Fishery Data Series No. 14-04

Fish Inventory and Anadromous Cataloging in the Susitna River, Matanuska River, and Knik River Basins, 2003 and 2011

by

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

During August, 2003, and July-August 2011, the Alaska Department of Fish and Game, Division of Sport Fish conducted an inventory of stream fish assemblages and associated aquatic and riparian habitats in a 53,445 km^2 study area comprising the upper Cook Inlet basin bounded by the Alaska Range to the north and west, the Chugach Mountains to the south, and the Copper River basin to the east. We visited 357 study sites in streams ranging in size from wadeable headwaters to the mainstem Susitna River. At each site, we collected data describing some or all of the following: site location; aquatic habitat; riparian vegetation; and fish-assemblage composition. Fish were collected primarily using backpack and boat mounted electrofishers. In total, 19 fish species, representing 12 genera and 7 families were found. Anadromous fish were documented at 114 study sites. As a result of this inventory, a total stream length of 830 km of previously unlisted anadromous fish habitat was added to the State of Alaska's *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes*.

Key words: fish inventory, stream survey, anadromous, *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes*, Anadromous Waters Catalog, electrofishing, Susitna River, Knik River, Matanuska River, Skwentna River, Yentna River, Alaska, Rainy Pass, Skwentna, Palmer, Wasilla, Willow, Talkeetna, freshwater fish, Arctic lamprey, *Lampetra camtschatica*, Pacific lamprey, *Lampetra tridentata*, longnose sucker, *Catostomus catostomus*, northern pike, *Esox lucius*, humpback whitefish, *Coregonus pidschian*, pygmy whitefish, *Prosopium coulteri*, round whitefish, *Prosopium cylindraceum*, Arctic grayling, *Thymallus arcticus*, pink salmon, *Oncorhynchus gorbuscha*, chum salmon, *Oncorhynchus keta*, coho salmon, *Oncorhynchus kisutch*, rainbow trout, *Oncorhynchus mykiss*, sockeye salmon, *Oncorhynchus nerka*, Chinook salmon, *Oncorhynchus tshawytscha*, Dolly Varden, *Salvelinus malma*, burbot, *Lota lota*, threespine stickleback, *Gasterosteus aculeatus*, ninespine stickleback, *Pungitius pungitius*, slimy sculpin, *Cottus cognatus*.

INTRODUCTION

The State of Alaska is committed to conserving fish habitat. Alaska is the only state with a constitutional mandate[1] to maintain sustained yields of fish stocks (ADCCED 2009), and the Alaska Department of Fish and Game (ADF&G) has a statutory responsibility to manage the use of wild fish stocks for sustained yield (AS 16.05.730(a)). Along with proper management of harvests, protection of fully functioning and connected aquatic habitats is necessary to sustain fish stocks supporting Alaska's commercial, subsistence, personal use, and recreational fishing economies.

The Alaska State Legislature has enacted several statutes to protect fish habitat. Alaska Statute (AS) 16.05.871 (the Anadromous Fish Act), along with the Fishway Act (AS 16.05.841, which requires that fish passage be maintained in any stream "frequented by salmon or other fish"), constitute Alaska's strongest and most comprehensive instream fish-habitat protection standards. Several other Alaska statutes specifically reference fish habitat, including multiple sections in AS 41.17 (Forest Resources and Practices Act) and AS 46.15 (Water Use Act), both administered by the Department of Natural Resources, and AS 46.03.758 (Civil penalties for discharges of oil), administered by the Department of Environmental Conservation.

The Anadromous Fish Act requires ADF&G to "specify the various rivers, lakes and streams or parts of them" that are important to the spawning, rearing or migration of anadromous fish. The *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes* (Anadromous Waters Catalog, AWC) and its associated atlas are the media used to accomplish this specification, and are adopted as regulation under 5 AAC 95.011. Activities and uses conducted in, or otherwise affecting, either any AWC-listed water bodies (under the

[1] The Constitution of the State of Alaska; Article 8, Section 4 – Sustained Yield states "Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses."

