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Growth standards for nine North American fish species

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Abstract Standard methods for comparing population characteristics within and among fish populations greatly enhance communications among fisheries scientists, improve the efficiency of data analysis, and provide insight that helps guide management actions. Although standard methods are available for comparing some fish population characteristics (e.g. length structure, body condition), similar methods are lacking for comparing growth. The purpose of this study was to provide standards (i.e. percentiles and a standard growth model) for nine ecologically and recreationally important fish species. Percentile distributions of mean back-calculated length at age were estimated using data obtained from the published literature and from data solicited from state and federal agencies throughout North America. Percentiles of growth were estimated for bluegill, *Lepomis macrochirus* Rafinesque, common carp, *Cyprinus carpio* Linnaeus, flathead catfish, *Pylodictis olivaris* (Rafinesque), largemouth bass, *Micropterus salmoides* (Lacepède), sauger, *Sander canadensis* (Griffith & Smith), smallmouth bass, *Micropterus dolomieu* Lacepède, white bass, *Morone chrysops* (Rafinesque) and yellow perch, *Perca flavescens* (Mitchill). Standard growth models (i.e. von Bertalanffy models) were developed for these species and for channel catfish, *Ictalurus punctatus* (Rafinesque). These results provide tools that will help scientists compare growth of fishes across North America.

KEYWORDS: growth standards, relative growth index, von Bertalanffy.

Introduction

Evaluation of fish population characteristics in a system often includes comparison to regional or statewide averages or to some standard, and a variety of techniques have been developed that allow comparison. For example, proportional stock density (PSD) enables standardised assessment of the length structure of fish populations (Willis, Murphy & Guy 1993), and relative weight (*W*r) provides a standardised assessment of fish condition among populations (Blackwell, Brown & Willis 2000). Extensive comparisons of growth began with Carlander (1969, 1977, 1997), where mean back-calculated length at age and mean lengths at age were calculated by state and region. Hubert (1999) used a similar technique by calculating percentile values of mean lengths at age for 102 channel catfish, *Ictalurus punctatus* (Rafinesque), populations throughout North America for use as growth standards. Analogous methods were used to develop percentile standards for walleye, *Sander vitreus* (Mitchill) (Quist, Guy, Schultz & Stephen 2003), white crappie, *Pomoxis annularis* Rafinesque, and black crappie, *P. nigromaculatus* (Lesueur) (Jackson & Hurley 2005). Percentiles illustrate the range of observed lengths and describe the percentage of lengths smaller than the standard. Another method of interpreting growth information was described by Casselman & Crossman (1986), who used von Bertalanffy growth models to estimate age-specific standard lengths for North American muskellunge, *Esox masquinongy* Mitchill, populations. This method was used to provide growth standards for walleye (Quist *et al.* 2003), black crappie and white crappie (Jackson & Hurley 2005).

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Standard lengths (L_s) represent predicted age-specific lengths from a standard growth model (i.e. the von Bertalanffy model). Following Quist *et al.* (2003), age-specific standard lengths can be applied to the relative growth index [RGI = $(L_t/L_s) \times 100$, where L_t = observed length at age (t) and L_s = predicted age-specific standard length]. This index can be used to summarise and interpret growth, with RGI values above 100 indicating fast growth and values below 100 indicating slower growth. Comparing growth to national averages or percentiles illustrates whether fish are growing faster or slower than other populations, as well as the relative magnitude of differences in growth. These evaluations can be used to provide insight on differences in growth based on environmental conditions (e.g. temperature, water quality, watershed protection) or management activities (e.g. harvest regulations, habitat improvements, trophic manipulations).

