Fishes of the Yellowstone to Yukon Region

YELLOWSTONE TO YUKON
CONSERVATION INITIATIVE

Technical Report #3
December 2007

By: David W. Mayhood

YELLOWSTONE TO YUKON
CONSERVATION INITIATIVE

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and
Yellowstone to Yukon Conservation Initiative

Cover photograph by Florian Schulz
Cutthrout (*Oncorhynchus clarki*);
A native fish species in the Y2Y region

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Preface

The Yellowstone to Yukon Conservation Initiative's (Y2YCI) goal is to restore and maintain biological diversity and landscape connectivity in the Cordilleran region of western North America. The region's diverse fish fauna is a key component of this biodiversity. Maintaining the distribution of native fish populations is a critical issue in regional conservation and management.

To provide a basis for addressing fish conservation in the Yellowstone to Yukon (Y2Y) region, historical and current lists of fish species occurrences were compiled for the 297 sub-basins comprising the Y2Y region. A cluster analysis was used on the presence-absence data to identify four natural faunal groups. These groups were explicable on the basis of their long geographic isolation and glacial-postglacial history, consistent with existing published zoogeographic analyses. The Arctic Interior Glaciated faunal group (Group 1) occupies the basins glaciated during the Wisconsinan glacial episode, and lies in Arctic drainages mostly east of the Continental Divide or within the Yukon River drainage (with one exception being the upper Stikine drainage). This group is derived primarily from the post-Wisconsinan invasion from refugia south and northwest of the Laurentide ice sheet. The Pacific Glaciated faunal group (Group 2) occupies four watersheds and watershed groups on the North Pacific coast west of the Continental Divide and south of the Yukon drainage. This faunal group has few species, most of which invaded post-glacially via the Pacific Ocean. The Pacific Columbia Refugium faunal group (Group 3) occupies most of the basins in the Y2Y region west of the Continental Divide. Most of this fauna survived the Wisconsinan maximum near or within this region south of the Cordilleran Ice Sheet, invading its northern glaciated basins post-glacially via interior routes and from the Pacific Ocean. The Interior Unglaciated faunal group (Group 4) occupies basins both west and east of the Continental Divide, and south of the Cordilleran and Laurentide Ice Sheets. Most of its fauna survived the Wisconsinan maximum more or less in place. At present, this entire region and the southern basins of the Pacific Columbia faunal group are occupied by a distinct artificial faunal group (Group 5) characterized by numerous widespread transplanted and non-native species, especially salmonids and centrarchids. Similarity analysis of historical and present faunal composition demonstrates increased homogenization of fish faunas within faunal Group 5, but greater dissimilarity among faunas within Group 3 as a result of fish introductions and extirpations. Within Group 1, some pairs of basins became more similar, while others became less similar after fish introductions and extirpations.

The greatest opportunities for protection of intact, largely uncontaminated fish faunas lie in the drainages of Group 2 and the most northerly drainages of Group 1. The greatest conservation need and immediate challenges, however, occur in the drainages of Group 5 in the southern one- third of the study area, where faunal composition, catchments, hydrology and water quality are highly modified. Specific recommendations are presented for dealing with data limitations, and for planning fish conservation activities by Y2YCI.

Acknowledgments

Rich Walker prepared the initial fish distribution table for the United States portion of the study area, which formed the basis for the updated version used in this paper. Rob Ament contributed to an earlier analysis, the data for which was used here, dealing with selected species only. Bill Haskins provided geographic information system (GIS) support, and the sub-basin base map for the study area. Marcy Mahr managed the project for the Yellowstone to Yukon Conservation Initiative. Numerous colleagues supplied data on fish distribution from their own field work and observations over a period of many years; others went out of their way to supply hard-to-obtain manuscript reports and file data. In this respect I am particularly indebted to R. S. Anderson, A. Colbeck, D. Donald, L. Fitch, S. Herman, K. Brewin, G. Haas, C. Hunt, T. Hurd, J. Kilistoff, M. Kraft, P. McCart, C. Pacas, J. Paczkowski, M. Pole, D. Radford, J. Rennels, L. Rhude, J. Stelfox, C. Ward, W. Westover, and D. Wig. Cynthia Lane, Nancy Ouimet, and Joanne Kadi of the Yellowstone to Yukon Conservation Initiative provided editorial assistance. The study as organized here was funded by the Wilburforce Foundation through a grant to the Yellowstone to Yukon Conservation Initiative; however, data used in the project were compiled over many years, primarily while the author was funded by Parks Canada.

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Introduction

The Yellowstone to Yukon Conservation Initiative (Y2YCI) is a bi-national effort to restore and maintain biological diversity and landscape connectivity throughout the Cordilleran region of western North America, from the Greater Yellowstone Ecosystem in Wyoming (Keiter and Boyce 1991) to the Peel Watershed in the Yukon (Willcox 1998). As one means of protecting and preserving the region's biodiversity, Y2YCI conducts scientific research to identify priority areas for large carnivore, bird and fish conservation. This report summarizes the results of one component of Y2YCI's aquatic research.

The background and limits of this effort were defined by the Atlas Project (Robinson and Sawyer 1997, Willcox et al. 1998). In that document, the problems and current status of selected elements of the region's aquatic ecosystems were briefly described (Schindler 1998, Mayhood et al. 1998). Partly in response to concerns identified in these short reviews, a workshop was held at Flathead Lake Biological Station in August 1999 to develop a strategy for aquatic conservation in the Yellowstone to Yukon region (Mahr 1999). Two recommendations arising from the workshop were to:

1. Map aquatic diversity areas for the entire Y2Y region; and,

2. Map fish species distribution for the entire Y2Y region (Mahr 1999).

Aquatic diversity areas and basin conservation planning analyses have since been completed for the Missouri and Columbia basins in Montana (Hitt and Broberg 2002, Oechsli and Frissell 2002, 2003). It is the purpose of this report to address item (2), above. Specifically, the objectives of this study are to:

1. Identify the status of fish species (present, absent, introduced, extirpated/extinct) in each sub-basin in the Y2Y region; and,

2. Compare the past (natural) and present distribution of fish species for each of the 23 major drainage basins in the Y2Y region.

Study Area

The study area is comprised of the 297 sub-basins in 23 major drainage basins of the Y2Y region (Figure 1). Some smaller basins have been consolidated since an earlier study (Mayhood et al. 1998), which used 340 sub-basins, but the overall study area boundaries remain the same. These major basins drain from the Continental Divide north, south, east and west ultimately to the Bering Sea, Pacific Ocean, Gulf of Mexico, Hudson Bay and the Beaufort Sea.

The principal physical, biological and economic characteristics of the Y2Y region and the major conservation issues within it have been described in the Y2Y Atlas (Willcox et al. 1998). The boundaries for this project differ in the north part of the study area from the Y2Y area as usually delineated (Willcox et al. 1998). As few data are available on fish in the Mackenzie Mountains of the Northwest Territories, that region was not included in this study.

Mountain Whitefish (*Prosopium williamsoni*)
Photo: © Jeremy Monroe

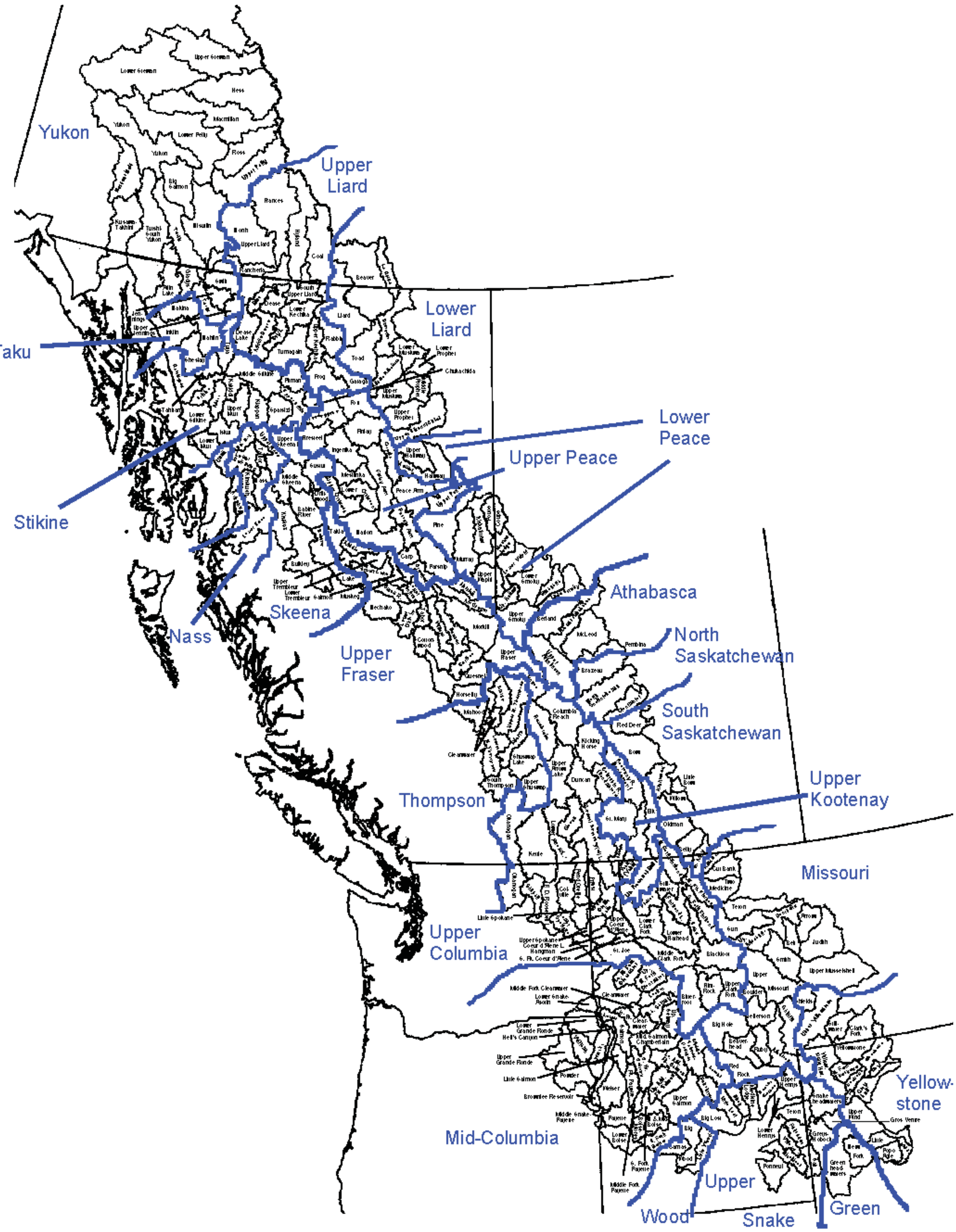


Figure 1. The 23 major drainage basins and 297 sub-basins of the Yellowstone to Yukon study region.

