacking pigment, dorsal to the posterior portion of the gut above the midline in small (4–12 mm) *Urophycis*, predominantly *U. tenuis*. This character forms as pigment develops on the anterior midline region above the gut in 4–6 mm larvae. Above this midline pigment is a small space with no pigment, and above this space is pigment that develops at about the same rate as pigment associated with the midline. These pigmented areas join posteriorly. This space is no longer present in 14–15 mm larvae. This character often cannot be considered in small *Urophycis* (about 5 mm) because the midline and dorsal pigments have not yet joined on the midtrunk region.

Dorsal row pigment — a longitudinal row of prominent, usually dark stellate melanophores located laterally between the midline and the dorsal fins of some *Urophycis* larvae about 6–15 mm. The row originates dorsal to the pectoral fin area and terminates on the caudal peduncle. Dorsal row pigment was present in 6–7 mm *Urophycis* but was usually not fully developed on the posterior flank or caudal peduncle by that size. Dorsal row pigment is the same as dorso-lateral pigment of Russell (1976, fig. 4).

Anal fin pigment — melanophores at the base of the rays on both sides of the fin.

Caudal peduncle pigment — a narrow shaft of pigment, symmetrical about the midline on *U. chuss* larvae. This character consists of both internal (along the vertebrae) and external pigments which extend posteriorly from pigment on the flank. In *U. tenuis*, pigment on the caudal peduncle does not appear as a narrow shaft but is broader and therefore less associated with the midline. Differences in caudal peduncle pigmentation are shown in fig. 3 of Markle *et al.* (1982).

TABLE 2. Stained *Urophycis* and *Phycis* specimens deposited in National Museum of Canada, Ottawa. (The 4.5 mm *P. chesteri* measured as notochord length.)

Urophycis chuss		*Urophycis tenuis*		*Phycis chesteri*	
SL mm	Cat. No.	SL mm	Cat. No.	SL mm	Cat. No.
5.3	84-1473	5.5	84-1476	4.5[a]	84-1478
6.5	84-1471	6.7[a]	84-1475	11.0[a]	84-1480
7.1[a]	84-1475	6.9	84-1475	13.1	84-1480
7.7	84-1470	7.7	84-1475	17.1	84-1481
8.1	84-1468	8.0	84-1476	18.1	84-1481
9.6	84-1467	9.1	84-1475	19.1	84-1481
10.6	84-1467	10.1	84-1476	28.1	84-1481
10.7[a]	84-1475	10.3[a]	84-1473	28.9[a]	84-1479
11.1	84-1468	11.4	84-1473	29.7	84-1465
12.9	84-1474	12.5	84-1475	30.2	84-1482
13.0	84-1469	13.8	84-1473		
14.7	84-1474	14.7	84-1473		
15.1[a]	84-1466	14.9[a]	84-1474		
15.6	84-1474	15.8	84-1475		
20.4	84-1469	27.8	84-1477		
29.6	84-1472	39.6	84-1477		
108.0	84-1484	97.8	84-1483		

[a] Specimens illustrated in Fig. 2, 3 and 4.

Caudal fin pigment — located on the posterior margin of the caudal peduncle and on caudal fin rays and membrane where they articulate with hypural elements. This pigment was present on *U. chuss* and *U. tenuis* as small as 6 mm. In these small larvae, the pigment consisted of one or two melanophores usually at the base of the hypural rays. In larger specimens (about 15 mm), the pigment had spread dorsally and ventrally to form the characteristic crescent-shaped band.

Because *U. chuss* does not occur in the Gulf of St. Lawrence (Beacham and Nepszy, 1980; Markle *et al.*, 1982), separation of *U. chuss* and *U. tenuis* from the Scotian Shelf was established by comparing a size series of known *U. tenuis* from the Gulf with larvae from the Scotian Shelf and by using characters common to both larvae and juveniles of each species. All cleared and stained specimens have been deposited in the National Museum of Canada, Ottawa (Table 2).

Results

The larvae and pelagic juveniles of *U. chuss*, *U. tenuis* and *P. chesteri* from the Northwest Atlantic were identified by differences in caudal fin-ray and epibranchial gillraker counts, body depth and pigmentation. Representative specimens of the three species are illustrated in Fig. 2, 3 and 4.

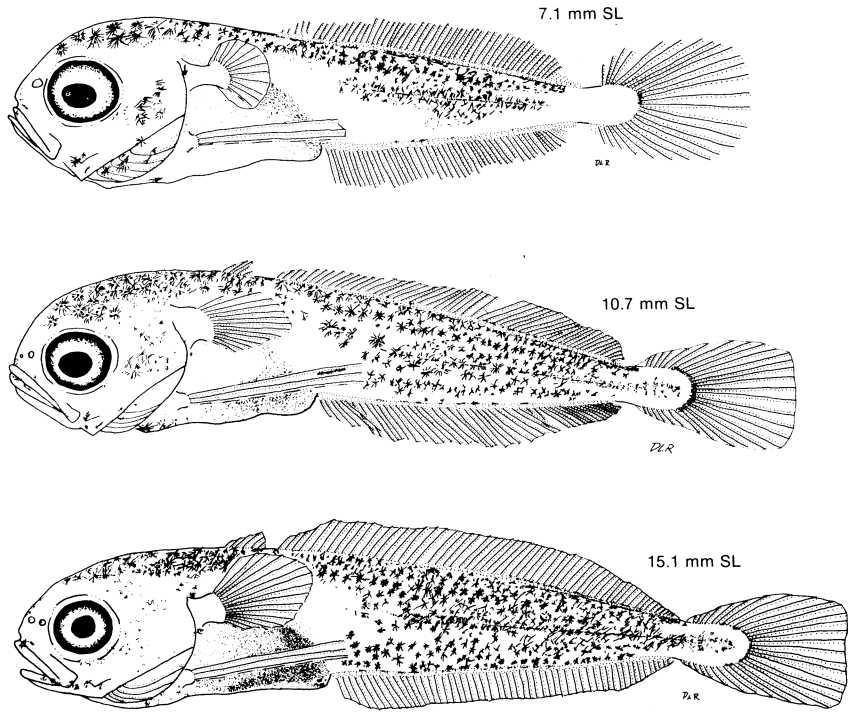

Fig. 2. Illustrations of three *U. chuss* specimens listed in Table 2.

