



Population characteristics of channel catfish near the northern edge of their distribution: implications for management

K. P. CARTER-LYNN

Idaho Department of Fish and Game, Coeur d'Alene, ID, USA

M. C. QUIST

U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, Moscow, ID, USA

M. LITER

Idaho Department of Fish and Game, Coeur d'Alene, ID, USA

Abstract Channel catfish, *Ictalurus punctatus* (Rafinesque), populations in six lakes in northern Idaho, USA, were sampled to describe their population characteristics. During the summers of 2011 and 2012, 4864 channel catfish were sampled. Channel catfish populations had low to moderate catch rates, and length structure was dominated by fish <400 mm. Channel catfish were in good body condition. All populations were maintained by stocking age-1 or age-2 fish. Growth of fish reared in thermally enriched environments prior to stocking was fast compared to other North American channel catfish populations. After stocking, growth of channel catfish declined rapidly. Once stocked, cold water temperatures, prey resources and (or) genetic capabilities limited growth. Total annual mortality of age 2 and older channel catfish was generally <40%. Tag returns indicated that angler exploitation was low, varying from 0 to 43% among lakes. This research provides insight on factors regulating channel catfish population dynamics and highlights important considerations associated with their ecology and management.

KEY WORDS: countergradient variation, exploitation, growth, *Ictalurus punctatus*, mortality, stocking.

Introduction

Catfishes (Ictaluridae) are among the more socially and economically important groups of fishes in North America. In the United States of America, they are the second most sought group of sport fishes following centrarchids (USFWS 2006). Among North American fisheries agencies, 60% consider catfishes to be moderately or highly important to anglers in their state or province (Michaletz & Dillard 1999). Although bullheads, *Amieurus* spp., blue catfish, *Ictalurus furcatus* (Lesueur) and flathead catfish, *Pylodictus olivaris* (Rafinesque), support recreational

fisheries, most anglers target channel catfish, *I. punctatus* (Rafinesque). Channel catfish are one of the most widely distributed catfishes in North America; their native distribution extends from southern Canada to the Gulf of Mexico and from the Rocky Mountains to the Atlantic coast (Lee *et al.* 1980). Due to their popularity with anglers and ability to survive in a diversity of habitats, they have been widely introduced and have become naturalised in systems beyond their native distribution (Hubert 1999a).

Channel catfish were initially stocked into northern Idaho lakes in 1985. These introductions were aimed at reducing densities of panfishes (e.g. yellow perch, *Perca*

Correspondence: Michael C. Quist, U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive MS1141, Moscow, ID 83844, USA (e-mail: mcquist@uidaho.edu)

Present address: University of Washington – Bothell, 18115 Campus Way NE, Box 358538, Bothell, WA, 98011, USA

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flavescens [Mitchill]; *Lepomis* spp.) and to diversify angling opportunities. Since that time, the Idaho Department of Fish and Game (IDFG) has continued to stock lakes in the Idaho Panhandle to support small fisheries that have developed for channel catfish. Despite a substantial investment of resources into channel catfish fisheries by IDFG, little is known about the performance or population dynamics of channel catfish in these systems.

Like most natural resource agencies tasked with evaluating channel catfish populations, IDFG has struggled with effectively sampling channel catfish in lentic systems. In the past, IDFG has used two floating and two sinking experimental gill nets, two modified fyke nets and 1 h of current-on electric fishing as their standard survey for small (<400 ha), lowland lakes. Between 1995 and 2010, these efforts resulted in the capture of <20 channel catfish per survey. Such catches are inadequate for drawing inference or describing population demographics (e.g. Vokoun *et al.* 2001; Michaletz & Sullivan 2002). Recently, tandem hoop nets have been shown to capture large numbers of channel catfish and accurately index abundance and length structure of channel catfish populations in lentic systems (e.g. Sullivan & Gale 1999; Michaletz & Sullivan 2002; Flammang & Schultz 2007; Buckmeier & Schlechte 2009; Flammang *et al.* 2011; Neely & Dumont 2011; Porath *et al.* 2011; Richters & Pope 2011; Wallace *et al.* 2011). New techniques for evaluating channel catfish populations provide an opportunity to evaluate the population characteristics of channel catfish in systems near the northern edge of their distribution and make broad comparisons with other populations. Given the importance of channel catfish as a sport fish and the need to provide information on their population dynamics, this study was conducted to describe the relative abundance, length structure, body condition, growth and mortality of channel catfish in six lakes in northern Idaho.

