Elevation and Stream-Size Thresholds Affect Distributions of Native and Exotic Warmwater Fishes in Wyoming

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ABSTRACT

This study was conducted to assess the influence of elevation and stream width on the occurrence of 28 native and six exotic fish species using data collected (1954-2003) from 1,114 stream reaches in Wyoming. Medians and ranges of elevation and stream width were used to assess how elevation and stream width influenced the occurrence of individual species and to indicate which species had large and small ranges of distribution. Twenty-four species were common at elevations below 1,550 m and 31 species occurred in streams less than 20 m wide. The six exotic species had the potential to overlap all of the native species with regard to both elevation and stream width. In general, species that were collected over a wide range of elevations were also collected over a wide range of stream widths. Red shiner (*Cyprinella lutrensis*) and river carpsucker (*Carpiodes carpio*) occurred over the smallest elevation ranges (< 250 m), whereas longnose sucker (*Catostomus catostomus*) was sampled over the greatest elevation ranges (> 2,500 m). Longnose sucker and white sucker (*Catostomus commersoni*) occurred over the greatest ranges in stream widths (> 90 m), and brook stickleback (*Culaea inconstans*), black bullhead (*Ameiurus melas*), and quillback (*Carpiodes cyprinus*) were found over the lowest ranges in stream widths (< 12 m). The distributions of native and exotic species in streams that transition from the Rocky Mountains to the Great Plains were largely explained by elevation and stream width.

INTRODUCTION

Ecological boundaries have become an important focus of recent research (Cadenasso et al. 2003, Strayer et al. 2003). Ecological boundaries occur where gradients in physical habitat affect ecosystem processes and they exist across a broad range of systems that vary from microscopic to global scales (Belnap et al. 2003, Cadenasso et al. 2003). Much research on ecological boundaries has focused on physical habitat boundaries in terrestrial systems, especially within the discipline of landscape ecology (e.g., Turner et al. 2001), but the same concepts can be applied to aquatic habitats because ecological boundaries reflect distributional patterns of organisms regardless of the system. Knowledge of ecological boundaries provides important insight as to the factors controlling the distribution of species.

Factors influencing the distribution of fishes have been the focus of numerous basic and applied studies (Tonn 1990, Matthews 1998). At local scales, the occurrence

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and abundance of individual fish species are influenced by habitat conditions and biotic interactions that act on small spatial and temporal scales (Williams et al. 1996, Matthews 1998), but before local factors can operate, large-scale processes affect the occurrence of a species. For example, local habitat features influence the occurrence and abundance of salmonids in streams (e.g., Binns and Remmick 1994); however, the elevation or latitude of a stream reach determines whether there is even a potential for salmonid species to occur due to their low tolerance for warm water temperatures (e.g., Wagner et al. 1997). Although zoogeographic events have an overriding influence on the occurrence of fishes (Cross et al. 1986), elevation and stream size are considered to be important factors influencing their large-scale distribution (Bozek and Hubert 1992, Nelson et al. 1992).

Several studies have investigated the role of elevation and stream size on the distributional patterns of fishes, but nearly all have focused on salmonids (e.g., Gard and Flittner 1974, Kozel and Hubert 1989, Bozek and Hubert 1992, Kruse et al. 1997, Stichert et al. 2001). Salmonids, however, often constitute only a small proportion of the fish fauna within a watershed. For example, approximately 20 species of fish are thought to be native to the Bighorn River basin of Wyoming, only one of which is a salmonid (cutthroat trout [*Oncorhynchus clarki*]; Baxter and Stone 1995). In other systems, such as the North Platte River drainage, Wyoming, no salmonids were native, but there were nearly 30 native species. Thus, understanding how elevation and stream size influence the distribution of warmwater fishes is important, but few studies have investigated factors governing distribution patterns of native and exotic fishes characteristic of warmwater stream systems. One reason for this paucity of research, particularly with regard to elevation, is because few areas have habitat gradients like those observed in systems that transition from the Rocky Mountains to the Great Plains.