The full utility of growth standards is limited because they have only been developed for a few species. Given the potential utility of growth comparisons, the objectives of this study were to estimate percentile values of mean back-calculated length at age for North American populations of bluegill, *Lepomis macrochirus* Rafinesque, common carp, *Cyprinus carpio* Linnaeus, flathead catfish, *Pylodictis olivaris* (Rafinesque), largemouth bass, *Micropterus salmoides* (Lacepède), sauger, *Sander canadensis* (Griffith & Smith), smallmouth bass, *Micropterus dolomieu* Lacepède, white bass, *Morone chrysops* (Rafinesque), and yellow perch, *Perca flavescens* (Mitchill). In addition, standard growth models, needed to calculate RGIs, were developed for each species. Only percentile values of growth had been calculated for channel catfish (Hubert 1999); therefore, a growth model was also developed for channel catfish. These species were selected because of their importance as sport fish (e.g. bluegill, largemouth bass) or their importance in affecting habitat quality (i.e. common carp; Crivelli 1983; Lougheed, Crosbie & Chow-Fraser 1998; Miller & Crowl 2006). The common carp is native to Europe and Asia, but has been widely introduced throughout much of North America (Panek 1987). Bluegill, channel catfish, flathead catfish, largemouth bass, sauger, smallmouth bass, white bass and yellow perch are native to North America, but have also been introduced to many areas where they are not native.

Methods

Mean back-calculated length at age data for bluegill, channel catfish, common carp, flathead catfish, largemouth bass, sauger, smallmouth bass, white bass and yellow perch were assembled from the peer-reviewed literature. Additional information was obtained by soliciting state and federal natural resource agencies throughout North America. Growth data were based on a variety of structures including opercles, otoliths, pectoral spines, dorsal spines, scales and vertebrae. Although some structures may provide biased age estimates for older fish (Marwitz & Hubert 1995; Kocovsky & Carline 2000; Isermann, Meerbeek, Scholten & Willis 2003), it was assumed the studies used structures that provided reasonably accurate estimates of age for the species and region. Growth data were only included from studies that contained at least 30 individuals. When multiple studies on a population were available, the study with the largest sample size was selected. As recognised by Hubert (1999), growth rates can vary substantially across the distribution of a species. Accordingly, it is important not only to include growth information from the entire distribution of a species, but also to minimise the influence of any one geographic region. Therefore, studies were limited to 10 populations from any state or province. Data were truncated for each species at the age when 25% of the populations did not include that age to minimise potential aging errors. For instance, if there were 100 populations of a given species, the oldest age present in at least 75 of the populations was the upper age limit used in the analysis. Further truncation occurred when growth standards were unreasonable (e.g. fifth percentile for age-7 bluegill was less than fifth percentile for age-6 bluegill).

Standards were computed from the distributions of mean back-calculated lengths at age for each species following Hubert (1999). Estimated percentiles of mean back-calculated lengths at age included the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. A von Bertalanffy growth model was estimated for each species using non-linear regression techniques (PROC NLIN) in Statistical Analysis System (SAS Institute 1996) following the method described in Quist *et al.* (2003). While sex-specific standards would be useful, available data rarely included information by sex ($<5\%$ of the populations). Thus, data were insufficient for calculating sex-specific standards.

Results and discussion

Growth data were obtained for 41 states and five Canadian provinces (Table 1). The number of populations from individual states or provinces varied from 1 to 60 (i.e. for all species), with South Dakota, Iowa, Oklahoma, Nebraska and Washington contributing the greatest number of populations. While the number

Table 1. Number of populations of bluegill (BLG), common carp (CRP), flathead catfish (FHC), largemouth bass (LMB), sauger (SAU), smallmouth bass (SMB), white bass (WHB), and yellow perch (YEP) used in development of growth standards from each state and province