Methods

Baited tandem hoop nets, similar to those described by Michaletz and Sullivan (2002), were used to sample channel catfish in six lakes in northern Idaho varying in surface area from 12 to 326 ha (Table 1). Although the fish assemblages vary among lakes, they all support fisheries for bluegill, *Lepomis macrochirus* Rafinesque, pumpkinseed, *L. gibbosus* (Linnaeus), black crappie, *Pomoxis nigromaculatus* (Lesueur), yellow perch and channel catfish. All of the lakes except Rose Lake support important fisheries for salmonids. Rainbow trout, *Oncorhynchus mykiss* (Walbaum), are stocked on an annual basis in most systems; kokanee, *O. nerka* (Walbaum), and cutthroat trout, *O. clarkii* (Richardson), are also stocked at varying frequencies in the study lakes. Cocolalla, Fernan, Hauser and Jewel lakes were sampled from 27 June to 11 August 2011. During 2012, Cocolalla, Fernan, Jewel, Rose and Smith lakes were sampled from 11 June to 19 July.

Each HNS⁻¹ consisted of three hoop nets separated by 2-m long bridles. Hoop nets were 3.4 m in length with seven, 0.91-m diameter metal hoops. Fingered crowfoot throats were attached to the second and fourth hoop. All nets were constructed of 25.4-mm bar-measure nylon mesh. Each net was baited with commercially prepared cheese logs (Boatcycle, Inc., Henderson, TX, USA) or soya bean, *Glycine max* (Linnaeus), cake (Max-Yield Cooperative, West Bend, IA, USA). Two HNS⁻¹ were set parallel to shore in the littoral zone of each lake at depths varying from 3 to 4 m. Nets were fished for 72–96 h with 1–3 sampling events conducted at each lake. Total length (mm) and weight (g) were measured from all captured channel catfish. Pectoral spines were removed for age and growth analysis following Sneed (1951) from approximately 10 fish per 10-mm length group (Quist *et al.* 2012). All channel catfish were

Table 1. Channel catfish annual stocking rate during 2007–2012, number of fish sampled, mean catch-per-unit-effort (CPUE), mean and minimum–maximum total length (mm), proportional size distribution (PSD), total annual mortality (*A*) and angler exploitation (μ) of channel catfish in six lakes in northern Idaho during 2011–2012

Lake	Surface area (ha)	Stocking rate (fish ha ⁻¹)	Number of fish	CPUE (fish HNS ⁻¹)	Total length, mm		PSD	<i>A</i>	μ
					Mean	Minimum–maximum			
Cocolalla	326	25	2615	233.5 (120.6)	325.2 (0.9)	181–555	3	32.4	3.9
Fernan	154	23	870	111.5 (37.4)	362.8 (1.5)	240–558	12	32.3	42.5
Hauser	223	23	506	22.5 (11.5)	308.4 (1.8)	206–507	2	40.1	11.7
Jewel	12	46	67	7.4 (1.9)	285.7 (6.2)	126–485	6	28.4	0.0
Rose	122	27	565	105.0 (65.1)	368.8 (1.6)	210–570	15	37.9	18.9
Smith	15	39	241	58.0 (34.9)	356.7 (2.7)	264–482	11	32.1	9.4

Total annual mortality represents mortality of age 2 and older fish. Numbers in parenthesis are 1 SE.

tagged with Carlin dangler tags to obtain estimates of angler exploitation (Michaletz *et al.* 2008).

Catch-per-unit-effort was estimated as the number of fish sampled HNS^{-1} per 72 h. Body condition of channel catfish was evaluated using relative weight (Wr ; Brown *et al.* 1995; Neumann *et al.* 2012). Relative weight was estimated as 100 times the actual weight of a fish divided by the length-specific standard weight for channel catfish (Neumann *et al.* 2012). Relative weight values >100 suggested that fish were in 'above average' body condition and Wr values <100 indicated 'below average' condition. Proportional size distribution (PSD) was used to summarise length structure of channel catfish populations and was estimated as 100 times the number of quality-length channel catfish (≥ 410 mm) divided by the number of stock-length channel catfish (≥ 280 mm; Neumann *et al.* 2012). No preferred-length channel catfish (≥ 610 mm) were sampled.

