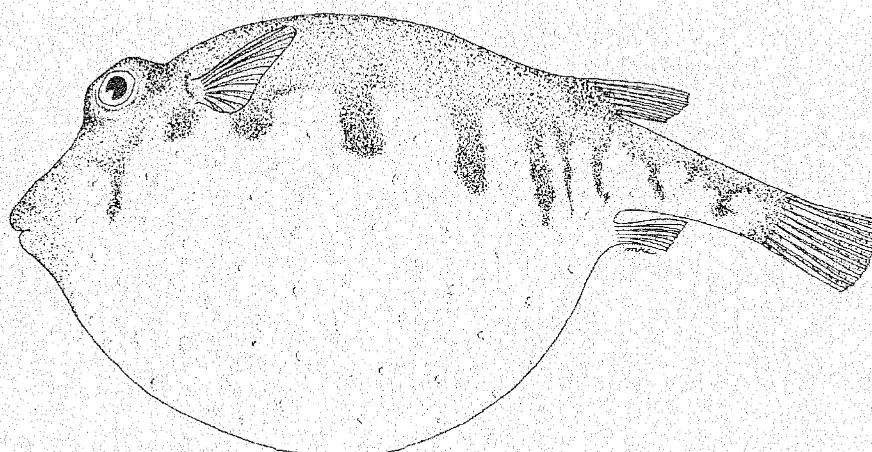

BIOLOGICAL & FISHERIES DATA

ON

NORTHERN PUFFER, *Sphoeroides maculatus*

(Bloch & Schneider)

FEBRUARY 1981

Biological and Fisheries Data

on

northern puffer, *Sphoeroides maculatus* (Bloch and Schneider)

by

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1. IDENTITY

1.1 Nomenclature

1.1.1 Valid Name

Sphoeroides maculatus (Bloch and Schneider).

Etymology: The generic name is derived from the Greek words σφαιρος meaning sphere and ειδος meaning resemblance. It is based on the front view of the fish. The specific name, maculatus, is Latin, meaning spotted (Jordan and Evermann, 1896).

1.1.2 Objective Synonymy (based on Shipp, 1974)

Tetrodon hispidus Schöpf, 1787

Tetrodon hispidus var. maculatus Bloch and Schneider, 1801

Tetrodon turgidus Mitchill, 1815

Stenometopus binummulatus (Bibron) Troschel, 1856

Gastrophysus turgidus Gill, 1873

Chilichthyes turgidus Yarrow, 1877

Cirrisomus turgidus Jordan and Gilbert, 1878

Spheroides maculatus Jordan and Edwards, 1886

Orbidus maculatus Moore, 1894[1]

Tetradon maculatus Nichols and Breder, 1927[2]

Tetrodon maculatus Truitt, Bean and Fowler, 1929

Sphoeroides maculatus Jordan, Evermann and Clark, 1930

Sphaeroides maculatus Fraser-Brunner, 1943

Tetrodon punctatus LeDanois, 1959

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[1]Correction in date from 1892 to 1894

[2]Correction in date from 1929 to 1927

1.2 Taxonomy

1.2.1 Affinities (based on Berg, 1965; Greenwood et al., 1966; and Bailey et al., 1970)

Phylum: Vertebrata
- Subphylum: Craniata
  - Superclass: Gnathostomata
    - Series: Pisces
      - Class: Osteichthyes
        - Subclass: Actinopterygii
          - (Group): (Teleostei)
            - Division: Euteleostei
              - Superorder: Acanthopterygii
                - Order: Tetraodoniformes
                  - Suborder: Tetraodontoidei
                    - Family: Tetraodontidae

Generic - Sphoeroides Anonymous, 1798

The generic description given by Jordan and Evermann (1896) is: "Body oblong, not elongate; skin variously prickly or smooth, sometimes with cirri. A single, short, simple nasal tube on each side, with 2 rather large openings near its tip. Dorsal and anal fins short, little falcate, at 6 to 8 rays each; caudal truncate or rounded, rarely slightly concave. Vertebrae 8+10=18. Frontal bones expanded sidewise and forming the lateral roof of the orbit, the postfrontals limited to the posterior portion."

Type - "The type of Sphoeroides maculatus has not been located and it is possible that none was ever designated, since Bloch's original description was after Schöpf. None exists among Bloch's other types in the Institute für Spezielle Zoologie und Zoologisches Museum, Berlin (K. Deckertipers, Comm.). The type locality (Long Island) and Bloch's description leave no reasonable doubt as to the identity of the species. Therefore, we designate the following specimen as the neotype: UF 12303, 146 mm SL, collected 3.2 miles north of Northport, Suffolk County, New York, July 1958." (Shipp and Yerger, 1969). Illustrations of a northern puffer are shown in Figure 1.

Specific - Sphoeroides maculatus (Bloch and Schneider, 1801)

The following species description is taken from Shipp (1974). (References to figures and tables from the original text have been omitted.) "Head 2.7 to 3 in SL in adults, longer in subadults. Snout 1.7 to 2.1 in head, longest in adults. Eye 4 to 8 in head, but most often large, about 5 in head. Least bony interorbit flat to slightly concave, moderately broad, 2.5 to 4 in snout, usually about 3.3 in snout, about 6.5 in head. Interorbits of adults average slightly broader than in juveniles. Dorsal slightly shorter than snout, usually 1.1 to 1.2 in snout, 2.3 in head, anal a little shorter, 1.2 to 1.5 in snout, 2.6 in head. Dorsal fin origin opposite posterior edge of anal opening, slightly

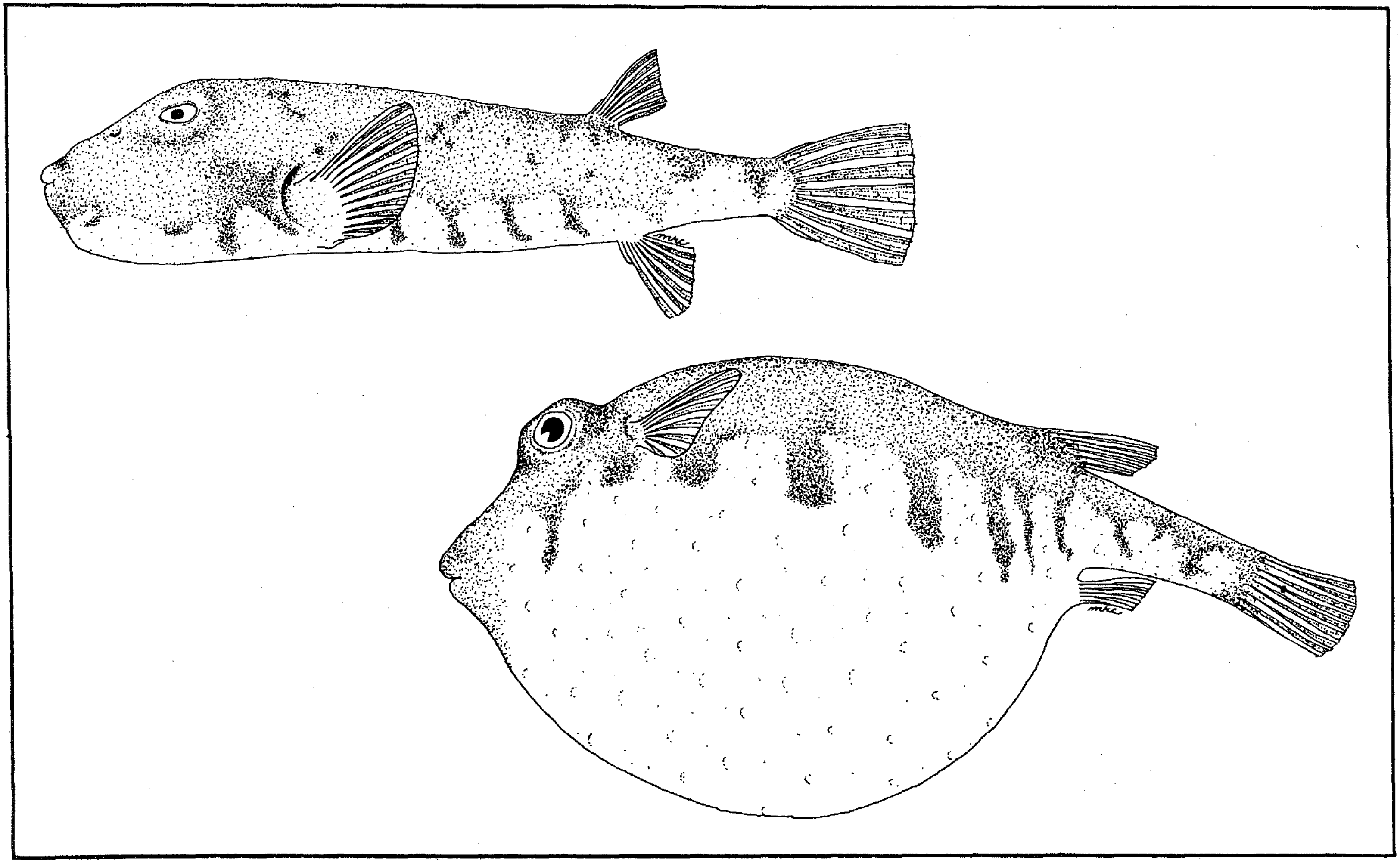

Figure 1. Adult northern puffer, Sphoeroides maculatus (illustrations by M. Cox).

anterior to anal fin origin. Caudal truncate or slightly rounded but often with the uppermost rays longest. Length of exposed medial caudal rays about equal to snout length, about 2 in head. Pectoral fins moderately long, about 1.3 in snout, 2.5 in head. Dorsal rays 8, anal rays 7, pectoral rays usually 15 or 16 (rarely 17). Caudal rays 11, with the first upper and two lower rays usually unbranched."

"Pigmentation restricted to dorsolateral surfaces. Basal pigmentation is usually gray, which fades laterally. Poorly defined black spots cover the dorsal surfaces, and a vague dark bar traverses the interorbital region. A vague dark saddle extends transversely across the dorsum and passes through the base of the dorsal fin. Another similar saddle is present across the dorsal area of the caudal peduncle. Tiny jet-black pepper spots (about 1 mm in diameter) are scattered over most of the pigmented surface, and are especially evident on the cheeks.... The flanks posterior to the pectoral fins are marked with 5-7 bars or elongate spots, usually vertical but occasionally slightly diagonal. These extend from the basal pigmentation of the dorsum to the lower margin of the flank, which lacks basal pigmentation. An intense black spot or bar is present at the posterior axil of the pectoral fin.... Distinct bars or spots are usually absent on the flanks anterior to the pectorals. The base and distal half of the caudal may be dusky with a lighter central region, but often the entire caudal may appear uniformly dusky. The other fins are nearly devoid of pigment."

"Lappets are never present. All body surfaces anterior to the anus or anal fin origin and dorsal origin are densely covered with strong, close-set prickles except around the mouth..." (Figure 2). "Almost the entire body is covered with small, slightly imbricate dermal structures..." which resemble fish scales.

The following key to the genus Sphoeroides of the Atlantic Ocean is from Shipp (1974). The figure and references from the original text have been omitted.