State or province	BLG	CRP	FHC	LMB	SAU	SMB	WHB	YEP	Sources
Alabama			2	4					FHC: Nash (1999), M. Maceina, unpublished data; LMB: Carlander (1977), D. Armstrong, unpublished data
Arkansas	6			4		1	3		BLG: Carlander (1977), S. Sammons, unpublished data; LMB: Carlander (1977), Jackson *et al.* (2005); SMB: Carlander (1997); WHB: Houser & Bryant (1970), Yellayi & Kilambi (1975), Carlander (1997)
Arizona			3						FHC: Young & Marsh (1990)
California	2			8					BLG: Carlander (1977); LMB: Carlander (1977)
Colorado						1		1	SMB: Patton & Hubert (1996); YEP: Carlander (1997)
Florida				10			1		LMB: Porak *et al.* (1986, 1987); WHB: Nordhaus *et al.* (1998)
Georgia	8		3						BLG: Carlander (1977), S. Sammons, unpublished data; FHC: Quinn (1988), Nash (1999), Grabowski *et al.* (2004)
Great Lakes					1	5	1	4	SAU: Carlander (1997); SMB: Carlander (1977), Danehy & Ringler (1991); WHB: Carlander (1997); YEP: Carlander (1997)
Iowa	10	10	2	10	3	7	7	6	BLG: Carlander (1977); CRP: Carlander (1969), Z. Jackson, unpublished data; FHC: Mayhew (1969), Carlander (1977); LMB: Carlander (1977), M. Steuck, unpublished data; SAU: Carlander (1997), M. Steuck, unpublished data; SMB: Carlander (1977), A. Jansen, unpublished data; WHB: Sigler (1949), Pelren (1970), Carlander (1997), M. Steuck, unpublished data; YEP: Carlander (1997)
Idaho	1			2		3			BLG: Schriever *et al.* (1996); LMB: Schriever *et al.* (1996); SMB: Carlander (1977)
Illinois	7			10	1	4	1		BLG: Carlander (1977); LMB: Carlander (1977), Storck *et al.* (1982), Perry & Tranquilli (1984), Garthause & Heidinger (1999), M. Steuck, unpublished data; SAU: Carlander (1997); SMB: Carlander (1977); WHB: Carlander (1997)
Indiana	10			10		2	1	3	BLG: Carlander (1997), Benson (2004), Carnahan (2005), Doll (2005a,b), Robertson (2005), M. Burlingame, unpublished data; LMB: Benson (2004), Carnahan (2005), Doll (2005a), Pearson (2005), Robertson (2005), M. Burlingame, unpublished data, C. Kowalik, unpublished data; SMB: Keller (2001), Price & Robertson (2005); WHB: Colvin (1993); YEP: Benson (2004), Robertson (2005), J. Doll, unpublished data
Kansas	4	2	4	3			10		BLG: Cross *et al.* (1959), Delp *et al.* (2000); CRP: Stucky & Klaassen (1971); FHC: Carlander (1977), Layher & Boles (1979), C. Paukert, unpublished data; LMB: Cross *et al.* (1959), Delp *et al.* (2000); WHB: R. Schultz, unpublished data
Kentucky				3			1		LMB: Carlander (1977), Buynak *et al.* (1991), Buynak & Mitchell (1999); WHB: Carlander (1997)
Louisiana				2					LMB: Carlander (1977), Meador & Kelso (1990)
Massachusetts				1		1		6	LMB: Carlander (1977); SMB: Carlander (1977); YEP: Carlander (1997)
Manitoba								1	YEP: Carlander (1997)
Maryland	1			1		1		1	BLG: Carlander (1977); LMB: Carlander (1977); SMB: Carlander (1977); YEP: Carlander (1997)
Maine						1			SMB: Carlander (1977)
Michigan	5			1					BLG: Carlander (1977), Price (1977), Schneider (1997); LMB: Carlander (1977)

Table 1. (Continued)