Anadromous Fish Act), or fish passage in any fish-bearing waters (under the Fishway Act) statewide, require prior approval from the ADF&G Division of Habitat, which is responsible for reviewing project plans and specifications submitted by permit applicants. Permitting biologists work closely with project applicants to ensure that project plans provide for the proper protection of fish habitat. If so, a Fish Habitat Permit is issued authorizing the activity. Permit applications may be denied if impacts to fish habitat cannot be adequately avoided, minimized, or mitigated.

Many other federal, state, and local government policies specify additional protections for anadromous fish habitat in Alaska. Like the Anadromous Fish Act, however, these only apply to those waters where anadromous fish use is explicitly documented, typically by reference to the AWC. For example, the National Marine Fisheries Service (NMFS) identifies Essential Fish Habitat (EFH) for Alaska stocks of Pacific Salmon in freshwater by reference to the AWC. Three of the U.S. Army Corps of Engineers' regional conditions for nationwide permits in Alaska specify additional requirements and restrictions for proposed projects located in or near AWC-listed water bodies. Other policies that protect AWC-listed water bodies are found in: area plans for state lands; state forest management plans; resource management plans for Bureau of Land Management (BLM) lands; federal and state regulations specifying waters closed to commercial and subsistence fishing; and city and borough ordinances.

Comprehensive fish-distribution information is required for effective land use, conservation, and restoration planning to identify sensitive and important habitats. State land management plans, such as the *Susitna Area Plan* and the *Bristol Bay Area Plan*, and more specific plans such as the *Kenai Peninsula Brown Bear Conservation Strategy*, identify management guidelines or specify geographic areas of concern based in large part on the known distribution of fish. Watershed and conservation planning efforts also rely heavily on knowledge of fish distributions and aquatic habitat characteristics and their spatial and temporal relationship to other resources and activities. Planning for habitat restoration programs, such as fish-passage enhancement, is also better informed with access to comprehensive fish-distribution information.

Resource developments, such as transportation and utility corridors, are most effectively informed if complete fish distribution data is available at project onset. If comprehensive fish-distribution information is provided during project scoping, projects can be designed to avoid habitat impacts; however, absence of comprehensive fish distribution information can lead to unintended fish habitat impacts.

All these fish-habitat conservation authorities and planning processes are limited, however, by the extent of current knowledge of fish habitats and their distribution. The Anadromous Fish Act, along with other federal, state, and local government policies that refer to the AWC, provides protection only to those waters listed in the AWC. Listing new water bodies requires site specific, direct, and unambiguous observations of anadromous fish followed by a biological and public review process. Habitat modeling, speculation, or professional judgment is not sufficient to add water bodies to the AWC.

Previous field inventories have demonstrated significant data gaps in the understanding of Alaskan freshwater fish distribution and habitat characteristics. For example, recent (2003–2008) anadromous waters cataloging work resulted in a 75% increase in the sum of the lengths of AWC-listed streams, and a 72% increase in the number of cataloged water bodies, in the Nushagak River basin. The state has limited authority to protect undocumented fish habitat.

To refine fish-habitat management in specific waters, resource agencies also need knowledge of local aquatic and riparian habitat characteristics. Since aquatic and riparian habitats vary in their sensitivity to human activities these habitat characteristics should be well understood when planning or permitting general or specific activities. Physical and biological characteristics of riparian and aquatic habitats are important factors in determining appropriate best management practices and mitigation strategies. Documenting habitat characteristics at fish-collection reaches also provides baseline information for comparison with future studies, and may contribute to improved understanding of fish–habitat associations.

Since statehood, ADF&G biologists have conducted numerous field surveys to provide information needed to manage and protect fish habitat. Typically, these surveys have targeted imminent or active development or resource extraction projects or other specific local issues (e.g., footprint of an individual project, individual species, or specific local drainages). While small scale, project driven surveys will continue to be necessary, effective and efficient management and protection of Alaska's fish habitat also requires a proactive and larger scale approach. ADF&G's Alaska Freshwater Fish Inventory (AFFI) program was implemented in 2002 to help meet this need.

The long term goal of the AFFI program is to complete a statewide baseline inventory of fish communities and associated aquatic and riparian habitats. Since 2002, we have completed AFFI projects covering 33 (Table 1) of Alaska's 139 subbasins:

Table 1.–Completed AFFI Projects since 2002.