A. Body entirely smooth, prickles totally lacking. Interorbit broad, usually 8% or more of standard length. Pigmentation mostly uniform, except usually a few dark spots on the flanks..... S. pachygaster (Müller and Troschel)

AA. Body usually with prickles (prickles often not exposed, but present beneath tiny pores in the integument). Interorbit of moderate to narrow width, usually 8% or less of standard length. If prickles absent, interorbit concave, narrow, 5%, or less of standard length. Pigmentation variously mottled.......................................B

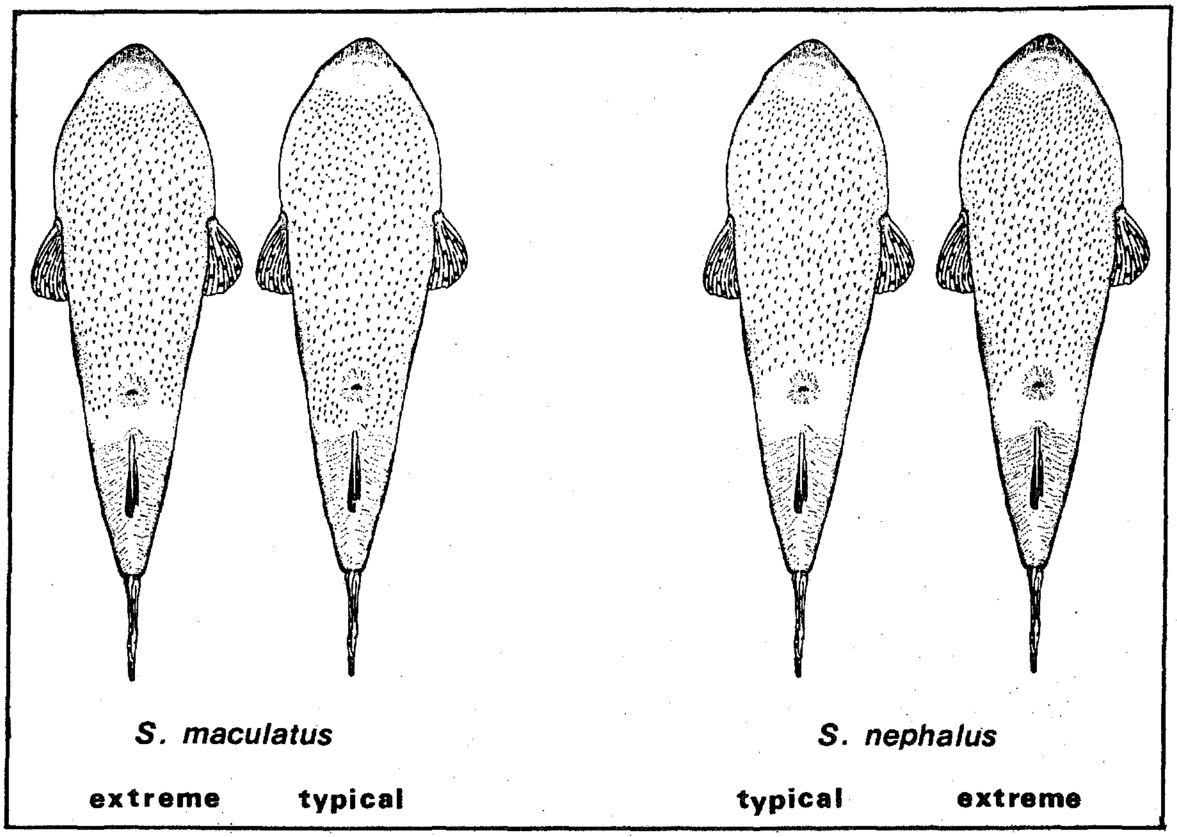

Figure 2. Distribution of prickles on the ventral surface of *Sphoeroides maculatus* and *S. nephalus*. Note posterior extent in relation to anal opening (from Shipp and Yerger, 1969).

B. Lappets (small fleshy tabs most easily seen when specimens are immersed in fluid) present on dorsal and/or lateral surfaces; sometimes only a single black pair on the dorsum about one-half the distance between the posterior margins of the orbits and the dorsal fin origin, and/or scattered light tan lappets concentrated near the posterolateral body margin......................C

BB. Lappets absent...H

C. A single pair of black lappets present on the dorsum. No lappets on posterolateral body surface. Cheeks marbled in subadult and adult males. From 1 to 5 diffuse dark blotches present on the lateral body surface posterior to the pectoral fin.....S. dorsalis Longley

CC. Black dorsal pair of lappets present or absent, light or tan lappets present on posterolateral portions of the body. Cheeks variously pigmented but not marbled..............................D

D. Lappets present as a black pair on the dorsum and light or tan lappets on posterolateral portions of body. One to three distinct dark blotches beneath eyes. Usually four distinct dark spots form the lower cheek margin, and four to six more such spots on the ventrolateral body angle form a row posterior to the pectoral fin, the more posterior ones less distinct.....S. marmoratus (Lowe)

DD. No black dorsal pair of lappets present. No dark blotches beneath eyes. Lower cheek, and ventrolateral body margin with or without marginal spots.....................................E

E. Lower lateral surfaces lacking pigment except for many tiny black flecks or speckles. Least bony interorbit narrow, about 5 or more in snout, pectoral rays usually 14, rarely 13 or 15.....S. yergi Shipp

EE. Lower lateral surface marked with blotches or spots, not with tiny black flecks or speckles. Least bony interorbit either broad, less than 5 in snout, or if narrow, pectoral rays usually 16 (rarely 15).................F

F. Pectoral rays 15 or 16. Lower cheek with three or four vague diagonal blotches, not evident in poorly preserved specimens.....S. tyleri Shipp

FF. Pectoral rays 13 to 15. Lower cheek with a row of four to six very distinct spots, or with many discrete spots of various shapes, but not with three or four vague diagonal blotches..G

G. Lower margin of lateral surface bounded by a regular series of distinct, uniform, rounded spots, four to six anterior and seven to nine posterior to the pectoral fin. Caudal fin with dark, sharply defined proximal and distal bars.....S. spengleri (Bloch)

GG. Lower margin of lateral surface with many broken blotches or spots, irregularly placed and shaped. Caudal fin with a poorly defined, vaguely barred pattern.....S. greeleyi Gilbert

H. One or two distinct, transverse, white interorbital bars, the posterior one often connected by a posterior perpendicular extension to a dorsal pattern of coarse white arches and circular markings.....S. testudineus Linnaeus

HH. Vague, dark interorbital bar. Dorsal pattern variously mottled, but not with coarse white arches and circular markings.......................I

I. Several (usually 6-8) distinct, vertically elongate bars posterior to pectoral fins. Dorsal and lateral surfaces in mature specimens (above 70 mm) covered with tiny (to 1 mm) jet black spots. Prickles on ventral surface extend posteriorly beyond the anus, usually to the anal fin origin. Pectoral rays 15-17, usually 16.....S. maculatus (Bloch and Schneider)

II. Lateral markings posterior to pectoral fins varied, but not distinct, vertically elongate bars. No tiny (to 1 mm) jet black spots over dorsal and lateral surfaces, except rarely a few beneath the eye. Prickles on ventral surface, if present, do not extend beyond the anus. Pectoral rays 13-17................J

J. Spot at axil of pectoral fin more intense than any other spots on body. Bony interorbit usually concave; least bony width narrow, more than 4 in snout. Adults often marked with discrete white (or green in fresh or live specimens) reticulate, vermiculate or circular markings.....S. nephelus (Goode and Bean)

JJ. Spot at axil of pectoral fin absent, or if present rarely more intense than any other spots on body. Body interorbit nearly flat, least bony width moderate, less than 4 in snout. Adults with diffuse, indiscrete white (or green in fresh or live specimens) markings, or no such markings at all..........................K

K. Pectoral rays 16, rarely 15 or 17. Prickles on dorsum present only in a narrow strip from nape to the level of the posterior margin of the pecotral fin. Prickles never present on cheeks or lateral surface......S. georgemilleri Shipp

KK. Pectoral rays 14 or 15 (rarely 13 or 16). Prickles on dorsum extend posteriorly from the nape (or anterior to nape) to dorsal fin origin, and often present on cheeks or on lateral surfaces posterior to pectoral fin........L

L. Snout and head extensively covered with prickles, which extend anteriorly on the snout to at least between the nasal papillae.....S. parvus Shipp and Yerger

LL. Prickles present on the head only on the interorbit, and posteriorly to the origin of the dorsal fin, not present anteriorly to between the nasal papillae. Individuals of S. greeleyi from some population of the Central American and southern Brazilian coast may rarely lack lappets and key here; see also GG.....S. greeleyi Gilbert

1.2.2 Taxonomic Status

Morpho-species.

1.2.3 Subspecies

None

1.2.4 Standard Common Names, Vernacular Names

Balloonfish, bellowsfish, blowfish, blower, bottlefish, globefish, northern puffer, puffer, rabbitfish, sea squab (market name), swell belly, and swell toad.

1.3 Morphology

1.3.1 External Morphology

See section 1.2.1 and Figure 1.

1.3.2 Cytomorphology

No information found.

1.3.3 Protein Specificity

No information found.

2. DISTRIBUTION

2.1 Total Area

Puffers are abundant on the Atlantic coast of the United States from Cape Cod, Massachusetts to northern Florida. The extent of their nearshore range is from southern Newfoundland to Flagler County, Florida. Offshore populations may extend south to latitude 27°30'N (Bigelow and Schroeder, 1953; Leim and Day, 1959; Shipp, 1974).

2.2 Differential Distribution

2.2.1 Spawn, Larvae, and Juveniles

Puffers spawn throughout their range of abundance in shoal water, close to shore. The eggs are demersal and have an adhesive covering, causing them to stick to each other or to submerged objects (Welsh and Breder, 1922).

The larvae are pelagic; no information was found concerning their distribution.

Juvenile puffers are semidemersal and inhabit the intertidal zone over smooth bottom (Merriman, 1947).

2.2.2 Adults

The adults are coastal fishes found from the tide line in estuaries to a depth of only a few fathoms offshore (Bigelow and Welsh, 1925). Where the range of the northern puffer overlaps that of the southern puffer (S. nephalus) off northeastern Florida, the former is found in open and deeper waters and the latter inhabit estuaries (Shipp and Yerger, 1969). Northern puffers are considered demersal, however, they are known to actively move throughout the water column (Nichols and Breder, 1927; Schwartz, 1964). They prefer sandy substrate, near to or amid sea wrack, but are also found over silt, mud, shell or gravel bottom (Nichols and Breder, 1927; deSylva et al., 1962; Freeman and Walford, 1974).

2.3 Determinants of Distribution

Temperature is an important factor in the distribution of puffers. The northern puffer is a temperate species, and in the northern part of its range, belongs to that group known as "summer fish". They are found in Chesapeake Bay from about April to November, and off southern New England from about early May to late October. With the onset of winter and colder water temperatures, they migrate to deeper water offshore and remain in a quiescent state on the bottom (Bigelow and Schroeder, 1953). Dovel (1971) reports that larval and juvenile puffers inhabit water temperatures from 16 to 26°C. The adults are found in temperatures ranging from 10.0 to 34.1°C (Tagatz, 1967; Richards and Castagna, 1970). They are found in salinities normal to a coastal and estuarine environment. The results of a survey made by Dovel (1971) show both larval and juvenile puffers occur in a salinity range of 12 to 21 o/oo. Richards and Castagna (1970) found juveniles at salinities up to 32.2 o/oo. The salinity range for adult fish is 6.7 to 34 o/oo (Tagatz and Dudley, 1961; Tagatz, 1967).

2.4 Hybridization

Although the ranges of the northern puffer and the southern puffer coincide off northeastern Florida, no specimens have been caught in this area to indicate hybridization occurs between the species (Shipp and Yerger, 1969).

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality

The sexes are separate.

3.1.2 Maturity

Both sexes of puffers are sexually mature by their second growing season (i.e. age 1). Individuals as small as 88 mm are capable of spawning (Laroche and Davis, 1973).

3.1.3 Mating

Little is known about the breeding habits of the northern puffer, but they are probably polygamous and promiscuous.

3.1.4 Fertilization

Egg fertilization is external.

