NOTES

An assessment of burbot (*Lota lota*) weight – length data from North American popuplations

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Abstract: Declining burbot (*Lota lota*) abundance across some portions of North America has prompted a search for additional evaluation tools, including a measure of condition. Weight–length data were compiled for 10 293 burbot from 79 North American populations. These data were used to develop a 75th percentile standard weight (W_s) equation using the regression-line-percentile technique. The proposed equation is $\log_{10} W_s = -4.868 + 2.898 \log_{10} \text{TL}$, where W_s is the standard weight in grams, and TL is the maximum total length in millimetres. The equation is valid for burbot ≥ 20 cm and will allow calculation of relative weights (W_r) for this species. Based on the length of the longest burbot in our data set (104.3 cm), we propose minimum standardized length categories of 20, 38, 53, 67, and 82 cm for stock, quality, preferred, memorable, and trophy length, respectively. The standard length categories will allow determination of mean W_r by length group, as well as calculation of stock density indices. Differences in W_r values were present between lentic and lotic burbot populations, suggesting variation in body shape and a need for establishment of different W_r objective ranges.

Résumé : Le déclin des populations de la Lotte (*Lota lota*) en certaines régions de l'Amérique du Nord a donné lieu à une demande plus grande de nouveaux outils d'évaluation, particulièrement pour mesurer la condition. Les données longueur–masse ont été recueillies chez 10 293 lottes provenant de 79 populations nord-américaines. Ces données ont servi à élaborer une équation décrivant la masse standard du 75ᵉ percentile (W_s) au moyen de la technique de la droite de régression basée sur les percentiles. L'équation proposée se lit comme suit : $\log_{10} W_s = -4{,}868 \pm 2{,}898 \log_{10} \text{TL}$, où W_s représente la masse standard en grammes et TL, la longueur totale maximale en millimètres. L'équation est valide dans le cas des lottes de 20 cm ou plus et permet le calcul de la masse relative (W_r) chez cette espèce. D'après la mesure de la lotte la plus longue de notre ensemble de données (104,3 cm), nous proposons les catégories suivantes de longueurs standardisées, 20, 38, 53, 67 et 82 cm correspondant respectivement à des poissons ordinaires, supérieurs, excellents, exceptionnels et de taille « trophée ». Ces catégories permettront la détermination de la masse W_r par classe de longueur et le calcul des indices de densité des stocks. Nous avons décelé des différences de W_r entre les populations lénitiques et lotiques de la Lotte, ce qui semble indiquer que la forme du corps peut varier et qu'il faudra peut-être établir différentes échelles objectives de W_r.

[Traduit par la Rédaction]

Introduction

The burbot (*Lota lota*) is the only member of the family Gadidae (cods) that lives in fresh water throughout its life (Scott and Crossman 1973). The range of burbot is circumpolar, extending across northern Europe, Asia, and North America (Ryder and Pesendorf 1992). Taxonomic differences between burbot from different regions have been disputed, but at least two phenotypes have been identified (Pivnicki 1970); however, all phenotypes are considered to be from a single species (McPhail and Lindsey 1970). This fish is adapted to both lentic (Lawler 1963; Bailey 1972) and lotic (Breeser et al. 1988) systems.

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Burbot have historically had limited commercial and recreational value, but have been recognized as an important piscivore in aquatic systems (Schram 1983). In more recent years, sport angling for burbot has increased in popularity and locally important recreational fisheries do exist; however, a decrease in numbers of fish harvested, possibly due to overexploitation, has been documented (Lafferty et al. 1992; Bernard et al. 1993). Reports of declining burbot populations and the possible listing of the species on the Idaho threatened species list are also of concern (V.L. Paragamian, Idaho Department of Fish and Game, personal communication). With a renewed interest in the status of burbot populations across North America, a reliable measure of body condition could play an important role in population assessment and in determining the effects of management actions.

Wege and Anderson (1978) first proposed the use of relative weight (W_r) as an index to evaluate fish condition; since then, this method has been successfully used as an

assessment tool for several species. The advantages of W_r are that it avoids the length-related bias of Fulton condition factors (e.g., K), which increase with increasing fish length, and that a W_r value of 100 represents the 75th percentile level for all fish species (Anderson and Gutreuter 1983). A well-developed and tested W_s equation should not exhibit length-related bias.