HUC	Name	Year
19020402	Matanuska	2011
19020501	Upper Susitna River	2003, 2011
19020502	Chulitna River	2003, 2011
19020503	Talkeetna River	2003, 2011
19020504	Yentna River	2003, 2011
19020505	Lower Susitna River	2003, 2011
19020601	Redoubt-Trading Bays	2002
19030301	Upper Nushagak River	2003, 2005, 2006
19030302	Mulchatna River	2003, 2005, 2006
19030303	Lower Nushagak River	2003, 2005, 2006
19030402	Farewell Lake	2007
19030403	Takotna River	2007

HUC	Name	Year
19030404	Holitna River	2009
19030405	Stony River	2007
19030501	Aniak	2009
19040301	MF-NF Chandalar Rivers	2010
19040404	Ramparts	2004
19040507	Tanana Flats	2004
19040508	Nenana River	2004
19040511	Lower Tanana River	2004
19040601	Upper Koyukuk River	2010
19040602	South Fork Koyukuk River	2010
19040701	Tozitna River	2004
19040801	Anvik River	2008
19040802	Upper Innoko River	2008
19040803	Lower Innoko River	2008
19040804	Anvik to Pilot Station	2008
19050102	Unalakleet	2009
19050103	Norton Bay	2004
19050105	Imuruk Basin	2004
19050201	Shishmaref	2004
19050202	Goodhope-Spafarief Bay	2004
19050203	Buckland River	2004

AFFI field surveys are typically watershed based, and follow standard AFFI protocols in sampling fish communities and aquatic and riparian habitats in all (or nearly all) non-AWC-listed streams draining at least 50 km^2 in the selected watersheds. All AFFI field data, along with other fish-collection records (e.g., selected records reported to ADF&G in scientific/educational fish-collection permit reports), are stored for long term usage in the AFFI database (AFFID) at the ADF&G regional office in Anchorage. ADF&G's *Fish Resource Monitor*, available at http://gis.sf.adfg.state.ak.us/FlexMaps/fishresourcemonitor.html, displays all AFFID sites on an interactive base map and provides public access to summary reports for all AFFID records, along with AFFI site photos.

During the summers of 2003 and 2011 we completed an AFFI field survey of stream fish assemblages and associated aquatic and riparian habitat characteristics, focusing on non-AWC-listed streams in 6 subbasins in Southcentral Alaska: the Matanuska and Knik rivers; the Upper Susitna River; the Chulitna River; the Talkeetna River; the Yentna River; and the Lower Susitna River.

Surveys in 2003 were limited to selected wadeable streams in the Susitna River basin (HUC 190205). In 2011 we expanded the study area to include HUC 19020402 and sampled additional non-AWC-listed streams including wadeable streams draining at least 50 km^2 that were missed in 2003 and nonwadeable streams draining at least 200 km^2. In 2011, we also sampled all the major rivers draining at least 1,500 km^2 throughout the study area and conducted an aerial survey for Chinook salmon spawners in the Upper Susitna River Subbasin upstream of Devils Canyon.

STUDY AREA AND SETTING

The 53,445 km^2 study area (Figure 1) comprised the upper Cook Inlet basin bounded by the Alaska Range to the north and west, the Chugach Mountains to the south, and the Copper River basin to the east. The study area was watershed based, encompassing all freshwaters draining to Cook Inlet and Knik Arm between the Lewis River to the west and the Knik River to the east, excluding any lands located within conservation unit boundaries (i.e., Denali National Park and Preserve [NP&P], Lake Clark NP&P, Denali State Park [SP] and Chugach SP). Major rivers in the study area included the Susitna, Yentna, Skwentna, Kahiltna, Deshka (Kroto Creek), Chulitna, Talkeetna, Maclaren, Tyone, Matanuska, and Knik rivers, all of which have a glacial source, except for the Tyone and Deshka rivers.

Subbasins and Major Water Bodies

Table 2 lists some physiographic characteristics of the 6 upper Cook Inlet subbasins comprising the study area. The landforms described below generally follow the physiographic boundaries delineated by Wahrhaftig (1965).

