

Original: For publication  
cc: Fish Division ✓  
Educ. -Game  
Inst. for Fish. Res.  
Hastings Fish. Res. Sta.  
J. E. Williams

Report No. 1663

April 17, 1963

NATURAL HYBRIDS BETWEEN ESOX AMERICANUS  
VERMICULATUS AND ESOX LUCIUS,  
FROM MICHIGAN

By John E. Williams

Hybridization in the pike family (Esocidae) has been reported frequently, usually between species which are of similar size. Hybrids have been noted between northern pike (Esox lucius) and muskellunge (Esox masquinongy) in Ontario (Gibson and MacPherson, 1954), Minnesota (Eddy, 1940, 1941, 1944), Lake Erie (Trautman, 1957), and Wisconsin (Black and Williamson, 1947); between northern pike and chain pickerel (Esox niger) in New York (Embody, 1918) and Massachusetts (Underhill, 1939); between chain pickerel and redfin pickerel (Esox a. americanus) in New Hampshire (Bailey, 1938), New York (Greeley and Bishop, 1933, and Greeley, 1939), and Massachusetts (Raney, 1957); and between chain pickerel and grass pickerel (Esox americanus vermiculatus) in Ohio (Trautman, 1957).

Until recently, hybrids between esocid species of different size were not reported. McCarraher (1960), however, reported natural hybridization between northern pike and grass pickerel in Watts Lake, Cherry County, Nebraska, and Schwartz (1962) documented the artificial production of this hybrid at the hatchery in Union City, Pennsylvania. Artificial hybrids between grass pickerel and muskellunge were recorded from Ohio by Tennant and Billy (1963),

### Materials and methods

On January 9, 1957, an angler brought to the Hastings Fisheries Research Station an esocid fish caught through the ice at Nortons Lake, Barry County. In coloration, the fish somewhat resembled a grass pickerel or a juvenile northern pike but was a sexually mature female, 22.2 inches long. Its large size, pickerel-like scales and other characteristics indicated that it might be a hybrid between the northern pike and grass pickerel. Dr. Reeve M. Bailey, Curator of Fishes, University of Michigan Museum of Zoology, verified the identification. The fish was deposited in the Museum's collection (UMMZ 173822).

In the fall of 1960 additional esocids were obtained from Nortons Lake. The lake is less than 2 acres in size, about 25 feet deep, and is the source of a tributary of the Little Thornapple River. Gill nets fished in Nortons Lake on November 3-7, 1960, caught 14 northern pike, 3 grass pickerel, and 2 hybrids (Fig. 1, Table 1). The hybrids were 15.7 and 17.8 inches in total length, and the smaller one is now UMMZ 178805.

Morphological and meristic characteristics of the hybrids from Nortons Lake and those described by McCarraher (1960) and Schwartz (1962), as well as those of the parent forms from Nortons Lake and other waters were compared. Specimens examined included 73 pike and 62 pickerel from various localities in Michigan.

Fig. 1. Esox lucius (top), two hybrids  
(center), and E. americanus vermiculatus (bottom)  
collected at Nortons Lake, Barry County, Michigan  
in November, 1960.



Figure 1

Table 1. Comparison of two species of Esox and their hybrids from Nortons Lake, Michigan, with hybrids from Nebraska and Pennsylvania (with means in parentheses)

Item	<u>E. ameri-</u> <u>canus</u>	<u>E. americanus vermiculatus</u> x <u>E. lucius</u>			<u>E. lucius</u>
	<u>vermicu-</u> <u>latus</u>	Michigan	Nebraska <sup>1</sup>	Pennsyl- vania <sup>2</sup>	
Number of fish	3	3	4	2	14
Date of collection	XI/60	I/57, XI/60	1959	VIII/61	XI/60
Total length in inches	11.0-11.7 (11.4)	15.7-22.2 (18.6)	18.2-20.0 (19.0)	12.5-13.1 (12.8)	13.1-18.8 (15.3)
Weight in pounds	0.33-0.38 (0.35)	0.84-2.75 (1.57)	1.40-2.20 (1.88)	0.54-0.63 (0.58)	0.38-1.19 (0.67)
Condition factor(C) <sup>3</sup>	21.7-24.6 (23.6)	19.8-24.8 (21.9)	23.1-28.5 (25.7)	27.6-28.0 (27.8)	16.3-20.0 (17.7)
Number of branchiostegal rays	11-13 (11.8)	13-15 (14.2)	12-14 (12.8)	13-14 (13.8)	14-15 (14.6)
Number of sensory pores	4	4	4-5 (4.5)	4	5
Number of lateral line scales	96-108 (102.3)	108-115 (113.0)	98-120 (106.7)	112-116 (114.5)	116-129 (120.6)
Percent of opercle scaled	100	67-75 (71.0)	30-45 <sup>4</sup>	25	31-37
Location of anterior nasal pore <sup>5</sup>	0.50-0.68 (0.60)	0.88-1.99 (1.36)	-	-	2.57-3.09 (2.89)

<sup>1</sup>Data from McCarraher, 1960.

