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Estimate of Production By a Population of Fathead Minnows, Pimpephales promelas, In a South Dakota Prairie Wetland

Ronald D. Payer

ESTIMATE OF PRODUCTION BY
A POPULATION OF FATHEAD
MINNOWS, PIMEPHALES PROMELAS, IN A
SOUTH DAKOTA PRAIRIE WETLAND

BY

RONALD D. PAYER

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusion of the major department.

Thesis Advisor   Date

Head of Major Department   Date

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RDP

ABSTRACT

Estimates of production and population densities were obtained for an autochthonous population of fathead minnows, *Pimephales promelas* Rafinesque, in a South Dakota prairie wetland. The study was conducted from May to September of 1976. Population estimates were obtained using a Schnabel-type mark and recapture model. Fish were marked either by finclipping or granular fluorescent pigments driven into the dermal tissue. Production estimates were derived both arithmetically and graphically. The estimated population of adult fathead minnows declined from 194 in May and June to 26 in July. Production by adults was estimated at 0.10 kg, or 0.0007 $gm/m^2/yr$. The population of young-of-the-year fathead minnows was estimated at 21,020 in July; 126,505 in August; and 105,297 in September. Production by young-of-the-year was estimated at 174.99 kg, or 1.75 $gm/m^2/yr$. Young-of-the-year contributed more than ninety-nine percent of the total net production, which was estimated at 175.09 kg, or 1.75 $gm/m^2/yr$. Chapman (1967) reported that lentic waters in temperate regions have produced 2 to 15 $gm/m^2/yr$ where a single species predominated. Production by fathead minnows in Pickering Slough was probably underestimated as a result of: 1) low initial brood stock density (less than five per acre); 2) receding water levels through the study period; 3) exclusion of sexual products from the estimate of net production; 4) exclusion of production by fry not surviving to be censused; and 5) exclusion of production in September and October.

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INTRODUCTION

An analysis of the production potential of freshwater prairie wetland fisheries is imperative to an understanding of their value. The fathead minnow, Pimephales promelas Rafinesque, inhabits prairie wetlands throughout southern Canada and the northern United States (Eddy 1969). Early investigations of the fathead minnow revolved around pond culture and utilization as a bait fish. More recent studies have been concerned with the effects of physical and chemical conditions on fathead minnows (McCarraher and Thomas 1968; Mossier 1971; Held and Peterka 1974). A small number of commercial bait dealers maintain the only harvest of fathead minnows in regional wetlands. The objective of this study was to determine population and production estimates for the fathead minnow in a selected prairie wetland.

The feasibility of using northern wetlands and their native fish populations for rearing introduced game fishes merits attention. Production of fathead minnows in prairie wetlands may provide sufficient forage to support introduced game fish through a growing season. Fry or fingerlings introduced in late spring may utilize native wetland invertebrates and fishes, providing stockable game fish the following autumn.

The feeding habits, environmental tolerances, and past studies of the northern pike, Esox lucius, indicate that it may be suitable for a wetland program of this type (McCarraher 1962; Johnson and Moyle 1969: Beyerle and Williams 1973). Similar stocking programs may be feasible for the walleye, Stizostedion vitreum (Walker and Applegate 1976), and the largemouth bass, Micropterus salmoides (Snow 1961; McCarraher 1971).

STUDY AREA

Pickering Slough is a glacially derived prairie wetland lying in the Coteau des Prairies region of eastern South Dakota (Schmidt 1967). The slough is privately owned and sustains limited irrigational usage [less than 2200 l (500 gal) per week]. A commercial bait dealer removed fathead minnows for one season in 1973. Pickering Slough is located in the S.E. quarter of section 16, T110N, R52W, in Brookings County.

Runoff from melting snow and spring rain provides an annual influx of water which maintains the wetland through the growing season. Regional precipitation averages 56.1 cm (22.1 in) annually, contrasted to an annual lake evaporation rate of 76.2 to 86.4 cm (30.0 to 34.0 in) (U.S. Weather Service). Precipitation was approximately 33.0 cm (13.0 in) below normal in 1976.

Pickering Slough has a natural drainage area of approximately 97 hectares (240 acres). An additional 35 hectares (85 acres) is drained by means of a manmade ditch extending 600 meters through adjacent cropland.

The surface acreage of the wetland ranges from a spring high of 16.2 hectares (40.0 acres) to complete dessication in the fall of exceptionally dry years. Surface acreages in 1976 were 16.2 hectares (40.0 acres) in May; 12.1 hectares (29.9 acres) in June; 10.2 hectares (25.2 acres) in July; and 5.1 hectares (12.6 acres) in August. The maximum recorded depth was 1.14 m (3.75 ft), excluding an adjoining dugout in which the maximum depth was 3.7 m (12.0 ft) (Figure 1). The dugout generally maintains water throughout the year, and provides