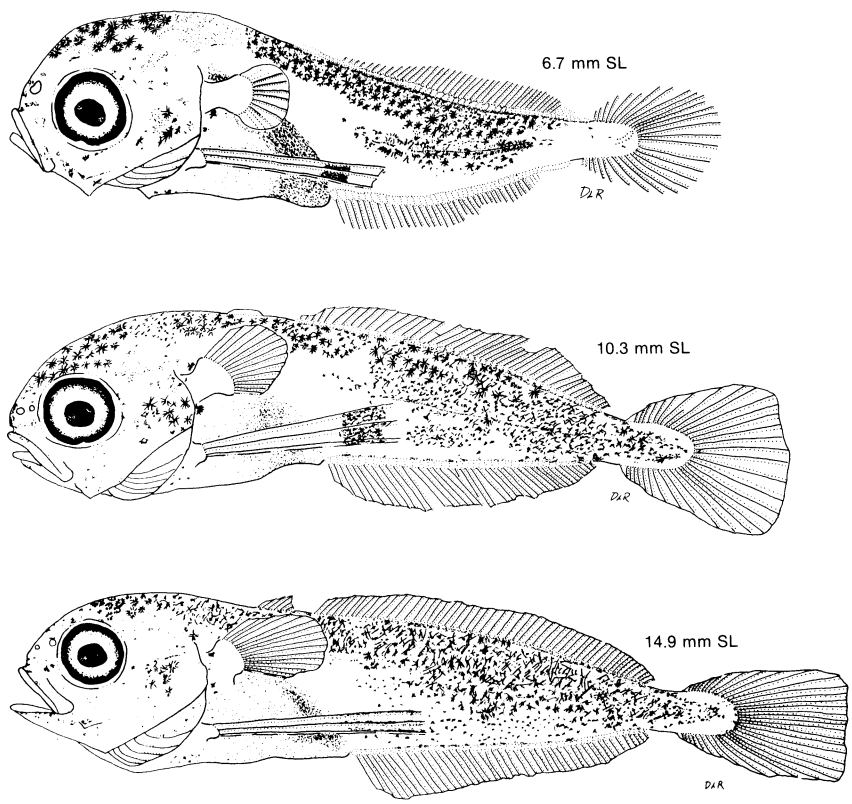

Fig. 3. Illustrations of three *U. tenuis* specimens listed in Table 2.

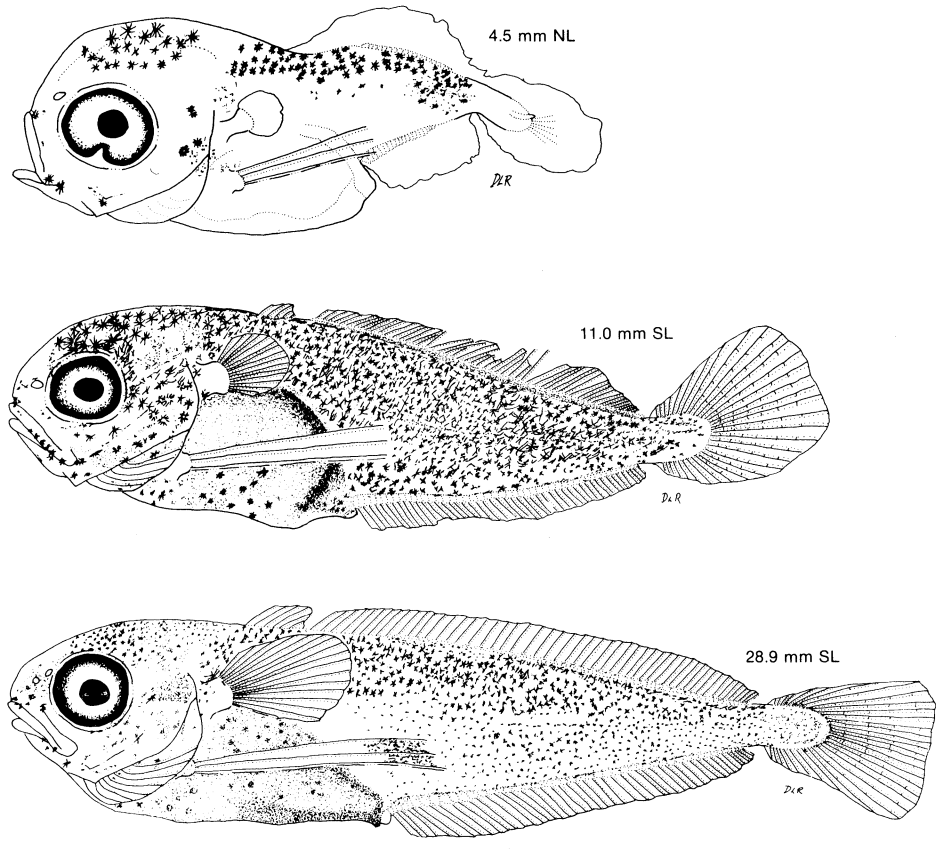

Fig. 4. Illustrations of three *P. chesteri* specimens listed in Table 2.

