IDENTIFICATION, GROWTH AND ECOLOGY OF LARVAL AND JUVENILE UROPHYCIS CHUSS (WALBAUM, 1792) AND UROPHYCIS TENUIS (MITCHELL, 1815) (PISCES: GADIDAE)

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IDENTIFICATION, GROWTH AND ECOLOGY OF LARVAL AND JUVENILE *UROPHYCIS CHUSS* (WALBAUM, 1792) AND *UROPHYCIS TENUIS* (MITCHILL, 1815) (PISCES: GADIDAE)

BY

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A thesis submitted to the School of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Science

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ABSTRACT

Pelagic Scotian Shelf Urophycis chuss and U. tenuis and Gulf of St. Lawrence Urophycis tenuis were identified using meristic, morphometric and pigment characters. These characters identify U. chuss and U. tenuis larvae as small as 5-7 mm SL. Pelagic U. tenuis are deeper bodied, have a higher caudal finray count and one less epibranchial gill raker than U. chuss. Adult complement of vertebrae, finrays and epibranchial gill rakers are developed for both species by 15.6 mm SL.

Pelagic Scotian Shelf Urophycis chuss grow 0.9 mm per day or ca. 28 mm per month. Young-of-the-year demersal U. tenuis grow 1.4 mm per day or 42 mm per month reaching ca. 250-280 mm by December. Inquiline U. chuss, associated with the sea scallop Placopecten magellanicus grow 0.4 mm per day or 11 mm per month. Post-inquiline one-year-old U. chuss average a minimum of 200 mm SL.

Nearshore arrival of pelagic juvenile Urophycis tenuis is delayed with increasing latitude. U. tenuis, a member of the summer ichthyofauna arrive and remain nearshore when water temperatures are highest. Time of nearshore arrival and growth data indicate a winter-spring spawning period. U. chuss larvae are pelagic during summer and become inquiline during September-October on the Scotian Shelf. The presence of a larger U. chuss size mode may indicate that two different year classes occupy scallops at the same time. U. chuss prefer larger scallops.

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GENERAL INTRODUCTION

Hakes of the genus Urophycis Gill, 1863 are abundant gadid fishes on the continental shelf and slope of the northwest Atlantic Ocean. The genus contains seven species endemic to the western Atlantic (Svetovidov 1948) including the red or squirrel hake, Urophycis chuss (Walbaum, 1792) and the white or common hake, Urophycis tenuis (Mitchill, 1815). U. chuss is found on the continental shelf from the south coast of Newfoundland (Markle et al. 1982) to North Carolina (Musick 1974). U. tenuis occurs on the continental shelf and slope from Iceland and Labrador to North Carolina and occasionally as far south as Florida (Musick 1974). U. tenuis is reported from the Gulf of St. Lawrence but U. chuss is not (Musick 1974; Beacham and Nepszy 1980, Markle et al. 1982).

As an underutilized commercial species Urophycis are fished primarily as by-catch by Canadian, American and European fishing vessels. The only directed hake (Urophycis) fishery in Canada occurs in the southern Gulf of St. Lawrence off eastern Prince Edward Island (Beacham and Nepszy 1980). This fishery is seasonal, peaking in summer but virtually absent from December to April. Since U. chuss is not reported from the Gulf, the fishery there is entirely dependent upon white hake. Historically, U. chuss and U. tenuis were not differentiated in Canadian fishery statistics (Nepszy 1968). U. chuss and U. tenuis are usually marketed as fresh or frozen fillets under the name "hake".

United States landings of Urophycis chuss in 1978 were 4.8 million pounds with an average ex vessel price of $0.11 per pound for a landed value of ca. 528 thousand dollars. In 1976, 9.1 million pounds of U. tenuis were landed in New England at an average ex vessel price of $0.133 per pound (Gendron 1980) for a landed value of 1.2 million dollars. Canadian landings of U. tenuis in 1976 were higher, being 23.3 million pounds (Gendron 1980). At $0.133 per pound the catch had a retail value of 3.1 million dollars.

As it is presently not possible to identify Urophycis chuss and U. tenuis larvae, the first objective of my study was to determine which characters would be useful to distinguish between these species. Once this was accomplished the second objective, determining species specific growth rates and the third objective, describing the post pelagic ecology of 0+ Urophycis, could be addressed. Each of these objectives is treated separately in the sections that follow.

IDENTIFICATION OF UROPHYCIS LARVAE

INTRODUCTION

Musick (1973) has shown how adult *Urophycis chuss* and *U. tenuis* may be distinguished. The larvae however remain essentially undescribed (Kendall and Naplin 1981) due to similarities among other *Urophycis* species, *Enchelyopus cimbrius*, *Gaidropsarus ensis* and *Phycis chesteri* (Hildebrand and Cable 1938, Cohen and Russo 1979, Markle 1982, Fahay 1983). Only *U. chuss* eggs and newly hatched laboratory reared larvae (< 2.2 mm) have been described (Miller and Marak 1959). Eggs, larvae and early juvenile stages of *U. tenuis* remain undescribed (Hardy 1978, Fahay 1983). Previous attempts to distinguish between *Urophycis* larvae (Merriman and Sclar 1952, Bigelow and Schroeder 1953) have been unsuccessful (Musick 1969). Nichols and Breder (1927) reported pelvic fins are shorter, body depth deeper and the head longer in juvenile *Phycis tenuis* (=*U. tenuis*). They also noted, such specimens might be easily confused with *Phycis chuss* (=*U. chuss*) as pelvic fins reach the origin of the anal fin, a character usually associated with *P. chuss* (Bigelow and Welsh 1925).

The purpose of this section is to show how the larvae of *Urophycis chuss* and *U. tenuis* may be identified, and to discuss comparative aspects of the early development of these fishes.

MATERIALS and METHODS

Allopatric pelagic Urophycis tenuis were collected from the southern Gulf of St. Lawrence in September 1979 aboard DFO R/V E.E. PRINCE (cruise 229, Table 1). Sympatric U. chuss and U. tenuis were collected from the Scotian Shelf during August and September 1978 aboard DFO R/V LADY HAMMOND (cruises 05, 06, and 07) and are deposited at the Huntsman Marine Laboratory, St. Andrews, New Brunswick. Most collections were made with a neuston net fitted with 1179 micron mesh net towed at 3-5 knots for approximately 10 minutes. Specimens were preserved in 5% formalin. Demersal juvenile U. chuss and U. tenuis were collected from Passamaquoddy Bay and vicinity and the Scotian Shelf by SCUBA diving, scallop dragging and beach seining (Table 1).

Superior and inferior caudal and pelvic finray counts were determined from demersal juveniles after fins were removed, cleared and stained (Hollister 1934). Superior and inferior caudal finrays are defined as dorsal-most rays (superior) and ventral-most rays (inferior) separated by hypural rays articulating from hypurals 1-2 and 3-5. Counts of meristic structures were also made on 11 Urophycis chuss larvae (5.3-15.6 mm Standard Length), 2 U. chuss juveniles (20.4 and 29.6 mm SL), 11 U. tenuis larvae (5.5-15.8 mm SL) and 3 U. tenuis juveniles (27.8-97.8 mm SL) which were cleared and stained (Taylor 1967, Dingerkus and Uhler 1977). Counts were determined for first and second dorsal finrays (D1 and D2), anal finrays (A), superior, inferior and hypural caudal finrays (C), right and left pectoral finrays (P1) and pelvic finrays (P2), vertebrae (precaudal and caudal) and epibranchial gill rakers. These counts, recorded for each species in Tables 2 and 3, are of ossified (stained by Alizarin red) and non-ossified or forming (stained by Alcian blue) structures. Ossification (page 12) is only discussed for those specimens that absorbed alizarin red stain. Structures were considered ossified even if only partly stained by alizarin red. All counts were made with the aid of a stereomicroscope. Caudal terminology follows that of Rosen and Patterson (1969). "Larval" U. chuss and U. tenuis are defined as individuals less than 18 mm SL; "juveniles" are equal to or greater than 18 mm SL.

Measurements, defined below, were taken from the left side of 344 unstained Urophycis (4.8-40.8 mm SL) using dial calipers and a stereomicroscope. All measurments were converted to percentage of standard length and all character means and ranges are given as percent standard length.

Standard length - tip of snout to posterior margin of hypurals.
Snout length - tip of snout to anterior margin of the orbit.
Head length - tip of snout to posterior margin of gill cover.
Preanal length - tip of snout to vent.
Second dorsal fin length - origin of first ray on the second dorsal fin to the posterior tip of the last ray (only from specimens > 10 mm SL).
Body depth at first dorsal fin - vertical distance from the base of the first dorsal fin to the ventral surface immediately below (only from specimens ≥ 10 mm SL).
Body depth at second dorsal fin - vertical distance from the origin of the second dorsal fin to the ventral surface immediately below (only from specimens > 10 mm SL).

Body depth at vent - vertical distance from dorsal to ventral surface measured at the vent.

Seven pigment characters were examined on 175-179 Urophycis larvae between 4.2-15.9 mm SL. Characters were determined as either present or absent, however, three characters (dorsal row pigment, caudal peduncle pigment and midline space) had to conform to a specific pattern or shape before they were considered as present. Determination of these three characters was often subjective. As yellow and red pigment is lost in formalin preserved larvae (Russell 1976) only the black pigment or melanophores are referred to. Pigment characters, defined below, are illustrated in Fig. 1.

Dorsal row pigment - a longitudinal row of prominent usually dark, stellate melanophores located laterally between the dorsal fins and the midline on some Urophycis chuss and U. tenuis between ca. 6 and 14 mm. The row originates dorsal to the pectoral fin - gut region and terminates on the caudal peduncle. Dorsal row pigment is present in 6-7 mm Urophycis, but usually is not fully developed on the posterior flank or caudal peduncle by this size. Dorsal row pigment is the same as "dorsal-lateral" pigment of Russell (1976); see page 23, Fig. 4.

Caudal fin pigment - located on the posterior margin of the caudal peduncle and on caudal finrays and membrane where they articulate with the caudal peduncle. The pigment band is ")" shaped in ca. 15 mm Urophycis and is present on both U. chuss and U. tenuis as early as 6 mm SL. In these small Urophycis, caudal fin pigment consists of one or two melanophores usually associated with the hypural rays. In larger specimens the pigment has spread dorsally and ventrally to form the characteristic ")" band of pigment. The character is recorded as present if at least one melanophore is present.

Pectoral fin pigment - usually one melanophore, but sometimes two or three, located on the ventral portion of the pectoral fin base. This external pigment should not be confused with internal gut pigment. The posterior edge of the operculum may have to be lifted as the pigment is sometimes covered by the operculum edge. If one or more melanophores are present at the base of the pectoral fin the character is recorded as present.

Midline space - an area lacking pigment dorsal to the posterior portion of the gut and midline in small Urophycis, predominantly U. tenuis, from ca. 4-11 mm SL. This character is formed as pigment develops on the anterior midline region above the gut in 4-6 mm SL Urophycis. Above pigment on the midline is a space where no pigment has developed. Above this space, again, is pigment that develops at about the same rate as pigment associated with the midline. These pigmented areas join posteriorly. In larger Urophycis (ca. 14-15 mm SL) this space is not present. Urophycis < 5 mm SL often cannot be considered for this character as pigment on the midline and that dorsal to it do not join on the mid-trunk region.

Caudal peduncle pigment - a shaft of pigment, symmetrical about the midline, on the caudal peduncle of U. chuss larvae. This character is composed of both internal (along the vertebrae) and external pigment associated with the midline extending posteriorly from pigment of the flank. In Urophycis chuss larvae the shaft of pigment is symmetrical, thin and pointed. This contrasts with U. tenuis where the development is not symmetrical (there is slightly more pigment dorsal to the midline). Refer also to Markle et al. (1982), page 2062, Fig. 3.

Anal fin pigment - individual melanophores immediately along either side of the anal fin at the base of the anal finrays. If any melanophores are present, the character is considered present.

Pelvic fin pigment - pigment on the distal 2/3 of the connecting membrane between the pelvic finrays. If any pigment is present, the character is present.

The tentative separation of Scotian Shelf Urophycis larvae into two groups was established by first comparing a size series of known Gulf of St. Lawrence U. tenuis larvae (U. chuss is not reported from the Gulf, Musick 1974, Markle et al. 1982) with Scotian Shelf larvae, and by using characters common to both juveniles and larvae of each species. Based upon differences in tentatively identified larvae, meristic, morphometric and pigment characters were chosen with the aim of separating sympatric Scotian Shelf U. chuss and U. tenuis larvae.

RESULTS

Meristic characters

Meristic characters are listed for each species in Tables 2 and 3. Adult complement of vertebrae, finrays and epibranchial gill rakers are developed for both species by 15.6 mm SL and are summarized in Table 4. With the exception of caudal finrays and epibranchial gill rakers the ranges of all meristics overlap considerably and are of limited use for separation of larvae. Caudal finray counts separate larvae greater than 7-8 mm SL (Fig. 2). This is the size at which larvae attain the adult complement of caudal finrays (Table 4). Despite differences in caudal finray counts, caudal finray structure is similar (Fig. 3).

Some Urophycis chuss and U. tenuis were observed to have 4 and 3 epibranchial gill rakers respectively (Fig. 4) and therefore epibranchial gill raker counts were occasionally higher than previously reported (Musick 1973).

Observations of cleared and stained pelvic fins revealed a loss of the third (most ventral) pelvic finray in both U. chuss and U. tenuis (Figs. 5 and 6). The third ray is essentially reduced to a nub and is not externally visible in adults.

Morphometric characters

Of the seven morphometric characters examined for Scotian Shelf Urophycis greater than 10 mm SL, body depth characters were most useful for identifying larvae (Figs. 7, 8 and 9). The nearly identical means and overlap of ranges for preanal length (U. tenuis, N=125, mean=45.2%; range=41.4-52.5%; U. chuss, N=88, mean=44.2%, range=40.4-50.6%), second dorsal fin length (U. tenuis, N=122, mean=54.2%, range=48.2-59.7%; U. chuss, N=81, mean=56.0%, range=49.9-61.7%), head length (U. tenuis, N=123, mean=25.0%, range=22.4-28.9%; U. chuss, N=85, mean=24.7%, range=19.3-28.8%) and snout length (U. tenuis, N=96, mean=5.1%, range=3.6-8.8%; U. chuss, N=41, mean=4.9%, range=3.8-6.2%) are of little use in species separation.