Methods

Historical and present fish-distribution data were interpreted principally from the sources documented below, which are listed in chronological order by major drainage basins or major basin groups. In most cases, the published interpretations of experts in watershed fishes were relied upon to identify native and introduced stocks. References to selected historical documents for particular drainages were included where they were found to be useful for interpreting native stocks. Other references dealing with specific questions of distribution are cited individually in the text.

General Study Area

The following sources were used for all major drainages, or in the case of the single-species reviews, for all drainages in which the relevant taxa are found:
Behnke (1992), Cavender (1978), Crossman (1978), Groot and Margolis (1991), Haas and McPhail (1991), Hocutt and Wiley (1986), Lee et al. (1980), McCart (1970), Miller et al. (1989), Nelson (1968), Scott and Crossman (1973), Slaney et al. (1996), and Williams et al. (1989).

Yukon Drainage

Helpful online databases exist for commercially important and sportfish species (British Columbia Fish Wizard 2004, Fisheries Information Summary System (FISS) British Columbia 2003, FISS Yukon 2003), but these are less reliable for noncommercial and non-sportfish species. Other sources used were Carl et al. (1959), McPhail and Lindsey (1970), Lindsey and McPhail (1986), and McPhail and Carveth (1993).

North Coast Drainages

Online databases (British Columbia Fish Wizard 2003, British Columbia FISS 2003) were the principal source of species occurrence and distribution data. Other sources used were Carl et al. (1959), McCart et al. (1980), McPhail and Lindsey (1986), Lindsey and McPhail (1986), and McPhail and Carveth (1993).

Thompson and Fraser River Drainages

The British Columbia Fish Wizard Database 2003 and the British Columbia FISS database 2003 were the principal source of fish-distribution information on sub-basins in these watersheds. These sources were supplemented with data and interpretations from Dymond (1932), Carl et al. (1959), McPhail and Lindsey (1986), and McPhail and Carveth (1993).

Several regularly updated online databases were relied on (British Columbia Fish Wizard 2003, British Columbia FISS 2003, MFISH 2003, United States Geological Survey (USGS) 2003), as was the most recent version of the Interior Columbia Basin Ecosystem Management Project fish databases (ICBEMP 2000) for fish-distribution data in the Columbia sub-basins. This information was supplemented with data and interpretations from Carl et al. (1959), Brown (1971), Ward (1974), Mudry and Anderson (1975), Simpson and Wallace (1982), Alger and Donald (1984), Donald and Alger (1984), McPhail and Lindsey (1986), Donald (1987), Nehlsen et al. (1991), McPhail and Carveth (1993), Mayhood (1995), Fuller et al. (1999), IFG (2003), and Wydoski and Whitney (2003).

Green River Drainage

The principle source of data for fish distribution in the Green River drainage within the Y2Y region came from Miller et al. (1982), especially Tyus et al. (1982), Holden (1991), Minckley et al. (1991), Baxter and Stone (1995), Fuller et al. (1999) and the USGS Nonindigenous Fishes database (USGS 2003).

Missouri River Drainages

The principal sources of data for Missouri drainages were MFISH (2003), Baxter and Stone (1995), Fuller et al. (1999), and USGS (2003). Henderson and Peter (1969), Paetz and Nelson (1970), Brown (1971), Clayton and Ash (1980), Cross et al. (1986), and Nelson and Paetz (1992) provided supplementary information.

Saskatchewan River Drainages

Alberta does not maintain a publicly accessible online database of fish-distribution data, so field office files of Alberta Fish and Wildlife were searched in Blairmore, Calgary and Rocky Mountain House between 1992 and 2003. For the southern portion of this region, stream and fish surveys conducted by Fitch (1978-1980), Radford (1975-1977), and Donald and Anderson (1976) were especially useful. Summaries for parts of the South Saskatchewan basin in the study area have been reported previously (Mayhood 1995, Mayhood et al. 1997). Another compilation summarizing much unpublished data for the Castle, Pincher Creek and St. Mary River basins within Y2Y (Mayhood, in preparation) was the source for most fish-distribution data in these basins. Additional valuable sources were the Canadian Department of the Interior (1879 to 1918), McIllrie and White-Fraser (1983, re: 1890), Sisley (1911), Prince et al. (1912), Department of Fisheries (1914-1937), Miller and Macdonald (1950), Miller and Paetz (1953), Henderson and Peter (1969), Paetz and Nelson (1970), Ward (1974), Crossman and McAllister (1986), Donald (1987), Gibbard and Sheppard (1992), Nelson and Paetz (1992), Donald and Alger (1993), and Sheppard et al. (2002).

Mackenzie River Drainages

As noted previously, Alberta does not maintain a publicly accessible online database of fish-distribution data. To determine distributions for the Mackenzie drainages, stream and lake files were searched in the office of Alberta Fish and Wildlife in Edson, Alberta. Similarly, there is no online database for the Liard basin within the Yukon Territory. Within British Columbia, Fish Wizard (2003) and the federal Department of Fisheries and Oceans' FISS (2003) were of some use, although fish data appeared to be incomplete for this region. Other important sources of distribution data were Canadian Department of the Interior (1879 to 1918), Sisley (1911), Prince et al. (1912), McPhail and Lindsey (1970), Lindsey and McPhail (1986), and Mayhood (1992). The Northern River Basin Study documents were also a valuable source, notably reports by Barton et al. (1993a, 1993b) and Boag (1993).

Data Limitations

The most serious limitation of fish-distribution data is the paucity of records for many sub-basins. In some cases no sampling has been done, while in other cases sampling has been completed but the data are not publicly available. The problem is most serious for the Liard basin within the Yukon Territory, where there are almost no published data. Fish-distribution data are also sparse, or at least hard to obtain, in the Mackenzie drainages in British Columbia, all Alberta drainages, and drainages in Wyoming. At the sub-basin scale, fish-distribution data are also much rarer for non-sportfish and non-commercial species than for sportfish and commercially important species. Nevertheless, the datasets are probably complete, or very nearly so, at the major-basin scale used in this analysis.

Another issue, especially among the salmonids, is that it has been impossible to distinguish native stocks from non-native stocks introduced within the native range. Such introductions have been almost ubiquitous in many major basins. The matter is an important one, because introduced stocks typically have different, genetically determined behavioural and ecological properties from the native stocks, and can interbreed with the native stocks. Distinguishing native from non-native and interbred stocks can properly be resolved only through detailed genetic studies, which have not yet been done in most basins.

Erroneous identifications appear to be another problem. Many highly unlikely occurrences were found in the online databases for British Columbia (which are still being proofed), especially among the Cyprinidae, Cottidae, and Catostomidae families. Errors were also found among other families, as well as in sub-basins throughout the study area. Perhaps the most reliable dataset was for the Columbia drainages in the United States. Great pains seem to have been taken with this set to verify distribution data (Thurow et al. 1997, ICBEMP 2000). Most records considered questionable were rated so because they were unconfirmed occurrences outside-of the known range as documented by reliable means such as, photographs or preserved specimens. Questionable records were noted as such during data collection, but were excluded from the analysis.

A particular challenge in British Columbia, and to some extent in the Yukon, is that biologists have not consistently distinguished between bull trout and Dolly Varden. These species are both widely distributed in British Columbia, closely resemble each other, and broadly overlap in certain major drainages. Until recently, many biologists considered bull trout and Dolly Varden to be a single species, recording all such char as Dolly Varden. In the Yukon, especially in headwaters near the Northwest Territories boundary, occasional records of Dolly Varden in fact may be bull trout (Reist et al. 2002). Unless these issues could be resolved through reference to the recent literature on taxonomy and distribution, I tabulated them as "Dolly Varden recorded within the known or expected range of bull trout."

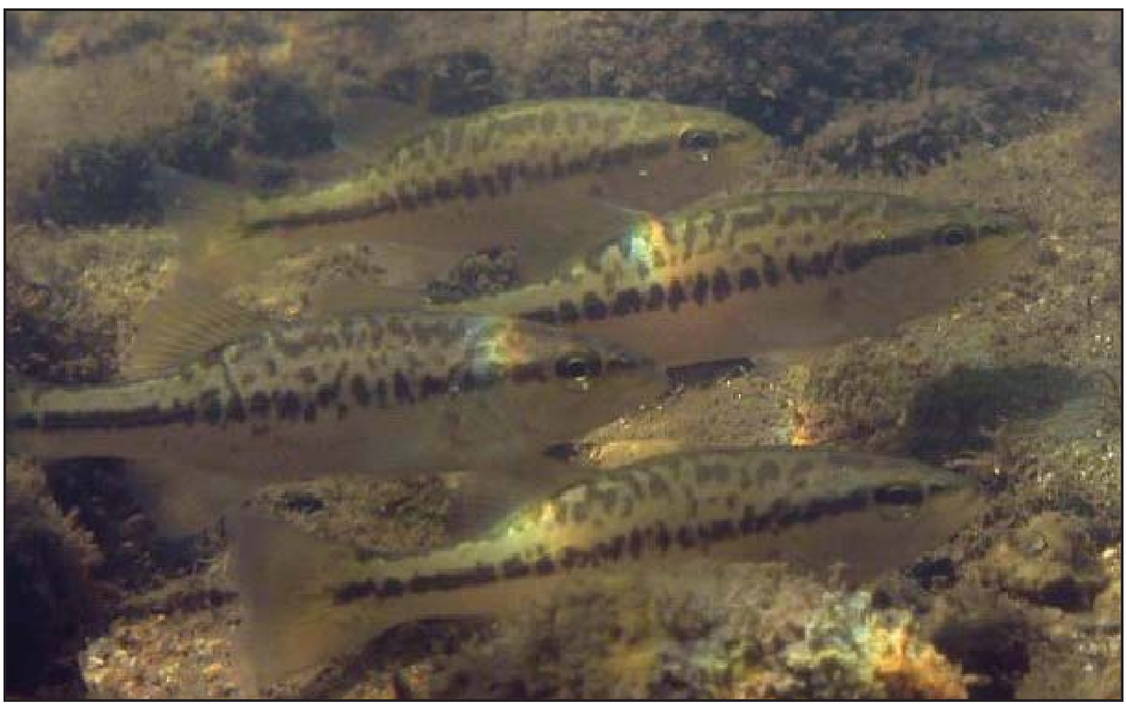
Among specialists, points of disagreement may occur with certain species. For example, Crossman's (1978) view that northern pike are native to the Missouri drainage within the Y2Y region was accepted, although Brown (1971) disagreed. The interpretation of Behnke (1992) for the native distribution of westslope cutthroat trout in northern Idaho was also accepted; Thurow et al. (1997) disagree with this assessment. There are also disagreements in the literature about the native occurrence of certain Great Basin chubs in the upper Snake River drainage. I accept the argument of Sigler and Sigler (1987) that the leatherside chub was introduced to the upper Snake River. Simpson and Wallace (1982) state that the species is native to the upper Snale River, although this argument is not well substantiated. Sigler and Sigler's (1987) wording implies that the same species is native to the Wood River, an upper Snake River tributary and suspected refugial enclave, so I have joined McPhail and Lindsey (1986) in adopting that interpretation. I also accept that the Utah chub is native to the lower Wood River in the upper Snake River basin (Sigler and Sigler 1987), even though Simpson and Wallace (1982) imply some doubt. Finally, I have assigned native status to three rare species (razorback sucker, bonytail chub and humpback chub) in the Green River within the study area, contrary to the distributions assigned by researchers who have worked extensively in that region (Tyus et al. 1982, Minckley et al. 1991). I argue that there were no barriers to upstream movement from documented populations a short distance downstream, and that, due to the paucity of early collecting, there is no evidence that these species did not use the Green mainstem within the study area at least seasonally.

