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Northern Pike, *Esox lucius*, in Alkaline Lakes of Nebraska

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Northern Pike, *Esox lucius*, in Alkaline Lakes of Nebraska[1]

Pike (*Esox lucius*) were studied in alkaline sandhill lakes from 1956 through 1961. Fry and fingerlings were released in alkaline environments as part of a continuing ecological study of survival and growth of northern pike in Nebraska waters. Survival and growth were determined by intensive nettings at release sites. Chemical, biological, and physi-

[1] A contribution of Federal Aid to Fisheries Restoration Project F-4-R (Nebraska).

TABLE 1.—*Survival of pike introductions in Nebraska habitats of varying alkalinities*

Lake or Pond	Concentrations in p.p.m.[1]						pH	Area (acres)	Survival
	CO_3	HCO_3	SO_4	Cl	Na	Total solids			
Smithys	769	2,035	120	325	1,800	3,449	9.8	40	50–58 hours
Hudson	290	1,282	30	50	—	1,710	9.5	131	Successful
Big Alkali	110	693	9	17	240	1,024	9.3	842	Successful
Ell	222	325	7	75	267	544	9.5	120	Successful
Smithy #1	254	633	600	234	4,200	9,230	10.5	0.5	36–48 hours[2]
Smithy #2	960	2,980	860	300	3,200	11,600	10.8	0.3	Unsuccessful[2]
Brunner	103	595	12	400	347	595	9.0	38	Successful
Little Alkali	1,139	3,369	344	350	1,184	6,250	10.3	38	6–12 hours
Skull	88	845	80	28	—	2,500	9.5	60	Unsuccessful
By-Way	598	1,795	—	200	—	2,480	9.8	36	Unsuccessful
Enders	31	315	15	87	—	376	9.0	367	Successful
Alkali	103	889	—	75	—	1,026	9.1	375	Successful

[1] Chemical data reflect average maximum readings during fall months. Potassium is included with sodium.
[2] Fry releases only.

cal characteristics of each lake were investigated (Table 1).

The majority of the nearly 2,000 Nebraska sandhill lakes may be classified as alkaline eutrophic of the bicarbonate–sulfate group (McCarraher[2]). Salts other than chlorides predominate in these natural lakes supporting a biota somewhat different from inland chloride or saline waters. The sandhill lakes differ chemically from inland mineral areas in other regions (Rawson and Moore, 1944; Huntsman, 1922; Moyle, 1956; Young, 1924).

The terms saline and alkaline have been used interchangeably by some investigators in the past when referring to inland mineral waters. Water quality is continually changing thus involving not only chemical concentrations but the physical and biological environment as well. The Nebraska, Minnesota, Saskatchewan, and North Dakota mineral waters may be classified as alkaline whereas the salterns and inland brine lakes of Utah, Nevada, and California are saline types.

The chemical–biological environment of Devils Lake, North Dakota, was discussed by Young (1924). Before 1889 this lake supported abundant pike populations in association with the ninespine stickleback (*Pungitius pungitius*) and fathead minnow (*Pimephales promelas*). Pike disappeared from Devils Lake as salinity increased from less than 0.3 percent in 1889 to 1.5 percent in 1923 with proportionally increased sodium, bicarbonate, and sulfate values. The loss of pike probably resulted primarily from increased salinity and secondarily from the loss of suitable spawning habitat. More recent introductions of pike in Devils Lake in salinities of 0.8 to 0.9 percent bicarbonate values between 600–705 p.p.m. and sulfate from 3,000–4,000 p.p.m. have evidently failed. The pH at a high of 8.7 was well below threshold limits.

Big Stone Lake is described as one of the more alkaline waters in Minnesota with a good northern pike population.[3] Bicarbonates here are from 112 to 167 p.p.m. and monocarbonate between 0 and 12 p.p.m. The pH values usually range from 8.0–9.0. Sulfates at 317 p.p.m. exceed normal readings for Nebraska pike lakes. All of the high carbonate and sulfate lakes in Minnesota physically suited for fish are capable of raising northern pike. Thus, high salinities and total alkalinity are not a limiting chemical condition in these waters.

