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*The Journal of Wildlife Management*, Vol. 20, No. 2. (Apr., 1956), pp. 114-124.

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*The Journal of Wildlife Management* is currently published by Allen Press.

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# THE PIKE, *Esox lucius* LINNAEUS, IN RELATION TO WATER- FOWL ON THE SENEY NATIONAL WILDLIFE REFUGE, MICHIGAN <sup>1</sup>

*Karl F. Lagler*

University of Michigan, Ann Arbor

The predatory habits of pike have been recognized by North American biologists for about a hundred years. The special role of the species in limiting waterfowl production has been explored by Bajkov and Shortt (1939), Ross (1940), and in greatest detail by Solman (1945) for the Saskatchewan and Athabaska River deltas in Canada. In these areas it was estimated that approximately 10 per cent (about 1,500,000 individuals) of such birds were destroyed by pike in an average year. In the early years of flooding of the pools on the Seney National Wildlife Refuge (1936 to 1941), concern was felt over the subjectively determined slow increment of the avian population as compared to that of pike, and led to the obvious question of how great a limiting factor the fish were in duck production. The problem of utilizing the obviously extensive pike resource for public enjoyment was also considered, even to the extent of using angling as a method to reduce the fish population if such control seemed desirable. The primary objectives of the investigation were: (1) to determine the nature, extent, and effect of the feeding habits of the northern pike on waterfowl, and (2) to formulate a plan for the management of the northern pike. The work was done at intervals from 1941 through 1953.

Field work was conducted in 1941 from July 4 through 7 and from August 22 through September 23; in 1942, from May 19 to July 31, which covered the period of duck nesting; and in 1943, from June 1 to

August 15. Short observation and sampling visits were also made in 1951, 1952 and 1953.

The investigation was instigated by J. Clark Salyer, II, Chief, Branch of Wildlife Refuges, U.S. Fish and Wildlife Service. Field operations were greatly facilitated by the cooperation and kindness of the refuge managers, the late C. S. Johnson and C. J. Henry, and their staffs, particularly Axel Mortenson and William Anderson. The help of other federal employees, especially John van Oosten, colleagues in the University, and many friends and anglers around Seney is gratefully acknowledged. My wife, Mary Jane Lagler, participated extensively in both the field and laboratory aspects of the study.

## DESCRIPTION OF THE AREA

The Seney National Wildlife Refuge comprises about 94,000 acres in Schoolcraft County, Michigan, southwest of Seney and west of Germfask. The tract lies in the basin of the Manistique River which flows southwesterly across the eastern lowlands of the Northern Peninsula to enter Lake Michigan. This low-lying physiographic province is poorly drained and much of the region is swampy. Most of it was flooded by glacial Lake Algonquin but not by the earlier Lake Nipissing (Scott, 1920). The sandy subsoil is overlain on the lowest areas by organic material (often fibrous peat). Ridges are interspersed among the plains and marshes of the Seney region and represent sand dunes of retreating levels of Lake Algonquin (Berquist, 1936). The dykes which impound tributaries of the Manistique River on the Refuge were constructed largely along dune lines.

In the decade following 1910, a large extent of the Seney marshes was drained by ditching for agricultural purposes. With the passage of this unsuccessful farming enterprise, the land reverted to plains vegetation

<sup>1</sup> Contribution from the Departments of Fisheries and Zoology, University of Michigan, and the U.S. Fish and Wildlife Service. Published with the permission of the Director of the Service. Supported at various times by the Associated Fishing Tackle Manufacturers and for completion of this report in the summer of 1954 by a Faculty Fellowship in the Rackham School of Graduate Studies of the University of Michigan.

(mostly sedges) or to swamps with little open water, where beaver dammed ditches and streams. In 1935 the U. S. Fish and Wildlife Service acquired the area and soon began the construction of dykes and water-level-control structures, aided and abetted by beaver (Beard, 1953). The resultant ponding made much good waterfowl habitat but, inadvertently, did the same for pike. The developmental program produced 19 major impoundments or "pools" by 1943. These pools are grouped in three units and have a total area of about 6,000 acres. The date of first filling and approximate water acreage as determined from maps and water levels in the 1940's follow (the figures in parentheses are the estimates of the 1950 conditions made by the refuge staff): Unit I—April, 1936: Goosepen, 40 (50). September, 1936: Lower F, 186 (130); Upper F, 39 (50); Show, 40 (45). April 1937: A, 225 (250); B, 313 (320); C, 271 (220); D, 195 (160); E, 491 (430); G, 172 (115); H, 144 (160); I, 121 (110); J, 221 (180). Unit II—September, 1939: C, 700 (640); A, 800 (500). April 1941: T, 300 (350); M, 1,200 (900). Unit III—September 1942: C, 800 (1,000).

Each pond has had a different history since first flooded and all have undergone extreme variations in water level. Some, such as B and H, have been drawn down as completely as possible for several months at a time in order to repair water regulatory structures or to manage waterfowl habitat. Even during such intervals, however, residual fish populations persisted in undrained depressions. Levels established after draw-down and alteration of control structures have invariably been lower than those first employed.