Matanuska Subbasin, HUC 19020402

The Matanuska Subbasin drains the northwestern slope of the Chugach Mountains and the southern slope of the Talkeetna Mountains. This subbasin is dominated by high and extremely rugged mountains and extensive alpine glaciers. Mountain slopes >60% are typical. The broad Matanuska and Knik valleys separate the 2 mountain ranges. Although the Matanuska Subbasin has the greatest mean elevation of all 6 upper Cook Inlet subbasins, due to the Matanuska and Knik valley lowlands, this subbasin has a substantial area below 600 m (see Table 2)[2].

The Matanuska and Knik rivers drain the Matanuska Subbasin. The Matanuska River originates from glaciers in the Chugach and Talkeetna mountains. From the confluence of Caribou Creek and the South Fork Matanuska River at an elevation of about 550 m, the mainstem Matanuska River flows west then south for about 110 km to Knik Arm. The Knik River flows west for 40 km into Knik Arm from the terminus of Knik Glacier at an elevation of 150 m elevation. Clearwater side channels within the mainstem Matanuska and Knik river braid plains provide suitable habitat for spawning salmon (Curran et al. 2011).

All tributaries in the Matanuska subbasin draining ≥ 200 km^2 have a glacial source. Wasilla (144 km^2), Jim (123 km^2), and Cottonwood (63 km^2) creeks are the only non-glacial streams draining ≥ 50 km^2 accessible to salmon in the Matanuska Subbasin[3].

A waterfall located approximately 9 km upstream on Caribou Creek prevents fish movement farther upstream into the Caribou Creek drainage.

There are 2 large (≥ 2 km^2) lakes in the Matanuska Subbasin: Inner Lake George (25 km^2) and Gull Lake (2.3 km^2).

We excluded 187 km^2 of the Matanuska Subbasin located in Chugach SP from our study area (Figure 1.–Study area map.).

Upper Susitna River Subbasin, HUC 19020501

Topography of the Upper Susitna River Subbasin is varied. Low rolling mountains are the most common landform, with ranges of moderately to extremely high rugged mountains, including the south slope of the Alaska Range, the Clearwater Mountains, and the north slope of the Talkeetna Mountains. Nearly level to rolling plains, thought to be the former bed of a large paleo-glacial lake, are widespread in the eastern portion of the subbasin. Broad, flat outwash plains occur at the foot of several Alaska Range glaciers in the Susitna and Maclaren River headwaters. Despite being the largest of the 6 upper Cook Inlet subbasins, the Upper Susitna River Subbasin provides the least area < 600 m elevation (Table 2), which is limited to the Susitna River valley floor downstream of the Oshetna River.

The upper Susitna River mainstem originates from glaciers in the Alaska Range at an elevation of about 850 m and flows south for approximately 110 km to the Tyone River confluence, picking up flow from 2 major tributaries, the Maclaren and Tyone rivers, in this segment. The Susitna River above the Maclaren River is unconfined and heavily braided. Downstream of the Tyone River confluence (elevation 670 m), the Susitna River swings westward and enters a more confined, single channel segment with a series of narrow, steep walled canyons for about 130 km, exiting Devils Canyon at Portage Creek (elevation 275 m). From Portage Creek, the Susitna River swings back southward through low rolling mountains for approximately 80 km to

2 Elevation appears to play an important role in limiting the extent of salmon distribution in upper Cook Inlet streams and throughout Alaska as over 95% of the total length of AWC (2012 version) listed streams in this region are below the 600 m contour. The highest elevation AWC water body in upper Cook Inlet is at 963 m in the Middle Fork Chulitna River (site no. 08C04 in this study).

3 Hicks Creek and 3 Caribou Creek tributaries drain >50 km^2 and apparently lack glaciers, but are likely not accessible to salmon.

Talkeetna at the confluence with the Chulitna and Talkeetna rivers at an elevation of approximately 110 m.

Six of the 25 upper Susitna River tributaries draining ≥ 200 km^2 flow from glaciers in the Alaska Range (5) and Talkeetna Mountains (1). At least 14 are clear (no glacial flow), and 5 more appear to be moderately influenced by small remnant glaciers.

A waterfall located approximately 6 km upstream on Tsusena Creek, and another about 1 km upstream on Deadman Creek, likely prevent fish from moving farther upstream into these drainages.