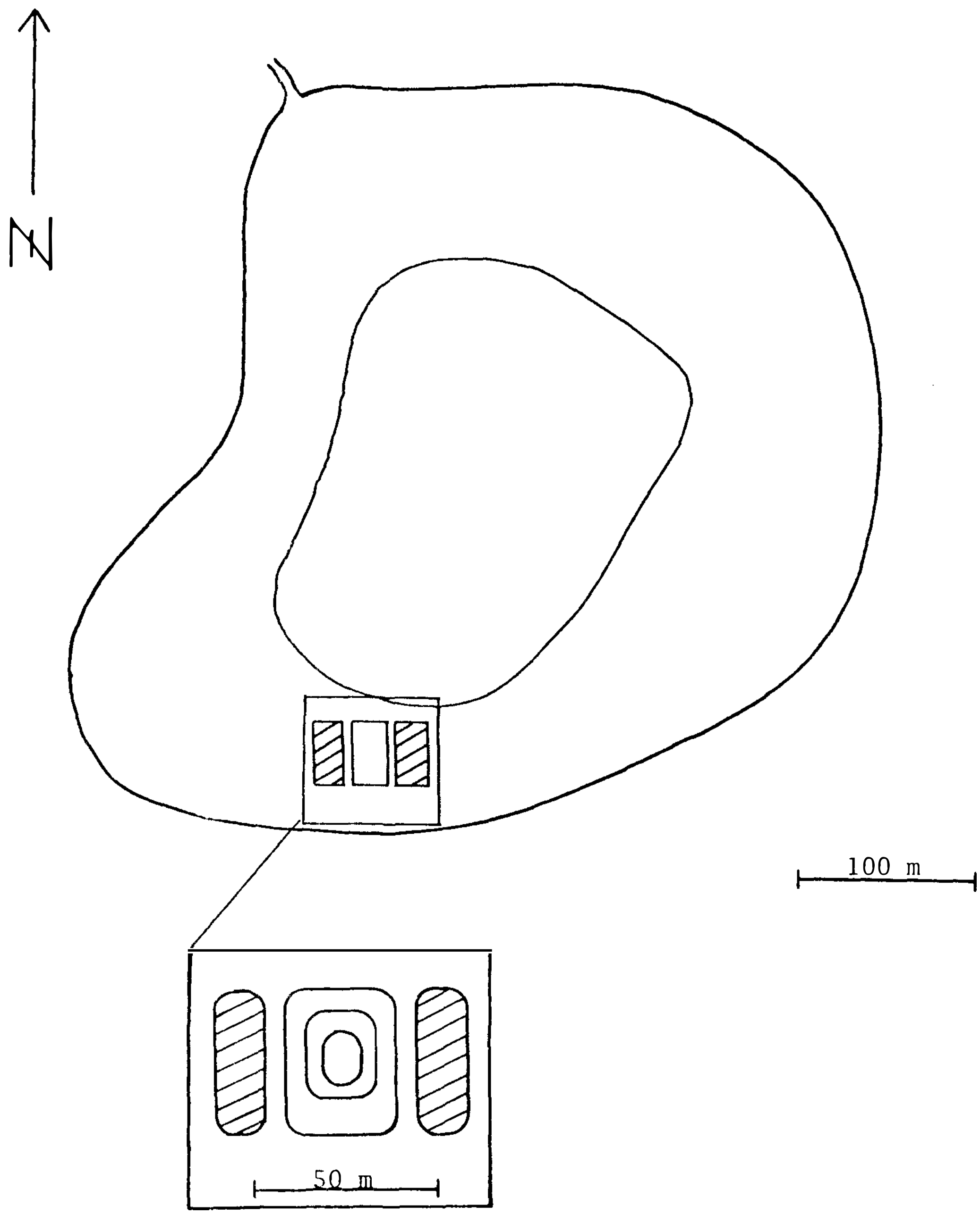

Figure 1. Bathymetric map of Pickering Slough, South Dakota. Insert depicts the adjoining dugout. Contour lines are at 1 m depth intervals.

winter habitat for the fathead minnows. Mean depth in Pickering Slough at the spring water level is 0.74 m (2.42 ft). Mean depths in 1976 were 0.74 m (2.42 ft) in May; 0.53 m (1.75 ft) in June; 0.41 m (1.33 ft) in July; and 0.15 m (0.50 ft) in August.

Ranges and mean values (in parenthesis) for basic water quality parameters through the study period included: Water temperature 11 to 24 C (18.7 C) [52 to 75 F (66 F)]; salinity 0.5 to 1.2 ppt (0.75 ppt); conductivity 710 to 1550 umhos (1135 umhos); dissolved oxygen 2.4 to 9.2 ppm (6.0 ppm); pH 8.2 to 10.8 (9.7); total alkalinity 130 to 580 ppm (395 ppm); total hardness 280 to 480 ppm (358 ppm); calcium hardness 110 to 210 ppm (154 ppm).

Regional air temperature extremes extend from a low of -35.5 C (-32.0 F) to a high of 42.4 C (108.0 F). The mean annual air temperature is 7.1 C (44.8 F) (U.S. Weather Service).

Row and grain crops constituted the principal vegetative cover on the drainage area and were contiguous with all sides of the wetland. Shoreline vegetation was dominated by *Typha, Scirpus,* and Gramineae. *Myriophyllum exalbescens* and *Lemna trisulca* quantitatively comprised the bulk of the aquatic vegetation, diminishing in significance with the rapid recession of the water level through the latter portion of the study period. *Sagittaria engelmanniana, Alisma gramineum, Scirpus fluviatilis, Potamogeton richardsonii,* and *P. pectinatus* were represented by intermittent patches over the entire wetland. Extensive portions of water surface were covered by the green algae *Cladophora* through most of June and July.

The resident vertebrate fauna of the wetland consisted primarily of waterfowl, muskrats, water snakes *(Thamnophis)*, and the eastern tiger salamander *(Ambystoma tigrinum)*. A dense population of larval tiger salamanders persisted until the diminishing water level caused their displacement. Common invertebrates included corixids, cladocerans, coleopterans, amphipods, and larval stages of Trichoptera, Ephemeroptera, and Chironomidae.

The wetland substratum was comprised of a layer of mire and organic detritus overlying a dense clay base. Large silt deposits were evident where the drainage ditch entered the wetland.

MATERIALS AND METHODS

Minnow samples were obtained three times weekly with twelve to fourteen single-entrance cylindrical traps constructed of 0.16 cm (1/16 in) mesh fiberglass screen. Each trap was 80 cm (32 in) long and was supported by three 40 cm (16 in) diameter steel hoops equidistantly spaced along the cylinder. A funnel attached to the anterior hoop tapered to a two-inch galvanized steel ring which formed the trap entrance. A cord extending from the galvanized ring through the cylinder to a wooden stake stabilized the entrance. A similar funnel equipped with a drawstring comprised the posterior portion of the trap and facilitated content removal. Each trap was held upright by a one-meter wooden stake from which also extended a 3.7 m (12.0 ft) lead of screen.

The wetland was arbitrarily divided into twenty-four 0.6 hectare (1.5 acre) units. Each unit was assigned a number which was recorded on a card. Six units were randomly chosen from the numbered cards for each week of the study period. The numbers of units becoming exposed by receding water levels during the study period were removed from the card sample. Two traps were placed in each of the designated units for three consecutive sample days. At least one trap was maintained in the dugout throughout the study.

Traps were distributed and checked from a boat at 24-hour intervals. The contents of each trap were emptied into a holding bucket and processed individually to allow both the liberation pattern and sampling effort to agree with the distribution of population density (Robson and Regier 1971). The number of fish in each trap was recorded and a subsample measured for total length to the nearest millimeter. One hundred minnows were measured for each sample day unless fewer were taken. A mean length for *P. promelas* was determined for each monthly period. Groups of twenty minnows of corresponding lengths were obtained from subsequent samples and a mean monthly weight estimated from them. Subsamples for weight determination were taken from the study area to ensure accurate condition factors for the minnows. A limited population and delayed spawn prohibited removal of minnows for weight determinations during May and June. Mean weights for these months were estimated using fathead minnows obtained from area wetlands of similar water quality.

Population and production estimates for *P. promelas* were computed independently for each month of the study period. Population density estimates were derived using a Schnabel-type mark and recapture model. Production estimates were obtained for adult fathead minnows: 1) arithmetically by arranging adjacent monthly biomass estimates; 2) graphically using Allen's weight-survivorship method (Chapman 1971). Production estimates were obtained for young-of-the-year fathead minnows utilizing both standing crop and adjacent monthly biomass estimates.