Pectoral spines were prepared following Koch and Quist (2007). Spines were sectioned at the distal end of the basal groove using a Buehler Isomet low-speed saw (Buehler, Lake Bluff, IL, USA). Spine sections were examined through a dissection microscope (7–45 \times). Two readers estimated the age of each structure and disagreements were resolved by mutual examination of questionable structures. Annulus spacing was measured with an image analysis system.

Back-calculated lengths at age were estimated using the Dahl-Lea method (Michaletz *et al.* 2009; Quist *et al.* 2012). Growth was compared to 102 populations across North America using percentiles of lengths at age provided by Hubert (1999b) and estimating the relative growth index (RGI; Jackson *et al.* 2008). Similar to Wr , the RGI was estimated as 100 times the mean back-calculated length at age divided by a standard length at age derived from populations across the species' distribution (Quist *et al.* 2012). Values above 100 indicated that growth was faster than other channel catfish populations in North America, whereas values <100 indicated slower growth. Linear regression was used to evaluate patterns in RGI values by regressing mean RGI against age for each population.

Age structure of each population was estimated using an age-length key (Quist *et al.* 2012). Total annual mortality was estimated using a weighted catch curve (Smith *et al.* 2012). Angler exploitation was estimated as the number of fish harvested by anglers (i.e. tag returns) divided by the number of fish tagged. A 53% reporting rate was assumed, which is typical of non-reward tags for non-anadromous fisheries in Idaho (Meyer *et al.* 2012). Tag loss was assumed to be 0% (Travnichek 2004; Holley 2006; Michaletz *et al.* 2011), and tagging mortality was assumed to be 3% based on work con-

ducted by Meyer *et al.* (2012). Cocolalla, Fernan and Hauser lakes were sampled in both 2011 and 2012, but major differences in catch rates, size structure or other metrics were not observed between years. Therefore, data for those lakes were summarised across years.

Results

In total, 4864 channel catfish were sampled from the study lakes. Relative abundance among lakes was highly variable; the lowest CPUE was in Jewel Lake (mean \pm SE; 7.4 ± 1.9 fish HNS^{-1}), and the highest catch rate was in Cocolalla Lake (233.5 ± 120.6 fish HNS^{-1} ; Table 1). Channel catfish mortality resulting from sampling was observed on only two occasions. Eight mortalities occurred in 2011 when a catch of 1113 channel catfish resulted in longer than normal handling time, and six mortalities occurred in 2012 when fish were captured and held at depths where oxygen concentrations were low. A variety of non-target species was caught, and their mortality was $<4\%$. Non-target species consisted mostly of bluegill, black crappie, pumpkinseed and tench, *Tinca tinca* (Linnaeus); these species composed approximately 90% of the bycatch.

The majority of channel catfish sampled were stock-to-quality length (280–410 mm); the largest channel catfish was only 570 mm (Table 1). Length structure was similar among populations, and PSDs were generally low. Fernan, Rose and Smith lakes generally had larger fish than the other lakes (i.e. higher mean length and PSD), but the differences were small. Channel catfish relative weights were typically >100 suggesting that fish were in good body condition (Fig. 1). Length-related patterns in body condition were not apparent.

Mean back-calculated length at age was estimated for 649 channel catfish across all six lakes (Table 2). Age estimates varied from 2 to 15 years. Channel catfish reached 410 mm (quality length) in 7–9 years across lakes. In general, RGI values were high at younger ages and declined with age for all populations (Table 3). Rates of decline were lowest in Cocolalla and Fernan lakes, and highest in Rose and Smith lakes. Similar to RGI values, channel catfish were generally in high percentiles of growth at age 3 (i.e. youngest age for which percentiles are available; Hubert 1999b). Growth quickly slowed to the point where fish were in the 25th or 10th percentile of channel catfish growth in North America by ages 4–7.