3.1.5 Gonads

The two gonads of a gravid puffer are dissimilar in that the left gonad is considerably larger than the right (Welsh and Breder, 1922). The left ovary of a ripe female is 1.2 to 2.0 times larger and 1.6 times heavier than the right. However, a fecundity estimate can be made from either a single or a combined ovarian sample as the eggs from both left and right ovaries are similar in size, ranging 0.35 to 0.7 mm in diameter (Figure 3). This size range is conservative as the ovaries used in the study were treated with Gilson's fluid which causes egg shrinkage (Merriman and Laroche, 1977). No information was found describing the size difference for the male gonads.

The fecundity of the puffer was first reported by Hildebrand and Schroeder (1928). They estimated the ovaries of a 265 mm fish contained 176,000 eggs of similar size. A subsequent study by Merriman and Laroche (1977) showed this to be low by about 273,000 eggs (Table 1). The total fecundity increases both as a linear function of fish weight (fecundity = -735.28 + 754.21 body weight in grams, the coefficient of determination $r^2 = 0.86$) and as a function of total length (Figure 4). The average relative fecundity is 5,204 eggs per gram ovarian net weight and 751 eggs per gram body weight. The amount of ovarian tissue when compared to the total body weight ranges from 6.3 to 19.2% with an average of 13.8%.

3.1.6 Spawning

The spawning season is protracted, beginning in late spring in the Chesapeake and progressing northward throughout the entire summer and early fall. No information was found on spawning time south of Cape Hatteras.

Mating has not been observed, but puffers probably spawn during daylight hours, as they are known to be quiescent and lie on the bottom at night (Schwartz, 1964; Wicklund, 1970). A pair of northern puffers spawned while in captivity. The eggs were deposited in the sand, partially buried in a circular pattern with a diameter about equal to the length of the fish. There was no evidence of parental care for the eggs (Breder and Clark, 1947).

The number of times puffers spawn during a spawning season is not known, but males may spawn more than once as they are ripe longer than females. Differences in sex ratio on the spawning grounds, which may be attributed to reproductive behavior, also indicates male spawn more than once. In both May and November, the ratio of males to females is 1:1. However, during the summer and early fall spawning season, this ratio changes to 1:3. When spawning peaks in June and July, males are least abundant (Laroche and Davis, 1973).

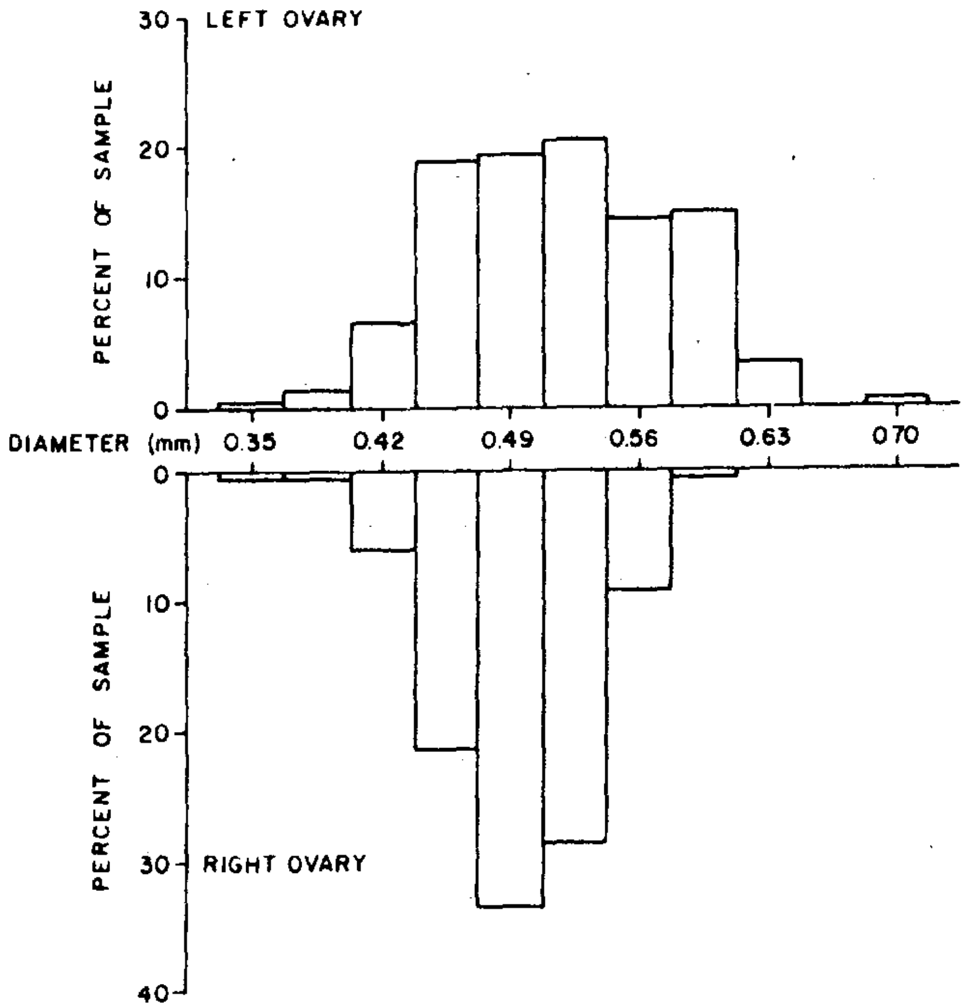

Figure 3. Size composition of northern puffer eggs from six ovaries in gravid condition (from Merriner and Laroche, 1977).

Table 1. Length, weight, ovary weight, and fecundity data for northern puffer from Chesapeake Bay, 1970 (modified from Merriner and LaRoche, 1977).

Total Length (mm)	Weight (gm)	Left Ovary (gm)	Right Ovary (gm)	Total Fecundity (10^3)	Eggs/gm Body (10^2)	Eggs/gm Ovary (10^2)
139	68	6.3	4.7	62.0	9	56
148	73	2.7	1.9	78.0	11	169
149	87	6.6	5.2	40.4	5	34
155	98	5.6	4.5	44.6	5	44
162	99	4.3	3.1	59.8	6	81
169	110	10.4	5.0	84.8	8	55
172	132	10.6	9.1	72.6	6	37
184	130	9.1	6.0	100.8	8	67
198	154	11.7	7.5	124.6	8	65
198	182	12.7	7.6	143.4	8	71
214	214	18.6	10.2	154.0	7	53
220	207	17.6	10.3	176.0	8	63
226	309	39.3	20.0	236.0	8	40
229	282	23.0	13.0	236.6	8	66
234	278	22.2	14.1	142.6	5	39
235	312	36.8	21.0	232.4	7	40
236	304	28.2	20.0	227.6	7	47
237	270	33.3	20.2	293.2	11	55
259	388	32.9	17.6	240.8	6	48
260	495	37.3	23.8	383.8	8	63
264	463	42.1	25.9	368.2	8	54
265	464	45.3	33.6	449.2	10	57
270	450	43.3	26.0	334.2	7	48
282	501	37.3	28.9	274.8	5	42

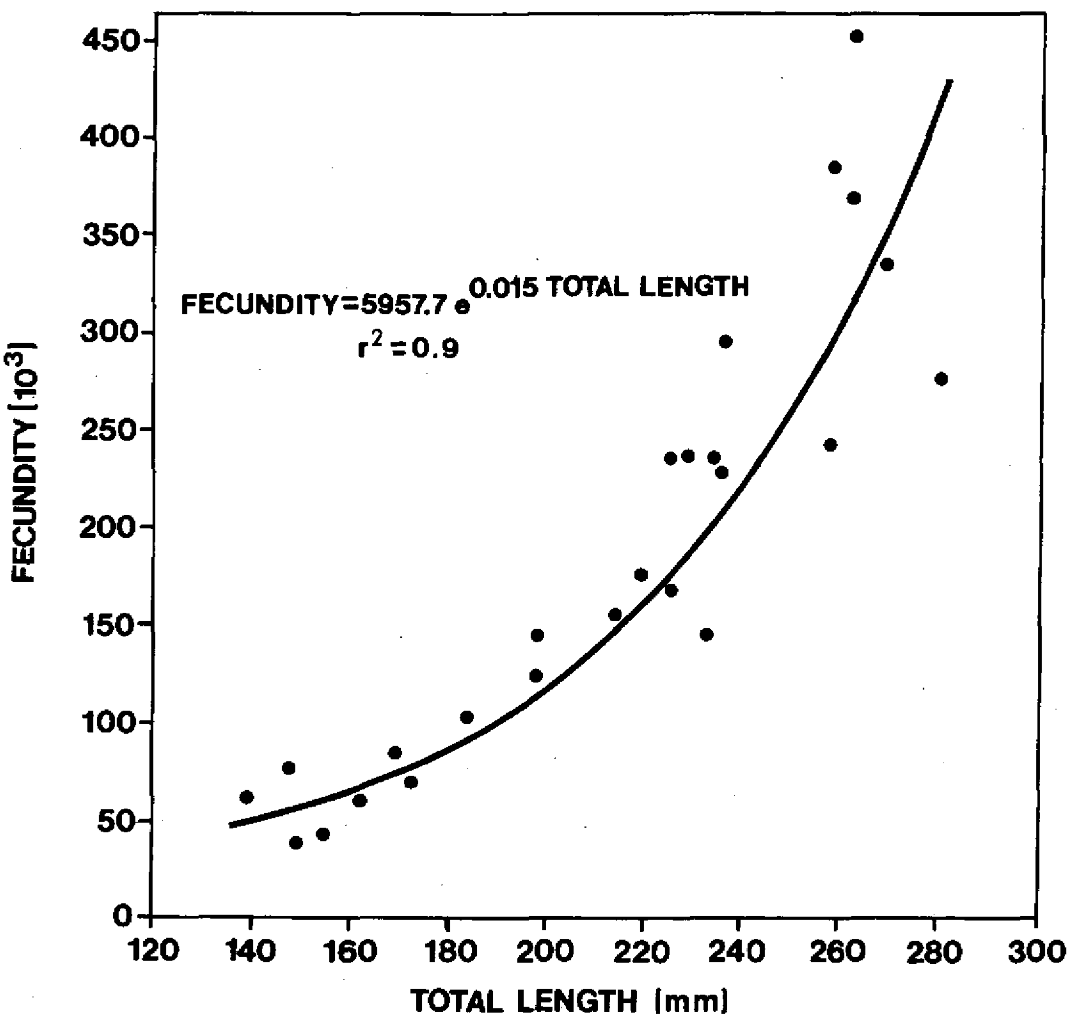

Figure 4. Total fecundity-total length relationship for northern puffer (from Merriner and Laroche, 1977).

3.1.7 Spawn

The following description of the eggs is based on reared samples (Welsh and Breder, 1922):

"The eggs are transparent, spherical, and invested with a smooth adhesive covering which is irregular in outline. They are demersal and readily become attached to any submerged object, or caked in a mass, owing to their adhesive nature. Where numbers adhere to a side of the container, close together and in a single layer, the adhesive envelope assumes a somewhat hexagonal appearance. The surfaces of the eggs are finely reticulated, rather resembling crepe paper. The eggs average about 0.874 mm. in diameter, varying from .85 to .91 mm., while the enveloping adhesive coat increases the diameter to an average of about .954 mm. A large number of colorless oil globules of low refractive index are present in a foamy cluster, which averages about .34 mm. in diameter, and a very faint yellowish olive tinge can be detected in the area in which the blastoderm is to develop." Illustrations of various egg stages are shown in Figure 5.