There are 14 large lakes scattered across the Upper Susitna River Subbasin, including 10 in the Tyone River watershed (Lake Louise, Susitna Lake, Tyone Lake and 7 smaller lakes), Sevenmile Lake (Maclaren River), Big Lake (Watana Creek), Butte Lake (Butte Creek), and the 6 interconnected Fog Lakes (Fog Creek).

We excluded 230 km^2 of the Upper Susitna River Subbasin located in Denali SP from our study area (Figure 1).

Chulitna River Subbasin, HUC 19020502

The Chulitna River Subbasin drains the southern slope of the Alaska Range. Extremely high and rugged mountains with extensive alpine and valley glaciers along the western flank of the subbasin are the dominant landform. Mountain slopes >60% are typical, and slopes >100% are common along Mt. McKinley's East and South buttresses and peaks and ridges in the Mt. Hunter and Mt. Huntington vicinity. The broad, gently sloping Chulitna River lowlands drain this subbasin to the south between flanking mountain ranges. The mountains west of the Chulitna lowlands are steep, relatively high in elevation and extensively glaciated while the mountains to the east are lower in elevation, rugged, and sparsely glaciated with small, remnant alpine glaciers. A flat, low elevation wetland plain occurs in the former confluence zone of the Tokositna, Ruth, and Eldridge glaciers. Although the Chulitna Subbasin drains some of the highest Alaska Range peaks and ridges, due to the Chulitna lowlands, this subbasin has a substantial area below 600 m (Table 2).

The Chulitna River mainstem coalesces in the upper subbasin at Honolulu (elevation 425 m) from 3 main forks, the glacial West Fork, the mostly clear (but glacially influenced) East Fork, and the clear Middle Fork. From the confluence, the mainstem Chulitna River flows south for approximately 110 km to the confluence with the Susitna and Talkeetna rivers at an elevation of approximately 110 m, picking up flow from 4 substantial Alaska Range glacial tributaries along the way. For most of its course, the mainstem Chulitna River channel is unconfined and heavily braided, but there are at least 2 canyon segments.

Nine of the 12 Chulitna River tributaries draining ≥ 200 km^2 flow from glaciers in the Alaska Range to the west. The remaining 3 flow mostly clear, but are influenced by small remnant glaciers in the mountains to the east.

A waterfall located approximately 1.5 km upstream on Pass Creek likely prevents fish from moving farther up into Pass Creek.

Swan, Byers, and Spink lakes, ranging from 1–1.5 km^2 in area, are the largest lakes in the Chulitna River subbasin.

Sixty-nine percent (4,625 km^2) of the Chulitna River subbasin lies within Denali NP&P or Denali SP boundaries, and was therefore excluded from our study area (Figure 1).

Talkeetna River Subbasin, HUC 19020503

The Talkeetna River Subbasin drains the western end of the Talkeetna Mountains. From a crest of moderately high, rugged (slopes typically exceed 60%), heavily glaciated mountains in the east, relief of the Talkeetna River Subbasin generally decreases westward through low, rolling mountains (slope <30%), and eventually to the Susitna lowlands near the mouth of the Talkeetna River. In the east, 2 main valleys, the upper Talkeetna River valley and the Sheep River valley, drain the north and south slopes, respectively, of the highest Talkeetna Mountains peaks. Chunilna (Clear) Creek drains much of the lower mountains to the west.

The mainstem Talkeetna River originates from mountain glaciers at about 1,370 m elevation. From its source, the swift and braided upper Talkeetna River flows north initially then swings westward for 70 km to the Prairie Creek confluence at elevation 460 m. The 55 km section from Prairie Creek to Sheep River (elevation 150 m) flows to the southwest and includes a 16 km long, steep walled, whitewater canyon. From Sheep River, the Talkeetna River continues westward another 22 km and empties into the Susitna River at elevation 110 m.

Three (upper Talkeetna River, Iron Creek, and Sheep River) of the 6 Talkeetna River tributaries draining ≥ 200 km^2 flow from glaciers on the crest of the Talkeetna Mountains. The remaining 3 (Prairie, Disappointment, and Clear creeks) head in the lower, non-glaciated western mountains and flow clear.