Analysis

Reported and confirmed occurrences of fish species were tabulated by sub-basin from the data sources for each major drainage basin. The status of each species in each sub-basin was coded as a native, introduced, extirpated or questionable record.

From the status table for each major drainage, I prepared species' presence-absence tables for present-day and historical periods. Unconfirmed records and occurrences based only on questionable records were not included. I then used Anderberg's dichotomy coefficient (Wilkinson 1992)[1] on the species' presence-absence data to measure similarity among faunas. Anderberg's coefficient is similar to the more familiar Jaccard coefficient in that it ignores shared absences of species, but Anderberg's coefficient gives greater weight to differences in species' composition between two faunas. Cluster analyses of the Anderberg coefficients were conducted using single, complete, average, median, centroid and Ward's minimum variance agglomerative linkage methods. The clusters obtained by all methods were robust, with few differences among them. The Ward's minimum variance method provided the most distinct dendrograms, and only those results are reported here. These and all other statistical computations were done with the SYSTAT statistical package (Wilkinson 1992).

1 The same coefficient is attributed to Sokal and Sneath by Legendre and Legendre (1983).



Largemouth Bass (*Micropterus salmoides*)
Photo: © Jeremy Monroe

These introduced centrarchids are typical of the non-native species that have transformed the Missouri and Columbia basin fish faunas.

Results

Data on historical and present fish occurrence and status were tabulated for the 297 sub-basins within 23 major basins in the Y2Y region. Occurrences were categorized as native, introduced, extirpated, or questionable. Where data were available (in the ICBEMP study area, for example), depressed status was also identified. These data are archived in 19 Excel spreadsheet files held by the Yellowstone to Yukon Conservation Initiative, and are freely available upon request. The detailed results are presented below, compiled by major drainage basin.

Overview

One hundred fifty-two (152) species and subspecies of fish are known to occur, or once occurred, in the 23 major drainage basins (Table 1). Of these, 104 are, or were, native to some part of the Y2Y region (Table 2). Five are now extirpated from the study area, and of these, two are fully extinct. The remaining 48 species are not native to the region. These observations are summarized by major drainage basin in Appendix A.

The rainbow trout is the most widespread species, occurring in all 23 major drainages, although it is native only to 13 of them. The most widespread native species is mountain whitefish: it is native to all 20 major drainages in which it occurs. Other widespread species are lake trout (20 drainages, introduced in 7 of them), longnose sucker (19/1), lake chub (19/1), longnose dace (18/1), bull trout (18/0, extirpated from 1 drainage), brook trout (17/17), and Arctic grayling (17/7). Although brook trout was by far the most widely-distributed exotic, two others were widespread as well: golden trout (9/9), and brown trout (9/9). The most widely transplanted native species within the study area were rainbow trout (transplanted into 10 major drainages), lake trout (7), Arctic grayling (7), yellow perch (7), Yellowstone cutthroat trout (6), kokanee (5), and walleye (5).

At the other end of the scale, 55 species or subspecies occur in only one major drainage. Twenty-four of these are exotics. Of the 31 native fishes restricted to just one major drainage, five have been extirpated and two of these are extinct. Most of the remaining native species are more widespread forms that in the study area are at or near the limits of their ranges. However, at least six (Jasper longnose sucker, Umatilla dace, Wood River sculpin, sand roller, Snake River fine-spotted cutthroat trout, Colorado River cutthroat trout), plus two extinct species (Banff longnose dace, Snake River sucker), are endemics with distributions wholly within or extending into the Y2Y region.

Table 1. Scientific and common names of the fishes of Yellowstone to Yukon drainages (Robins et al. 1991a, 1991b).

Family	Subfamily	Scientific Name	Group	Common Name
Petromyzontidae		*Lampetra ayresi*		river lamprey
Petromyzontidae		*Lampetra camtschatica*		Arctic lamprey
Petromyzontidae		*Lampetra richardsoni*		western brook lamprey
Petromyzontidae		*Lampetra tridentata*		Pacific lamprey
Acipenseridae		*Acipenser fulvescens*		lake sturgeon
Acipenseridae		*Acipenser transmontanus*		white sturgeon
Acipenseridae		*Scaphirynchus platorynchus*		shovelnose sturgeon
Hiodontidae		*Hiodon alosoides*		goldeye
Clupeidae		*Alosa sapidissima*		American shad
Cyprinidae		*Acrocheilus alutaceus*		chiselmouth
Cyprinidae		*Carassius auratus*		goldfish
Cyprinidae		*Couesius plumbeus*		lake chub
Cyprinidae		*Cyprinus carpio*		common carp
Cyprinidae		*Cyprinella lutrensis*		red shiner
Cyprinidae		*Gila atraria*		Utah chub
Cyprinidae		*Gila bicolor*		tui chub
Cyprinidae		*Snyderichthys copei*		leatherside chub
Cyprinidae		*Gila cypha*		humpback chub
Cyprinidae		*Gila elegans*		bonytail
Cyprinidae		*Gila robusta*		roundtail chub
Cyprinidae		*Hybognathus argyritis*		western silvery minnow
Cyprinidae		*Hybognathus hankinsoni*		brassy minnow
Cyprinidae		*Hybognathus placitus*		plains minnow
Cyprinidae		*Macrhybopsis gelida*		sturgeon chub
Cyprinidae		*Margariscus margarita*		pearl dace
Cyprinidae		*Mylocheilus caurinus*		peamouth

Family	**Subfamily**	**Scientific Name**	**Group**	**Common Name**
Cyprinidae		*Notropis atherinoides*		emerald shiner
Cyprinidae		*Notropis blennius*		river shiner
Cyprinidae		*Notropis hudsonius*		spottail shiner
Cyprinidae		*Notropis stramineus*		sand shiner
Cyprinidae		*Phoxinus eos*		northern redbelly dace
Cyprinidae		*Phoxinus neogaeus*		finescale dace
Cyprinidae		*Phoxinus* hybrid sp.		n. redbelly X finescale hybrid sp.
Cyprinidae		*Pimephales promelas*		fathead minnow
Cyprinidae		*Platygobio gracilis*		flathead chub
Cyprinidae		*Ptychocheilus uregonensis*		northern pikeminnow
Cyprinidae		*Puntius tetrazona*		tiger barb
Cyprinidae		*Rhinichthys cataractae*		longnose dace
Cyprinidae		*Rhinichthys cataractae smithi*		Banff longnose dace
Cyprinidae		*Rhinichthys falcatus*		leopard dace
Cyprinidae		*Rhinichthys osculus*		speckled dace
Cyprinidae		*Rhinichthys Umatilla*		Umatilla dace
Cyprinidae		*Richardsonius balteatus*		redside shiner
Cyprinidae		*Semotilus atromaculatus*		creek chub
Cyprinidae		*Tinca tinca*		tench
Cobitidae		*Misgurnus anguillicaudatus*		oriental weatherfish
Cobitidae		*Misgurnus mizolepis*		Chinese fine-scaled loach
Catostomidae		*Carpiodes carpio*		river carpsucker
Catostomidae		*Catostomus ardens*		Utah sucker
Catostomidae		*Catostomus catostomus*		longnose sucker
Catostomidae		*Catostomus catostomus lacustris*		Jasper longnose sucker
Catostomidae		*Catostomus columbianus*		bridgelip sucker
Catostomidae		*Catostomus commersoni*		white sucker
Catostomidae		*Catostomus discobolus*		bluehead sucker

Family	Subfamily	Scientific Name	Group	Common Name
Catostomidae		*Catostomus latipinnis*		flannelmouth sucker
Catostomidae		*Catostomus macrocheilus*		largescale sucker
Catostomidae		*Catostomus platyrhynchus*		mountain sucker
Catostomidae		*Chasmistes muriei*		Snake River sucker
Catostomidae		*Cycleptus elongatus*		blue sucker
Catostomidae		*Ictiobus bubalus*		smallmouth buffalo
Catostomidae		*Ictiobus cyprinellus*		bigmouth buffalo
Catostomidae		*Moxostoma macrolepidotum*		shorthead redhorse
Catostomidae		*Xyrauchen texanus*		razorback sucker
Characidae		*Piaractus brachypomus*		pirapatinga
Ictaluridae		*Ameiurus melas*		black bullhead
Ictaluridae		*Ameiurus natalis*		yellow bullhead
Ictaluridae		*Ameiurus nebulosus*		brown bullhead
Ictaluridae		*Ictalurus furcatus*		blue catfish
Ictaluridae		*Ictalurus punctatus*		channel catfish
Ictaluridae		*Noturus flavus*		stonecat
Ictaluridae		*Noturus gyrinus*		tadpole madtom
Ictaluridae		*Pylodictis olivaris*		flathead catfish
Esocidae		*Esox americanus vermiculatus*		grass pickerel
Esocidae		*Esox lucius*		northern pike
Esocidae		*Esox lucius* X *masquinongy*		tiger muskellunge
Umbidae		*Umbra limi*		central mudminnow
Osmeridae		*Thaleichthys pacificus*		eulachon
Salmonidae	Coregoninae	*Stenodus leucichthys*		inconnu
Salmonidae	Coregoninae	*Coregonus artedi*	ciscoes	cisco
Salmonidae	Coregoninae	*Coregonus autumnalis*	ciscoes	Arctic cisco
Salmonidae	Coregoninae	*Coregonus clupeaformis*	broad whitefishes	lake whitefish
Salmonidae	Coregoninae	*Coregonus nasus*	broad whitefishes	broad whitefish