Due to the lack of information on factors influencing the large-scale distribution of fish species native to the Great Plains, this study was conducted to assess the distributional patterns of fishes in systems along the Rocky Mountain-Great Plains interface. Specifically, we described elevation and stream-width thresholds (i.e., ecological boundaries) and ranges for 28 native and six exotic fishes in lotic systems of Wyoming.

METHODS

We compiled data on the occurrence of fishes, elevation (m above mean sea level), and mean wetted stream width (m) from 1,114 stream reaches sampled throughout Wyoming during 1954-2003. Most data were collected by personnel from the University of Wyoming or the Wyoming Game and Fish Department; however, some data from federal agencies (e.g., U.S. Fish and Wildlife Service) were also used. Although streams were sampled throughout Wyoming, we focused on fishes that were either endemic to the Missouri River drainage or had been introduced (Table 1). All of the species can be considered warmwater species due to their presence in streams with summer water temperatures greater than 20°C (Winger 1981). Species that were collected from less than 10 reaches were excluded from the analysis.

Ecological boundaries were identified by calculating median, percentile, maximum, and minimum values of elevation and stream width for reaches where each species was collected. Elevation and stream-width ranges (i.e., maximum minus minimum values) were also calculated for each species. Spearman's rank correlation was used to examine the relationship between elevation and stream width using both median values and ranges. All analyses were conducted using Statistical Analysis Software (SAS Institute 1996) and $\alpha = 0.05$.

Table 1. Common names, scientific names, and abbreviations of 34 fish species used to examine elevation and stream width boundaries in Wyoming. Origin represents whether the species is native (N) or exotic (E).

Common name	Scientific name	Abbreviation	Origin
Hiodontidae			
Goldeye	*Hiodon alosoides*	GDE	N
Cyprinidae			
Central stoneroller	*Campostoma anomalum*	STR	N
Lake chub	*Couesius plumbeus*	LKC	N
Red shiner	*Cyprinella lutrensis*	RDS	N
Common carp	*Cyprinus carpio*	CRP	E
Brassy minnow	*Hybognathus hankinsoni*	BMN	N
Plains minnow	*Hybognathus placitus*	PMN	N
Common shiner	*Luxilus cornutus*	CSH	N
Bigmouth shiner	*Notropis dorsalis*	BMS	N
Sand shiner	*Notropis stramineus*	SDS	N
Fathead minnow	*Pimephales notatus*	FHM	N
Flathead chub	*Platygobio gracilis*	FHC	N
Longnose dace	*Rhinichthys cataractae*	LND	N
Creek chub	*Semotilus atromaculatus*	CKC	N
Catostomidae			
River carpsucker	*Carpiodes carpio*	RCS	N
Quillback	*Carpiodes cyprinus*	QBK	N
Longnose sucker	*Catostomus catostomus*	LNS	N
White sucker	*Catostomus commersoni*	WHS	N
Mountain sucker	*Catostomus platyrhynchus*	MTS	N
Shorthead redhorse	*Moxostoma macrolepidotum*	SRH	N
Ictaluridae			
Black bullhead	*Ameiurus melas*	BBH	N
Channel catfish	*Ictalurus punctatus*	CCF	N
Stonecat	*Noturus flavus*	STC	N
Gadidae			
Burbot	*Lota lota*	BBT	N
Fundulidae			
Plains topminnow	*Fundulus sciadicus*	PTM	N
Plains killifish	*Fundulus zebrinus*	PKF	N
Gasterosteidae			
Brook stickleback	*Culaea inconstans*	BSB	E
Centrarchidae			
Rock bass	*Ambloplites rupestris*	RKB	E
Green sunfish	*Lepomis cyanellus*	GSF	E
Smallmouth bass	*Micropterus salmoides*	SMB	E
Percidae			
Iowa darter	*Etheostoma exile*	IDT	N
Johnny darter	*Etheostoma nigrum*	JDT	N
Sauger	*Sander canadensis*	SAR	N
Walleye	*Sander vitreus*	WAE	E

RESULTS

Several species were restricted to low (< 1,400 m) elevations (e.g., rock bass, river carpsucker, goldeye, flathead chub), while others were more common at higher (> 1,800 m) elevations (Fig. 1). Twenty-four species were most common at elevations below 1,550 m, and eight were most common at elevations between 1,550 and 2,000 m. Mountain sucker and brook stickleback were most frequently sampled above 2,000 m. Cumulatively, minimum and maximum elevations for the six exotic species (i.e., rock bass, smallmouth bass, walleye, green sunfish, common carp, and brook stickleback) overlapped with median elevations for all native species.