#### GENERAL LIMNOLOGY OF THE POOLS

In general physical characteristics, the pools of the Refuge are much alike. The retaining dykes extend predominantly in an east-west direction and thus determine main axes and distribution of depths for most of the impoundments. The average depth of water is between 2 and 3 feet and seldom exceeds 5, except in the borrow pits near the dykes where the extreme water depth is 15 feet.

The margins of the pools are irregular. This feature, coupled with the presence of many small islands, gives a high value for

shoreline development. The bottom is predominantly fibrous peat; sand (in borrow pits and along dykes, ridges, and islands) and bog ore (scattered patches) occur only sparingly. The water is varying light brown in color and, because of plankton and turbulence effect of wind on fine bottom materials, it is turbid (Secchi disc readings range only from 2.0 to 9.5 feet).

The principal sources of water, other than precipitation, for the pools are four streams which enter the Refuge from the north: Holland, Walsh, and Marsh Creeks and the Driggs River. Of these, the Driggs is most important and permanent and provides 80 per cent of the area's water supply at lowest stream stages (C. S. Johnson, Quarterly Narrative Report, May-July, 1939).

Surface-water temperatures in pools from late June through early August ranged from 60 to 91°F. but were mostly between 66 and 79. These temperatures fluctuated widely and rapidly but were usually close to the air temperature because of the shallowness of the water. Thermal gradients in borrow pits, however, often exceeded an average decline of 1°F. per foot of depth increase.

Dissolved oxygen in summer was ordinarily at or near saturation except near the bottom of a few of the deeper borrow pits (where it was never completely depleted). Anaerobiosis occurred under the ice cover of pools having little or no stream flow through them as evidenced by occasional winterkill of fish.

The water in the pools was not extremely hard; the methyl orange alkalinity ranged from 27 to 75 ppm. Except for impoundment T in Unit II, which was slightly acid (pH 6.0), pH values ran from 7.2 to 9.7. Pollution did not exist on the Refuge or on its tributaries in an amount that might be biologically significant.

Water plants, although most were submerged, flourished in the pools and constituted one of their most evident biological characteristics. The sources of this vegetation were both natural and artificial. Natural invasion was primarily exemplified by *Anacharis (Elodea) canadensis*, which apparently came from the streams of the area where it occurred in quiet back-waters upstream from the impoundments. Other plants in this category were *Chara*, *Nitella*, *Polygonum*, *Myriophyllum*, and *Utricularia*. Species planted (but also perhaps of native

origin) include *Najas flexilis*, *Scirpus* spp., *Vallisneria spiralis*, *Potamogeton pectinatus*, and, sparingly, *Zizania aquatica*.

Plankton and insect naiads and larvae were abundant in Refuge waters. The most evident plankton was algae which often formed conspicuous surface blooms. Measured volumes of plankton in gravity-concentrated, formalin-preserved samples ranged from 0.1 to 2.3 cc. per 10 gallons of sub-surface water and averaged about 0.5 cc.

Chief invertebrates were the aquatic stages of mayflies (Ephemeroptera) and dipteran midges (Ceratopogonidae and Tenedipidae), leeches (Hirudinea), and crayfishes (Decapoda). Numbers of invertebrates other than crayfish ranged from 23 to 748 per square foot of bottom materials, as sampled by Ekman dredge. Many of the kinds represented are of value as food for fish, as well as for waterfowl (shown by duckling food studies made by Uhler and reported by Beard, 1953:425). The leech and crayfish populations appeared to be more abundant than in nearby natural waters.

Sport fishes and several species which they use for food inhabited the refuge waters. As far as practicable the names employed follow those in Special Publication No. 1 of the American Fisheries Society, 1948.

#### SPORT FISHES

*Esox lucius* Linnaeus. Pike. Common in all pools and present in tributary and effluent streams.

*Salmo trutta fario* Linnaeus. Brown trout. Stocked and seasonally common in streams entering from north.

*Salvelinus f. fontinalis* (Mitchill). Eastern brook trout. Rare in streams entering from north.

*Stizostedion v. vitreum* (Mitchill). Yellow wall-eye. Reported rare following introduction by stocking in Pools E, F, I, and J in 1938. None were seen during this study.

*Perca flavescens* (Mitchill). Perch. Common in pools.

*Lepomis gibbosus* (Linnaeus). Pumpkinseed. Common in pools.

*Lepomis m. macrochirus* Rafinesque. Bluegill. Ripe fish (11 males and 75 females) introduced into Pool I in June 1942. Established sparsely there by 1944 and in Pool F by 1952. Not otherwise encountered in 1941-1943 collections.

*Ameiurus n. nebulosus* (LeSueur). Northern brown bullhead. Common to abundant in all pools.

#### FORAGE FISHES

*Catostomus c. commersoni* (Lacépède). White sucker. Uncommon in pools.

*Moxostoma aureolum* (LeSueur). Golden redhorse. Rare in pools and streams.

*Semotilus a. atromaculatus* (Mitchill). Northern creek chub. Uncommon in streams.

*Rhinichthys atratulus meleagris* Agassiz. Western blacknose dace. Uncommon in swifter portions of streams.