<sup>2</sup>Data from Schwartz, 1962.

<sup>3</sup> $C = \frac{W10^5}{L^3}$  where W = weight in pounds and L = total length in inches.

<sup>4</sup>As emended from McCarraher, 1960 by personal communication.

<sup>5</sup>Distance of the anterior nasal pore from the anterior naris, expressed as a percentage of the total body length.

Meristic counts and measurements were obtained from different groups of fish (Tables 2 and 3), but no preserved fish were used for measurements. Except where specifically noted, all counts and measurements were performed as described by Hubbs and Lagler (1958). Counts included branchiostegal rays, mandibular sensory pores, lateral line scales, and (2 hybrids only) vertebrae and dorsal and anal fin rays. Measurements included total, head, snout, and postorbital head lengths, as well as total weight and the distance from the anterior naris to the anterior nasal pore. Ratios obtained included: head length:total length; snout length:postorbital head length. The percentage of the total body length represented by the distance from the anterior naris to the anterior nasal pore was calculated, as was the percentage of scalation of the opercle in the pike and hybrids.

Anatomical characteristics of hybrids  
and parent forms

Characters of the grass pickerel x northern pike hybrids from Michigan, Nebraska, and Pennsylvania, together with the characteristics of parent forms from Nortons Lake, are given in Table 1. Some of the important distinguishing characteristics of northern pike and grass pickerel (from Michigan and elsewhere) are given in Tables 2 and 3.

Table 2. -- Comparison of *Esox lucius* from Michigan lakes with those from other waters (with means in parentheses)

Item	Michigan lakes				Other waters			
	Nortons	Lower Scott	East Turk	Miscellaneous	Nebraska <sup>1</sup>	Minnesota <sup>2</sup>	Wisconsin <sup>3</sup>	Manitoba <sup>4</sup>
Number of fish	14	6	29	38	-	200	50	150
Total length in inches	13.1-18.8	15.3-22.6	13.2-18.1	5.6-28.1	-	-	2.9-32.2	-
Number of branchiostegal rays	14-15 (14.6)	14-16 (14.6)	15-17 (15.3)	-	14-16	12-16 (14.3)	13-16 <sup>5</sup> (14.8)	13-16 (14.9)
Number of sensory pores	5	-	3-7 (4.9)	-	5	4-5 <sup>6</sup> (5.0)	4-6 (5.0)	-
Number of lateral line scales	116-129 (120.6)	115-136 (128.8)	116-129 (123.2)	-	120-125	117-132	-	-
Percent of opercle scaled <sup>7</sup>	31-37 (34.2)	-	-	29-51 (36.4)	50	-	-	-
Location of anterior nasal pore <sup>8</sup>	2.57-3.08 (2.89)	-	-	2.42-3.45 (2.80)	-	-	-	-

<sup>1</sup> Data from McCarraher, 1960.

<sup>2</sup> Data from Eddy, 1944.

<sup>3</sup> Data from Black and Williamson, 1947.

<sup>4</sup> Data from Crossman, 1960.

<sup>5</sup> Original data indicated 26-31 rays (both sides combined).

<sup>6</sup> Original data indicated 8-10 pores (both sides combined).

<sup>7</sup> Determined from 2 fish from Nortons Lake and 7 fish from miscellaneous lakes.

<sup>8</sup> Distance of the anterior nasal pore from the anterior naris, expressed as a percentage of the total body length.