State or province	BLG	CRP	FHC	LMB	SAU	SMB	WHB	YEP	Sources
Minnesota	8	1		5	3	3		4	BLG: Carlander (1977), Shroyer *et al.* (2003), J. Meerbeek, unpublished data; CRP: Carlander (1969); LMB: Carlander (1977), Smagula & Adelman (1983), Shroyer *et al.* (2003), J. Meerbeek, unpublished data; SAU: Carlander (1997), J. Meerbeek, unpublished data; SMB: Johnson & Hale (1977), J. Meerbeek, unpublished data; YEP: Carlander (1997)
Missouri	4	4	2	8		2	1		BLG: Serns & Strawn (1975), Carlander (1977); CRP: Purkett (1958), Carlander (1969); FHC: Purkett (1958), K. Sullivan, unpublished data; LMB: Carlander (1977), Novinger (1987); SMB: Carlander (1977); WHB: Carlander (1997)
Mississippi			4	1					FHC: Insaurralde (1992), Francis (1993), Schramm & Eggleton (2006); LMB: Miranda *et al.* (1987)
Montana	1			1	1			4	BLG: Brown & Logan (1960); LMB: Brown & Logan (1960); SAU: Carlander (1997); YEP: Brown & Logan (1960), Carlander (1997)
New Brunswick						1			SMB: Carlander (1977)
North Carolina	10		4	7					BLG: Carlander (1977); FHC: Guier *et al.* (1981), Kwak *et al.* (2006); LMB: Carlander (1977)
North Dakota	1	2		1	3	2	2	10	BLG: Kreft & Power (1996); CRP: Nelson (1974), Kreft & Power (1996); LMB: Kreft & Power (1996); SAU: Carlander (1997); SMB: Kreft & Power (1996); WHB: Nelson (1974), R. Hiltner, unpublished data; YEP: Kreft & Power (1996), Carlander (1997)
Nebraska	10	1	2	10	3	3	10	10	BLG: K. Hurley, unpublished data; CRP: Hesse *et al.* (1978); FHC: Hesse *et al.* (1978), Guier *et al.* (1981); LMB: K. Hurley, unpublished data; SAU: K. Hurley, unpublished data; SMB: K. Hurley, unpublished data; WHB: Carlander (1997), K. Hurley, unpublished data; YEP: Carlander (1997), K. Hurley, unpublished data
New Mexico				1			1		LMB: Carlander (1977); WHB: Carlander (1997)
New York						2	1		SMB: Carlander (1977); WHB: Carlander (1997)
Ohio	1				8	5		2	BLG: Carlander (1977); SAU: S. Schell, unpublished data; SMB: Carlander (1977); YEP: Carlander (1997)
Oklahoma	10	9	6	10		9	10		BLG: Carlander (1977); CRP: Houser (1956), Jenkins & Finnell (1957), Carlander (1969); FHC: McCoy (1953), Jenkins & Finnell (1957), Carlander (1969), Turner (1982); LMB: Carlander (1977), J. Long, unpublished data; SMB: Carlander (1977), Orth *et al.* (1983), Gilliland *et al.* (1991), J. Long, unpublished data; WHB: Baglin & Hill (1976), Carlander (1997)
Ontario								1	YEP: Sun & Harvey (1986)
Pennsylvania	6			1		3		4	BLG: Carlander (1977); LMB: Carlander (1977); SMB: Carlander (1977), Heisey *et al.* (1980); YEP: Carlander (1997)
Quebec								4	YEP: Ridgway & Chapleau (1994)
South Carolina	1		2					1	BLG: Belk & Hales (1993); FHC: Bulak (1998); YEP: Carlander (1997)

of populations from each state or province was limited to 10, it was rare that more than 10 populations per state or province were available (only 27 of 368 species-state or province combinations). The total number of populations varied from 35 to 147 among species, and all species except flathead catfish and sauger had more

Table 1. (Continued)