Family	Subfamily	Scientific Name	Group	Common Name
Salmonidae	Coregoninae	*Coregonus sardinella*	ciscoes	least cisco
Salmonidae	Coregoninae	*Prosopium coulterii*	round whitefish	pygmy whitefish
Salmonidae	Coregoninae	*Prosopium cylindraceum*	round whitefish	round whitefish
Salmonidae	Coregoninae	*Prosopium williamsoni*	round whitefish	mountain whitefish
Salmonidae	Thymallinae	*Thymallus arcticus*	grayling	Arctic grayling
Salmonidae	Salmoninae	*Salvelinus alpinus*	charr	Arctic charr
Salmonidae	Salmoninae	*Salvelinus confluentus*	charr	bull trout
Salmonidae	Salmoninae	*Salvelinus fontinalis*	charr	brook trout
Salmonidae	Salmoninae	*Salvelinus malma*	charr	Dolly Varden
Salmonidae	Salmoninae	*Salvelinus namaycush*	charr	lake trout
Salmonidae	Salmoninae	*Salvelinus fontinalis* X *namaycush*	charr	splake
Salmonidae	Salmoninae	*Oncorhynchus aguabonita*	western trout	golden trout
Salmonidae	Salmoninae	*Oncorhynchus clarki bouvieri*	western trout	Yellowstone cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus clarki* behnkei	western trout	Snake R. fine-spotted cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus clarki clarki*	western trout	coastal cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus clarki henshawi*	western trout	Lahontan cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus clarki lewisi*	western trout	westslope cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus clarki pleuriticus*	western trout	Colorado River cutthroat trout
Salmonidae	Salmoninae	*Oncorhynchus mykiss*	western trout	steelhead
Salmonidae	Salmoninae	*Oncorhynchus mykiss*	western trout	rainbow trout
Salmonidae	Salmoninae	*Oncorhynchus gorbuscha*	Pacific salmon	pink salmon
Salmonidae	Salmoninae	*Oncorhynchus keta*	Pacific salmon	chum salmon
Salmonidae	Salmoninae	*Oncorhynchus kisutch*	Pacific salmon	coho salmon
Salmonidae	Salmoninae	*Oncorhynchus nerka*	Pacific salmon	sockeye salmon
Salmonidae	Salmoninae	*Oncorhynchus nerka*	Pacific salmon	kokanee
Salmonidae	Salmoninae	*Oncorhynchus tshawytscha*	Pacific salmon	Chinook salmon
Salmonidae	Salmoninae	*Salmo salar*	Atlantic salmon & trout	Atlantic salmon
Salmonidae	Salmoninae	*Salmo trutta*	Atlantic salmon & trout	brown trout

Family	Subfamily	Scientific Name	Group	Common Name
Salmonidae	Salmoninae	*Salmo trutta* X *Salvelinus fontinalis*	intergeneric hybrid	tiger trout
Percopsidae		*Percopsis omiscomaycus*		trout perch
Percopsidae		*Percopsis transmontana*		sand roller
Gadidae		*Lota lota*		burbot
Poeciliidae		*Gambusia affinis*		western mosquitofish
Poeciliidae		*Poecilia reticulata*		guppy
Poeciliidae		*Poecilia latipinna*		sailfin molly
Poeciliidae		*Poecilia mexicana*		shortfin molly
Poeciliidae		*Xiphophorus hellerii*		green swordtail
Poeciliidae		*Xiphophorus maculatus*		southern platyfish
Poeciliidae		*Xiphophorus variatus*		variable platyfish
Gasterosteidae		*Culaea inconstans*		brook stickleback
Gasterosteidae		*Gasterosteus aculeatus*		threespine stickleback
Cottidae		*Cottus aleuticus*		coastrange sculpin
Cottidae		*Cottus asper*		prickly sculpin
Cottidae		*Cottus bairdii*		mottled sculpin
Cottidae		*Cottus beldingii*		Paiute sculpin
Cottidae		*Cottus cognatus*		slimy sculpin
Cottidae		*Cottus confusus*		shorthead sculpin
Cottidae		*Cottus leiopomus*		Wood River sculpin
Cottidae		*Cottus rhotheus*		torrent sculpin
Cottidae		*Cottus ricei*		spoonhead sculpin
Cottidae		*Myoxocephalus thompsonii*		deepwater sculpin
Centrarchidae		*Ambloplites rupestris*		rock bass
Centrarchidae		*Lepomis cyanellus*		green sunfish
Centrarchidae		*Lepomis gibbosus*		pumpkinseed
Centrarchidae		*Lepomis gulosus*		warmouth
Centrarchidae		*Lepomis macrochirus*		bluegill

Family	Subfamily	Scientific Name	Group	Common Name
Centrarchidae		*Micropterus dolomieu*		smallmouth bass
Centrarchidae		*Micropterus salmoides*		largemouth bass
Centrarchidae		*Pomoxis annularis*		white crappie
Centrarchidae		*Pomoxis nigromaculatus*		black crappie
Percidae		*Etheostoma exile*		Iowa darter
Percidae		*Perca flavescens*		yellow perch
Percidae		*Sander canadensis*		sauger
Percidae		*Sander vitreus*		walleye
Sciaenidae		*Aplodinotus grunniens*		freshwater drum
Cichlidae		*Cichlasoma nigrofaciatum*		convict cichlid
Cichlidae		*Hemichromis letourneuxi*		African jewelfish
Cichlidae		*Tilapia* ssp.		tilapia
Cichlidae		*Oreochromis mossambicus*		Mozambique tilapia
Pleuronectidae		*Platichthys stellatus*		starry flounder

Table 2. Numbers of fish taxa (total, native, introduced, extirpated, or extinct) by major drainage basin, compiled from Appendix A.

	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone
Total known	19	25	10	25	10	27	38	38	35	64	25	59	20	36	33	20	29	26	33	28	44	66	40
Native	18	25	10	25	10	27	36	35	32	30	14	27	10	15	12	19	27	23	30	22	30	35	17
Introduced	1	0	0	0	0	0	2	3	3	34	11	32	10	21	21	1	2	3	3	6	14	31	23
Extinct	0	0	0	0	0	0	0	0	0	3	0	1	1	2	3	0	0	0	0	0	1	0	0

Cluster Analysis

Most drainages cluster similarly in both the native historical (Figure 1) and present-day (Figure 2) dendrograms. The most obvious exceptions are seen in the various Columbia, Missouri and Green river drainages south of the study area. In those drainages, the present-day clusters are markedly different from the historical clusters. Dividing each dendrogram into four clusters produces the following five groups (Figure 4a, 4b). Their zoogeographic interpretation is provided in the discussion.

Group 1 (historical and present) - Yukon, Upper Stikine, Upper and Lower Liard, Upper and Lower Peace, Athabasca, Saskatchewan

Group 2 (historical and present) - Taku, Lower Stikine, small coastal drainages, Nass

Group 3 (historical) - Skeena, Upper Fraser, Thompson, Upper Columbia, Upper Kootenay, Middle Columbia

Group 3 (present) - Skeena, Upper Fraser, Thompson

Group 4 (historical) - Wood, Upper Snake, Green, Yellowstone, Missouri

Group 5 (present) - Upper and Middle Columbia, Upper Kootenay, Wood, Upper Snake, Green, Yellowstone, Missouri

Groups 1 and 2 are comprised of the identical drainages historically and in the present day. Group 3 is comprised of three of the same drainages presently as it contained historically, but the more southerly drainages in the historical Group 3 cluster with several other southerly drainages in the present-day dendrogram. Group 4 drainages are the most southerly, differing distinctly from the other basins historically. In the present, however, they group with the more southerly drainages of Group 3, forming a distinctive Group 5.

Arctic Grayling (*Thymallus arcticus*)
Photo: © Jeremy Monroe

This Y2Y native fish is still abundant in the far north, but has been decimated wherever human development has encroached significantly into its drainages.

