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# The Relative Weight ( $W_r$ ) Condition Index as a Predictor of Growth, Prey Abundance and Environmental Conditions

Hongsheng Liao

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THE RELATIVE WEIGHT ( $W_r$ ) CONDITION INDEX AS A PREDICTOR  
OF GROWTH, PREY ABUNDANCE AND ENVIRONMENTAL CONDITIONS  
(TITLE)

BY

HONGSHENG LIAO

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1994

YEAR

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## ABSTRACT

We evaluated the relative weight ( $W_r$ ) condition index for assessment of growth, prey availability and environmental conditions in fish populations. Standard weight ( $W_s$ ) equations for pumpkinseed (*Lepomis gibbosus*) and golden shiner (*Notemigonus crysoleucas*) from 302 pumpkinseed and 285 golden shiner populations, with well over 10,000 fish of each species, were developed with regression-line-percentile (RLP) technique. The proposed  $W_s$  equation in metric units for pumpkinseed is  $\log_{10}W_s = -5.179 + 3.237 \log_{10}TL$ , and for golden shiner is  $\log_{10}W_s = -5.593 + 3.302 \log_{10}TL$ . The English-unit versions of these equations were also developed. Evaluation of relationships of  $W_r$  with fish growth and other ecological variables were made from ten southern Quebec lakes in 1987 and 1988, with over 2,000 fish of each species. Size-specific growth and size-specific  $W_r$  were calculated using stock and quality length of each species. Lake, year, season, and length affected  $W_r$ , but not sex of fish. No significant relationships were found between  $W_r$  and growth among lakes or among individual fish. Significant correlations were found between  $W_r$  and prey availability and chlorophyll a, but not fish biomass, macrophyte biomass, and temperature. Our results suggest that  $W_r$  can reflect prey availability of fish populations better than other physiological or ecological conditions of fish. We recommend that  $W_r$  be used cautiously as an assessment tool in freshwater fishes.

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## INTRODUCTION

Condition indices are widely used in assessment of freshwater fish populations (Nielsen and Johnson 1983; Schreck and Moyle 1990; Murphy et al. 1991; Kohler and Hubert 1993). Condition indices measure the "plumpness" or "robustness" of fish, and are calculated from very easily obtained and readily available length-weight data; these data are routinely collected as part of research and management assessments. Condition is tacitly assumed to reflect characteristics of fish, such as health, "well-being", reproductive state and growth, as well as characteristics of the environment, such as habitat quality, water quality and prey availability (Anderson and Gutreuter 1983; Busacker et al. 1990; Ney 1990).

There has been much debate concerning the use of condition indices in recent literature, centering largely around methodological issues such as the appropriateness of various indices (Bolger and Connolly 1989; Cone 1989; Springer et al. 1990). Recently, the relative weight ( $W_r$ ) condition index (Wege and Anderson 1978) has become popular, prompting discussion regarding the various methods for generating the necessary standard weight ( $W_s$ ) equations (Murphy et al. 1990, 1991). A more fundamental issue regarding the use of condition indices remains unresolved, however, and that is how to interpret condition of fish in natural populations. What does condition predict? Evidence for the relationships suggested above is

scattered throughout the literature on condition, but is largely anecdotal. We are aware of no previous attempts to thoroughly and rigorously evaluate the use of  $W_r$  as an assessment tool for predicting growth, prey availability and other factors for fish populations in nature.

The primary purpose of this study was to evaluate  $W_r$  as an assessment tool in freshwater fish populations. To do this, we were able to take advantage of a larger study of littoral fish communities, invertebrate prey availability, limnological conditions and growth of two fish species in ten lakes in southern Quebec (Pierce et al. in press). First, we developed standard weight ( $W_s$ ) equations for two of the three dominant species in these lakes, pumpkinseed Lepomis gibbosus and golden shiner Notemigonus crysoleucas. Using these equations to calculate  $W_r$ , we addressed the following objectives: 1) analyses of sources and patterns of variation in  $W_r$ , and 2) exploration of relationships of  $W_r$  with growth, fish biomass, prey biomass and limnological variables. Results of this evaluation illustrate strengths and weaknesses of  $W_r$  as an assessment tool for fish populations in nature, and hopefully will help guide the use of  $W_r$  for other species.

## STUDY LAKES AND SPECIES

Evaluation of  $W_r$  was conducted in ten lakes located in the Eastern Townships region of southern Quebec, Canada (Fig. 1). Several previous studies describe a variety of characteristics of these lakes, including pelagic zooplankton and phytoplankton (Pace 1984, 1986), littoral periphyton (Cattaneo 1987), sediments (Rowan et al. 1992), macrophytes (Chambers and Kalff 1985; Duarte and Kalff 1986; Anderson and Kalff 1988), benthos (Rasmussen 1988a, b), growth of yellow perch (Boisclair and Leggett 1989a, b, c), littoral fish sampling conditions (Pierce et al. 1990), and littoral fish communities (Pierce et al. in press).

Pumpkinseed and golden shiner are common and widely distributed littoral zone fishes in North America (Scott and Crossman 1973; Lee 1981). Together, they account for 30% of the littoral zone fish biomass in our study lakes, and are the second (golden shiner) and third (pumpkinseed) most abundant littoral species in these lakes (Pierce et al. in press).

## MATERIALS AND METHODS

Development of Standard Weight Equations - We obtained weight-length data from 302 pumpkinseed and 285 golden shiner populations (Appendix A, B), with well over 10,000 fish of each species, distributed widely across the

species' ranges to develop standard weight ( $W_s$ ) equations for each species. The data were of two general types: 1) weights and lengths of individual fish, or 2) regressions describing weight-length relationships of populations. Individual weights and lengths were provided by management and research personnel, along with site names, locations, and occasionally additional descriptive information. Most of these data sets contained no information regarding age, growth or sex. Weights were either reported as or converted to the nearest 0.1 g (wet), and lengths (total length) to the nearest mm. Eight or more individual fish and  $r^2 \geq 0.80$  for the regression of weight ( $\log_{10}$ ) on length ( $\log_{10}$ ) were minimum criteria for including populations in the development of  $W_s$  equations. Regressions describing weight-length relationships of many additional populations were taken from published studies, agency reports and data compilations. The same inclusion criteria used above were used for these regressions, when known. Regressions reported without sample size and  $r^2$  were assumed to be valid and included.

$W_s$  equations for pumpkinseed and golden shiner were developed using the regression-line-percentile (RLP) technique (Murphy et al. 1990). The RLP technique is currently the consensus favorite for developing  $W_s$  equations because it weights each population equally and produces  $W_r$  estimates of low variance and free of length bias (Murphy et al. 1991). For each population, we computed a (or used the existing) linear regression of weight ( $\log_{10}$ ) on length ( $\log_{10}$ ). We set up 50 mm and 300 mm as minimum

and maximum of the length range, respectively. At the midpoint (i.e., 55 mm, 65 mm, 75 mm, etc.) of each 1-cm length interval within this range, we calculated a predicted  $\log_{10}$  weight using the weight-length regression and then back-transformed these values to predicted arithmetic weights. For each length interval, the 75th percentile was then calculated from the predicted weights of all the populations in the data set. Finally, the 75th percentile weights were  $\log_{10}$ -transformed and regressed against the corresponding  $\log_{10}$ -transformed midpoint lengths, yielding the  $\log_{10}$ - $\log_{10}$  version of the  $W_s$  equation. Further details and rationale for the RLP technique is given in Murphy et al. (1990).

Fish Sampling for Evaluating  $W_r$  - Using beach seines as described by Pierce et al. (1990), we sampled pumpkinseed and golden shiner in each of the ten lakes once in early summer (hereafter referred to as "early") and once in late summer (hereafter referred to as "late") during 1987 and 1988. The early summer period was from 18 June to 26 June in 1987, and from 4 July to 15 July in 1988. The late summer period was from 24 August to 17 September in 1987, and from 8 September to 22 September in 1988. Details of the early and late sampling are presented elsewhere (Pierce et al. in press). Additional samples of both species were obtained from 9 May to 20 May, 1988, and are hereafter referred to as "spring" samples.

Captured fish were anesthetized immediately in 2-phenoxyethanol, put

on ice, and frozen within a few hours. In the laboratory, a length-stratified random subsample of at least 50 fish,  $\geq 50$  mm total length, of each species from each combination of lake and sampling date was weighed (wet) to the nearest 0.01 g on an electronic balance and measured (total length) to the nearest mm. A few subsamples contained less than 50 fish, reflecting low abundance on the corresponding sampling date. Scale samples for age and growth analysis were collected from each fish in spring and late 1988 subsamples. Pumpkinseed scales were taken at the tip of the depressed left pectoral fin; golden shiner scales were taken above the lateral line dorsal to the tip of the depressed left pectoral fin. Sex was determined for the spring subsamples only.

Determination of Size Classes for Test Populations - We used the length categorization system of Gabelhouse (1984) to establish meaningful sizes (lengths) for comparisons of  $W_r$ , and to examine relationships of  $W_r$  with growth and other variables. "Stock" and "quality" lengths of 80 mm and 150 mm, respectively, were used for pumpkinseed (Gabelhouse 1984). Using the rationale of Gabelhouse (1984) and 305 mm as an estimate of maximum length (Becker 1983), we set "stock" length as 70 mm (23% of maximum) and "quality" length as 120 mm (39% of maximum) for golden shiner. We recognize that, for the traditional purposes of fishery management, these length categories are meaningless for golden shiner;

they are used only to provide a basis for analysis of the influence of size on  $W_r$  and for comparisons with other species.

$W_r$  of Test Populations -  $W_r$  was calculated for all fish using the equation

$$W_r = (W \cdot W_s^{-1}) \times 100 \quad (1)$$

(Wege and Anderson 1978), where  $W$  is the wet weight of the fish and  $W_s$  is the length-specific standard weight predicted from the appropriate  $W_s$  equation described above. These individual  $W_r$  values were used to explore sources of variation in  $W_r$  and the relationship with growth of individuals as described below.

For each subsample (i.e., for each combination of species, lake and sampling date),  $W_r$  was regressed against total length. If the regression was significant ( $H_0: b=0, \alpha=0.05$ ), it was used to generate size-specific  $W_r$  estimates (see above) for that subsample. If the regression was not significant, the subsample mean  $W_r$  was used to represent  $W_r$  for all sizes present in that subsample. Neither regressions nor subsample means were extrapolated beyond the ranges of fish sizes occurring in subsamples; this resulted in no  $W_r$  estimates for some size classes on some sampling dates.

For comparing  $W_r$  with growth and food availability across lakes, size-specific estimates from the early and late subsamples from both years were averaged by species and lake. This produced size-specific "average" estimates of  $W_r$  for each species in the ten lakes, and prevented unequal



weighting of sampling periods due to variable numbers of fish in subsamples.

Growth of Test Populations - Growth rates of individual fish were estimated by aging and back-calculation of lengths at previous ages using scales (Busacker et al. 1990). Ten or more scales per fish were cleaned and mounted between glass slides; large, opaque scales were impressed on acetate slides. All scales on slides were viewed when assigning ages to fish, and a single reader did all aging. Scales from 30 fish of both species were viewed by a second reader and age assignments were in 100% agreement. Ages assigned by reading scales corresponded well with length-frequency distributions.

Radii and inter-annular distances on ten scales per fish were measured using a dissecting microscope (25x magnification), drawing tube, and computerized digitizing tablet as described in Frie (1982). Regenerated or otherwise distorted scales were not digitized, resulting in fewer than ten replicate scales measured from some fish. Replicate measurements were then averaged for each fish, providing precise estimates of scale growth increments for back-calculations (Newman and Weisberg 1987).

We used the Fraser-Lee technique (Busacker et al. 1990) for back-calculation of lengths at previous ages based on scale growth increments. Intercepts ( $a$ ) for back-calculation were generated from regressions of fish

length on scale radius from 1095 pumpkinseed and 1127 golden shiner distributed approximately equally among all ten study lakes. Whereas all fish from spring and late 1988 subsamples were used in generating body-scale relationships, fish older than 5 years were omitted from back-calculations to avoid potential errors from incorrect aging of older fish. Pumpkinseed and golden shiner back-calculations were based on an average of 81 and 104 fish per lake, respectively.

Using the back-calculated lengths at previous ages and differences between successive lengths as estimates of annual growth increment, we regressed annual growth increments against length at the start of the growing season for each species in each lake. All regressions had negative slopes, indicating decreasing annual growth with increasing size. Growth rates of young-of-year fish were simply estimated as lengths at first annulus and were not included in regressions, since initial length was length at hatching and essentially the same for all fish. Quadratic regressions were used to improve fit when both linear and quadratic terms were significant ( $H_0: b = 0, \alpha = 0.05$ ). These size-specific growth regressions explained averages of 51% and 60% of the variation in annual growth of pumpkinseed and golden shiner populations, respectively, and allowed estimation of "average" growth of a population at stock and quality lengths, similar to the way in which size-specific  $W_t$  estimates were obtained (see above). Expressing growth as a function of fish size has several advantages over the

more traditional age-specific approach, especially when comparing growth among populations (Gutreuter 1987; Osenberg et al. 1988; Putman et al. in review).