Total annual mortality of age 2 and older channel catfish was similar across the six populations (mean \pm SE; $33.9 \pm 1.8\%$), varying from 28% in Jewel Lake to 40% in Hauser Lake (Table 1). As of 1 July 2014, 42 tags of the 540 released tags had been reported to IDFG. Uncor-

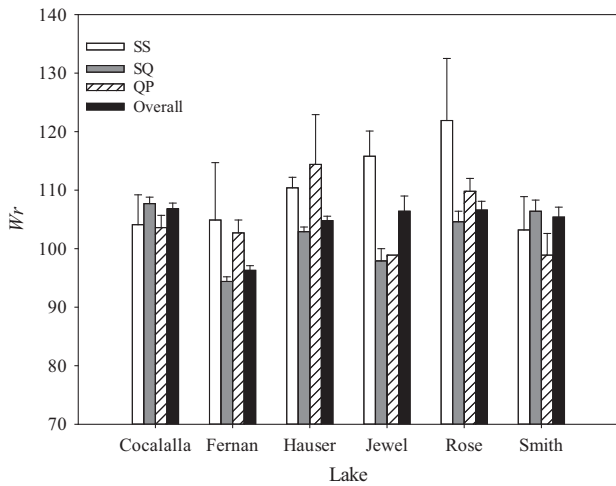


Figure 1. Mean relative weight (W_r) of channel catfish sampled from six lakes in northern Idaho during 2011–2012 by standard length category and for all fish sampled (overall). Standard length categories include substock length (SS; <280 mm), stock-to-quality length (S-Q; 280–409 mm) and quality to preferred length (Q-P; 410–609 mm). No channel catfish greater than preferred length (610 mm) were sampled. Error bars represent one standard error.

rected exploitation estimates were <10% for all lakes except Fernan Lake (21%). No tags were returned from Jewel Lake. After applying corrections for non-reporting and tagging mortality, estimates of angler exploitation were generally <15%, except for Rose (19%) and Fernan lakes (43%; Table 1).

Discussion

Historically, one of the major hindrances to management of channel catfish in lentic systems has been inadequate data resulting from an inability to effectively sample channel catfish (Michaletz & Dillard 1999). The same has been true in Idaho, where prior efforts using gill nets, modified fyke nets and electric fishing have failed to provide adequate samples of channel catfish. However, tandem hoop nets seem to be an effective technique for sampling channel catfish in Idaho lakes. With the advent of effective sampling techniques for channel catfish in lentic systems, a wealth of information has emerged on the population structure and dynamics of channel catfish from across their distribution.

One of the most important factors influencing fish population dynamics and guiding management actions is abundance. Recent research suggests that tandem hoop nets provide accurate information on the relative abundance of channel catfish populations (Michaletz & Sullivan 2002; Flammang *et al.* 2011; Wallace *et al.* 2011). Moreover, the similarity in techniques currently being used to evaluate channel catfish populations facilitates

Table 2. Mean back-calculated length at age (mm) for channel catfish sampled from six lakes in northern Idaho during 2011–2012

Lake	Number of fish	Age, years													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cocolalla	132	134.7 (6.6)	270.0 (3.9)	309.7 (3.2)	341.5 (3.2)	369.9 (3.6)	390.4 (4.5)	394.9 (11.8)	423.4 (17.0)	486.6 (a)	515.2 (a)	535.1 (a)	543.0 (a)		
Fernan	116	115.1 (6.2)	237.2 (4.7)	290.2 (3.7)	332.1 (3.5)	365.1 (3.3)	386.9 (3.8)	407.6 (4.3)	429.5 (5.3)	456.3 (8.1)	451.8 (14.9)	484.3 (2.4)	532.6 (a)		
Hauser	168	136.2 (6.0)	253.2 (4.2)	288.9 (3.4)	305.7 (4.5)	322.1 (4.8)	331.1 (8.1)	349.5 (7.8)	360.8 (8.5)	414.6 (13.1)	425.9 (18.6)	435.3 (a)	438.6 (a)	458.9 (a)	476.3 (a)
Jewel	54	174.3 (6.9)	222.3 (5.9)	238.3 (6.9)	252.4 (8.6)	280.4 (10.8)	303.3 (18.2)	354.4 (29.9)	368.1 (40.7)						
Rose	101	231.1 (4.4)	297.9 (3.7)	332.9 (3.6)	358.1 (3.8)	387.9 (5.6)	397.9 (6.6)	416.5 (11.3)	436.1 (12.8)						
Smith	78	203.9 (5.2)	273.1 (4.1)	316.3 (4.9)	346.0 (5.0)	367.3 (7.9)	393.7 (9.3)	425.7 (7.5)							

a = Not estimable. Number in parenthesis represents one SE.