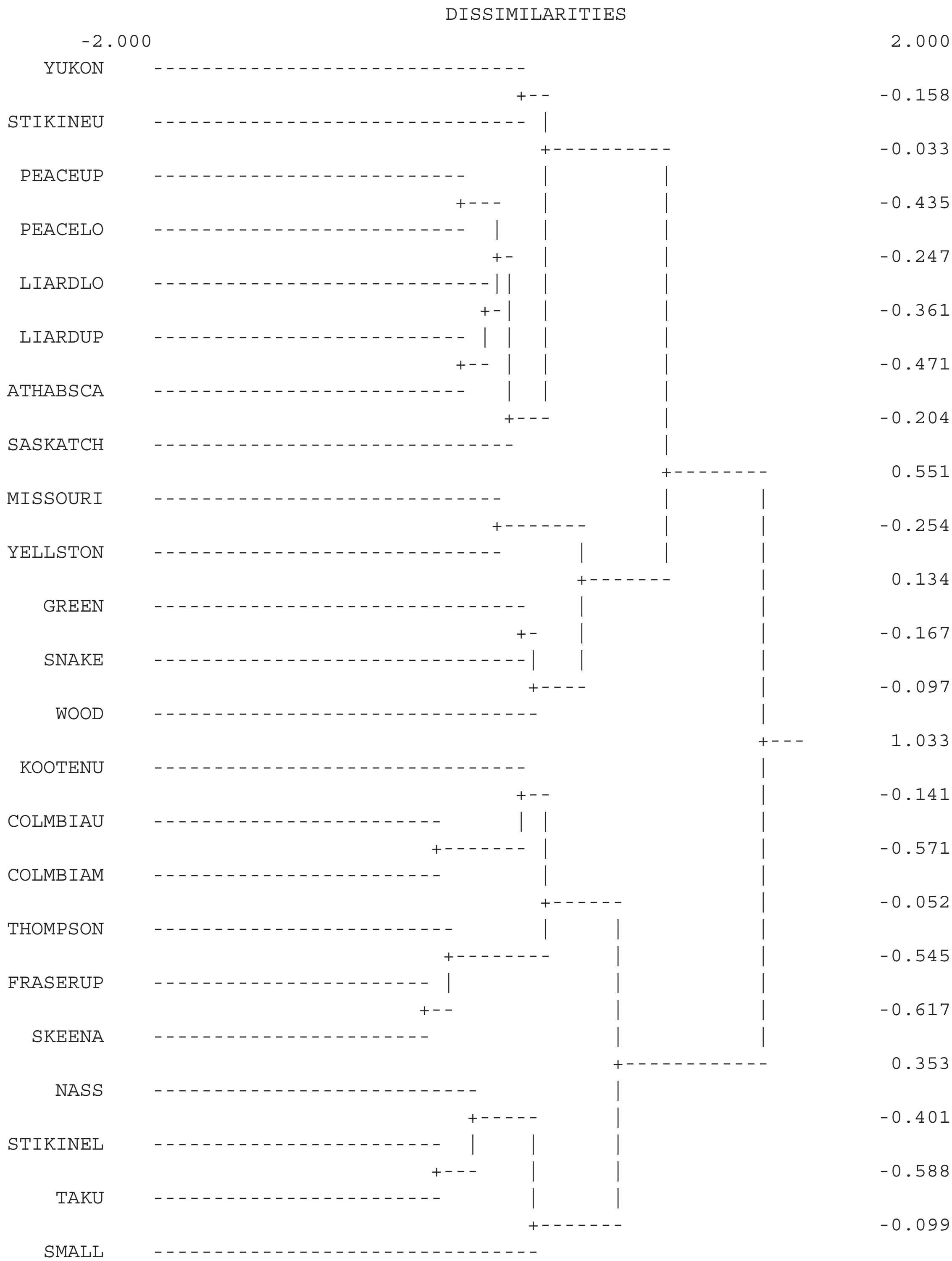


Figure 2. Relative similarity of native fish historical faunas among the 23 major drainages in the Y2Y region, calculated by Ward's minimum variance method on Anderberg's dichotomy coefficient.

```
                                     DISSIMILARITIES
      -2.000                                                             2.000
   SMALL    -------------------------------
                                           +----                        -0.099
    TAKU    -----------------------        |   |
                                   +---    |   |                        -0.588
STIKINEL    -----------------------   |    |   |
                                      +-----   |                        -0.401
    NASS    --------------------------         |
                                               +-------------            0.172
  SKEENA    -----------------------            |            |
                                   +-          |            |           -0.556
FRASERUP    ------------------------|          |            |
                                    +-----------            |           -0.513
THOMPSON    -------------------------                       |
                                                            +-----       0.964
   GREEN    ------------------------------                  |
                                         +-                 |           -0.227
   SNAKE    ------------------------------|                 |
                                          +--               |           -0.155
    WOOD    ------------------------------- |               |
                                            +------------   |           -0.005
COLMBIAM    ----------------------------    |           |   |
                                       +--  |           |   |           -0.345
COLMBIAU    ---------------------------- |  |           |   |
                                         +--+           |   |           -0.195
KOOTENUP    ------------------------------  |           |   |
                                            |           |   |           -0.055
YELLSTON    ----------------------------    |           |   |
                                       +-----           |   |           -0.346
MISSOURI    ----------------------------                |   |
                                                        +----            0.668
SASKATCH    --------------------------                  |
                                     +------            |               -0.443
ATHABSCA    --------------------------     |            |
                                           +--          |               -0.086
 LIARDUP    --------------------------     | |          |
                                     +--   | |          |               -0.474
 PEACEUP    -------------------------- |   | |          |
                                       +---- |          |               -0.354
 PEACELO    ---------------------------|     |          |
                                      +-     |          |               -0.418
 LIARDLO    ---------------------------      |          |
                                             +-----------                0.011
   YUKON    ------------------------------   |
                                         +----                          -0.189
STIKINEU    ------------------------------
```

Figure 3. Relative similarity of present-day fish faunas among the 23 major drainages in the Y2Y region, calculated by Ward's minimum variance method on Anderberg's dichotomy coefficient.

Similarity Analysis

Over the entire study area, faunal similarity as measured by Anderberg's coefficient increased from the native condition to the present day by a mean of 7.9 percent among all possible pairwise comparisions of basins (Wilcoxon signed ranks Z = 4.976, n = 253, Ts = 85, $p < 0.001$), but there were wide variations in the changes.

Group 1 - Overall, faunas within Group 1 have not become more similar (Wilcoxon signed ranks Z = 1.370, n = 28, Ts = 10, $p > 0.05$). Ten basin pairs have become less similar, while 17 basin pairs have become more similar. One basin pair showed no change in similarity. In general, southern drainages have become more distinct from northern basins as the southern basins received more introduced species. Geographically closer drainages usually have become more similar as they have received similar introduced species.

Group 2 - There have been no changes in similarity among drainages in Group 2. None of these drainages has received introduced species, and none has had any extirpations.

Group 3 - All but one pair of drainages in Group 3 have become less similar. More than half have become less similar by 40 percent or more. Differences among drainages were primarily caused by differences in introduced species.

Group 4 - All drainages within Group 4 have more similar faunas now. Similarity coefficients of half of Group 4 drainages have increased more than 200 percent. All five basins have received common introductions, especially centrarchids.

Group 5 - Of the 27 drainage pair faunas within Group 5, all but two are more similar now than under native conditions. Many common salmonids, cyprinids and centrarchids have been widely introduced among drainages in this group. In the Green River drainage, the extirpation of several upper Colorado River catostomids and cyprinids contributed to making this basin more similar to others within the group.

White sucker (*Catostomus commersoni*)
Photo: © Jeremy Monroe

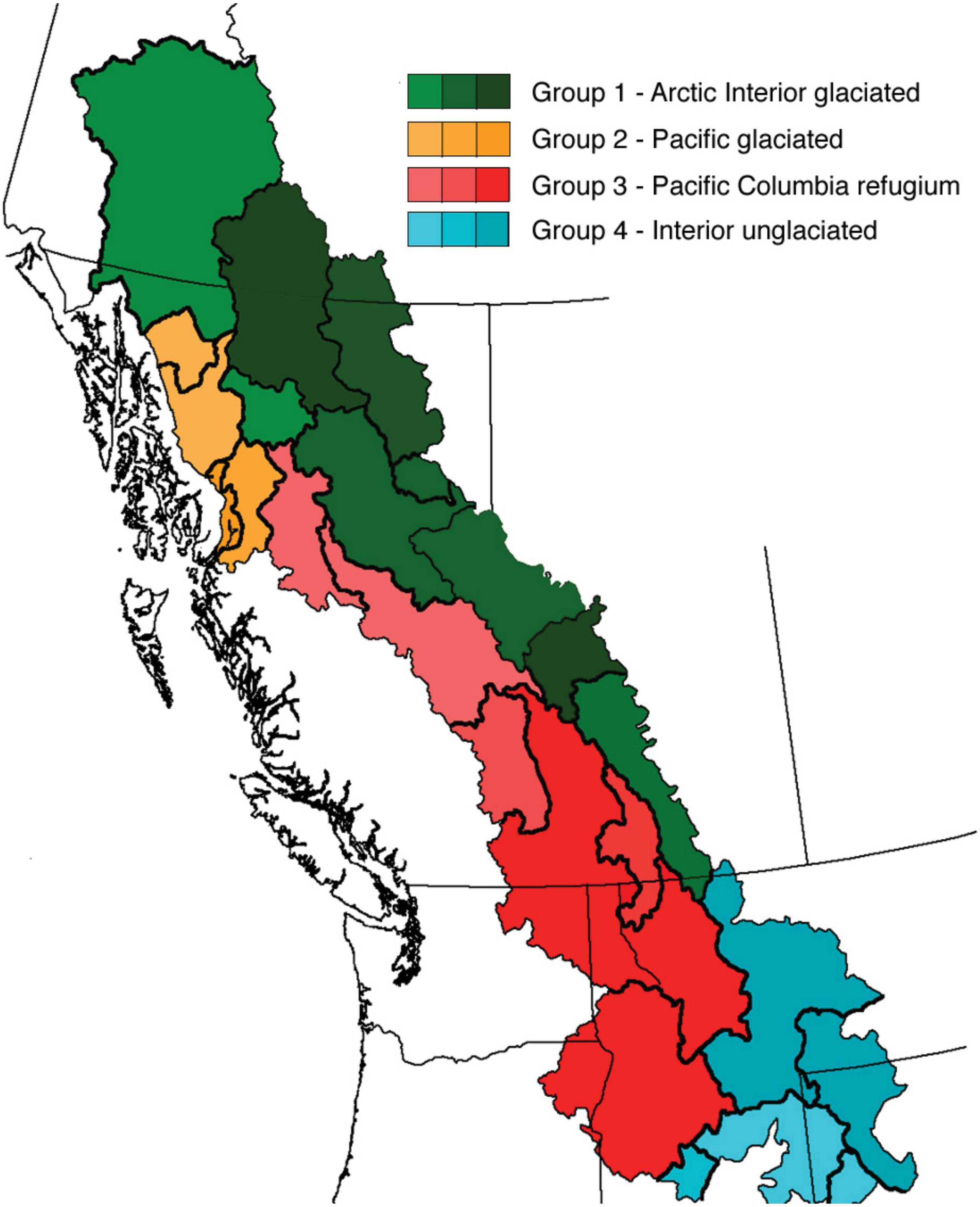


Figure 4a. Drainage basins grouped by faunal similarity as identified by cluster analysis – native.