Meristics

The numbers of fin rays (dorsal, anal, caudal, pectoral and pelvic), epibranchial gillrakers, and vertebrae for each species are listed in Table 3. The adult complement of vertebrae and pelvic fin rays was attained very early in the larval stage of each species (<5.5 mm) (Table 4). In *U. chuss* and *U. tenuis*, the caudal and anal fin rays were next to attain their full complement (7.7–8.0 mm), followed by the second dorsal fin rays, first dorsal fin rays and epibranchial gillrakers, with the pectoral fin rays being the last to attain the adult number (about 15–16 mm). In *P. chesteri*, epibranchial gillrakers may be the last character to attain the adult complement. With the exception of epibranchial gillrakers the ranges of all meristic characters of the three species overlapped to some extent, the least amount of overlap being for caudal fin-ray counts in *U. chuss* (28–34) and *U. tenuis* (33–39), with the range of counts in *P. chesteri* being similar to that in *U. chuss* (Fig. 5). Despite the differences in fin-ray counts, the caudal structure was similar in *U. chuss* and *U. tenuis* (Fig. 6). Apparent differences in the structure of the neural spine on the second preural centrum are atypical and cannot be used to distinguish between *U. chuss* and *U. tenuis*.

Observations of cleared and stained pelvic fins from larvae and juveniles of various sizes revealed the extreme reduction of the ventral-most fin ray with growth (Fig. 7). This third ray was reduced to a nub and was not visible externally in adults.

Morphometrics

The means and ranges of the proportional measurements (percent of standard length) for snout length, head length, preanus length and second dorsal fin length were essentially the same in the three species and were of no use in species separation (Table 5). However, despite some overlap in the ranges, the mean percentages for body depth at the vent and at the origins of the first and second dorsal fins were lowest in *U. chuss*, intermediate in *U. tenuis* and highest in *P. chesteri*. Thus, the measurements of body depth at these three positions were the most useful morphometric characters for species separation at the larval and early juvenile stages (Fig. 8).

Morphometric data of *U. tenuis* from the Gulf of St. Lawrence had character means which were similar to those for the Scotian Shelf specimens.

TABLE 3. Numbers of fin rays, epibranchial gillrakers and vertebrae in larval and juveile *U. chuss*, *U. tenuis* and *P. chesteri* of various sizes (D1 = first dorsal, D2 = second dorsal, Sup = superior, Hyp = hypurals, Inf = inferior, R = right, L = left, Pc = precaudal, and C = caudal.)

SL	Dorsal		Anal	Caudal				Pectoral		Pelvic		Gill	Vertebrae		
(mm)	D1	D2	(A)	Sup	Hyp[a]	Inf	Total	R	L	R	L	rakers	Pc	C	Total
							U. chuss								
5.3	—	—	—	9	2+5	7	23	—	—	3	3	0	14	35	49
6.5	3	46	41	11	3+5	8	27	12	12	3	3	1	15	35	50
7.7	5	49	47	11	3+5	9	28	12	13	3	3	1	15	34	49
8.1	3	49	45	12	3+6	11	32	13	13	3	3	2	15	34	49
9.6	4	57	51	12	3+6	11	32	13	14	3	3	2	14	35	49
10.6	8	58	49	13	3+5	12	33	13	13	3	3	2	14	35	49
11.1	7	54	46	12	3+6	11	32	14	15	3	3	2	15	34	49
12.9	9	55	51	11	3+6	11	31	14	15	3	3	3	14	35	49
13.0	9	55	51	11	3+6	11	31	14	15	3	3	2	15	35	50
14.7	9	58	54	11	3+6	11	31	16	15	3	3	3	15	34	49
15.6	9	53	56	11	3+6	11	31	16	15	3	3	3	15	34	49
20.4	11	55	50	11	3+6	11	31	15	17	3	2	3	16	32	48
29.6	11	55	52	12	3+5	10	30	16	16	3	3	3	15	34	49
108.0	10	58	54	13	3+6	11	33	17	17	3	—	3	15	34	49
							U. tenuis								
5.5	—	27	29	8	3+6	9	26	—	—	3	3	0	15	35	50
6.9	—	46	39	11	3+6	12	32	8+	12	3	3	0	15	35	50
7.7	4	43	37	13	3+6	11	33	9	9+	3	3	1	16	34	50
8.0	4	44	43	14	3+6	12	35	10	13	3	3	1	16	35	51
9.1	4	46	40	14	3+5	12	34	12	14	3	3	1	16	34	50
10.1	8	48	41	13	3+6	13	35	12	12	3	3	1	15	34	49
11.4	7	51	45	14	3+6	13	36	14	14	3	3	1	16	34	50
12.5	5+	52	46	14	3+6	13	36	14	14	3	3	2	15	35	50
13.8	8	51	43	14	3+6	13	36	15	15	3	3	2	16	34	50
14.7	10	52	46	14	3+6	13	36	15	16	3	3	2	16	34	50
15.8	10	52	49	15	3+6	14	38	15	17	3	3	2	15	35	50
27.8	10	54	47	13	3+5	12	33	17	17	3	3	2	16	33	49
39.6	11	56	48	14	3+6	14	37	17	17	3	3	2	16	33	49
97.8	11	58	52	15	3+6	14	38	17	15	3	3	2	16	34	50
							P. chesteri								
4.5[b]	—	—	—	—	—	—	—	—	—	—	—	—	15	~35	~50
13.1	—	~56	48	13	3+6	12	34	16	16	3	3	3	15	35	50
17.1	9	55	47	13	3+6	13	35	16	16	3	3	3	14	36	50
18.1	9	54	49	12	3+6	12	33	16	16	3	3	4	14	34	48
19.1	10	55	49	12	3+6	12	33	18	18	3	3	4	15	36	51
28.1	9	62	52	12	3+6	11	32	16	16	3	3	4	15	35	50
29.7	11	56	47	12	3+6	12	33	16	16	3	3	4	15	35	50
30.2	9	56	50	12	3+6	12	33	16	17	3	3	4	15	36	51

[a] Hypurals 1–2 and 3–5.
[b] Notochord length (mm).

