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Vol. 28, No. 11, November 1971

Journal of the Fisheries Research Board of Canada

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Reprinted from
Journal of the Fisheries Research Board of Canada
Vol. 28, No. 11, p. 1811–1814, 1971

Survival of Some Freshwater Fishes in the Alkaline Eutrophic Waters of Nebraska

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McCarraher, D. B. 1971. Survival of some freshwater fishes in the alkaline eutrophic waters of Nebraska. J. Fish. Res. Bd. Canada 28: 1811–1814.

Of 14 species of freshwater fishes held in cages in one or more of 13 alkaline lakes and ponds in Nebraska, few species survived more than a month where carbonate alkalinity, mostly as compounds of Na_2CO_3 and KCO_3, was above 300 mg/liter. Of the 14 species tested, Sacramento perch (*Archoplites interruptus*), fathead minnow (*Pimephales promelas*), northern pike (*Esox lucius*), and the black bullhead (*Ictalurus melas*), were the most tolerant of alkaline environments. Most centrachid fishes except *A. interruptus* and the green sunfish (*Lepomis cyanellus*), did not survive more than a month in alkaline waters greater than 950 mg/liter total alkalinity. A lake classification index for slightly alkaline to strongly alkaline environments is presented, along with suggested fish species for introduction into such waters.

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Sur un total de 14 espèces de poissons dulcaquicoles maintenus en cages dans un ou plusieurs de 13 lacs et étangs alcalins du Nebraska, peu d'espèces survécurent plus d'un mois là où les carbonates alcalins, surtout des composés de Na_2CO_3 et KCO_3, dépassaient 300 mg/liter. Des 14 espèces soumises aux essais, la perche de Sacramento (*Archoplites interruptus*), le méné à grosse tête (*Pimephales promelas*), le grand brochet (*Esox lucius*), et la barbue noire (*Ictalurus melas*), se sont avérés les plus tolérants pour les milieux alcalins. La plupart des centrarchidés, sauf *A. interruptus* et le crapet vert (*Lepomis cyanellus*), n'ont pu vivre plus d'un mois dans des eaux d'alcalinité totale excédant 950 mg/liter. On présente un index de classification des lacs, de légèrement à fortement alcalins, et on suggère les espèces à introduire dans chacun de ces milieux.

Received December 14, 1970

Past investigations into the survival of freshwater fishes in the inland mineral waters of North America have been directed mainly toward the chloride–sulfate type of habitat (Rawson and Moore 1944). This report on inland mineral lakes describes water quality characteristics of 13 lakes of various alkalinities scattered throughout the 52,000 km^2 sandhill region of Nebraska. Field investigations were conducted from 1960 to 1967 to determine the survival of 14 fish species in one or more of the 13 lakes. Based partially on these experimental results, a list of fish species is suggested for introduction into slightly alkaline to strongly alkaline environments.

The ecological relation between alkalinity and northern pike (*Esox lucius*), fathead minnow (*Pimephales promelas*), and the Sacramento perch (*Archoplites interruptus*), along with a general limnological assessment of these lakes was described earlier (McCarraher unpublished data 1962; McCarraher and Thomas 1968; McCarraher and Gregory 1970).

Methods and materials — Some of the experimental fish (*Micropterus salmoides*, *M. dolomieui*, *Ambloplites rupestris*, *Ictalurus punctatus*, *Morone americana*, *M. chrysops*, and *Pomoxis nigromaculatus*) were taken from hatchery stock and selected for robustness and freedom from external parasites. The remaining species (*E. lucius*, *Stizostedion vitreum vitreum*, *Cyprinus carpio*, *Lepomis cyanellus*, *Perca flavescens*, *Ictalurus melas*, *A. interruptus*, and *Aplodinotus grunniens*) were captured by seines and frame nets from freshwater lakes. All species were either age I or II and were chemically–thermally tempered to lake water for 2–4 hr.

The fish, except those of two species, were then released into 1.1-m^3 cages constructed of 8-mm mesh galvanized wire, and the cages anchored near shore in about 0.5–1 m depth. The cages were examined each hour for the first 6 hr and dead or distressed fish removed. If the fish survived the initial 48-hr period, the cages were then checked every 2–3 days. That mortality of the experimental fish was due to starvation rather than the direct influence of alkaline

Printed in Canada (J1993)

TABLE 1. Survival of some freshwater fishes and related water chemistry, in milligrams per liter, in Nebraska lakes of various alkalinities.