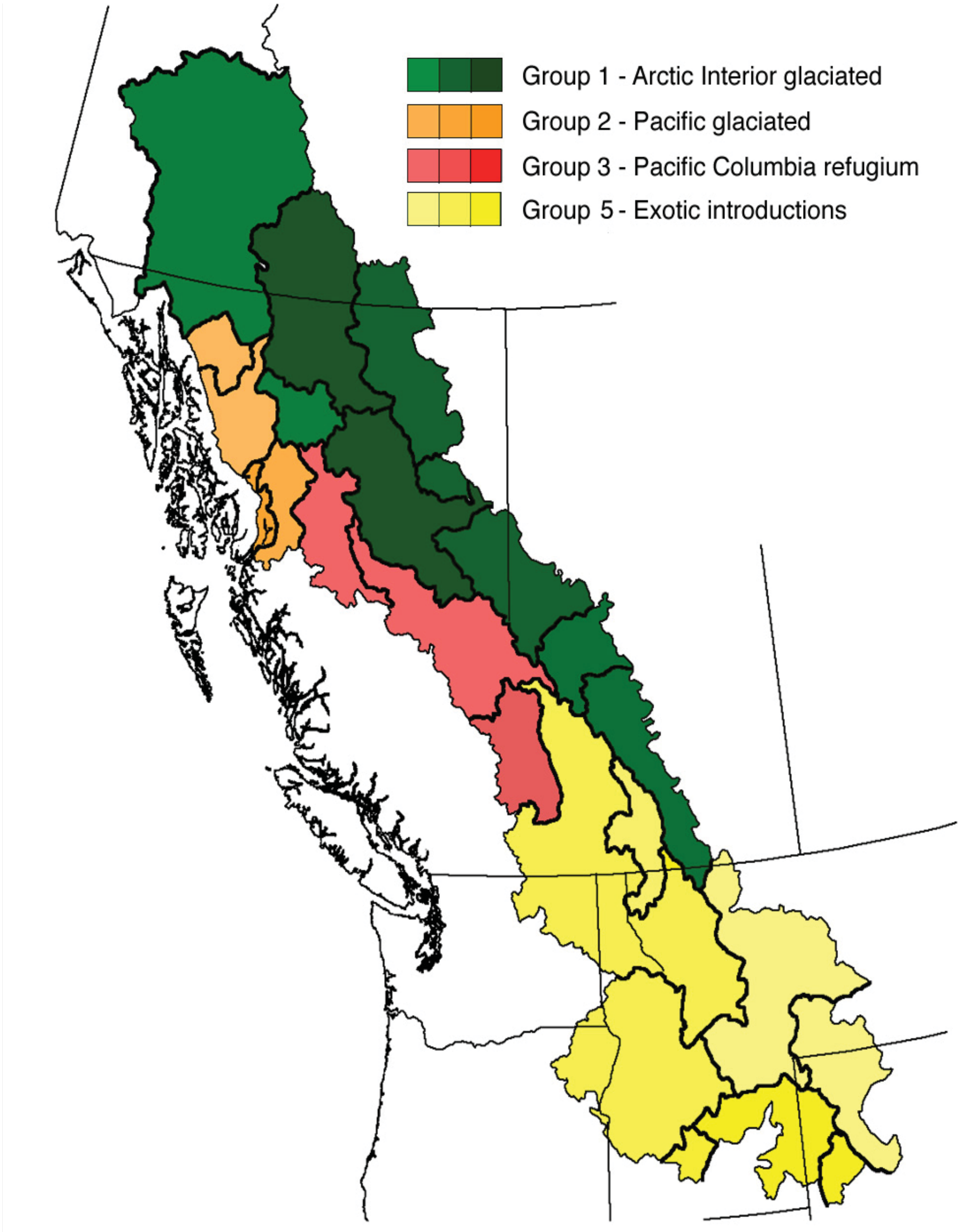


Figure 4b. Drainage basins grouped by faunal similarity as identified by cluster analysis – present.

Discussion

Zoogeography

During the Pleistocene, most of the study area within Canada and most of the higher headwater areas of the region within the United States were covered by glaciers. Fish were unable to occupy these areas, and survived the Pleistocene in refugia beyond the limits of the ice. For Y2Y region fishes, the most important refugia existed in the northern Yukon and Alaska (Beringian refugium), south of the Cordilleran Ice Sheet in the lower Columbia basin (Columbian refugium), south of the Laurentide Ice Sheet in the Missouri and Mississippi basins (Missourian and Mississippian refugia), and possibly in isolated ice-free areas between the Cordilleran and Laurentide Ice Sheets in the north (Nahanni refugium) and south (Banff-Jasper, or Ice-free Corridor refugium) (Cross et al. 1986, Crossman and McAllister 1986, Lindsey and McPhail 1986, McPhail and Lindsey 1986, Mayhood 1992). Apart from these, only at low elevations in the southern parts of the study area was it possible for fishes to survive the Pleistocene more or less in place.

As the ice retreated, fish invaded the Y2Y region from the refugial areas, often from more than one refugium. Not all parts of the study area were accessible to all species, because fish were restricted by the vagaries of changing drainage patterns. The Continental Divide was clearly the greatest single barrier to postglacial dispersal. As a result, the majority of species became restricted in their distributions to certain parts of the study area.

Group 1 - Arctic Interior Glaciated - The rivers of this group drain mostly glaciated northern interior parts of the continent, and flow to the Arctic Ocean or the Bering Sea.

A large proportion of the fish fauna of Group 1 drainages, especially in the south, is derived from the Mississippian, and possibly the Missourian, refugia (Crossman and McAllister 1986, Lindsey and McPhail 1986). The Yukon drainage was primarily colonized by fishes from the Beringian refugium, which also contributed some species to more southern drainages in the group. Several species survived in both northern and southern refugia, invading Group 1 drainages from both directions postglacially. As a result, the faunas at the species level appear more similar than their complex derivation would suggest.

A much smaller proportion of the fish fauna of Group 1 drainages is derived from the Columbian refugium, some members of which were able to cross the Continental Divide at several locations. Few of these Columbian species are widely distributed in Group 1 drainages.

Group 2 - Pacific Glaciated - The drainages of this group, now flowing to the Pacific Ocean, were completely glaciated during the Pleistocene. They were mostly isolated from interior drainages by late deglaciation and extensively mountainous drainage divides. As a result, postglacial invasion via those routes was limited, and invasion from the Columbian refugium via the Pacific was relatively more important than in other drainage groups west of the Continental Divide. These factors tended to favour numerical domination of the fauna by euryhaline (saltwater-tolerant) species (McPhail and Lindsey 1986).

An apparent anomaly is the exclusion of the Upper Stikine River drainage from this group, and its inclusion in Group 1. Access to the Upper Stikine by fish from the Pacific is completely blocked by the Grand Canyon of the Stikine, a narrow, 300-meter deep slot in the earth that is clearly pre-Pleistocene in origin, and through which the great river flows torrentially for long distances. The fish fauna of the Upper Stikine is depauperate and dominated exclusively by interior-derived fishes as a result. This means it is more similar to the Yukon drainage fauna, and thereby to the Group 1 fauna east of the Continental Divide.

Group 3 - Pacific Columbia Refugium - The rivers in Group 3 drain to the Pacific Ocean, and most of the drainages were completely ice-covered during the Pleistocene. Only the lower-elevation and most southerly parts of the Columbia drainages were ice-free and acted as refugia during that time. Group 3 drainages are isolated from the drainages of Group 1 to the east by the Continental Divide. As a result, the drainages of this region are heavily dominated by species from the Columbian refugium. They are differentiated from the Group 2 fauna by the much greater presence of stenohaline (saltwater-intolerant) species that colonized the region via interior routes, and were unable to reach Group 2 drainages by such means (McPhail and Lindsey 1986).

Group 4 - Interior Unglaciated - Group 4 is a disparate set of drainages that forms the headwaters of major rivers flowing ultimately to the Pacific (via the Columbia River), the Gulf of Mexico (via the Missouri-Mississippi River), and the Gulf of California (via the Colorado River), and was at least partially unglaciated during the Pleistocene, or immediately adjacent to such refugial areas. The Columbia and Colorado drainages are separated by the Continental Divide from the Missouri drainages, and from each other by a mountainous divide. These three major drainages consequently have fundamentally differing fish faunas, but share certain species as a result of headwater transfers (McPhail and Lindsey 1986, Cross et al. 1986, Minckley et al. 1986, Sigler and Sigler 1987). The small Wood River drainage is isolated from its Snake River mainstem and has a somewhat distinct fauna, while the Snake River sub-basins in the study area have been isolated from the rest of the Columbia basin by Shoshone Falls (McPhail and Lindsey 1986). Faunas in Group 4 drainages survived the Pleistocene in place or invaded from local refugia.

Group 5 - Exotic Introductions - The Group 5 fauna is defined primarily by accidental or intended introductions (especially of common species not native to the area) and transplantations, and to some extent by extirpations and extinctions. The tendency has been to homogenize once-distinct faunas. These changes have almost certainly been facilitated by habitat damage, especially from dams, that commonly favour introduced generalist species at the expense of locally adapted native stocks.

Changes in the Fish Fauna

Human-induced changes, especially the widespread introduction of non-native species and the transplantation of common native species, have tended to make the fish fauna of the Y2Y region more homogeneous overall (Figure 3). There are wide variations within and among faunal drainage groups. The lack of change in the similarity of the faunas among Group 1 drainages as a whole results from a masking of effects. Some drainages have become more similar as the result of receiving common species introductions, while the uneven distribution of introductions has created greater differences among other drainages. This effect of variable introductions is most pronounced in Group 3 drainages, where most drainages, and the group overall, have become less faunally homogeneous. In contrast, the southern Group 3 drainages and the Group 4 drainages have been converted into an entirely new, much more internally homogeneous Group 5 as a result of widespread introductions of common non-native species and transplantations of common natives.

The biological and ecological consequences of these changes in fish faunas are not clear at the scale of the present analysis. The fact that many introductions occurred in only a few drainages, and that the fish have remained there, means that any consequences are limited to and contained in those few drainages for the time being. On the other hand, the complete transformation of the southern drainages of the Y2Y region into a new readily identifiable faunal group suggests the possibility of profound ecological consequences for that region.

Natural aquatic ecosystems and their fish communities usually develop over a long time, and are the integrated consequences of many factors, including adaptation in response to local environmental pressures, among them competition and predation from other native stocks. When common non-native species and hatchery stocks of native species (both of which are adapted to other, often profoundly different, conditions) are introduced, we should expect changes in not only the structure, but also the function of the recipient ecosystems. This is especially true when the introductions are made into ecosystems that have undergone recent, profound habitat changes, as is commonly the case. It is certainly the case in Group 5 drainages, most of which have experienced extensive damming, especially on the mainstems. In such cases, the question of whether it is the habitat damage or the introduced species that have caused the changes is largely irrelevant. The critical point is that introductions almost invariably have accompanied major habitat changes, and in many cases these changes would have to be reversed to eliminate the introduced species.

Conservation Goals

Preserving the fish diversity of the Y2Y region is an integral component of Y2YCI's conservation efforts. The intent in restoring and protecting native fish diversity is also to restore and protect other species and processes that contribute to aquatic integrity.

A reasonable approach to achieving these goals is to protect the most ecologically valuable drainages and rivers (Frissell et al. 1996, Oechsli and Frissell 2002, 2003, Hitt and Broberg 2002, Saunders et al. 2002), and the most genetically and demographically important native fish populations (Thurow et al. 1997). Certainly it is prudent to try to halt further degradation of native faunas, protecting those that remain in the best condition from future introductions and habitat degradation. For such purposes, the most faunistically natural major drainages and sub-basins in the Y2Y region are found in the northern third of the study area, specifically Group 2 drainages and the northern Group 1 drainages (Yukon, Upper Stikine, Liard and Peace). It is therefore the fauna in these basins that merit the highest priority for protection.

But protecting selected drainages and fish stocks is not enough to meet Y2YCI's fish conservation goals, because this does not address the need to *restore* drainages. Protected areas are inevitably too small, and protected areas and fish stocks are always part of larger unprotected ecosystems. Protected areas should be seen as critical but small parts of conservation plans, which ultimately must focus on maintaining the ecological integrity of large landscapes.