Using fish from late 1988 subsamples only, we estimated recent growth of individual fish as the difference between length at capture and back-calculated length at the last annulus. These recent growth increments were then regressed against length at last annulus for each species in each lake, similar to the procedure described above. Residuals from these regressions were used as length-corrected estimates of recent growth, and were examined for each species within each lake for correlation with  $W_r$ .

#### Fish Biomass, Prey Biomass and Limnological Variables in Study Lakes -

Biomass of pumpkinseed, golden shiner and the total littoral fish community was estimated from the early and late samples described above. Detailed descriptions of the procedures and analysis of these samples are presented elsewhere (Pierce et al. 1990, in press).

Invertebrate prey and limnological variables were sampled several times during the months of May through September, 1987 and 1988. Littoral sediment-dwelling and epiphytic macroinvertebrate prey were sampled as described in Rasmussen (1988a). Organisms were identified, counted and measured for conversion to biomass using length-mass regressions (Smock 1980; C. W. Osenburg, Univ. of California-Berkely,

unpublished data; J. B. Rasmussen, unpublished data).

Littoral zooplankton prey were sampled at 0700 h by triplicate bottom-to-surface vertical hauls with a 30.5-cm diameter, 75- $\mu$ m mesh net. Depths were recorded to the nearest 0.1 m, and were generally near 3 m. A filtering efficiency of 46%, estimated by several calibrations with pooled Schindler-Patalas trap samples taken at 1-m intervals, was applied as a correction factor in biomass calculations. Samples were preserved in a sucrose-formalin solution (Haney and Hall 1973). Organisms in subsamples (usually 10% of sample) were identified and counted, and at least thirty individuals of each taxon were measured for conversion to biomass using length-mass regressions (Dumont et al. 1975; Culver et al. 1985).

Water temperatures were estimated using a combination of littoral and pelagic temperature profiles at 1-m depth intervals. Littoral temperature profiles were recorded near fish sampling areas from the surface to the bottom (approx. 3 m). Pelagic profiles were recorded at off-shore locations from the surface to a depth of 3 m. Temperatures from individual profiles were averaged across depths, and these values were then averaged over the two years of sampling for each lake. Chlorophyll a concentrations were determined from integrated epilimnetic water samples obtained from off-shore locations using a tube sampler; triplicate 500-ml subsamples were vacuum-filtered (65  $\mu$ ) and frozen in the field, and extracted in the laboratory (Strickland and Parsons 1968). We sampled submerged littoral macrophyte

biomass concurrently with fish samples as described in Pierce et al. (1990).

Statistical Analyses - Data were analyzed using linear regression, quadratic regression, Analysis of Variance (ANOVA) and correlation analysis.

Hundreds of linear regressions of  $\log_{10}$ -transformed length and weight data were performed to generate  $W_s$  equations using the RLP method. Lake, yearly and seasonal variation in  $W_r$  of both species was evaluated with 3-way ANOVAs with interactions, and sex and lake variation was evaluated with 2-way ANOVAs with interactions.  $W_r$  data were analyzed untransformed. Relationships of  $W_r$  with growth and other variables were examined using regression and correlation analysis. Growth data were analyzed untransformed; other variables were transformed as described in Pierce et al. (in press). All analyses were performed using the CORR, GLM, REG and UNIVARIATE procedures of SAS (SAS Institute Inc. 1988).

## RESULTS

### Standard Weight Equations

The proposed standard weight ( $W_s$ ) equation for pumpkinseed is

$$\log_{10}W_s = -5.179 + 3.237 \log_{10}TL, \quad (2)$$

and for golden shiner is

$$\log_{10}W_s = -5.593 + 3.302 \log_{10}TL, \quad (3)$$

where  $W_s$  is standard weight in grams and TL is total length in millimeters.

The English unit equivalent of the equation for pumpkinseed is

$$\log_{10}W_s = -3.288 + 3.237 \log_{10}TL, \quad (4)$$

and for golden shiner is

$$\log_{10}W_s = -3.611 + 3.302 \log_{10}TL, \quad (5)$$

where  $W_s$  is standard weight in pounds and TL is total length in inches. The metric versions of these  $W_s$  equations were used to calculate  $W_r$  of individual fish from test populations.

#### Influence of Fish Length on $W_r$

Plots of  $W_r$  of individual fish showed variable relationships with fish length, depending on species, lake and sampling date (e.g., Fig. 2). Regressions of  $W_r$  on length were significant ( $H_0: b = 0, \alpha = 0.05$ ) in 40% of the pumpkinseed subsamples and 33% of the golden shiner subsamples (early and late subsamples only). For both species, 31% of the significant regressions had positive slopes and 69% had negative slopes. Significant regressions for a given species and lake were usually all either positive or negative, although there were both significant positive and negative regressions for golden shiner in two lakes (Brompton and d'Argent). There was no case of significant regressions occurring in all subsamples of a given species and lake, but it was common for at least one subsample to have a

significant regression. The examples in Fig. 2 are representative of the overall pattern of relationships of  $W_r$  with length; correlations were ephemeral, perhaps reflecting changing relative ecological conditions for fish of different sizes over time.

#### Spatial and Temporal Variation in $W_r$

$W_r$  of both species varied significantly among lakes, years and seasons (Table 1; Figs. 3, 4). All interactions were highly significant in ANOVAs for both species (Table 1), making interpretations difficult. These can be considered conservative tests of the effects of lake, year and season since variation due to length was contained in the error SS. Figures 3 and 4 illustrate this, showing that while  $W_r$  tended to be higher in some lakes and lower in others, the temporal patterns differed considerably among lakes. Early  $W_r$  was higher than late  $W_r$  in some lakes, while the reverse was true in others. In some lakes, early  $W_r$  was higher than late  $W_r$  in one year, and the reverse in the other year. The only consistent pattern was that the lowest  $W_r$ s occurred in spring in most lakes.

#### Influence of Sex on $W_r$

There were no significant differences in  $W_r$  between males and females of either species in the spring subsamples (Table 2). The spring samples were collected from all lakes just prior to the beginning of the

spawning seasons of both species, and thus at a time when sexual differences in  $W_r$ , if any, would likely be most evident. The highly significant lake effects (Table 2), here in the absence of interacting temporal effects, further support the previous inference of significant differences in  $W_r$  among lakes.

#### Intra- and Interspecific Relationships in $W_r$ Among Lakes

Intraspecific correlations of  $W_r$  of stock and quality length fish among lakes showed mixed results.  $W_r$  estimates of stock length pumpkinseed were not significantly correlated with  $W_r$  estimates of quality length pumpkinseed among the ten lakes ( $r=0.65$ ,  $\underline{P}=0.059$ ). In contrast, the corresponding correlation for golden shiner was significant ( $r=0.83$ ,  $\underline{P}=0.003$ ) suggesting, perhaps, that  $W_r$  responses to environmental conditions are less influenced by size than in pumpkinseed.

Interspecific correlations of  $W_r$  estimates of both stock and quality length fish among lakes were nonsignificant (stock length:  $r=0.42$ ,  $\underline{P}=0.227$ ; quality length:  $r=0.50$ ,  $\underline{P}=0.167$ ), suggesting that  $W_r$  responses of the two species to environmental conditions in lakes differed.

#### Relationship of $W_r$ with Growth

We found little evidence for a relationship between  $W_r$  and growth. There were no significant correlations of size-specific  $W_r$  estimates with



corresponding size-specific growth estimates among lakes (Table 3).

Although these results suggest a general lack of relationship, they are based on lake means of seasonally and annually varying  $W_r$  estimates and therefore could potentially contain confounding individual and temporal variation. As a test of the relationship of  $W_r$  and growth among individual fish, we examined correlations of growth residuals (length-corrected estimates of recent growth) with  $W_r$  in each subsample (e.g., Fig. 5c, d). These correlations compare late summer  $W_r$ s with growth during that summer among individual fish in subsamples. 80% of these correlations for both species were nonsignificant ( $P > 0.05$ ; e.g., Fig. 5c). Three of the four significant ( $P < 0.05$ ) correlations were negative (e.g., Fig. 5d), contrary to the a priori expectation of positive relationship.

#### Relationships of $W_r$ with Fish Biomass, Prey Biomass and Limnological

##### Variables

We found no evidence of density-dependence in  $W_r$  estimates among lakes for either species (Table 3). Neither correlations of  $W_r$  with total fish biomass nor with conspecific biomass were significant.

The strongest relationships in our dataset were between  $W_r$  estimates and benthic prey biomass estimates among lakes, especially for pumpkinseed (Table 3).  $W_r$  of both stock and quality length pumpkinseed was positively correlated with total benthos biomass; the quality length

relationship was particularly strong (Table 3).  $W_r$  of stock length pumpkinseed was positively correlated with chironomid biomass (Fig. 6a) and  $W_r$  of quality length pumpkinseed was positively correlated with gastropod biomass (Fig. 6b). We found no significant correlations between  $W_r$  of either species and littoral zooplankton biomass (Table 3).

Chlorophyll a was the only limnological variable significantly correlated with  $W_r$ , and only for pumpkinseed. Correlations with chlorophyll a were positive (stock length:  $r = 0.67$ ,  $P = 0.035$ ; quality length:  $r = 0.75$ ,  $P = 0.019$ ). All correlations of  $W_r$  with temperature and macrophyte biomass were nonsignificant ( $P > 0.05$ ).

## DISCUSSION

Relations of  $W_r$  against fish length may reflect effects of ecological conditions on fish of different size (Willis et al. 1991). Generally speaking, positive regressions suggest that larger fish have better conditions; inversely, negative regressions show that smaller fish have better conditions. No significant regressions explain that both larger and smaller fish have similar conditions. In this study, we found both positive and negative relationships of  $W_r$  with fish length, supporting that significant regressions between  $W_r$  and length should be due to the responses of different size fish to different environmental factors. Our analysis of intraspecific relationships

of  $W_r$ , provided additional evidence for length effects. On one hand, lack of correlations of intraspecific  $W_r$  in pumpkinseed explained that pumpkinseed had different conditions from stock to quality length; on the other hand, correlations of intraspecific  $W_r$  in golden shiner explained that golden shiner had similar conditions from stock and quality length, supporting that this length variation in  $W_r$  is due to different food habits of different size fish (Flickinger and Bulow 1993).

Moreover, considering differences of trophic state among lakes, it would be reasonable that  $W_r$  varied with lakes. Variation in  $W_r$  were significant among study lakes. Spatial variation in  $W_r$  was found and due to soil fertility (Willis et al. 1991). In this study,  $W_r$  of pumpkinseed and golden shiner were only related to prey biomass but not total fish and conspecific fish biomass, supporting that lake variation in  $W_r$  is due to prey availability.

Prey availability additionally varied with years and seasons, this would, in turn, account for temporal variation in  $W_r$ . Ephemeral temporal variation in  $W_r$  also resulted from interactions of several causal factors, including switching prey resources (Dawe 1988; Gabelhouse 1991), fish abundance (Dawe 1988), spawning (Le Cren 1951; Gabelhouse 1991; Neumann and Murphy 1991), and water level (Neal 1963; Mitzner 1972). Effects of water level on  $W_r$  were not examined because our data sets did not contain any corresponding information on the ten lakes. However, the lowest  $W_r$ s occurred in spring in most study lakes, suggesting that spawning

may induce temporal variation in  $W_r$ .

Although the spring samples were collected just prior to the beginning of the spawning seasons, sex variation in  $W_r$  were not found in this study; likewise, condition factors (K) are generally similar for males and females of channel catfish (Simco et al. 1989). Consequently, it is suggested that  $W_r$  cannot reflect differences in weight-length relationship of both sexes.

$W_r$  varied with other sources in complex ways, suggesting that it might be difficult to interpret  $W_r$  as a function of growth and fish biomass. Previous results are contradictory regarding if  $W_r$  can reflect fish growth. Gutreuter and Childress (1990) found that  $W_r$  could not precisely explain growth of largemouth bass and white crappies from Texas reservoirs sampled during autumn. Similarly, Buck and Thoits (1970) found that growth and body condition (K) were not necessarily correlated. However, Wege and Anderson (1978) found significant correlations between  $W_r$  and growth at age II largemouth bass. Willis (1989) indicated that the best relationship occurred when mean  $W_r$  was plotted as a function of length at annulus 2 of northern pike. Willis et al. (1991) also found significant correlations between mean  $W_r$  of yellow perch sampled from March to May and length at annulus 7 and between mean  $W_r$  of fish sampled from June to November and length at annulus 2. However, the relationships observed between  $W_r$  and growth at specific ages probably cannot completely describe growth of fish populations including several age groups. Actually,

relative weight condition index (or other body condition indices) reflects the relationship between length and weight of fish; thus, a rapid increase of fish length did not necessarily account for a rapid increase of fish weight (Papoulias and Minckley 1992); which probably explain why significant correlations between  $W_r$  and growth could not be found in some cases. In addition, lack of relationships between  $W_r$  and growth might be the result of interactions among several physiological (e.g., length) and ecological conditions (e.g., prey availability) of fish as discussed above. For example, Gabelhouse (1991) stated that the  $W_r$  of white crappies could not reflect growth when feeding conditions became poor during the summer and early fall; and was related to availability of gizzard shad. Consequently,  $W_r$  is not sensitive to fish growth, suggesting that it is possible that  $W_r$  is unable to detect any change in fish conditions which can influence fish growth, such as fish density. Fish density can influence fish growth (Keast and Harker 1977; Hall et al. 1979; Hanson and Leggett 1985). Probably, because  $W_r$  is not sensitive to fish growth as discussed above,  $W_r$  cannot detect any changes in fish density. This might explain why lack of significant correlations between  $W_r$  and fish biomass were found in our study.