TABLE 4. Range of meristic characters in adults and approximate size of development in *U. chuss*, *U. tenuis* and *P. chesteri* larvae. Adult ranges compiled from Musick (1973), Markle (1982), Wenner (1983), and this study.

	U. chuss		*U. tenuis*		*P. chesteri*	
Characters	Adult range	Size (mm SL)	Adult range	Size (mm SL)	Adult range	Size (mm SL)
First dorsal fin rays	9–11	12.9	10	14.7	8–11	<17.1
Second dorsal fin rays	53–64	9.6	50–58	11.4	50–63	<13.1
Anal fin rays	45–56	7.7	41–52	8.0	43–53	<13.1
Caudal fin rays	28–34	7.7	33–39	7.7	28–35	<13.1
Pectoral fin rays	16	15.6	16	14.7	14–17	<13.1
Pelvic fin rays	3[a]	<5.3	3[a]	<5.5	3[a]	~4.5[b]
Epibranchial gillrakers	3	12–14	2	12	4–5	16–18
Total vertebrae	45–50	<5.3	47–50	<5.5	45–52	~4.5[b]

[a] Third ray rudimentary in demersal juveniles and adults.
[b] Notochord length (mm).

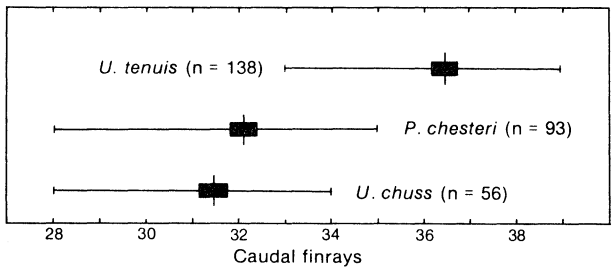

Fig. 5. Range of caudal fin-ray counts (with mean ± 2 standard errors) in *U. tenuis* (26–176 mm), *U. chuss* (65–228 mm) and *P. chesteri* (from Wenner, 1983).

Pigmentation

Comparison of observations on seven pigment characters (Fig. 1) was possible only for *U. chuss* and *U. tenuis* larvae because there were too few *P. chesteri* larvae in the same length range (4–16 mm). All seven characters were present in *U. chuss* and *U. tenuis* (Fig. 9), but three of these characters (pelvic fin, anal fin and caudal fin pigment) were not useful for species separation because they were present in some specimens over the same length range of both species. Pelvic fin pigment, which occurred on the posterior two-thirds of the fin membrane in some *U. chuss* and *U. tenuis*, was also present in the majority of *P. chesteri* available.

The characters that were most helpful in species separation of *U. chuss* and *U. tenuis* were pectoral fin, dorsal row and caudal peduncle pigments and the midline space (lack of pigment) (Fig. 9). Pectoral fin pigment in *U. chuss* developed at 8–10 mm and was present in all larger larvae, whereas this pigment was present in all *U. tenuis* larvae (4–16 mm). Dorsal row pigment was present in some *U. chuss* larvae (6–15 mm), but no *U. tenuis* larvae from the Scotian Shelf and only one larva (11 mm) from the Gulf of St. Lawrence had this pigment. Caudal peduncle pigment was observed in many *U. chuss* larvae (7–16 mm), but no *U. tenuis* from the Scotian Shelf and only one larva (10 mm) from the Gulf of St. Lawrence had this pigment. The midline space character was primarily associated with *U. tenuis* larvae (4–12 mm). It developed at 4–6 mm, was present in all 5–9 mm larvae from the Gulf of St. Lawrence (6–8 mm larvae from the Scotian Shelf), and occurred in some 9–12 mm larvae (Fig. 9). It was observed only in two *U. chuss* larvae (7–8 mm). Pigmentation concealed the midline space character in larvae longer than about 10–12 mm.

Developmental osteology

Ossification generally occurred in the anterior to posterior direction, with the mandibular arch, dentary, premaxilla, branchiostegals, cleithra and parasphenoid ossifying first. Precaudal vertebrae ossified before the caudal vertebrae. All vertebrae were ossified by 8.1 mm in *U. chuss* and by 17.1 and 27.8 mm in *P. chesteri* and *U. tenuis* respectively. All except the 10 posterior vertebrae were ossified by 13.1 mm in *P. chesteri*, and all except the 12 posterior vertebrae were ossified by 13.8 mm in *U. tenuis*.