State or province	BLG	CRP	FHC	LMB	SAU	SMB	WHB	YEP	Sources
South Dakota	10	4	1	10	5	10	10	10	BLG: Carlander (1977), Willis *et al.* (2001); CRP: Carlander (1969); FHC: G. Adams, unpublished data; LMB: Carlander (1977), Willis *et al.* (2001); SAU: Carlander (1997); SMB: Willis *et al.* (2001), G. Adams, unpublished data; WHB: Carlander (1997), Soupir *et al.* (1997), Willis *et al.* (1997); YEP: Nelson (1974), Willis *et al.* (2001), Brown & St. Sauver (2002)
Saskatchewan								1	YEP: Carlander (1997)
Tennessee	3	1	1	6	6	4	4		BLG: Carlander (1977); CRP: Carlander (1969); FHC: Carroll & Hall (1964); LMB: Carlander (1977); SAU: Carlander (1997); SMB: Carlander (1977), Marinac-Sanders & Coble (1981); WHB: Myhr (1971), Carlander (1997)
Texas	5		1	4		1	2		BLG: Serns & Strawn (1975), Carlander (1977); FHC: Pate (1980); LMB: Carlander (1977); SMB: Robertson & Winemiller (2001); WHB: Muoneke (1994), Carlander (1997)
Utah		2					1	2	CRP: McConnell (1952), Carlander (1969); WHB: Carlander (1997); YEP: Carlander (1997)
Virginia	1			1		5	1	1	BLG: Smith & Kauffman (1991); LMB: Carlander (1977); SMB: Carlander (1977), Austen & Orth (1988), King *et al.* (1991); WHB: Colvin (1993); YEP: Carlander (1997)
Washington	10			10		10		10	BLG: Mueller (1997a), Mueller & Downen (1999a), Downen & Mueller (2000a,b), Mueller & Downen (2000), Jackson & Caromile (2001), Osborne & Petersen (2001), Caromile & Jackson (2002a), Couto & Caromile (2006), Petersen & Osborne (2006); LMB: Mueller (1997a), Mueller & Downen (1999b), Downen & Mueller (2000b), Jackson & Caromile (2000, 2001), Caromile & Jackson (2002a), Divens & Osborne (2004, 2005), Couto & Caromile (2006), Petersen & Osborne (2006); SMB: Mueller (1997b), Downen & Mueller (2000c,d), Mueller *et al.* (2001), Caromile & Jackson (2002b), Mueller *et al.* (2002), Osborne, Divens and Baldwin (2003), Osborne, Petersen and Jackson (2003), Divens & Osborne (2004), Woller *et al.* (2004); YEP: Mueller (1997b), Downen *et al.* (1999), Mueller & Downen (1999b,c), Caromile *et al.* (2002), Downen & Mueller (2000b,d,e), Verhey & Mueller (2001), Verhey *et al.* (2001)
Wisconsin	10	4		2	1	4	1	6	BLG: Parker (1958), Carlander (1977); CRP: Carlander (1969); LMB: Parker (1958), Carlander (1977); SAU: Carlander (1997); SMB: Carlander (1977), Marinac-Sanders & Coble (1981); WHB: Priegel (1971); YEP: Carlander (1997)
West Virginia			1			1			FHC: Guier *et al.* (1981); SMB: Austen & Orth (1988)
Wyoming		1				3			CRP: Wichers (1976); SMB: Mullner & Hubert (1993)
Otoliths	9	5	3	16					
Scales	131			130	14	87	69	32	
Spines*		9	16						
Other[†]	5	27	19	1	21	7		60	
Total	145	41	38	147	35	94	69	92	

*Includes spines and fin rays.

Includes vertebrae, opercles, a combination of structures or data for which the structure was not reported.

than 40 populations represented in the analysis. Flathead catfish and sauger have a limited spatial distribution in North America compared with the other species used in this study (Lee, Gilbert, Hocutt, Jenkins, McAllister & Stauffer 1980), which likely led to the low number of populations available for this analysis. Largemouth bass and bluegill had the highest number of populations, probably because of their importance as sport fish and widespread distribution in North America (Lee *et al.* 1980). The resulting percentiles of mean back-calculated lengths at age are presented in Table 2 and growth models are provided in Table 3.

Table 2. Age, sample size (*n*), and percentile values of mean back-calculated lengths (mm) for North American populations of eight fish species