Of the three body depth characters, body depth at vent (U. tenuis, N=125, mean=18.2%, range=16.4-20.2%; U. chuss, N=89, mean=15.9%, range=14.7-18.1%) was more useful than body depth at the first dorsal fin (U. tenuis, N=97, mean=21.3%, range=18.9-25.2%; U. chuss, N=41, mean=19.3%, range=17.4-22.9%) and body depth at the second dorsal fin (U. tenuis, N=97, mean=20.0%, range=16.0-23.7%; U. chuss, N=41, mean=18.5%, range=16.2-23.5%) for identifying larvae.

As the relationship body depth / standard length X 100 is not linear for the size range of specimens examined, (Figs. 7, 8 and 9) body depth character means and ranges are determined only for the linear portion of the relationship, i.e. for specimens greater than 10 mm SL. Below 10 mm SL there is much more variation in these characters making them less useful for species identification (Figs. 7, 8 and 9).

Morphometrics from Gulf of St. Lawrence Urophycis tenuis greater than 10 mm SL had character means similar to or greater than comparable means of Scotian Shelf U. tenuis. Ranges generally fall within the ranges observed for Scotian Shelf U. tenuis.

Pigment characters

Pigment characters helpful with separation of Urophycis chuss and U. tenuis larvae are dorsal row pigment, pectoral fin pigment, midline pigment, and caudal peduncle pigment (Fig. 10). Other than these characters, pigment development in U. chuss and U. tenuis larvae appears very similar (Figs. 11 and 12).

Dorsal row pigment was present in some Urophycis chuss larvae between 6-15 mm (Fig. 10). No Scotian Shelf U. tenuis larvae were observed with dorsal-row pigment and only one Gulf of St. Lawrence U. tenuis larva (11 mm) had the character.

Pectoral fin pigment is present in both Urophycis tenuis and U. chuss larvae (Fig. 10). It is developed by 4 mm SL in U. tenuis and was observed in all specimens examined. The character develops between 8-10 mm in some U. chuss and was present in all U. chuss greater than 10 mm. This character is useful in separating larvae between ca. 4 and 8 mm SL.

The midline space character is present in both Urophycis chuss and U. tenuis larvae (Fig. 10). It is primarily associated with U. tenuis appearing in some between 4-12 mm. It develops at 4-6 mm in U. tenuis, is present in all specimens from 6-8 mm (5-9 mm in the Gulf of

St. Lawrence) and is present in some Gulf of St. Lawrence U. tenuis between 9 and 12 mm. The character was present in two U. chuss larvae (7.2 and 7.3 mm). Pigmention after ca. 10-12 mm conceals the character.

Caudal peduncle pigment was observed in Urophycis chuss larvae between 7-16 mm (Fig. 10). The character was not observed in Scotian Shelf U. tenuis but was observed in one Gulf of St. Lawrence U. tenuis larva between 10-11 mm.

Pelvic, anal and caudal fin pigmentation are present in both species at the same stages of development and were of no use in identification of larvae (Fig. 10).

Ossification

Urophycis chuss

By 6.5 mm SL all vertebrae, except the 3 posterior vertebrae, premaxillary, dentary, parasphenoid, branchiostegals, cleithra and most bones of the mandibular arch are ossified. The only fins ossified are the pelvic fins, where ossification is evident at the base of each ray. The mid sections of the epibranchial and ceratobranchial of the first gill arch were ossified. Gill rakers on the first gill arch were only ossified at the point of articulation with the epibranchial and ceratobranchial.

At 8.1 mm SL all vertebrae, all pectoral finrays except the ventral 3 rays, pelvic finrays except for their extreme tips, the first 33 anal finrays, all caudal finrays except the first 3 superior and first 2 inferior rays, the frontal bone and most bones of the mandibular arch were ossified. The only supporting bones of the caudal fin that are ossified are the bases of the neural and haemal spines of the second preural centrum and the base of hypurals 1 and 2.

By 11.1 mm SL all pectoral and pelvic finrays were ossified for over 2/3 their length. The anterior 4 first dorsal, 49 second dorsal, 35 anal finrays and all caudal finrays, except the first 2 superior and first 2 inferior rays, were ossified. Supporting elements of the caudal fin including dorsal and ventral accessory bones, haemal and neural spines of the second preural centrum, epurals 1 and 2, parahypural and hypurals 1–5 were ossified. No pterygiophores were ossified. Epibranchial, ceratobranchial and gill rakers appear at the same state of ossification as at 6.5 mm.

By 20.4 mm SL all finrays were ossified except the three posterior rays of the anal fin. The extreme tips of all finrays were not ossified. The first 7, 49 and 40 intermediate pterygiophores of the first dorsal, second dorsal and anal fins respectively were ossified. Epibranchial, ceratobranchial and gill rakers were ossified.

At 29.6 mm SL the 3 posterior rays of the anal fin were not ossified. The first 10, 53 and 50 intermediate pterygiophores of the first dorsal, second dorsal and anal fin respectively were ossified. Epibranchial, ceratobranchial and gill rakers were ossified. Scales, when stained with alcian blue, were first visible at this size.

Urophycis tenuis

The first U. tenuis larva to pick up alizarin red stain was 8.0 mm SL. At this size the first 38 vertebrae, premaxillary, dentary, branchiostegals, cleithra, parasphenoid and most bones of the mandibular arch were ossified. Five dorsal pectoral finrays and all pelvic finrays were ossified at the base of each ray. Epibranchial, ceratobranchial and gill rakers were not ossified.

By 13.8 mm SL the first 38 vertebrae, 8 first dorsal and 9 second dorsal finrays were ossified. No anal finrays were ossified. All caudal finrays, except the first 6 superior and first 7 inferior rays were ossified. The 12 dorsal pectoral finrays were ossified. By 15.8 mm SL the first 40 caudal vertebrae were ossified. Epibranchial, ceratobranchial and gill rakers (at the point of articulation) were ossified.

At 27.8 mm SL all vertebrae and pectoral finrays were ossified. The anterior 8, 12 and 28 rays of the first dorsal, second dorsal and anal fins respectively were ossified. All caudal finrays except the first 2 superior and 3 inferior rays were ossified. This is the first size at which supporting elements of finrays were ossified. Dorsal and ventral accessory bones, hemal and neural spines of the second preural centrum, epurals 1 and 2, parahypural and hypurals 1-5 of the caudal fin were ossified. The first 36 and 26 intermediate pterygiophores of the second dorsal and anal fins respectively were ossified. Proximal and distal elements of pterygiophores were not ossified for any fins. Epibranchial, ceratobranchial, hypobranchial and all gill rakers were ossified.

At 39.6 mm SL all finrays were ossified except the last two rays of the second dorsal and anal fins and the first superior and inferior rays of the caudal fin. All intermediate pterygiophores were ossified except the following posterior 3, 2 and 2 pterygiophores of the first dorsal, second dorsal and anal fins respectively. No proximal elements of the pterygiophores were ossified. Distal elements were ossified at the point of articulation with the intermediate pterygiophore. Scales, stained by alcian blue, were first observed at this size.

By 97.8 mm SL all finrays were ossified. The proximal elements of the pterygiophores were not ossified. The distal elements of the pterygiophores, although more ossified than in previous specimens, were still not fully ossified.

DISCUSSION

Previously juvenile Urophycis tenuis and U. chuss were identified to a minimum of ca. 18 mm SL (Markle et al. 1982) based upon differences in epibranchial gill raker counts (Musick 1973). The adult complement of epibranchial gill rakers is developed and is readily apparent in cleared and stained larvae as small as ca. 12-14 mm (Table 4). There is, however, variation in this adult complement as occasional specimens were observed with an additional gill raker (Fig. 4).

Total caudal finray counts also separate Urophycis chuss and U. tenuis (Figs. 2 and 3). The ranges are similar to those previously reported (Markle 1982). The small overlap of counts and the early development of the adult complement (7-8 mm, Table 4) makes differences in caudal finray counts a good character for separation of U. chuss and U. tenuis.

Hildebrand and Cable (1938), and Nichols and Breder (1927), have reported U. chuss as slender bodied relative to other Urophycis. Body depth measurments (at origin of D1, D2 and vent; Figs. 7, 8 and 9) of pelagic Scotian Shelf U. chuss and U. tenuis confirm these observations. U. tenuis tends to be the deeper-bodied of the two species.

Pigment characters (especially caudal peduncle, pectoral fin, dorsal row pigment and midline space characters) are most helpful with larval separation when pigment development is at its most dynamic stage. This occurs at ca. 4-10 mm. Above and below these sizes there is much less change in overall pigment pattern (Figs. 11 and 12) and differences in pigment pattern are not as apparent.

Both species have pelvic fin pigmentation which is also present in other hake-like larvae including Phycis chesteri (personal observation), Enchelyopus cimbrius (Bigelow and Schroeder 1953) and Gaidropsarus ensis (Markle 1982). Urophycis regia apparently lacks pelvic fin pigmentation (Hildebrand and Cable 1938).

Ossification, observed in cleared and stained larvae (Tables 2 and 3) occurs in an anterior to posterior direction for both Urophycis species. The first structures to ossify include the bases of the mandibular arch, dentary, premaxilla, branchiostegals, cleithra and parasphenoid. Anterior vertebrae ossify before posterior vertebrae. The pelvic fins are the first fins to ossify in both species. Ossification of examined structures occurs at a larger size in U. tenuis than in U. chuss. U. chuss has all finrays but the three posterior anal finrays ossified by 20.4 mm, in contrast with U. tenuis which attains approximately the same stage of fin development at 39.6 mm, twice the size of U. chuss. Finrays ossify before supporting pterygiophores.

There are three pelvic finrays for Urophycis chuss and U. tenuis at all sizes examined (Figs. 5 and 6). The ventral ray is greatly reduced in larger specimens of Urophycis. This ventral rudimentary ray is difficult to see in adults that are not cleared and stained. The reduction of this finray appears size dependent, but may also be habitat dependent as the ray becomes rudimentary at about the time the fish becomes demersal. The ventral pelvic finray of the large pelagic U.

tenuis juvenile (63.7 mm SL in Fig. 6) is longer than the same ray in the smaller but demersal specimen (53.1 mm SL). Ontogenetic change in number of pelvic finrays for hake-like genera has been previously reported (Markle 1982). Phycis and Urophycis are the only genera where loss of a single pelvic finray occurs. Larval Enchelyopus and Gaidropsarus initially have 4 pelvic finrays at 2-4 mm. This increases to the adult complement of 6 for Enchelyopus obtained at ca. 14 mm and 8-9 pelvic finrays for Gaidropsarus obtained at ca. 22 mm. Loss of pelvic fin pigment also appears to be habitat dependent. New demersal U. chuss and U. tenuis have only traces of the pigment remaining.

GROWTH

INTRODUCTION

Growth rates for Urophycis chuss and U. tenuis are poorly understood (Nichy 1974). Adults have been difficult to identify (Musick 1967, 1969) and it has previously been impossible to distinguish between larvae of the two species (Kendall and Naplin 1981, Fahay 1983). Species-specific growth rates are therefore difficult to determine. Conventional methods of preparing and examining U. tenuis otoliths have been ineffective (Hunt 1982). Otoliths are often unreadable, with confusing growth increments.

Despite these problems, age-length estimates have been determined for adult Gulf of St. Lawrence Urophycis tenuis (Nepszy 1968, Beacham and Nepszy 1980, Hunt 1982) and adult U. chuss from Georges Bank (Rikhter 1970). These data indicate that adult growth is rapid.

Growth rates of larval and small juvenile Urophycis are unknown or poorly understood (Markle et al. 1982). Pelgic Gulf of St. Lawrence U. tenuis grow ca. 10-22 mm per month and demersal U. chuss collected from scallops grow 10-15 mm per month (Musick 1969, Markle et al. 1982, Steiner et al. 1982). Early growth does appear to be fast (Markle et al. 1982, Steiner et al. 1982).

In this study I present data on the age-length relationship for U. chuss and U. tenuis less than one-year-old.

MATERIALS and METHODS

Collection Sites and Gears

Larval and juvenile Urophycis chuss and U. tenuis were primarily collected from the central Scotian Shelf, St. Andrews, Passamaquoddy Bay, New Brunswick (Fig. 13), and Bellevue, Trinity Bay, Newfoundland (Fig. 14). Details of collections are summarized in Table 1. Passamaquoddy Bay inquiline U. chuss collection data and length frequencies are summarized in Table 5 and Fig. 15.

Data Collection

Unless otherwise stated, all lengths are standard length, measured with dial calipers to 0.1 mm. All weights are whole weight measured in the field with a beam balance and in the laboratory with a Mettler balance. Weight was determined to the nearest 0.1 gram after each specimen was blotted dry.

Methods of processing Urophycis differed slightly for pelagic and demersal individuals. Pelagic Urophycis collected from the Scotian Shelf (R/V LADY HAMMOND 40; Table 1) were measured, placed on filter paper in plastic Petri dishes, and usually frozen within 5-10 minutes to preserve otoliths. Pelagic specimens were not weighed due to the difficulty of accurately weighing small larvae at sea. Passamaquoddy Bay demersal juveniles were measured, weighed and to preserve otoliths frozen at ca. -20 °C within 2-3 hours after capture. All specimens remained frozen until just prior to processing.

In the laboratory, thawed Urophycis were identified and measured. Sagittae were removed from Urophycis > ca. 15 mm following Fitch (1951) and from smaller Urophycis following Pannella (1980b). Prior to otolith removal, thawed pelagic U. chuss (4.5-28.2 mm SL) were placed on individual microscope slides. Addition of two to three drops of 95% or absolute ethanol moistened tissues of the head region, allowing easier extraction of sagittae. Otoliths, ranging in size from 100 to 1500 microns, were removed using fine forceps and insect pins mounted on wooden rods under a 10 X 4 binocular dissecting microscope. Reflected light was used during otolith removal. Transmitted light was used while separating otoliths from otic sack and adhering tissues. Once isolated, two drops of 100% glycerine were added to preserve the otoliths and to help re-locate them again prior to mounting. If neither otolith required grinding both were left on the same slide and were mounted together. If grinding was required each otolith was placed on an individual microscope slide.