Mark and recapture techniques were used to obtain population estimates. The fathead minnow population in Pickering Slough through May and June was small enough to permit removal of pectoral fins as a marking technique. A mass-marking technique introduced by Jackson (1959) was selected for marking samples through the remainder of the study period. This method entails forcing granular fluorescent pigments into the dermal tissue of the minnows by means of compressed gas passing through a low-pressure sandblast gun. Advantages of this technique include: 1) large numbers of fish may be processed in a relatively short time; 2) little handling is required; 3) no effect on mobility or behavior of marked fish is apparant; 4) predators are unable to distingquish between marked and unmarked fish; 5) low mortalities are attributed to handling and marking (Andrews 1972).

Salmonids have been the primary target fishes for previous applications of fluorescent pigments (Phinney et al. 1967; Kallemeyn 1968; Phinney and Mathews 1969; Hennick and Tyler 1970). Andrews (1972), however, tested the method relative to survival and mark retention of P. promelas, and concluded that mark retention was highly variable after 232 days, but dependable prior to that time.

Phinney et al. (1967) found that mark retention among experimental groups of salmonids was comparable at application pressures ranging from 80 to 160 psi. Andrews (1972) determined that pressures of 100 to 110 psi gave a maximum percentage of marked fathead minnows without appreciable mortality. In this study groups of P. promelas of varying lengths were sprayed at pressures ranging from 75 to 160 psi and periodically inspected for mark retention. Results indicated that pressures below 120 psi did not consistantly provide mark retention in excess of thirty days. Pressures in excess of 150 psi caused unacceptable levels of fish mortality. An application pressure of 130 psi was selected as optimal. A recommendation by Andrews (1972) that fathead minnows smaller than 35 mm total length not be marked was adhered to after experimental spraying resulted in high mortalities from this size group.

Lots of 15 to 24 minnows were placed in a shallow 30 x 30 cm (12 x 12 in) dip net and pigment applied from approximately 45 cm (18 in) (Hennick and Tyler 1970). The pigment was directed onto the fish at an angle approximating 45°, resulting in rotation of the minnows in the net. This insured that both sides of the fish were exposed to sprayed pigment (Andrews 1972). Marked individuals were randomly released within the unit in which they were captured. Mortality resulting from marking techniques ranged from 0 to 15 percent, and appeared to be correlated with daily weather conditions.

Compressed nitrogen gas was selected as a driving force because of its biological inertness, ready availability, and utilization in a previous study (Kallemeyn 1968). Nitrogen cylinders were obtained from Dakota Welding Supply, Watertown, South Dakota. A size "Q" cylinder at 2400 psi was capable of marking approximately 1200 fathead minnows at an application pressure of 130 psi. Pressure was regulated by a bivalve bronze gauge coupled to the sandblaster by a 7.6 m (25 ft) pressure hose.

Three colors of granular fluorescent pigments were obtained from Scientific Marking Materials, Seattle, Washington. To facilitate independent population estimates a different color was used each month. Red and orange pigments were not utilized in successive months in concurrence with a recommendation by Kallemeyn (1968).

Captured minnows were examined for pigments in a portable plywood darkbox containing a battery-operated ultraviolet light. The light was an MSL-48 multiband portable obtained from Ultraviolet Products Incorporated, San Gabriel, California, and operated on two six-volt lantern batteries.

Fathead minnows were placed in moistened black pans in lots of twelve to eighteen and examined for fluorescent pigments. Positive identification of recaptures was difficult at times because of limited mark retention by some individual fish. This difficulty was augmented by granules of residual spray which accumulated on the equipment and fish. Experience and frequent rinsing of the trays alleviated the problem in most cases. If the validity of a mark remained uncertain, the side of the minnow was gently stroked. This smeared residual spray but left dermal marks unaffected.

Monthly estimations of minnow densities were derived using the Schnabel formula, which is a multiple-census technique. The equation:

$$N = \frac{\Sigma(C_t M_t)}{\Sigma R}$$

was used, where:

N = estimate of population density

C_t = total sample taken at time t

M_t = total number of marked fish at large at the start of the interval Δt

R = number of recaptures in a sample (Ricker 1975).

Estimates derived from the Schnabel formula are asymmetrically distributed. Confidence limits were calculated by treating the number of recaptures (ΣR) as a Poisson variable and obtaining confidence coefficients at the 0.95 level from tables presented by Ricker (1975). Table values were sufficient for Poisson variables of up to fifty, after which confidence coefficients were computed from:

$$1 - P = 0.95 \qquad \Sigma R + 1.92 \pm 1.96 \sqrt{\Sigma R + 1.0} \qquad \text{(Ricker 1975).}$$

Confidence coefficients were substituted for the sum of recaptures in the original Schnabel formula to obtain 0.95 confidence limits.

Assumptions applying to the valid utilization of the Schnabel method include: 1) marked and unmarked fish suffer equal mortality rates; 2) marked fish are as vulnerable to capture techniques as are unmarked fish; 3) marked fish do not lose their marks; 4) marked fish become randomly mixed with the unmarked population, or that distribution of fishing effort is proportional to the number of fish present in different parts of the water unit; 5) all marks are recognized; 6) only a negligible amount of recruitment to catchable population occurs during the period through which recoveries are being made (Ricker 1975). Population estimates throughout the study were made at close enough intervals to retain the validity of the assumption requiring negligible recruitment. Delury (1958) suggests that it would rarely be possible to obtain useful values for rates of accession or loss from the Schnabel method.

Production estimates were derived from:

$$P = G\overline{B}$$

where:

P = production estimate (wet weight) during Δt

G = instantaneous rate of weight increase

$$G = \frac{\log_e \overline{w}_2 - \log_e \overline{w}_1}{\Delta t}$$

$\overline{w}_1$, $\overline{w}_2$ = mean weights at times t_1 and t_2, respectively

$\overline{B}$ = mean biomass during Δt (determined linearly)

$$\overline{B} = \frac{B_1 + B_2}{2}$$

B_1, B_2 = biomass present at times t_1 and t_2, respectively

(Chapman 1971).

Variances around production estimates were computed from estimates of G and $\overline{B}$, the component statistics used to estimate P. The variance for B_1 and B_2 were determined from:

$$V(B) = \overline{w}^2 V(N) + N^2 V(\overline{w})$$ (Chapman 1971),

where the variance for $\overline{w}$ is estimated by:

$$V(\overline{w}) = \frac{\Sigma w^2 - \frac{(\Sigma w)^2}{n}}{n(n-1)}$$ (Cochran 1963),

and V(N) is calculated from:

$$\frac{\sigma N}{N} = \sqrt{\frac{N}{\Sigma C_t M_t}}$$ (after Chapman 1954),

where the symbols utilized by Chapman (1971) are substituted to facilitate contiguity.