*Chrosomus eos* Cope. Northern redbelly dace. Common in pools and in their tributaries and outlets.

*Notemigonus crysoleuces auratus* (Rafinesque). Western golden shiner. Common to abundant in all pools.

*Notropis d. dorsalis* (Agassiz). Rare in few pools and affluents.

*Notropis v. volucellus* (Cope). Northern mimic shiner. Rare.

*Notropis h. heterolepis* Eigenmann and Eigenmann. Northern blacknose shiner. Mostly common to abundant in all pools.

*Pimephales p. promelas* Rafinesque. Northern fathead minnow. Abundant in pools.

*Pimephales notatus* (Rafinesque). Bluntnose minnow. Common in pools.

*Umbra limi* (Kirtland). Western mudminnow. Rare to common in pools, particularly in small isolated parts, including beaver ponds and in marshy affluents.

*Hadropterus maculatus* (Girard). Blackside darter. Rare in pools, present in tributaries.

*Boleosoma n. nigrum* (Rafinesque). Central Johnny darter. Rare in pools and affluents; most common on sandy bottom.

*Poeciliichthys exilis* (Girard). Iowa darter. Common to abundant in pools.

*Poeciliichthys flabellaris lineolatus* (Agassiz). Northern fantail. Rare in swifter portions of streams entering from north.

*Cottus b. bairdi* Girard. Northern muddler. Rare in tributaries.

*Eucalia inconstans* (Kirtland). Stickleback. Common in rivulet affluents and in marshy portions of pools, including beaver flowages.

#### CHARACTERISTICS OF PIKE POPULATION

DISTRIBUTION — Although pike were spread throughout the waters of the Refuge,

the distribution was uneven and changed seasonally and with life-history stages. Other than in headwater marshes during spawning season (presumed), locations of greatest concentration of adults were always associated with moving and/or deeper water. In late May, particularly large numbers of adults were found in moderate to strong currents on the downstream sides of various barriers to movement constituted by low dams, spillboxes (where water from one pool would fall a few feet into the next one downstream), gate-valves, etc. These fish were probably post-spawning migrants which had concentrated in the flowing channels after leaving the marshy spawning grounds and before dropping downstream to summer habitat in pools. Similar aggregations, although not so numerous, were found at the dam over which Pool D falls into Pine Creek. Here, however, the concentration extended in some degree throughout the summer as evidenced by occasional hook-and-line catches at the rate of 20 or more per fisherman hour during June through September in various years. In the pools themselves, adult fish were most frequently encountered from June through September in or about the margins of borrow pits. By midsummer, they were characteristically absent from the marshy portions of pools and from those bays or arms in which the water was rusty and turbid from the oxidation of iron. These distributional data are based on hook-and-line catches and on captures in gill nets, fyke nets, and seines.

Young-of-the-year pike were present in the shallowest and quietest parts of the headwater marshes in May and June. By July they had spread to water as much as two feet deep, although most stayed in water less than one foot deep. Throughout the first summer of life these fish remained in this habitat as indicated by periodic seine collections from May through September and on samples obtained in July and August by the use of rotenone.

Rarely, both young and adults became stranded by falling water levels in particular areas of seasonal concentration. Starvation and increased vulnerability to angling and to predation acted as population checks in these locations.

**NUMBERS PER UNIT AREA**—Although pike are highly predaceous fish, their populations may be relatively dense per unit area in

natural waters. Solman (1945) estimated natural populations in June and July of at least 27 individuals per acre in a section of Baptizing Creek, Lower Saskatchewan River Delta. The size of these pike was "large enough to eat ducklings" (*ibid.*, p. 168), which is estimated to be about 14 inches total length. On the Seney Refuge, approximations for comparable calendar intervals were from 10 to 12 per acre for fish of this size and larger as determined in a mark-and-recapture estimate (Schnabel, 1938), and from two poisoning experiments. That a high natural mortality may greatly change such values in a single growing season was shown by Carbine (1944) who found a 99 per cent loss of young-of-the-year from May to October.

The three best population estimates of numbers of pike older than young-of-the-year were for Pool I in Unit I and for Pools T and C in Unit II. Some statements as to certain minimal densities can also be made for other areas.

Pool I yielded 2,569 pike (about 22 per acre of its 120 acres); 560 of these were gill-netted in the spring of 1940, 290 trapped early in 1941, and 1,719 were recovered following treatment with rotenone on July 5-7, 1941. All were eight inches or more in length and were in their second year of life or older. Spot-poisoning of a six-acre section of Pool T in August 1952, killed 42 individuals (7 per acre) which ranged from 13.5 to 25.8 inches in length. Application of the Schnabel (1938) method of estimation gave an approximation of 8,647 pike for Pool C or about 12.4 individuals 14 inches or more in length for each of the 700 acres. In 1941, Pool M yielded 2,497 individuals mostly between 12 and 24 inches in length, or approximately 2 per acre. The greatest part of these fish was netted just below the spill of Pool C into the headwater marshes of Pool M.

