Climatological Factors Influencing Yellow Perch Production in Semi-Permanent Wetlands

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ABSTRACT Climatological factors such as temperature, wind, and precipitation have been reported to affect fish reproduction and recruitment in large lakes; however, little is known about these relationships in shallow, semi-permanent wetlands. We utilized age-0 yellow perch (*Perca flavescens)* aquacultural harvest data to model climate effects on variability of juvenile yellow perch year class strength in semi-permanent wetlands. Overall, March through May precipitation, April air temperature, and a wetland parameter (i.e., intrinsic characteristics) provided the best-supported model. These results potentially indicate that spring weather patterns have an influence on yellow perch year class strength in semi-permanent wetlands.

KEY WORDS Climatic effects, *Perca flavescens,* recruitment, wetlands, yellow perch

Climate factors can influence the survival and growth of yellow perch (*Perca flavescens*) throughout its range. Constant or increasing temperature has shown a positive relationship to survival and growth of yellow perch (Clady 1976, Pope et al. 1996, Ward et al. 2004). Fluctuations in temperature can affect embryonic development of gills, jaw, and overall body size (Newsome and Aalto 1987). Low temperatures can hinder primary and secondary production, or timing (Wetzel 2001), thereby reducing prey availability and ultimately affect yellow perch survival and growth (Graeb et al. 2004). Precipitation (Pope et al.1996, Ward et al. 2004) and increased water levels (Henderson 1985) have also been positively related to abundance of larval yellow perch, likely a result of increased spawning habitat. Other researchers have reported that strong winds can dislodge egg masses from raised substrates causing a decrease in viable yellow perch eggs (Clady 1976, Aalto and Newsome 1993). Although, Fisher et al. (1996) and Day (1983) did not observe any stranded yellow perch egg masses following high wind events.

The influence of climatic factors varies among systems largely due to water body size and complexity. Koonce et al. (1977) found that temperature did not directly affect year-class strength of yellow perch in Lake Erie but suggested that temperature may only influence recruitment during drastic climate events. In large South Dakota lakes, Ward et al. (2004) found negative relations between larval abundance and May wind speed at Pickerel Lake, and March wind speed at East 81 Lake and Lake Madison; however, those populations typically spawn late April through early May (Hanchin et al. 2003, Fisher 1996). Consequently, Ward et al. (2004) hypothesized that wind speed may be a surrogate for other climatic events (e.g., cold fronts or unstable weather conditions) that could affect larval survival.

Timing and duration of certain climatic events during early developmental stages can also influence larval yellow perch hatching and survival. Precipitation most likely benefits yellow perch if it occurs prior to spawning by increasing spawning and rearing habitat availability. Strong winds may be most detrimental during the egg and hatching stages of yellow perch due to physical damage, dislodging, and siltation caused by increased wave action. Fluctuations in water temperature may cause deformities during larval development (Newsome and Aalto 1987) but also may be influential throughout egg development and early larval stages. Much of the aforementioned research has been conducted on large permanent lakes; however, little is known about the extent of climatic effects on yellow perch reproduction and recruitment in semi-permanent wetlands. Due to the small size of semi-permanent wetlands, climatological effects are likely more pronounced, inducing even greater variability in yellow perch reproduction and recruitment. Therefore, our objective was to examine relationships between climate factors and age-0 yellow perch relative abundance in semi-permanent wetlands.

STUDY AREA

Semi-permanent wetlands (n = 11) throughout Brookings, Lake, Minnehaha, and McCook counties, South Dakota, were utilized as natural rearing systems for yellow perch production between 1988 and 2005 (Table 1, Fig. 1). We defined wetlands as semi-permanent because water covered the land throughout the growing season in most years (Cowardin et al. 1979); wetlands ranged in size from 13 to 49 ha. North Twin and South Twin were considered one wetland during some high water years when the two waters were interconnected. Fish communities in these wetlands were relatively simple with fathead minnows (*Pimephales promelas*) and yellow perch occurring in all wetlands and walleye (*Sander vitreus*; n = 7) and black

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bullhead (*Ameiurus melas*; n = 8) occurring in most wetlands. Other species considered rare in a few of the wetlands included largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis annularis*) and black crappie (*P. nigromaculatus*; Table 1).