The objectives of this study were (i) to develop a 75th-percentile-based W_s equation for burbot, using the recommended regression-line-percentile (RLP) technique (Murphy et al. 1990), (ii) to assess the validity of the proposed burbot W_s equation, (iii) to establish minimum total lengths for a length-categorization system (Gabelhouse 1984) to assess burbot stocks, (iv) to compare mean W_r values by length category between lentic and lotic systems, and (v) to suggest W_r objective ranges for burbot populations.

Data base

Weight—length data for burbot were solicited from fisheries research and management agencies across Canada and the United States. Data were obtained for 10 293 fish from 79 populations (Table 1). All weights were reported as wet weight (g) and lengths as maximum total length (TL; mm). Data sets submitted with length measurements as fork length (FL) were treated as TL measurements because FL and TL are equivalent for burbot. When data sets were obtained for several years from a burbot population, the year for which the greatest range in length measurements and largest sample size was obtained was used. Data were analyzed using the Statistical Analysis System (SAS Institute Inc. 1992) microcomputer software, and significance for all statistical analyses was set at 95% ($\alpha = 0.05$). All weight—length data sets were examined as scatter plots, and outliers (± 3 standard deviations) were eliminated from subsequent analyses to prevent gross errors from influencing development and testing of the W_s equation.

Development and evaluation of the W_s equation

### Determination of minimum and maximum lengths
The minimum length for which W_r values should be calculated was determined by assessing the variation about the mean weight by centimetre-length group for our entire data base (Murphy et al. 1990). Green's coefficient, which determines variance independently of sample size (Elliot 1977), was plotted to determine the inflection point at which the coefficient was greater than -0.1. The inflection point occurred at the 20 cm length group. At lengths shorter than 20 cm, weight measurements were probably imprecise.

The maximum TL used to develop the W_s equation was 104.3 cm, the longest fish in our data set. This specimen was collected from the Peace River, Alberta, by the Northern River Basins Study group (R.B. More, personal communication).

Proposed W_s equation
Log_{10} weight — log_{10} length regressions were calculated for burbot 20 cm and longer from each population (Table 1). We randomly selected 50 of the populations to develop the W_s equation and used the remaining 29 to test the proposed

Fig. 1. Plot of the y intercept as a function of the slope for weight—length regressions from 79 burbot populations across North America. The five burbot populations not included in the development of the standard weight (W_s) equation are identified.
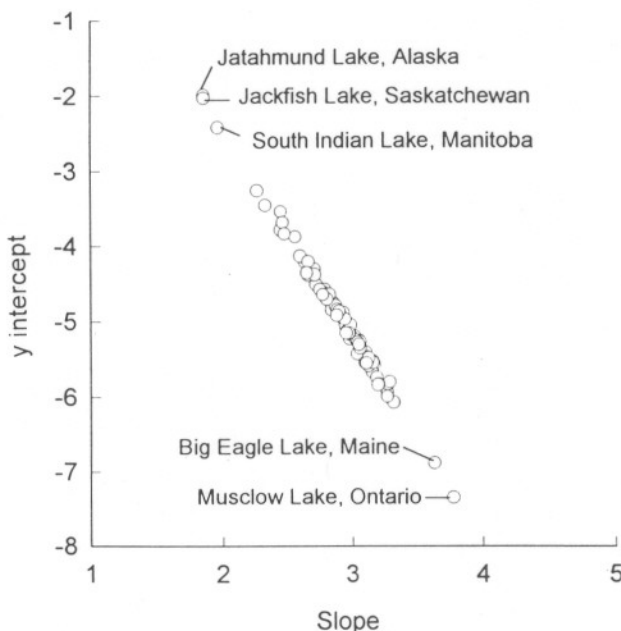
equation for potential length-related bias. Populations that had extreme values for the slope of the regression equation were not used in developing the W_s equation (Pope et al. 1995). Jatahmund Lake in Alaska, Jackfish Lake in Saskatchewan, South Indian Lake in Manitoba, Big Eagle Lake in Maine, and Musclow Lake in Ontario were not used in the development data set (Fig. 1), but were included in the test group of populations.