Before otoliths were mounted, glycerine was dissolved with 2-3 drops of 95% or absolute ethanol and wiped from the slide while the otolith was viewed through a microscope. The otoliths were air dried and a drop or two of Epon mounting medium was added. The Epon was spread as thinly as possible since thin preparations require less grinding time. Microscope slides were placed in a drying oven at 50°C for approximately 24 hours to harden the Epon.

Grinding is required if all increments from the nucleus to the edge of the otolith are not visible. An increment is defined as a wide inner clear band and a narrow dark outer band adjacent to it (Laroche et al. 1982; Fig. 16 this study). Otoliths were ground by hand against #400 sand paper. To facilitate grinding, the otolith and sand paper were kept wet. By alternately grinding and observing increments through a compound microscope, I was able to tell when the nucleus was exposed. To enhance the appearance of increments a drop of ethanol or glycerine was added (Pannella 1982b). To etch otoliths a drop of 0.1N hydrochloric acid was added and then removed after 5-10 seconds.

Once otoliths were ground, the increments were counted. Two series of counts were made (two counts per series) of all increments (daily and subdaily) and later of just daily increments present in each otolith. Three methods of counting increments were attempted: 1) counting increments directly from the otolith using a compound microscope, 2) photographing each otolith and counting increments from a composite photograph and 3) projecting the image of the otolith onto a white background using a microprojector (Morris 1983).

The third method proved to be most satisfactory and yielded the counts reported here. With the microprojector it was possible to obtain a tracing of the increments present in each otolith. Adjusting the microscope focusing mechanism highlighted certain increments that otherwise would not have been visible or countable in a single focal plane.

Two methods of determining frequency of otolith increments were attempted for Urophycis tenuis larvae and juveniles. The first method involved raising fertilized eggs collected from ripe Gulf of St. Lawrence U. tenuis. These eggs were transported from Souris, Prince

Edward Island, to DFO Biological Station, St. Andrews, NB. where they were held in aerated brood jars suspended in a water bath at 12 C. The objective was to raise U. tenuis larvae and compare the number of daily increments present in otoliths to the known daily age thereby obtaining the rate of increment deposition. The second method of determining increment periodicy was by raising 9 juvenile beach seined U. tenuis (58.3-108.1 mm SL) under stressful conditions with the aim of producing a stress notch on the sagitta over a known time interval (Pannella 1980b). Three U. tenuis were placed in each of three holding tanks (tanks measuring ca. 45cm X 40cm X 30cm) at DFO St. Andrews, NB. Photoperiod, temperature and food were altered markedly between 18-26 August (Table 6) to stress fish and notch otoliths (Pannella 1982b). Salinity samples, fish length and weight were determined on 21 July, 18 August, 26 August and 8 September; temperature was measured daily. Fish were not fed the usual ground herring or chopped squid meal on the day when lengths and weights were determined. Each fish was anaesthetized in a 4-8% solution of tertiary amyl alcohol while lengths and weights were measured. An additional 4 U. tenuis (129-188 mm SL) were raised from 18 September to 18 January. These U. tenuis were fed daily on alternating weeks. As temperature and salinity remained at ambient Passamaquoddy Bay conditions, these U. tenuis were only stressed by alternating the feeding schedule.

Data Analysis

Data management and analyses were performed using the Statistical Analysis System (SAS) (Helwig and Council 1979). All estimates of significance were based on $p = 0.05$.

Most data were analysed using regression analysis. Simple least squares linear regression analyses were performed on data having no error in the independent variable, i.e. length frequency plots where date of capture (DOC) is the independent variable (Sokal and Rohlf 1969, Ricker 1973, 1975, Laws and Archie 1981). For each regression, sample size (n), correlation coefficient (r-squared) and regression equation were determined.

To determine the difference betweeen the two series of otolith counts for pelagic Urophycis chuss, the first count was plotted against the second and the slope was calculated by simple least squares linear regression. This slope was compared to a theoretical line of slope =1, a line of perfect agreement, using a t-test. The mean of each set of counts was plotted against U. chuss standard length to obtain an estimate of daily age and total increments at length.

To determine spawning time for Passamaquoddy Bay caught Urophycis tenuis, 95% confidence intervals were included on the regression of length vs. date of capture. The regression and confidence limits were extrapolated to size at hatch (2.0 mm) to determine spawning time.

Residuals of all significant regressions were plotted and visually examined for approximate evenness of observations above and below the predicted line. Residuals were also examined for patterns which, when present, could represent anomalies in the data (Montgomery 1976). Lengths of October and November Passamaquoddy Bay U. tenuis were converted from total length to standard length by the equation TL = 1.1(SL) + 1.23 (n=30, r squared = 0.97), where TL and SL are total and standard length, in millimeters.

RESULTS

Urophycis chuss

Daily and subdaily growth increments were observed in sagittae of pelagic larval and juvenile *Urophycis chuss* between 4.5-28.2 mm SL (Figs. 16, 17 and 18). When present, subdaily increments were weakly defined. Usually only one subdaily increment was observed between daily increments. Few subdaily increments were observed in sagittae from small *U. chuss* (ca. 4.5-8.0 mm) as the mean number of daily and total increments were similar (Figs. 17 and 18). More subdaily increments were observed in larger otoliths (Figs. 17 and 18).

Growth of pelagic Scotian Shelf *Urophycis chuss* larvae and juveniles between 4.5-28.2 mm SL is linear (Fig. 17). No significant differences in slopes were observed between increment counts and a theoretical line of slope =1 for daily (t = 1.789; df=29) and total (t = 1.269; df=29) increments. The mean of the two daily increment counts was plotted against standard length to obtain a growth rate of 0.9 mm per day or 28 mm per month for pelagic *U. chuss* between 4.5-28.2 mm SL (Fig. 17).

Regression analysis performed on Passamaquoddy Bay inquiline and trawled *Urophycis chuss* data was only significant for the inquiline individuals (F=28.9, df=1,24, Fig. 19). Growth (length) appears linear for inquiline *U. chuss* between 63.9-117.9 mm SL (Fig. 19) and a monthly growth rate of 11 mm (0.4 mm per day) is calculated.

Urophycis tenuis

Verification of daily growth increment periodicity in Urophycis tenuis otoliths was unsuccessful. The traditional method of raising known age larvae and comparing their age to the number of otolith growth increments (Brothers et al. 1976, Barkman 1978, Tsuji and Aoyama 1982) failed due to overcrowding and subsequent death of developing eggs in brood jars. The second method of marking or notching otoliths (Pannella 1980b) was unsuccessful, because stress notches, if present, could not be differentiated from regular growth increments when otoliths were examined. Therefore it was not possible to directly determine the presence of daily increments.

Growth (length) is linear for Passamaquoddy Bay demersal Urophycis tenuis (40–250 mm) collected between June and November by beach seine and shrimp trawl (Fig. 20). A growth rate of 42 mm per month or 1.4 mm per day is calculated (Fig. 20). This regression is significant (F=1771.4, df=1,181). Extrapolation of data in Fig. 20 indicates Passamaquoddy Bay U. tenuis would be 250–280 mm SL by December.

Passamaquoddy Bay Urophycis tenuis (mean = 99.4 ± 27.1 mm SL, Fig. 20) are larger in August than Trinity Bay U. tenuis (mean = 75.9 ± 8.2 mm SL, Fig. 21).

Of the nine demersal juvenile Urophycis tenuis (58.3–108.1 mm SL) placed in holding tanks on 21 July, seven survived to 8 September. Lengths and weights of these fish appear in Table 7. Individual daily growth, lengths and weights, appear in Table 8. The maximum gain in length and weight was 2.5 mm and 2.8 grams per day (Table 8). The mean growth rate was 34 mm per month or 1.1 mm per day (Fig. 22). This regression (Fig. 22) was significant (F=23.0, df=1,26).

Of the 4 demersal juvenile Urophycis tenuis (129.4-188.2 mm SL) placed in holding tanks on 18 September 1981, all survived to 18 January 1982. Initial and final lengths and weights appear in Table 9. Growth rates varied from 8.1-14.3 mm per month or 0.3-0.5 mm per day.

DISCUSSION

Urophycis chuss

Pannella (1971) first reported daily growth increments from otoliths of adult Urophycis chuss, Gadus morhua and Merluccius bilinearis. An average of 360 growth bands per annuli were deposited during the first 3-4 years in sagittae of U. chuss. The consistency of this average supports the conclusion that one growth band is deposited each day (Pannella 1971). Daily growth increments have since been verified in sagittae from numerous larval and adult fishes (Brothers et al. 1976, Barkman 1978, Brothers 1981, Laroche et al. 1982). These regularly occurring well-defined daily increments, consisting of alternating light and dark bands, were observed in all U. chuss sagittae examined. Subdaily increments were also observed.

The presence of subdaily increments in pelagic U. chuss sagittae is supported by the following observations. Pannella (1980a) reports growth patterns of planktonic organisms, both invertebrates and vertebrates are characterized by an extremely high number of increments in relation to their actual age in days. Therefore the actual daily age is less than the number of increments visible in the prepared otoliths, indicating the presence of subdaily increments. Pannella (1980a) also observed that subdaily increments were often present in "fast growing" sagittae, presumably from faster growing fishes. Markle et al. (1982) and Steiner et al. (1982) indicate U. chuss is a fast growing fish, and thus U. chuss would be likely to produce subdaily increments.

Luczkovich and Olla (unpubl., noted by Steiner et al. 1982) report growth rates as high as 1 mm per day for pelagic U. chuss. Results of my study indicate pelagic U. chuss between 4.5–28.2 mm grow 28 mm per month or 0.9 mm per day (Fig. 17), in close agreement with the observations of Luczkovich and Olla. These results imply extremely slow growth during the first 20 days. Newly hatched U. chuss larvae average 2.0 mm (Miller and Marak 1959) and require 20 days to reach 5 mm (Fig. 17) indicating a growth rate of 3 mm in 20 days or 0.15 mm per day.

The environmental or physiological origin of subdaily patterns is unknown. Subdaily patterns could be related to some activity performed twice a day. It would not appear that these subdaily increments are related to twice daily feeding activity. Pelagic Urophycis chuss are euryphagous and feed opportunistically throughout the day with only one peak period of feeding between 1700–2100 hours (Coates-Markle 1982). Subdaily increments could be produced by lunar or tidal affects as noted in other studies (Pannella 1980a). If this were the case then the time representing the formation of one increment would be 12.4 hours instead of 24 hours.

Scotian Shelf Urophycis chuss leave the neuston by ca. 30 mm SL (Markle et al. 1982) and become demersal at approximately 27–38 mm (Fig. 15). Based upon growth rates for pelagic U. chuss (Fig. 17) these newly settled demersal inquilines (collected in late September, R/V LADY HAMMOND, Table 1) are between ca. 1–2 months old and were spawned during July–August. This growth rate agrees with Steiner et al. (1982) who estimate 23–30 mm and 40 mm U. chuss are approximately 1 and 2 months old. The July–August spawning period for Scotian Shelf U.

chuss agrees with Markle et al. (1982).

This study indicates Passamaquoddy Bay and vicinity inquiline Urophycis chuss (63.9-117.9 mm SL) grow ca. 11 mm per month during late spring and summer (Fig. 19). Musick (1969) reports a growth rate of 10 mm per month for inquiline U. chuss. Markle et al. (1982) estimate a minimum annual growth rate of 100 mm based upon May-June Georges Bank length frequency data. Therefore the monthly growth rate is ca. 10 mm based upon a July-August spawning on Georges Bank (Musick 1974).

Steiner et al. (1982) report a growth rate of 11 mm in 21 days based upon November-December length frequency data. This is a monthly growth rate of 15.7 mm. An important feature of the Steiner et al. (1982) study was that growth was calculated at a time when recruitment of small Urophycis chuss into scallop beds and emigration of larger U. chuss away from the bed are small. These conditions minimize the difference between the calculated apparent population growth and the true growth rate. Samples collected before November-December contain high numbers of newly recruited pelagic individuals whereas after December few, if any, recruits arrive, but instead a net emigration of larger U. chuss away from the scallop bed occurred. Steiner et al. (1982) collected no inquiline U. chuss between June and August, the time when most of Passamaquoddy Bay collections were made (Table 5). In the collections discussed above all estimates of growth were determined at periods of high recruitment (September-December; Musick 1969) or periods of high emigration (May-August, this study; May-June, Markle et al. 1982).

The regression in Fig. 19 illustrates the size structure of

Passamaquoddy Bay inquiline *U. chuss* during late spring and summer. During these months a growth rate of 11 mm per month or 0.4 mm per day is predicted. I suspect that this growth rate is an underestimate as May to August are months of high emigration of *U. chuss* from scallop beds in Passamaquoddy Bay. Therefore only the smallest *U. chuss* (of that year class) inhabit scallops at this time as the others have outgrown their scallop hosts. The regression (Fig. 19) should therefore be only used as a predictor of growth while *U. chuss* is inquiline and not used to estimate growth of similar size *U. chuss* that are not inquiline.

Temperature has been found to be important in determining growth rates of inquiline *Urophycis chuss* (Steiner et al. 1982). In laboratory studies mean growth rates (calculated from Steiner et al. 1982; Table 1) increased with increasing temperature. Growth rates ranged from 0.62 mm per day (18.9 mm per month) at 6.7°C to 1.44 mm per day (43.3 mm per month) at 11.5°C. Bottom water temperatures in Passamaquoddy Bay ranged from 4.4–11.1°C (Table 5), while the range for the Steiner et al. (1982) November-December collections off New Jersey was 9.9–10.0°C. Colder water temperatures of Passamaquoddy Bay compared to those of Steiner et al. (1982), along with differences in sampling time, may be responsible for differences in growth rates.

As May-August is a period of high emigration of inquiline *Urophycis chuss* from scallop beds, it is possible that trawled *U. chuss* (collected 14 August to 11 September; Fig. 19) were previously inquiline during winter-spring in Passamaquoddy Bay and had to leave their scallop hosts due to increased growth. *U. chuss* originally recruited to the benthos in the fall are capable of growing 250 and possibly 300 mm by the following fall for an annual growth rate of 250-300 mm (Steiner et al. 1982). Therefore the trawled U. chuss (Fig. 19) may be one year olds that were spawned the previous summer having grown an average of ca. 200 mm. As these U. chuss are less than the 250-300 mm post inquiline U. chuss reported by Steiner et al. (1982) they may represent the late spawned fish of the previous year class.