Median stream widths where individual species occurred were highly variable among species (Fig. 1). Many species (e.g., plains topminnow, brook stickleback, black bullhead) were only sampled in small streams, whereas other species (e.g., smallmouth bass, sauger, walleye) were most common in large river systems. Based on median values, 31 species were most often sampled in streams less than 20-m wide. Median stream width for smallmouth bass was 21 m, and 45 m or greater for sauger and walleye. Similar to elevation, minimum and maximum stream widths for exotic species overlapped median stream widths for all native species.

The ranges (i.e., maximum minus minimum value) in elevation and stream width differed among species (Fig. 2). Red shiner and river carpsucker occurred over the smallest ranges in elevation, whereas mountain sucker and longnose sucker were sampled over the greatest ranges in elevation. Ten species had elevation ranges less than 600 m, and six species had ranges greater than 1,500 m. Most (i.e., 18 species) species had

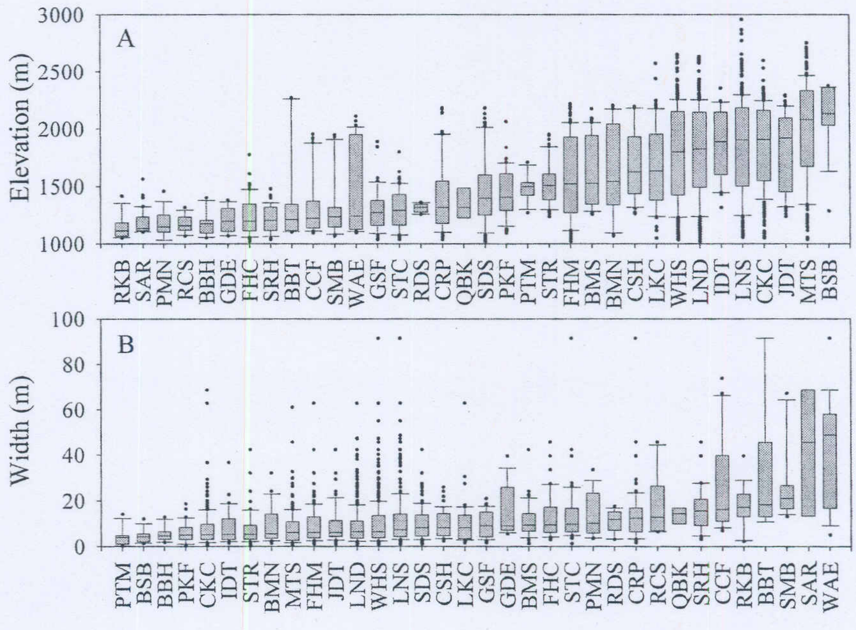

Figure 1. Box plots of (A) elevation (m above mean sea level) and (B) stream width for fish species sampled from 1,114 stream reaches in Wyoming. The top of the box is the 75th percentile, the horizontal line within the box is the median, and the bottom of the box is the 25th percentile. Solid circles represent data points that are beyond the 10th and 90th percentiles (indicated by the horizontal bars). Species abbreviations are provided in Table 1.

elevational ranges of 700 to 1,500 m. Ranges in stream width were lowest for brook stickleback, black bullhead, and quillback, and highest for common carp, stonecat, longnose sucker, and white sucker. Eight species occurred over width ranges less than 30 m, 12 species had ranges of 30 to 50 m, seven species had ranges of 50 to 70 m, and seven species were sampled over width ranges greater than 80 m.