The greatest challenges for meeting Y2YCI's goals lie in the substantially modified drainages of the southern third of the study area, especially those in Group 5. Here the need to protect and restore watersheds and their natural faunas is the most urgent, yet the opportunities to accomplish both are the most limited. It is in these drainages that Y2YCI will have to focus most of its resources to meet its conservation goals.

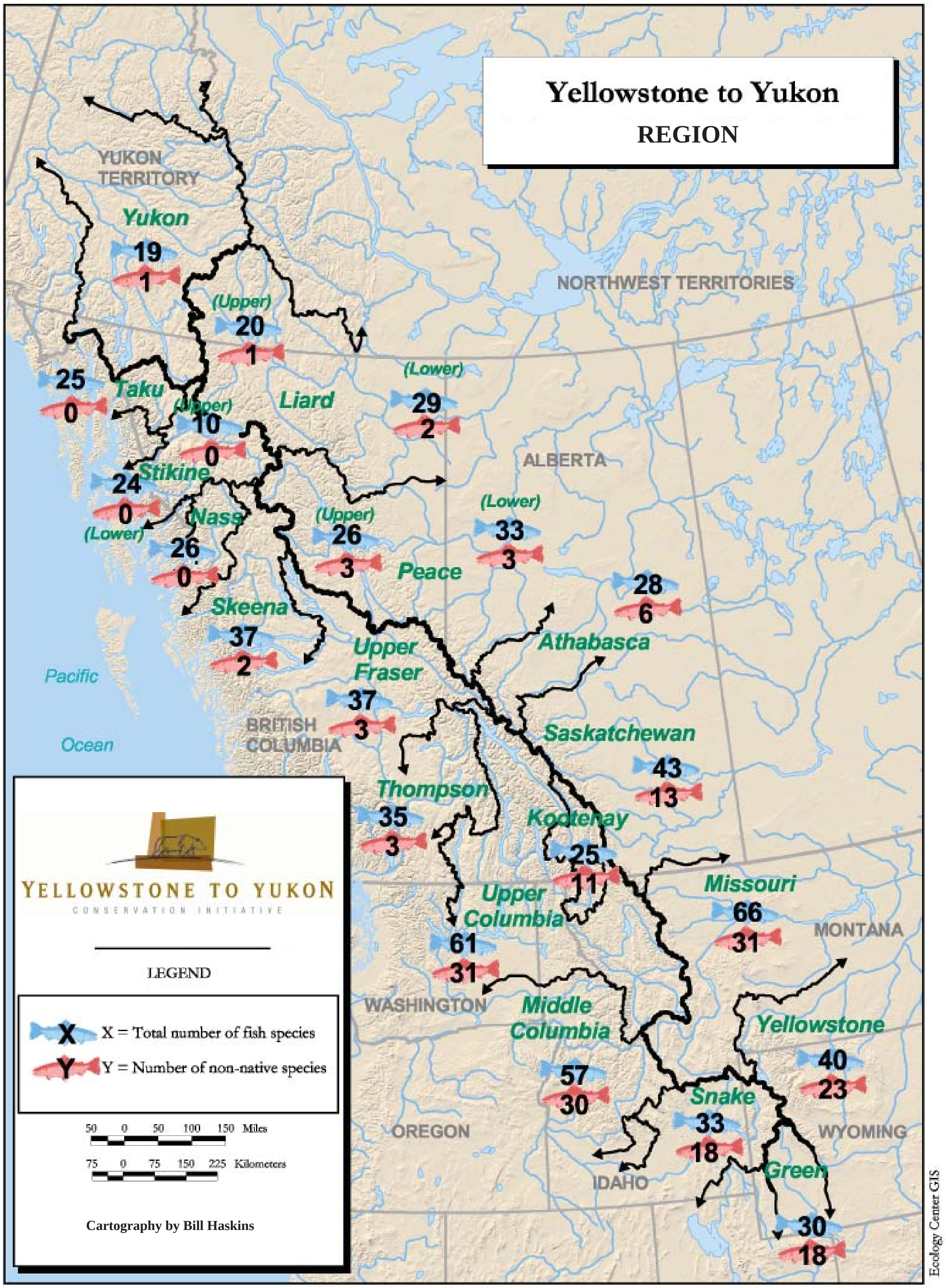


Figure 5. Frequencies of native and non-native fish species by major basin, Yellowstone to Yukon region.

Recommendations

Data Limitations

Studying fish distribution in many parts of the Y2Y region is seriously hampered by the inadequacy of existing databases. The following steps are suggested to ameliorate the problems encountered in this study:

•Jurisdictions that do not provide online public access to fish-distribution data by individual streams and lakes should develop such systems. The systems used in Montana, British Columbia, and the Yukon provide excellent models. These databases should be submitted to a simple but rigorous quality-control procedure to ensure the accuracy of the data entered (see the following recommendation).

•Distribution data for non-sportfish or non-commercial species are almost nonexistent for many sub-basins. Even when extensive directed studies of these species are not financially feasible, mandatory submissions of voucher specimens captured by license-holders would fill many gaps. The specimens so obtained, sportfish and non-sportfish, commercial and non-commercial, should be directed to agency ichthyologists hired specifically to deal with these collections, as well as other recognized specialists. Collection data and identifications should be subjected to rigorous quality control by the ichthyologists responsible, and entered into the public database for the relevant jurisdiction.

Conservation Action

This study provides an overview of the historical and present fish faunas in the Y2Y region. It shows the present situation, and it identifies the ultimate, ideal goals of conservation activities. Some specific recommendations follow that Y2YCI might promote for moving toward that goal.

1) Maintain fish faunas in major basins with near-natural conditions.

At the scale of this analysis, there remain several major basins within the Y2Y region that have minimally altered native-fish populations. In these basins, the full complement of native species still occupies the sub-basins, and there are very few, if any, introduced species. Most of the northernmost major basins in Group 1, and all of those in Group 2, are of this type. It is critically important to maintain the fish faunas of these major basins in their present near-natural condition. These are the last large basins in the study area that have extensive drainage networks with natural or near-natural fish faunas. Such large control areas against which we can measure human-induced changes are becoming exceedingly rare.

1a) Stop introductions.
Stop "official" (government- promoted or government-sanctioned) introductions of non-native fish species, as well as supplemental stocking of native species. Exceptions might be made for carefully thought-out proposals to supplement selected stocks at risk, with identical or similar ones for genuine conservation purposes. All such plans need to be based on scientifically sound, independently peer-reviewed analyses, and reviewed in a publicly transparent process for their conservation implications.

Illegal introductions are a serious problem that is almost impossible to prevent, but education and vigorous enforcement programs may help. These should be directed at the most likely principal perpetrators — those with ready access to non-native fish, and the means of transport to move them. Educational programs geared to young people will probably prove to be especially useful in the long term. Instances of non-native introductions, whether officially sanctioned or illegal, should be reviewed with a view to developing plans for removing the introduced taxa or limiting their spread.

1b) Prevent overfishing and negative habitat alterations.
Overfishing and habitat change are commonly critical factors in the decline of native stocks, and in the introduction and spread of non-native fish species. Accordingly, fish management and habitat protection practices in these drainages need to be meticulously reviewed and closely monitored.

2) Protect intact sub-basins in the southern two-thirds of the Y2Y region.

Throughout the southern two-thirds of the study area there are fewer opportunities to retain natural fish faunas, because most of the major drainages have been substantially damaged already. In this case, a reasonable approach would be to examine drainages at the sub-basin level, or at a smaller scale if necessary, to find those basins that hold the least modified fish faunas or that are most important for sustaining the native fauna in the major basins, preferably both. Special management approaches could then be advanced to ensure that these smaller drainage units maintain their function.
The aquatic-diversity area studies of Oechsli and Frissell (2002, 2003) provide one means of identifying critical drainages based on a broader range of aquatic ecosystem criteria. River integrity assessments (Hitt and Broberg 2002) supply complementary data. Both of these approaches, as well as stock-level life-history analyses, all suitably adapted and refined, will need to be employed to identify critical drainages for protection or special management.

3) Review fish conservation issues for major basins in Group 5 and develop conservation plans.

The major drainages in Group 5 pose the greatest challenge for conservation. In these basins, widespread faunal changes have usually accompanied pervasive habitat modifications, many of which would probably have to be reversed to enable any major reversal of fortune for the remaining native fish stocks. Extensive road networks, urbanization, resource development, recreational use, forestry and agriculture are all widespread and often intensive in these basins. These activities and developments have profoundly damaged native fish habitat and fish populations. In particular, dams continue to block movements of numerous migratory species both upstream and downstream, while their reservoirs have provided new habitats favouring introduced species. Introductions of non-native species and stocks have been extremely thorough in most of these drainages.

In the Group 5 drainages, any conservation work will have to be specific to clearly articulated (and probably carefully limited) conservation objectives. It will be especially important in each major basin and most sub-basins to conduct highly focused analyses of the remnant native faunas and their relationships to the introduced fishes and the modified habitats to assist recovery, restoration and conservation plans. While some completed work (Oechsli and Frissell 2002, 2003) identifies a number of smaller basins for protection and special management, many of the existing problems of Group 5 drainages are caused by issues outside of the Y2Y region, or by historical events that cannot be reversed. Y2YCI might begin by reviewing fish conservation problems in each individual major basin as a means of identifying and prioritizing specific projects for action.