Mean weights were predicted for the midpoints of 1 cm length intervals from 20 cm (the minimum reliable length) to 104.3 cm (the longest fish in our data base) for each population, and the 75th percentile of the means in each interval was determined. The 75th-percentile weights were regressed on length to develop the proposed W_s equation as suggested by Murphy et al. (1990).

The proposed W_s equation is

[1] $\log_{10} W_s = -4.868 + 2.898 \log_{10} TL$

where W_s is the standard weight in grams and TL is the maximum total length in millimetres. Using Imperial units, the equivalent of the equation is

[2] $\log_{10} W_s = -3.454 + 2.898 \log_{10} TL$

where W_s is the standard weight in pounds and TL is the maximum total length in inches.

Evaluation of potential length-related biases
In the past, W_s equations developed by means of other techniques have produced W_r values that were length-biased, meaning that W_r values consistently increased or decreased with fish length. For example, Neumann and Murphy (1991) regressed W_r on length for 80 black crappie (*Pomoxis nigromaculatus*) populations. Of the 56 populations that

Table 1. Data for fish from burbot populations used in the development and testing of the standard weight (W_s) equation.

Water body	Water type[a]	Use[b]	N[c]	Regression information[d]			PSD[e]	Mean relative weight[f]				
				Intercept	Slope	r		S-Q	Q-P	P-M	M-T	T
Alaska												
Harding Lake	1	T	56	−5.252	3.055	0.99	75	107	107	113	115	104
Fielding Lake	1	D	107	−5.244	3.017	0.99	59	85	88	86	94	109
West Twin Lake	1	D	96	−3.454	2.327	0.93	92	95	80	70		
Tyone Lake	1	T	22	−5.383	3.058	0.97	68	79	79	92		
Jatahmund Lake	1	T	17	−1.987	1.856	0.91	100		129	90	81	
Round Tangle Lake	1	D	12	−4.505	2.723	0.87	25	86	72	90		
Susitna Lake	1	D	13	−5.206	3.010	0.99	54	85	94	97		
Tolsona Lake	1	D	31	−3.786	2.445	0.94	84	94	74	74		
Paxson Lake	1	D	126	−5.195	3.017	0.98	88	88	103	100	99	121
Summit Lake	1	T	29	−5.411	3.105	0.95	59	98	99	129		
Lake Louise	1	D	114	−4.780	2.856	0.96	75	102	96	95	88	132
Moose Lake	1	D	27	−3.258	2.265	0.98	89	115	85	73	74	
Tanana River	3	D	590	−5.197	2.993	0.98	70	82	85	86	92	
Alberta												
Smoky River	3	T	55	−5.553	3.109	0.98	95	72	76	81	87	75
Peace River	3	D	152	−5.828	3.205	0.98	97	68	73	77	86	93
Athabasca River	3	T	87	−5.835	3.201	0.99	97	63	70	74	79	87
Wapati River	3	D	15	−4.644	2.773	0.98	93	76	80	72		
Lesser Slave River	3	T	20	−4.355	2.651	0.98	95	74	74	66		
Idaho												
Kootenai River	3	D	56	−5.236	2.979	0.94	93	71	71	78	78	
Manitoba												
Lake Winnipeg, northwest	2	D	25	−5.027	2.948	0.96	84	97	94	87	115	
Lake Winnipeg, Victoria Beach	2	D	30	−4.737	2.844	0.95	80	100	98	101		
Churchill River	3	T	13	−4.387	2.661	0.70	100		74	68		
South Indian Lake	1	T	11	−2.416	1.965	0.70	100		86	79		
Maine												
Moosehead Lake	1	D	212	−5.475	3.110	0.99	49	85	89	101	119	
First Roach Pond	1	D	115	−4.577	2.788	0.97	93	99	100	97	102	
Allagash Lake	1	D	44	−4.210	2.636	0.98	82	96	96	83		
Chamberlain Lake	1	T	24	−5.061	2.947	0.98	88	92	87	85	105	
Ross Lake	1	D	19	−4.880	2.867	0.94	100		72	80	80	
Big Eagle Lake	1	T	9	−6.881	3.630	0.76	100		97	102		
St. Froid Lake	1	T	32	−5.935	3.271	0.99	19	69	88	83		
Square Lake	1	D	47	−6.069	3.318	0.99	49	71	81	97		84
Michigan												
Lake Michigan	2	T	1726	−4.885	2.931	0.95	86	113	124	120	107	107
Minnesota												
Lake Superior, northwest	2	T	34	−4.307	2.708	0.97	100		114	108	111	
Leech Lake	1	D	577	−5.570	3.172	0.94	78	105	105	122	127	
Lake Mille Lacs	1	D	121	−4.754	2.854	0.91	74	99	103	96		
Rainy Lake	1	D	192	−4.614	2.779	0.95	88	95	86	89	115	120
Montana												
Smith River	3	D	43	−4.921	2.889	0.97	72	89	84	85	82	
Fort Peck Reservoir	4	D	296	−5.666	3.156	0.95	96	77	78	84	91	89
Missouri River	3	D	90	−4.887	2.857	0.98	66	76	76	74	72	
Tiber Reservoir	4	T	167	−5.431	3.042	0.89	99	85	73	68	77	62
Lake Koocanusa	4	D	115	−5.589	3.128	0.95	83	75	77	86	81	
Kootenai River	3	D	163	−5.178	2.985	0.96	75	85	83	89	77	
Yellowstone River	3	D	591	−4.135	2.598	0.96	87	104	87	79	79	80
New Hampshire												
Statewide	1	D	195	−4.641	2.825	0.94	98	118	105	110	104	96