Correlations of  $W_r$  with prey availability provide evidence that  $W_r$  can reflect prey selectivity and ontogenetic diet shifts in these species. Both pumpkinseed and golden shiner feed on insects (Scott and Crossman 1973); whereas large pumpkinseed also feed on snails (Osenberg et al. 1988).

Furthermore, pumpkinseed shift diet between 45 and 70 mm standard length (Mittelbach 1984). Lack of correlations of  $W_r$  from stock length to quality length for pumpkinseed explains the diet shift of this species; whereas correlations of  $W_r$  for golden shiner shows that diets remain similar from stock length to quality length. Clearly, these results are consistent with our analysis of relationship between  $W_r$  and prey biomass for pumpkinseed and golden shiner. Johannes et al. (1989) found that zooplankton abundance had little indirect or direct influence on golden shiner recruitment and abundance. This result is consistent with our analysis of relationship between  $W_r$  and zooplankton biomass for golden shiner. Pumpkinseed have less dependence on zooplankton during their life history than golden shiner, thus, it is reasonable that we did not find any correlations between  $W_r$  and zooplankton for pumpkinseed. Furthermore, diet or prey availability can influence weight-length relationships of fish (Dawe 1988; Friedland et al. 1988), which may induce changes not only in length but also in weight of fish at the same time. Finally, the lack of interspecific correlations between both species probably demonstrate that both species did not experience similar food limitation in our study lakes. These results suggest that  $W_r$  is the most sensitive to prey availability among ecological variables.

Based on our results,  $W_r$  can reflect chlorophyll a but not macrophytes and temperature. Since chlorophyll a is an index of lake trophic state

(Carlson 1977), it may reflect feeding conditions of fish. Likewise, chlorophyll a is strongly correlated with fish yields and production (Liang et al. 1981; Jones and Hoyer 1982; Downing et al. 1990), thus, it might be also correlated with  $W_r$ . We did find significant correlations between  $W_r$  and chlorophyll a for pumpkinseed but not for golden shiner. Mechanism causing no significant correlations between  $W_r$  and chlorophyll a for golden shiner remains unknown. Previous studies showed contradictory results regarding effects of macrophytes on fish conditions. Colle and Shireman (1980) stated that harvestable largemouth bass had low condition (K) values once hydrilla coverage was above 30%; however, smaller largemouth bass were not as adversely affected until percent coverage exceeded 50%; inversely, Bain and Boltz (1992) found that vegetation density did not influence condition unless major changes in vegetation density occur throughout the system. However, reduction of macrophytes can influence production or standing crop of fish positively or negatively (Durocher et al. 1984; Wiley et al. 1984). Perhaps,  $W_r$  is not as sensitive as fish production or standing crop to changes induced by reduction of macrophytes. There may be two explanations for lack of correlations between  $W_r$  and temperature. First,  $W_r$  is not sensitive to changes of temperature; secondly, prey availability is more important to fish growth than temperature (Donald et al. 1980).

Finally,  $W_r$  may be influenced by interactions of a variety of physiological and ecological conditions, suggesting that variation in  $W_r$  and

relationships of  $W_r$  with other fish conditions are complicated. Perhaps, this would help fishery biologists and managers to understand implications of  $W_r$  as an assessment of growth, prey availability and other environmental conditions in fish populations.

## IMPLICATIONS

Analysis of length and temporal variation in  $W_r$  showed how  $W_r$  could be used precisely to analyze fish populations. Length effects on  $W_r$  may indicate differing environmental "quality" for fish of different sizes. For example, different size individuals of the same species often have different food habits; consequently, fish of different lengths could have considerably different  $W_r$  (Flickinger and Bulow 1993). Thus, length effects should be examined before a mean population  $W_r$  is used to characterize a population. Temporal variation in  $W_r$  may be asynchronous among populations, thus, assessing  $W_r$  at one "standard" period for comparing several populations (i.e., fall sampling) may not be appropriate. To compare  $W_r$  among populations during one year, sampling should be done at more than one time and averages of temporal sampling periods should be taken.

More work must be done before  $W_r$  can become an ideal predictor of prey availability and growth of fish.  $W_r$  may be a fairly good predictor of prey availability. However, we suggest that this relationship should be



demonstrated for other species before generality can be assessed. Since previous studies and our study showed that  $W_r$  could reflect growth only partially, it should be used cautiously as an indicator of growth before it is examined under what conditions  $W_r$  can reflect growth very well. Our results suggest that  $W_r$  can only partially reflect physiological or ecological conditions of fish. As a result, we recommend that  $W_r$  be used cautiously as an assessment tool in freshwater fishes.

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Table 1. Summary of ANOVAs testing the effects of lake, year and season on W<sub>t</sub> of pumpkinseed and golden shiner in ten southern Quebec lakes. Data are from the early and late summer samples, 1987 and 1988. SS are type III (SAS 1985).

Species	Source of variation	df	SS	F	P
Pumpkinseed	Lake (L)	9	16837.6	28.56	0.0001
	Year (Y)	1	21.8	0.33	0.56
	Season (S)	1	767.2	11.71	0.0006
	L x Y	9	5797.9	9.84	0.0001
	L x S	9	8047.1	13.65	0.0001
	Y x S	1	3606.2	55.06	0.0001
	L x Y x S	9	2351.9	3.99	0.0001
	Error	2495	163421.1		
Golden shiner	Lake	9	19215.6	29.41	0.0001
	Year	1	1854.8	25.54	0.0001
	Season	1	724.3	9.98	0.0016
	L x Y	9	5021.1	7.68	0.0001
	L x S	9	10444.7	15.98	0.0001
	Y x S	1	11060.8	152.33	0.0001
	L x Y x S	9	12154.5	20.92	0.0001
	Error	2565	186241.8		

Table 2. Summary of ANOVAs testing the effects of lake and sex on W<sub>t</sub> of pumpkinseed and golden shiner in ten southern Quebec lakes. Data are from the spring samples, 1988. SS are type III (SAS 1985).

Species	Source of variation	df	SS	F	P
Pumpkinseed	Lake (L)	9	13769.4	27.65	0.0001
	Sex (S)	1	13.8	0.25	0.62
	L x S	9	355.3	0.71	0.70
	Error	461	25510.7		
Golden shiner	Lake	9	6191.0	18.1	0.0001
	Sex	1	13.68	0.32	0.57
	L x S	9	422.1	1.41	0.20
	Error	413	17690.7		

Table 3. Correlations of relative weight ( $W_t$ ) of pumpkinseed and golden shiner with growth, fish biomass and prey biomass in ten southern Quebec lakes.  $p$  values are given in parentheses. All data used in correlations are lake averages; fish and prey biomass data are from Pierce et al. (in press). Spring 1988  $W_t$  data were not included in calculation of lake averages.

Variable	Pumpkinseed		Golden shiner	
	Stock length	Quality length	Stock length	Quality length
Growth <sup>1</sup>	0.41	-0.24 (0.242)	0.37 (0.539)	0.51 (0.291, 0.129)
Littoral fish biomass	Total	0.38 (0.283)	0.07 (0.864)	0.50, 0.59 (0.133, 0.072)
	Conspecific	0.28 (0.440)	0.280 (0.461)	-0.30, 0.01 (0.389, 0.989)
Littoral benthos biomass	Total	0.69 (0.027)	0.90 (0.001)	0.10, 0.41 (0.739, 0.244)
	Gastropods	0.53 (0.115)	0.84 (0.004)	-0.08, 0.26 (0.929, 0.467)
	Chironomids	0.72 (0.018)	0.58 (0.098)	0.60, 0.72 (0.063, 0.019)
Littoral zooplankton biomass	0.22	0.19 (0.538)	0.44 (0.626)	0.41 (0.202, 0.242)

<sup>1</sup>Appropriate size-specific growth estimates were used for comparison with  $W_t$  (i.e., growth of stock length fish compared with  $W_t$  of stock length fish, growth of quality length fish compared with  $W_t$  of quality length fish).

## Figure Legends

Figure 1. Location of southern Quebec lakes sampled in this study for evaluation of relative weight ( $W_r$ ). Lakes Bromont and Hertel are shown at twice actual size for clarity (b).

Figure 2. Example of variation in relative weight ( $W_r$ ) among individual pumpkinseed and relationships with fish length. Data points represent individual fish from Lake Brompton collected on early 1988 (a.) and late 1988 (b.) sampling dates. Vertical dashed lines indicate stock (80 mm) and quality (150 mm) lengths. Shaded areas indicate  $W_r < 100$ . Among-fish variation was similar in other lakes and in golden shiner. Where no significant relationship with total length existed, as in a.,  $W_r$  for both length classes was represented by the mean  $W_r$  for that date (99.5 in this case). Where a significant relationship with total length existed, as in b.,  $W_r$  was estimated by solving the  $W_r$ -total length regression for stock and quality lengths (98.7 and 104.0, respectively, in this case).

Figure 3. Temporal changes in relative weight ( $W_r$ ) of stock length (80 mm) and quality length (150 mm) pumpkinseed in southern Quebec lakes. Length classes indicated in upper left panel. Overlapping data points indicate a nonsignificant regression of  $W_r$  on fish length, and are represented by the mean  $W_r$  for that date. Nonoverlapping data



points represent size-specific  $W_r$  estimates from a significant regression of  $W_r$  on fish length for that date. Missing data points indicate no fish of that size sampled on that date. Shaded areas indicate  $W_r < 100$ .

Figure 4. Temporal changes in relative weight ( $W_r$ ) of stock length (70 mm) and quality length (120 mm) golden shiner in southern Quebec lakes. Details same as Fig. 2.

Figure 5. Example relationships of recent growth increments with length and growth residuals with relative weight ( $W_r$ ) in individual golden shiner collected in late 1988 from Roxton Pond and Lac d'Argent, Quebec. Lengths at last annuli and recent growth increments since last annuli (a. and b.) were estimated by back-calculation. Growth residuals (c. and d.) are residual variation in growth not explained by regressions of growth increments on length (a. and b.), and thus represent length-corrected estimates of growth of individual fish since the last annulus. These length-corrected growth estimates of individual fish were then examined for correlation with  $W_r$  (c. and d.) for each species in each lake.

Figure 6. Relationships of relative weight ( $W_r$ ) of stock length (80 mm) pumpkinseed with chironomid biomass (a.), and quality length (150 mm) pumpkinseed with gastropod biomass (b.) in ten southern Quebec lakes. Data points represent lake averages; prey data are from

Pierce et al. (*in press*). Spring 1988  $W_r$  data were not included in calculation of lake averages. Shaded areas indicate  $W_r < 100$ .