METHODS

We stocked adult pre-spawn yellow perch into each wetland each spring to provide adequate broodstock to potentially produce a year class of age-0 yellow perch (mean stocking density = 33/ha). In the fall following stocking, we harvested yellow perch with modified fyke nets (6.4-mm bar mesh) set perpendicular to the shore. We sorted captured yellow perch into two categories (age-0 and age-1+) based on their total length (<120 mm TL at first fall). We did not have effort data (number of nets and number of days) for all wetlands, because net set durations were variable (set for 1 to 3 days before removing catches) and often not recorded during the early years of the study. Thus, total fall harvest (number of age-0 yellow perch/ha) from each wetland was used in the analysis. We calculated total fall harvest as the total weight of age-0 yellow perch harvested multiplied by the number/kg, derived by subsampling. This likely provided comparative abundance measures because yellow perch are continuously harvested until each population is depleted to such a low level that additional harvest effort is not warranted. However, decreasing fall water temperatures may also hinder yellow perch catch rates. We recorded a harvest failure when an effort of 5 to 10 modified fyke nets set overnight resulted in a catch of zero. We estimated surface area for each wetland in ArcView™ 3.2 (ESRI; Redlands, California, USA) from data (wetland polygons digitized from 1983 and 1984 aerial photography) obtained from the National Wetlands Inventory Brookings, South Dakota.

We obtained climate data [maximum and minimum daily air temperature (°C) and monthly precipitation (cm)] for monitoring stations in Brookings, Arlington, Madison, and Sioux Falls from the South Dakota State Climate Office and assigned to each wetland based on location (Fig. 1). We calculated mean daily air temperature by averaging each daily maximum and minimum temperature and then averaging all daily means within the specified time periods. Because wind data (hourly wind speed; km/hr) were not available for all stations, we assigned either Brookings or Sioux Falls municipal airport wind data according to wetland proximity to those monitoring stations (maximum distance = 48 km).

The critical window when climate factors are most influential on yellow perch recruitment in semi-permanent wetlands is unknown. Thus, we developed multiple exploratory models for each climate variable (i.e., temperature, precipitation, and wind; Table 2). We calculated mean temperatures by taking the mean of the daily mean temperature. Thermal indices were the cumulative decreases in daily mean temperature for the given time interval, thus low index values would represent a warm interval and high index values would represent a cool interval. We compared mean temperature for each day with the previous day. If the second day was lower than the first day, we calculated the difference between mean temperatures. We summed all of the negative differences to estimate the thermal index. We used a wetland identifier parameter [unique identifier for each wetland (i.e., wetland number)] in all models to account for variability in harvest among wetlands within years due to intrinsic wetland limitations (e.g., spawning habitat, productivity, and prey availability) on yellow perch production. Importantly, we included total age-0 yellow perch harvest (# / ha) as the response variable in all models. To avoid the potential for colinearity among variables included in the model selection process, we examined all relationships using scatterplot and correlation matrix utilities (Systat 2000); these analyses showed that variables used in models were not correlated ($R^2 < 0.37$, $P > 0.56$).

We used an information theoretic approach to evaluate relative support for yellow perch production models. Model selection was based on Akaike's information criterion (AIC). Due to small sample size [e.g. sample size (n) / number of parameters (k) < 40], we used second order AIC (AIC_c) to calculate the difference in AIC_c between each model and the best supported model (Δ_i), and model weights (w_i) for each model (Burnham and Anderson 2002). Initially, we evaluated all potential simple models from each of the available climate model groups (i.e., wind, temperature, and precipitation) to determine the most influential time interval for that climate factor (Table 2). Next, we compared 9 models containing combinations of the variables from the best climate group models to assess overall climate effects on the variability of age-0 yellow perch abundance.

RESULTS

A total of 55 harvests, ranging from 0 to 21,326 yellow perch/ha, from 11 wetlands over 17 years were used in the model selection analyses (Table 1). Yellow perch in 9 of 11 wetlands had at least one year of presumed recruitment failure (i.e., 0 yellow perch/ha).