In Saskatchewan, pike apparently disappeared from water having more than 6,034 p.p.m. salinity (Rawson and Moore, 1944). Bicarbonate alkalinity (Table 2) seldom influenced pike survival in the Saskatchewan Lakes, and all the pH values were below survival thresholds recorded in Nebraska. The pH range for six pike lakes having high concentrations of sulfates was 8.3 to 8.9 with an average of 8.5. These lakes might be described as sulfate mineral waters with some intermediate mixtures between sulfate and chloride types.

Huntsman (1922) found pike in the saline waters of the Quill Lakes in Saskatchewan. The water chemistry structure of the Quill Lakes and Devils Lake is similar, but a number of physical differences exist. Pike were common in Big Quill Lake between 1910 and 1913 when the salinity ranged from 1.6 per-

[2] McCarraher, D. B. (1961) Sandhill Lakes Survey. Job Completion Report, F-4-R, 1954-61: 1-83.

[3] Personal communication from John B. Moyle.

TABLE 2.—*Comparative percent composition of total solids for alkaline pike habitats in Saskatchewan, Minnesota, North Dakota, and Nebraska*

	Saskatchewan Lakes[1]	Big Quill Saskatchewan 1922	Devils Lake North Dakota 1911	Big Stone Lake Minnesota	Nebraska Lakes 1954–62[2]
CO_3	1.4	14.2	0.0	1.9	18.6
HCO_3	11.6	0.8	9.0	26.1	67.3
SO_4	57.3	50.6	54.1	49.6	1.8
Cl	3.3	11.7	10.5	1.9	1.4
Na	11.6	15.3	25.9	5.7	3.5
Mg	10.6	7.1	4.5	6.9	6.7
Salinity (percent)	.28	1.6	.84	—	.11

[1] Lakes are Lenore, Fishing, Wakow, Last Mountain, Carlyle, and Echo (Rawson and Moore, 1944).
[2] Lakes are Hudson, Big Alkali, Alkali, Ell, Brunner, and Enders.

cent to 1.9 percent. Aside from pike, nine-spine stickleback and the white sucker (*Catastomus commersoni*) were the only species recorded.

DISCUSSION

In Nebraska, successful introductions of pike have been made in alkaline sites where the mean annual total alkalinity values do not exceed 1,000 p.p.m. Monocarbonate and bicarbonate ions are high, but other salts are proportionally low. About 95 percent of North American waters supporting fish life have a pH less than 8.6. The majority of sandhill lakes in Nebraska containing pike have pH values between 8.5 and 9.5. Carbonates, in themselves, are not especially detrimental to fish life. However, their buffering action upon pH may cause a high pH toxicity value over a prolonged period.

High alkalinities have an important effect in lowering the temperature of maximum density, resulting in vernal circulation the year around. Dissolved oxygen content remains adequate for pike survival in alkaline lakes having an average depth of four feet. Alkaline lakes sustain only trace amounts of free carbon dioxide. This is due in part to the withdrawal of bicarbonate at a greater rate than monocarbonates are precipitated and to pH above 8.6.

Fish growth-rate variation in alkaline water is thought to be a function of physical and biological environment rather than water chemistry. Northern pike from Big Alkali and Hudson Lakes have recently exhibited a bleached coloration. Bennett and Pedley (1930) indicated that certain fish species found in Big Alkali Lake, Nebraska, were bleached by the alkaline water.

In carbonate alkalinities of about 800 p.p.m., some fish species became covered with a thick coat of slime with inflammation of skin and with noticeable loss of color near the fins (Young, 1922).

The physiological effect of increasing alkalinity on the reproductive potential of pike was observed in Big Alkali Lake during 1956–58 where alkalinity increased 40 percent during a 10-month period. Netting in the spring of 1959 failed to take ripe fish, and potential spawners placed in hatchery freshwater ponds failed to reproduce. Subsequent spawning run collections confirmed the lack of a 1959 year-class in Big Alkali Lake.

Physiological effects of various salt combinations on pike reproduction and consequent species survival have been recorded from Devils Lake, North Dakota (Young, 1924). Northern pike began disappearing from the lake after 1889 when the water level was decreasing and total alkalinity increased above 800 p.p.m. The total salt content had risen from 8,471 p.p.m. in 1889 to a high of 15,210 p.p.m. by 1923.