3.2 Pre-Adult Phase

3.2.1 Embryonic Phase

The incubation period for puffer eggs is 112 hours at a water temperature of about 20°C. Two hours following fertilization, first cleavage is complete, and by 16 hours, the germ ring begins to form. At 24 hours, the embryo is distinct, and by hour 44 it is more than half way around the yolk. At 70 hours, vertebral somites are visible and scattered black chromatophores appear along each side of the embryo. The eyes are now distinct, the tail tip is free and the oil globules are located in the dorsal part of the yolk. At 90 hours, red and orange chromatophores appear along each side in addition to those of black already present. Several small black chromatophores are present on the tip of the snout and in the posterior portion of the iris. Numerous large black dendritic chromatophores are on the ventral surface of the yolk. The oil globules have combined in a few large droplets. Just prior to hatching the embryo increases in pigment content. The pigmentation extends posteriorly and ends abruptly midway between the vent and the tip of the notochord. Where the pigmentation terminates, a brilliant opaque chrome yellow spot appears on the dorsal surface of either the embryo or the newly hatched larva (Figure 5) (Welsh and Breder, 1922).

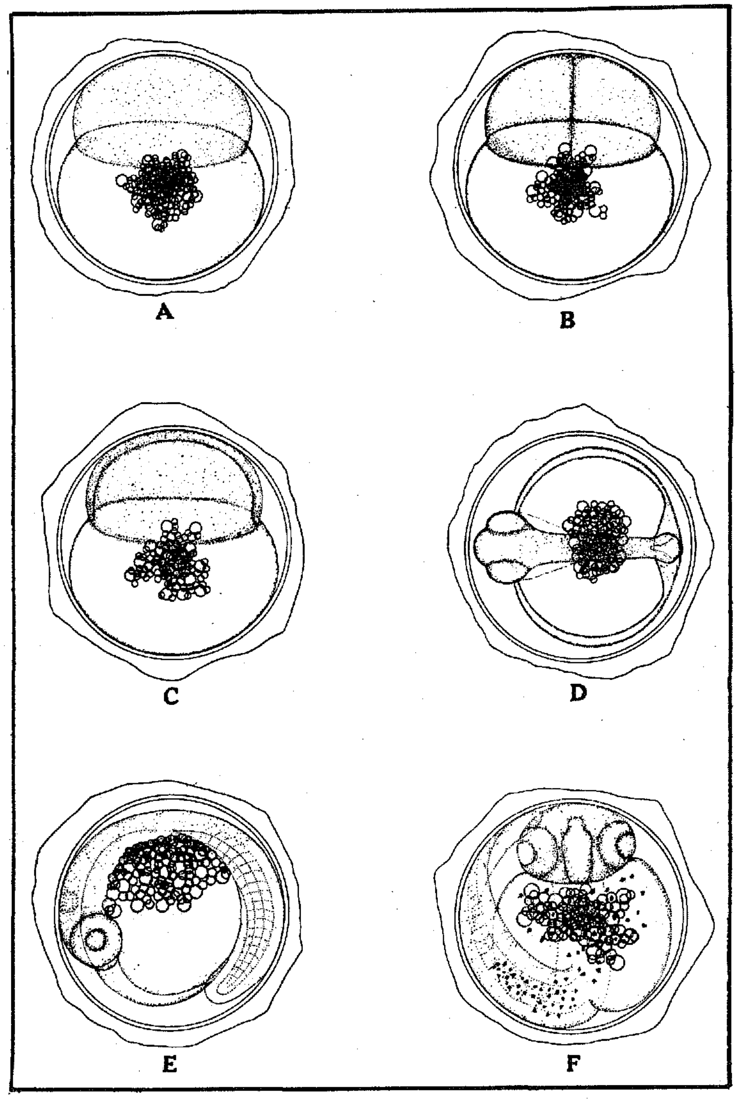

Figure 5. Northern puffer eggs. A. unfertilized egg; B. egg with blastoderm of two cells; C. egg showing early stage in the differentiation of the embryo (16½ hours after fertilization); D. egg showing a moderately advanced stage of differentiation of the embryo (40 hours after fertilization); E. egg with moderately advanced embryo (70 hours after fertilization); F. egg with advanced embryo (90 hours after fertilization) (from Welsh and Breder, 1922).

3.2.2 Larval Phase

Most larvae hatch tail first and are about 2.4 mm long. The small yolk sac still contains oil globules. Pigmentation on the body consists of many brilliant red, orange, yellow, and black chromatophores. Numerous small tubercles are present over most of the body. Twenty-four hours after hatching the nostrils are visible, the lateral line organs being to appear, the pectorals are distinct and the eye pupil is black. At 48 hours the yolk material is reduced, the mouth and vent are open and green pigmentation appears, particularly in the iris. After 72 hours the mouth is functioning. When the larvae are 7 mm long, they possess many diagnostic adult characters, and are capable of inflation. They are, however, more thick in stature than adults, have larger eyes, and lack the adult color pattern (Figure 6) (Welsh and Breder, 1922).

3.2.3 Adolescent Phase

The general morphology of juvenile fish as such is similar to that of adults, but there are differences in pigmentation patterns between the two. Young fish lack the dark black "pepper" spots which appear when the individual is from 40 to 100 mm long. The large dark lateral marks on the juveniles become oblong in shape and characterize adult patternization. The development of prickles occurs in individuals as small as 10 mm (Shipp and Yerger, 1969).

3.3 Adult Phase

3.3.1 Longevity

No information found.

3.3.2 Hardiness

Laboratory experiments on the effect of sudden changes of water temperature indicate puffers can withstand the recovery from heat shock better than cold shock (Tables 2 and 3). The upper mean tolerance limit for these fish is 32.5°C for a period of 72 hours, and they cannot withstand temperatures below 8°C (Hoff and Westman, 1966). Results from thermal tests by Gift and Westman (1971) show a mean upper avoidance temperature of 31.1°C (range: 30.6-31.7°C). In comparing these results with the reported temperature range of 10.0 to 34.1°C as found in nature (see section 2.3), there is good agreement with the low temperature. An apparent discrepency exists with the high temperature of 34.1°C reported from field survey data and the laboratory test result of 32.5°C. The difference may be attributed to variation between surface and bottom temperatures. Only surface temperature was reported.

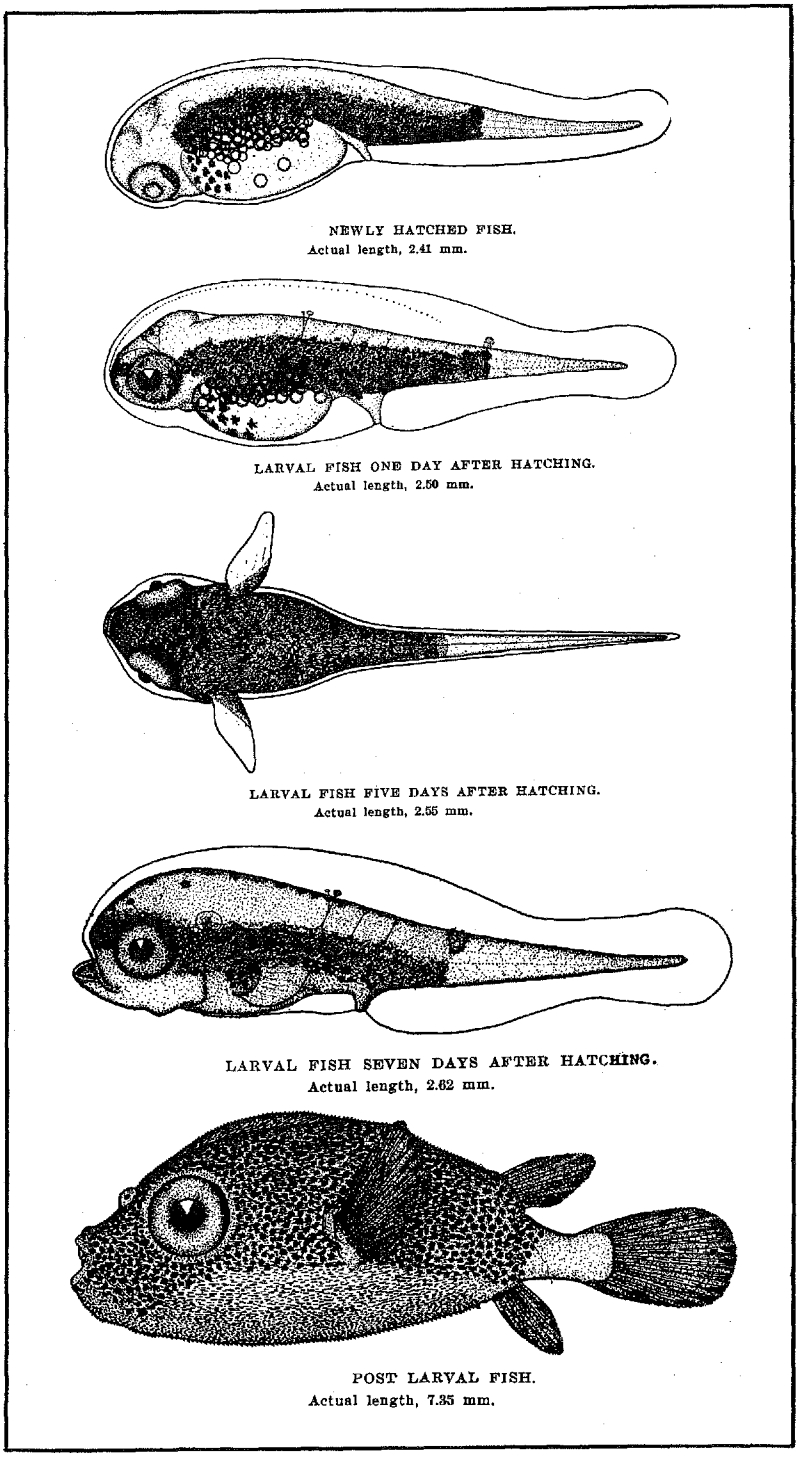

Figure 6. Northern puffer larvae (from Welsh and Breder, 1922).

Table 2. Percent survival of northern puffer at various low temperatures in relation to preceding acclimation temperature (from Hoff and Westman, 1966).

Accl. Temp. (°C)	Test Temp. (°C)	# of Fish	Mean Length (cm)	Mean Weight (g)	Percentage Surviving After 1 hr	3 hr	6 hr	24 hr	48 hr	72 hr	Tlm*
28	16.0	5	15.3	75.8	100	100	100	100	100	100	
28	14.0	10	14.7	72.2	90	90	90	90	80	80	
28	12.0	10	15.9	79.3	80	60	60	40	10	10	
28	10.0	10	14.9	74.0	80	10	00	00	00	00	
					-	11.6	11.7	12.3	13.0	13.0	*
21	12.0	5	14.2	69.7	100	100	100	100	80	80	
21	10.0	10	14.6	74.8	90	70	70	70	50	30	
21	8.0	10	15.6	78.9	50	30	30	20	00	00	
					8.0	9.0	9.0	9.2	10.0	10.7	*
14	10.0	5	13.8	62.3	100	100	100	100	100	100	
14	8.0	10	15.1	72.8	90	80	80	60	40	20	
14	6.0	10	14.6	67.4	60	10	10	00	00	00	
					0	7.1	7.1	7.7	8.4	8.8	*
10	7.5	5	14.2	64.9	100	100	100	80	60	20	

*Tlm refers to the estimated low median tolerance limits.

Table 3. Percent survival of northern puffer at various high temperatures in relation to preceding acclimation temperature (from Hoff and Westman, 1966).