Application of the DeLury (1947) method of population estimation to pike trapping data for 1941 (records from C. S. Johnson, Quarterly Narrative Report, May-June, 1941) provided the following approximations of standing crops: In Pools I and F, 2.3 per acre; in I, F, and J combined, 1.3 per acre. However, 2.1 fish per acre were removed from these waters while the data were being gathered and the last sets of the nets were still yielding fish. It is rather certain, therefore, that these estimates are sub-

stantially smaller than the actual populations, which are more accurately represented by the value previously given for Pool I.

The foregoing ranges of population density for pike on the Seney Refuge resemble those obtained by netting comparable game-fish waters in Minnesota (Moyle, Kuehn, and Burrows, 1950); they found 6.9 pounds per acre with a range from 0.0 to 42.5.

It appears that the standing population of pike 14 inches and greater in length may be estimated to have averaged about 10 per acre during the term of this study. If this is so, the total number of such fish present each year would approximate 60,000.

**GROWTH**—In the waters of the Seney Refuge, many pike attain the length of 14 inches during the second growth season. Average total lengths in inches for 460 individuals, collected in July through September 1941, according to number of annuli on their scales follow (the number of specimens for each average is given in parentheses): 0, 3.9 (215); I, 11.9 (74); II, 18.1 (107); III, 20.2 (51); IV, 24.8 (14); V, 24.5 (7); VI, 29.1 (1); VII, 25.4 (1). Obviously incomplete annuli were regarded as false and not counted in assessment of the foregoing (Williams, 1955).

**FOOD**—The generally piscivorous habit which is commonly associated with pike (documented by Solman, 1945: 161) is substantiated by the data in Table 1. Fish comprised about two-thirds of the food contained in stomachs of specimens collected by angling and netting and occurred in about half of all the specimens examined. Crayfish were next most abundant in volume (about one-fifth of the mass) and were present about as often as fish. There was no great difference in materials ingested in the two periods of sampling, 1941-43 and 1950-52.

The results of this detailed study supported the general findings of Refuge personnel who opened most of the 1,472 fish netted in May-June 1940, and found that fish, crayfish, and insects were the most common foods but that no waterfowl were present in the stomachs. The general consensus was that most feeding was done by pike in daylight hours and that the fish is essentially diurnal in its activity. This opinion is supported by Eddy (1954) and by the failure to catch pike on the Refuge by hook-and-line after the onset of darkness.

Ducklings were encountered in less than

TABLE 1.—FOOD OF 1841 PIKE, 12 INCHES OR MORE IN LENGTH, 1941-43 AND 1950-52, IN WATERS OF THE SENEY REFUGE, MICHIGAN, BY ANGLING AND NETTING<sup>1</sup>

Food item	Percentage frequency of occurrence		Percentage composition by volume	
	1941-43	1950-52	1941-42	1952
Mammals.....	.....	5.6	0.3	4.7
Birds.....	0.3	.....	2.1	.....
Frogs.....	2.1	6.4	2.2	5.9
Sport fish.....	20.2	25.6	36.0	35.7
Forage fish....	31.5	8.0	33.0	28.9
Fish remains...	0.2	16.8	0.5	0.8
Crayfish.....	42.9	49.6	23.1	21.4
Insects.....	11.6	8.0	1.8	0.1
Mollusks.....	0.9	1.6	0.1	0.1
Leeches.....	15.0	4.8	0.9	2.5
Number of pike	1254	125	378	84
(all of which contained food)				

<sup>1</sup> Annotated list of food items giving numbers of individuals eaten and other information. MAMMALS: *Microtus p. pennsylvanicus*, 7 individuals; remains, 1 individual. BIRDS: *Tringa flavipes*, 1; *Anas p. platyrhynchos*, 1; *Anas* sp., 2. FROGS: *Rana clamitans*, 5; *Rana pipiens*, 2; *Rana* sp., tadpoles, 17, adults, 18. SPORT FISH: *Ameiurus n. nebulosus*, 198; *Esox lucius*, 40; *Lepomis gibbosus*, 102; *Lepomis* sp., 5; *Perca flavescens*, 18. FORAGE FISH: *Catostomus c. commersoni*, 15; *Pimephales p. promelas*, 295; *Notemigonus crysoleucas auratus*, 83; Cyprinidae, 368; *Umbra limi*, 36; *Chrosomus eos*, 39; *Notropis h. heterolepis*, 9; *Poeciliichthys exilis*, 38; *Eucalia inconstans*, 81. FISH REMAINS: 57 individuals. CRAYFISH: *Cambarus robustus*, 46; *Cambarus d. diogenes*, 250; *Orconectes virilis*, 28; *Orconectes propinquus*, 10; Cambarinae, 702. INSECTS (Adults unless otherwise indicated): Ephemeroptera, 2; *Anax junius*, 4; Libellulidae nymph, 1; Anisoptera nymphs, 65; Zygoptera nymphs, 241; Trichoptera larvae, 15, pupae, 2; Dytiscidae, 2, larvae, 3; Gyrinidae, 1; Corixidae, 2; Gerridae, 8; Belostomatidae, 2; remains, 80. MOLLUSKS: Pelecypoda, 1; *Helisoma antrosom*, 8; *Campeloma* sp., 1; Gastropoda, 5. LEECHES: Hirudinea, 267. MISCELLANEOUS (Not included in Table 1): Fragments of higher plants, in 14 stomachs; fish eggs, 23; garter snake, *Thamnophis sirtalis*, 1; offal (stomach of *Esox lucius*) in 1 stomach.