Table 3. Comparison of Esox americanus vermiculatus from Michigan waters with those from other locations  
(with means in parentheses)

Item	Michigan waters					Other waters		
	Nortons Lake	Sugarloaf Lake	Scotts Lake	Kalamazoo Lake	Miscella- neous	Nebraska <sup>1</sup>	Minne- sota <sup>2</sup>	Ontario <sup>3</sup>
Number of fish	3	17	19	19	7	-	-	20
Total length in inches	11.0-11.7	5.5-11.6	7.5-13.2	5.4-10.2	7.6-13.8	-	-	-
Number of branchi- ostegal rays	11-13 (11.8)	10-12 (11.3)	10-13 (11.8)	-	12-13 (12.4)	11-13	11-13	9-13 (11.7)
Number of sensory pores	4	4	-	-	-	4	-	-
Number of lateral line scales	96-108 (102.3)	99-117 (104.0)	92-112 (100.9)	-	94-114 (105.6)	90-110	105+	-
Location of anterior nasal pore <sup>4</sup>	0.59-0.68 (0.64)	0.74-1.29 (0.94)	-	0.38-0.93 (0.57)	0.88-1.10 (1.02)	-	-	-

<sup>1</sup>Data from McCarraher, 1960.

<sup>2</sup>Data from Eddy and Surber, 1947.

<sup>3</sup>Data from Crossman, 1960.

<sup>4</sup>Distance of the anterior nasal pore from the anterior naris, expressed as a percentage of the total body length.

Body measurements. --In pike, total length/head length averaged 3.85; in pickerel, 3.74. The ratio was related to size. Equal-size fish of the two species had similar ratios, and the presence of a considerable number of pike over 14 inches (nearly maximum length for grass pickerel) in the sample resulted in a higher average factor for this species. The smaller fish have relatively longer heads than do the larger ones, which is a continuation of the allometric growth of pike noted by Franklin and Smith (1960). Incidentally, these authors reported that the relative head length of fingerling pike declined from 33.6 percent to 31.9 percent of the total length, as the total length increased from 40 to 110 mm. In the Michigan hybrids, however, total length/head length ranged from 3.62 to 3.71 (average, 3.65); for 38 pike (about the same size as the hybrids) the factors ranged from 3.77 to 4.08 (average, 3.88).

Head length/snout length gave a slightly larger average figure for pickerel (2.11) than for pike (2.06), i. e., the pickerel snout is slightly shorter, relatively, than the pike snout. This ratio, too, is associated somewhat with size, ranging in the pickerel from 2.08 for smaller fish (5 to 8 inches in length) to 2.15 for larger fish (8 to 12 inches); for smaller pike (6 to 8 inches) the factor was 1.94, and for larger fish (12 to 28 inches), 2.09. The ratios for Michigan hybrids were 2.12 to 2.22, indicating that their snouts were more pickerel-like, i. e., proportionately shorter than pike snouts.

McCarragher (1960) mentions that in Nebraska hybrids the "distance from tip of upper jaw to the center of the eye is less than the distance from center of eye to posterior edge of opercle," but this is generally true of pike and pickerel also. For Michigan fish 5 to 12 inches long (hybrids excepted) postorbital head length/ snout length gave 0.99 to 1.07 (average, 1.03) for pike, 1.09 to 1.28 (average, 1.18) for pickerel, and 1.14 to 1.25 for hybrids.

Location of anterior nasal pore. --In the Esocidae there are generally two pairs of sensory pores associated with the nares on top of the snout. The relationship of these and other head pores is illustrated by Black and Williamson (1947) for northern pike, muskellunge, and their hybrids from Wisconsin. In the pike and pickerel one pair of pores (posterior nasal pore) is usually located between the left and right naris, each pore being approximately half-way between the naris and the midline of the snout. The other pair of pores is anterior to the nares but is considerably further forward on the pike than it is on the pickerel. To determine the diagnostic value of this character, the distance between the naris and the anterior nasal pore was measured (two measurements for each fish) on 46 pike, 31 pickerel, and 3 hybrids; the value was expressed as a percentage of the total length. In some fish there were considerable differences between pairs of measurements (shown by vertical connecting lines on Fig. 2), but without exception the distance was as great or greater in pike (4 to 20 mm.) than in pickerel (1-4 mm.).

Fig. 2. Correlation between the distance of the anterior nasal pore from the anterior naris and the total body length in Esox americanus vermiculatus, E. lucius, and their hybrids from Michigan. Vertical connecting lines indicate the pores from opposite sides of the same fish are not equidistant.