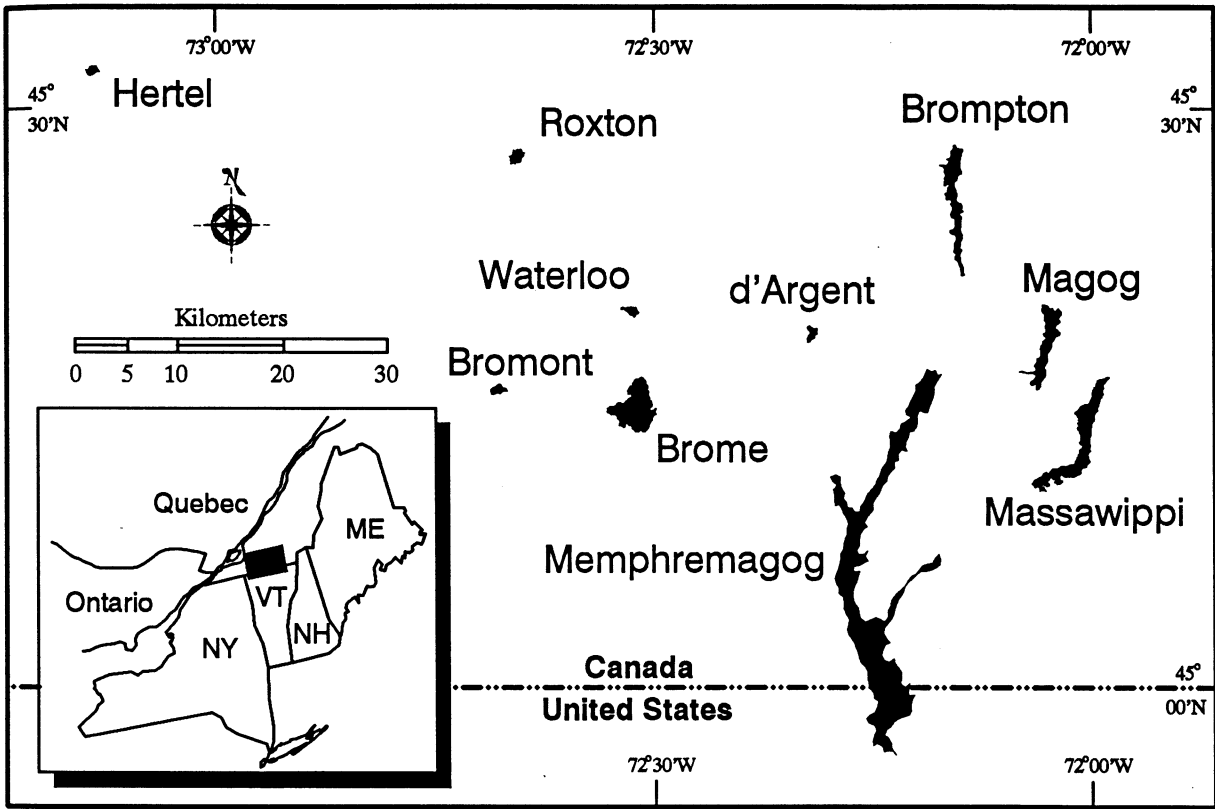


Fig. 1

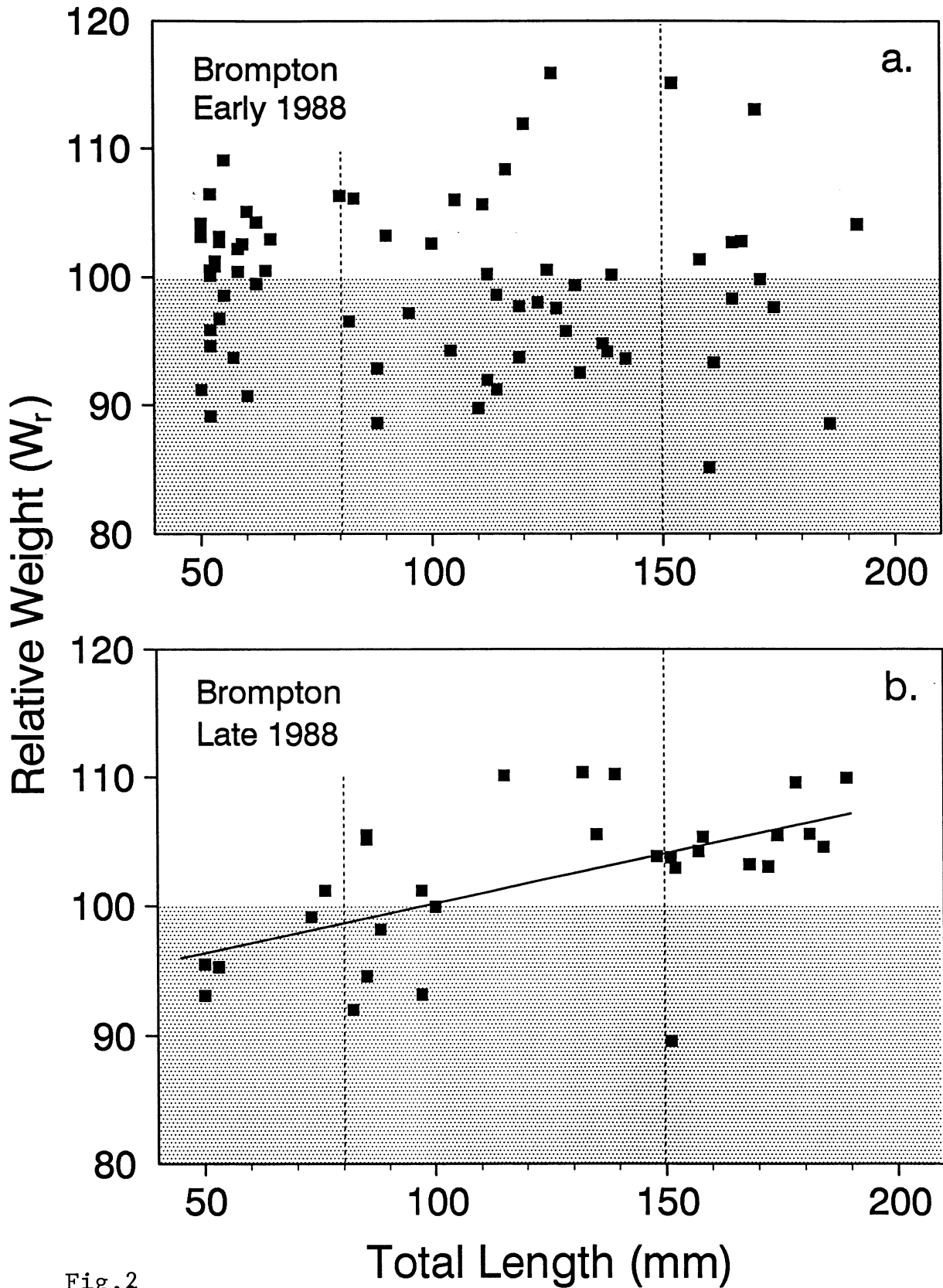


Fig.2

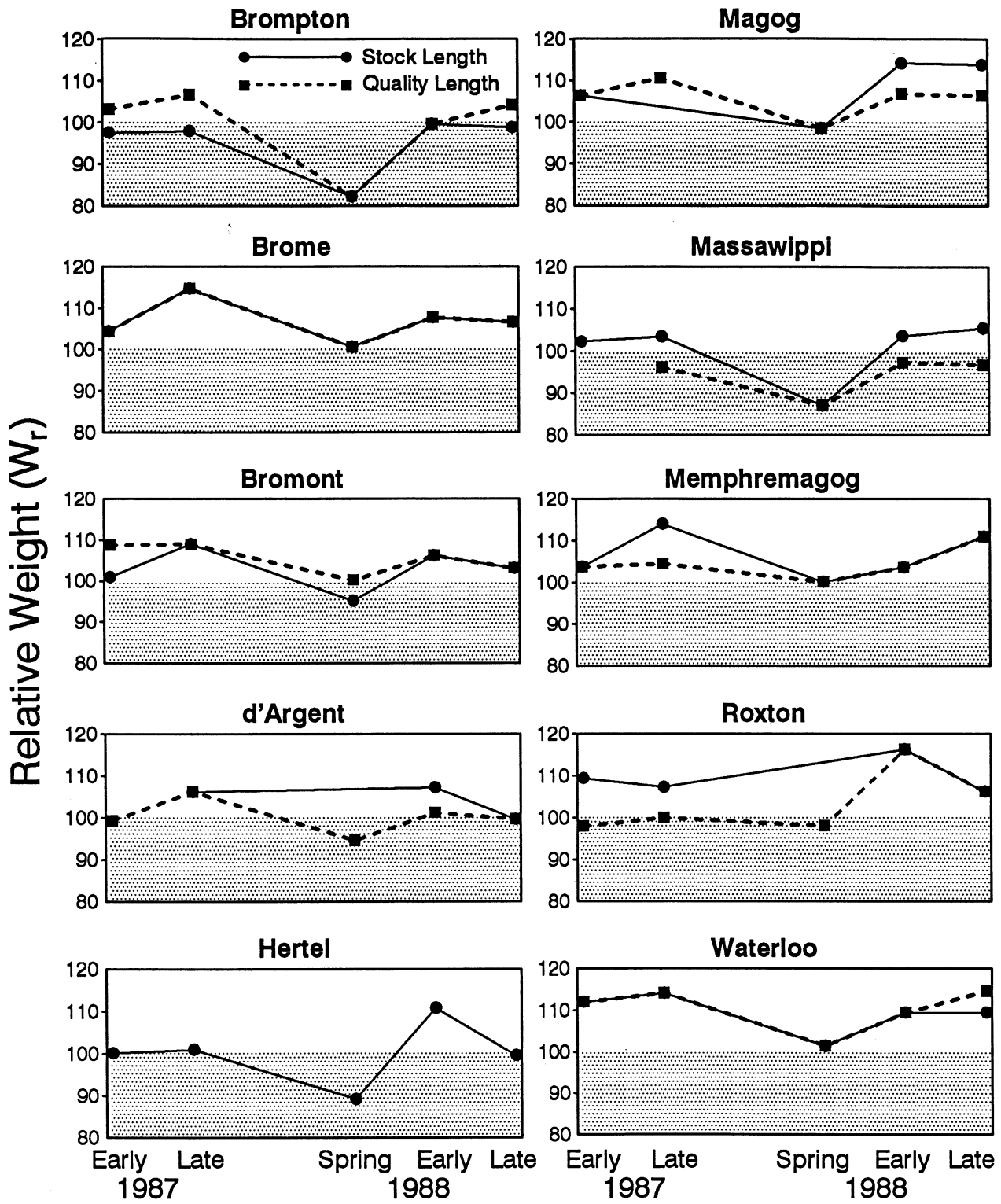


Fig. 3

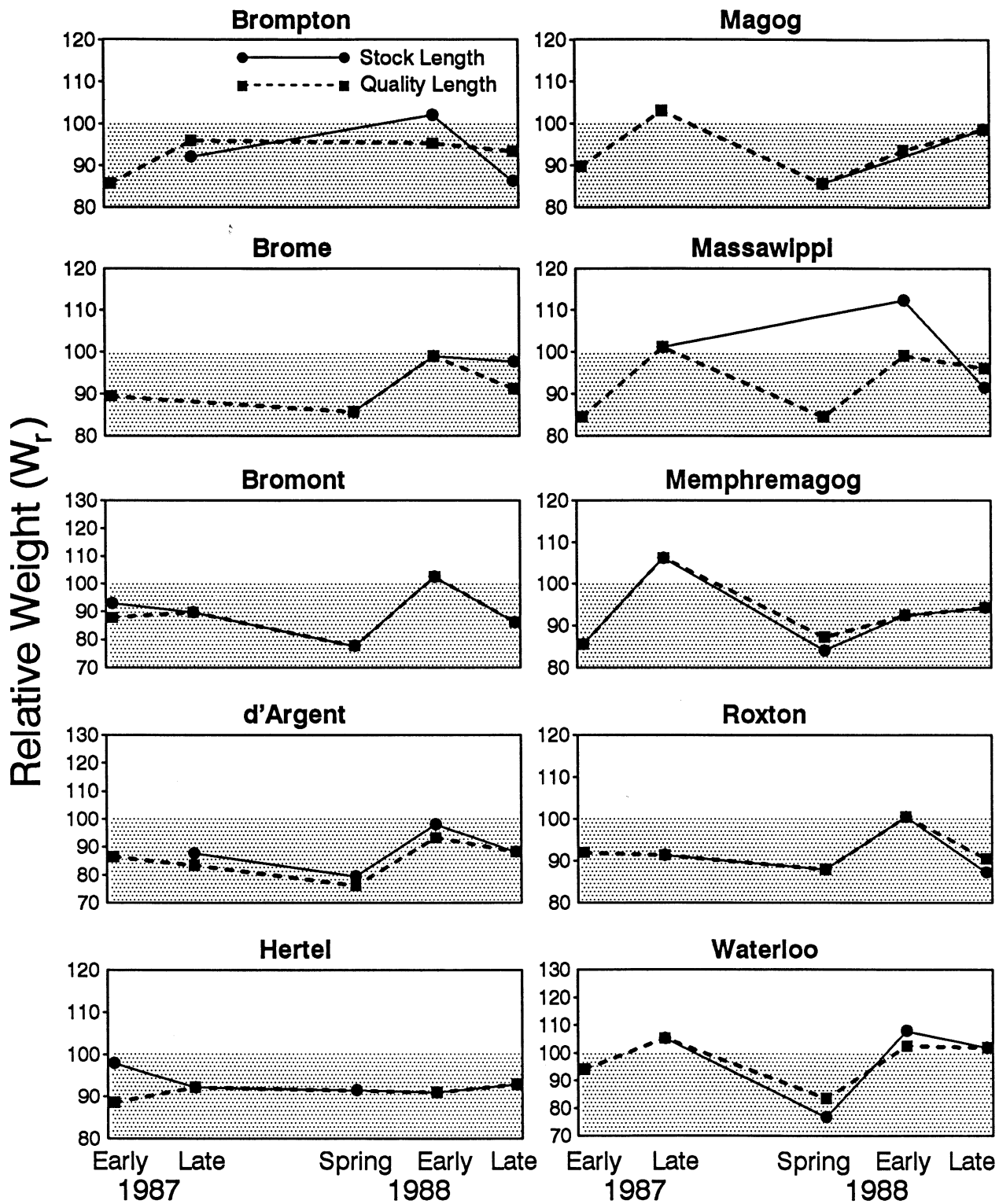


Fig. 4