A wide range of values for climatological variables were encountered during this study. Precipitation ranged from 1.1 cm in April of 1996 to 56.4 cm accumulated in the September through May period of 1999. April mean temperatures ranged from 4.0 (1995) to 11.3° C (1988) and May mean temperatures ranged from 10.8 (1997) to 21.6° C (1988). Cooling index values ranged from 45.0 (May 1995) to 187.5 (April and May 2004) and mean wind speed ranged from 6.79 to 9.85 km/hr.

Table 1. Surface area (ha), shoreline development index (SDI), range of harvest (number/ha), mean harvest (number/ha; standard error) and county of semi-permanent wetlands used as yellow perch rearing ponds in eastern South Dakota, 1988–2005.

Wetland	County	N[a]	Area	SDI	Range of harvest	Mean harvest	Other species[b]
Dry Lake	Brookings	5	18.8	1.1	0–684	137 (137)	FHM LMB
Fods	Lake	6	23.2	1.6	0–21,326	4,951 (3,411)	FHM WAE BBH
Knappen	Brookings	3	20.7	1.2	0–1,240	413 (413)	FHM WAE LMB BLG WHC
Little Brush	Brookings	12	14.1	1.1	0–5,974	2,354 (584)	FHM BBH
Lukes	McCook	3	48.9	3.2	0–937	312 (312)	FHM BBH
Nelson	Brookings	4	26.8	2.2	0–1,637	597 (389)	FHM WAE
Schaefer	Minnehaha	6	26.5	1.8	0–6,060	1,165 (987)	FHM WAE BBH
South Brush	Brookings	2	13.1	1.5	0–19	10 (9)	FHM WAE BBH
Twin North	Minnehaha	3	39.9	1.2	504–3,021	1,695 (730)	FHM WAE BBH
Twin South	Minnehaha	2	44.4	1.8	329–3,223	1,776 (1,447)	FHM WAE BBH
Twin (combined)	Minnehaha	7	84.3	N/A	22–930	439 (120)	FHM WAE BBH
Wise	Minnehaha	2	30.3	2.1	0–195	98 (98)	FHM BLC

[a] N = number of years used as a yellow perch rearing pond; [b] FHM = fathead minnow, LMB = largemouth bass, WAE = walleye, BBH = black bullhead, WHC = white crappie, and BLC = black crappie.

Variability in yellow perch harvest was best explained by the March through May precipitation model (Table 2). The April mean temperature model had better relative support compared with the other temperature models. Additionally, the mean May wind speed model best explained variability in yellow perch harvest. However, overall yellow perch abundance was best explained by the climate model that included April temperature, March through May precipitation, and wetland identifier parameters (Table 2). We conducted post hoc comparisons between similar models with and without the wetland identifier parameter to examine the effect of wetland habitat has on yellow perch production. Models that contained the wetland identifier as a parameter were better supported than similar models that omitted the wetland identifier; therefore, a substantial amount of yellow perch production variability is likely caused by intrinsic biotic (e.g., predation, food availability) or abiotic (e.g., mean depth, nutrients) factors. Mean spring temperature and total spring precipitation appeared to influence age-0 abundance more than mean spring wind speed (Table 2).

DISCUSSION

Temperature and precipitation were the most influential climatic factors observed in this study. These variables have been found to be positively related to year class strength for yellow perch in many systems (Clady 1976, Pope et al. 1996, Ward et al. 2004). Similarly, Eshenroder (1977) found that yellow perch recruitment in Saginaw Bay was correlated to spring temperature. Conversely, Koonce et al. (1977) found that temperature did not directly affect the year-class strength of yellow perch in Lake Erie, suggesting that temperature may only have influenced recruitment during drastic or rapid cooling events, which consequently are rare in large lakes. The cooling index used in this study may not be an accurate method for determining the severity of negative fluctuations in temperature. The cooling index used was the cumulative decreases in mean daily temperature, which could mask short-term, episodic changes in the rate of temperature decrease or the magnitude of a short-term temperature event.