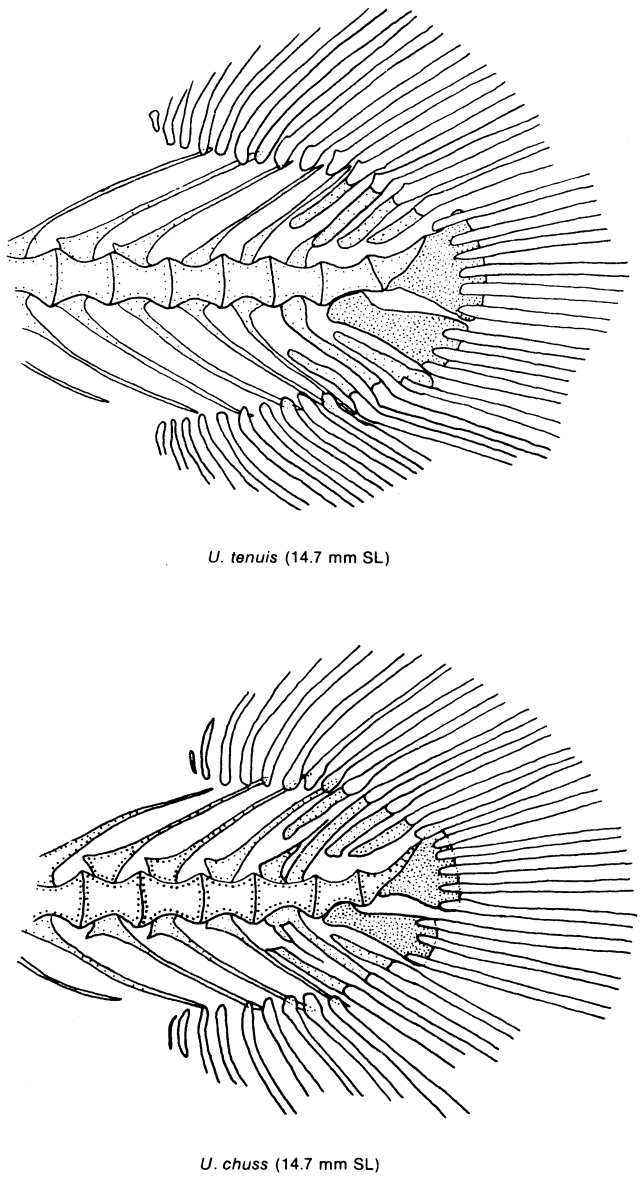

Fig. 6. Caudal osteology of *U. tenuis* and *U. chuss* larvae.

Pelvic fin rays were the first to ossify, all being complete by 4.5 mm in *P. chesteri* and by 6.5 and 8.0 mm in *U. chuss* and *U. tenuis* respectively. All pectoral fin rays were ossified by 11.1 mm in *U. chuss*, all except the ventral-most ray were ossified by 13.8 mm in *U. tenuis*, and all except the three ventral-most rays were ossified by 17.1 mm in *P. chesteri*. The caudal fin rays associated with the hypurals ossified before the superior and inferior rays. All caudal fin rays were ossified by 20.4 mm in *U. chuss*, and all except two rays were ossified by 19.1 and 39.6 mm in *P. chesteri* and *U. tenuis* respectively.

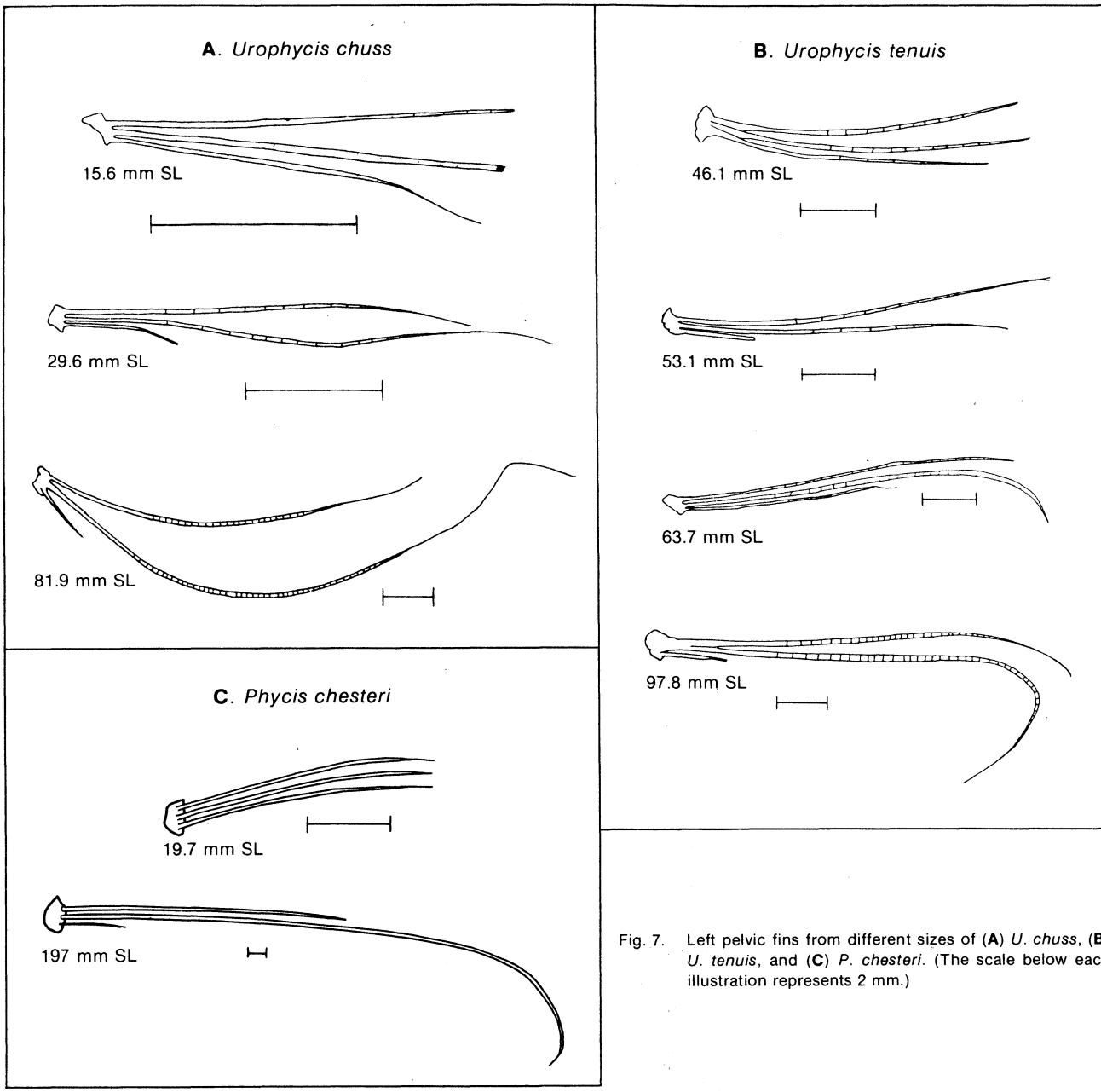

Fig. 7. Left pelvic fins from different sizes of (**A**) *U. chuss*, (**B**) *U. tenuis*, and (**C**) *P. chesteri*. (The scale below each illustration represents 2 mm.)