Table 1 (*concluded*).

Water body	Water type[a]	Use[b]	N[c]	Regression information[d]			PSD[e]	Mean relative weight[f]				
				Intercept	Slope	r		S-Q	Q-P	P-M	M-T	T
New York												
Oneida Lake	1	D	169	−4.378	2.712	0.96	93	109	98	97		
North Dakota												
Lake Sakakawea	4	T	17	−5.358	3.062	0.97	100		95	86	109	93
Northwest Territories												
Alexie Lake	1	D	95	−5.528	3.162	0.96	99	119	111	118	114	
Liard River	3	D	54	−5.989	3.271	0.98	100		79	83	91	95
Slave River	3	D	220	−5.248	3.030	0.96	100		96	96	101	127
Great Slave Lake	2	D	106	−4.911	2.907	0.94	99	89	96	96	98	91
Mackenzie River, north	3	D	149	−5.548	3.100	0.96	100		79	76	79	85
Arctic Red River	3	D	22	−5.133	2.958	0.96	100		66	78	88	80
Mackenzie River, south	3	T	28	−5.741	3.189	0.96	100		82	85	96	92
Ohio												
Lake Erie	2	D	61	−5.824	3.277	0.96	95	73	123	127	114	
Ontario												
Lake Opeongo	1	D	232	−5.272	3.060	0.98	69	100	110	107	92	
Lake Aylen	1	T	13	−6.229	3.451	1.00	92	84	136	138		
Lake Huron, basin	2	D	129	−5.278	3.042	0.97	98	91	94	100	89	
Lake Huron, Georgian Bay	2	D	118	−5.309	3.053	0.96	86	88	96	94		
Experimental Lake 625	1	D	36	−4.898	2.897	0.96	92	98	92	107		
Musclow Lake	1	T	10	−7.349	3.772	0.93	100		69	90	89	
Trout Lake	1	D	13	−4.793	2.872	0.98	92	97	103	100		
Lake Nipigon	1	D	9	−4.207	2.663	0.93	100		106	100	115	
Lake Ontario	2	T	66	−5.047	2.989	0.97	95	108	118	118	126	
McDonald Lake	1	D	29	−5.228	3.033	0.99	4	94	87			
Saskatchewan												
Davin Lake	1	T	21	−4.703	2.804	0.94	95	76	85	81		
Diefenbaker Lake	4	T	24	−5.488	3.126	0.98	100		101	102	110	108
Jackfish Lake	1	T	26	−2.026	1.857	0.89	100		108	95	80	
Jan Lake	1	T	17	−3.876	2.561	0.97	100		118	117	110	
Lac Île-A-La-Crosse	1	T	34	−3.541	2.449	0.85	100		126	123	110	
Last Mountain Lake	1	D	20	−3.685	2.463	0.88	95	133	101	98		
Smoothstone Lake	1	D	20	−4.843	2.885	0.96	95	89	93	109	94	97
Wisconsin												
Lake Superior, south	2	T	940	−4.968	2.943	0.91	95	106	107	109	100	
Lake Winnebago	1	D	531	−4.867	2.899	0.94	65	102	102	103	99	
Wyoming												
Bull Lake	4	D	86	−5.157	2.975	0.98	88	84	83	83	90	87
Bighorn Lake	4	T	161	−5.188	2.963	0.97	89	72	71	75	75	63
Bighorn River	3	D	34	−3.837	2.477	0.90	91	95	87	67	85	
Ocean Lake	1	T	35	−4.920	2.881	0.99	94	79	82	78	83	
Boysen Reservoir	4	D	209	−4.286	2.644	0.97	91	90	83	75	81	84
Yukon												
Lake Laberge	1	T	43	−4.930	2.912	0.98	86	94	95	98	90	