Table 3. Mean relative growth index (RGI) for age-1 to age-10 channel catfish sampled from six lakes in northern Idaho during 2011–2012

Lake	Age (years)										β_1
	1	2	3	4	5	6	7	8	9	10	
Cocolalla	107.9 (5.3, a)	141.6 (2.1, a)	123.7 (1.3, 90)	112.1 (1.1, 75)	104.5 (1.0, 50)	97.9 (1.1, 50)	89.8 (2.7, 25)	88.8 (3.6, 25)	95.4 (b, 25)	95.3 (b, 25)	-4.15 (1.26)
Fernan	92.1 (4.9, a)	124.4 (2.5, a)	115.9 (1.5, 75)	108.9 (1.1, 75)	103.1 (0.9, 50)	97.0 (0.9, 50)	98.7 (0.9, 25)	90.1 (1.1, 25)	89.4 (1.5, 25)	83.6 (2.7, 10)	-2.84 (1.02)
Hauser	109.0 (4.8, a)	132.8 (2.2, a)	115.4 (1.4, 75)	100.3 (1.5, 50)	90.9 (1.4, 25)	83.0 (2.0, 10)	79.5 (1.8, 10)	75.7 (1.8, 10)	81.3 (2.6, 10)	80.6 (3.4, 10)	-5.36 (1.14)
Jewel	139.6 (5.6, a)	116.6 (3.1, a)	95.1 (2.8, 50)	82.8 (2.8, 10)	79.2 (3.1, 10)	76.0 (4.6, 5)	80.6 (6.8, 10)	77.2 (8.5, 10)			-8.02 (1.95)
Rose	184.9 (3.5, a)	156.2 (1.9, a)	132.9 (1.4, 95)	117.5 (1.2, 75)	109.6 (1.6, 75)	99.7 (1.7, 50)	94.8 (2.6, 25)	91.5 (2.7, 25)			-12.72 (1.75)
Smith	163.2 (4.2, a)	143.2 (2.2, a)	126.3 (1.9, 90)	113.5 (1.7, 75)	103.7 (2.2, 50)	98.7 (2.3, 50)	86.9 (1.7, 25)				-12.16 (1.06)

a = Percentile not available for ages less than age 3.

b = Not estimable.

Slope estimates (β_1) from a regression of RGI against age are presented as an indication of the reduction in growth with age.

For the RGI values, the first number in parenthesis represents one standard error of the mean RGI, and the second number represents the North American growth percentile (Hubert 1999b) for age-3 to age-10 channel catfish.

The number in parenthesis associated with the slope is an estimate of the standard error of the slope.

comparisons among systems. For instance, Flammang *et al.* (2011) sampled channel catfish in 29 Iowa lakes using tandem hoop nets and found that catch rates were around 100 fish per series. Michaletz and Sullivan (2002) reported catches of about 90 channel catfish HNS⁻¹ in Missouri lakes. Other studies have found catches varying from 20 to 1600 fish HNS⁻¹ (Richters & Pope 2011; Wallace *et al.* 2011). These studies all used the same general sampling gear and estimated catch rates per 72-h set. Small differences in gears (e.g. type of bait, exact diameter of hoops) might complicate comparisons, but it is interesting that catch rates in northern Idaho (approximately 72 fish HNS⁻¹) were well within the range of values reported for populations in the midwestern and southern United States.

Even though catch rates were similar to other systems, population structure and demographics of channel catfish in Idaho were quite different from what has been reported in other portions of their distribution. In general, channel catfish in northern Idaho lakes were small compared to other populations. The highest PSD observed across the study lakes was 15, and no fish >570 mm were sampled. Proportional size distribution values for channel catfish populations averaged over 50 for Iowa lakes (Flammang *et al.* 2011), over 40 for Nebraska lakes (Richters & Pope 2011) and from 35 to 66 for large Missouri River reservoirs (Bouska *et al.* 2011). Similar results have been reported for channel catfish across their native distribution (Michaletz & Sullivan 2002; Barada & Pegg 2011; Keller 2011). In addition to higher PSDs, nearly all of these studies have reported catches of preferred- (≥ 610 mm) and memorable-length (≥ 710 mm) channel catfish. Because these studies used the same gear, including mesh sizes, differences in length structure are unlikely due to gear selectivity alone. Rather, poor length structure in Idaho lakes is likely a function of slow growth.