TABLE 5. Summary of morphometric data for *U. chuss*, *U. tenuis* and *P. chesteri* larvae and pelagic juveniles, with means and ranges expressed as percentages of standard length. (The body depth measurements at D1 and D2 pertain to specimens ⩾10 mm.)

	U. chuss			*U. tenuis*			*P. chesteri*		
Measurement	No.	Mean	Range	No.	Mean	Range	No.	Mean	Range
Body depth at vent	89	15.9	14.7-18.1	125	18.2	16.4-20.2	30	20.9	19.1-25.4
Body depth at D1	41	19.3	17.4-22.9	97	21.3	18.9-25.2	29	24.4	22.2-28.8
Body depth at D2	41	18.5	16.2-23.5	97	20.0	16.0-23.7	27	23.7	21.1-29.6
Snout length	41	4.9	3.8-6.2	96	5.1	3.6-8.8	30	4.8	2.5-6.4
Head length	85	24.7	19.3-28.8	123	25.0	22.4-28.9	32	24.8	22.4-28.6
Preanus length	88	44.2	40.4-50.6	125	45.2	41.4-52.5	33	45.5	42.9-50.8
D2 fin length	81	56.0	49.9-61.7	122	54.2	48.2-59.7	33	58.5	50.7-63.1

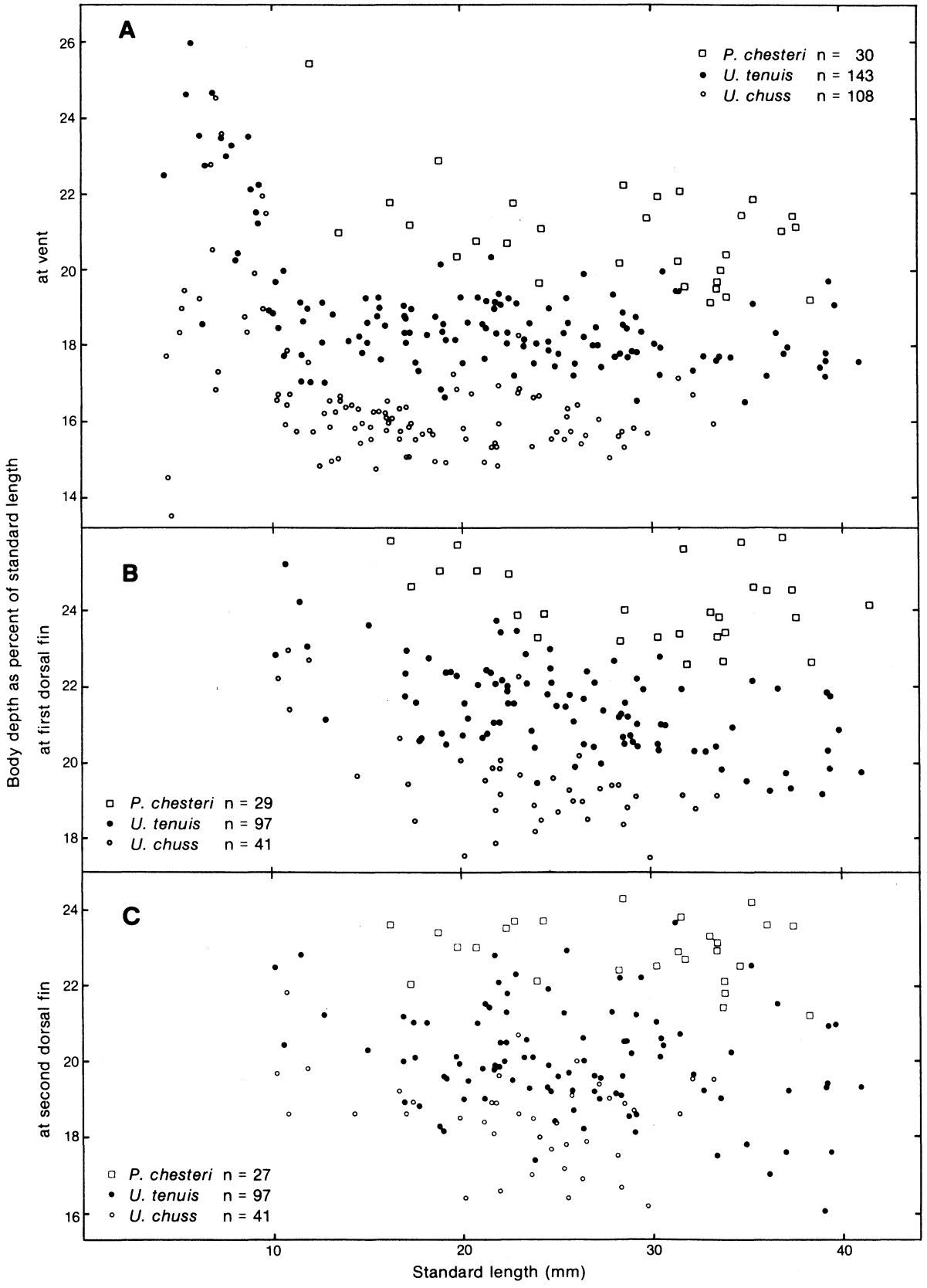

Fig. 8. Body depth (as percent standard length) in pelagic *P. chesteri*, *U. tenuis* and *U. chuss* at (**A**) the vent, (**B**) the origin of first dorsal fin, and (**C**) the origin of second dorsal fin.