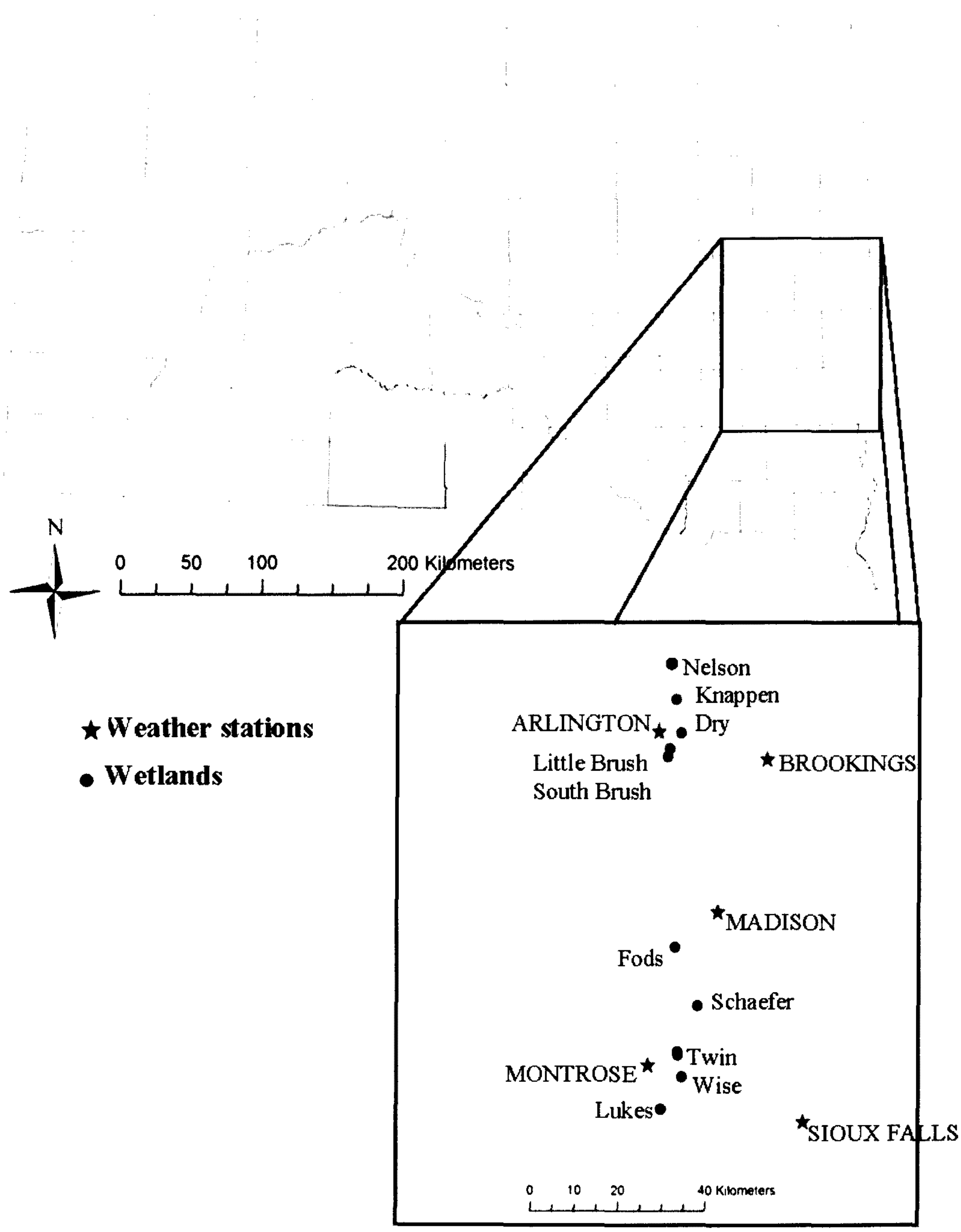

Figure 1. Locations of wetlands (dots) and nearby weather recording stations (stars; city names) used in AIC analysis of wind, precipitation, and temperature effects on yellow perch juvenile production in eastern South Dakota, 1988–2005.

Table 2. Models developed to explain variability in yellow perch harvest in semipermanent wetlands throughout eastern South Dakota, 1988–2005.