one per cent of individuals 14 inches long or longer which contained food as compared to a corresponding percentage of 4.8 calculated from the data of Solman (1945). Bajkov and Shortt (1939) and Ross (1940) en-

countered values of 2.0 and 0.74 per cent respectively but apparently included in their calculations all fish regardless of size and whether or not they contained food (which would automatically make their values relatively lower than those given above). Interestingly, in Canadian waters muskrats were preyed upon by pike, but not at Seney in spite of its substantial population. An indication of the abundance of muskrats in the early years of this study at the Seney Refuge is seen in the yield of 17,000 rats to share-trappers there in the 1942 season. For the years 1944 through 1954, the annual catch of these mammals, however, has not exceeded 4,000.

**INFLUENCE OF AVAILABILITY ON FOOD HABITS**—Availability has a strong effect on the food eaten by pike. In early July 1941, Pool I was poisoned with rotenone. Small fish, mostly minnows and the Iowa darter, showed distress at the toxicant almost immediately on its application in any area, and pike were observed to feed very actively on these debilitated, erratically moving individuals. Examination of contents of the stomachs of 104 such pike showed them to be consistently gorged with small fish which composed 85 per cent of their food by volume, an increase for this category over the average food picture (Table 1). There is no reason to suspect that Pool I had a forage population sufficiently different from other refuge waters to account for this deviation in food habits and the increased availability by debilitation of the prey appears to be accountable. It may also be concluded that specimens thus obtained are unreliable for use in ordinary food studies. Data on these are not included in Table 1. In the poison series from Pool I, comparable percentages for frequency and volume respectively in each category were as follows: sport fish, 19.2 and 33.8; forage fish, 92.3 and 51.3; fish remains, 7.7 and 0.8; crayfish, 34.6 and 13.9; insects, 5.8 and trace; leeches, 8.7 and 0.2.

The influence of availability of food on pike feeding and the gluttonous propensities exhibited suggest strongly that if ducklings had been more available than they were on the Refuge, more would have been eaten.

**PREDATORY CAPABILITY OF PIKE**—Although most food organisms consumed were substantially smaller than predator pike themselves, fish ingested were sometimes

TABLE 2.—SIZES, IN MILLIMETERS, OF SOME FISH EATEN BY NORTHERN PIKE WHICH AVERAGED 20 INCHES IN TOTAL LENGTH, SENEY REFUGE, 1941-43 and 1950-52

	Average total length	Range	Number of individuals
<b>SPORT SPECIES</b>			
<i>Ameiurus n. nebulosus</i> ....	123.9	70-184	23
<i>Esox lucius</i> .....	291.9	97-375	15
<i>Lepomis gibbosus</i> .....	45.0	30-127	100
<i>Perca flavescens</i> .....	75.2	25-142	10
<b>FORAGE SPECIES</b>			
<i>Notemigonus c. auratus</i> ...	62.7	38-102	46
<i>Pimephales p. promelas</i> ..	49.1	29- 86	208
<i>Chrosomus eos</i> .....	46.4	32- 67	21
<i>Catostomus c. commersoni</i>	124.7	45-406	15
<i>Notropis h. heterolepis</i> ....	48.1	38- 64	7
<i>Umbra limi</i> .....	72.6	45-105	27
<i>Poeciliichthys exilis</i> .....	38.5	29- 68	41
<i>Eucalia inconstans</i> .....	42.9	26- 67	40
Cyprinidae.....	54.4	47- 57	5

more than half as long as the feeding individual (Table 2). Frequently a portion of the tail of such prey was seen still protruding from mouth of the captor. The anterior end of the food specimen was variously digested and ranged from superficial integumentary penetration to disarticulation and partial solution of the head bones. Actual length measurements of entire food items or replications by comparison with preserved whole individuals of the same species gave a measure of the predatory capability of pike (Table 2).

Twelve pike in the 1941-43 series taken by angling and netting contained white suckers whose original size could be ascertained. These prey organisms ranged in total lengths from 0.11 to 0.52 of the like dimension of the pike which consumed them (average, 0.25). Fifteen pike in the same lots were cannibalistic and took others with a length relationship, ranging from 0.20 to 0.56 and averaging 0.43. Earlier a 13-pound, 28.5-inch specimen had been found which contained a 2-pound sucker and a 1-pound pike. There is also a record of a 27-inch individual which had a 1.5 pound, 21-inch pike in it (C. S. Johnson, Quarterly Narrative Report, August-October, 1940).

From the point of view of fishery management, the conclusion of Moyle, *et al.* (1950) for certain Minnesota waters that pike are the most valuable fish, seems to apply at the Seney Refuge. Although spawning stocks of

pumpkinseeds and perch were present in all pools, their numbers were not great. Furthermore, it seemed unlikely that overpopulation and stunting of these or other species (except possibly the brown bullhead) might occur in the presence of pike populations such as those present.