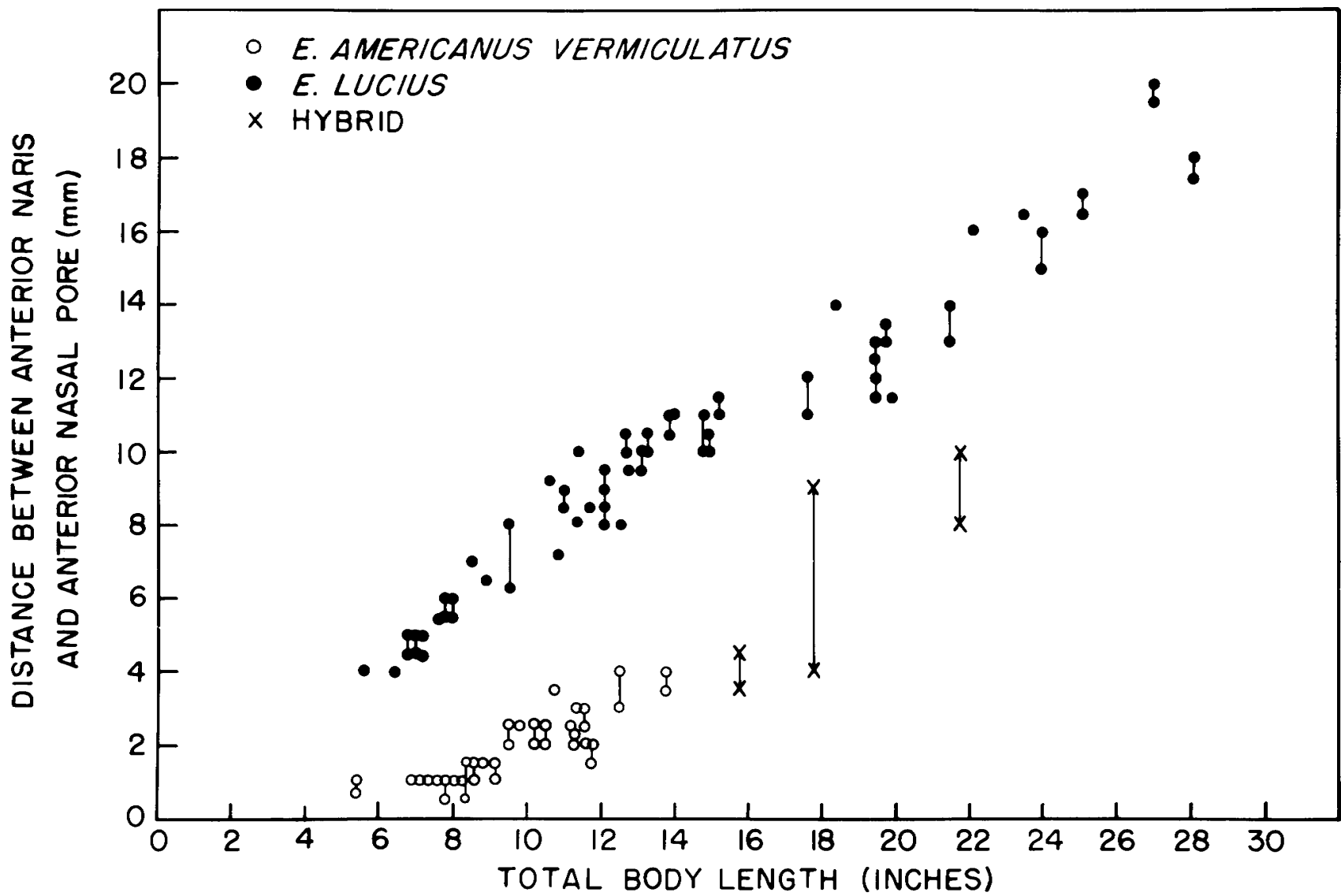


Figure 2

Among pike the distance represented 2.42 to 3.45 percent (average, 2.82) of the total length. In the pickerel the distance averaged 0.71 percent of the total length (range, 0.38 to 1.29). The pores on the pike average 4.0 times as far from the naris as do those of the pickerel. The closest anterior pore found on the pike was still 1.9 times as far from the nares as the furthest pore found on the pickerel.

The average distance of the anterior nasal pore from the naris on the three hybrid fish was 1.36 percent of the total length (range, 0.88 to 1.99), i. e., roughly intermediate to the parent forms but overlapping the pickerel to some degree. Location of the pore varied considerably among the three hybrids, but in no instance was located within the pore-location range of the pike (Fig. 2).