The variance of B was estimated by:

$$V(\overline{B}) = 1/4 \left[V(B_1) + V(B_2) + 2cov(B_1, B_2) \right]$$ (Chapman 1971).

The covariance term equals zero, since the samples used to estimate B_1 and B_2 are independent.

The variance of G could be estimated from several (k) subsamples as:

$$V(G) = \frac{\Sigma Gi^2 - \frac{(\Sigma Gi)^2}{k}}{k(k-1)}$$ (Chapman 1971).

The estimated variance of P is therefore:

$$V(P) = V(G\overline{B}) = G^2 V(\overline{B}) + \overline{B}^2 V(G) + 2G(\overline{B})cov(G,\overline{B}),$$

where:

$$cov(G,\overline{B}) = r\sqrt{V(G)V(\overline{B})}$$

r = coefficient of correlation between G and B.

The r value was set equal to zero, resulting in a slight overestimation of V(P) if, as one would expect, G and $\overline{B}$ are negatively correlated (Chapman 1971).

Ninety-five percent confidence limits for P may be estimated from:

$$2\sqrt{V(P)}$$ (Chapman 1971).

Production was also computed using a graphical method derived by Allen (1950), in which the number of individuals (N) in the population at successive points in time are plotted against the mean weight ($\overline{w}$) of an individual at corresponding times. No confidence limits were obtained for graphical estimates.

In using either Allen curves or the Ricker computational formulas for production estimations, growth and mortality functions can rarely be predicted. To account for changes in instantaneous rates of growth and mortality and the effects of recruitment, growth and survivorship must be assessed over short time intervals (Chapman 1971). Production rates are determined on the basis of tissue elaboration, regardless of whether or not all tissue survives to the end of a given time interval (Ivlev 1966).

Basic water chemistry data taken weekly included total hardness, dissolved oxygen, pH, total alkalinity, and calcium hardness, all of which were determined using a Hach Model DR-EL chemical kit, Hach Chemical Corporation, Ames, Iowa. Water temperature, salinity, and conductivity readings were obtained using a Model 33 S-C-T meter, distributed by the Yellow Springs Instrument Company, Yellow Springs, Ohio.

RESULTS AND DISCUSSION

Pickering Slough, with the exception of the adjoining dugout, probably sustains an annual winterkill. A small population of fathead minnows survives the winter in the dugout and disperses throughout the wetland in the spring. Carlander and Sprugel (1955) reported that fathead minnows may survive winterkill in muskrat burrows under similar conditions.

Fathead minnows generally initiate spawning activities when the water temperature 152 mm (6 in) beneath the surface is approximately 17.8 C (64.0 F) to 18.3 C (65.0 F) (Markus 1934; Isaak 1961; Flickinger 1971). Markus (1934) noted that the secondary sexual characteristics of the male fathead minnow became evident approximately thirty days prior to the deposition of the first eggs. Male fathead minnows in Pickering Slough first displayed secondary sexual characteristics during the second week of May. Gravid females were observed one week later. The optimal spawning temperature (17.8 C) was first attained on 10 June. Free-swimming fry were observed one week later.

ADULT FATHEAD MINNOWS

Population Estimates

The ability to easily distingquish between adult and young-of-the-year fathead minnows facilitated the independent treatment of production and population data for the two age-classes. The assumption was made that mortality among adults prior to the initiation of spawning was negligible, and that the population of adults consequently remained relatively stable through May and June. Census data obtained through these two months were consolidated and a single Schnabel estimate derived. Utilization of data from both periods served to increase the precision of the population estimate and reduce the risk of statistical bias resulting from too few recaptures (Ricker 1975). The population estimate for adult fathead minnows present in May and June was 194. This figure was used in the computation of production estimates for both intervals. Mark and recapture data, population estimates, and confidence limits for the adult population in May and June are found in Table 1.

An independent Schnabel estimate for adult minnows present in July after spawning indicated a reduction in brood stock of approximately 87 percent. Previous studies have indicated post-spawning mortality rates of 80 to 100 percent (Markus 1934; Dobie et al. 1956). Dobie et al. (1956) found that a majority of breeding males died within thirty days following the onset of spawning activities, and females within sixty days. All adult fathead minnows taken from May through July in Pickering Slough were sexed and male to female ratios determined. Sex ratios of 1.5:1.0 in May, 1.3:1.0 in June, and 1.4:1.0 in July suggested that post-spawning mortality rates were similar for both male and female minnows in Pickering Slough. The population of adult fathead minnows present in July was estimated at 26 fish. Mark and recapture data, population estimate,

Table 1. Mark and recapture data, population estimate, and confidence intervals for adult fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, from 1 May to 1 July, 1976.

DATE	NUMBER CAUGHT C_t	NUMBER MARKED	RECAPTURES R	MARKED FISH AT LARGE M_t	C_tM_t
4-29	7	7	-	-	-
5-11	4	4	0	7	28
5-12	3	3	0	11	33
5-18	1	1	0	14	14
5-19	0	0	0	15	0
5-25	15	15	0	15	225
5-26	13	11	2	30	390
5-27	3	1	2	41	123
6-1	0	0	0	42	0
6-2	0	0	0	42	0
6-4	1	1	0	42	42
6-8	2	2	0	43	86
6-9	16	12	3	45	720
6-10	15	11	4	57	855
6-15	2	1	1	68	136
6-16	0	0	0	69	0
6-17	0	0	0	69	0
6-22	11	8	3	69	759
6-23	15	8	7	77	1155
6-24	25	13	11	85	2125
6-29	1	0	1	98	98
6-30	0	0	0	98	0
7-1	16	-	9	98	1568
TOTAL	150	98	43	98	8357

$$N = \frac{\Sigma C_tM_t}{\Sigma R} = \frac{8357}{43} = 194 \quad P(144 \leqq N \leqq 269) = 0.95$$

and confidence limits for the population of adult fathead minnows in July are listed in Table 2.

Production Estimates:

Production estimates are expressed in terms of wet weight of tissue elaboration. Production contributed by sexual products was not included in the estimate of total net production. Production by the adult population in May was estimated at 0.058 kg, or 0.0004 gm/m^2. Production by adults in June was estimated at 0.043 kg, or 0.0004 gm/m^2. All production values were adjusted for changing water levels throughout the study period. Arithmetically derived production estimates for the population of adult fathead minnows in Pickering Slough through May and June are listed in Table 3.