Urophycis tenuis

Growth rates could not be determined for pelagic Urophycis tenuis in my study. Based upon Gulf of St Lawrence (Northumberland Strait) length frequency modes, pelagic U. tenuis larvae and juveniles are estimated to grow 10-22 mm per month (Markle et al. 1982).

Von Bertalanffy growth curves determined from otolith and length frequency data indicate Gulf of St. Lawrence Urophycis tenuis grow 200-250 mm during their first year (Hunt 1982). Similarly Markle et al. (1982) report rapid growth for Passamaquoddy Bay U. tenuis which reach 250 mm by December. If growth rates for Gulf of St. Lawrence and Passamaquoddy Bay 0+ U. tenuis are similar, it appears 0+ U. tenuis grow ca. 250 mm during their first year. Underfed laboratory-raised U. tenuis average 206 mm by January (Table 9). Faster growth rates would have been observed if these fish were fed regularly. As most of the U. tenuis collected in Passamaquoddy Bay were less than 250 mm they belong to the 0+ year class. Not all the U. tenuis sampled in Passamaquoddy

Bay (size range 40-408 mm SL) belong to the 0+ year class. Combined data from Hunt (1982) and Beacham and Nepszy (1980) indicate 2+, 3+ and 4+ Gulf of St. Lawrence U. tenuis are approximately 330-350 mm, 400-440 mm and 470-500 mm long. Therefore some of the larger U. tenuis taken in Passamaquoddy Bay belong to the second and third year classes. Regression analysis on Passamaquoddy Bay U. tenuis less than 250 mm SL indicate a monthly growth rate of 43 mm, or 1.4 mm per day (Fig. 20). This is similar to an annual growth rate of 250 mm and possibly 300 mm for U. chuss (Steiner et al. 1982).

ECOLOGY

INTRODUCTION

Although very similar in morphology, Urophycis chuss and U. tenuis have different life histories that are most apparent during the early demersal juvenile stages. U. chuss is inquiline with scallops and U. tenuis occupies the nearshore shallows (Markle et al., 1982). The least amount of coexistence between species occurs in these habitats (Markle et al., 1982). U. chuss spawns in summer and overwinters with scallops, leaving its scallop host during winter-summer (depending upon location) when it has either outgrown its host or cold water temperatures force it to leave (Musick 1974). Depending upon the location, U. tenuis spawns during winter-spring. Juveniles move inshore during spring-summer and use the shallows as a nursery. In both habitats predation is probably reduced (Able and Musick 1976, Garman 1983), survival is increased and growth appears to be rapid (Markle et al. 1982).

Urophycis chuss and U. tenuis ecologies have been described from the Scotian Shelf, Bay of Fundy, Gulf of St. Lawrence and Gulf of Maine (Musick 1969, 1974, Nepszy 1968, Beacham and Nepszy 1980, Markle et al. 1982). These studies have focused primarily on adult stages with secondary or no emphasis on pelagic or early demersal stages. Most studies on young 0+ Urophycis have dealt with feeding ecology. Feeding habits have been reported for sympatric pelagic Scotian Shelf U. chuss and U. tenuis (Coates-Markle 1982), for inquiline U. chuss (Garman

1983) and small demersal U. tenuis (Bowman 1981, Imrie and Daborn 1981). Activity, shelter usage, growth and recruitment of inquiline U. chuss are discussed by Steiner et al. (1982) and the peculiar sand hiding behavior of small juvenile U. tenuis is described by McAllister (1960).

It is the purpose of this section to report and contrast ecological observations on primarily young (0+) Urophycis chuss and U. tenuis from Passamaquoddy Bay New Brunswick, Trinity Bay, Newfoundland and the Scotian Shelf.

MATERIALS and METHODS

Irregular beach seining at St. Andrews, N.B. was usually conducted at low tide during night. Beach seining was conducted bimonthly at Bellevue, Newfoundland. Two consecutive low tides were sampled on each trip, allowing comparison of consecutive day-night collections. Two 24-hour beach seine series were conducted, one each at St. Andrews and Bellevue. Fishing effort was consistent over the 24 hours with two 5-10 minute tows every hour in water 1.5 meters deep. Predominant substrate types were mud-sand at St. Andrews and small rock-cobble at Bellevue. Surface temperature was determined with a hand-held mercury thermometer. Salinity samples from Trinity Bay were determined by a temperature compensated salinity refractometer (American Optical Company); samples from Passamaquoddy Bay were analysed with an Autosal Model 1800 (Guildline Instruments).

Inquiline Urophycis chuss were collected by SCUBA diving on scallop beds in Passamaquoddy Bay and vicinity (Fig. 13). All collections were taken either at high or low tide during daylight. Additional inquiline U. chuss were collected on the Scotian Shelf during daylight. Bottom temperature was determined for St. Andrews scallop collections with a U.S. Divers underwater thermometer. St. Andrews and Scotian Shelf Urophycis were usually frozen within 1-2 hours after capture. Bellevue Urophycis were preserved in 10% formalin. Scallop and beach seining collection data are summarized in Tables 1, 5 and 10.

Standard lengths were recorded for Bellevue and St. Andrews Urophycis; only St. Andrews Urophycis were weighed. Each fish was cut from the vent to the isthmus and from the isthmus to each pectoral fin to expose the stomach. The stomach was severed at the posterior end of the esophagus and anterior to the pyloric caeca, removed and weighed. Stomach and contents were preserved in 10% formalin. Scallops (Plactopecten magellanicus) were measured from the hinge to the opposite end of the upper shell. For large catches of scallops, approximately half were measured.

Two inquiline U. chuss collected by Mr. R. Hooper (Department of Biology, Memorial University of Newfoundland) from Hermitage Bay in October 1970 (Table 1) represent the northern limit for U. chuss. They have been deposited in the National Museum of Canada (NMC catalogue number 82-008).

RESULTS

Urophycis chuss

Two fishes, Liparis inquilinus (Able, 1973) and Urophycis chuss, were collected from scallops (Placopecten magellanicus) during this study. Liparids were only observed in Scotian Shelf scallops.

Twenty-six inquiline Urophycis chuss were sampled from 1078 scallops collected in Passamaquoddy Bay and vicinity between May and August (Table 5). Occupancy rates (100 X number of scallops occupied by U. chuss/number of scallops for each collection) of U. chuss in scallops were between 0.5–6.0% (Table 5). A total of 25 scallops containing 12 U. chuss for occupancy rates between 20.0-100.0% (Table 10) were collected from the Scotian Shelf (R/V LADY HAMMOND 40 and 64; Table 1). No inquiline U. chuss or liparids were observed in any of 1239 scallops collected from Fox Harbour (Placentia Bay, Nfld.; Fig. 14) between October and November 1980. Where possible bottom temperature, depth and substrate type were recorded for each scallop collection (Table 5 and 10). The first Passamaquoddy Bay inquiline U. chuss were collected in mid-May (Fig. 19). This collection contained the highest occupancy rate observed from Passamaquoddy Bay (Table 5). The last Passamaquoddy Bay inquiline U. chuss were collected in mid-August (Table 5). Scallop collections during the remainder of August and September yielded no inquiline U. chuss (Table 5). The smallest and largest inquiline U. chuss collected from Passamaquoddy Bay were 63.9 and 117.9 mm SL (Fig. 19).

All scallops collected in Passamaquoddy Bay were greater than 90 mm but only scallops larger than 120 mm contained inquiline Urophycis chuss (Fig. 23). Scotian Shelf and Passamaquoddy Bay inquiline U. chuss length frequencies appear in Fig. 15.

Three Urophycis chuss length modes were observed from Scotian Shelf scallops collected in September-October (Fig. 15). All inquiline U. chuss less than 40 mm SL were new arrivals to the benthos. New inquiline U. chuss were identified by the presence of silver sides and traces of black pigment on pelvic fin tips. The second mode (> 90 mm SL) taken on the same cruise, had typical benthic coloration with dark dorsal and lateral surfaces and no pelvic fin pigmentation. The smallest and largest inquiline U. chuss collected on the Scotian Shelf were 27.2 and 111.7 mm SL (Fig. 15).

Scotian Shelf inquiline Urophycis chuss greater than 60 mm SL were only collected from scallops larger than 140 mm (Fig. 24). Of the six new demersal inquiline U. chuss, five were removed from scallops less than 140 mm SL (Fig. 24). One Scotian Shelf scallop (138 mm) contained two (36.5 and 37.4 mm SL) newly recruited inquiline U. chuss. No new recruits were collected from Passamaquoddy Bay scallops.

Twenty Urophycis chuss (> 160 mm SL) were collected with a shrimp trawl off Deer Island (Fig. 13) in Passamaquoddy Bay (Table 1). The stomach fullness index indicates U. chuss stomachs were fuller in the morning than afternoon (Fig. 25).

Urophycis tenuis

All beach seined Urophycis were identified as U. tenuis; no U. chuss were seined at either Bellevue, Trinity Bay or St. Andrews, Passamaquoddy Bay. Young-of-the-year U. tenuis arrived in Passamaquoddy Bay by 20 June (Fig. 20) when mean monthly water temperature and salinity were approximately 11°C and 29.5 ppt. (Table 1?; Fig. 26). First arrival in Bellevue was recorded on 24 July when mean monthly water temperature and salinity were approximately 13.5°C and 29.5 ppt. (Fig. 26; Table 11). The last collection of seined Passamaquoddy Bay U. tenuis (64.5-133.8 mm SL) was made on 12 August (Fig. 20). No U. tenuis were collected on any of the three seine attempts (17 and 18 August and 6 September) after this date. The last U. tenuis collected in Trinity Bay was 64.2 mm SL, caught on 23 October (Fig. 21). No U. tenuis were collected after 23 October even though seining continued throughout winter.

The first individuals to arrive at sampling sites were small (40-64 mm SL) with typical pelagic Urophycis coloration; dark bluish-green dorsal, silver sides and long, trailing, black-tipped pelvic fins (Table 12). New nearshore arrivals occurred throughout summer (Table 12). The smallest U. tenuis seined at St. Andrews and Bellevue were 39.1 and 48.5 mm SL respectively (Table 12; Figs. 20 and 21). The largest seined specimens taken at each site were 142.4 and 97.9 mm SL respectively (Figs. 20 and 21). Large (> 50 mm SL) pelagic U. tenuis were also collected at sea during September (Table 13).

Urophycis tenuis at both St. Andrews and Bellevue were most susceptible to beach seining at night (Table 14; Fig. 27).

The index of stomach fullness indicates fullest stomachs occur during hours of darkness, especially between 0000 and 0800 hours (Fig. 28). Empty and full stomachs were observed in both day and night collections. Analysis of variance performed on stomach weights (expressed as percent fish weight) of 72 beach seined Urophycis tenuis (Fig. 28) indicates U. tenuis caught between 0000-0400 hours had stomachs that were significantly fuller than U. tenuis caught at any other time interval examined ($F=9.29$, $df=4,67$).

Extrapolation of the least squares regression line in Fig. 20 to a standard length of approximately 2 mm (the size at which Urophycis spp. eggs hatch; Hildebrand and Cable 1938, Miller and Marak 1959, Barans and Barans 1972) indicates late May as an approximate spawning time for Passamaquoddy Bay caught U. tenuis. Ninty-five percent confidence limits for this regression indicate a spawning period of May-June.

One U. tenuis was collected at Portugal Cove, Conception Bay, Nfld. This 92 mm SL U. tenuis had benthic coloration but was taken in a floating wooden crate in 9-10 meters of water (Table 1).

An examination of the literature indicates nearshore arrival of pelagic juvenile Urophycis tenuis is delayed with increasing latitude between New England and Newfoundland (Table 15).

DISCUSSION

Urophycis chuss

All demersal Urophycis chuss (< 120 mm SL) were collected from inside the mantle cavity of live sea scallops, Placopecten magellanicus. No small U. chuss (< 120 mm SL) were trawled in Passamaquoddy Bay even though small U. tenuis (< 120 mm SL) were collected by the small mesh shrimp trawl. All known populations of post-pelagic U. chuss are associated with scallops in this symbiotic relationship (Markle et al. 1982). It is not known if the relationship is facultative or obligatory.

Steiner et al. (1982) present laboratory evidence suggesting the relationship is facultative. In two experiments empty bivalves and depressions underneath live scallops were preferred by juvenile Urophycis chuss over mantle cavities of live scallops. Seeking any object that provides shelter appears to be a primary goal of juvenile Urophycis chuss (Steiner et al. 1982). Association with scallops should be advantageous for U. chuss as the only fishes reported to prey on P. magellanicus are Gadus morhua, Hippoglossoides platessoides and Anarhichas lupus (Bourne 1964, Mackenzie 1979). These fishes do not take many large scallops as most predation occurs on smaller juveniles (Mackenzie 1979).

The only other fish species observed in scallops during this study was Liparis inquilinus (Able 1973). Contrary to Bigelow and Schroeder (1953) no Urophycis tenuis were inquiline in scallops. Their report of inquiline U. tenuis may be due to misidentification, as they treat the two species together. The only other fish reported in P. magellanicus is Pholis gunnellus. A single 120 mm TL P. gunnellus was found within the mantle cavity of a 125 mm scallop collected in the vicinity of Frenchman Bay, Maine (Garman 1983).

Occupancy rates of scallops harboring Urophycis chuss varied temporally and spatially. Occupancy rates were higher on the Scotian Shelf (Table 10) than from Passamaquoddy Bay (Table 5). There are three possible reasons for this. First, Passamaquoddy Bay scallops were collected at a time of high emigration of U. chuss away from scallop beds (May-August). Secondly, there are few large scallops on the Scotian Shelf (Bourne 1964). As the central Scotian Shelf is a spawning area for U. chuss (Markle et al. 1982), the few scallops that are present would be expected to have high occupancy rates. Thirdly, high infestation rates are also due to time of sampling. U. chuss spawn on the Scotian Shelf in July-August (Markle et al. 1982). Since U. chuss grow 0.9 mm per day (Fig. 17) and remain pelagic until ca. 30 mm (Markle et al. 1982, Fig. 10) September and October should be months of high recruitment of pelagic U. chuss to the benthos and scallops. Steiner et al. (1982) collected their first inquiline U. chuss of the new year class in September.