Mandibular sensory pores. --The number of sensory pores on the underside of the mandible has been used for separating species of Esocidae. However, the small size of grass pickerel and the large amount of pigment on the underside of the lower jaw make the pores difficult to see. Also, among pike the number of pores varies; consequently the character is not considered to be reliable for distinguishing between these two species. All pickerel from Michigan had four pores on each side (Table 4). In Wisconsin, pike have been reported to have four to six mandibular pores (Black and Williamson, 1947), but those from Michigan had an even greater range of three to seven. Hybrids in Michigan all had four pores as did those from Pennsylvania (Schwartz, 1962), but those from Nebraska (McCarragher,

Table 4.--Frequency of occurrence of counts of branchiostegal rays, mandibular sensory pores, and lateral line scales of Esox americanus vermiculatus, E. lucius, and their hybrids from Michigan waters. Counts from both sides are included. (N = number of counts,  $\bar{x}$  = mean, S = standard deviation and  $2S\bar{x}$  = twice the standard error of the mean)

No.	Branchiostegal rays				Mandibular pores				Lateral line scales						
	Total		Formulae		Total		Formulae		Total		Formulae				
	<u>E. a.</u> <u>verm.</u>	Hybrid	<u>E.</u> <u>lucius</u>	No.	<u>E. a.</u> <u>verm.</u>	Hybrid	<u>E.</u> <u>lucius</u>	No.	<u>E. a.</u> <u>verm.</u>	Hybrid	<u>E.</u> <u>lucius</u>	No.	<u>E. a.</u> <u>verm.</u>	Hybrid	<u>E.</u> <u>lucius</u>
-	-	-	-	-	-	-	-	-	-	-	-	92	3	-	-
10	2	-	-	IV+6	1	-	-	3	-	-	1	93	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	94	1	-	-
-	-	-	-	-	-	-	-	-	-	-	-	95	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	96	3	-	-
-	-	-	-	-	-	-	-	-	-	-	-	97	1	-	-
-	-	-	-	-	-	-	-	-	-	-	-	98	2	-	-
11	26	-	-	V+6	8	-	-	-	-	-	-	99	4	-	-
-	-	-	-	IV+7	5	-	-	-	-	-	-	100	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	101	5	-	-
-	-	-	-	-	-	-	-	-	-	-	-	102	3	-	-
-	-	-	-	-	-	-	-	4	26	6	7	103	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	104	4	-	-
12	36	-	-	VI+6	8	-	-	-	-	-	-	105	1	-	-
-	-	-	-	V+7	20	-	-	-	-	-	-	106	2	-	-
-	-	-	-	-	-	-	-	-	-	-	-	107	4	-	-
-	-	-	-	-	-	-	-	-	-	-	-	108	1	2	-
-	-	-	-	-	-	-	-	-	-	-	-	109	1	-	-
-	-	-	-	-	-	-	-	-	-	-	-	110	1	-	-
13	7	1	-	VI+7	3	1	-	-	-	-	-	111	-	-	-
-	-	-	-	V+8	2	-	-	-	-	-	-	112	2	-	-
-	-	-	-	-	-	-	-	5	-	-	73	113	2	-	-
-	-	-	-	-	-	-	-	-	-	-	-	114	1	3	-
-	-	-	-	-	-	-	-	-	-	-	-	115	-	1	1
-	-	-	-	-	-	-	-	-	-	-	-	116	-	-	3
14	-	3	18	VII+7	-	-	3	-	-	-	-	117	1	-	3
-	-	-	-	VI+8	-	3	15	-	-	-	-	118	-	-	5
-	-	-	-	-	-	-	-	-	-	-	-	119	-	-	8
-	-	-	-	-	-	-	-	-	-	-	-	120	-	-	6
-	-	-	-	-	-	-	-	-	-	-	-	121	-	-	6
-	-	-	-	-	-	-	-	-	-	-	-	122	-	-	5
15	-	2	45	VIII+7	-	1	-	6	-	-	4	123	-	-	5
-	-	-	-	VII+8	-	1	34	-	-	-	-	124	-	-	2
-	-	-	-	VI+9	-	-	3	-	-	-	-	125	-	-	5
-	-	-	-	-	-	-	-	-	-	-	-	126	-	-	5
-	-	-	-	-	-	-	-	-	-	-	-	127	-	-	2
-	-	-	-	-	-	-	-	-	-	-	-	128	-	-	4
16	-	-	9	IX+7	-	-	1	-	-	-	-	129	-	-	3
-	-	-	-	VIII+8	-	-	5	-	-	-	-	130	-	-	1
-	-	-	-	-	-	-	-	-	-	-	-	131	-	-	-
-	-	-	-	VII+9	-	-	1	-	-	-	-	132	-	-	1
-	-	-	-	-	-	-	-	7	-	-	1	133	-	-	1
-	-	-	-	-	-	-	-	-	-	-	-	134	-	-	-
17	-	-	4	VIII+9	-	-	2	-	-	-	-	135	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	136	-	-	1
N	71	6	76	-	47	6	64	-	26	6	86	-	42	6	67
$\bar{x}$	11.7	14.1	15.0	-	-	-	-	-	4.0	4.0	5.0	-	103.0	112.2	122.6
S	0.69	0.69	0.75	-	-	-	-	-	-	-	0.47	-	6.25	2.97	4.49
$2S\bar{x}$	0.16	0.56	0.17	-	-	-	-	-	-	-	0.10	-	1.93	2.42	1.10