Graphical representation of production by adults through May and June is illustrated by an Allen curve in Figure II. Estimates of 0.058 and 0.041 kg were obtained for May and June, respectively. Minor discrepancies between arithmetic and graphical production estimates result from interpretation of the weight-survivorship curve, since both methods estimate the same parameter.

Production estimates were not available for July, since the adult minnow population declined from an estimated 26 to near zero in August. No adult fish were taken after 22 July.

Total production by adult fathead minnows in Pickering Slough was estimated at 0.10 kg, or 0.0007 gm/m^2/yr. The exclusion of released sexual products and production by the adult population in July resulted in an underestimation of total net production.

Table 2. Mark and recapture data, population estimate, and confidence intervals for adult fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, from 1 July to 1 August, 1976.

DATE	NUMBER CAUGHT C_t	NUMBER MARKED	RECAPTURES R	MARKED FISH AT LARGE M_t	C_tM_t
7-7	1	1	-	-	-
7-8	9	5	4	1	9
7-9	17	9	7	6	102
7-13	9	3	4	15	135
7-14	15	4	9	18	270
7-15	10	1	5	22	220
7-20	0	0	0	23	0
7-21	1	0	1	23	23
7-22	1	-	0	23	23
TOTAL	63	23	30	23	782

$$N = \frac{\Sigma C_t M_t}{\Sigma R} = \frac{782}{30} = 26 \qquad P(18 \leqq N \leqq 39) = 0.95$$

Table 3. Arithmetically computed production data for adult fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, from 1 May to 1 July, 1976.

DATE	MEAN WEIGHT (gm) $\overline{W}$	INSTAN. GROWTH RATE G	STOCK NUMBERS N	STOCK BIOMASS (gm) B	MEAN BIOMASS (gm) $\overline{B}$	PRODUCTION (gm) $P \pm 0.95$ CL
5-1	5.1		194	989.4		
		0.0572			1018.5	58.3 ± 19.2
6-1	5.4		194	1047.6		
		0.0715			599.2	42.8 ± 14.2
7-1	5.8		26	150.8		

Total production by adults = ΣP = 101.1 gm

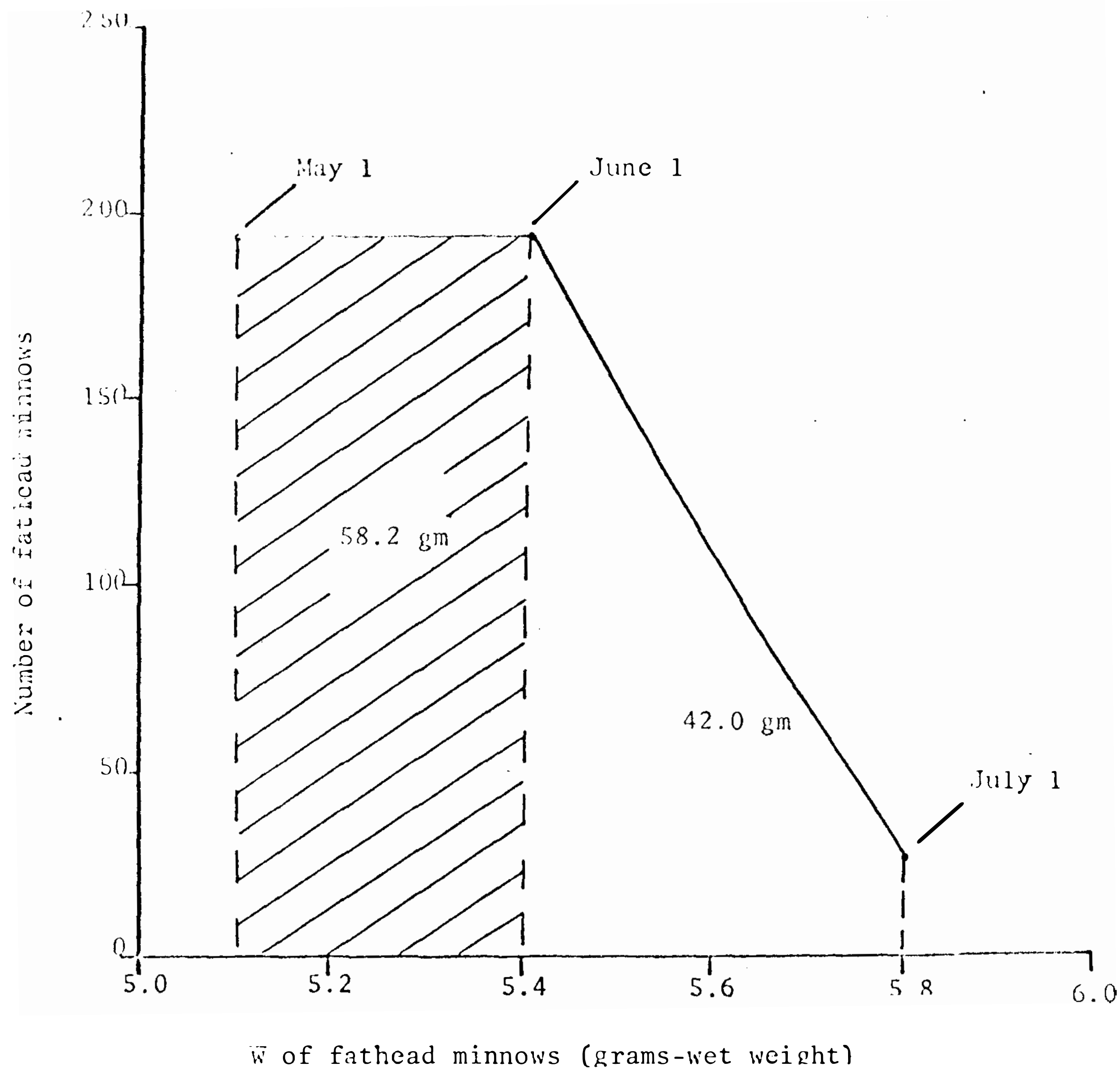

Figure II. Graphical representation of production (tissue elaboration) by adult fathead minnows, *Pimephales promelas*, in Pickering Slough, South Dakota, from 1 May to 1 July, 1976. The area beneath the curve covered by diagonal lines represents production through May, the clear area production through June.

YOUNG-OF-THE-YEAR FATHEAD MINNOWS

Population Estimates:

Young-of-the-year fathead minnows in Pickering Slough were censused in July, August and September. Recruitment of young-of-the-year fishes into the censusable population occurred into early August. Population samples and mark and recapture data were taken three times weekly to compensate for any violation of the assumption that recruitment be negligible to validate estimates derived by the Schnabel method (Ricker 1975). Fathead minnows in Pickering Slough did not spawn during August or September due to receding water levels. The only inhabitable water throughout September was in the dugout, with only scattered puddles occurring over the remainder of the wetland.