Lake	Survival time[a]	Total alkalinity range	Average CO_3 alkalinity	Total dissolved solids	pH	Cl	SO_4	K	Na	Ca	Total hardness
				Northern pike							
Big Alkali	Indefinite	460–950	130	1120	9.3	20	14	90	210	38.0	50
Smithys Pond #1	36–48 h	886–880	254	9230	10.5	235	600	–	4200	50.0	12
Hudson	12–14 m	820–1250	290	1170	9.5	30	30	300	350	20.0	200
Smithys L.	50–58 h	2035–2050	769	3449	9.8	140	120	1800	1600	35.0	120
Smithys Pond #2	6– 8 h	3936–3940	960	11600	10.8	300	860	–	3200	0.0	140
Little Alkali	6–12 h	4500–4508	1139	6250	10.3	350	344	–	1184	4.0	10
				Walleye							
Big Alkali	2– 4 y	300– 980	85	860	9.3	17	12	80	120	30.0	42
Smithys L.	10–18 h	1890–1895	714	2315	9.6	160	40	750	1000	48.8	114
McKeel Pond #2	28–30 d	1921–2060	680	2980	9.4	140	40	1200	1100	59.0	152
Little Alkali	4–10 h	2810–2810	940	2130	9.7	–	–	660	720	–	20
				Black bullhead							
Walgren	Indefinite	380– 700	110	380	8.5	8	4	4	18	102.0	329
Smithys L.	30–33 d	1802–2160	620	2050	9.5	80	38	700	800	50.0	130
Smithys Pond #1	18–22 h	3280–3300	1802	4320	9.9	50	160	900	1800	4.0	20
				Channel catfish							
Smithys L.	10–18 h	1890–1895	714	2315	9.6	160	40	750	1000	48.0	114
				White perch							
Walgren[b]	Indefinite	380– 700	110	380	8.5	8	4	4	18	102.0	329
Rogers	6– 8 d	1700–1780	578	1980	9.3	34	14	215	300	20.0	768
Smithys L.	18–20 h	2176–2180	918	2860	9.8	90	50	1200	1600	30.0	115
Smithys Pond #1	12–14 h	3280–3215	1800	4300	9.9	50	160	910	1800	10.0	20
				White bass							
Little Alkali	4–10 h	2810–2810	940	2130	9.7	–	–	660	720	–	20
Smithys Pond #1	6– 9 h	3706–3715	2256	5100	9.8	68	190	1900	2200	4.0	14
				Drum							
Smithys L.	10–18 h	1890–1895	714	2315	9.6	160	40	750	1000	48.0	114
				Largemouth bass & bluegill							
Big Alkali	Indefinite	300– 950	85	860	9.3	17	12	80	120	30.0	42
Stout	3– 4 m	270– 420	145	500	9.5	99	38	92	80	56.0	119
McKeel Pond #1	10–11 d	1143–1250	442	1275	9.3	100	60	250	450	40.0	2118
				Rock bass							
McKeel Pond #5	12 d	1360–1410	272	1410	9.5	80	44	200	350	52.0	80
McKeel Pond #2	28–30 d	1921–2060	680	2980	9.4	140	40	1200	1100	59.0	152
				Sacramento perch							
Walgren	Indefinite	380– 700	110	380	8.5	8	4	4	18	102.0	329
White	12–18 m	1100–2100	466	1880	9.1	29	620	187	435	33.0	48
Smithys L.	96–98 d	1906–3060	816	2223	9.5	170	38	800	1200	50.0	120
Little Alkali	22–24 d	2040–2870	1026	2850	9.7	100	120	775	740	17.0	35
				Smallmouth bass							
Little Alkali	4–10 h	2810–2810	940	2130	9.7	–	–	660	720	–	20
				Green sunfish							
East Twin	6–12 m	1430–2960	530	2830	9.5	100	43	500	655	22.0	100
				Fathead minnow							
White	12–18 m	1100–2100	466	1880	9.1	29	620	187	435	33.0	48

[a]h, hours; d, days; m, months; y, years.
[b]Western distribution limit in North America.

compounds was unlikely, as food organisms were found in the stomachs of dead fish. *Pimephales promelas* and *S. vitreum vitreum* were not confined to cages but were released directly into Big Alkali and Smithys lakes. These releases were examined periodically with gill- and frame nets.

Dissolved oxygen concentrations remained at 5.8 mg/liter or above throughout the tests. Water quality was determined by standard methods (American Public Health Association 1965). Alkalinity and *p*H values were determined immediately following the collection of water samples from lake and pond sites shown in Table 1.

Results and discussion — Of the 14 species tested, those with the most noteworthy tolerance to alkalinity were the Sacramento perch and the fathead minnow; they survived 12–18 months in lakes where the total alkalinity ranged from 1000 to 2000 mg/liter. The green sunfish, the next most tolerant species to medium alkaline waters, occurs naturally in several sandhill lakes where the maximum seasonal alkalinity does not exceed 2000 mg/liter (e.g., East Twin Lake, Table 1). The species has survived and reproduced in Skull Lake, where the alkalinity fluctuates between 400 and 960 mg/liter (McCarraher and Thomas 1968).