Aquatic vegetation in Nebraska lakes is primarily sago pondweed (*Potamogeton pectinatus*), muskgrass (*Chara* sp.), and hardstem bulrush (*Scirpus acutus*). These plants are associated with pike spawning sites in lakes with closed drainage basins. Sago pondweed is present in nearly 80 percent of the alkaline lakes, and is important in providing adequate spawning habitat. Huntsman (1922) reported *P. pectinatus* as the only submergent aquatic plant found in the Quill Lakes of Saskatchewan.

Introductions of fathead minnow in three lakes survived only in Hudson Lake (Figure 1). The fathead minnow appears to withstand total alkalinity approaching 1,400 p.p.m. and a pH near 9.8. This species is an important forage fish for young pike. The fathead minnow was also widespread in all the saline lakes of Saskatchewan having salinities below 29,000 p.p.m. (Rawson and Moore, 1944). Axolotls, common in Nebraska alkaline lakes, provide abundant forage for adult pike.

Numerous prairie pools contain phyllopod shrimp during the spring months. Both ano-

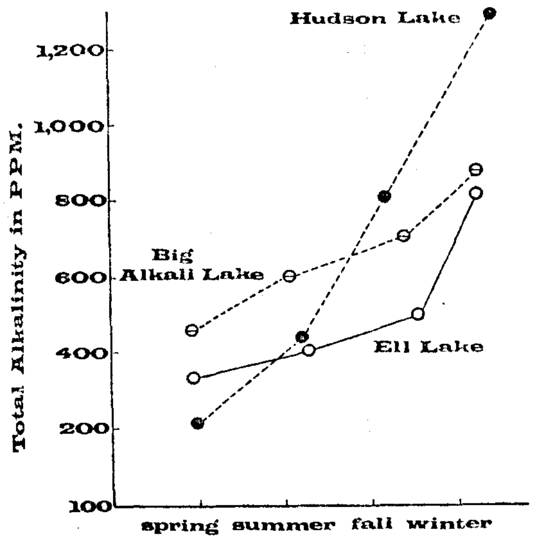

FIGURE 1.—Total alkalinity recorded in four seasons.

stracan and notostracan shrimps are seasonally abundant in these drainage pools and are forage items for fingerling pike (McCarraher, 1959). The salinity of many pools (0.5–3.5 percent) exceeds that of the lake basin. For the most part these shrimp tend to drain into the lake. On occasion pike have entered these alkaline pools to feed on shrimp.

CONCLUSIONS

The northern pike is moderately euryionic and has survived in Nebraska waters having average pH values of 9.5. A permissible range of 9.5–9.8 has been recorded for periods up to four months. Prior acclimatization appears to increase euryionic tolerance levels. In Nebraska, 48 percent of the pike habitat exceeds the 9.0 pH level. The tolerance of pike to variations of water alkalinity is not uniform. Salinity, an expression of all ionic constituents present, may not delimit pike survival because the actions of the bicarbonate and monocarbonate ions become toxic before salinity reaches lethal levels.

Of Nebraska's alkaline lakes that support pike, 15 percent have less than 250 p.p.m. of bicarbonate, 60 percent have less than 400 p.p.m., and 95 percent have less than 600 p.p.m. Bicarbonates comprise 86.6 percent and monocarbonates 13.2 percent of total alkalinity values for pike habitat. In those mineral waters which do not support fish life, about 75 percent of the alkalinity is bicarbonate whereas 25 percent is monocarbonate. The ratio of bicarbonate to monocarbonate does not drastically change from the moderately alkaline to the highly alkaline lakes. Pike did not survive over a 12-month period in waters having total alkalinities in excess of 1,200 p.p.m. Bicarbonate levels in Nebraska lakes were 60.8 percent greater than recorded for pike habitat in Saskatchewan, North Dakota, and Minnesota. However, sulfate ion levels are considerably lower. Seasonal variations in the bicarbonate and monocarbonate ions are characteristic for most alkaline lakes and become pronounced in those lakes having total alkalinity values above 400 p.p.m.

Growth of pike populations residing in mineral waters with total alkalinity limits near 1,000 p.p.m. appears to be slightly less than the calculated average in less alkaline waters. It has not been determined whether a gradual increase of alkalinity content will cause the suppression of annual growth increment if other environmental conditions remain equal.

Fry appear to be more sensitive to extremes of pH, bicarbonate, and monocarbonate than adults. This lack of tolerance undoubtedly accounts for failures of fry introduced into several lakes (Table 1).

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