The interaction between elevation and stream width illustrated interesting patterns related to the distribution of each species (Fig. 3). Several species (e.g., brook stickleback, mountain sucker, creek chub, Iowa darter, johnny darter, longnose sucker, white sucker) were most often sampled from high-elevation streams (i.e., $\geq$ 1,800 m) with channels less than 10-m wide. At elevations between 1,400 and 1,700 m, several species were common including lake chub, common shiner, plains topminnow, brassy minnow, and central stoneroller. Similar to species most common at high elevations, those most frequently sampled at intermediate elevations (i.e., 1,400-1,700 m) were only common in stream less than 10-m wide. At low elevations (i.e., < 1,400 m), some species were most often sampled in small streams (e.g., black bullhead); whereas, other species were most common in larger streams and rivers (e.g., river carpsucker, quillback, channel catfish, smallmouth bass, sauger, walleye). An interesting pattern was also observed with regard to the ranges of species, where the ranges in elevation were positively correlated (r = 0.52, P = 0.001) with the ranges in stream width among species (Fig. 4). Therefore, species sampled over a wide range of elevations were generally sampled over a wide range of stream widths.

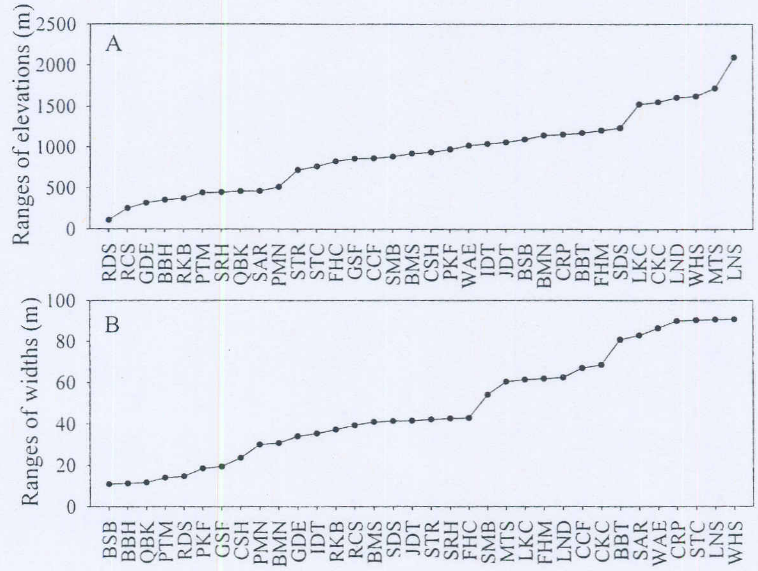

Figure 2. Range (maximum minus minimum) in (A) elevation (m above mean seal level) and (B) stream width (m) for fish species sampled from 1,114 stream reaches in Wyoming. Species abbreviations are provided in Table 1.

DISCUSSION

The specific mechanisms regarding the influence of elevation and stream size on fishes are generally understood. Elevation accounts for climatic variation and provides a surrogate measure of thermal conditions (Bozek and Hubert 1992, Isaak and Hubert

2001). Because fishes are poikilothermic and nearly every aspect of their ecology is related to temperature (e.g., spawning, growth), it is not surprising that elevation is a dominant factor influencing their large-scale distributions (Gard and Flittner 1974, Kozel and Hubert 1989, Bozek and Hubert 1992). Stream width is a measure of stream size, but it also reflects climatic conditions, location in the watershed, and discharge (Bozek and Hubert 1992, Allan 1995). For instance, large streams tend to occur at lower elevations, and have lower gradients, higher discharge, and warmer water temperatures.

Fish assemblages vary longitudinally within a stream system and can occur in discrete zones (Echelle and Schnell 1976, Rahel and Hubert 1991, Edds 1993). However, in most stream systems zonation is gradual with modest additions of species at increased distances downstream (Rahel and Hubert 1991, Matthews 1998). In montane regions, both zonation and addition may be observed. Rahel and Hubert (1991) showed that a combination of large-scale zonation (i.e., salmonids versus warmwater species) and addition of species within zones best described longitudinal patterns of fish assemblage structure in a Wyoming stream. Although our study did not focus on a single stream system, patterns in the distribution of species along elevation and stream-width gradients were apparent. The species examined in this study would be classified as warmwater species (Winger 1981); therefore, most longitudinal patterns would be attributed to species additions within the warmwater zone.