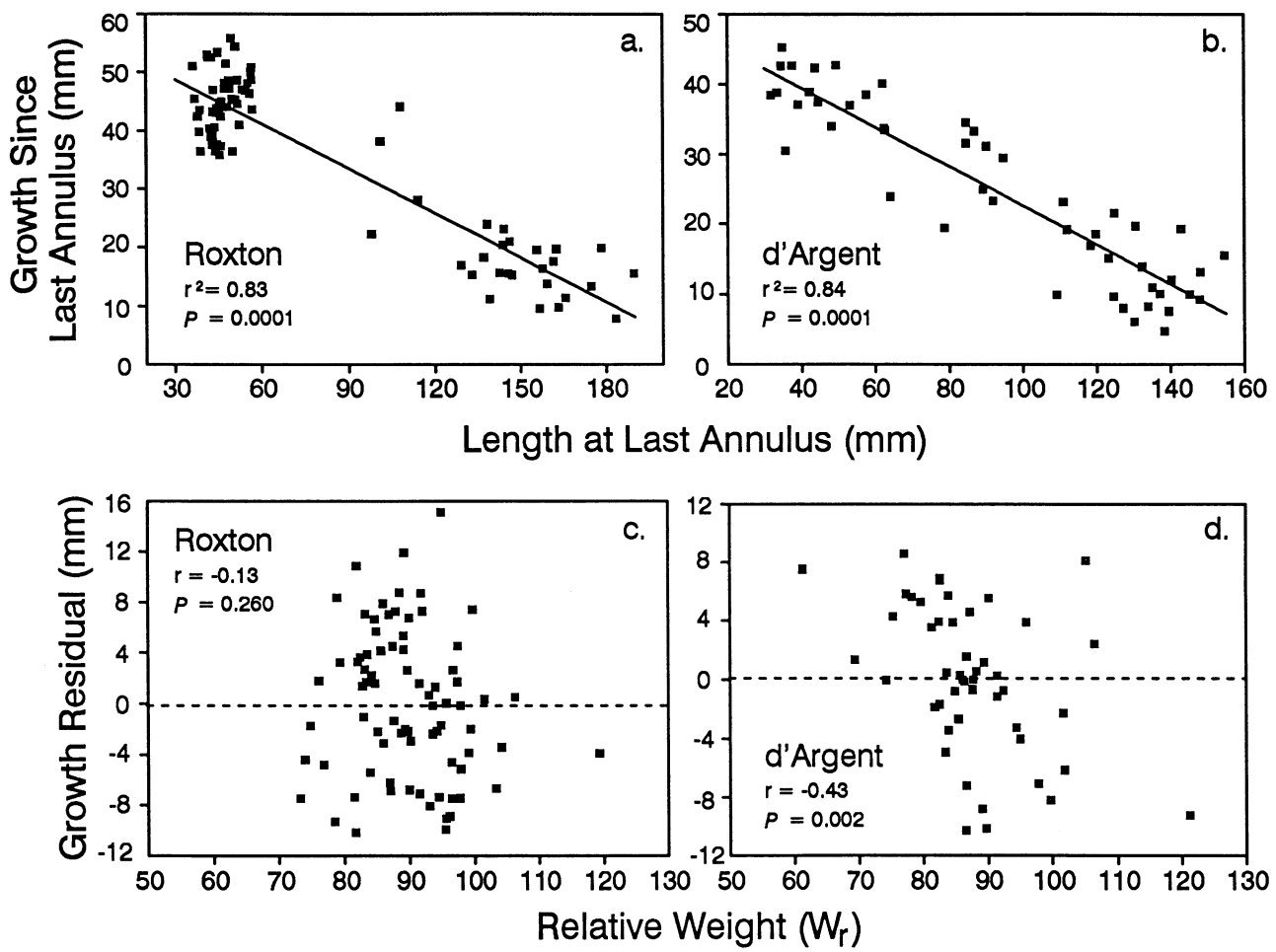


Fig. 5

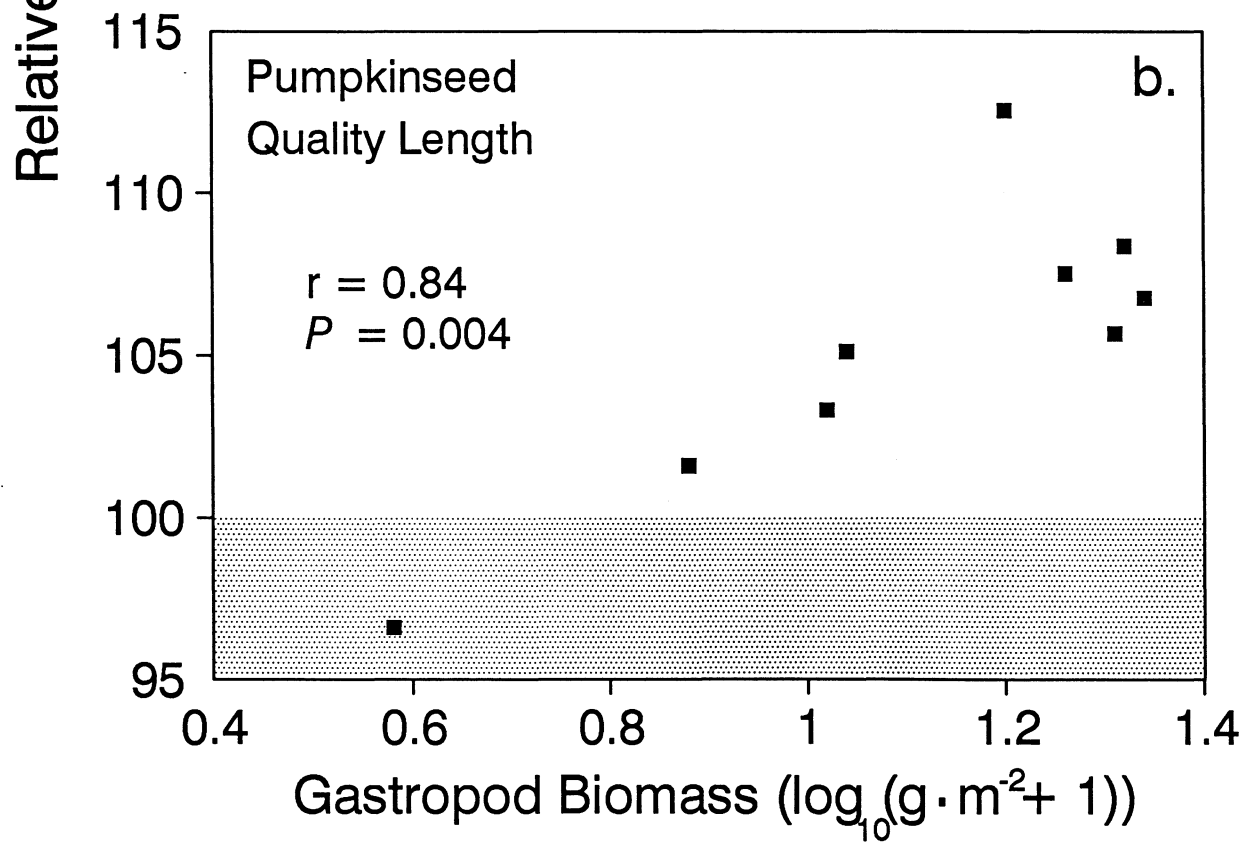
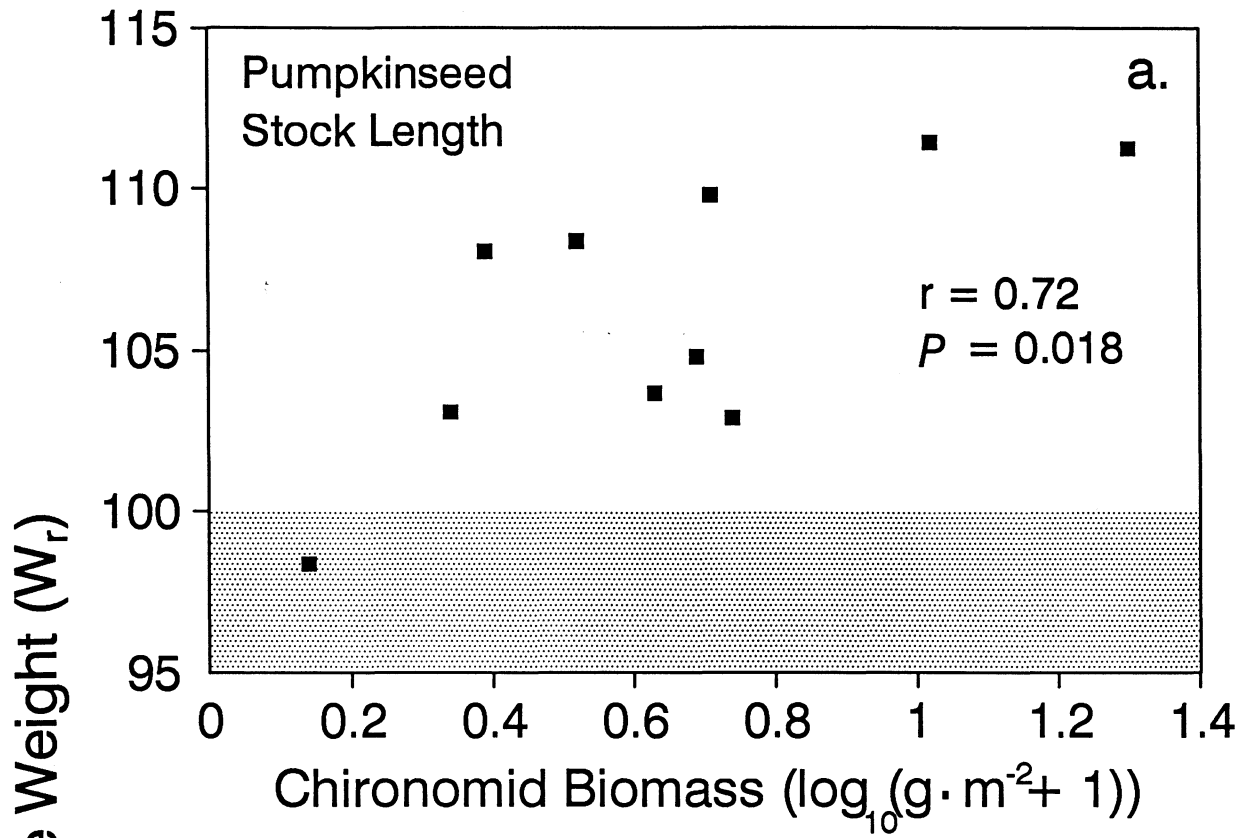


Fig. 6



Appendix A. Pumpkinseed Population Data Used to Develop Standard-Weight Equation.