Young-of-the-year fathead minnow populations in Pickering Slough were estimated at 21,020 in July; 126,505 in August; and 105,297 in September. The decline in September may be associated with a reduction in available space. The entire population was confined to the dugout throughout the last three weeks of September. Mark and recapture data, population estimates, and confidence limits for young-of-the-year fathead minnows are listed in Tables 4, 5 and 6 for July, August and September, respectively.

Production Estimates:

Young-of-the-year production was estimated for July and August only,

Table 4. Mark and recapture data, population estimate, and confidence intervals for young-of-the-year fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, during July, 1976.

DATE	NUMBER CAUGHT C_t	NUMBER MARKED	RECAPTURES R	MARKED FISH AT LARGE M_t	C_tM_t
7-7	103	87	-	-	-
7-8	0	0	0	87	0
7-9	44	34	0	87	3828
7-13	198	172	4	121	23958
7-14	70	57	2	293	20510
7-15	93	67	0	350	32550
7-20	56	54	0	417	23352
7-21	101	77	3	471	47571
7-22	147	117	3	548	80556
7-28	470	392	13	665	312550
7-29	203	134	11	1057	214571
7-30	33	-	2	1191	39303
TOTAL	1518	1191	38	1191	798749

$$N = \frac{\Sigma C_t M_t}{\Sigma R} = \frac{798749}{38} = 21{,}020 \qquad P(15302 \leqq N \leqq 29804) = 0.95$$

Table 5. Mark and recapture data, population estimate, and confidence intervals for young-of-the-year fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, during August, 1976.

DATE	NUMBER CAUGHT C_t	NUMBER MARKED	RECAPTURES R	MARKED FISH AT LARGE M_t	C_tM_t
7-30	33	18	-	-	-
8-3	160	148	1	18	2880
8-4	30	28	0	166	4980
8-5	52	46	2	194	10088
8-10	380	339	2	240	91200
8-11	698	688	15	597	404142
8-12	1591	1021	18	1247	1983977
8-17	1085	920	24	2268	2460780
8-18	417	349	9	3188	1329396
8-19	1457	1024	38	3537	5153409
8-23	768	256	23	4561	3502848
8-24	452	397	9	4817	2177284
8-25	380	-	10	5214	1981320
TOTAL	7503	5214	151	5214	19102304

$$N = \frac{\sum C_t M_t}{\sum R} = \frac{19102304}{151} = 126{,}505 \qquad P(107871 \leqq N \leqq 148361) = 0.95$$

Table 6. Mark and recapture data, population estimate, and confidence intervals for young-of-the-year fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, during September, 1976.

DATE	NUMBER CAUGHT C_t	NUMBER MARKED	RECAPTURES R	MARKED FISH AT LARGE M_t	C_tM_t
8-29	128	112	-	-	-
8-30	28	28	0	112	3136
8-31	2380	1381	23	140	333200
9-8	1296	1157	22	1521	1971216
9-13	1232	1180	20	2678	3299296
9-20	1277	1206	26	3858	4926666
9-27	124	-	15	5064	627936
TOTAL	6465	5064	106	5064	11161450

$$N = \frac{\sum C_tM_t}{\sum R} = \frac{11161450}{106} = 105{,}297 \qquad P(87070 \leq N \leq 127341) = 0.95$$

since early dessication of the wetland prohibited the collection of data during subsequent months. No attempt was made to measure hatching success or survival rates of fry to a length at which marking techniques were applicable (35 mm). The exclusion of production by fry not surviving to be censused and of production during September and October, normally included in the growing season, resulted in an underestimation of production by young-of-the-year. Production by fry that did survive to be censused was estimated as biomass present at the time the first population estimate of young-of-the-year was obtained.

Production by young-of-the-year fathead minnows in July could not be estimated by either the arithmetic or graphic methods as applied to the adult populations. A five-fold population increase from July to August invalidated the use of individual mean weights for production computations, as mean weights were determined only from the censusable population (fishes over 35 mm in length). The use of arithmetic calculations required the assumption that those fry recruited into the population during the sample period had an original weight equivalent to that of the monthly mean, causing the tissue elaborated between hatching and the attainment of the monthly mean to be lost in the production computations. Arithmetic and graphic computations resulted in a production estimate of about one-half of the biomass present in July. Since all tissue elaborated by young-of-the-year was produced during the study period, the estimate of biomass or standing crop would be a minimal estimate of production. Production by young-of-the-year was therefore estimated as the mean biomass in July plus production in August, which was arithmetically estimated. The estimated production by young-of-the-year in July was 171.29 kg, or 1.68 gm/m^2. Production in August was estimated at 3.71 kg, or 0.07 gm/m^2. Total tissue elaboration by young-of-the-year fathead minnows through the study period was estimated at 174.99 kg, or 1.75 gm/m^2/yr. Arithmetically derived production estimates for young-of-the-year fathead minnows through July and August are listed in Table 7.

Total net production by the fathead minnow population in Pickering Slough was obtained by summing production estimates for the two age-classes, and was estimated at 175.09 kg, or 1.75 gm/m^2/yr. Diminishing surface area and large fluctuations in minnow population densities and production levels over the growing season complicated data interpretation. Production estimates obtained from Pickering Slough during 1976 must be evaluated with the existing drought conditions in mind. Additional studies conducted during periods of normal precipitation should result in higher, more realistic production values for fathead minnows in prairie wetlands. Studies conducted on two or three wetlands simultaneously would also provide a basis for statistical analysis.

Comparative Analysis:

A production conversion of 1.8 gm/m^2 was obtained for the fathead minnows in Pickering Slough over the four months during which they were studied. Chapman (1967) reports that lentic waters in temperate regions produced from 2 to 15 gm/m^2/yr where a single species predominated. Gerking (1962) estimated production by bluegill, *Lepomis macrochirus,* in Wyland Lake, Indiana, to be 9.1 gm/

Table 7. Arithmetically computed production data for young-of-the-year fathead minnows (*Pimephales promelas*) in Pickering Slough, South Dakota, from 1 July to 1 September, 1976.