A waterfall located approximately 3.5 km upstream on Disappointment Creek likely prevents fish from moving farther up into Disappointment Creek.

There are 2 large (≥ 2 km^2) lakes in the Talkeetna River subbasin: Stephan Lake (3.6 km^2) at the head of Prairie Creek, and; Larson Lake (2.4 km^2), located in the lower Talkeetna River drainage between Sheep River and Clear Creek.

Yentna River Subbasin, HUC 19020504

Extremely high and rugged mountains with extensive alpine and valley glaciers rim the Yentna River Subbasin, from southern Alaska Range peaks in the north including McKinley (6,194 m), Foraker (5,304 m), Hunter (4,442 m), and Russell (3,557 m), to the northern Tordrillo Range peaks Torbert (3,479 m) and Gerdine (3,431 m) in the south. Along the crest of the Alaska Range and Tordrillo Mountains, slopes >60% are typical, and slopes >100% are common. Connecting the higher ranges to the north and south, a continuous rim of moderately high (1,500–2,400 m), but still very rugged, lightly glaciated mountains arcs along the western flank of the subbasin. From its western mountain crest, the Yentna River Subbasin descends steeply to broad glacial outwash plains gently sloping to the Susitna River in the southeast. Although the Yentna River Subbasin drains North America’s highest peak, of the 6 subbasins comprising the study area, this subbasin has the second greatest amount of area below 600 m elevation due to the presence of the extensive Yentna lowlands (Table 2).

The mainstem Yentna River originates at the terminus of Yentna Glacier at 213 m elevation in Denali NP and flows south through a broad braid plain for 45 km to the confluence with the West Fork at 61 m elevation. The next 60 km segment coalesces to a single meandering channel (with side channels) and flows southeast to a right bank confluence with a major tributary, the

Skwentna River, at 38 m elevation. From the Kahiltna River, the Yentna River traverses the final 45 km to the Susitna River at 12 m elevation.

Eleven of the 17 Yentna River Subbasin tributaries draining ≥ 200 km^2 flow from glaciers in the Alaska Range or Tordrillos. The other 5 are clear, and 1 is mostly clear with some glacial influence.

No waterfalls which would prevent fish passage are documented on streams draining > 200 km^2 in the Yentna River Subbasin.

There are 4 large (≥ 2 km^2) lakes in the Yentna River Subbasin: Chelatna Lake (15.7 km^2) at the head of Lake Creek; Shell (6.1 km^2) and Hewitt lakes (2.6 km^2) near Skwentna, and; Hiline Lake (2.1 km^2) in the Talachulitna River drainage.

Twenty-seven percent (4,317 km^2) of the Yentna River subbasin lies within Denali NP&P or Lake Clark NP&P boundaries, and was excluded from our study area (Figure 1).

Lower Susitna River Subbasin, HUC 19020505

The Susitna lowlands are the dominant landform of the Lower Susitna River Subbasin, covering over 60% of the subbasin. This level to rolling (slope generally < 5%), low elevation (sea level—300 m elevation) plain bisects the subbasin from north to south, and is contiguous with the adjacent Matanuska and Knik, Chulitna, and Yentna lowlands. The basin floor is comprised of fine textured glacio-lacustrine deposits ringed by coarse glacial tills and outwash (Nowacki et al. 2001). The eastern quarter of the subbasin drains the moderately high elevation (1,200–2,300 m), rugged (slopes frequently > 60%) western slope of the Talkeetna Mountains rimming the upper Kashwitna River catchment, with glaciers capping the northern aspect of its crest above about 1,830 m elevation. A western lobe of the Lower Susitna River Subbasin, comprising the Alexander Creek and Lewis River watersheds, drains low (300–1,200 m), rolling (slopes generally 15–60%) mountains (Beluga Mountain, Mount Susitna, and Little Mount Susitna).

Near Talkeetna, the lower Susitna River mainstem coalesces from 3 major tributaries, the upper Susitna, Chulitna, and Talkeetna rivers, draining their respective subbasins described above. From Talkeetna, the Susitna River mainstem flows south through a broad braid plain along the western toe of the Talkeetna Mountains for about 80 km to the right bank confluence with the Deshka River at about 20 m elevation, then continues another 19 km south to the right bank Yentna River confluence at about 12 m elevation. From the Yentna River mouth, the Susitna River flows another 40 km south into Cook Inlet.