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Appendix

Appendix A. Distribution and status of fishes in the major drainage basins of Y2Y. 1-native, 3-introduced, 9- extirapted

Fish Species	Common Name	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone	TOTAL
Lampetra	unid.lamprey				1		1	1	1																4
Lampetra ayresi	river lamprey		1					1	1																3
Lampetra camtschatica	Arctic lamprey	1																							1
Lampetra richardsoni	western brook lamprey						1	1	1	1															4
Lampetra tridentata	Pacific lamprey		1		1		1	1	1	1	9		1												8
Acipenser fulvescens	lake sturgeon																					1			1
Acipenser transmontanus	white sturgeon		1					1	1	1	1		1												6
Scaphirynchus platorynchus	shovelnose sturgeon																						1		1
Hiodon alosoides	goldeye																	1					1	1	3
Alosa sapidissima	American shad							3					3												2
Acrocheilus alutaceus	chiselmouth								1		1		1												3
Carassius auratus	goldfish								3	3	3		3		3										5
Couesius plumbeus	lake chub	1	1	1	1		1	1	1	1	1	1				3	1	1	1	1	1	1	1	1	19
Cyprinus carpio	common carp									3	3		3	3		3							3	3	7
Cyprinella lutrensis	red shiner															3									1
Gila atraria	Utah chub													1	1	3							3		4
Gila bicolor	tui chub												3												1
Snyderichthys copei	leatherside chub													1	3										2
Gila cypha	humpback chub															9									1
Gila elegans	bonytail															9									1
Gila robusta	roundtail chub															1									1
Hybognathus argyritis	western silvery minnow																						1		1
Hybognathus hankinsoni	brassy minnow								1										1	1			1		4
Hybognathus placitus	plains minnow																						1		1
Macrhybopsis gelida	sturgeon chub																						1		1
Margariscus margarita	pearl dace																1	1		1	1	1			5
Mylocheilus caurinus	peamouth						1	1	1	1	1	1	1						1	1					9
Notropis atherinoides	emerald shiner																					1	1		2
Notropis blennius	river shiner																					1			1
Notropis hudsonius	spottail shiner																		3		1	1	3		4

Fish Species	Common Name	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone	TOTAL
Notropis stramineus	sand shiner																						1		1
Phoxinus eos	northern redbelly dace							1	1											1		1	1		5
Phoxinus neogaeus	finescale dace								1								1	1	1	1	1	1	1		8
Phoxinus hybrid	redbelly X finescale																			1			1		2
Pimephales promelas	hybrid sp. fathead minnow														3	3				1	1	1	1	3	7
Platygobio gracilis	flathead chub																	1		1			1	1	4
Ptychocheilus oregonensis	northern pikeminnow						1	1	1	1	1	1	1						1	1					9
Puntius tetrazona	tiger barb														3										1
Rhinichthys cataractae	longnose dace						1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	18
Rhinichthys cataractae ssp. *smithi*	Banff longnose dace																					9			1
Rhinichthys falcatus	leopard dace							1	1	1	1		1												5
Rhinichthys osculus	speckled dace										1		1	1	1	1									5
Rhinichthys umatilla	Umatilla dace										1														1
Richardsonius balteatus	redside shiner						1	1	1	1	1	1	1	1	1	1			1	1		3	3	3	15
Semotilus atromaculatus	creek chub															3								1	2
Tinca tinca	tench										3					3									2
Misgurnus anguillicaudatus	oriental weatherfish												3												1
Misgurnus mizolepis	Chinese fine-scaled loach												3												1
Carpiodes carpio	river carpsucker																						1	1	2
Catostomus ardens	Utah sucker														1	3									2
Catostomus catostomus	longnose sucker	1	1	1	1		1	1	1	1	1	1				3	1	1	1	1	1	1	1	1	19
Catostomus catostomus ssp. *lacustris*	Jasper longnose sucker																				1				1
Catostomus columbianus	bridgelip sucker								1	1	1		1	1											5
Catostomus commersoni	white sucker							1	1	1						3	1	1	1	1	1	1	1	1	12
Catostomus discobolus	bluehead sucker														1	1									2
Catostomus latipinnis	flannelmouth sucker															1									1
Catostomus macrocheilus	largescale sucker						1	1	1	1	1	1	1	1					1	1					10
Catostomus platyrhynchus	mountain sucker									1			1		1	1						1	1	1	7
Catostomus muriei	Snake River sucker														9										1
Catostomus elongatus	blue sucker																						1		1
Ictiobus bubalus	smallmouth buffalo																						1		1

Fish Species	Common Name	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone	TOTAL
Ictiobus cyprinellus	bigmouth buffalo																						1		1
Moxostoma macrolepidotum	shorthead redhorse																					1	1	1	3
Xyrauchen texanus	razorback sucker															9									1
Piaractus brachypomus	pirapatinga												3												1
Ameiurus melas	black bullhead										3	3	3										3	3	5
Ameiurus natalis	yellow bullhead										3														1
Ameiurus nebulosus	brown bullhead								3		3		3		3										4
Ictalurus furcatus	blue catfish												3												1
Ictalurus punctatus	channel catfish										3		3	3									1	1	5
Noturus flavus	stonecat																						1	1	2
Noturus gyrinus	tadpole madtom												3												1
Pylodictis olivaris	flathead catfish												3												1
Esox americanus ssp. *vermiculatus*	grass pickerel												3												1
Esox lucius	northern pike	1	1								3	3	3				1	1	3	1	1	1	1		12
Esox lucius X masquinongy	tiger muskellunge										3												3	3	3
Umbra limi	central mudminnow										3														1
Thaleichthys pacificus	eulachon		1		1		1	1																	4
Stenodus leucichthys	inconnu	1																1							2
Coregonus artedi	cisco																					3			1
Coregonus autumnalis	Arctic cisco																	1							1
Coregonus clupeaformis	lake whitefish	1						1	1	1	3						1	1	1	1	1	1			11
Coregonus nasus	broad whitefish	1																							1
Coregonus sardinella	least cisco	1																							1
Prosopium coulterii	pygmy whitefish	1						1	1	1	1						1	1	1	1	1	1			11
Prosopium cylindraceum	round whitefish	1	1														1	1							4
Prosopium williamsoni	mountain whitefish			1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Thymallus arcticus	Arctic grayling	1	1	1	1						3	3	3		3	3	1	1	1	1	1	3	1	3	17
Salvelinus alpinus	Arctic charr												3												1
Salvelinus confluentus	bull trout	1	1	1	1		1	1	1	1	1	1	1		9		1	1	1	1	1	1			18
Salvelinus fontinalis	brook trout							3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	17
Salvelinus malma	Dolly Varden		1	1	1	1	1	1	1								1		1			3			10

Fish Species	Common Name	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone	TOTAL
Salvelinus namaycush	lake trout	1	1	1	1			1	1	1	3	3	3		3	3	1	1	1	1	1	1	3	3	20
Salvelinus fontinalis X namaycush	splake										3										3	3		3	4
Oncorhynchus aguabonita	golden trout										3		3	3	3	3					3	3	3	3	9
Oncorhynchus clarki ssp. bouvieri	Yellowstone cutthroat trout										3	3	3		1						3	3	3	1	8
Oncorhynchus clarki behnkei	Snake River fine-spotted cutthroat trout														1										1
Oncorhynchus clarki	coastal cutthroat trout		1		1	1	1	1		1															6
Oncorhynchus clarki ssp. *henshawi*	Lahontan cutthroat trout										3														1
Oncorhynchus clarki ssp. *lewisi*	westslope cutthroat trout									1	1	1	1							3	3	1	1	3	9
Oncorhynchus clarki ssp. *pleuriticus*	Colorado River cutthroat trout															1									1
Oncorhynchus mykiss	steelhead		1		1	1	1	1	1	1	1		1												9
Oncorhynchus mykiss	rainbow trout	3	1	1	1	1	1	1	1	1	1	3	1	3	3	3	1	3	1	3	1	3	3	3	23
Oncorhynchus gorbuscha	pink salmon		1		1	1	1	1	1	1															7
Oncorhynchus keta	chum salmon	1	1		1	1	1	1										1							7
Oncorhynchus kisutch	coho salmon	1	1		1	1	1	1	1	1	9		9										3	3	12
Oncorhynchus nerka	sockeye salmon		1		1	1	1	1	1	1	1		1												9
Oncorhynchus nerka	kokanee		1		1		1	1	1	1	1	1	1		3	3			1			3	3	3	15
Oncorhynchus tshawytscha	Chinook salmon	1	1		1	1	1	1	1	1	9		1	9				1					3		13
Salmo salar	Atlantic salmon										3														1
Salmo trutta	brown trout										3		3	3	3	3					3	3	3	3	9
Salmo trutta X Salvelinus. ssp. *fontinalis*	tiger trout										3					3								3	3
Percopsis omiscomaycus	trout perch										3							1		1	1	1			5
Percopsis transmontana	sand roller												1												1
Lota lota	burbot	1		1	1			1	1	1	1	1					1	1	1	1	1	1	1	1	16
Gambusia affinis	western mosquitofish										3		3									3		3	4
Poecilia reticulata	guppy														3								3		2
Poecilia latipinna	sailfin molly																					3	3		2
Poecilia mexicana	shortfin molly														3								3		2
Xiphophorus hellerii	green swordtail																						3		1
Xiphophorus maculatus	southern platyfish																						3		1
Xiphophorus variatus	variable platyfish																						3		1

Fish Species	Common Name	Yukon	Taku	Stikine Up.	Stikine Lo.	Small	Nass	Skeena	Fraser	Thompson	Columbia Up.	Kootenay Up.	Columbia Mid.	Wood	Snake	Green	Liard Up.	Liard Lo.	Peace Up.	Peace Lo.	Athabasca	Saskatchewan	Missouri	Yellowstone	TOTAL
Culaea inconstans	brook stickleback										3							1		1	1	1	1	1	7
Gasterosteus aculeatus	threespine stickleback		1		1	1	1	1																	5
Cottus aleuticus	coastrange sculpin		1		1		1	1																	4
Cottus aleuticus	prickly sculpin		1	1	1		1	1	1	1	1		1					1	1	1					12
Cottus bairdii	mottled sculpin										1		1		1	1							1	1	6
Cottus beldingii	Paiute sculpin												1		1										2
Cottus cognatus	slimy sculpin	1	1		1		1	1	1	1	1	1					1	1	1	1					13
Cottus confusus	shorthead sculpin										1		1		1							1	3		5
Cottus leiopomus	Wood River sculpin													1											1
Cottus rhotheus	torrent sculpin									1	1	1	1												4
Cottus ricei	spoonhead sculpin																1	1	1	1	1	1			6
Myoxocephalus thompsonii	deepwater sculpin																					1			1
Ambloplites rupestris	rock bass										3														1
Lepomis cyanellus	green sunfish										3												3		2
Lepomis gibbosus	pumpkinseed										3	3	3			3							3	3	6
Lepomis gulosus	warmouth												3												1
Lepomis macrochirus	bluegill										3		3	3		3							3	3	6
Micropterus dolomieu	smallmouth bass										3	3	3	3	3								3		6
Micropterus salmoides	largemouth bass										3	3	3	3									3	3	6
Pomoxis annularis	white crappie												3										3		2
Pomoxis nigromaculatus	black crappie										3		3		3								3	3	5
Etheostoma exile	Iowa darter																				1	1	1		3
Perca flavescens	yellow perch										3	3	3	3	3					1		1	3	3	9
Sander canadensis	sauger																						1		1
Sander vitreus	walleye										3		3		3			1		1			3	3	7
Aplodinotus grunniens	freshwater drum																						1		1
Cichlasoma nigrofaciatum	convict cichlid														3										1
Hemichromis letourneuxi	African jewelfish																					3			1
"Tilapia"	tilapia														3										1
Oreochromis mossambicus	Mozambique tilapia										3				3										2
Platichthys stellatus	starry flounder				1																				1