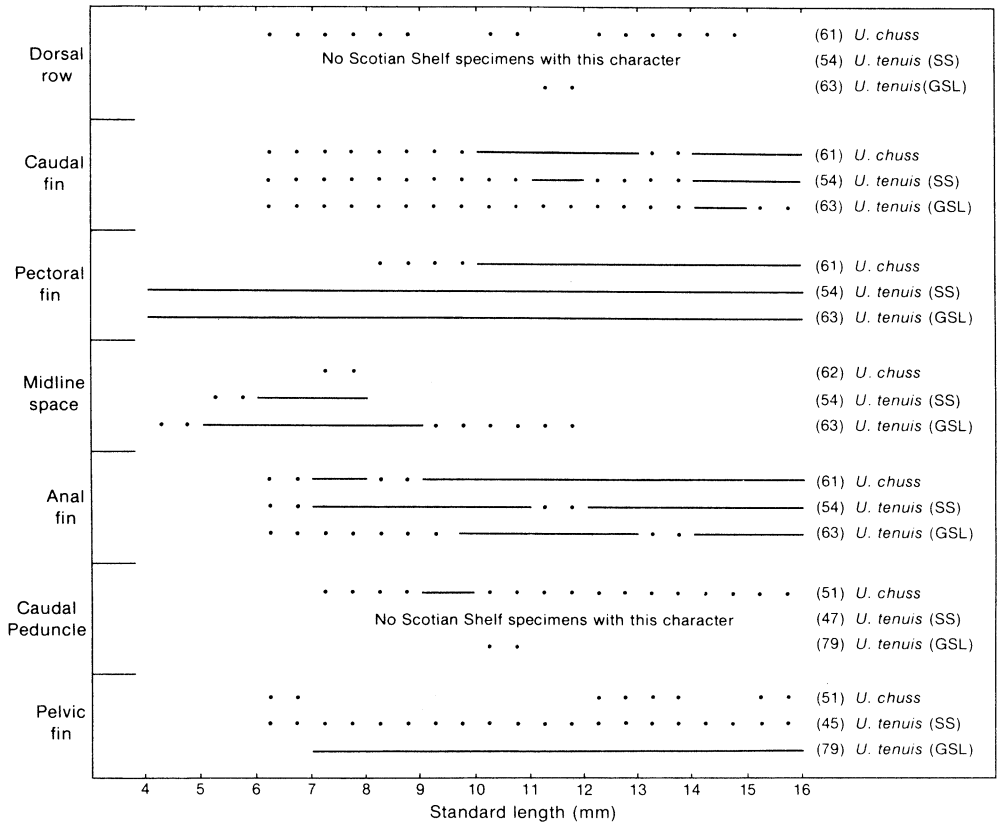

Fig. 9. Development of pigment characters in *U. chuss* (upper row), *U. tenuis* from the Scotian Shelf (middle row) and *U. tenuis* from the Gulf of St. Lawrence (lower row); dots indicate pigment on some specimens and solid line indicates pigment in all specimens. (Numbers of specimens in parenthesis.)

The anterior rays of the first dorsal, second dorsal and anal fins generally ossified before the posterior rays of these fins. The fin rays ossified before the supporting pterygiophores. All first dorsal fin rays were ossified by 18.1 and 20.4 mm in *P. chesteri* and *U. chuss* respectively but not until 39.6 mm in *U. tenuis*. All second dorsal fin rays were ossified by 20.4 and 30.2 mm in *U. chuss* and *P. chesteri* respectively. In *U. tenuis*, the two posterior-most rays of the second dorsal fin were still not ossified by 39.6 mm, but ossification was complete in the 97.8 mm specimen. All anal fin rays were ossified by 30.2 mm in *P. chesteri*, all except three posterior rays were ossified by 20.4 mm in *U. chuss*, and all except two were ossified by 39.6 mm in *U. tenuis*.

The pelvic fins were the first, and the first dorsal and pectoral fins were the last, to develop the full adult complement of fin rays in each species. Additional details on ossification in pelagic *U. chuss* and *U. tenuis* have been reported by Methven (MS 1983).

Key to Identification of *U. chuss*, *U. tenuis* and *P. chesteri* Larvae and Pelagic Juveniles

Specimens 7-10 mm SL*

1. a) Caudal fin rays 33-39 ..... *U. tenuis*
   b) Caudal fin rays 28-35 ..... *U. chuss* or *P. chesteri*

Specimens 10-16 mm SL**

1. a) Body depth (as percent SL) at vent 19.1-25.4 ($\bar{x}$ = 20.9), at D1 22.2-28.8 ($\bar{x}$ = 24.4) and at D2 21.1-29.6 ($\bar{x}$ = 23.7) ..... *P. chesteri*
   b) Body depth (as percent SL) at vent 14.7-20.2, at D1 17.4-25.2 and at D2 16.0-23.7 2
2. a) Caudal fin rays 33-39; body depth (as percent SL) at vent 16.4-20.2 ($\bar{x}$ = 18.2), at D1 18.9-25.2 ($\bar{x}$ = 21.3) and at D2 16.0-23.7 ($\bar{x}$ = 20.0) ..... *U. tenuis*
   b) Caudal fin rays 28-34; body depth (as percent SL) at vent 14.7-18.1 ($\bar{x}$ = 15.9), at D1 17.4-22.9 ($\bar{x}$ = 19.3) and at D2 16.2-23.5 ($\bar{x}$ = 18.5) ..... *U. chuss*

Specimens >16-18 mm SL**

1.	a) Epibranchial gillrakers 2-3	2
	b) Epibranchial gillrakers 4-5	*P. chesteri*
2.	a) Epibranchial gillrakers 2; body depth (as percent SL) at vent 16.4-20.2 ($\bar{x}$ = 18.2), at D1 18.9-25.2 ($\bar{x}$ = 21.3) and at D2 16.0-23.7 ($\bar{x}$ = 20.0); caudal fin rays 33-39 ($\bar{x}$ = 36.5)	*U. tenuis*
	b) Epibranchial gillrakers 3; body depth (as percent SL) at vent 14.7-18.1 ($\bar{x}$ = 15.9), at D1 17.4-22.9 ($\bar{x}$ = 19.3) and at D2 16.2-23.5 ($\bar{x}$ = 18.5); caudal fin rays 28-34 ($\bar{x}$ = 31.5)	*U. chuss*

* Differences in dorsal row, pectoral fin, caudal peduncle and midline space pigment characters were helpful in separation of *Urophycis* >7-8 mm.