Growth of channel catfish in northern Idaho lakes was similar to other North American populations during the first few years of life. Although channel catfish in this study had high longevity relative to other systems (Hubert 1999b; Mosher 1999), their growth rapidly declined around age 2. Idaho Department of Fish and Game purchases fingerling channel catfish from Fish Breeders of Idaho, Inc. (Hagerman, Idaho) who obtains channel catfish (fry and fingerlings) from private hatcheries in Arkansas, Missouri and Oklahoma (Leo Ray, owner, personal communication). Channel catfish are raised in geothermal water where they grow fast prior to stocking at age 1 or age 2, which explains the high RGI values and growth percentiles at early ages. Once fish were stocked, they grew little. Depending on the system, mean RGI values decreased by 3–13% per year. The

mechanisms associated with poor growth are unknown, but may be due to prey production and density-dependent interactions, cold water temperatures and short growing seasons or a genetic predisposition for slow growth.

Channel catfish populations are often regulated by density-dependent mechanisms. In Missouri lakes, the average length of channel catfish was inversely related to the stocking rate (Michaletz & Sullivan 2002). Flammang *et al.* (2011) showed that mean length, body condition and growth were inversely related to density of channel catfish in Iowa lakes. Although relationships among CPUE or stocking rate and length structure, growth and condition were not explicitly tested, no patterns were evident by examining the data. The observation that total annual mortality rates were not excessive compared to other populations (e.g. Michaletz *et al.* 2008; Bouska *et al.* 2011) and that fish were in good body condition suggests that other mechanisms are largely responsible for poor growth and length structure of channel catfish observed in the current study.

Like all fishes, growth of channel catfish is dependent on suitable water temperatures. The optimal temperature for growth of channel catfish is 30–32 °C (Kilambi *et al.* 1971; Andrews & Stickney 1972; Hubert 1999a). Growth is slow at temperatures near 20 °C (McCammon & LaFauce 1961; Andrews & Stickney 1972), and little to no growth occurs at temperatures <18 °C (Starostka & Nelson 1974; Hubert 1999a). Fredericks *et al.* (1997) evaluated water temperatures in Cocolalla Lake using a thermograph placed at a depth of 1.5 m. Water temperatures seldom exceeded 20 °C. Similar data are unavailable for the other study lakes; however, midday surface temperatures during the warmest months of the year (June to August) were as low as 15 °C and rarely exceeded 20 °C. Also, all of the study lakes, except Rose Lake, support salmonid fisheries. Even Rose Lake has a limited capacity to support salmonids, but it is purposefully managed as a warmwater fishery (Jim Fredericks, IDFG, personal communication). Not only are water temperatures not conducive for channel catfish growth, but also fish in northern Idaho experience a very short growing season (i.e. number of frost-free days). Durham *et al.* (2005) showed that growth of channel catfish in Texas reservoirs was closely related to the length of the growing season. Intermediate growing seasons (~270 frost-free days) resulted in faster growth than short or long growing seasons. The shortest growing season in their study was 187 days; lakes in the present study experience growing seasons of 120–150 frost-free days per year. One of the most northerly populations of channel catfish is in the Red River, Manitoba. Channel

catfish in the system are extremely large and provide a popular trophy fishery. Channel catfish in the Red River grow at a rate similar to or slightly slower than channel catfish at more southern latitudes (Macdonald 1990; Stewig 2006). In the lower portion of the system, growing seasons are short (<120 days), but water temperatures are often >20 °C and regularly approach 30 °C (Macdonald 1990). Not only are temperatures generally suitable for growth, but also channel catfish live for over 20 years and are thereby able to reach large sizes in the system (Macdonald 1990; Stewig 2006). In northern Idaho, the combination of cold water temperatures and short growing seasons likely results in poor growth and length structure of channel catfish.