Accl. Temp. (°C)	Test Temp. (°C)	# of Fish	Mean Length (cm)	Mean Weight (g)	Percentage Surviving After 1 hr	3 hr	6 hr	24 hr	48 hr	72 hr	Tlm*
28	31.0	5	14.6	72.4	100	100	100	100	100	80	
28	32.5	10	15.4	76.9	90	80	80	80	60	50	
28	33.5	10	14.7	77.3	90	60	60	40	20	0	
					-	-	-	33.2	33.0	32.5	*
21	30.0	5	15.1	70.3	100	100	100	100	100	100	
21	31.0	10	14.3	70.9	100	80	80	80	60	60	
21	32.0	10	15.6	80.3	100	70	70	50	30	20	
					-	-	-	32.0	31.4	31.2	*
14	27.0	5	14.6	69.0	100	100	100	100	100	100	
14	30.0	5	14.0	62.2	100	80	60	60	60	60	
14	32.0	10	15.3	68.7	80	20	10	0	0	0	
					-	31.0	30.5	30.2	30.2	30.2	*
10	25.0	5	15.3	79.6	100	100	100	100	100	100	
10	30.0	10	14.2	64.7	80	70	60	40	20	0	
					-	-	-	29.2	28.2	27.5	*

*Tlm refers to the estimated upper median tolerance limits.

3.3.3 Competitors

No information found.

3.3.4 Predators

No specific information was found on natural marine predators. The fish hawk, Pandion haliaetus, may prey upon the puffer, however the only account found describes the unsuccessful attempts by a fish hawk to capture these fish as they would inflate themselves out of the birds talons (Nichols and Breder, 1927).

3.3.5 Parasites, Diseases, Injuries, and Abnormalities

Wilson (1932) found cyclopoid copepods parasitic to northern puffers collected from the Woods Hole, Massachusetts area. Specimens of the copepods Tucca corpulentus Wilson and Pseudochondracanthus diceraus Wilson were attached to the fins and gills, respectively of puffers. Ho (1968) examined copepod collections at the U. S. National Museum and reported catalogue number 79595 labeled P. diceraus collected by Wilson from "Gills, Spheroides maculatus" as misidentified. These are instead T. corpulentus.

The following parasitic worms were found by Linton (1904) in northern puffers from the Beaufort, North Carolina area:

Nematoda - Ascaris spp.
- A. habena Linton

Cestoda - Tetrarhynchus bisulcatus Linton

Trematoda - Distomum vibex Linton
- Gasterostomum gracilescens Rudolphi

3.4 Nutrition and Growth

3.4.1 Feeding

Throughout their range puffers appear to be opportunistic feeders, preying mainly on available invertebrates. Their powerful jaws enable them to crush and devour anything they capture (Isaacson, 1963; Shipp and Yerger, 1969). When preying on small crabs, northern puffers attempt to paralyze the crustacean by making the first bite in front so as to sever the nerve ganglion. Puffers are known to unite in a group to attack a blue crab (Nichols and Breder, 1927). Feeding occurs during daylight as puffers are nocturnally inactive.

3.4.2 Food

The following is a composite list of dietary constituents as reported by various sources:

Pelecypods (including scallops, jingle shells, clams, Solemya sp., oysters, mussels, razor clams), gastropods (including Haminoea), barnacles (Balanus sp.), limpets, crabs (including blue, mud), isopods, hermit crabs, shrimp (including mantis), cumaceans, amphipods, caprellids, sea urchins (including Arbacia sp.), sea urchin spines, tests of sea urchins (Moira atropos), annelids, worm tubes, bryzoa, sponges, sea anemones, sea squirts, seaweed, algae, and watermelon seed (Linton, 1904; Townsend, 1916; Hildebrand and Schroeder, 1928; Isaacson, 1963).

3.4.3 Growth Rate

Marcellus (1972) calculated the linear growth rate for young-of-the-year fish of approximately 16 mm TL to be 1.11 mm/day over a term of 45 days. In 1969 the growth rate was 0.93 mm/day over a time period of 60 days. Table 4 has length-frequency observations from young-of-the-year fish collected during summer and autumn.

Growth marks on the vertebrae of northern puffer are used for age determination. The saccular otoliths develop growth rings, but they are difficult to interpret. In larger fish the annuli cannot be distinguished. For all age groups, females are larger than males (Figure 7). An analysis of annuli shows most growth takes place during the first growing season from June to October. It is during this period that the significant difference in lengths obtained by males and females take place. Thereafter the growth difference between the sexes is not significant (Figure 8) (Laroche and Davis, 1973).

3.4.4 Metabolism

Experimental results indicate that the northern puffer is a relatively sluggish fish. Fish activity is generally related to the concentration of various blood constituents such as hemoglobin, erythrocyte number, iron, and sugar. For example, those species with a high hemoglobin concentration can carry on metabolic functions at a higher rate than species with low amounts of hemoglobin. The hemoglobin content in the blood of northern puffer is not considered high and ranges from 5.99 to 12.50 gm/100 ml (mean 9.41 gm/100 ml); the erythrocyte count ranges from 209 to 502/cu mm/10^4 (mean 341/cu mm/10^4) (Eisler, 1965). Active pelagic fish have a higher blood iron concentration than fish that are benthic oriented and relatively

Table 4. Length-frequency of young-of-the-year northern puffer (from Laroche and Davis, 1973).

Total Length (mm)	June sex unknown	July sex unknown	August M	August F	September M	September F	October M	October F	November M	November F	December sex unknown
18-22	1										
23-27	6										
28-32	3										
33-37	1										
38-42											1
43-47											
48-52											
53-57											
58-62		1									
63-67		1									
68-72		2									
73-77											
78-82											
83-87											
88-92		2			5	4					
93-97					2	6					
98-102		3	1		4	2					
103-107					1	1					
108-112			1			1					
113-117					1	1					
118-122					1						
123-127					1						
128-132					1	3					
133-137					2	3					
138-142					2	3					
143-147					1	4	1	1			
148-152						1					
153-157											
158-162									1	1	
163-167						1		1		1	
168-172										2	
173-177										1	
178-182										1	
183-187										2	
N	11	9	2		21	30	1	2	1	8	1

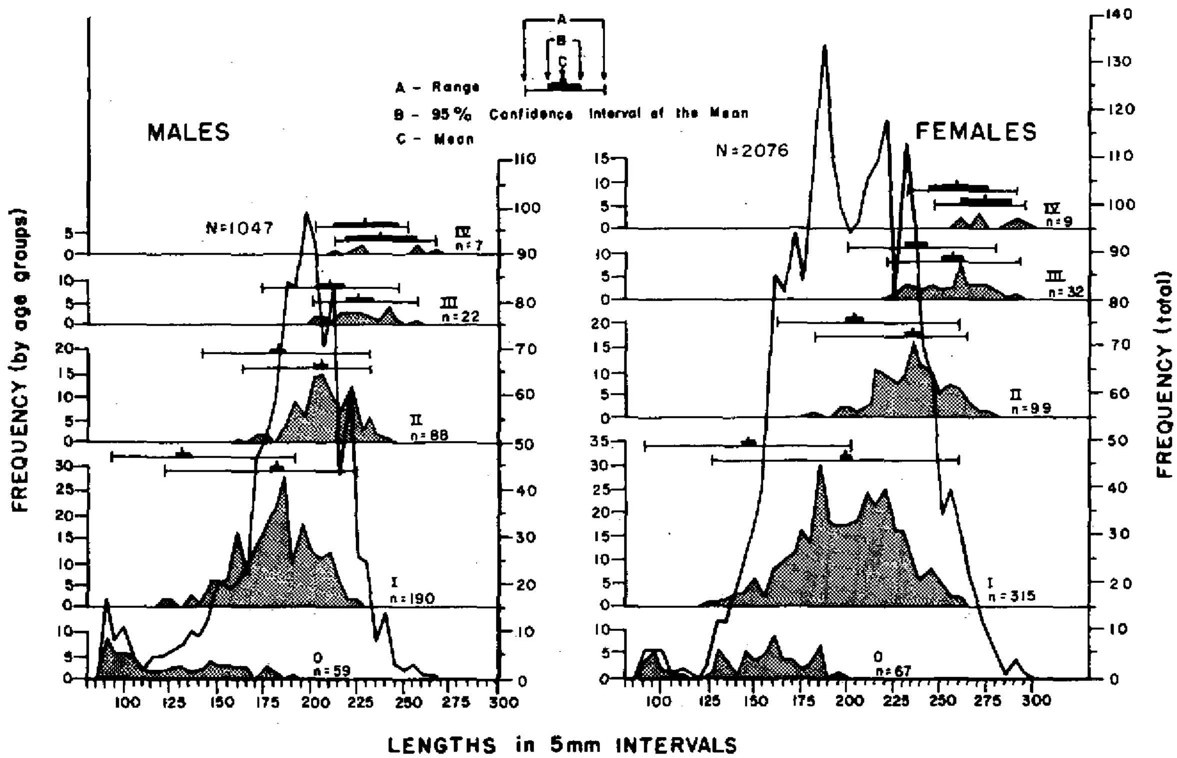

Figure 7. Length-frequency distributions of the northern puffer. Shaded polygons for each age group; unshaded polygon represents fish from the entire 1970 collection: distribution characteristics for each age group are shown above polygons with calculated lengths above measured lengths (from Laroche and Davis, 1973).

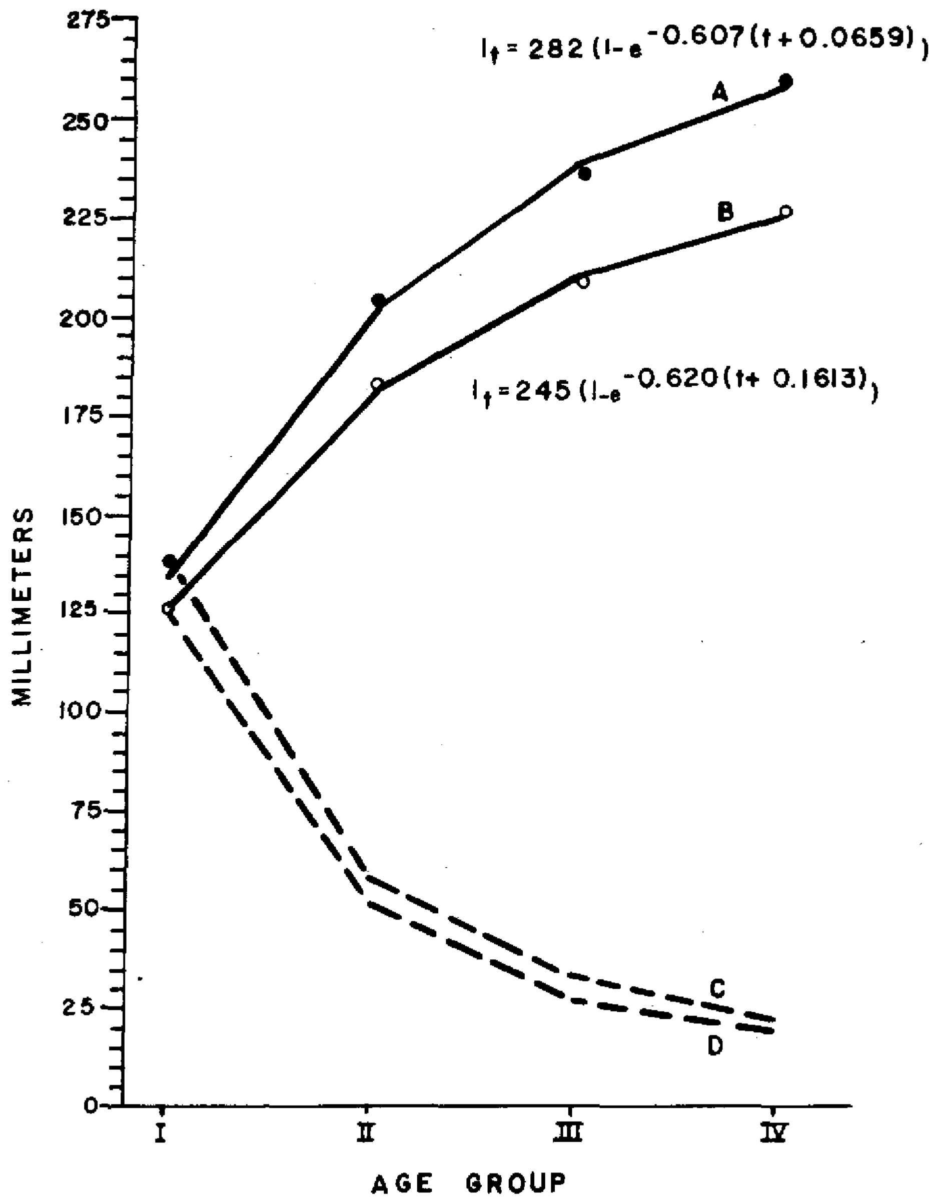

Figure 8. Growth curves of female (A) and male (B) northern puffer fitted by the vonBertalanffy growth equation and plots of increments in length of females (C) and males (D) (circles represent calculated length) (from Laroche and Davis, 1973).