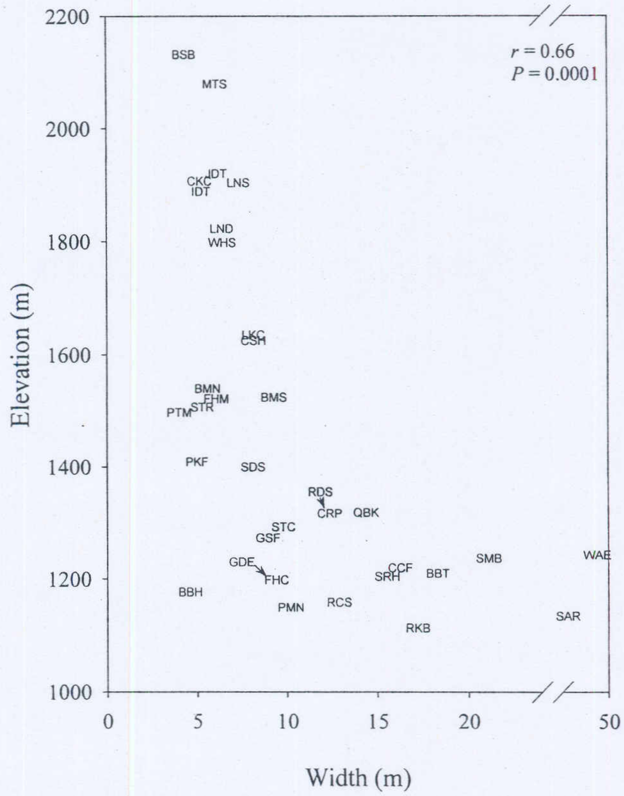

Figure 3. Relationship between median elevation (m above mean sea level) and median stream width (m) for fish species sampled from 1,114 stream reaches in Wyoming. The axis break occurs between stream widths of 25 to 45 m. Species abbreviations are provided in Table 1.

Based on our analysis, the six exotic species collectively have the potential to overlap with every native species examined. Although local habitat conditions will determine whether an exotic species is able to persist, this information may allow managers to predict the potential influence of exotic species on native fishes and it provides insight as to how exotic species may spread when introduced into a new stream system. From a different perspective, many of the exotic species (e.g., walleye, smallmouth bass) are actively managed to provide recreational angling opportunities and the observed distributional patterns can help managers establish realistic expectations regarding the establishment of sport fisheries. For example, smallmouth bass was most common at elevations of about 1,200 m and was not found above 2,000 m. Consequently, establishing a smallmouth bass fishery above 2,000 m is unrealistic and those populations between 1,200 and 2,000 m will likely result in marginal fisheries along the Rocky Mountain-Great Plains interface in Wyoming (Patton and Hubert 1996).

The species examined in our study exhibited thresholds for elevation and stream width. There were several similarities and differences in their ecology relative to other portions of their distribution. Some species, such as mountain sucker, longnose sucker, and longnose dace are typically distributed at high elevations or latitudes (Lee et al. 1980). We found similar results for these species in Wyoming. Because the core distributions of most species examined in this study are in the midwestern U.S. (Lee et al. 1980, Cross and Collins 1995), we might expect those species to be most common at the