1960) had either four or five. The frequency of occurrence of different numbers of mandibular pores in pike, pickerel, and hybrids from Michigan is shown in Table 4. Nearly 10 percent of the pike had four mandibular pores--a number which would normally be associated with pickerel.

Branchiostegal rays. --The number of branchiostegal rays is a character of considerable importance for separating northern pike and muskellunge as well as for distinguishing between northern pike and grass pickerel. Pike collected from Nortons Lake (Table 1) had 14 to 15 rays (one side), whereas pickerel had 11 to 13 rays. Pike from other Michigan waters had 14 to 17 rays, and Eddy (1944) reported 12 to 16 rays for pike from Minnesota. Pickerel from Michigan waters had from 10 to 13 branchiostegals, or close to the "usually 11 to 13" recorded by Eddy and Surber (1947). In hybrid specimens from Michigan the number of branchiostegal rays ranged from 13 to 15.

The frequency of occurrence of various numbers of branchiostegal rays from either side is shown in Table 4. Although the counts for Michigan specimens of pike and pickerel did not overlap, data from Eddy (1944) and Crossman (1960), indicate that occasionally pike may have only 12 or 13 branchiostegal rays and that pickerel may have as many as 14.

Designating the branchiostegals on the ceratohyal by Roman numerals and those more posteriorly and laterally on the epihyal by Arabic numerals (Table 4) gives a more valuable expression of the



extreme variation found in fish species that have a high number of meristic parts. Crossman (1960) has demonstrated that along with the interpopulation variation which would be expected there was exceptional intrapopulation variation and even bilateral asymmetry in many Esocid fishes.

Fin rays. -- Eddy (1944) reported 17 to 19 rays in the dorsal fin of pike from Minnesota, but several other published reports give only from 14 to 17 rays. Seemingly most workers did not count the three or four rays that can be found only by dissection at the anterior end of the fin. Such dissection on two of the hybrids from Michigan revealed 18 and 21 dorsal rays. McCarraher (1960) reported 15 to 16 rays in the dorsal fins of the Nebraska hybrids, and Schwartz (1962) identified only 16 and 17 rays in those from Pennsylvania.

Anal-fin rays are also extremely difficult to count, but dissection of two Michigan hybrids revealed 15 and 18 rays. Schwartz (1962) counted only 14 anal rays on Pennsylvania hybrids.

Vertebrae. -- Two hybrids from Michigan were X-rayed and their vertebrae counted. Two post-terminal vertebrae were included in the count, but a small terminal ossification visible on the radiograph was not included, as it probably would not be visible on dissection. Gosline (1960) has defined the terminal vertebrae as that centrum which articulates with the lowermost of the three subaxial hypurals. The vertebrae counts of 55 and 56 agree closely with those found by Schwartz (1962) after X-raying 5 hybrids from Nebraska and Pennsylvania

(54 and 55 vertebrae). He also found 60 to 62 vertebrae present in pike (three individuals) and 48 to 50 vertebrae present in pickerel (five specimens) by X-ray.

Scale characteristics. --Scales of northern pike and grass pickerel are quite different. On pickerel scales the scallops at the anterior edge of the scale are connected by radii extending from the focus, much as in centrarchid or percid scales. On pike scales however, adjacent scallops overlap for 25 to 50 percent of the distance from the scale margin to the focus; from this point to the focus the radii are similar in appearance to those of the pickerel.

Secondly, lateral scales of the pickerel have the exposed (posterior) portion of the scale wider (laterally) than the distance from the focus to the posterior margin. In lateral scales from pike, the distance from the focus to the posterior margin is greater than the width of the exposed portion of the scale.