After mid-August no inquiline Urophycis chuss were collected from Passamaquoddy Bay scallops (Table 5). Juvenile U. chuss remain inquiline until they outgrow their scallop hosts or until water temperatures colder than about 4°C either kill the hake or force them to seek warmer temperatures in deeper water (Musick 1974). All bottom water temperatures in my study except one were above ca. 4°C (Table 5), suggesting U. chuss outgrew their scallop hosts.

The absence of Passamaquoddy Bay inquiline Urophycis chuss after mid-August may also be due to sampling artifact. Both U. chuss and U. tenuis prefer sand-mud substrates, occurring rarely on rock, shell or gravel (Battle 1952, Bigelow and Schroeder 1953, Leim and Scott 1966, Musick 1974). Of the 18 scallop collection dives, 5 were done in areas where a small rock-gravel substrate predominated (Table 5). No inquiline U. chuss were sampled on any of these dives, 4 of which were after mid-August. These data may reflect U. chuss preference for scallops on sand-mud substrates.

An unusual feature of the September Scotian Shelf scallop data is the presence of two size classes of U. chuss. The newest recruits (spawned ca. 1-2 months earlier) are silver sided with pelvic fins slightly pigmented on the posterior tips. All were less than 40 mm SL (Fig. 15). The second size class had typical benthic coloration and were greater than 90 mm SL (Fig. 15). These larger U. chuss could represent the last remaining individuals of the previous year class as were observed in the Passamaquoddy Bay collections (Fig. 15). Alternately, inquiline U. chuss greater than 90 mm could represent exceptionally fast growing new recruits of the same year class as individuals less than 40 mm. If so, these larger U. chuss would be among the first demersal recruits.

Two Urophycis chuss size modes were not present in Passamaquoddy Bay scallops even though U. chuss is known to spawn in the bay (Markle et al. 1982). The absence of the smallest mode (Fig. 15) could be due to several reasons. First, had scallop collections been made through September-October (months of high recruitment of just spawned pelagic *U. chuss* to scallops) the newly recruited *U. chuss* from the July-August spawning in Passamaquoddy Bay might have been observed. Secondly, if spawning was delayed then recruitment of pelagic individuals to the benthos would be delayed accordingly. Thirdly, recently spawned larvae may be expatriated from Passamaquoddy Bay by strong tidal currents (Forrester 1960).

Markle et al. (1982) found no inquiline *Urophycis chuss* inside scallops less than 90 mm and concluded *U. chuss* prefer larger scallops. Steiner et al. (1982) also reported a preference for larger scallops. They observed the length of an individual hake was never greater than the length of its scallop host, although on occasion the ratio approached 1:1. This trend is also present in my Passamaquoddy Bay collections (Fig. 23). Furthermore smaller Scotian Shelf *U. chuss* were found in smaller scallops and larger *U. chuss* in bigger scallops (Fig. 24). This agrees with Steiner et al. (1982) who report small scallops contain only small fish but large scallops contain all possible sizes of fish.

U. chuss are abundant in scallops during the day and less abundant at night (Steiner et al. 1982). Laboratory and field studies indicate *U. chuss* are more active at night and that much of this activity is related to feeding (Steiner et al. 1982). Nocturnal feeding is inferred in my study by the index of stomach fullness determined from *U. chuss* collected during daytime (Fig. 25), which show fuller stomachs in the morning that tend to empty towards afternoon. This trend is present for both inquiline and trawled U. chuss. Vinogradov (1977-Tables 8 and 9) indicates feeding of demersal U. chuss is heaviest between 0200-0230 hours. The lowest index of stomach fullness was recorded between 1800-1830 hr. These data agree with the nocturnal feeding habits of U. chuss inferred in this study and Steiner et al. (1982).

The data contrast with feeding data reported for pelagic Urophycis chuss. Heaviest feeding by Scotian Shelf pelagic U. chuss occurs between 1700-2100 hrs. with feeding continuing to approximately midnight (Coates-Markle 1982). Heaviest diel feeding therefore appears to switch from primarily dusk for pelagic U. chuss to late night and early morning for demersal U. chuss.

Urophycis tenuis

Juvenile (O+) Urophycis tenuis actively migrate inshore during the spring and summer (Musick 1969). My study indicates this migration is pelagic, not demersal. The first individuals to arrive nearshore possess typical pelagic coloration. They are small (40-64 mm SL), dark bluish-green on the dorsal surface, silver on the lateral surfaces and have long, trailing, black-pigmented pelvic fins. These pelagic characters are lost when U. tenuis becomes demersal. Development of demersal characters upon settlement is described for U. chuss by Musick (1969) and, based upon seined individuals, the same changes appear in U. tenuis although the rate of change may be different. Adult characteristics (coloration and body shape) develop in 12-48 hours once settlement has occurred. Once settled, U. chuss resemble the adult being dark brown above and white below (Musick 1969). The ventral fins which trailed at the side of the body now extend forward as the fish slowly swims over the bottom, presumably using them for food searching (Bardach and Case 1965, Pearson et al. 1980).

Once inshore, Urophycis tenuis apparently continue to visit the water column to some extent even after they have become demersal and developed adult coloration and shape. One individual (91.8 mm SL, Table 1) caught in Portugal Cove, Nfld., had typical adult coloration (dark dorsal and lateral surfaces, white ventral surface and no black tipped pelvic fins) but was caught at the surface in water about 9-10 meters deep. Needler (1940) reported U. tenuis caught in surface gillnets located at the mouth of the Bideford River, Prince Edward Island. Stomach contents also indicate "demersal" U. tenuis forage in the water column (Bigelow and Schroeder 1953, Petrov 1973, Imrie and Daborn 1981). Depending upon sampling time and location, frequency of occurrence of pelagic crustacean food items in U. tenuis varies from 3.3 to 24.4% (Petrov 1973). Although Bigelow and Schroeder (1953) did not distinguish between U. tenuis and U. chuss they note Urophycis feed far enough off the bottom to forage on pelagic euphausiids Meganyctiphanes and Thysanoessa. Similarly, Imrie and Daborn (1981) note U. tenuis collected in Minas Basin, Bay of Fundy had been feeding on a broad spectrum of food including euphausiids, amphipods, nematodes, isopods, polychaetes, copepods and mysids. Imrie and Daborn (1981) note in terms of biomass the benthic component was always dominant and U. tenuis apparently did not utilize terrestrial or salt marsh arthropods. Bowman (1981) reports planktonic euphausiids and calanoid copepods were not found in any of the 23 stomachs sampled from U. tenuis (50-200 mm TL) collected between the mid-Atlantic Bight and Scotian Shelf.

Urophycis tenuis is a member of the summer ichthyofauna at the sampling sites in Passamaquoddy and Trinity Bays. Its presence onshore during summer has been previously reported from Montsweag Bay, Maine, (Fried 1973) and Cumberland Basin (Markle et al. 1982). U. tenuis utilize the nearshore shallows apparently as a nursery, arriving in Passamaquoddy Bay by late June and in Bellevue, Trinity Bay by late July. U. tenuis arrives and remains nearshore when water temperatures are the warmest (Fig. 26). U. tenuis is essentially absent from the nearshore region in Passamaquoddy Bay, N.B. and Bellevue, Nfld. by late August and late September respectively, although one individual was taken on 23 October at Bellevue, Nfld. Surface salinity varied only after periods of rainfall, otherwise salinity was relatively unaltered (Table 11).

Although it is well documented that Urophycis prefer sand-mud-silt bottoms to rocky bottoms (Battle 1952, Bigelow and Schroeder 1953, Leim and Scott 1966, Musick 1974), all the U. tenuis sampled at Bellevue, Trinity Bay were taken on a small rock-cobble bottom. Those sampled in Passamaquoddy Bay (beach seine and trawl) were taken on mud bottoms.

The onshore arrival of Urophycis tenuis is protracted, with new pelagic juveniles arriving throughout the summer (Table 12). This suggests a protracted spawning period. Regression analysis on length frequency data from Passamaquoddy Bay indicate peak spawning during the end of May. A spawning period of May-June is predicted when 95% confidence limits are calculated for this regression (Fig. 20).

Urophycis tenuis do not appear to spawn in Passamaquoddy Bay. Spawning does take place in the Bay of Fundy during winter-spring (Battle 1951, Markle et al. 1982) but it is not known if the Passamaquoddy Bay U. tenuis are from a local or Bay of Fundy spawning.

Most Urophycis tenuis were collected during night (Table 14; Fig. 27). Although little is known about day/night differences in fish catches (McCleave and Fried 1975), most information available indicates greater catches (number of species, total individuals or biomass) are obtained at night (Livingston 1976, Horn 1980), although McCleave and Fried (1975) collected fewer total individuals at night. Similarly Markle et al. (1982) found the catchability of neustonic Scotian Shelf pelagic juvenile U. tenuis to be strongly influenced by time of day. Most individuals were caught at night.

Diel activity patterns and daytime net avoidance are two factors believed responsible for differences in abundance and composition of net-caught fishes (Horn 1980). In this study, the vast majority of Urophycis tenuis were taken at night (Table 14; Fig. 27). Targett and McCleave (1974) found similar results in Montsweag Bay, Maine, where U. tenuis is an important demersal component of the ichthyofauna at night but is rarely found during the day.

Evidence suggests daytime gear avoidance is secondary to diel activity patterns in explaining differences in day-night beach seine catches. Targett and McCleave (1974) used a 30.5 meter beach seine while a 9 meter seine was used in this study. Net avoidance would be expected to be less with a larger seine, but the findings of the two studies are similar. Urophycis tenuis is absent from the daytime ichthyofauna of Montsweag Bay, Passamaquoddy Bay and Trinity Bay.

Diel activity patterns may explain differences between day and night catches. If Urophycis tenuis move nearshore at night (when they are caught by beach seine) and offshore during the day this activity pattern may be related to feeding. Fig. 28 shows stomachs are fuller at night, especially between 0000-0800 hrs. indicating U. tenuis are feeding at or near this time. There is little information available on diel feeding patterns of U. tenuis. Pelagic U. tenuis collected from the Scotian Shelf in August were feeding throughout the day (Coates-Markle 1982). Heaviest feeding occurred between 0800-1000 hrs. and 1800-2100 hrs. Reduced gut fullness was observed at late evening (2300 hrs.) and early morning (0400 hrs), which were periods of heavy feeding for demersal nearshore juvenile U. tenuis (Fig. 28). Heaviest feeding therefore switches from primarily crepuscular for pelagic individuals to nighttime for demersal U. tenuis.

Despite an active inshore migration of juvenile Urophycis tenuis during the spring and summer (Musick 1969), large pelagic U. tenuis are found many miles offshore (Table 13, this study; Musick 1969, Markle et al. 1982). Musick (1969) reports taking 5 specimens of U. tenuis (58-72 mm) during the summer on Georges Bank and specimens up to 71 mm in length in surface nets from the Gulf of St. Lawrence during September. Pelagic U. tenuis migrate to the bottom at 80 mm or smaller in shallow harbours and estuaries (Musick 1974). Whether or not these offshore U. tenuis migrate inshore to utilize the nearshore shallows during fall is unknown, but this is unlikely. Year round beach seining at Bellevue, Nfld., collected U. tenuis only between July and October.

Atlantic coast juvenile Urophycis tenuis arrive nearshore during spring-summer. Table 15 indicates nearshore arrival is delayed at northerly latitudes.

If egg development and growth of larvae and juveniles of pelagic Urophycis tenuis is similar from New England to Newfoundland, then a winter-spring spawning period would be predicated for U. tenuis.

Besides Bellevue, Nfld., the only report of small Urophycis tenuis seined in Newfoundland waters are young (0+) U. tenuis seined at five sites from Cape Rich to Flower Cove, adjacent to the Strait of Belle Isle in northeast Newfoundland (Huntsman 1954). A June survey of nearshore Newfoundland marine fishes sampled no U. tenuis at collection sites around the island (Van Vliet 1970). Collections were taken approximately 1 month before U. tenuis were seined in Bellevue (late July), suggesting U. tenuis had not arrived nearshore at the time of sampling.

GENERAL DISCUSSION and SUMMARY

Before discussing growth and ecology of 0+ Urophycis chuss and U. tenuis it was necessary to identify the larvae using meristic, morphometric and pigment characters. These characters enabled separation of U. chuss and U. tenuis larvae as small as 5-7 mm SL. Pelagic U. tenuis are deeper bodied, have a higher caudal finray count and one less epibranchial gill raker than U. chuss. The adult complement of epibranchial gill rakers develops at ca. 12-14 mm SL. Differences in caudal finray counts and pigment characters develop at a smaller size and separate larvae less than 12-14 mm SL. The adult complement of all meristic characters examined are developed by 15.6 mm SL.

For specimens ca. > 14 mm SL differences in epibranchial gill raker counts and body depth are the quickest and easiest characters to use. Below 14 mm and down to ca. 7-8 mm SL careful counts of stained caudal finrays separate larvae. Differences in pigment development (especially caudal peduncle pigment) and body depth (to ca. 10 mm SL) also separate larvae below 14 mm SL.

Urophycis chuss and U. tenuis larvae may most likely be confused with other hake-like larvae including Phycis chesteri, Enchelyopus cimbrius and Gaidropsarus ensis. Urophycis chuss and U. tenuis larvae may be separated from these larvae by the presence or absence of pterotic spines, initial number of pelvic finrays and differences in pigmentation. The reader should refer to Markle (1982) for elaboration of these differences. Confusing U. chuss and U. tenuis with other Urophycis is unlikely as these are the most northerly occurring Urophycis species. Other Urophycis rarely, if, ever, occur on the Scotian Shelf (Urophycis cirrata, U. earlli, U. floridana and U. regia).

Once larvae were identified I was able to determine a growth rate of ca. 28 mm per month for pelagic U. chuss based upon examination of daily increments in otoliths. As the majority of pelagic Urophycis collected on the Scotian Shelf (in September) were U. chuss I was not able to determine a growth rate for pelagic U. tenuis. Pelagic Scotian Shelf U. chuss become demersal during early fall when 27-39 mm SL, or 1-2 months old. As U. chuss spawn on the Scotian Shelf during July-August (Markle et al. 1982) larvae that become demersal during fall are from this recent spawning.

Once demersal, young Urophycis chuss inhabit the mantle cavity of scallops, Placopecten magellanicus. U. chuss lose their silvery pelagic coloration becoming white on the bottom with dark dorsal and lateral surfaces. During September two size classes (27-39 and > 96 mm SL) inhabit Scotian Shelf scallops.