[a]1, lakes < 19 000 km²; 2, lakes ≥ 19 000 km²; 3, rivers; 4, reservoirs.

[b]D, development; T, testing.

[c]Sample size.

[d]Regressions of $\log_{10}$ weight − $\log_{10}$ length.

[e]Proportional stock density, calculated as the number of fish of quality length (≥38 cm) divided by the number of stock-length fish (≥20 cm) and multiplied by 100.

[f]Mean relative weights (W_r) calculated with the proposed burbot W_s equation for stock- to quality-length (S-Q; 20−38 cm), quality- to preferred-length (Q-P; 38−53 cm), preferred- to memorable-length (P-M; 53−68 cm), memorable- to trophy-length (M-T; 68−82 cm), and trophy-length (T; ≥82 cm) groups for each population.

Fig. 2. Means of population mean relative weights (W_r) for stock- to quality-length (S-Q), quality- to preferred-length (Q-P), preferred- to memorable-length (P-M), and memorable- to trophy-length (M-T) categories for burbot populations collected from rivers, reservoirs, large lakes ($\geq 19\,000$ km^2), and small lakes ($< 19\,000$ km^2). Vertical bars represent ± 1 standard error. Means with the same letter in each length category are not significantly different ($\alpha = 0.05$).
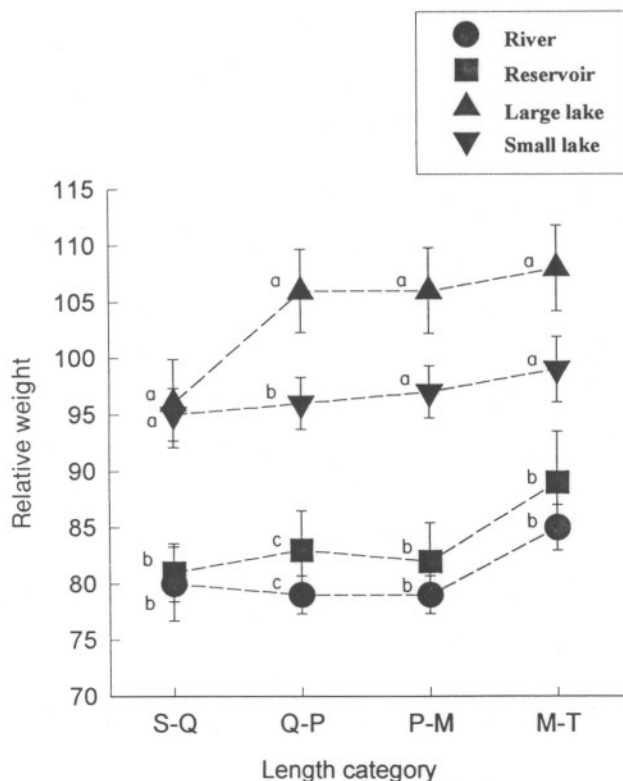
exhibited significant slopes for the relationship between W_r and length, 52 had a positive slope and only 4 had a negative slope. The authors then proposed a new W_s equation for black crappies using the RLP technique.