The third difference between the scales of the two species is in the appearance of regenerated or other fast-growing scales. In pickerel scales the pieces or sections of circuli in the regenerated areas are grouped in loose bundles or aggregations, resembling the fronds of ferns, and are oriented in various directions; regenerated pike scales, on the other hand, show an unoriented mixture of short, curved pieces of circuli.

Scales from the three Michigan hybrids resembled those of pike in having overlapping scallops, and in the 17.8-inch fish scale

dimensions were pike-like. Regenerated scales of the hybrids were similar to those of pickerel.

Lateral line scales. --Enumeration of lateral line scales is more tedious than most meristic counts and is, therefore not often done under field conditions. Seldom are scales on both sides of the body counted, although there is often considerable variation between sides. In published records the range in number of lateral line scales for pike is from 117 to 132 (Eddy, 1944), and for pickerel the range is from 90 to 110 (McCarragher, 1960).

Counts of lateral line scales for Michigan pike ranged from 115 to 136 (Table 2); for pickerel, from 92-117 (Table 3). Only one example of an overlap in the lateral line scale was found; one side of a slightly damaged pickerel had 113 scales and the other 117, but distortion of scale rows may have caused an incorrect count.

From Table 4 it can be seen that the number of lateral line scales averaged 122.6 in pike, 103.0 in pickerel, and 112.2 in hybrids. It appears that the lateral line scale count is, with perhaps a rare exception, an excellent character to use in separating these two species.

Scalation of opercle. --Authors usually describe the opercle of northern pike as "half-scaled" or "scaled on the top half only" and that of the pickerel as "entirely scaled." Although the opercle of the pickerel is undoubtedly entirely scaled, examination of the opercle of the pike reveals that it is usually considerably less than 50 percent

scaled. The opercles of the hybrids from Michigan appeared to be considerably more than "1/4" scaled as reported from Pennsylvania (Schwartz, 1962), but were not entirely scaled (Fig. 1).

A method of measuring the percentage of the opercle which was scaled was devised by drawing a horizontal base line, on a photograph of an esocid head, from the center of the orbit to the top of the opercular slit. The scaled and unscaled areas of the opercle (without the membrane) below this base line were then outlined in pencil and divided into squares, triangles, etc., for area calculation in square mm. It was then simple to obtain the percentage of scalation by adding the areas of all scaled and unscaled portions. Clear photographs of nine pike and the three hybrid heads were secured in which the edge of the scaled area could be determined. The amount of scalation of the pike opercle varied between 29 and 51 percent (average, 36 percent) and in the hybrids from 66 to 75 percent (average, 71 percent). Thus, the percentage of opercular scalation of the three Michigan hybrids is intermediate between the parent forms.

Color pattern. --Although the color pattern of pike is extremely variable, an acceptable description of it in fish over 12 to 15 inches in length would include a dark, greenish background with small, bean-shaped, cream-colored spots along the side (Fig. 1). As the fish grows the number of spots increases but their size remains much the same. The median fins are spotted, and on juveniles there is a distinct, dark, vertical, subocular bar, or

"tear drop," extending downward from the eye past the maxillary. This bar becomes indistinct on sub-adults and disappears completely in the adults.

The grass pickerel usually has a black or brown vermiform pattern on a yellowish background (Fig. 1). The median fins are not spotted and the subocular bar is quite distinct on fish of any size.

The Michigan hybrids (Fig. 1) closely resemble the description given by Schwartz (1962) and McCarraher (1960). The pattern of transverse light bars and spots is strikingly different from the markings of pike or pickerel. Subocular bars are prominent and the median fins are unspotted.

#### Sex, maturity, and age

Although the Nebraska hybrids (McCarraher, 1960) were all longer than 18 inches, and were captured during the winter and spring, they were all found to be immature females, apparently sexually sterile. However, in Wisconsin eggs have been obtained from hybrid northern pike x muskellunge (Black and Williamson, 1947). The largest Michigan hybrid (22.2 inches) was a mature female with well developed ovaries present in January, but the two smaller fish were both immature females in November.

From their scales, the Michigan hybrids were estimated to be II (15.7 inches), III (17.8 inches), and V (22.2 inches) years of age.