Site Code	State or Province	Lake Name	Sample Size	Regression Parameter		r <sup>2</sup>	Source of Data
				Intercept	Slope		
1	California	Lower Susan		-6.2320	3.3320		a
2	Illinois	Bangs	22	-5.9139	3.3833	0.9610	b
3		Cross	20	-4.7918	3.0584	0.9350	..
4		Defiance	18	-6.9528	4.1274	0.8964	..
5		Diamond	58	-6.6250	3.9115	0.9817	..
6		Duck Valley	15	-5.1568	3.2464	0.9987	c
7		Foxchain	101	-5.1605	3.2364	0.9323	b
8		Honey	30	-5.1917	3.2308	0.9279	..
9		Island	16	-5.0040	3.1638	0.9969	c
10		Milliken	8	-5.9655	3.5661	0.9735	b
11		Round	28	-6.0584	3.6194	0.9426	..
12		Sand	8	-6.1283	3.6945	0.9354	..
13		Taylor	16	-7.1732	4.1656	0.9496	..
14		Turner	37	-5.1061	3.1893	0.8767	..
15		Zurich	17	-4.8687	3.0757	0.8327	..
16	Iowa	Clear	150	-4.7400	3.1856		a
17	Michigan	Blueberry	154	-5.0524	3.1658	0.9791	d
18		Dead	64	-5.2718	3.2623	0.9845	..
19	Montana	Horseshoe	331	-5.2231	3.2380		a
20	New York	Adir	21	-5.1746	3.2367	0.9777	e
21		Alder	15	-4.9094	3.0980	0.9901	..
22		Arquett	10	-4.4181	2.8180	0.9521	..
23		Bald	22	-4.3031	2.8370	0.9443	..
24		Bear	24	-4.1827	2.7366	0.9559	..
25		Bear P.	24	-5.1501	3.2168	0.9917	..
26		Beaver	12	-4.6493	2.9909	0.9620	..
27		Beaver P.	8	-7.2380	4.1150	0.9839	..
28		Bigdeer	20	-5.3813	3.3538	0.9189	..
29		Bighope	10	-4.2046	2.6738	0.8775	..
30		Bigotter	18	-5.6793	3.4134	0.9382	..
31		Black	8	-6.2213	3.6851	0.9945	..
32		Blue	25	-4.5576	2.9073	0.9725	..
33		Boyd	24	-5.4393	3.3395	0.9893	..
34		Brewer	12	-3.4949	2.9560	0.9617	..
35		Bridge	12	-4.6953	2.9358	0.9636	..
36		Brother01	8	-4.9480	3.0916	0.9727	..
37		Brueyer	15	-4.7993	3.0424	0.9606	..
38		Buck01	11	-5.0427	3.1437	0.9438	..
39		Buck02	13	-5.4973	3.3846	0.9523	..
40		Bullhead	8	-5.8765	3.4999	0.9779	..
41		Burnt	27	-5.0045	3.1354	0.9296	..
42		Butler	13	-5.0974	3.1628	0.8337	..
43		Chain	23	-5.2925	3.2645	0.9709	..
44		Charley	15	-3.4351	2.3219	0.8485	..
45		Charlie	24	-4.1773	2.6987	0.8093	..
46		Chase	9	-5.5762	3.4022	0.9708	..
47		Chaumont	14	-3.7796	2.6240	0.9053	..
48		Cheney	10	-5.4844	3.3189	0.9914	..
49		Church	21	-6.0346	3.5877	0.8152	..
50		Clear01	17	-5.5254	3.4262	0.9863	..
51		Clear02	10	-6.6365	3.8304	0.9542	..
52		Clear03	18	-4.2340	2.6724	0.9498	..
53		Colton	20	-4.3944	2.9083	0.9722	..
54		Copeland	26	-5.4074	3.3230	0.9871	..
55		Copper	10	-5.0816	3.1774	0.9860	..
56		Cowhorn	29	-4.8057	2.9844	0.9423	..
57		Cranberry	9	-5.2753	3.2487	0.9132	..
58		Crooker	8	-5.1333	3.2031	0.9849	..
59		Deer	32	-4.5623	2.9763	0.8922	..
60		Deer P.	16	-4.2445	2.7304	0.9415	..
61		Deso	13	-4.4324	2.8780	0.9872	..
62		Duan	9	-4.9732	3.1110	0.9967	..
63		Eagle	26	-5.4255	3.3360	0.9743	..

64	Eagle P.	9	-5.1146	3.1912	0.9004	..
65	East	24	-4.7529	2.8886	0.9548	..
66	Fall	19	-4.0245	2.7154	0.8569	..
67	Ferris	23	-4.5412	2.8809	0.9904	..
68	First	21	-4.5734	2.9066	0.9463	..
69	First P.01	15	-4.8532	3.0473	0.9235	..
70	First P.02	14	-5.2984	3.2619	0.9937	..
71	Fish	10	-5.4077	3.2968	0.9318	..
72	Fish P.01	14	-4.6043	2.8810	0.9718	..
73	Fish P.02	12	-5.5697	3.4515	0.8373	..
74	Flow	26	-6.0894	3.5926	0.8775	..
75	Follenby	10	-3.6668	2.5542	0.9953	..
76	Forest	22	-5.1330	3.1821	0.9932	..
77	Francies	25	-5.8659	3.5607	0.8700	..
78	Franklin	8	-5.7956	3.5165	0.9432	..
79	Gibbs	16	-4.5867	2.8896	0.9171	..
80	Goose01	8	-5.7554	3.4674	0.9887	..
81	Graves	14	-5.3596	3.3410	0.9853	..
82	Hadlock	34	-5.2093	3.2387	0.9935	..
83	Halfmoon	9	-6.2658	3.7156	0.9379	..
84	Handsome	13	-4.5279	2.8597	0.9687	..
85	Harris	10	-4.9313	3.1083	0.9794	..
86	Heath	10	-5.7179	3.4895	0.9925	..
87	Hidden	19	-3.8935	2.6718	0.8989	..
88	Hitchens	28	-5.1768	3.2253	0.9808	..
89	Hornet	19	-4.3281	2.7442	0.9436	..
90	Horseshoe01	24	-4.7684	3.0509	0.9924	..
91	Horseshoe02	16	-4.2465	2.7327	0.9523	..
92	Huckleberry	19	-6.6282	3.8786	0.9375	..
93	Independence	9	-5.3068	3.2936	0.9345	..
94	Iron	11	-5.3750	3.4274	0.9563	..
95	Jocks	16	-5.4515	3.3697	0.9923	..
96	Joeindia	29	-5.3684	3.2966	0.9588	..
97	Jones	16	-4.9502	3.1333	0.9550	..
98	Jordan	22	-4.7290	2.9724	0.9525	..
99	Kilkenny	24	-4.7817	3.0477	0.9749	..
100	Kings	25	-5.6575	3.4260	0.9651	..
101	Lakes01	26	-4.6588	2.9743	0.9758	..
102	Lakes02	22	-6.4148	3.8244	0.8979	..
103	Latham	18	-4.7555	3.0079	0.9381	..
104	Leonard	14	-5.6310	3.4317	0.9947	..
105	Lily	20	-3.5830	2.5147	0.8928	..
106	Lilypad	25	-4.2588	2.7913	0.9594	..
107	Limekiln	14	-4.5057	2.8782	0.8392	..
108	Little01	16	-3.7604	2.4080	0.8452	..
109	Little02	13	-5.3151	3.2721	0.9805	..
110	Little04	14	-4.9743	3.1358	0.9743	..
111	Little05	29	-5.2104	3.2272	0.9973	..
112	Little06	25	-4.9727	3.1281	0.9796	..
113	Little07	20	-4.4920	2.8807	0.8228	..
114	Little08	12	-5.0682	3.1685	0.9926	..
115	Lone	24	-3.7867	2.4395	0.9458	..
116	Long01	8	-4.0793	2.7023	0.9634	..
117	Long02	12	-5.0849	3.1631	0.9171	..
118	Long04	23	-5.2780	3.2469	0.9822	..
119	Loon	14	-5.1874	3.2239	0.9936	..
120	Loon P.	20	-5.1364	3.2193	0.9761	..
121	Lower	10	-4.7089	2.9885	0.9534	..
122	Mayes	8	-4.9490	3.0981	0.9960	..
123	Mile	14	-5.4582	3.3628	0.9857	..
124	Minnow	18	-6.9236	3.9856	0.9067	..
125	Mohegan	12	-5.6357	3.4466	0.9872	..
126	Monday	9	-4.9687	3.1002	0.9345	..
127	Moody01	20	-5.0877	3.2328	0.9827	..
128	Moody02	11	-5.1989	3.2003	0.9394	..
129	Mountain	22	-6.3850	3.8262	0.9380	..
130	Mud01	26	-4.2047	2.6650	0.9056	..
131	Mun02	9	-5.4122	3.3205	0.9921	..
132	Mud03	8	-4.9023	3.1059	0.9612	..

133	Mud04	21	-5.1508	3.1869	0.9960	..
134	Mud05	22	-5.0274	3.1242	0.9850	..
135	Mud06	23	-5.3478	3.2611	0.9547	..
136	Mud07	26	-6.0990	3.6574	0.9800	..
137	Muskrat	18	-4.6865	2.9805	0.9195	..
138	Nebo	23	-4.6808	2.9960	0.9859	..
139	Nelson	9	-6.1878	3.6612	0.9625	..
140	Nichols	11	-5.2559	3.2383	0.9883	..
141	Nicks	8	-4.5268	2.8714	0.9235	..
142	North	18	-4.5875	2.9337	0.9789	..
143	Northern01	13	-4.6193	2.8655	0.9219	..
144	Northern02	22	-4.3950	2.8265	0.9690	..
145	North01	14	-5.2986	3.2764	0.9598	..
146	North02	12	-5.7892	3.5022	0.8917	..
147	North03	23	-4.7913	3.0637	0.9863	..
148	Okara	9	-4.7676	2.9940	0.9695	..
149	Oliver	26	-4.4939	2.8684	0.9653	..
150	One	34	-5.6282	3.4368	0.9966	..
151	Otter01	8	-5.7183	3.5183	0.9657	..
152	Ozon	25	-4.3505	2.8692	0.8651	..
153	Partlow	28	-6.0513	3.6334	0.9794	..
154	Partlow P.	27	-4.9846	3.0931	0.9829	..
155	Pickwack	12	-4.2783	2.7731	0.9741	..
156	Pine01	28	-5.3062	3.2774	0.9750	..
157	Pine02	11	-5.4934	3.3511	0.9372	..
158	Pleasant01	14	-4.9144	3.0840	0.9710	..
159	Pleasant02	10	-5.2679	3.2730	0.9943	..
160	Plumador	19	-5.4609	3.3571	0.9875	..
161	Polliwog	28	-4.6354	2.9245	0.9110	..
162	Queer	10	-4.5784	2.8915	0.9955	..
163	Ragged	22	-4.5698	2.9078	0.9212	..
164	River	12	-4.5287	2.8574	0.9526	..
165	Rock	20	-5.9522	3.6011	0.9847	..
166	Rock P.01	25	-4.1814	2.7257	0.9229	..
167	Rock P.02	16	-4.4629	2.8380	0.8176	..
168	Rock P.03	23	-3.4906	2.3904	0.8853	..
169	Rock P.04	8	-5.0327	3.1546	0.9497	..
170	Round	20	-4.0155	2.6251	0.9834	..
171	Round P.03	23	-5.0148	3.1278	0.9049	..
172	Round P.04	25	-5.8212	3.5086	0.9396	..
173	Round P.05	12	-6.7813	3.8973	0.9681	..
174	Saint	18	-4.7170	2.9641	0.9824	..
175	Salmon	21	-4.9276	3.0987	0.8866	..
176	Sampson	15	-4.4513	2.9516	0.8916	..
177	Santa	10	-6.7705	3.9900	0.8107	..
178	Second01	16	-3.7658	2.4816	0.9785	..
179	Second02	15	-5.5910	3.4141	0.9687	..
180	Seepage	13	-7.4827	4.3719	0.8863	..
181	Sheltered	10	-5.7947	3.4820	0.9673	..
182	Sixth	27	-4.6773	2.9842	0.9444	..
183	Slouch	8	-5.3910	3.3623	0.9862	..
184	Sly	24	-5.4905	3.3351	0.9819	..
185	Smith	30	-4.0153	2.7157	0.8743	..
186	Snider	20	-5.0344	3.1515	0.8940	..
187	Snow	10	-5.3304	3.2575	0.9751	..
188	Snyder	12	-4.1669	2.7660	0.9914	..
189	Soft01	15	-5.3987	3.3183	0.9820	..
190	Soft02	30	-5.6624	3.4505	0.9837	..
191	Sound	10	-3.8587	2.5967	0.8922	..
192	South	9	-5.2252	3.2636	0.9952	..
193	Spectacle	25	-5.8943	3.5034	0.9132	..
194	Sperry	23	-6.1607	3.6363	0.8462	..
195	Spruce	15	-4.8710	3.0551	0.9935	..
196	Star	13	-4.8032	3.0578	0.9889	..
197	Sterling	14	-5.4114	3.3024	0.9058	..
198	Stoner	10	-5.3422	3.2864	0.9144	..
199	Surprise	9	-6.1597	3.7071	0.9082	..
200	Swamp	24	-4.7785	3.0144	0.9787	..
201	Tamarack	24	-5.0919	3.1491	0.8684	..