In this study, we used 24 randomly selected burbot populations plus the 5 outlying populations to test for length-related bias of the proposed W_s equation. Six populations have significant slopes ($P \leq 0.05$) for the relationship between W_r and length; four relationships have a positive slope and two a negative slope. Thus, we believe that length-related bias in W_r values should not be a problem with the proposed W_s equation.

Proposed standard length categories

Gabelhouse (1984) recommended that minimum stock, quality, preferred, memorable, and trophy lengths be chosen from length ranges bounded by 20−26, 36−41, 45−55, 59−64, and 74−80%, respectively, of the world record length. The burbot with the world record length listed by the International Game Fish Association was 97.5 cm and was caught in Lake Michigan, Michigan. However, the longest burbot submitted in our data set was 104.3 cm, which exceeded the world record length. Based on our 104.3-cm fish, we recom-

mend that 20 cm (8 in.), 38 cm (15 in.), 53 cm (21 in.), 67 cm (26 in.), and 82 cm (32 in.) be used as the minimum stock, quality, preferred, memorable, and trophy length, respectively.

Lentic versus lotic burbot condition

Mean W_r values were calculated by length category for each population (Table 1) to compare fish condition between populations from lentic and lotic environments. Lentic systems were further categorized into lakes $\geq 19\,000$ km^2, lakes $< 19\,000$ km^2, and reservoirs. Relative weights were normally distributed, so analysis of variance using the SAS General Linear Model (GLM) procedure (SAS Institute Inc. 1992) was utilized to determine if there were significant differences among the four environments. Because the data set was unbalanced, we compared the least-squares means using the GLM procedure and the TDIFF option. The TDIFF option analyzes the null hypothesis that the least-squares means for W_r by water-body type are equal. Riverine and reservoir burbot populations had significantly lower mean W_r values across length categories than both lake types (Fig. 2). Trophy-length fish were not included in this analysis because of a small sample size.

Discussion

The W_s equation proposed in this paper will allow determination of W_r values for burbot. Murphy et al. (1991) cautioned that population mean W_r values not be used to evaluate fish condition without determining whether W_r varied with fish length. They suggested that mean W_r values be calculated by length category. The standard length categories proposed in this paper will allow such calculations for burbot. In addition, stock-density indices (Willis et al. 1993) can be calculated using the proposed five-cell model for length categories of burbot.

Our analysis of burbot condition from different water-body types may be additional evidence that two different burbot phenotypes do exist. Pivnicki (1970) described the burbot from Alaska south to the Mackenzie River system as having a long and low caudal peduncle. A second phenotype with a short and high caudal peduncle was also described from southern Canada and the United States. Phenotypic differences in burbot populations, although previously described in geographic terms, may be due to evolutionary adaptation to different water-body types because lower condition populations in riverine and reservoir habitats are present throughout the range of the species. Even though reservoirs are typically classified as lentic, their origin in lotic systems may have provided the genetic template through which burbot with lower condition values are likely to occur. However, the cause of lower condition in river and reservoir burbot populations may alternatively be attributable to environment, genetics, or some combination of the two.

We found that burbot populations from rivers and reservoirs had consistently lower W_r values across length categories than lake populations. Therefore, we suggest that different objective ranges be considered. An appropriate burbot W_r objective range for lake populations might be 100 ± 5, which was suggested as an objective range for largemouth bass (*Micropterus salmoides*) (Anderson 1980).

Our results indicate that an objective range of 100 ± 5 may not be applicable to river and reservoir burbot populations. We suggest that a preliminary W_r objective range for burbot in rivers and reservoirs is 80 ± 5, but further investigation is necessary to verify both of the suggested objective ranges.

Analysis of condition is a simple tool for population assessment. W_r values can be monitored and analyzed for trends over time. This information can provide insight into ecological variability in an aquatic system. It is important, however, that weight – length data be collected and recorded in a standardized fashion, as there can be substantial seasonal variation in condition (Pope and Willis 1996).