		Percentiles						
Age	*n*	5%	10%	25%	50%	75%	90%	95%
Bluegill								
1	145	29	34	39	49	64	77	81
2	145	58	61	74	94	111	124	136
3	142	88	91	105	130	146	165	179
4	137	112	119	135	152	173	193	203
5	112	127	135	151	173	191	208	223
6	70	137	145	163	185	206	221	233
Common carp								
1	41	87	95	120	132	173	236	290
2	41	175	196	231	264	338	376	429
3	39	226	249	306	348	437	505	518
4	39	279	299	356	429	495	549	635
5	39	338	338	402	488	556	577	691
6	33	368	381	431	512	605	632	648
7	32	401	419	451	556	639	658	696
8	26	409	449	470	570	655	721	724
Flathead catfish								
1	38	61	76	89	132	164	230	260
2	38	124	155	181	235	268	348	352
3	38	211	231	251	324	382	479	509
4	38	254	296	341	446	498	571	605
5	38	280	340	437	554	621	678	710
6	34	366	390	520	613	710	752	765
7	33	409	442	603	676	773	821	833
8	32	458	503	618	729	827	896	925
9	25	500	511	675	762	902	1,000	1,003
Largemouth bass								
1	147	71	78	94	114	152	177	185
2	147	134	153	179	216	264	287	312
3	144	193	210	255	286	332	361	377
4	137	238	264	310	340	388	419	445
5	131	287	305	348	385	434	462	483
6	110	332	345	385	426	474	506	523
7	95	348	377	409	452	494	533	559
8	73	376	403	442	472	511	559	582
Sauger								
1	35	122	126	143	188	229	241	252
2	35	201	241	266	311	333	373	378
3	30	266	295	341	371	396	428	442
4	22	311	325	388	424	445	464	466
5	17	315	347	406	461	485	514	517
Smallmouth bass								
1	94	68	74	82	90	99	111	118
2	94	130	140	152	165	180	212	231
3	93	167	184	214	236	259	297	332
4	91	209	221	258	290	328	358	387
5	78	239	263	297	337	379	420	437
6	63	280	294	326	376	411	432	461
7	46	281	310	356	398	427	457	473
White bass								
1	69	108	120	132	144	168	213	227
2	67	204	210	226	257	286	340	349
3	65	244	259	286	323	337	376	388
4	62	272	288	322	356	375	416	421
5	46	297	309	343	378	396	427	440
Yellow perch								
1	92	46	56	70	80	94	106	126
2	92	94	104	114	134	163	177	186
3	89	120	130	153	175	206	229	236
4	86	144	153	180	204	235	251	264
5	71	168	178	204	224	257	272	280
6	52	175	200	225	245	264	282	310

Table 3. Standard growth models for North American populations of nine fish species. For each model, age is fish age in years and L_s is the age-specific standard length in millimeters

Species	Equation	R^2	*P*-value
Bluegill	$L_s = 225.0\,[1-e^{-0.293\,(\text{age}-0.111)}]$	0.74	<0.0001
Channel catfish	$L_s = 843.6\,[1-e^{-0.096\,(\text{age}+0.669)}]$	0.97	<0.0001
Common carp	$L_s = 632.4\,[1-e^{-0.283\,(\text{age}+0.053)}]$	0.65	<0.0001
Flathead catfish	$L_s = 1{,}266.5\,[1-e^{-0.103\,(\text{age}+0.050)}]$	0.95	<0.0001
Largemouth bass	$L_s = 550.0\,[1-e^{-0.245\,(\text{age}+0.053)}]$	0.97	<0.0001
Sauger	$L_s = 477.8\,[1-e^{-0.491\,(\text{age}+0.013)}]$	0.76	<0.0001
Smallmouth bass	$L_s = 498.6\,[1-e^{-0.229\,(\text{age}-0.141)}]$	0.97	<0.0001
White bass	$L_s = 396.6\,[1-e^{-0.565\,(\text{age}-0.113)}]$	0.78	<0.0001
Yellow perch	$L_s = 280.5\,[1-e^{-0.332\,(\text{age}+0.031)}]$	0.97	<0.0001

Age estimates for the mean back-calculated length at age data used in this study were completed using a variety of hard structures. Certain structures (e.g. scales) have been shown to underestimate the age of fish, but the age at which this occurs varies among species (Marwitz & Hubert 1995; Kocovsky & Carline 2000; Isermann *et al.* 2003). These concerns were addressed by truncating the ages that were included in the analysis and compared percentiles of growth among structures to provide insight on potential biases associated with different structures. Although many have raised concerns that scales tend to overestimate growth by underestimating age (e.g. Isermann *et al.* 2003), results of the analysis indicated no major differences between structures used in this study. For example, the tenth percentile of age-8 largemouth bass growth was 400 mm using scale data. The same percentile using otoliths was 404 mm. The 50th percentile for age-6 flathead catfish growth was 613 mm using otolith data and 617 mm using spines. Similar results were observed across all species and structures used in the analysis, suggesting that structures did not have a significant influence on the growth standards. Another possible concern regarding the data used in this study involves the use of different back-calculation techniques. While the use of several back-calculation techniques (i.e. Fraser-Lee, direct proportion) may increase variation in a data set, several studies have illustrated that errors associated with different back-calculation methods are minor. For example, Pierce, Rasmussen & Leggett (1996) compared mean back-calculated lengths at age of pumpkinseed *Lepomis gibbosus* (Linneaus) and golden shiner *Notemigonus crysoleucas* (Mitchill) using three different back-calculation techniques (Fraser-Lee, one based on the scale proportion hypothesis, and one based on the body proportion hypothesis). Results of their study illustrated that growth estimates were nearly identical among techniques and similar to empirical observations of growth. Additionally, some researchers may prefer the use of mean length at age (i.e. at capture) to mean back-calculated length at age. However, such an approach has its own issues that may be more tenuous than those for back-calculated length at age. In particular, use of mean length at age would require that fish be sampled at the same time of year across North America. These data are unavailable and may cause more concern with regard to data structure and quality than back-calculated length at age.