** Differences in epibranchial gillrakers will separate *U. chuss* and *U. tenuis* larvae as small as 12-14 mm, but *P. chesteri* at 12-14 mm has only 3 and not the adult complement (4-5) that develops at 16-18 mm.

Discussion

Pelagic *U. chuss* and *U. tenuis* as small as 18 mm have previously been separated on the basis of differences in epibranchial gillraker counts (Musick, 1973; Markle *et al.*, 1982). The adult complement of epibranchial gillrakers in *U. chuss* (3) and *U. tenuis* (2) can be used to identify larvae as small as 12-14 mm, and the adult complement in *P. chesteri* (4-5) will identify larvae greater than 16-18 mm.

The early development of caudal fin rays and differences in caudal fin-ray counts help to separate *U. chuss* and *U. tenuis* larvae as small as 7-8 mm, the size at which they attain the adult complement. The caudal fin-ray counts in this study were within the ranges reported by Markle (1982) for *U. chuss* (29-34) and *U. tenuis* (34-38). However, the adult complement of caudal fin rays in *P. chesteri* (32-35 this study; 28-35, Wenner (1983); 32-37, Markle (1982)) overlaps the ranges for *U. chuss* and *U. tenuis*.

There were three distinct pelvic fin rays in pelagic *U. chuss*, *U. tenuis* and *P. chesteri* (Fig. 7). The single branched ray that was reported in adult *Urophycis* (Bigelow and Schroeder, 1953) was not observed, and the four rays in *Phycis* larvae of the Northeast Atlantic (Russell, 1976) were not found in *P. chesteri* from the Northwest Atlantic. The ventral pelvic fin ray was greatly reduced but was still present in demersal juveniles of the three species. The reduction of this ventral fin ray and the loss of pelvic fin pigment occur at about the time when juveniles of each species become demersal. The ventral pelvic fin ray in the large pelagic *U. tenuis* juvenile (63.7 mm) (Fig. 7B) was longer than that in the smaller demersal specimen (53.1 mm). In *U. chuss* (Fig. 7A), the ventral fin ray was greatly reduced in the 29.6 mm specimen, this being about the size when the juveniles become demersal (Markle *et al.*, 1982). Juvenile *U. tenuis* remain pelagic to a larger size than *U. chuss* and retain the long ventral pelvic fin ray until they become demersal (Markle *et al.*, 1982). For Northeast Atlantic *Phycis* juveniles, loss of the fourth ventral pelvic fin ray and pelvic fin pigmentation occurs at the size (about 30 mm) of settlement on the bottom (D'Ancona, 1933). *Phycis* and *Urophycis* are the only hake-like genera in which extreme reduction of a single pelvic fin ray occurs (Markle, 1982). Larval *Enchelyopus* and *Gaidropsarus* initially have 4 pelvic fin rays at 2-4 mm, and this number increases to 6 in *Enchelyopus* at about 14 mm and to 8-9 in *Gaidropsarus* at 22 mm.

Differences in body depth among pelagic *Urophycis* sp. have been reported previously (Nichols and Breder, 1927; Hildebrand and Cable, 1938). In this study, *P. chesteri* was deeper-bodied than *U. tenuis* which in turn was deeper-bodied than *U chuss* (Fig. 8). The greater variability in body depth at the vent (as percent of SL) in small *U. chuss* and *U. tenuis* (<10 mm) than in larger specimens was possibly due to difficulty in obtaining precise measurements of the smallest larvae. The greater body depth at the origin of the first and second dorsal fins in *P. chesteri* than in the other two species (Fig. 8) was due largely to ventral extension of the gut which, in cross-section, was V-shaped, in contrast to the rounded guts of *U. chuss* and *U. tenuis*.

Pelvic fin pigment was present in larvae of all three species involved in this study. Other gadids with similar pigment include pelagic *Enchelyopus cimbrius* (Bigelow and Schroeder, 1953; Fahay, 1983), *Gaidropsarus ensis* (Markle, 1982), and eastern Atlantic *Phycis* sp. (Russell, 1976). However, *Urophycis regia* apparently lacks pelvic fin pigmentation (Hildebrand and Cable, 1938; Fahay, 1983). The overall pigmentation of *P. chesteri* (>11 mm) is similar to that in *U. chuss* and *U. tenuis*. Pigment development seems to be most dynamic in *P. chesteri* between 4 and 11 mm (Fig. 4) as it spreads over the head and trunk. At 4.5 mm, the band of pigment on the trunk extends ventrally almost to the anal finfold. In *U. chuss* and *U. tenuis* larvae, this pigment did not reach the anal fin rays until about 7 mm.

The anterior-to-posterior trend in ossification of structures in *U. chuss*, *U. tenuis* and *P. chesteri* has been reported for several fishes (Barlow, 1961). The

head structures, cleithra and precaudal vertebrae ossified before the caudal vertebrae, and anterior rays of the dorsal and anal fins ossified before the posterior rays. Like *Brosme brosme*, *Enchelyopus cimbrius* and *Gaidropsarus ensis*, the pelvic fins were the first to develop and ossify. All fins had their adult complement of rays and nearly all rays were ossified by 20.4 mm in *U. chuss*, in contrast to 30.2 and 39.6 mm in *P. chesteri* and *U. tenuis* respectively. Although the rate of ossification differs among species, these differences should not be used to identify individual larvae due to the overlap in rates of ossification as well as variability and unpredictability in the staining process (Taylor, 1967).

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