Although some large pelagic Urophycis tenuis (50-70 mm SL) were collected during the September Scotian Shelf cruise most had migrated inshore where they were abundant during summer. New nearshore arrivals are 40-60 mm SL and undergo a pelagic to demersal change in coloration. U. tenuis were collected at night in shallow water (1.5 meters). It appears U. tenuis remain nearshore reaching ca. 150 mm before moving offshore.

Nearshore arrival of pelagic juvenile Urophycis tenuis is delayed with increasing latitude. Juveniles arrive during May in New England, June in the Bay of Fundy and Atlantic coast of Nova Scotia, and July in the Gulf of St. Lawrence and eastern Newfoundland.

There was complete habitat separation between young demersal Urophycis chuss and U. tenuis. No U. chuss were caught in nearshore beach seine collections and no U. tenuis were taken from inside the mantle cavity of Placopecten magellanicus. Both species are in habitats where predation is presumably reduced and where growth appears to be rapid (Able and Musick 1976, Markle et al. 1982, Garman 1983).

Urophycis tenuis spawned in late winter and spring are 250-280 mm by December, (i.e. in approximately 8-10 months) whereas U. chuss spawned during mid-late summer average ca. 200 mm after 12 months growth.

These data support life history strategies proposed by Markle et al. (1982). Urophycis tenuis grows fast relative to U. chuss. Annual growth during the first year is ca. 250-280 mm whereas U. chuss grows 200 mm. U. tenuis delays maturation until the fourth year once reaching ca. 500 mm. Slower growing U. chuss mature during the second year when approximately 300 mm (Beacham and Nepszy 1980, Markle et al. 1982). This "get big quick" strategy exhibited by U. tenuis is achieved, in part, by delayed maturation relative to U. chuss.

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Table 1. Summary of U. chuss and U. tenuis collections.

Life history stage	Habitat (depth)	Date	Region	Vessel and cruise.	Gears	Number collected	Range of standard lenghths (mm)
				Urophycis chuss			
larval & juvenile	pelagic	18-28/09/80	central Scotian Shelf	R/V LADY HAMMOND 40	1 m neuston and bongo nets, .333 and 1.179 mm mesh	> 100	ca. 4-39
juvenile	scallop beds (46-61 m)	23-25/09/80	central Scotian Shelf	R/V LADY HAMMOND 40	1 m Digby scallop drag 79 cm wide, 7.5 cm rings	10	27-112
juvenile	scallop beds (11 m)	-/10/70	Hermitage Bay, Newfoundland	-	Scuba	2	52-55
juvenile	scallop beds (9-27 m)	18/05/-13/08/81	Passamaquoddy Bay, New Brunswick and vicinity	-	Scuba	26	64-118
juvenile	scallop beds (51 m)	3/10/81	Scotian Shelf	R/V LADY HAMMOND 64	1 m Digby scallop drag 79 cm wide, 7.5 cm rings	2	ca. 65-75
juvenile	demersal (35-85 m)	14/08-9/09/81	Passamaquoddy Bay, N.B.	R/V PANDALUS II and MISS MICHELLE	shrimp trawl	20	165-228
				Urophycis tenuis			
larval & juvenile	pelagic	18-28/09/80	central Scotian Shelf	R/V LADY HAMMOND 40	1 m neuston and bongo nets, .333 and 1.179 mm mesh	> 100	13-68
juvenile	nearshore (1.5 m)	20/06-12/08/81	Passamaquoddy Bay, N.B.	-	9 m beach seine, 9 mm stretch mesh	80	40-142
juvenile	nearshore (1.5 m)	24/07/-23/10/82	Bellevue, Trinity Bay, Nfld.	-	9 m beach seine, 9 mm stretch mesh	116	48-98
juvenile	nearshore (35-85 m)	14/07/-16/11/82	Passamaquoddy Bay, N.B.	R/V PANDALUS II and MISS MICHELLE	shrimp trawl	155	75-408
juvenile	pelagic (surface)	5/10/81	Portugal Cove, Conception Bay, Nfld.	-	floating wooden crate	1	92
larval & juvenile	pelagic	5-14/09/79	southern Gulf of St. Lawrence	R/V E.E. PRINCE 229	1 m neuston net 1.179 mm mesh	2044	4-37

Table 2. Meristics determined from cleared and stained U. chuss.

SL	D_1	D_2	A	Caudal fin: Superior	Caudal fin: Hypurals	Caudal fin: Inferior	P_1: R	P_1: L	P_2: R	P_2: L	Epibranchial gillrakers	Vertebrae: Precaudal	Vertebrae: Caudal	Vertebrae: Total
5.3	-	-	-	9	5+2	7	-	-	3	3	0	14	35	49
6.5	3	46	41	11	5+3	8	12	12	3	3	1	15	35	50
7.7	5	49	47	11	5+3	9	12	13	3	3	1	15	34	49
8.1	3	49	45	12	6+3	11	13	13	3	3	2	15	34	49
9.6	4	57	51	12	6+3	11	13	14	3	3	2	14	35	49
10.6	8	58	49	13	5+3	12	13	13	3	3	2	14	35	49
11.1	7	54	46	12	6+3	11	14	15	3	3	2	15	34	49
12.9	9	55	51	11	6+3	11	14	15	3	3	3	14	35	49
13.0	9	55	51	11	6+3	11	14	15	3	3	2	15	35	50
14.7	9	58	54	11	6+3	11	16	15	3	3	3	15	34	49
15.6	9	53	56	11	6+3	11	16	15	3	3	3	15	34	49
20.4	11	55	50	11	6+3	11	15	17	3	2	3	16	32	48
29.6	11	55	52	12	5+3	10	16	16	3	3	3	15	34	49
108.0	10	58	54	13	6+3	11	17	17	3	-	3	15	34	49

NOTE: Abbreviations, SL, standard length; D_1, first dorsal fin; D_2, second dorsal fin; A, anal fin; P_1, pectoral fin; P_2, pelvic fin; R, right; L, left.

Table 3. Meristics determined from cleared and stained U. tenuis.

SL	D_1	D_2	A	Caudal fin Superior	Caudal fin Hypurals	Caudal fin Inferior	P1 R	P1 L	P_2 R	P_2 L	Epibranchial gillrakers	Vertebrae Precaudal	Vertebrae Caudal	Vertebrae Total
5.5	-	27	29	8	6+3	9	-	-	3	3	0	15	35	50
6.9	-	46	39	11	6+3	12	8+	12	3	3	0	15	35	50
7.7	4	43	37	13	6+3	11	9	9+	3	3	1	16	34	50
8.0	4	44	43	14	6+3	12	10	13	3	3	1	16	35	51
9.1	4	46	40	14	5+3	12	12	14	3	3	1	16	34	50
10.1	8	48	41	13	6+3	13	12	12	3	3	1	15	34	49
11.4	7	51	45	14	6+3	13	14	14	3	3	1	16	34	50
12.5	5+	52	46	14	6+3	13	14	14	3	3	2	15	35	50
13.8	8	51	43	14	6+3	13	15	15	3	3	2	16	34	50
14.7	10	52	46	14	6+3	13	15	16	3	3	2	16	34	50
15.8	10	52	49	15	6+3	14	15	17	3	3	2	15	35	50
27.8	10	54	47	13	5+3	12	17	17	3	3	2	16	33	49
39.6	11	56	48	14	6+3	14	17	17	3	3	2	16	33	49
97.8	11	58	52	15	5+3	14	17	15	3	3	2	16	34	50

NOTE: Refer to Table 2 for abbreviations.

Table 4. Approximate size (mm SL) at which larvae develop adult complement of meristic characters. Adult range (in parentheses) compiled from this study, Svetovidov 1948, Musick (1973) and Markle (1982).

Character	*U. chuss*	*U. tenuis*
D_1 Finrays	12 (9-11)	14 (10)
D_2 Finrays	9 (53-64)	11 (50-58)
A Finrays	7 (45-57)	8 (41-52)
C Finrays	8 (29-34)	7 (33-39)
P_1 Finrays	15 (16)	14 (16)
P_2 Finrays	< 5	< 5 (3)*
Epibranchial gillrakers	12-14 (3)	12 (2)
Total vertebrae	< 5 (45-50)	< 5 (47-50)

* based upon 2 fish (335 and 340 mm SL)
Refer to Table 2 for abbreviations.

Table 5. Passamaquoddy Bay inquiline U. chuss - scallop data. "-" indicates data not collected. Occupancy rate = 100 x no. of scallops occupied by U. chuss/no. of scallops.

Date	Number of U. chuss	Number of scallops	Occupancy rate	Bottom temp. (°C)	Depth (meters)	Substrate	Local time
18 May	9	150	6.0%	4.4	20	sand	1600
17 June	0	-	-	-	15	mud-silt	1906
20 June	2	-	-	8.5	-	-	-
21 June	0	-	-	-	20	mud	1645
04 July	1	35	2.9	10.0	21	mud-sand	1430
12 July	1	203	0.5	9.7	23	mud-sand	1615
15 July	0	-	-	-	9	gravel	-
18 July	3	121	2.5	9.4	21	sand	1915
19 July	0	-	-	-	20	sand-silt	0930
25 July	1	66	1.5	-	15	mud	1315
26 July	4	163	2.5	11.1	18	mud	1400
08 August	1	52	1.9	-	17	mud	1315
09 August	1	22	4.5	-	21	mud	1936
13 August	3	266	1.1	11.1	21	mud	1715
19 August	0	-	-	-	21	gravel	1100
23 August	0	-	-	-	27	gravel	1245
25 August	0	-	-	-	21	gravel	1545
13 September	0	-	-	-	24	gravel	1805

Table 6. Experimental conditions for laboratory reared *U. tenuis* (July - September 1981). Underlining indicates changes made to experimental conditions between 18-26 August.

Date	Tank #	Temperature (°C)	Salinity (ppt)	Photoperiod (light:dark)	Food (g/day)
21 July - 17 August	3	13.1 - 15.0	30.7	12L : 12D	ca. 1
	4	13.1 - 15.0	30.7	12L : 12D	ca. 1
	5	13.8 - 15.0	30.7	12L : 12D	ca. 1
18-26 August	3	18.8 - 20.6	29.6	12L : 12D	ca. 1
	4	13.9 - 16.5	29.6	12L : 12D	None
	5	15.1 - 16.5	29.6	24D	ca. 1
27 August - 8 September	3	13.2 - 16.9	30.1	12L : 12D	ca. 2
	4	13.2 - 16.9	30.1	12L : 12D	ca. 2
	5	13.9 - 16.9	30.1	12L : 12D	ca. 2

Table 7. Lengths and (weights) of individual laboratory reared juvenile *U. tenuis* (July-September). Standard length in millimeters; weight in grams.

Date (1981)	Tank and (specimen number) 3(1)	3(2)	3(3)	4(1)	4(2)	4(3)	5(1)	5(2)	5(3)
21 July	58.3(1.6)	67.4(2.7)	71.3(3.7)	70.4(3.4)	61.8(2.1)	67.0(2.9)	108.1(13.2)	75.1(4.5)	61.2(2.6)
18 August	67.5(2.9)	86.0(6.8)	93.2(7.4)	94.2(8.1)	-	93.1(8.4)	139.2(29.9)	98.2(10.8)	-
26 August	76.2(4.2)	96.7(9.2)	103.0(11.5)	101.7(9.0)	-	99.6(9.0)	153.7(40.0)	108.2(14.0)	-
8 September	99.4(9.3)	123.6(18.9)	135.1(24.0)	125.5(18.2)	-	115.6(15.3)	183.2(75.9)	135.5(27.6)	-

Table 8. Mean daily length and (weight) gain of individual laboratory reared juvenile *U. tenuis*, same specimens as Table 7. Standard length in millimeters; weight in grams.

Date (1981)	Tank and (specimen number) 3(1)	3(2)	3(3)	4(1)	4(3)	5(1)	5(2)
21 July - 17 August	0.3(0.1)	0.6(0.1)	0.6(0.1)	[illegible].9(0.2)	1.0(0.2)	1.6(0.6)	0.9(0.2)
18 August - 26 August	1.1(0.2)	1.3(0.3)	1.3(0.5)	0.9(0.1)	0.8(0.1)	1.8(1.3)	1.6(0.4)
27 August - 8 September	1.8(0.4)	2.[illegible](0.8)	2.5(1.0)	1.8(0.7)	1.2(0.5)	2.3(2.8)	2.1(1.0)

Table 9. Lengths and (weights) of individual laboratory reared juvenile *U. tenuis* (September 1981 - January 1982). Standard length in millimeters; weight in grams.

Date	Specimen Number			
	1	2	3	4
18 September	163.7(39.7)	152.7(32.4)	188.2(57.3)	129.4(18.7)
18 January	221(70.5)	185(57.0)	238(95.4)	180(32.3)

Table 10. Scotian Shelf inquiline U. chuss - scallop data from cruises R/V LADY HAMMOND 40 and 64. Occupancy rate = 100 x no. of scallops occupied by U. chuss/no. of scallops.

Date	Scallop tow no.	Number of U. chuss	Number of scallops	Occupancy rate	Depth (meters)	Local time
23-09-80	22	1	1	100%	50	1553
23-09-80	23	6*	8	62.5	55	1820
24-09-80	32	1	1	100	48	1552
24-09-80	35	1	3	33.3	46	1758
25-09-80	60	1	5	20.0	61	1435
03-10-81	01	2	7	28.6	51	0818

* 2 inquiline U. chuss in one scallop.

Table 11. Mean monthly nearshore surface salinities at beach seining sites in St. Andrews and Bellevue.

Location	Month	Salinity (ppt.)
St. Andrews N.B.	June 1981	29.5
	July 1981	29.9
	August 1981	28.5
Bellevue Nfld.	June 1982	29.5
	July 1982	27.8
	August 1982	21.0
	September 1982	27.3

Table 12. Lengths of U. tenuis newly recruited to the bottom at St. Andrews, N.B. and Bellevue, Nfld.