202	Tanaher	9	-2.9549	2.2423	0.8121	..	
203	Taylorville	16	-6.5398	3.8516	0.9532	..	
204	Thayer	20	-4.6716	2.9768	0.8325	..	
205	Third	20	-5.1433	3.1781	0.9803	..	
206	Tomar	16	-4.6767	2.9400	0.9448	..	
207	Tooley	10	-3.8496	2.6843	0.9721	..	
208	Triangle	9	-7.5098	4.3331	0.8504	..	
209	Trout	23	-5.4299	3.3260	0.9944	..	
210	Trout P.01	11	-5.0980	3.1533	0.9341	..	
211	Trout P.02	21	-6.0613	3.6436	0.9388	..	
212	Trout P.03	23	-3.9619	2.6040	0.9618	..	
213	Twin	11	-4.9841	3.1016	0.9611	..	
214	Unnamed01	15	-4.5659	2.8993	0.9801	..	
215	Unnamed02	23	-4.9925	3.1226	0.9955	..	
216	Unnamed03	15	-5.2133	3.2262	0.9463	..	
217	Unnamed04	16	-5.1832	3.2381	0.9603	..	
218	Unnamed05	21	-4.8840	3.0623	0.9814	..	
219	Unnamed06	19	-4.8928	3.0447	0.9869	..	
220	Unnamed07	11	-5.4241	3.3339	0.9697	..	
221	Unnamed09	8	-5.4444	3.3441	0.9960	..	
222	Unnamed10	26	-5.3148	3.2553	0.8944	..	
223	Unnamed11	10	-5.2080	3.2304	0.9918	..	
224	Unnamed12	23	-5.1472	3.2071	0.9001	..	
225	Unnamed13	16	-3.3546	2.1801	0.8432	..	
226	Unnamed14	8	-4.6062	2.8495	0.9761	..	
227	Unnamed15	8	-5.7331	3.4430	0.9866	..	
228	Upper01	12	-4.9202	3.0916	0.9104	..	
229	Upper02	19	-5.0613	3.1206	0.9862	..	
230	Utowana	15	-5.4717	3.3638	0.9726	..	
231	Valentine	14	-5.6950	3.4218	0.9834	..	
232	Vandernb	25	-5.6204	3.3967	0.9794	..	
233	West	22	-4.4370	2.9094	0.9917	..	
234	West P.	23	-4.5820	2.8808	0.9569	..	
235	Wheeler	11	-5.3136	3.2651	0.9912	..	
236	Wilcox	21	-4.5082	2.8317	0.9012	..	
237	Wilkie	19	-5.1751	3.1612	0.9905	..	
238	Willis	16	-5.2621	3.2607	0.9902	..	
239	Willis P.	22	-4.9460	3.0924	0.9776	..	
240	Windfal01	8	-5.0758	3.1517	0.9952	..	
241	Windfal02	22	-5.1945	3.2309	0.9354	..	
242	Wing	21	-4.8176	3.0408	0.9160	..	
243	Wolf01	13	-5.7347	3.4651	0.8808	..	
244	Wolf02	20	-4.9967	3.1033	0.9541	..	
245	Woodwort	22	-4.4225	2.8638	0.9772	..	
246	Worcester	17	-5.3059	3.2818	0.9974	..	
247	Pennsylvania	Alanconnie	629	-5.2130	3.2620	a	
248	Virginia	Albemarle	136	-5.3167	3.2872	f	
249		Beaverdam	21	-5.0577	3.1316	0.8570	..
250		BeaverCreek	28	-5.6217	3.4143	0.9771	..
251		Brittle	142	-5.3151	3.2897	0.9619	..
252		Burke	25	-4.2211	2.8071	0.9786	..
253		Chesdin	119	-5.3668	3.2719	0.8917	..
254		Cohoon	32	-4.7259	2.9928	0.9504	..
255		Hardwood	91	-4.9213	3.0665	0.9459	..
256		Kilby	104	-5.7801	3.4935	0.9701	..
257		Leehall	227	-5.1971	3.2141	0.9309	..
258		Manassas	23	-4.3188	2.8008	0.8748	..
259		Meade	101	-4.8110	3.0417	0.8937	..
260		Mott Run	72	-6.1832	3.6764	0.9293	..
261		Occoquan	81	-4.9416	3.0876	0.9241	..
262		Orange	107	-5.1473	3.2069	0.9741	..
263		Pelham	30	-5.3069	3.2553	0.9479	..
264		Powhatan	18	-5.6912	3.4381	0.9115	..
265		Prince	112	-5.5795	3.3757	0.9464	..
266		Satewood	11	-5.0853	3.1852	0.9456	..
267		S.F.Shenandoah01	33	-6.8384	4.0147	0.9243	..
268		S.F.Shenandoah02	31	-5.7660	3.5033	0.9426	..
269		S.F.Shenandoah03	29	-5.6875	3.4700	0.9230	..
270		Shenandoah R.01	64	-6.1334	3.6506	0.9335	..

271		Shenandoah R.02	25	-5.8666	3.5723	0.9033	..
272		Smith	170	-4.7203	2.9910	0.8010	..
273		Westbranck	93	-5.0742	3.1545	0.9781	..
274		Whitehurst	207	-4.8636	3.0642	0.9316	..
275	Wisconsin	Beartrack		-6.3829	3.7851		g
276		Greenquist		-6.0867	3.6317		..
277		Herby		-4.2643	2.7986		..
278		Horseshoe		-6.1137	3.7607		..
279		Loveless		-4.5225	2.9187		..
280		Pear		-5.4622	3.3104		..
281		Picker		-6.0970	3.6491		..
282		Scott		-6.1201	3.6465		..
283	Ontario	Atkins	98	-5.3377	3.3386	0.9900	h
284		Cataraqui	53	-4.8292	3.0556	0.9700	..
285		Little Round	65	-4.9653	3.0928	0.9900	..
286		Long Pond	154	-3.9300	3.2700	0.9900	i
287		Lower Ottawa		-4.4870	2.9740		j
288		Lower Beverly		-5.2892	3.3212		k
289		Opinicon	99	-5.0327	3.1350	0.9463	l
290		Upper Beverly		-5.1235	3.2619		k
291		Upper Ottawa		-4.8670	3.1560		j
292	Quebec	Brompton	307	-5.2290	3.2637	0.9966	m
293		Brome	318	-5.1879	3.2520	0.9968	..
294		Bromont	460	-5.2140	3.2620	0.9961	..
295		d'Argent	233	-5.1350	3.2151	0.9981	..
296		Hertel	426	-4.9829	3.1343	0.9883	..
297		Magog	453	-5.0893	3.2051	0.9946	..
298		Massawippi	351	-5.0255	3.1544	0.9898	..
299		Memphremagog	381	-5.0353	3.1821	0.9973	..
300		Roxton	353	-5.1008	3.2082	0.9962	..
301		Waterloo	328	-5.1173	3.2244	0.9977	..
302		Vert		-5.0080	3.1950		n

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- a: Carlander 1977.  
b: D. Austen, Illinois Nat. Hist. Survey, personal communication.  
c: V. Santucci, Max McGraw Wildlife Foundation, personal communication.  
d: J. Schneider, Michigan Dept. Nat. Resources, personal communication.  
e: J. Gallagher, New York Dept. Envir. Conservation, personal communication.  
f: N. Cunningham, Virginia Comm. of Game and Inland Fisheries, personal communication.  
g: H. Snow, Wisconsin Dept. Nat. Resources, personal communication.  
h: Complak 1980.  
i: Mahon and Balon 1977.  
j: Boyle 1977.  
k: Deacon and Keast 1987.  
l: J. Claussen, Illinois Nat. Hist. Survey, personal communication.  
m: Unpublished data.  
n: Beaulieu et al. 1979.

Appendix B. Golden Shiner Population Data Used to Develop Standard-Weight Equation

Site Code	State or Province	Lake Name	Sample Size	Regression Parameter		r <sup>2</sup>	Source of Data
				Intercept	Slope		
1	Alabama	Research	79	-6.3910	3.2607	0.7940	a
2	Florida	Apopka	359	-5.4276	3.1526	0.9706	b
3		Beauclai	439	-4.9241	2.8913	0.9298	..
4		Denham	637	-4.6563	2.7562	0.9055	..
5	Illinois	Beaver Dam	34	-4.8018	2.9431	0.9688	c
6		Beaver P.	9	-5.3431	3.2010	0.9025	..
7		Brag P.	11	-6.9324	3.8848	0.8536	..
8		Dawson L.	68	-6.9516	3.8870	0.9600	..
9		Diamond	17	-5.5196	3.2658	0.9300	..
10		Forest L.	31	-5.7642	3.3693	0.9816	..
11		Foxchain	24	-7.3582	4.1301	0.9226	..
12		Gravpit2	10	-5.2053	3.1884	0.9186	d
13		Iamcanal	89	-5.2132	3.1037	0.8862	c
14		Idot	11	-7.1523	4.0054	0.9494	..
15		Leaquana	12	-5.9529	3.4593	0.9703	..
16		Monerese	23	-3.8509	2.5011	0.8981	..
17		Pierce L.	37	-5.7827	3.3840	0.8939	..
18		Redhills	9	-4.4545	2.7961	0.8797	..
19		Samparrs	41	-5.1815	3.1141	0.9221	..
20		Sand L.	20	-6.4969	3.7071	0.9833	..
21		Sangchri	10	-5.0858	3.0336	0.9681	..
22		Turner L.	71	-6.7038	3.7646	0.9176	..
23		Wolf L.	27	-7.1276	3.9709	0.9430	..
24		Wood L.	45	-5.7520	3.3456	0.9412	..
25	Iowa	East		-5.3060	3.2940		e
26	Missouri	Mississippi R.	32	-5.2829	3.0876	0.9823	f
27	New York	Adir	25	-5.2899	3.0944	0.9380	g
28		Alder01	20	-5.8846	3.4348	0.9904	..
29		Amber	25	-5.3330	3.1547	0.9372	..
30		Balsam	25	-4.7416	2.8014	0.8295	..
31		Bass	29	-6.0262	3.4841	0.9898	..
32		Bear P.	26	-6.4104	3.6636	0.9744	..
33		Bear02	12	-6.6761	3.8464	0.8209	..
34		Beaver01	29	-5.0427	3.2060	0.9666	..
35		Beaver02	37	-5.8054	3.3930	0.9664	..
36		Beaver P.	25	-3.9117	2.4226	0.8710	..
37		Bennett	31	-5.9588	3.4486	0.9867	..
38		Benson	29	-5.4132	3.1901	0.9692	..
39		Bigotter	12	-6.4029	3.6890	0.9778	..
40		Birch	25	-5.6361	3.2716	0.9604	..
41		Black	25	-6.4753	3.6672	0.8303	..
42		Bloody	8	-4.8357	2.8908	0.9165	..
43		Blue	25	-5.2116	3.1036	0.8844	..
44		Bradley	22	-5.3892	3.1885	0.8751	..
45		Brandy	26	-5.1155	3.0238	0.8933	..
46		Bridge	12	-6.9595	3.9861	0.9676	..
47		Brown	8	-6.8778	3.9246	0.8255	..
48		Buck01	12	-3.4030	2.1717	0.8177	..
49		Buck02	29	-5.6075	3.2896	0.9618	..
50		Bullhead	22	-5.0597	2.9951	0.9069	..
51		Bullpout	24	-5.3351	3.1641	0.9806	..
52		Burge	8	-5.0144	2.9639	0.9682	..
53		Cartridg	25	-4.5536	2.7370	0.8012	..
54		Cat	20	-4.8211	2.9335	0.8814	..
55		Catamoun	26	-6.0323	3.4741	0.9378	..
56		Challis	25	-4.3053	2.6565	0.8985	..
57		Charlie	26	-5.5068	3.2203	0.9393	..
58		Charlip01	26	-5.1547	3.0686	0.8836	..
59		Charlip02	20	-5.9081	3.4397	0.9634	..
60		Cheney	20	-4.8549	2.8804	0.9370	..
61		Clear01	24	-5.8701	3.4011	0.9729	..
62		Clear02	10	-4.6003	2.8037	0.8455	..
63		Clear P.01	16	-4.7309	2.8403	0.9131	..

64	Clear P.02	10	-5.0606	3.0152	0.9338	..
65	Clear P.03	25	-4.7943	2.9079	0.9734	..
66	Clear P.04	25	-4.2236	2.6096	0.8519	..
67	Cold	30	-7.0755	4.0115	0.9685	..
68	Coldspri	10	-5.6716	3.2896	0.9551	..
69	Copeland	25	-5.6198	3.2824	0.9251	..
70	County	15	-6.4804	3.7060	0.9796	..
71	Crooked	29	-5.4399	3.1954	0.9788	..
72	Crotched	25	-4.9300	2.9190	0.8819	..
73	Deer01	22	-5.2040	3.0880	0.9766	..
74	Deer02	14	-5.5089	3.2455	0.8050	..
75	Deer03	25	-5.7363	3.3730	0.9280	..
76	Deer04	9	-5.3679	3.1657	0.9915	..
77	Dry	11	-4.1605	2.6468	0.9536	..
78	Duck	25	-3.6274	2.2545	0.8440	..
79	Eagles	26	-5.8676	3.3928	0.9452	..
80	Engle	19	-4.6277	2.7807	0.9174	..
81	Ensign	15	-5.3958	3.1426	0.8379	..
82	Figure	24	-5.4269	3.2033	0.9296	..
83	First	26	-5.0627	3.0320	0.8640	..
84	Fish	8	-4.0839	2.6189	0.9485	..
85	fishbroo	10	-6.2668	3.6263	0.9797	..
86	Forest P.	23	-5.8178	3.3791	0.9600	..
87	Francis	25	-6.1843	3.5589	0.9547	..
88	Franklin	18	-4.4107	2.7586	0.8908	..
89	French	25	-6.8703	3.9624	0.8129	..
90	Giant	8	-7.4561	4.0983	0.8955	..
91	Goose01	29	-5.4062	3.1929	0.9344	..
92	Goose02	25	-4.4953	2.7160	0.8964	..
93	Goosepun	25	-5.6336	3.3046	0.9731	..
94	Grass	25	-4.5224	2.7512	0.8703	..
95	Grassr	25	-6.2616	3.6415	0.9620	..
96	Gray	99	-6.0054	3.4910	0.9025	..
97	Gregory	10	-6.0560	3.5180	0.8870	..
98	Grizzie	10	-5.8159	3.4170	0.9672	..
99	Hatching	10	-5.7966	3.3594	0.9883	..
100	Haymeado	22	-3.8310	2.3771	0.8821	..
101	Heath	18	-5.6126	3.3095	0.9939	..
102	Heavens	25	-5.3265	3.1571	0.9869	..
103	Hewitt	26	-5.9032	3.4487	0.9776	..
104	Hidden	28	-5.1696	3.1210	0.9142	..
105	Hitchcoc	25	-5.1939	3.0885	0.9599	..
106	Hitchens	26	-5.0891	3.0408	0.9530	..
107	Horseshoe01	27	-5.1328	3.0434	0.9633	..
108	Horseshoe02	10	-5.8090	3.3577	0.9959	..
109	Howard	25	-6.3293	3.6632	0.9475	..
110	Inout	25	-5.0087	2.9897	0.9227	..
111	Jabe	29	-4.0568	2.5369	0.8610	..
112	Jocks	28	-5.5361	3.2791	0.9673	..
113	Joeindi	25	-4.8729	2.9518	0.9827	..
114	Johns	31	-6.0801	3.5269	0.9132	..
115	Jug	25	-5.8420	3.3945	0.9603	..
116	Kayuta	12	-6.1821	3.5847	0.9900	..
117	Kings	25	-4.9039	2.9755	0.8499	..
118	Lapland	15	-6.4657	3.7260	0.9675	..
119	lder02	11	-5.3870	3.1764	0.9966	..
120	Lem	38	-5.6415	3.3246	0.9664	..
121	Lewey	19	-5.8837	3.4044	0.9769	..
122	Lily	27	-5.9113	3.4203	0.9742	..
123	Lilypad01	27	-4.3087	2.6099	0.8320	..
124	Limekiln	23	-4.8683	2.9782	0.8328	..
125	Little02	21	-5.2370	3.1580	0.9005	..
126	Little03	10	-3.9199	2.4508	0.9249	..
127	Little05	26	-4.2326	2.6215	0.9417	..
128	Little06	20	-5.2171	3.0707	0.9417	..
129	Little08	25	-3.0320	2.0122	0.8614	..
130	Little09	25	-5.7678	3.3821	0.9502	..
131	Little10	24	-5.2203	3.1191	0.9727	..
132	Little11	26	-5.7025	3.3165	0.9867	..