RELATION TO WATERFOWL—On the Seney Refuge young waterfowl of a size vulnerable to predation by pike are abroad for about three months each year, as disclosed by personal observations, Refuge records, and Beard (1953). In Canadian waters Solman (1945) estimated that the same period lasted for about 80 days. Extremes of the calendar interval concerned are in April and August, with specific dates varying according to weather of the year and bird species. At Seney, ducklings occurred in only 3 (0.2%) of 1,218 pike (14 inches in length or longer) taken during this interval.

To complement the information on the low incidence of pike predation on ducklings, many broods were observed for different lengths of time from blinds or by stalking. In all instances they were watched on water areas in which it could be assumed with certainty that pike were present. These broods were under close scrutiny for a total of 5,535 duckling minutes in May and June of 1942. The young were all small, less than one-quarter grown (mostly about fist-size), and could easily have been taken by the average 20-inch pike present. Kinds included black duck, mallard, ring-necked duck, American merganser, hooded merganser and Canada goose. Numbers in the broods ranged from 5 to 12. No evidence of pike predation was seen and no birds showed alarm. To the foregoing kinds may be added baldpate, blue-winged teal and wood duck, the young (and adults) of which were kept under rather intensive surveillance by Beard (1953) both in pools and adjacent beaver marshes with no indication of pike disturbing them.

That pike are not consistently a menace of young waterfowl was disclosed in two simple experiments. In one of these, a live downy mallard was tethered to a fly-fishing rod with 25 feet of monofilament 2× leader material. The living bird was then towed and guided over and through the water of a spill-pool. It was not attacked by pike, yet at this spot, 10 minutes before beginning the trial, a 25-inch pike had been hooked

and released and within 15 minutes of the end of the experiment two additional specimens, 20 and 26 inches long (both with empty stomachs) had been caught. The fish were taken on a 5/8-ounce casting spoon "gold-plated" on both sides, carrying a treble hook, cast in the areas frequented by the tied bird, and retrieved within one foot or less of the water's surface.

In another experiment, 8 pike ranging from 19 to 26 inches in length were placed in a 3-by-8-foot hardware-cloth enclosure in a foot of water. Although the pike fed somewhat reticently on sunfishes and minnows offered them on three successive days, they did not take two downy mallards left in the enclosure for 12 hours on the fifth day of the series.

The 0.2 per cent incidence of waterfowl in pike food may be compared with the findings of Solman (1940 and 1941 manuscript reports to Ducks Unlimited, Winnipeg) in the Lower Saskatchewan Delta, Manitoba. As computed from Solman's data (*ibid.*), frequency of occurrence of ducklings was approximately 3.8 per cent (29 of 759 pike which had food in them and were 14 inches or longer contained ducklings). About 19 times as many pike in Manitoba waters contained young waterfowl as in the Seney area. This greater frequency may be due to the presence per unit of area of more ducklings, of more pike, of fewer buffer forage organisms, or to different interactions of these and other habitat variables. The protective role of abundant forage fishes of Seney and the apparently lesser number of birds and of pike certainly could account for the total difference. The average size of pike in both populations is much the same with the greatest numbers of individuals of avian predatory capacity falling between the lengths of 14 and 17 inches and ranging upward to 3 feet in length (but with individuals studied for food averaging about 20 inches).

In the Canadian waters studied for Ducks Unlimited (Solman, 1945), the loss of ducklings was estimated at one for each 1.4 acres of water or, 0.6 bird per acre) during the 39-day period from June 13 to July 21, 1941. Feeding experiments showed that, on the average, 0.43 per cent of the weight of duckling is digested per hour by pike (19 to 29.5 inches long) and that about 10 days is required for complete digestion! Since duck-

lings were found to be available to pike for about 80 days in the 1941 season it was considered possible that a pike might eat 8 ducklings during this period. Assuming no interval between feedings the loss of ducklings was estimated as follows (on tenuous ground): With a pike population estimated at 27 per acre, of which about one per cent was presumed to eat ducklings on eight occasions during the season, the calculated loss of ducklings amounted to about two ducklings per acre per season. This did not diverge greatly from the observed loss of 0.6 duckling per acre for 39 days (half of the season). The observed loss is, of course, smaller since it is unlikely that the total loss would show in a study of this kind. If the actual loss is between the observed and calculated figures, it might equal about one duckling per 0.6 acres (1.7 per acre) of this type of water area per person. If identical conditions are assumed for Seney, a loss of one duckling for each 0.6 acre of water per season, for an estimated 6,000 acres the loss would be some 10,000 ducklings. But, this is perhaps more ducklings than are produced annually on the area and since some young come all the way through the season, this cannot be the case. In some of the better-than-average brood areas of the Refuge, Beard (1953) reported a mean production of about three young (range, 1.7 to 4.6) per acre per year for 1947 through 1949.

#### CONTROL OF PIKE

The biological and economic risks of predator control and the oft-times undesirable, and sometimes unexpected, results of this practice are generally known among biologists. On the basis of present information on the Seney Refuge, certainly it would be unwise to instigate any wholesale decimation of pike. Yet much could be learned of value here and elsewhere by the conduct of a sound, long-range experimental program.