An important concept when comparing growth of fishes across a broad spatial extent is countergradient variation in growth (Conover 1990). Growth is usually assumed to be faster at southern latitudes due to warmer temperatures, longer growing seasons and increased diversity of prey items. Such patterns have been reported for a variety of fishes (Braaten & Guy 2002; Quist *et al.* 2003; Porter *et al.* 2014); however, several studies have shown that the lengths of fish of the same age are equal to or greater in populations from higher latitudes (Isley *et al.* 1987; Conover 1990; Conover & Present 1990). These observations suggest that fish are growing faster at northern latitudes to compensate for a short growing season (i.e. countergradient growth). Rypel (2011) examined the potential for countergradient growth in five species of North American ictalurids. The author summarised data for 113 channel catfish populations located from about 30°N to 50°N. Using a measure of normalised growth (i.e. mean length at age 6 divided by the mean annual air temperature), Rypel found that growth increased significantly and predictably with latitude, thereby suggesting a strong pattern of countergradient growth for channel catfish in North America. Growth estimates calculated from normalised growth data from the study lakes in Idaho were compared to growth estimates predicted from the normalised growth–latitude relationship presented by Rypel (2011). Interestingly, normalised growth of channel catfish in Idaho lakes was 6–10% lower than predicted based on the latitude of the lakes. Although the specific mechanisms for countergradient growth are unknown, they likely have a genetic basis (Conover & Schultz 1995; Conover *et al.* 1997). For instance, countergradient growth has been shown to result from genetic variation in largemouth bass, *Micropterus salmoides* (Lacepède) (Isley *et al.* 1987); Atlantic silverside, *Menidia menidia* (Linnaeus) (Conover & Present 1990); striped bass, *Morone saxatilis* (Walbaum) (Conover *et al.* 1997); and mummichog, *Fundulus heteroclitus* (Linnaeus) (Schultz *et al.* 1996).

Rypel (2011) argued that a genetic basis was likely responsible for growth differentiation of catfishes. Because channel catfish stocked in Idaho originate from southern populations, they may never grow at a rate that provides high-quality fisheries (i.e. high length structure) in northern Idaho. As such, obtaining fish from a northern population might be an interesting option for resource managers charged with managing channel catfish near the northern edge of their distribution.

Channel catfish across North America are often stocked to support put-grow-take fisheries (Michaletz & Dillard 1999). Large fingerlings (>175 mm) are stocked because they are generally large enough to avoid predation by black basses *Micropterus* spp. and other predators, yet small enough to avoid excessive costs associated with rearing and transportation (Krummrich & Heidinger 1973; Storck & Newman 1988; Bonar *et al.* 1997; Michaletz *et al.* 2008). Nevertheless, balancing the number stocked with the size of fish is often difficult. Shaner *et al.* (1996) found that lakes in Alabama with high stocking rates had high densities of channel catfish that, in turn, had poor growth, poor length structure and low vulnerability to angler harvest. Michaletz *et al.* (2008) found that exploitation of channel catfish in Missouri lakes was unrelated to the stocking rate but closely related to the length at stocking, with large fish being more vulnerable to catch and harvest than small fish. A 425 mm channel catfish was about 40 times more likely to be caught and 55 times more likely to be harvested during the first year than a 175 mm fish. During the course of this study, length at stocking varied from about 120 to 330 mm but was generally around 250 mm. Angler exploitation was typically low in the study lakes, suggesting low effort or low susceptibility of stocked fish to catch and harvest – both of which could result from poor length structure of channel catfish populations. Put-grow-take fisheries, such as those in Idaho for channel catfish, are common when angler effort and exploitation are not excessive and when conditions provide for adequate survival and growth. In contrast, put-take fisheries are typical in systems where angler effort is high and long-term survival of stocked fish is low (Radonski & Martin 1986; Trushenski *et al.* 2010). Put-take fisheries may also be useful in systems where fish do not grow and recruit to the fishery in a reasonable amount of time, such as channel catfish at the northern extent of their distribution.

Channel catfish in northern Idaho lakes were small, in good body condition, exhibited low-moderate total annual mortality, low angler exploitation and slow growth following stocking. Growth seems to be the factor most limiting the length structure of channel catfish and their associated fisheries. Good body condition, cou-

pled with reasonable total annual mortality rates, suggests that prey production is not limiting growth. Rather, low water temperatures and a short growing season, coupled with stocking southern-origin channel catfish, likely hinder the ability of channel catfish to reach lengths preferred by anglers. Therefore, shifting management from a put-grow-take fishery to a put-take fishery or stocking channel catfish that originate from a northern population may provide for more angler opportunity and better return to the creel.

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