Location	Standard length (mm)	Date of capture
St. Andrews	55.9	20 June 1981
	44.8	9 July 1981
	50.7	16 July 1981
	55.9	16 July 1981
	52.8	22 July 1981
	54.4	23 July 1981
	53.1	23 July 1981
	55.6	23 July 1981
	55.7	23 July 1981
	53.1	23 July 1981
	58.8	23 July 1981
	51.5	29 July 1981
	40.6	29 July 1981
	60.2	30 July 1981
	39.1	9 August 1981
	50.5	9 August 1981
Bellevue	48.5	24 July 1982
	50.3	24 July 1982
	57.2	14 August 1982
	61.0	15 August 1982
	64.2	23 October 1982

Table 13. Lengths of neustonic *U. tenuis* (> 50 mm SL) from the Scotian Shelf, R/V LADY HAMMOND 40.

Station number	Standard length (mm)
199	58.8
200	52.2
201	67.7
201	63.3
201	62.7
213	54.7
236	50.9
248	63.7

Table 14. Beach seine collections of U. tenuis at low tide, day and night, at St. Andrews and Bellevue.

Location	Date	Local time	Number of U. tenuis
St. Andrews N.B.	28 July 1981	1630	0
	29 July 1981	0530*	5
	29 July 1981	1630	0
	30 July 1981	0615*	2
Bellevue Nfld.	24 July 1982	0530*	2
	24 July 1982	1745	0
	14 August 1982	2330*	2
	15 August 1982	1330	0
	21 August 1982	1625	0
	22 August 1982	0515*	2
	4 September 1982	1615	0
	5 September 1982	0510*	8
	23 October 1982	0615*	0
	23 October 1982	1925*	1

* indicates sampling during darkness

Table 15. Month of onshore arrival of *U. tenuis* in New England and the Atlantic provinces.

Location	Month of arrival	Reference
Woods Hole, Massachusetts	May	Musick 1969
Passamaquoddy Bay, N.B.	June	this study
Cumberland Basin Bay of Fundy, N.S.	June	Markle et al. 1982 (Fig. 11)
near Lunenburg, N.S.	June	Markle et al. 1982
near Sheet Harbour, N.S.	June	Markle et al. 1982
St. Georges Bay, N.S.	July	Kenchinton 1980
north central P.E.I.	July	McAllister 1960
Bellevue, Trinity Bay, Nfld.	July	this study

FIGURE 17 Generalized hake indicating pigment characters and their location.

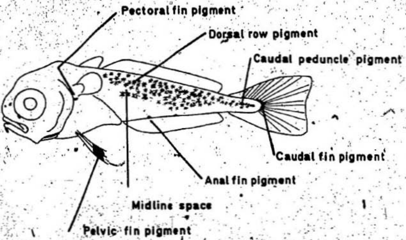

Pectoral fin pigment
Dorsal row pigment
Caudal peduncle pigment
Caudal fin pigment
Anal fin pigment
Midline space
Pelvic fin pigment

FIGURE 2. Total caudal finray counts for U. tenuis (26.1-176.1 mm SL) and U. chuss (65.1-228.4 mm SL). Mean, 2 standard errors and 1 standard deviation (on either side of the mean) and the range are indicated.

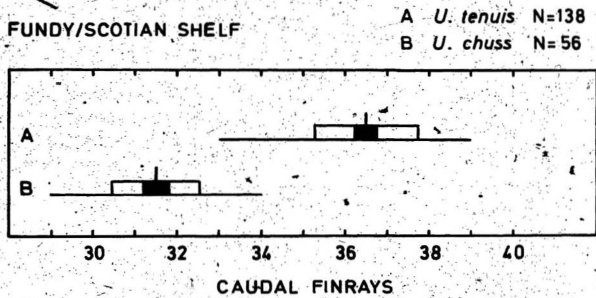
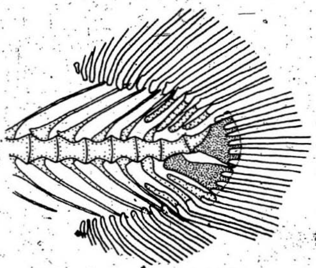
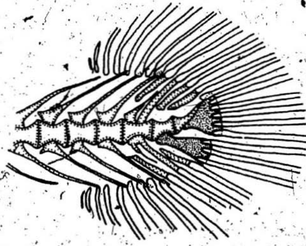

FUNDY/SCOTIAN SHELF
A U. tenuis N=138
B U. chuss N=56
A
B
30
32
34
36
38
40
CAUDAL FINRAYS

FIGURE 3. Caudal osteology of *U. tenuis* and *U. chuss*, both 14.7 mm SL.



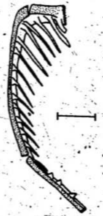
U. tenuis



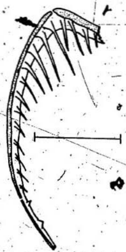
U. chuss

FIGURE 4. First gill arch from U. tenuis and U. chuss showing an additional gill raker on the epibranchial observed in some specimens for each species. Full scale equals 1 millimeter.

GILL ARCHES



U. tenuis
48.1 mm SL



U. chuss
25.5 mm SL

FIGURE 5. Reduction of the third pelvic finray in *U. chuss* (15.6, 29.6 and 81.9 mm SL). Full scale equals 2 millimeters.

Urophycis chuss

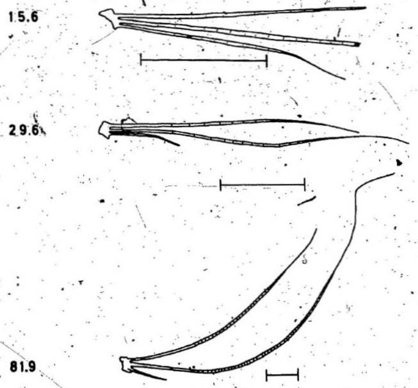
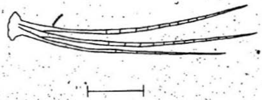


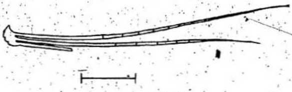
FIGURE 6. Reduction of the third pelvic finray in *U. tenuis* (46.1, 53.1, 63.7 and 97.8 mm SL). Full scale equals 2 millimeters.

Urophycis tenuis

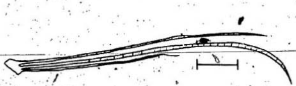
46.1



53.1



63.7



97.8

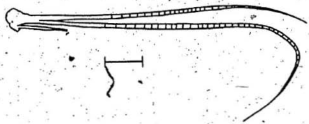
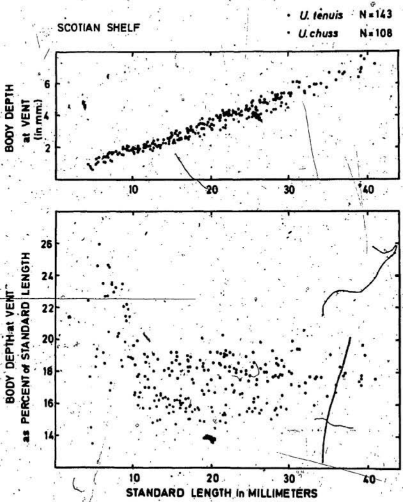


FIGURE 7. Body depth at vent and as percent of standard length for U. chuss and U. tenuis.



SCOTIAN SHELF
U. tenuis N=143
U. chuss N=108
BODY DEPTH at VENT (in mm.)
6
4
2
10
20
30
40
BODY DEPTH at VENT as PERCENT of STANDARD LENGTH
26
24
22
20
18
16
14
10
20
30
40
STANDARD LENGTH in MILLIMETERS

FIGURE 8. Body depth at origin of first dorsal fin and as percent of standard length for U. chuss and U. tenuis.

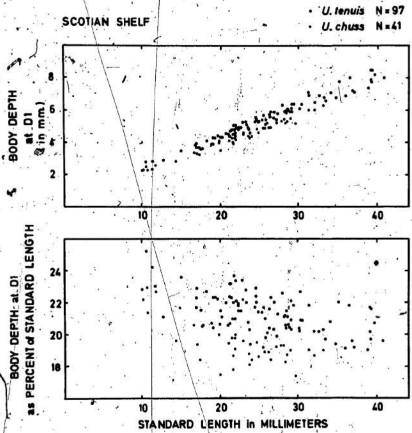

SCOTIAN SHELF
U. tenuis N = 97
U. chuss N = 41
BODY DEPTH at D1 (in mm.)
BODY DEPTH at D1 as PERCENT of STANDARD LENGTH
STANDARD LENGTH in MILLIMETERS

FIGURE 9. Body depth at origin of second dorsal fin and as percent of standard length for U. chuss and U. tenuis.

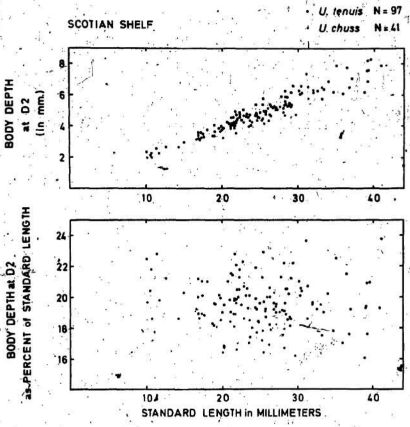

SCOTIAN SHELF
• U. tenuis N = 97
▲ U. chuss N = 41
BODY DEPTH at D2 (in mm.)
2
4
6
8
10
20
30
40
BODY DEPTH at D2 as PERCENT of STANDARD LENGTH
16
18
20
22
24
10
20
30
40
STANDARD LENGTH in MILLIMETERS

FIGURE 10. Development of pigment for U. chuss and U. tenuis larvae. Dotted lines indicate some specimens have pigment, solid lines indicate all specimens have pigment. The upper line for each pigment character refers to U. chuss (Scotian Shelf); middle line refers to U. tenuis (Scotian Shelf); lower line refers to U. tenuis (Gulf of St. Lawrence).

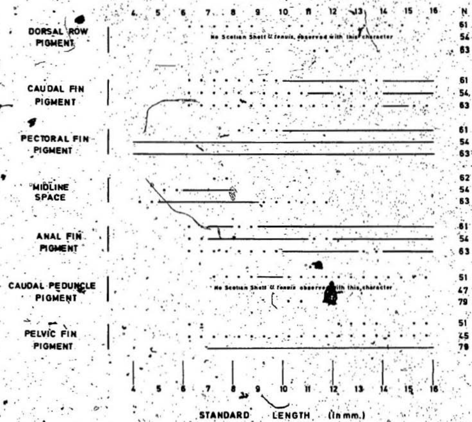

N
DORSAL ROW PIGMENT
No Scotian Shelf α tenuis observed with this character
CAUDAL FIN PIGMENT
PECTORAL FIN PIGMENT
MIDLINE SPACE
ANAL FIN PIGMENT
CAUDAL PEDUNCLE PIGMENT
No Scotian Shelf α tenuis observed with this character
PELVIC FIN PIGMENT
61 54 63
61 54 63
61 54 63
62 54 63
61 54 63
51 47 79
51 45 79
4 5 6 7 8 9 10 11 12 13 14 15 16
STANDARD LENGTH (in mm.)

FIGURE 11. Larval *Urophycis chuss*. Standard lengths are in millimeters.

Urophycis chuss

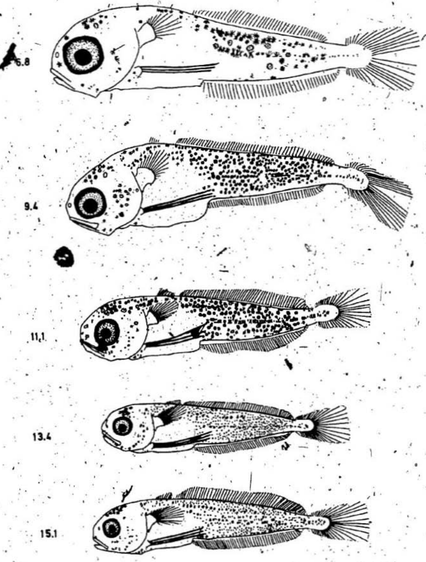


FIGURE 12. Larval Urophycis tenuis. Standard lengths are in millimeters.

Urophycis tenuis

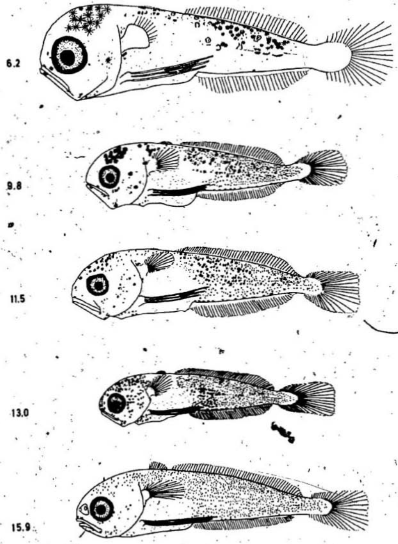


FIGURE 13. Chart of Passamaquoddy Bay, New Brunswick. Scallop collection sites are indicated by diagonal hatching.

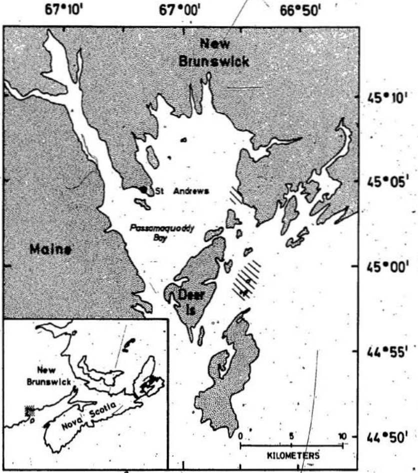

67°10'
67°00'
66°50'
New Brunswick
45°10'
45°05'
45°00'
44°55'
44°50'
St Andrews
Passamaquoddy Bay
Maine
Deer Is
New Brunswick
Nova Scotia
0
5
10
KILOMETERS

FIGURE 14. Map of eastern Newfoundland indicating collection sites.

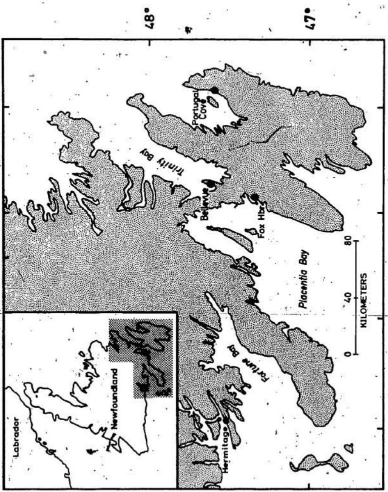

48°
47°
53°
54°
55°
56°
Trinity Bay
Portugal Cove
Bellevue
Fox Hbr
Placentia Bay
Fortune Bay
Hermitage
0
40
80
KILOMETERS
Labrador
Newfoundland

FIGURE 15. Length frequency of inquiline U. chuss from Passamaquoddy Bay and vicinity (A) and Scotian Shelf (B). Diagonal hatching indicate number of newly demersal inquiline U. chuss.