inactive. The northern puffer iron values rank it as an inactive fish. Concentrations range from 17.1 to 28.8 mg/100 cc blood with an average of 21.5 mg/100 cc blood (Hall and Gray, 1929). Blood sugar is also similarly related and in the northern puffer the sugar concentration ranges from 4.5 to 41.3 mg/100 cc blood with an average of 23.1 mg/100 cc. Tests made to determine the effect of insulin in blood sugar showed that puffers did not experience shock with a reduction in blood sugar concentration whereas more active species, i.e. mackerel and menhaden, shocked when similarly tested (Gray and Hall, 1930). The volume of blood flow in relation to cardiac output usually remains proportional to the overall metabolism of an organism. For puffer, Root (1931) and Brown (1957) computed the minimum cardiac output to be 15.5 ml/kg/mm based on an oxygen capacity of 6.75 ml/O_2/100 ml of blood, and a maximum oxygen consumption of 1.05 ml/kg/min.

3.5 Behavior (for reproductive behavior, see 3.1.6; for feeding behavior see 3.4.1).

3.5.1 Migrations and Local Movements

Northern puffers are sluggish and move by the use of fins rather than by forceful body action (Townsend, 1916). They are known to partially bury themselves in soft bottom by a shoveling motion of their specially developed post-clavicular apparatus (Parr, 1927). They move through the water column during daylight, but at night become quiescent and lie on the bottom. If taken off the bottom at night and released, they swim for a short time and then descend back to the bottom (Wicklund, 1970). This difference in diel activity was also observed by Schwartz (1964) for specimens in captivity. Briggs (1962) noted that anglers caught more northern puffers during the day. Juveniles may also exhibit a similar diel variation in activity. Surface meter net collections indicate significantly more juvenile tetrodontids collected during the day than at night (Fahay, 1975).

3.5.2 Schooling

Young fish are found in large rambling schools, however, adults are more solitary (Fish, 1954).

3.5.3 Response to Stimuli

Blowfish are capable of inflating themselves for a temporary period. The inflating mechanism consists of "the powerful muscles of the first branchiostegal ray, which depress a pad covering the ceratohyals, thus expanding the mouth cavity and drawing in water or air. The elevation of the ceratohyals forces the fluid into the sac, which is a ventral diverticulum of the stomach, partially separated from it by a sphincter-like ring. Fluid is retained in the diverticulum by the strong oesophageal sphincter and by the pylorus. The flap-like breathing valve in the mouth does little or nothing in this connection. The opercular valves prevent leakage during the compression stroke, but the distended state of the sac can be maintained even they they are held open or removed. The fluid in the sac is released by the relaxation of the oesophageal sphincter which allows the fluid to escape from the fish through the oral and opercular openings" (Breder and Clark, 1947). The water used in inflation is released in intermittent spurts at first, followed by a stream and finally declining to a trickle (Gudger, 1919). Volumes of water used for inflation are given in Table 5. The inflation capacity can be related to the standard length of the fish (Figure 9) or with the formula: $(S.L.\cdot 0.61)^3 \cdot 0.0005236 = cc$ (Breder and Clark, 1947).

Defensive swelling usually occurs with the accompaniment of sounds which are described as long bursts of creaking erk-erks. These sounds are caused mainly by the grinding of the upper and lower jaw plates and to a small degree the swim bladder may aid as an amplifier (Fish, 1954). Similar sounds are made during feeding and may serve to attract other puffers that are remote from the feeder (Breder and Clark, 1947). Laboratory tests with the use of electric stimulation produced sounds consisting of low dull thumps and usually did not induce inflation of the fish (Fish, 1954; Fish and Mowbray, 1970).

When puffers are exposed to temeratures approaching their thermal tolerance (see section 3.3.2), they show certain characteristic behavioral changes. Heat shock is exhibited by an increase in both respiratory and general activity along with equilibrium disturbances such as darting, floating, surfacing, tail elevation, constant fin movement, and imbalance. Cold shock is characterized by convulsive spasms, equilibrium loss and increased respiratory activity (Hoff and Westman, 1966; Gift and Westman, 1971). When subjected to gradually colder temperatures, different behavior patterns are displayed. For example, the feeding aim is adversely affected below 12.8°C. Puffers will not inflate, even if stimulated when the temperature is less than 10°C. Swimming becomes sluggish and the fish remain near the bottom. When the temperature drops to 4.4°C they were observed to ascend in a horizontal, upright position. Swimming remained sluggish. The fish will succumb to temperatures of 3.3-4.4°C by decreasing all activity and sinking to the bottom (Schwartz, 1964).

Table 5. Inflation capacity of northern puffer from specimens in lower New York Harbor, May and June 1926 (all values read to the nearest unit of the quantities mentioned) (from Breder and Clark, 1947).

	Standard Length (mm)	Weight of Fish (g)	Capacity (cc)	Weight of Water[1] (percent)	Spherical Values[2] Diameter (mm)	Volume (cc)	39% Greater than 'D'[3]
	98	57	141	248	10	0.5	16
	106	57	177	314	50	64	82
	106	57	192	340	75	221	123
	116	71	207	292	100	524	164
	118	71	207	292	120	901	197
	128	85	244	288	130	1150	213
	131	99	266	268	150	1768	246
	133	85	200	236	200	4189	328
	140	-	301	-	250	8181	410
	143	99	370	373			
	144	133	355	314			
	145	127	422	330			
	149	219	406	185			
	150	127	437	346			
	162	141	414	284			
	169	198	630	318			
	172	226	732	323			
	174	226	694	307			
	174	254	819	322			
	175	227	561	248			
	180	219	677	308			
	184	283	769	272			
	195	290	755	260			
	195	283	800	283			
	195	255	814	319			
	198	283	875	309			
	202	340	979	288			
	215	397	1185	298			
Means	157	181	522	295			

[1]The figures in this column represent the weight of the contained water as "x" percent of the weight of the fish.

[2]The values for the volume of a sphere calculated according to the formula: $D^3 \cdot 0.0005236$ in which D = diameter and 0.0005236 = a constant which is equal to $1/6\pi$ moved to the appropriate decimal place to accommodate mm of diameter and cc of volume since $V = \pi D^2 \cdot 1/6D$ or $1/6\pi D^3$

[3]These values represent the diameter of the sphere increase by 39%. cf. Figure 9.

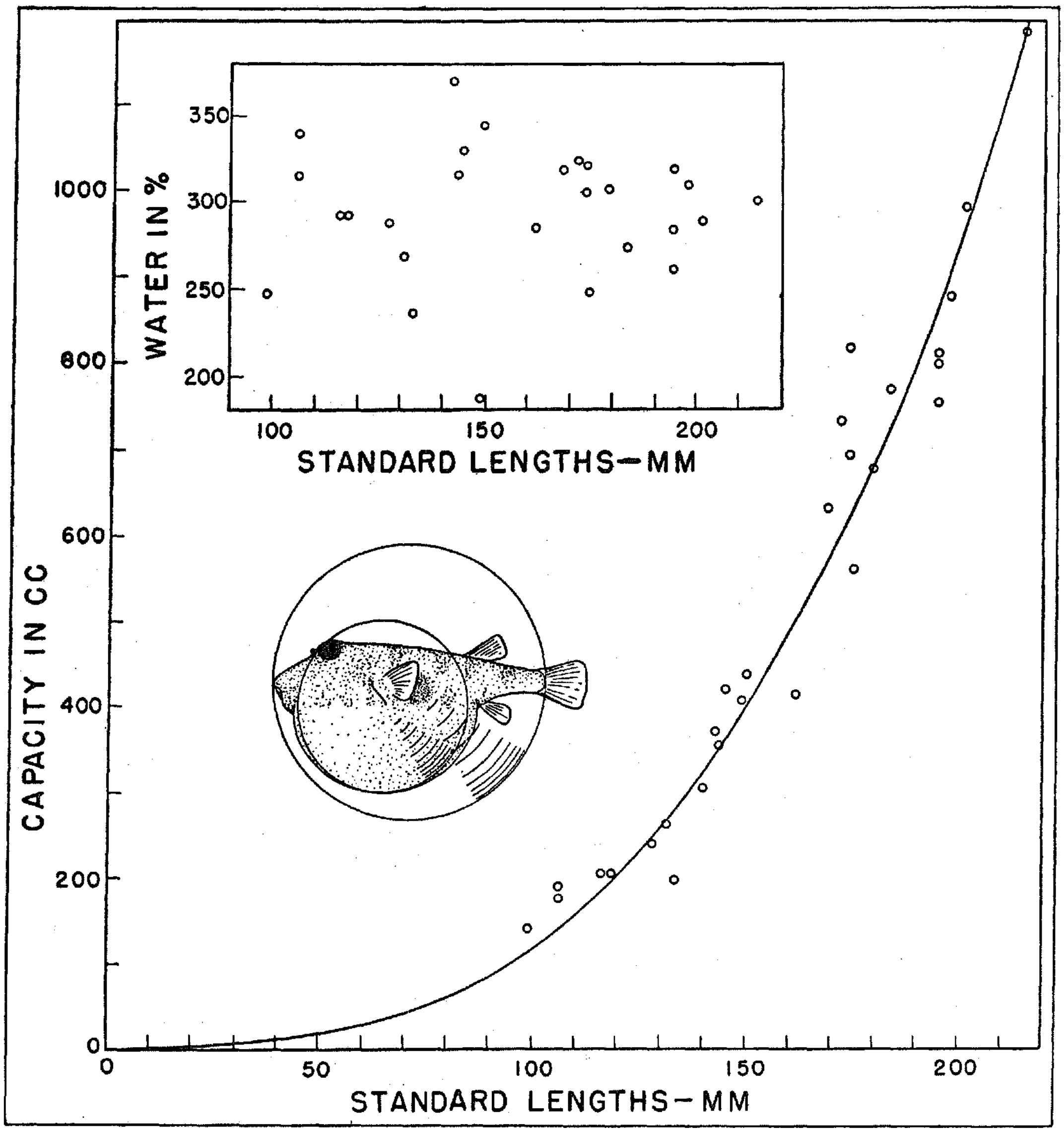

Figure 9. Inflation of northern puffer (from Breder and Clark, 1947).

3.6 Toxicity

3.6.1 General

The family Tetraodontidae includes many species that are notably toxic. A type of fish poisoning is commonly known as puffer poisoning. A species which is toxic in one area may not be poisonous in another. The toxicity of these fish is largely influenced by their reproductive cycle. Prior to and during their spawning season they are most poisonous. Many researchers believe that toxic algae may be a component in the production of tetradotoxin. The skin, liver, ovaries, and intestines are generally the most toxic parts of the puffer. The musculature may at times be poisonous. Tetradotoxin cannot be determined by the size or appearance of the fish. Small puffers can contain enough toxin to be lethal. The poison acts mainly on the nerve centers of the victim. Death is a result of suffocation and cardiac paralysis. Cooking the fish cannot destroy the toxin and there is no known antidote for puffer poisoning (cf Halstead, 1978).