Acknowledgements

References

Anderson, R.O. 1980. Proportional stock density (PSD) and relative weight (W_r): interpretive indices for fish populations and communities. *In* Practical fisheries management: more with less in the 1980's. *Edited by* S. Gloss and B. Shupp. New York Chapter, American Fisheries Society, Cazenovia, N.Y. pp. 27 – 33.

Anderson, R.O., and Gutreuter, S.J. 1983. Length, weight, and associated structural indices. *In* Fisheries techniques. *Edited by* L.A. Nielsen and D.L. Johnson. American Fisheries Society, Bethesda, Md. pp 283 – 324.

Bailey, M.M. 1972. Age, growth, reproduction, and food of the burbot, *Lota lota* (Linnaeus), in southwestern Lake Superior. Trans. Am. Fish. Soc. 101: 667 – 674.

Bernard, D.R., Parker, J.F., and Lafferty, R. 1993. Stock assessment of burbot populations in small and moderate-size lakes. N. Am. J. Fish. Manage. 13: 657 – 675.

Breeser, S.W., Stearns, F.D., Smith, M.W., West, R.L., and Reynolds, J.B. 1988. Observations of movements and habitat preferences of burbot in an Alaskan glacial river system. Trans. Am. Fish. Soc. 117: 506 – 509.

Elliot, J.M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Publ. No. 25.

Gabelhouse, D.W., Jr. 1984. A length-categorization system to assess fish stocks. N. Am. J. Fish. Manage. 4: 273 – 285.

Lafferty, R., Parker, J.F., and Bernard, D.R. 1992. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1991. Fisheries Data Ser. No. 92-20, Alaska Department of Fish and Game, Juneau.

Lawler, G.H. 1963. The biology and taxonomy of the burbot, *Lota lota*, in Heming Lake, Manitoba. J. Fish. Res. Board Can. 20: 417 – 433.

McPhail, J.D., and Lindsey, C.C. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Board Can. No. 173.

Murphy, B.R., Brown, M.L., and Springer, T.A. 1990. Evaluation of the relative weight (W_r) index, with new applications to walleye. N. Am. J. Fish. Manage. 10: 85 – 97.

Murphy, B.R., Willis, D.W., and Springer, T.A. 1991. The relative weight index in fisheries management: status and needs. Fisheries (Bethesda), 16(2): 30 – 38.

Neumann, R.M., and Murphy, B.R. 1991. Evaluation of the relative weight (W_r) index for assessment of white crappie and black crappie populations. N. Am. J. Fish. Manage. 11: 543 – 555.

Pivnicki, K. 1970. Morphological variation in the burbot *Lota lota* and recognition of the subspecies: a review. J. Fish. Res. Board Can. 27: 1757 – 1765.

Pope, K.L., and Willis, D.W. 1996. Seasonal influences on freshwater sampling data. Crit. Rev. Fish. Sci. 4. In press.

Pope, K.L., Brown, M.L., and Willis, D.W. 1995. Proposed revision of the standard weight (W_s) equation for redear sunfish. J. Freshwater Ecol. 10: 129 – 134.

Ryder, R.A., and Pesendorf, J. 1992. Food, growth, habitat, and community interactions of young-of-the-year burbot, *Lota lota* L., in a Precambrian Shield lake. Hydrobiologia, 243/244: 211 – 227.

SAS Institute Inc. 1992. SAS user's guide, version 6. SAS Institute, Inc., Cary, N.C.

Schram, S. 1983. Seasonal movements and mortality estimates of burbot in western Lake Superior. Fish Management Rep. No. 119, Wisconsin Department of Natural Resources, Madison.

Scott, W.B., and Crossman, E.J. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. No. 184.

Wege, G.J., and Anderson, R.O. 1978. Relative weight (W_r): a new index of condition for largemouth bass. *In* New approaches to the management of small impoundments. *Edited by* G.D. Novinger and J.G. Dillard. Spec. Publ. No. 5, North Central Division, American Fisheries Society, Bethesda, Md. pp. 79 – 91.

Willis, D.W., Murphy, B.R., and Guy, C.S. 1993. Stock density indices: development, use, and limitations. Rev. Fish. Sci. 1: 203 – 222.