The utility of RGI in evaluating differences in growth was illustrated by Quist *et al.* (2003) who concluded that percentiles provided a more descriptive interpretation of growth, while the RGI allowed for more refined analyses. As an example of how these standards can be used, bluegill populations in two natural lakes, West Okoboji Lake ($n = 60$ individuals) and Swan Lake, Iowa ($n = 52$ individuals; Z. Jackson, unpublished data) were examined. Mean back-calculated lengths of bluegills from West Okoboji were between the 25th and 50th percentiles at ages 1–3, indicating relatively slow growth at early ages. Growth increased at later ages where mean back-calculated lengths were between the 50th and 75th percentiles at age 4, at the 75th percentile at age 5 and between the 75th and 90th percentiles at age 6. In contrast, bluegills from Swan Lake were near the 25th percentile for all ages. The patterns are further illustrated by examining RGI values (Fig. 1). Bluegills exhibited slow growth for the first 3 years and then increased at older ages in West Okoboji Lake, whereas fish in Swan Lake were growing relatively slowly at all ages. Overall mean RGI values (i.e. across all ages) for each population were 96 in West Okoboji Lake (SD 16.0) and 86 in Swan Lake (SD 1.9). Differences in lake characteristics likely influenced differences in growth. West Okoboji Lake (1565 ha) is characterised as having good water quality (e.g. relatively low nutrients, high water clarity), whereas Swan Lake (57 ha) is characterised as having poor water quality (i.e. excessively high nutrient concentrations, low water clarity; J. Larscheid, unpublished data).

Comparing growth between lakes using standardised measures can aid in the identification of factors contributing to poor growth and help guide management actions. Jackson & Hurley (2005) stated that RGI will likely take a similar path as other indices and become commonly used in the evaluation and communication of fish growth. However, this contention is based on the premise that standards are developed and available to scientists. The standards provided in this

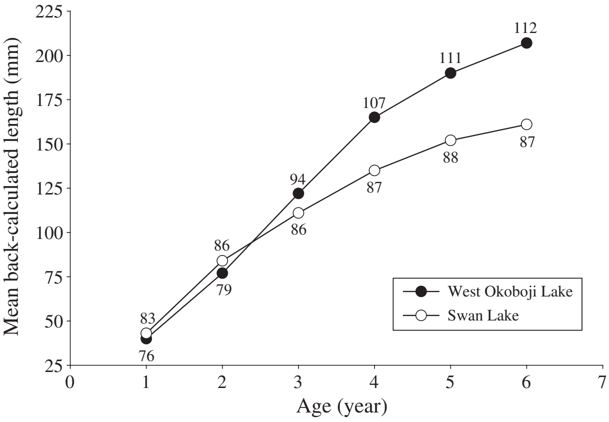

Figure 1. Mean back-calculated lengths and relative growth index (RGI; numbers near symbols) values at each age for bluegills sampled from two lakes in Iowa.

study offer fisheries scientists another tool for identifying and establishing management goals, evaluating management objectives and providing insight into environmental conditions and management activities that affect growth. Revising and updating these standards may be required in the future as more data become available, but disseminating the standards to facilitate their application and evaluation by fisheries scientists is of foremost importance.

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