3.6.2 Specific

At Homestead, Florida on March 23, 1963, a women died from eating a puffer, possibly S. maculatus (Halstead, 1967). Northern puffers from the Titusville, Cocoa, and Miami areas in Florida were tested for toxic properties. The skin, muscle, liver, and gonads were analyzed, and in most cases, proved toxic, with the skin having the highest degree of toxicity. Skin extracts were injected into test animals which caused a decrease in blood pressure and in some a depressor-pressor effect (Larson, Lalone and Rivas, 1960).

Specimens collected from the Chesapeake Bay and adjacent areas were tested for toxicity. Most of these fish proved to be non-toxic. For a few, the gut, liver, and ovaries were toxic, each during a different month; May, June, and July, respectively. To determine if puffers migrating up the coast already contained toxic properties, a sample of fish collected in early spring from the Morehead City, North Carolina area was tested. Results were negative. In all instances the flesh of the northern puffer was non-toxic (Robinson and Schwartz, 1968).

Yudkin (1945) found the ripe ovaries of northern puffer to contain a cardio-inhibitor substance, similar to tetradotoxin. The concentration of this substance increased with the maturity of the ovary. However, it was never present in amounts considered lethal to humans.

4. POPULATION

4.1 Structure

4.1.1 Sex Ratio

See section 3.1.6, spawning.

4.1.2 Age Composition

No information was found on age composition. Northern puffers are sexually mature by the first spawning season after hatching (Laroche and Davis, 1973).

4.1.3 Size Composition

The maximum size for puffers is 35.6 cm (14 inches) but most are less than 25.4 cm (10 inches) in length (Bigelow and Schroeder, 1953). A comparison of the length to weight relationship between sexes shows males weigh less than females at a given length. The modal weight of females is about 82 grams more than males for fish collected off New Jersey (Figure 10) (Welsh and Breder, 1922). Laroche and Davis (1973) examined fish collected from Virginia waters and found about 89 to 99% of the variation in weight is associated with variation in length of pre- and post-spawning puffers of each sex (Figure 11). "Puffers of both sexes were heavier after recovery from spawning (late July to November) than fish of comparable length before spawning (April to early July). Covariance tests...indicated that this difference in weight was not significant in females but was in males at the 5% level. A large increase in muscle and liver tissue occurred during the growing season but was not quantified. By November fish appeared more robust and had larger livers than in April."

A comparison of the length to weight data on fish collected from both Virginia and New Jersey shows that for a corresponding length, Virginia puffers are heavier even though the feeding habits are similar in the two areas (Isaacson, 1963). Isaacson used data for New Jersey puffers from the published material of Welsh and Breder (1922). Wilbur and Schneider (1967) compared the weight of various body organs, i.e. the heart, liver, spleen, and gut to the entire body weight of the fish. Their results did not indicate any sex-related differences in organ-body weight ratios.

4.2 Abundance and Density

No information found.

4.3 Natality and Recruitment

No information found.

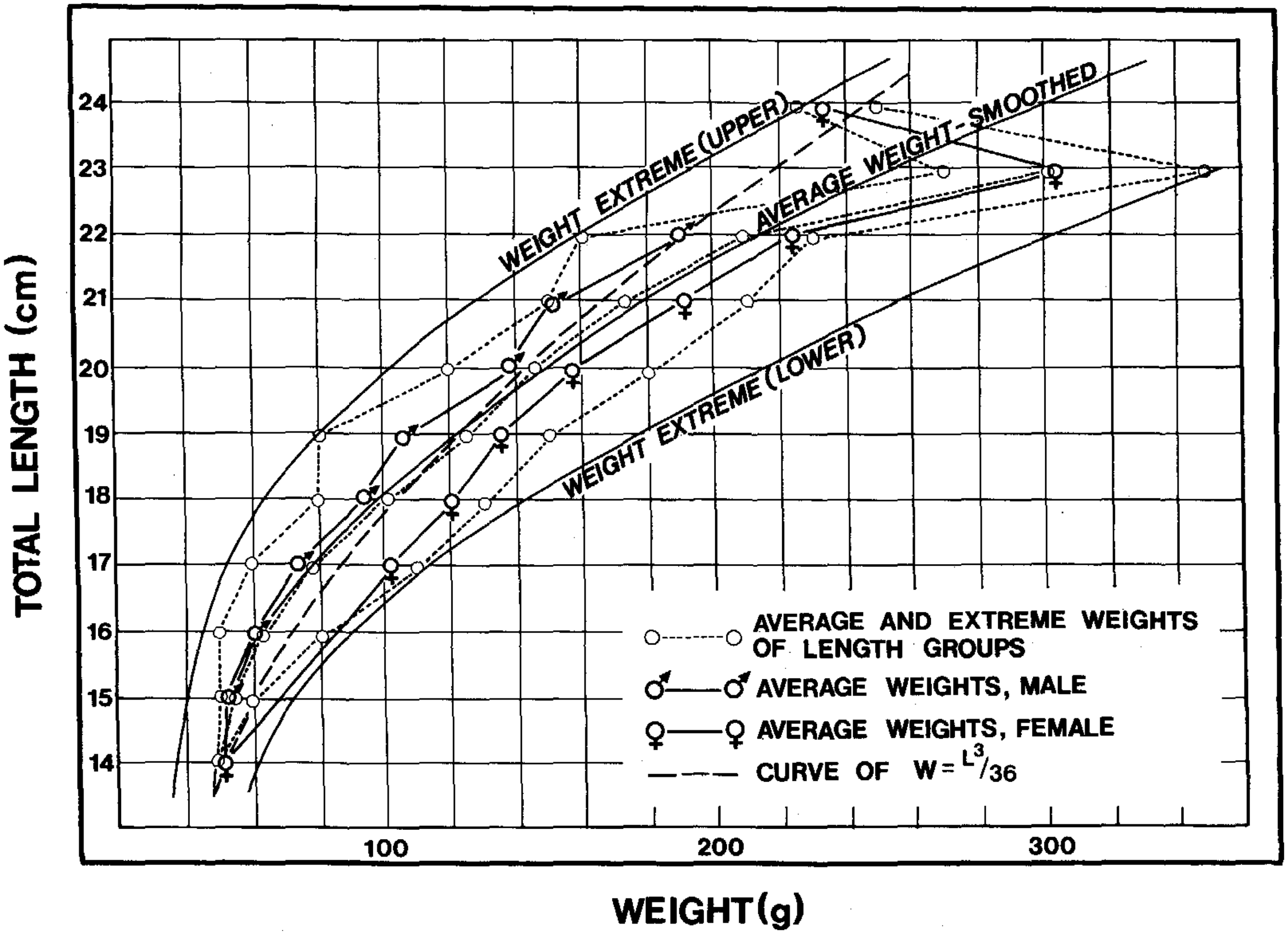

Figure 10. Length-weight relationship of adult northern puffer (from Welsh and Breder, 1922).

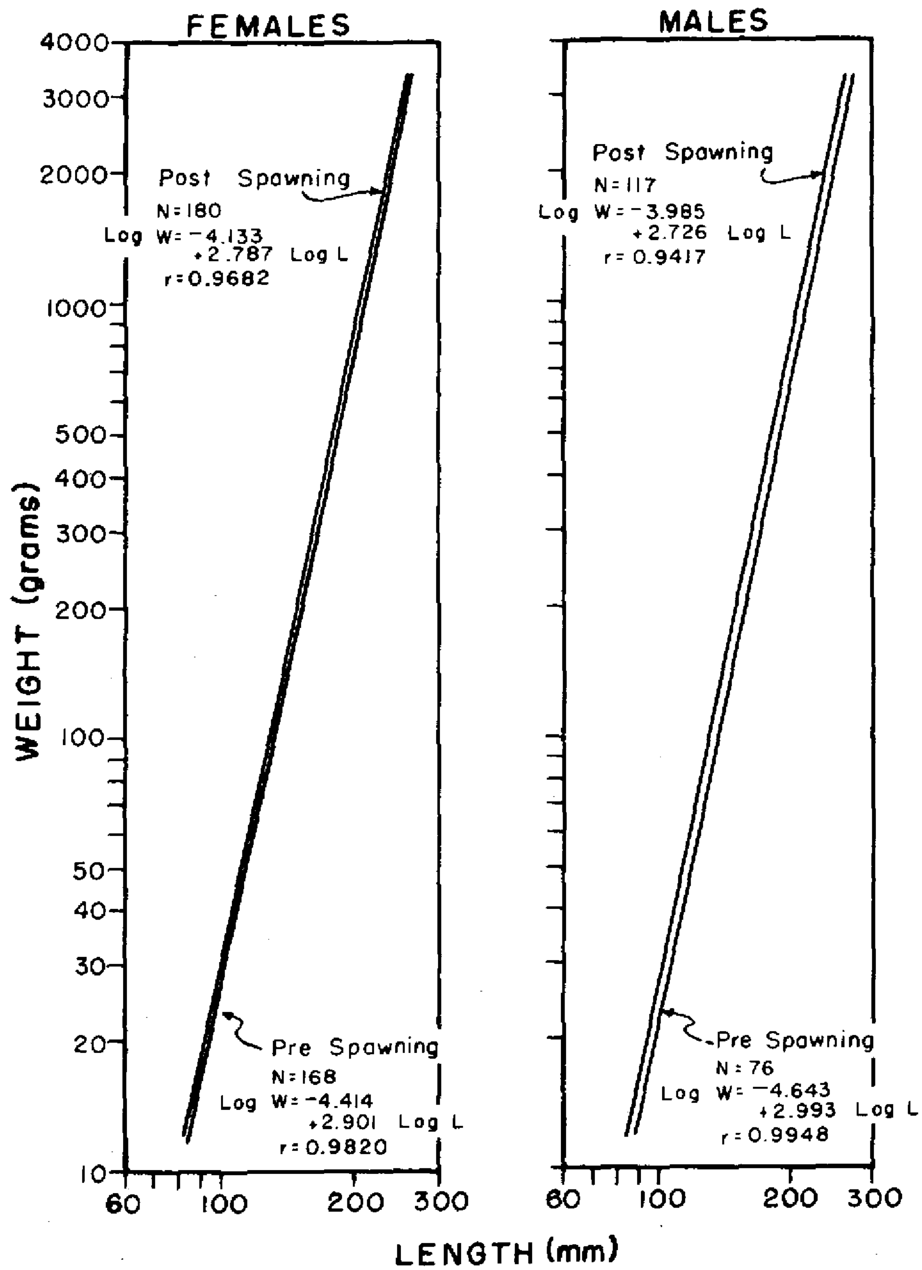

Figure 11. Weight-length relationships for northern puffers in prespawning (April to early July) and post-spawning condition (late July to November) (from Laroche and Davis, 1973).

4.4 Mortality and Morbidity

No information found.

4.5 Dynamics of Population

No information found.

4.6 The Population in the Community and the Ecosystem

A wide variety of other fishes cohabit the same area as northern puffer, however, the interrelationships of the species in the community and ecosystem are not known. The results of surveys such as those of Abbe (1967), Warfel and Merriman (1944) and Schaefer (1967), deal with the relative abundance in which puffers occur. For this type of information source the reader should consult the bibliography.

There is no information available on the cyclic fluctuations of puffer populations. Documented evidence on changes in environmental factors and their effect on the population is scarce. Wicklund (1970) proposed that the mass puffer kill which occurred off the New Jersey coast in mid-May 1969 was attributed to a combination of nocturnal behavior and an influx of cold water. Bottom temperatures ranged from 4 to 9°C in the New York Bight during that time period (see 3.3.2, 3.5.1, and 3.5.3).