Some common methods commensurate with marsh- and water-bird production by which pike populations may be reduced are gill netting, seining, trapping, poisoning, dynamiting, and angling.

**GILL NETTING**—Gill netting as a means of removing pike was tried on the Refuge during 1940 (C. S. Johnson, Quarterly Narrative Report, May-July, 1940) and in this study in 1941. Several were taken but the abundant brown bullheads clogged the nets

and required many man hours for their removal because the serrate pectoral spines of this catfish became entangled in the mesh. One three-and-a-quarter-hour set of 100 feet of a 3-inch-stretch-mesh gill net in a spill-pool yielded 8 pike and 47 bullheads (Collection L41:627). Another set of this gear overnight in another plunge basin of the same kind took 11 pike and 118 bullheads (L41:643) and required two man hours to clear the net of the catfish. Although most of the bullheads were living when the net was lifted, almost all of the pike were dead. The same fate was reported for practically all of 1,472 pike taken by this means in 1940 (C. S. Johnson, *op. cit.*).

**SEINING**—Seining is adaptable for pike removal in waters free from obstructions. Artificial impoundments such as most of those at Seney contain too many snags for this method to be used efficiently. In addition, seining under any circumstances would be most effective in reducing the numbers of small pike and would be least effective for individuals 20 inches and more in length which are the most serious menaces to waterfowl (Solman, 1945). Cost per pike taken in seining operations on the Refuge in 1941 was 4.8 cents (C. S. Johnson, Quarterly Narrative Report, May-July, 1941).

**TRAPPING**—Trapping with fykes or other shallow-water trap nets is about as satisfactory a means for taking pike as is gill netting. It has an advantage, in that most fish caught are in good condition for transferral to other waters—and pike are currently deemed very valuable as population controls in certain sport-fish complexes (Smith, 1941). However, individuals of certain sizes, depending on the mesh of the trap twine, tend to gill themselves, and others to injure themselves by ramming the sides of the net. More than a thousand specimens were taken in trap nets in the spring of 1941 for transplantation to state waters at an approximate cost of 57 cents per fish (C. S. Johnson, Quarterly Narrative Report, May-July, 1941).

Traps in the form of weirs have been shown to be effective for capturing pike (Carbine, 1942 and 1944). They are particularly applicable to small watercourses traversed by adults enroute to spawning grounds or by young on migration from the marshes in which they hatched. A makeshift mechanical weir was operated at the outfall

of Pool C into the head-marsh of Pool M and captured 266 individuals longer than 14 inches from June 9 through 19, 1943. Adaptation of electrical or electro-mechanical weirs such as used in sea lamprey control (Applegate, Smith, and Nielsen, 1952), almost certainly would have been as effective. The use of barriers to keep pike away from breeding and brood areas of waterfowl, as reported effective by Benson (1941) in Manitoba, would not be applicable here.

**POISONING**—Poisoning of waters with rotenone can be a successful method of killing pike as first suggested by E. E. Crawford (in Refuge Biological Report, manuscript, 1935). The method is not absolute, however, and is not at all selective in most situations. Approximate cost per pike in Pool I in 1941 by this means was 5.4 cents. Most of the individuals destroyed, however, were young of the year.

An opportunity for control peculiar to a development such as the Seney Refuge would be by induced winterkill. In some pools at this station winterkill could be brought about merely by shutting off the inflowing water at existing control structures. As indicated previously, winterkill has occurred naturally (*e.g.*, C. S. Johnson, Quarterly Narrative Report, May-July, 1938) in some of the isolated portions of certain of the impoundments and may at least partly account for apparent variations in pike population from pool to pool.

**DYNAMITING**—Selective use of explosives on concentrations of pike would doubtless kill individuals of the species. However, the two attempts which were made during the course of this study failed. In the summer of 1952, a submerged 2-stick and a 3-stick charge of dynamite were detonated successively in two borrow-pits of Pool A in Unit II. Pike were presumably present in these waters when the detonations took place but only small minnows (mostly golden shiners and blacknose shiners) were seen killed and were dipped from the water. The same two depressions were then poisoned with rotenone. No pike appeared in this trial either. Perhaps none were present or else they fled the disturbances. The area was not isolated from the main pool.

**ANGLING**—Angling is another method that has been used for removing pike as well as collecting them for study. The means has been both popular with the public and

has afforded considerable recreational benefit while in progress. Certain waters of the Seney Refuge were opened for sport fishing in an experimental control program during parts of the years 1941 through 1944 and such fishing for this species has been adopted as general policy since then. In the four years mentioned, nearly 3,000 anglers took almost 4,500 pike 14 or more inches in length. The most common form of fishing was bait-casting with treble-hook spoons in the daytime from the dykes.

Several things favor the use of angling on a permit system for pike control, at least in situations such as that at the Refuge: (1) the fishery is selective for the sizes of pike which constitute the greatest potential hazard for waterfowl; (2) sound recreational and educational values are obtained; (3) the angling pressure can be controlled and shifted from pool to pool as desired; (4) it is possible that an index to the level of the pike population may be developed from creel census returns and used as a basis for shifting or intensifying the rod pressure.