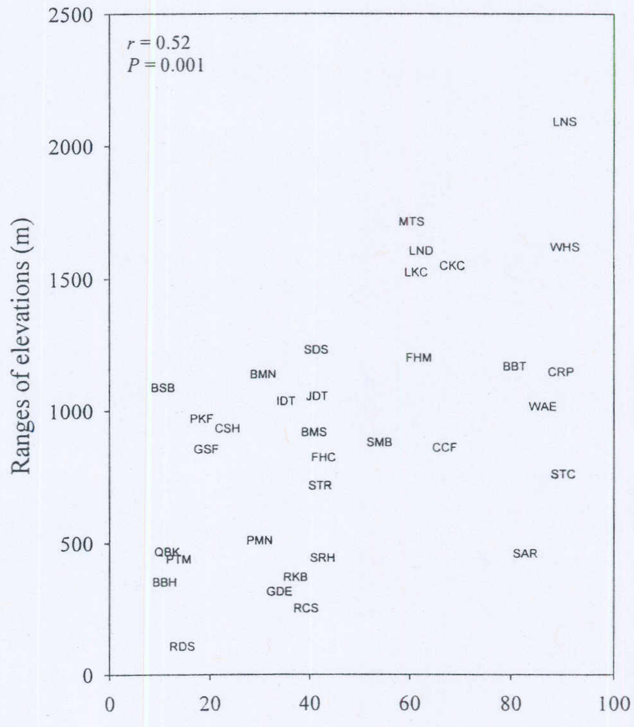

Figure 4. Relationship between the range (maximum minus minimum) in elevation (m above mean sea level) and range in stream width (m) for fish species sampled from 1,114 stream reaches in Wyoming. Species abbreviations are provided in Table 1.

lowest elevations and only have an upper elevational threshold. However, this was not observed, suggesting that the lack of some species from reaches at low elevations reflects an interaction with stream size. For example, creek chub was most common in mid- to high-elevation reaches in Wyoming, but it is common in streams at much lower elevations throughout the Great Plains (Lee et al. 1980). Most rivers and streams at lower elevations in Wyoming are turbid and dynamic with regard to flows and physical habitat (e.g., substrate; Baxter and Stone 1995). Thus, habitat in low-elevation streams and rivers is not suitable for creek chub and similar species such as common shiner, central stoneroller, and lake chub (Baxter and Stone 1995, Cross and Collins 1995). Rather, these species were most common in transitional areas (i.e., foothills) where streams are smaller and more stable. Similar results were reported by Probst (1982) in Rocky Mountain-Great Plains streams of Colorado where many Great Plains species (e.g., creek chub, common shiner) were distributed in streams that were transitional between high-elevation, mountain streams and low-elevation, turbid prairie rivers.

Many species were collected over a wide range of elevations and stream widths. Species native to the Great Plains are often considered generalist or tolerant species due to the dynamic, harsh environmental conditions characteristic of the Great Plains region (Fausch and Bestgen 1997). Although the species examined in this study may be considered generalists as a group, some species were much less tolerant than others. Elevation and stream-width ranges of the sampled species were correlated and may reflect a relationship between elevation and stream width of stream reaches. However, the relationship was not very strong because some species had high ranges on one axis and intermediate or low ranges on the other axis. For instance, sauger, stonecat, walleye, channel catfish, common carp, and burbot were found across wide ranges of stream widths, but they were found over elevation ranges of only 500 to 1,200 m. In contrast, longnose sucker, white sucker, mountain sucker, longnose dace, lake chub, and creek chub were collected across similar ranges of stream widths, but all had elevation ranges greater than 1,500 m. Brook stickleback, plains killifish, common shiner, and green sunfish were all sampled from narrow ranges of stream widths and had elevation ranges of about 1,000 m; whereas, red shiner, black bullhead, plains topminnow, and quillback were species with low ranges for both elevation and stream width.

The declining status of fishes throughout North America, and especially in the western U.S. (Richter et al. 1997), illustrates the need for managers to not only conserve those species that are rare, but to identify species that may become rare in the future. Nearly all of the species in need of conservation in Wyoming, such as suckermouth minnow (*Phenacobius mirabilis*) and sturgeon chub (*Macrhybopsis gelida*), were not included in our analysis because they were present in less than 10 of the sampled reaches. Additionally, their ranges were extremely low for elevation (< 200 m) and stream width (< 10 m), suggesting that ranges may be used to identify changes in the status of species (e.g., a wide range reduced to a narrow range) or to identify those species that might become rare in the future. Species such as longnose sucker, white sucker, longnose dace, and fathead minnow had high ranges for elevation and stream width and are ubiquitous in Wyoming. Thus, it is unlikely that these generalist species will become rare in Wyoming. In contrast, red shiner, plains topminnow, black bullhead, and quillback had relatively small ranges in Wyoming, and due to narrow tolerances of elevation and stream width, these species may be become rare in the future.

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