5. EXPLOITATION

5.1 Fishing Equipment

The recreational fishery consists of hook and line fishing from both shore and boats (Table 6). The most popular method is bottom-bait fishing and almost any natural bait such as sand worm, cut fish or clam is used. As puffers readily take bait, they are considered a nuisance by some anglers seeking other fish species (Bigelow and Schroeder, 1953). These fish are also known to strike small artificial lures such as jigs (McLane, 1965). Northern puffers are not fished for specifically on a commercial basis, and are incidental to the main catch. They are reported in the catch of the following types of gear: otter trawl, pound net, haul seine, hand line, drift net, gill net, floating trap, pots and traps, and fyke net.[3] The types used depend upon custom, season, and effectiveness for a particular geographic area (Table 7). In the Chesapeake Bay, for example, puffers are taken with pound nets in the spring and with crab pots in the summer and fall (Lyles, 1966). The pound net accounted for 65% of all puffers caught commercially during 1950-1970.

5.2 Fishing Area

Puffers are caught throughout their range of abundance (see 2.1 and 2.2.2).

[3]Information obtained from U. S. Statistical Digest, Bureau of Commercial Fisheries and National Marine Fisheries Service.

Table 6. Angler catch statistics of puffers in 1960, 1965, and 1970 (all values in thousands) (Clark, 1963; Deuel and Clark, 1968; Deuel, 1973).

Year	Region*	Number of Fish Caught			Estimated Weight (lbs)	# of Anglers
		from Boats	from Shore	Total		
1960	North Atlantic	4,566	1,871	6,437	3,220	271
	Middle Atlantic	4,200	56	4,256	1,700	71
	South Atlantic	-	18	18	10	4
1965	North Atlantic	12,297	8,129	9,426	12,941	439
	Middle Atlantic	11,271	6,524	17,795	10,855	454
	South Atlantic	2,625	1,849	4,474	2,076	155
1970	North Atlantic	9,141	1,821	10,962	7,899	416
	Middle Atlantic	13,025	14,583	27,608	16,568	653
	South Atlantic	2,373	6,729	9,102	4,440	252

*Region: North Atlantic: Atlantic coast from Maine to and including New York.

Middle Atlantic: Atlantic coast from New Jersey to Cape Hatteras, North Carolina.

South Atlantic: Atlantic coast from Cape Hatteras, North Carolina to southern Florida including the Florida Keys.

5.3 Fishing Seasons

Fished during the warmer months in the northern part of its range (Bigelow and Schroeder, 1953). Probably fished year-round in the southern part of its range.

5.4 Fishing Operations and Results

Sport - refer to Tables 6 and 9.

Commercial - refer to Tables 7, 8, and 9.

McHugh (1972) reviewed the history of northern puffer landings in New York state. The following is a condensed version of his report.

The northern puffer became an important food fish as a result of meat rationing during World War II which promoted the coastal fisheries. The largest catch from the New York area was almost 1,060 t in 1945. Thereafter, the catch dropped off to less than 430 t, increased to another high with almost a million pounds landed in 1963, and then decreased again to 41 t in 1969. The decrease in puffer landings in New York was attributed to the development of the Chesapeake Bay fishery which in turn caused a large drop in prices (McHugh, 1969). The decrease in the puffer catch from the bays along the eastern portion of Long Island may be attributed to overfishing, the decline of pound net fishing or by natural causes. The decrease has been considerable, from a high in 1963 of over 385 t (more than 90% of the total commercial landings of puffer in New York) to 41 t in 1969 (less than 35% of the total puffer landings in New York. Results based on the recent increase in fishing activity for puffers in Long Island Sound and the ocean, suggest that the fishery may virtually be an underexploited resource in state waters. This fish is considered an important species comprising the New York coastal export fishery. However, puffers did not make up a large portion of export fishery in the bays of eastern Long Island and therefore did not effect the commercial fishery there (Briggs, 1968). The rise in the 1960 to 1963 commercial landings is attributed to an actual abundance increase. This was substantiated by sport fishery studies. From 1960 to 1962 the sport catch in Great South Bay rose from 58,000 to about 314,000 fish (Briggs, 1965). The sport catch in 1963 was slightly less than the previous years. Results from beach seine catches along the south shore of Long Island in 1962 and 1963 showed puffers comprised about 66% of the catch. In 1961, puffers made up less than 1% of the catch (Schaefer, 1967).

Northern puffer sold in the fresh fish trade are dressed, skinned, and the meat sold under the market name of sea squab. The protein quality of the meat is about equal to beef (Darling and Nilson, 1946). In periods of abundance when the supply exceeds the market demand, some are frozen for future sale (Lyles, 1965). Some are also used for reduction into fish meal (Table 8) (Lyles, 1966).

Table 7. Commercial landings (in thousands of pounds) of northern puffer by state and gear for five year intervals from 1950-1970 inclusive. A - indicates no record (Anderson and Peterson, 1953; Anderson and Power, 1957; Power, 1962; Lyles, 1967; Wheeland, 1973).

State/Gear	1950	1955	1960	1965	1970
Rhode Island					
Floating trap	14.2	7.4	16.8	-	-
Otter trawl	1.0	0.6	-	-	-
Connecticut					
Hand line	0.1	-	-	-	-
Otter trawl	0.2	0.9	-	-	-
New York					
Haul seine	25.0	8.7	4.0	-	-
Drift net	6.0	-	-	-	-
Pound net	718.5	138.2	278.9	383.0	62.2
Otter trawl	39.4	0.1	16.1	19.5	133.6
New Jersey					
Hand line	-	0.1	-	0.2	-
Pound net	24.0	18.4	22.1	4.4	-
Otter trawl	8.4	1.8	12.1	48.5	0.9
Delaware					
Fyke; hoop net	-	-	-	2.0	-
Otter trawl	-	-	-	-	-
Maryland					
Haul seine	-	-	-	-	0.8
Pot; trap	-	-	372.4	1,233.5	679.0
Fyke; hoop net	-	-	-	0.7	0.1
Pound net	1.7	3.7	0.9	617.9	19.9
Otter trawl	14.1	6.0	16.6	13.5	0.5
Virginia					
Haul seine	103.0	70.2	40.6	1,766.8	107.1
Hand line	0.9	-	0.6	0.5	-
Fyke net	1.9	4.9	-	-	-
Pot; trap	-	113.9	246.6	195.0	200.4
Gill net	-	-	-	1.0	2.5
Pound net	555.3	275.3	641.5	8.666.5	505.9
Otter trawl	66.6	12.5	6.2	38.6	5.7
North Carolina					
Haul seine	23.5	-	50.0	-	-
Gill net	2.3	-	-	-	37.8
Pot; trap	-	-	-	7.2	2.7
Pound net	-	-	-	-	2.8
Otter trawl	24.8	287.0	298.1	403.9	74.1

Table 8. Annual commercial landings (in thousands of pounds) of northern puffer by region, 1950-1977. A - indicates no record; a () indicates portion of landings used for industrial products (reduction into fish meal) (Bureau of Commercial Fisheries, National Marine Fisheries Service Statistical Digests Nos. 29-69, and U. S. Department of Commerce State Landing Statistics for 1976-1977).

Year	REGION*				Total
	New England	Middle Atlantic	Chesapeake	South Atlantic	
1950	15	822	744	51	1,632
1951	41	866	687	50	1,644
1952	39	586	438	166	1,229
1953	26	533	275	203	1,037
1954	8	354	623	243	1,228
1955	9	167	487	287	950
1956	6	310	600	69	985
1957	8	530	489	490	1,517
1958	1	299	259	159	718
1959	7	194	831	253	1,285
1960	17	333	1,326	348	2,024
1961	-	566	1,160	294	2,020
1962	4	684	1,363	303	2,354
1963	-	1,116	2,125	466	13,707
1964	-	685	5,147	283	6,114
1965	-	457(150)	12,535(2,880)	411	13,403
1966	-	265	8,102(3,632)	291	8,558
1967	-	74	7,744 (617)	380	8,198
1968	-	230	3,766 (300)	307	4,303
1969	-	264	4,593 (200)	201	5,058
1970	-	197	1,522	177	1,896
1971	-	121	582	43	746
1972	-	7	77	56	140
1973	-	4	10	7	21
1974	-	9	1	-	10
1975	-	6	<1	-	6
1976	-	7	2	7	16
1977	-	7	8	3	18

*Region: New England: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut

Middle Atlantic: New York, New Jersey, Delaware

Chesapeake: Maryland, Virginia

South Atlantic: North Carolina, South Carolina, Georgia, Florida (east coast)

Table 9. A comparison of commercial and sportfish landings (in thousands of pounds) of northern puffer by region for the years 1960, 1965, and 1970. A - indicates no record (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973; Lyles, 1967; Power, 1962; Wheeland, 1973).

Year	Region*	Weight			% of Total Weight	
		Commercial	Sportfish	Total	Commercial	Sportfish
1960	North Atlantic	316	3,220	3,536	9	91
	Middle Atlantic	1,707	1,700	3,407	50	50
	South Atlantic	-	10	10	-	100
1965	North Atlantic	402	12,941	13,343	3	97
	Middle Atlantic	13,000	10,855	23,855	55	45
	South Atlantic	-	2,076	2,076	-	100
1970	North Atlantic	196	7,899	8,095	2	98
	Middle Atlantic	1,640	16,568	18,208	9	91
	South Atlantic	-	4,440	4,440	-	100

*Region: North Atlantic: Atlantic coast from Maine to and including New York.

Middle Atlantic: Atlantic coast from New Jersey to Cape Hatteras, North Carolina.

South Atlantic: Atlantic coast from Cape Hatteras, North Carolina, to southern Florida including the Florida Keys.

6. PROTECTION AND MANAGEMENT

6.1 Regulatory Measures

No information found.

6.2 Control or Alteration of the Physical Features of the Environment

No information found.

6.3 Control or Alteration of the Chemical Features of the Environment

No information was found on control or alteration of the chemical features of the environment. However, laboratory tests indicate that puffers are more resistant to endrin than other marine fishes such as bluefish (Pomatomus saltatrix), winter flounder (Pseudopleuronectes americanus), striped mullet (Mugil cephalus), American eel (Anguilla rostrata), mummichog (Fundulus heteroclitus), striped killifish (Fundulus majalis), northern pipefish (Syngnathus fuscus), and Atlantic silversides (Menidia menidia). Eisler and Edmunds (1966) exposed northern puffers to graded concentrations of endrin, a chlorinated hydrocarbon insecticide. Those specimens exposed to concentrations of 10.0 ppb expired within 24 hours. Fifty percent of those exposed to 3.1 ppb of endrin died within 96 hours. Serum cholesterol levels in puffers exposed to endrin were repeatedly higher than in the control fish. As cholesterol metabolism is mainly the work of the liver, the test data suggest that endrin either intensifies cholesterol production by the liver, or restricts its excretion to the bile duct. The transfer of potassium, sodium, and calcium from the liver into the serum increases as the endrin concentration increases.

6.4 Control or Alteration of the Biological Features of the Environment

No information found.

6.5 Artificial Stocking

No information found.

7. AQUACULTURE

Scientists at the New York Ocean Science Laboratory tested the feasibility of raising northern puffers on a commercial basis. This program had the following objectives: 1) to attempt to induce spawning out of season; 2) to grow puffers from eggs to adults; and 3) to genetically manipulate puffers to obtain superior strains of fish.

Experimental results for the first two objectives were successful. Work is being done on the third objective in which the male genes are inactivated by irradiation with cobalt 60. Selective breeding is therefore attained only through the female genes. After egg fertilization the resultant embryos have only half the normal number of chromosomes. Although the number of chromosomes can be increased by subjecting the fish embryo to cold shock, such treatment by lowering the water temperature has not proven successful. The embryos did not survive the temperature changes used (National Fisherman, 1975).

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