### Natural hybridization

Fisheries workers in Wisconsin (Black and Williamson, 1947) and Minnesota (Eddy, 1944) have observed northern pike and muskellunge spawning together naturally. Frequently, I have observed spawning northern pike and spawning grass pickerel in Michigan, often on the same dates and within a few feet of each other. Despite the proximity, pairing between members of different species was never observed. Perhaps the secondary sex characteristics displayed by each species (e. g., vivid green coloration of the opercle, cheek, and snout of the male northern pike, and the bright yellow dorsal stripe on the head and body of the male grass pickerel) enable the fish to recognize mates of the same species. Natural hybrids may be the result of accidental fertilization when both pairs spawn nearly simultaneously in proximity; thus, a very small area of suitable spawning habitat might increase the possibility of accidental hybridization.

### Acknowledgments

The author wishes to thank Drs. Paul H. Eschmeyer, Reeve M. Bailey, and Mr. Walter R. Crowe for review and criticism of the manuscript. Dr. Bailey was especially helpful in obtaining the X-rays and in offering other technical assistance and advice. Mr. Paul Earl prepared the figures.

Literature cited

- Bailey, R. M. 1938. The fishes of the Merrimack watershed. New Hampshire Fish & Game Dept. Biol. Surv. Rept. (3): 149-85.
- Black, J. D., and L. C. Williamson. 1947. Artificial hybrids between muskellunge and northern pike. Trans. Wisc. Acad. Sci. 38: 299-314.
- Crossman, E. J. 1960. Variation in number and asymmetry in branchiostegal rays in the family Esocidae. Canadian J. Zool. 38(2): 363-75.
- Eddy, S. 1940. Do muskellunge and pickerel interbreed? Prog. Fish-Cult. (48): 25-6.
- \_\_\_\_\_. 1941. Muskellunge and muskie hybrids. Minn. Conserv. Volunteer 3(14): 41-4.
- \_\_\_\_\_. 1944. Hybridization between northern pike (Esox lucius) and muskellunge (Esox masquinongy). Proc. Minn. Acad. Sci. 12: 38-43.
- \_\_\_\_\_, and T. Surber. 1947. Northern fishes. Univ. of Minn. Press, Rev. Ed. 276 p.
- Embody, G. C. 1918. Artificial hybrids between pike and pickerel. J. Hered. 9(6): 253-6.
- Franklin, D. R., and L. L. Smith, Jr. 1960. Notes on the early growth and allometry of the northern pike, Esox lucius L. Copeia 1960(2): 143-4.

- Gibson, M. B., and J. W. MacPherson. 1954. Esox lucius x Esox masquinongy hybrids. M.S. Rept. to Director, Ont. Fish. Res. Lab., Dept. of Zool., Univ. of Toronto.
- Gosline, W. A. 1960. Contributions toward a classification of modern isospondylous fishes. Bull. British Mus. (Nat. Hist.), Zool. 6: 327-65.
- Greeley, J. R. 1939. The freshwater fishes of Long Island and Staten Island with annotated list. In: A biological survey of the freshwaters of Long Island, N. Y. Cons. Dept. Suppl. to 28th Ann. Rept.: 29-44.
- \_\_\_\_\_, and S. C. Bishop. 1933. Fishes of the Upper Hudson watershed with annotated list. In: A biological survey of the Upper Hudson watershed. N. Y. Cons. Dept. Suppl. to 22nd Ann. Rept.: 64-101.
- Hubbs, C. L., and K. F. Lagler. 1958. Fishes of the Great Lakes region. Cranbrook Inst. Sci. Bull. 26: xiii + 213 p.
- McCarragher, D. B. 1960. Pike hybrids (Esox lucius x E. vermiculatus) in a Sandhill Lake, Nebraska. Trans. Am. Fisheries Soc. 89 (1): 82-3.
- Raney, E. C. 1957. Natural hybrids between two species of pickerel (Esox) in Stearns Pond, Massachusetts. Mass. Div. Fish & Game Suppl. to Fish. Rept. for some central, eastern, and western Massachusetts lakes, ponds, and reservoirs, 1951-52: 15 p.



- Schwartz, F. J. 1962. Artificial pike hybrids, Esox americanus  
vermiculatus x E. lucius. Trans. Am. Fisheries Soc. 91  
(2): 229-30.
- Tennant, D. L., and G. Billy. 1963. Artificial hybridization of the  
muskellunge and grass pickerel in Ohio. Prog. Fish-Cult.  
25(2): 68-70.
- Trautman, M. B. 1957. The fishes of Ohio. Ohio State Univ.  
Press, 683 p.
- Underhill, A. H. 1939. Cross between Esox niger and Esox  
lucius. Copeia 1939(4): 237.

INSTITUTE FOR FISHERIES RESEARCH

John E. Williams

Report approved by W. R. Crowe

Typed by M. S. McClure