Northern pike survived for about 14 months in the medium alkaline waters of Hudson Lake until the total alkalinity exceeded 1200 mg/liter and the carbonate alkalinity exceeded 600 mg/liter (Table 1). In Big Alkali Lake, a pike population has survived since the early 1950's, the success of annual recruitment depending upon the alkalinity concentration of the water during the spawning season; alkalinity values in excess of 950 mg/liter normally cause extensive mortality of eggs and fry (unpublished data).

The black bullhead, *Ictalurus melas*, and the channel catfish, *I. punctatus*, revealed noteworthy differences in ability to survive. *Ictalurus melas*

TABLE 2. Some suggested fish species for introduction into alkaline eutrophic lakes of the world.

Lake type[a]	Total alk. range	Carbonate alk. range	K + Na range	Species
Slightly alkaline	<900	<250	<200	*Ambloplites rupestris*
				Aplodinotus grunniens
				Ictalurus punctatus
				Lepomis macrochirus
				Micropterus dolomieui
				Micropterus salmoides
				Morone americana
				Pomoxis nigromaculatus
Medium alkaline	900–1200	300–600	200–350	*Cyprinus carpio*
				Esox lucius
				Ictalurus melas
				Lepomis cyanellus
				Morone chrysops
				Perca flavescens
				Stizostedion vitreum vitreum
Moderately alkaline	1200–1800	550–850	350–400	*Archoplites interruptus*
				Clupeonella abrau[b]
				Fundulus kansae
				Pimephales promelas
				Tilapia aurea[b]
Strongly alkaline	1800–3000+	900–1200+	400–2000+	*Craterocephales fluviatilis*[b]
				Culaea inconstans
				Cyprinodon variegatus
				Fundulus majalis
				Mugil cephalus[b]
				Tilapia galilaea
				Tilapia aurea[b]

[a]Refers to the author's classification of alkaline waters based on his examination of about 1200 lakes in North America and Africa.

[b]Species not presently found in North American alkaline waters but may have potential for successful adaptation.

survived for a considerably longer period than *I. punctatus* in the strongly alkaline water of Smithys Lake.

The walleye, *S. vitreum vitreum*, survived up to 4 years in Big Alkali Lake, where carbonate alkalinity seldom exceeded a range between 60 and 90 mg/liter. Fingerling and adult fish can survive in Big Alkali Lake; however, natural reproduction was greatly curtailed when carbonate alkalinity values exceeded 90 mg/liter during spawning season (unpublished data). Early aquaria studies by Young (1923) using various concentrations of alkaline compounds indicated that walleye could not survive with carbonate alkalinity concentrations greater than 72 mg/liter, whereas Rawson and Moore (1944) reported that the species survived in saline lakes of Saskatchewan where the total alkalinity was about 483 mg/liter. The salts of these saline lakes are for the most part sulfates of sodium and magnesium and therefore chemically different from those of Nebraska lakes.

Channel catfish (*I. punctatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), and rock bass (*A. rupestris*), were found to be unsuitable for medium to strongly alkaline waters and are suitable only for introduction into waters classified as slightly alkaline (Table 2). Aquaria experiments with alkaline water by Young (1923), Calabrese (1969), and Stiemke and Eckenfelder (1947) all indicated that the death point for *L. macrochirus* in a Na_2CO_3 solution was 120–160 mg/liter. Observations by the author (unpublished data for 1954–1965) showed that survival of *L. macrochirus* and *M. salmoides* in Big Alkali Lake depended on the carbonate alkalinity remaining below 250 mg/liter for periods greater than 3 months of the year. By contrast, Renfro (1959) has described significant survival of *M. salmoides* in noncarbonate chlorosulfate waters below 9‰ total dissolved solids with progressive lethal effects between 9 and 15‰.

Sacramento perch not only appeared to have superior survival qualities for alkaline waters but is presently found living in several of the noncarbonate saline lakes of North Dakota, Colorado, and Nevada (McCarraher and Gregory 1970).

The fathead minnow inhabits numerous alkaline–saline lakes throughout the northern Great Plains (Nebraska, South Dakota, North Dakota, and the prairies of southern Saskatchewan and Manitoba) (McCarraher and Thomas 1968). The green sunfish, together with the Sacramento perch and the fathead minnow, are the most adaptable of Nebraska's fish fauna for survival in alkaline waters.

A list of species for intorduction into alkaline waters (Table 2) is suggested on the basis of experiments in Nebraska lakes; other species, not tested, are included for consideration.

Acknowledgments — The advice and editorial assistance of Mr R. E. Thomas and the encouragement of Mr G. Foster during the course of this study is gratefully acknowledged.

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