DATE	MEAN WEIGHT (gm) $\bar{W}$	INSTAN. GROWTH RATE G	STOCK NUMBERS N	STOCK BIOMASS (gm) B	MEAN BIOMASS (gm) $\bar{B}$	PRODUCTION (gm) P $\pm$ 0.95 CL
July 1	0.605		21,020	12,717		
		0.80559			92,003	171,288
Aug. 1	1.354		126,505	171,288		
		0.02336			158,615	3,705 $\pm$ 1,106
Sept. 1	1.386		105,297	145,942		

Total production by young-of-the-year = ΣP = 174,993 gm

m^2/yr. Cooper et al. (1963) reported production values of 5.0 to 8.0 gm/m^2/yr for largemouth bass in a small pond, while Hansen (1963) estimated that a largemouth bass-bluegill combination produced 7.5 to 12.6 gm/m^2/yr. Northern pike production in Lake Windermere was estimated at 0.14 to 0.51 gm/m^2/yr (Johnson 1966).

Most production estimates for the fathead minnow have been restricted to cultural environments. Annual production rates of 148 lb/acre have been obtained by stocking 1000 adult fathead minnows per acre and fertilizing breeding ponds. The addition of soybean cake increased production to approximately 1,200 lb/acre (Prather et al. 1953). Hedges and Ball (1953) obtained 212 pounds of fathead minnows per acre from an initial stock of 1000 breeding adults per acre. Production rates of up to 328 lb/acre have been obtained in several states (Dobie et al. 1948). Most production estimates for the fathead minnow are from fertilized waters where fry were transferred to growing ponds. Care should be taken in comparing these estimates with those obtained from natural environments.

The production estimate of 1.8 gm/m^2 obtained for fathead minnows in Pickering Slough over the four month study period may be converted for comparative purposes to 16.1 lb/acre. Production estimates for Pickering Slough must be viewed as signally minimal with regards to the production potential of the wetland. Of primary consideration is the initial brood stock density, which was estimated as less than twelve adult fish per hectare (five per acre). Estimates of brood stock density for Pickering Slough are less than one percent of stocking densities suggested in several studies for extensive rearing of fathead minnows (Hedges and Ball 1953; Prather et al. 1953). Production was also adversely affected by progressively receding water levels during the study period. The surface area of Pickering Slough diminished more than 99 percent by 1 September. The exclusion of sexual products, of production by fry not surviving to be censused, and of production in September and October further reduced the estimate of total net production. While the resulting estimate of total net production by fathead minnows in the wetland must be viewed as minimal, the values obtained are representative of production estimates from lentic waters in temperate regions where a single species predominated. Production estimates for the fathead minnow in Pickering Slough in 1976 are not indicative of the production potential of prairie wetlands, pointing out the need for additional studies under more favorable environmental conditions. Studies conducted during periods of average precipitation while utilizing various brood stock densities and computing fecundity and natural mortality of fry would provide more comprehensive information.

Production by young-of-the-year minnows constituted more than 99 percent of the total net production by fathead minnows in Pickering Slough, a relatively high value when compared to studies of more long-lived species. Allen (1951) estimated that 95 percent of brown trout, *Salmo trutta*, production by a year-class in Horokiwi Stream occurred during the first two years of life, while Hunt (1966) reported 80 to 95 percent of brook trout, *Salvelinus fontinales*, production in Lawrence Creek also occurred during their first two years.

The growth rate for young-of-the-year fathead minnows in Pickering Slough is comparable to that obtained by Hedges and Ball (1953) for an extensively reared population of fathead minnows in a Michigan pond. Growth rates for young-of-the-year from Pickering Slough and from a one-acre Michigan pond having a broodstock density of 1000 fish are compared in Figure III.

CHARACTERISTICS OF PICSIVOROUS SPECIES

To utilize a body of water for rearing purposes, the food resources available in that unit must first be assessed and compared to the dietary requirements of the species to be stocked. The capacity of a water unit to support a piscivorous species may be determined through calculations of production by the fish species on which it feeds. The ability of prairie wetlands to support stocked piscivorous species depends on production by the autochthonous fish populations. A brief appraisal is made of the food requirements of northern pike, largemouth bass, and walleye relative to production by fathead minnows in Pickering Slough.

Northern Pike

Microcrustaceans and immature insects comprise the bulk of the first foods of northern pike fry (Matveeva 1955; Franklin and Smith 1963; Priegel and Krohn 1975). Young pike may feed almost exclusively on fish by the time they reach 34 mm in length (Matveeva 1955).