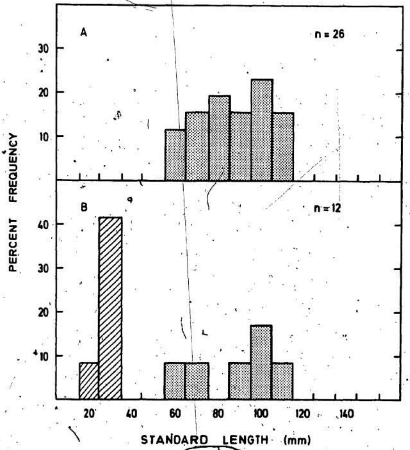

A
n = 26
B
n = 12
30
20
10
40
30
20
10
PERCENT FREQUENCY
20
40
60
80
100
120
140
STANDARD LENGTH (mm)

FIGURE 16. An anterior-posterior ground 1.1 mm sagitta, removed from a 40-day-old U. chuss. Bars indicate daily increments.

FIGURE 17. Mean daily increments at length data for pelagic Scotian Shelf U. chuss. DI = daily increments.

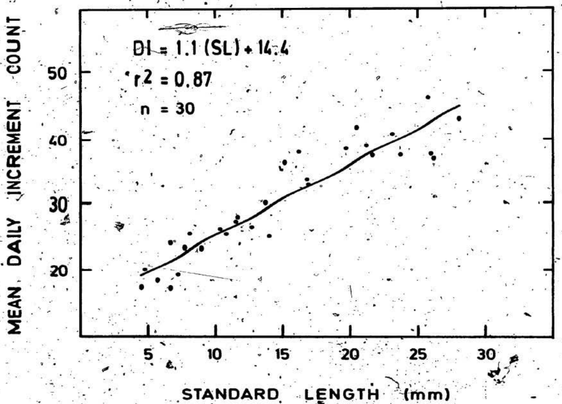

DI = 1.1 (SL) + 14.4
r2 = 0.87
n = 30
MEAN DAILY INCREMENT COUNT
50
40
30
20
5
10
15
20
25
30
STANDARD LENGTH (mm)

FIGURE 18. Mean number of total otolith increments related to standard lehgth for Scotian Shelf pelagic U. chuss. TI = total increments.

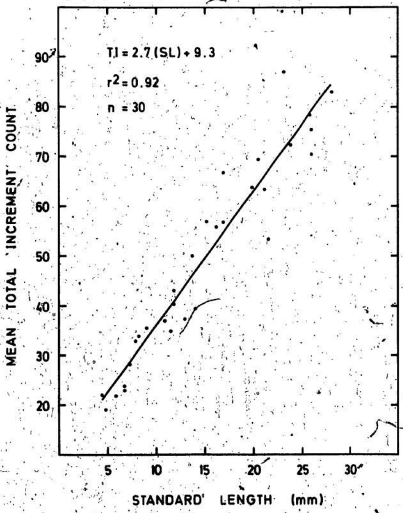
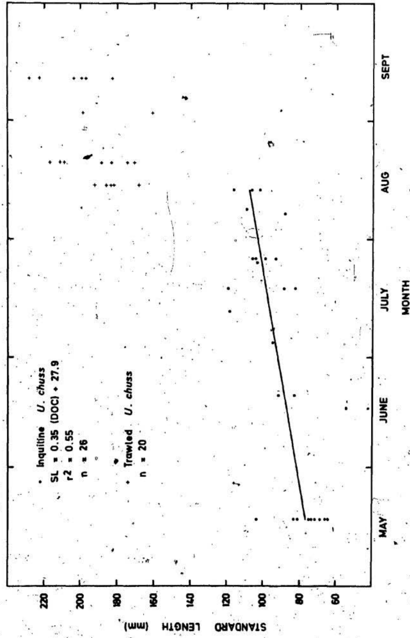

TI = 2.7 (SL) + 9.3
r2 = 0.92
n = 30
MEAN TOTAL INCREMENT COUNT
90
80
70
60
50
40
30
20
5
10
15
20
25
30
STANDARD LENGTH (mm)

FIGURE 19. Lengths of Passamaquoddy Bay, NB., *U. chuss* collected May to September, 1981. DOC = julian date of capture.



• Inquiline U. chuss
SL = 0.35 (DOC) + 27.9
r2 = 0.55
n = 26
+ Trawled U. chuss
n = 20
STANDARD LENGTH (mm)
220
200
180
160
140
120
100
80
60
MAY
JUNE
JULY
AUG
SEPT
MONTH

FIGURE 20. Lengths of Passamaquoddy Bay, NB. *U. tenuis* collected June to November, 1981. The regression line is calculated for *U. tenuis* < 250 mm SL. Diagonal lines on the X axis represent estimated spawning time with 95% confidence limits around the regression. DOC = julian date of capture.

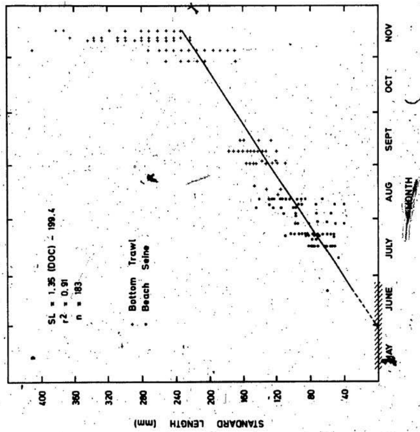

SL = 1.35 (DOC) - 199.4
r2 = 0.91
n = 183
Bottom Trawl
Beach Seine
STANDARD LENGTH (mm)
400
360
320
280
240
200
160
120
80
40
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
MONTH

FIGURE 21. Lengths of Bellevue, Trinity Bay, Newfoundland *U. tenuis* collected July - October, 1982.

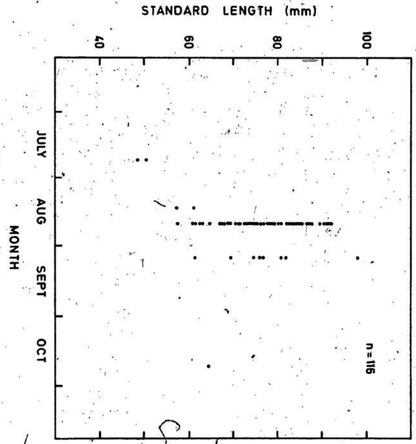

STANDARD LENGTH (mm)
40
60
80
100
JULY
AUG
SEPT
OCT
MONTH
n = 116

FIGURE 22. Lengths of laboratory reared U. tenuis July to September, 1981. DOC = julian date of capture.

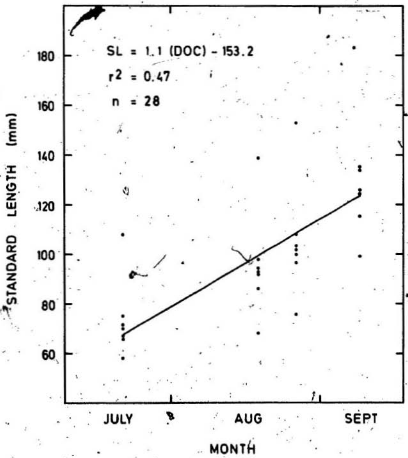

SL = 1.1 (DOC) - 153.2
r^2 = 0.47
n = 28
STANDARD LENGTH (mm)
180
160
140
120
100
80
60
JULY
AUG
SEPT
MONTH

FIGURE 23. Length frequency of scallops collected from Passamaquoddy Bay and vicinity (A) and length frequency of scallops harboring <u>U. chuss</u> (B).

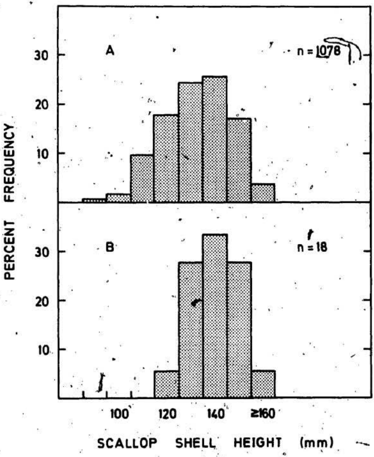

A
n = 1078
B
n = 18
PERCENT FREQUENCY
30
20
10
100
120
140
≥160
SCALLOP SHELL HEIGHT (mm)

FIGURE 24. Length frequency of scallops collected from the Scotian Shelf (A) by R/V LADY HAMMOND cruises 40 and 64 and length frequency of scallops harboring U. chuss (B).

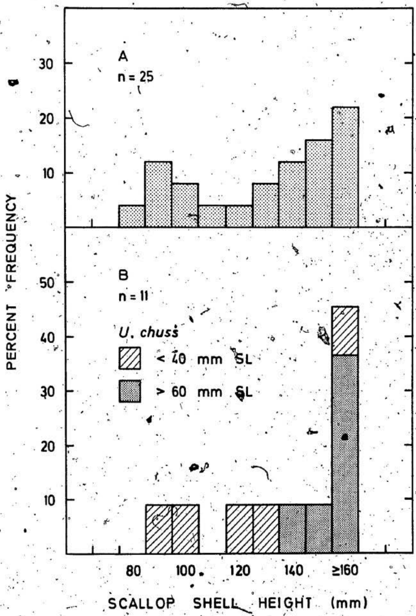

A
n = 25
B
n = 11
U. chuss
< 40 mm SL
> 60 mm SL
PERCENT FREQUENCY
30
20
10
50
40
30
20
10
80
100
120
140
≥160
SCALLOP SHELL HEIGHT (mm)

FIGURE 25. Index of stomach fullness (+ 1 sd.) for inquiline (SCUBA) and bottom trawled U. chuss from Passamaquoddy Bay. Numbers indicate sample size at each time interval.

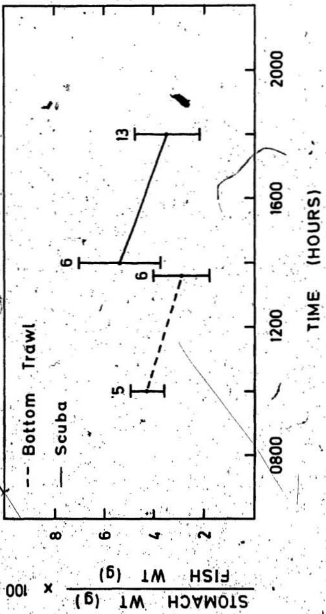

-- Bottom Trawl
— Scuba
STOMACH WT (g) / FISH WT (g) x 100
TIME (HOURS)
0800
1200
1600
2000
2
4
6
8
5
6
6
13

FIGURE 26. Mean monthly nearshore surface water temperatures at Bellevue, Nfld. and St. Andrews, NB. Dashed lines represent data from this study. Solid lines represent data from Ledrew (1972) for Bellevue and Lauzier and Hull (1969) for St. Andrews. Shading represents months when U. tenuis were seined at each site.

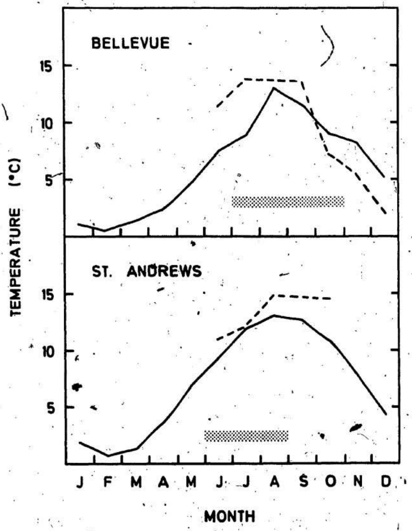

BELLEVUE
ST. ANDREWS
15
10
5
15
10
5
TEMPERATURE (°C)
J F M A M J J A S O N D
MONTH

FIGURE 27. Diel differences in 24 hour beach seine collections of *U. tenuis* collected at Bellevue, Trinity Bay (TB), and St. Andrews, Passamaquoddy Bay (PB). Stippled area represents hours of darkness. "H" and "L" are high and low tides.

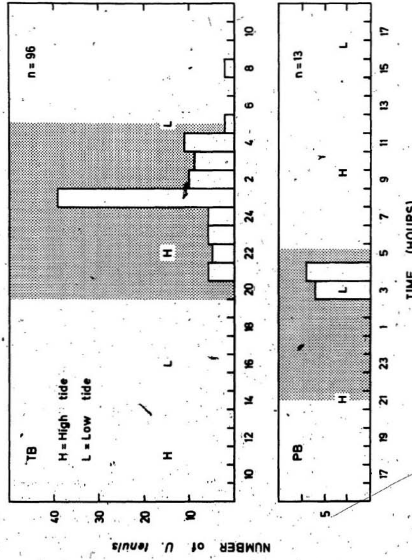
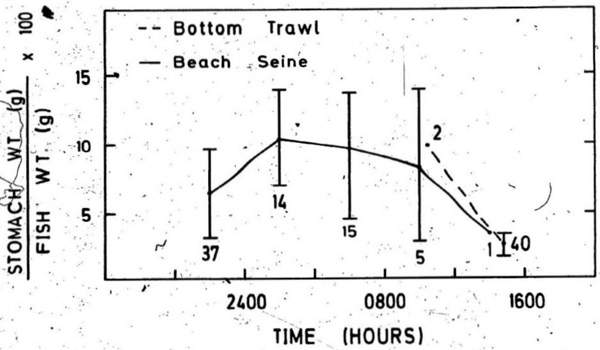

TB
H = High tide
L = Low tide
n = 96
PB
n = 13
TIME (HOURS)
NUMBER of U. tenuis

FIGURE 28. Index of stomach fullness (± 1 sd.) for seined and trawled *U. tenuis* from Passamaquoddy Bay. Numbers indicate sample size at each time interval.


-- Bottom Trawl
— Beach Seine
STOMACH WT (g) / FISH WT (g) x 100
15
10
5
37
14
15
5
2
1
40
2400
0800
1600
TIME (HOURS)