Unrestricted use of angling as a control, however, might be a greater menace to waterfowl production than the pike would be if left alone. Human disturbance of ducks during the rearing and post-nuptial moult periods has been shown to cause them to desert parts of the refuge pool and marsh areas (Beard, 1953). However, the use of a permit system for confinement of public travel and fishing activities to regions adjacent to the deepest open waters (along selected dykes) has afforded control where desired along with recreational use. Such regulated exploitation of the fishery resource has apparently conflicted very little with the best psychological interests of the birds during the period critical for them.

An inventory of anglers' catches was kept for the fishing seasons on the Refuge during the years 1941 through 1944 (Table 3). In all, 1,080 parties composed of 2,951 fishermen and an uncounted number of accompanying visitors used the resource. The anglers put in 9,707 recorded hours of fishing for pike in addition to much unlisted time for perch and bullheads. The total catch of legal-sized pike (14 inches) was 4,714 and gave an average return of 0.46 fish per hour (equivalent to a 20-inch pike for every two hours of fishing; actual size range of those caught was 14 to 40.5 inches).

TABLE 3.—SUMMARY OF CREEL CENSUS ON PIKE FISHING, SENEY REFUGE, 1941-1944

	Sept. 12- Dec. 17 1941	May 15- July 31 1942	May 23- July 31 1943	May 15- Aug. 15 1944
Number of parties . . . .	100	442	342	196
Number of fishermen . . .	235	1238	866	552
Keeper pike caught . . .	531	1426	2107	384
Average length of legal- sized fish (inches) . . .	19.6	19.9	20.7	20.9
Small fish caught . . . .	70	62	201	16
Parties that caught no fish . . . . .	20	143	50	56
Fisherman hours . . . . .	733.0	4287.8	3598.7	1087.5
Number of pike per fisherman hour . . . . .	0.72	0.33	0.59	0.35

That both population density and angler savvy are related to fishing success was shown in the Seney records as elsewhere (Lagler and de Roth, 1953). In four successive years, 1941-1944, the catch per hour for legal pike ran successively 0.72, 0.33, 0.59, 0.35. In the first year the fishing was done mostly by local residents. Sites knowingly chosen were widely distributed and were the natural areas of concentration for pike. In 1942, when the return dropped to 0.33 legal fish per angler hour tourists and others joined in the public fishing which was confined principally to the northern and eastern parts of Pools C, E, and F. In 1943 it was chiefly carried out in more recently flooded pools of Unit II (M, C, and A) and the take increased. In 1944, A, B, D, and the southern part of E, all in Unit I, bore the load, and the catch per unit of effort fell again. However, the general impressions relative to differences in population density of pike obtained from personal netting, angling, and survey of the pools were substantiated by the creel returns.

#### SUMMARY AND CONCLUSIONS

Habitat favorable to pike and to waterfowl, as well as to a wide variety of other marsh and aquatic organisms, was created by flooding portions of the lowlands at the Seney National Wildlife Refuge in the years 1936 through 1942.

Within five years of inundation pike appeared in all 19 of the refuge pools in numbers up to at least 22 per acre (exclusive of young-of-the-year) and averaged between 19 and 20 inches in length (based on gill-net,

trap, and hook-and-line samples of upwards of 6,700 individuals from all pools).

Fish and crayfish were by far the most important and most consistently eaten food of 1,841 pike 12 inches or more in length taken by angling or netting. Waterfowl were present in only 3 of 1,218 pike 14 inches long or longer which were collected during the 90-day waterfowl brooding season (percentage frequency of ducklings in this lot of pike was about 0.2). Pike were profoundly influenced in their feeding by availability of small forage minnows, on which they gorged themselves during a control experiment with rotenone. However, they spurned tethered ducklings in natural waters and free-swimming individuals in an experimental enclosure when the birds were offered for relatively brief periods.

The basis for pike control on the Seney Refuge rests upon the following premise, in part at least warranted by the data in hand: elimination of each 500 pike "meals" may be expected to result in the saving of the life of a duckling. Unfortunately the frequency with which pike feed is not known so that the "meals" cannot be translated accurately into numbers of pike to be removed. Experiments on periodicity of feeding, for example those of Solman (1945), are too tenuous to be acceptable for use in extrapolation. If, however, each of the pike on the Seney Refuge large enough to eat a duckling, had a meal per day, and if there are as many as 60,000 such fish on the area, some 60,000 meals are eaten daily. Ducklings are available to pike for about 90 days each year on the Refuge. The duck population is thus exposed, in this hypothesis, to a predation pressure of 5,400,000 pike-meal-units per season. The observed incidence of approximately one duckling in each 500 pike opened (of sizes large enough to eat ducklings and all containing some food) might be considered as an incidence of one such bird per 500 meals. This could mean an annual duckling mortality on the area of 10,800.

Of several means of control tried on the Refuge, angling had the widest human appeal and appeared to cost least per fish removed. Unless properly restricted, however, it was recognized that angler activity might interfere with waterfowl production as much or more than the pike themselves, by disturbing the parent birds.

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Accepted for publication July, 1954.