133	Little12	28	-5.3074	3.1722	0.8684	..
134	Long P.02	18	-5.3571	3.1903	0.9697	..
135	Long01	25	-4.6375	2.7912	0.9194	..
136	Long02	23	-5.6036	3.3084	0.9499	..
137	Long03	10	-5.0772	3.1097	0.9511	..
138	Long04	23	-5.1896	3.0873	0.9716	..
139	Long04	30	-5.4854	3.2274	0.9887	..
140	Loon	8	-6.1082	3.5440	0.9017	..
141	Marion	28	-6.1557	3.5527	0.9785	..
142	Mason	25	-6.0827	3.5082	0.9596	..
143	Massawep	22	-5.4469	3.2154	0.9813	..
144	Mayes	23	-5.1482	3.0600	0.9721	..
145	Middle01	10	-4.0903	2.5949	0.9134	..
146	Middle02	33	-5.4853	3.2235	0.9483	..
147	Mile	25	-5.4140	3.1822	0.9124	..
148	Moose	25	-5.3993	3.1734	0.9774	..
149	Moosehea	25	-3.8777	2.4074	0.8890	..
150	Mud02	14	-5.2153	3.0822	0.9906	..
151	Mud03	19	-5.4946	3.2405	0.9785	..
152	Mud05	15	-6.0203	3.4991	0.9063	..
153	Mud06	12	-6.6875	3.8355	0.9378	..
154	Mud07	26	-5.3960	3.1743	0.9417	..
155	Mud09	26	-5.4906	3.2246	0.9930	..
156	Mud10	11	-4.0267	2.5537	0.9610	..
157	Munson	8	-6.0215	3.4407	0.9839	..
158	Murphy	26	-5.9574	3.4287	0.9748	..
159	Nebo	16	-5.3479	3.1632	0.9596	..
160	New	25	-6.3586	3.6550	0.9724	..
161	Newman	15	-5.8724	3.4244	0.9889	..
162	Nichols	25	-5.2648	3.1022	0.9116	..
163	Nicks	25	-5.0278	3.0140	0.9700	..
164	North P.	9	-6.1830	3.5671	0.9517	..
165	North01	21	-5.5587	3.2444	0.9748	..
166	North02	9	-5.1778	3.0506	0.9429	..
167	North03	31	-6.3392	3.7050	0.9821	..
168	Norther01	25	-4.6563	2.8450	0.9074	..
169	Norther02	15	-5.4038	3.1922	0.9740	..
170	Okara	25	-7.5817	4.2142	0.9827	..
171	Okslip	8	-5.9022	3.4183	0.9851	..
172	Oliver	25	-4.9948	2.9872	0.8293	..
173	Olmstead	25	-5.8423	3.4058	0.9560	..
174	Ormsbee	24	-5.5922	3.2698	0.9737	..
175	Otter	26	-6.0063	3.4681	0.8102	..
176	Otter P.	10	-4.1605	2.5544	0.8569	..
177	Palmer	25	-4.6538	2.8268	0.9803	..
178	Panther	25	-5.7400	3.3348	0.9809	..
179	Piercefi	22	-5.5172	3.2418	0.9654	..
180	Pine	24	-5.9952	3.4830	0.9917	..
181	Pink	10	-3.9109	2.5851	0.9310	..
182	Pitchfor	24	-5.4457	3.1855	0.9677	..
183	Polehill	25	-5.4608	3.1854	0.9620	..
184	Potter	30	-5.2256	3.1082	0.9499	..
185	Puffer	31	-6.1399	3.5472	0.9824	..
186	Putnam	9	-6.4035	3.6823	0.9762	..
187	Rainbow	17	-5.3478	3.1380	0.9560	..
188	Rat	15	-5.0519	2.9991	0.9058	..
189	Ray	25	-4.3680	2.6900	0.8490	..
190	Rock01	23	-5.0722	3.0580	0.8916	..
191	Rock02	23	-5.3522	3.1598	0.9529	..
192	Roe's	23	-5.7959	3.3927	0.9480	..
193	Roiley	20	-5.4788	3.2182	0.9406	..
194	Roll	10	-6.9500	3.9555	0.9544	..
195	Rose	25	-4.7677	2.8916	0.9161	..
196	Round P.02	9	-5.8929	3.3960	0.9842	..
197	Round P.01	25	-3.6317	2.2633	0.8427	..
198	Round01	25	-5.7401	3.3684	0.9217	..
199	round03	31	-6.1991	3.5776	0.9939	..
200	Salmon	24	-5.2409	3.1225	0.9349	..
201	Sampson	28	-7.4432	4.2181	0.9218	..



202	Schley	26	-5.0197	3.0189	0.8265	..
203	Scotch	25	-5.5079	3.2349	0.8952	..
204	Second P.01	8	-8.2782	4.6406	0.9756	..
205	Second01	21	-5.2503	3.1216	0.9541	..
206	Second02	27	-5.6544	3.2847	0.9232	..
207	Seepage	28	-5.6913	3.3407	0.9603	..
208	Shaw	25	-6.0028	3.5103	0.8883	..
209	Snell	26	-3.9327	2.4583	0.8465	..
210	Snider	12	-5.4976	3.2557	0.8537	..
211	Snow	25	-5.6843	3.2835	0.9815	..
212	Soft01	25	-5.2845	3.1552	0.9784	..
213	Soft02	24	-5.8091	3.3939	0.9587	..
214	Sound	12	-5.3028	3.1110	0.9761	..
215	South P.	23	-5.5552	3.2689	0.8037	..
216	Souther02	24	-5.7722	3.3471	0.9386	..
217	Souths	27	-5.0597	3.0052	0.9327	..
218	Spectacle01	15	-3.6601	2.3301	0.9764	..
219	Spring	9	-5.0965	3.0336	0.9821	..
220	Square	25	-3.6926	2.3248	0.8228	..
221	Sterling	28	-5.5139	3.2286	0.8931	..
222	Sunset	20	-6.1296	3.5514	0.9146	..
223	Tanaher	10	-6.0194	3.4962	0.9206	..
224	Taylorve	15	-6.0775	3.5372	0.8737	..
225	Thayer	25	-6.2719	3.5953	0.9427	..
226	Thevly	25	-6.9449	3.9718	0.9541	..
227	Third01	11	-6.0406	3.4622	0.9221	..
228	Third02	25	-6.1512	3.5438	0.9445	..
229	Thirteen	26	-5.6970	3.2978	0.8492	..
230	Tiff	10	-6.9502	3.9709	0.8408	..
231	Tooley	28	-6.2018	3.5781	0.9760	..
232	Trout02	26	-3.7820	2.4067	0.8284	..
233	Tub	25	-5.8551	3.4193	0.9674	..
234	Twin P.01	26	-5.8650	3.4123	0.9649	..
235	Twin P.02	26	-5.4371	3.1922	0.9306	..
236	Unnamed02	25	-6.8490	3.8772	0.9082	..
237	Unnamed03	15	-6.0709	3.4940	0.8539	..
238	Unnamed04	20	-5.7795	3.3759	0.9893	..
239	Unnamed05	25	-5.3898	3.1927	0.9634	..
240	Unnamed06	13	-5.7024	3.3236	0.9333	..
241	Unnamed07	20	-5.3342	3.1501	0.8831	..
242	Unnamed08	8	-5.5343	3.2624	0.9881	..
243	Unnamed09	29	-5.1080	3.0437	0.9245	..
244	Unnamed10	27	-5.1136	3.0820	0.9478	..
245	Unnamed11	25	-4.6746	2.8483	0.8870	..
246	Unnamed12	9	-5.5054	3.2334	0.9139	..
247	Unnamed13	25	-4.5633	2.8563	0.8792	..
248	Unnamed14	21	-4.4975	2.7475	0.9006	..
249	Unnamed15	12	-5.5990	3.3144	0.8870	..
250	Unnamed16	11	-4.5183	2.7572	0.8773	..
251	Unnamed17	11	-5.2514	3.1587	0.9752	..
252	Unnamed19	31	-5.1059	3.0478	0.9682	..
253	Unnamed21	19	-5.6423	3.3164	0.9776	..
254	Unnamed23	25	-4.9310	2.9751	0.9661	..
255	Unnamed24	25	-4.3638	2.6762	0.9273	..
256	Unnamed26	19	-4.5061	2.7167	0.9207	..
257	Unnamed28	18	-5.7801	3.3590	0.9092	..
258	Unnamed29	8	-4.9634	2.9775	0.8864	..
259	Unnamed32	11	-6.2956	3.6164	0.8955	..
260	Vanden	26	-5.8992	3.4090	0.9609	..
261	West	18	-5.8080	3.3945	0.9792	..
262	Wheeler	25	-4.5311	2.7759	0.9817	..
263	Whortleb	9	-5.3515	3.1507	0.9477	..
264	Willis P.	25	-6.5638	3.7463	0.9638	..
265	Willis	25	-5.3949	3.1774	0.9144	..
266	Windfall	26	-5.8379	3.3978	0.9613	..
267	Winnebag	8	-5.6111	3.2812	0.9428	..
268	wolf	20	-6.3678	3.6405	0.9066	..
269	Woodbury	29	-4.6987	2.8264	0.8062	..
270	Worcester	25	-5.8660	3.4182	0.9803	..

271	Nova scotia	Jesse		-5.5210	3.3100		e
272	Ontario	Cataraqui	49	-5.7608	3.3654	0.9900	h
273		Little Round	8	-4.9863	2.9865	0.9900	..
274		Atkins	92	-3.3113	3.1390	0.9800	..
275		Long P.	195	-4.7500	3.5300	0.9900	i
276	Quebec	Brompton	271	-5.7761	3.3762	0.9885	j
277		Brome	236	-5.3201	3.1516	0.9908	..
278		Bromont	239	-5.5931	3.2780	0.9810	..
279		d'Argent	434	-5.6158	3.2841	0.9926	..
280		Hertel	388	-5.5082	3.2403	0.9746	..
281		Magog	421	-5.4311	3.2031	0.9840	..
282		Massawippi	260	-5.0219	3.0073	0.9597	..
283		Memphremagog	289	-5.5160	3.2458	0.9913	..
284		Roxton	280	-5.6136	3.2973	0.9916	..
285		Waterloo	226	-5.4423	3.2223	0.9903	..

a: J. Putman, Auburn University, personal communication.

b: J. Benton, Florida Game and Freshwater Fish Commission, personal communication.

c: D. Austen, Illinois Nat. Hist. Survey, personal communication.

d: V. Santucci, Max McGraw Wildlife Foundation, personal communication.

e: Carlander 1977.

f: R. Maher, Illinois Nat. Hist. Survey, personal communication.

g: J. Gallagher, New York Dept. Envir. Conservation, personal communication.

h: Complak 1980.

i: Mahon and Balon 1977.

j: Unpublished data.