Model	N[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	LL[e]	w_i[f]
Mar to May precipitation + wetland	56	4	887.9	0.00	1.00	0.46
Apr to May + wetland	56	4	889.5	1.62	0.45	0.20
Nov to May precipitation + wetland	56	4	890.5	2.59	0.27	0.13
Apr precipitation + wetland	56	4	890.7	2.78	0.25	0.11
Nov to Apr precipitation + wetland	56	4	892.1	4.16	0.13	0.06
Temperature (mean)						
Apr temp + wetland	56	4	888.8	0.00	1.00	0.87
Apr to May temp + wetland	56	4	894.3	5.42	0.07	0.06
May temp + wetland	56	4	896.2	7.39	0.02	0.02
Apr cooling index + wetland	56	4	896.4	7.55	0.02	0.02
Wind (mean speed)						
May + wetland	56	4	895.2	0.00	1.00	0.53
Apr + wetland	56	4	896.8	1.63	0.44	0.24
Apr to May + wetland	56	4	896.9	1.68	0.43	0.23
Climatological comparisons						
Temp + precipitation + wetland	56	5	886.4	0.00	1.00	0.48
Precipitation +wetland	56	4	887.9	1.50	0.47	0.23
Temp + wind + precipitation + wetland	56	6	888.8	2.40	0.30	0.14
Temp + wetland	56	4	888.8	2.44	0.29	0.14

[a] N = sample size; [b] K = number of parameters; [c] AIC_c = second order Akaike's Information Criterion (Burnham and Anderson 2002); [d] ΔAIC_c = Difference in AIC relative to minimum AIC; [e] LL = Log likelihood; [f] Akaike weight (Burnham and Anderson 2002). Climatological comparison models included data from the time periods of the most supported models in the precipitation, temperature, and wind analyses.

Spring precipitation also has been positively related to yellow perch larval densities (Pope et al. 1996, Ward et al. 2004). A potential explanation for this relationship could be that rising water levels inundate terrestrial vegetation, thus increasing the amount of suitable spawning habitat. This explanation is consistent with Henderson's (1985) findings that recruitment was a function of water levels in Lake Huron. Water level data for these wetlands was not available; however, we believe that the precipitation models served as a surrogate for water levels, especially because of the long time period encompassed by this study.

Strong winds during the spring have been related to decreased larval yellow perch abundance (Clady 1976, Aalto and Newsome 1993, Pope et al. 1996, Ward et al. 2004). Strong winds can cause increased wave action which has been reported to dislodge egg masses from substrates or to cover eggs with silt causing the eggs to suffocate (Clady 1976, Aalto and Newsome 1993), however, during this study, our models indicated that no major wind effect was observed. In small wetlands, wave height can be restricted due to short fetch distance, thus wetlands used in our study may not be as susceptible to wind effects as large lakes.

Addition of the wetland identifier parameter increased the relative support of each model indicating that other in-lake factors also affected age-0 yellow perch production in these wetlands. Other factors that have been reported to positively influence yellow perch recruitment are vegetation abundance [e.g., spawning habitat (Willis et al. 1997)], food availability and size structure (Graeb et al. 2004), and parental stock size (Sanderson et al. 1999), while juvenile density (Sanderson et al. 1999) and predatory effects (Hartman and Margraf 1993) show a negative relationship to recruitment. Wetlands in the current study are stocked with adult yellow perch in early spring (pre-spawn period) to assure adequate brood stock followed by depletion of the system by trapnetting during the subsequent fall. Parental stock size should be adequate and any intraspecific competition with the previous year class should be low.

MANAGEMENT IMPLICATIONS

Mean temperature combined with total precipitation were the most influential variables affecting yellow perch recruitment in small wetlands. Deep wetlands could be chosen as natural perch rearing systems because they hold more water, which could potentially reduce the negative effects of cold weather events. Additionally, wetlands with larger immediate watersheds also should be considered because increased precipitation and water levels during the spring has been correlated with yellow perch recruitment. Future research examining potential relationships between wetland characteristics (i.e., size, shape, depth, and watershed area) and the extent of climatological effects on yellow perch recruitment in wetlands used as rearing ponds also is warranted. Also, vegetation coverage, food availability, and fish community structure and composition all likely affect yellow perch recruitment thus, future research should examine the biotic effects on yellow perch recruitment within wetland habitats.

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