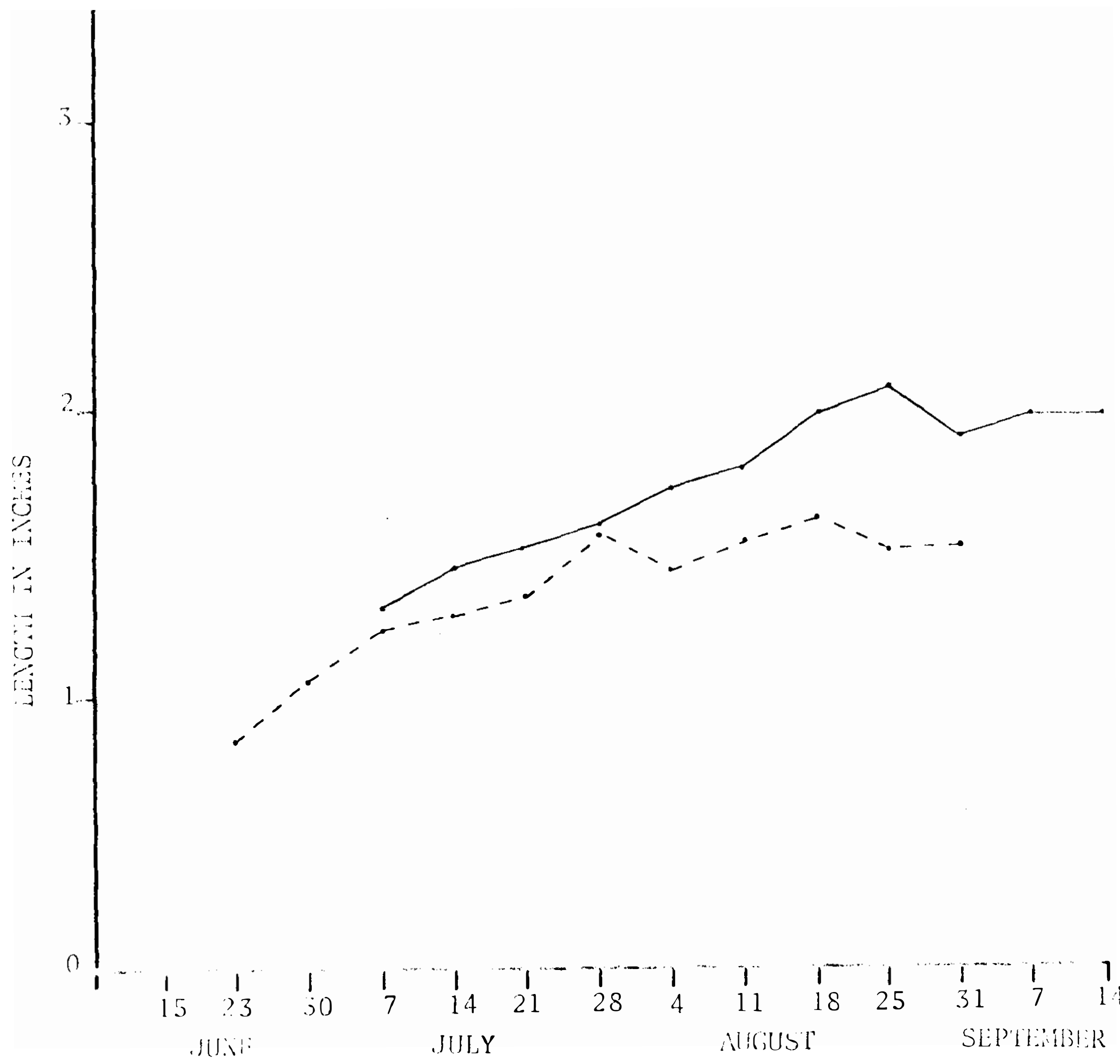

Figure III. Growth rates of young-of-the-year fathead minnows from Pickering Slough, South Dakota, in 1976 (solid line) and from a one-acre Michigan pond (dotted line) (Hedges and Ball 1953).

Quantities of microcrustaceans and immature insects observed in Pickering Slough through the first half of July appeared to be sufficient to provide dietary requirements for a population of pike through the period of transition to a piscivorous diet. High densities of conchostracan shrimp evident in May and June might provide an intermediate food source. Large numbers of tiger salamander larvae were present from June through August, initially appearing at approximately the same time as did fathead minnow fry. McCarraher (1962) reported that pike utilized salamanders as a food source in Nebraska waters.

Northern pike require 1.385 grams of minnow to maintain each gram of body weight per year. Maintenance requirements in June are approximately 45 mg/gm/wk, compared to 25 mg/gm/wk from October through April. After maintenance requirements are met, 1.0 gram of food produces 0.485 grams of growth (Johnson 1966). Stocking ratios for pike fry are variables dependent on project objectives and existing envrionmental conditions. Production by fathead minnows in Pickering Slough during the 1976 growing season could have maintained 126.42 kg of pike.

Largemouth Bass

The largemouth bass is a second piscivorous species which might subsist in a prairie wetland through a growing season. Bass show a preference for clear, lentic waters having an abundance of aquatic vegetation (Trautman 1957). McCarraher (1971) reported that bass were suitable for the slightly alkaline waters of Nebraska.

Bass initiate feeding on microcrustaceans, with insects becoming a major food item when the bass reach approximately 40 mm in length (Mullan and Applegate 1970). Bass in excess of 80 mm feed almost exclusively on fish and large insects (Lewis et al. 1961).

Thompson (1941) reported that 2.5 pounds of live minnows produced 1.0 pound of bass when fed at optimum rates (3.5 to 4.0 percent of body weight per day). Prather (1950) found that an average of 4.0 pounds of forage would produce 1.0 pound of bass, and that larger bass required a higher ratio because of increased maintenance requirements. Prather reported that bass smaller than 2.0 oz required 2.4 pounds of minnow for each pound of gain, while 2.0 to 6.0 oz bass require 4.2 pounds of minnow for an equal gain.

Snow (1961) found that fathead minnows were selected by bass over either goldfish, *Carassius auratus*, or bluegill, and resulted in the best growth and food conversion ratios of the three forage species. Snow estimated conversion ratios of fathead minnows by bass as 4.9, 3.2 and 4.4, while Prather (1950) estimated conversion ratios of 5.12, 2.06 and 3.44. Based on data provided by Prather (1955), production generated by the fathead minnow population in Pickering Slough would have produced 73.0 kg (161 pounds) of bass.

Walleye

The walleye is the third species considered for stocking in prairie wetlands. The walleye is tolerant of a wide range of environmental conditions, reaching its greatest abundance in large, shallow, turbid lakes (Scott and Crossman 1973).

Walker and Applegate (1976) reported that 25,000 walleye fingerlings stocked in a South Dakota pond on 13 June, 1973, fed primarily on *Diaptomus* species until mid-July, when they began feeding on fathead minnows. The fathead minnow population was depleted by mid-August, forcing the walleye to seek alternate food sources. Walker recovered 17.7 percent of the original number of fingerlings, all of which were of a stockable size.

Smith and Moyle (1943) reported that additional minnows must be added to a pond a few weeks after stocking walleye. Many stocking efforts in waters already containing minnows have failed. The average yield from thirteen ponds containing minnows was 5.5 pounds per acre.

Walleye generally initiate active feeding before complete absorption of yolk reserves has occurred. First foods consist mostly of copepods supplemented by cladocera and fish (Houde 1967). Smith and Moyle (1943) reported that walleye fry stocked in natural ponds began feeding on rotifers, copepods, and cladocerans, shifted to an insect-crustacean diet with an increase in size, and finally fed almost exclusively on fish. Walleye will utilize any forage species readily available to them but change their diets according to the species and lengths of forage fish (Parsons 1971; Scott and Crossman 1973). The length of forage species sought increases with the length of the walleye (Parsons 1971).

CONCLUSIONS

Production by the fathead minnow population in Pickering Slough was estimated as 16.1 lb/acre in 1976. Production potential was underestimated as a result of: 1) low initial brood stock density (less than five per acre); 2) receding water levels through the study period; 3) exclusion of sexual products from the production estimate; 4) exclusion of production by fry not surviving to be censused; and 5) exclusion of production in September and October. Production estimates for fathead minnows in Pickering Slough approached production expectations for temperate waters dominated by a single fish species.

The requirement of live food sources for northern pike, largemouth bass, and walleye causes hatchery rearing of these species to be economically infeasible. The capability of rearing these fishes from fry to fingerlings or to yearlings in a natural habitat, utilizing autochthonous food resources, would be of considerable value. Prairie wetlands appear to have sufficient quantities of microcrustaceans and immature insect forms to support populations of stocked piscivores through the transition to fish diets. Production by autochthonous populations of fathead minnows should provide an adequate forage base once the stocked species becomes more exclusively piscivorous.

Additional investigations of prairie wetlands during periods of normal precipitation should provide more realistic population and production estimates for fathead minnow populations. The definitive test of the value of prairie wetlands for rearing purposes must consist of acutally stocking the wetland with the desired species, monitoring the results and evaluating the success of the program.

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