Eleven of the 14 Lower Susitna River Subbasin tributaries draining > 200 km^2 are clear, 2 (Kashwitna River and Sheep Creek) are mostly glacial, and 1 (Little Susitna River) is mixed.

No waterfalls which would prevent fish passage are documented on streams draining > 200 km^2 in the Lower Susitna River Subbasin.

There are 8 large (≥ 2 km^2) lakes in the Lower Susitna River Subbasin, including: Big (12.2 km^2); Figure Eight (7.2 km^2); Flat Horn (5.7 km^2); Red Shirt (4.7 km^2); Trapper (4.7 km^2); unnamed (near Figure Eight, 3.2 km^2); Nancy (3.1 km^2), and; Alexander (3.0 km^2) lakes.

Since there are no national or state parks intersecting the Lower Susitna River Subbasin, the entire subbasin was included in our study area.

Table 2.–Summary characteristics of the 6 upper Cook Inlet subbasins comprising the study area.

		Area[a]		Elevation (m)		Glaciated area[d]		Lake/pond area[d]	
HUC	Name	km^2	km^2 < 600 m[b]	Max[c]	Mean[b]	km^2	% of HUC	km^2	% of HUC
19020402	Matanuska	9,070	1,820	4,016	1,208	2,033	22	53	0.6
19020501	Upper Susitna River	16,277	754	4,055	1,068	788	5	412	2.5
19020502	Chulitna River	6,712	1695	5,761	1,078	1,406	21	40	0.6
19020503	Talkeetna River	5,274	951	2,697	1,095	315	6	30	0.6
19020504	Yentna River	15,895	7,274	6,194	822	2,353	15	115	0.7
19020505	Lower Susitna River	9,579	7,593	2,377	326	83	1	224	2.3
Total		62,807	20,087	6,194	916	6,978	11	874	1.4

[a] *Source*: Watershed Boundary Dataset for Alaska. Available at: http://datagateway.nrcs.usda.gov/ [Accessed January 5, 2011].

[b] *Source*: National Elevation Dataset for Alaska. Available at http://ned.usgs.gov/ [Accessed January 18, 2006].

[c] *Source*: National Geographic TOPO! 1:63,000 scale topographic maps for Alaska. ArcGIS map service available at http://www.esri.com/data/free-data/ [Accessed February 23, 2011].

[d] *Source*: National Hydrography Dataset for Alaska. Available at http://nhd.usgs.gov/ [Alaska dataset dated October 11, 2011 downloaded April 11, 2012].

Climate

The study area has a transitional climate from the maritime influence of the Pacific coast to the continental climate of the Interior. The maritime influence is mitigated due to sheltering from the surrounding mountains, especially the Chugach Mountains, which block warm, moist Pacific air, forming a rain shadow on the north side of the mountains. The eastern portion of the Upper Susitna River Subbasin (i.e., the Tyone River drainage), which is on a high plateau contiguous with the Copper River basin, experiences a continental climate more similar to Interior Alaska with warm summers, cold winters, and light and irregular precipitation.

Mean annual air temperature varies throughout the study area from 0–2 C (32–36 F) at low elevations, to -4 C (25 F) throughout most of the Upper Susitna River Subbasin, to less than -6 C (21 F) in the Alaska Range and Talkeetna and Chugach mountains (Jorgenson et al. 2008). Permafrost is discontinuous (50–90%) over most of the study area, but varies in extent from absent/isolated patches in the Susitna, Matanuska, and Knik lowlands to continuous (90–100%) in the eastern portion of the Upper Susitna River Subbasin (Brown et al. 1998).

Mean annual precipitation ranges from <38–76 cm in the Susitna and Matanuska valleys and along the perimeter of the Copper River basin to 152–305 cm in the Alaska Range and Talkeetna Mountains, to as high as 711+ cm along the crest of the Chugach Mountains (PRISM 2000).

Fish Species Previously Documented In The Study Area

HDR (2011) summarized existing information (largely from studies conducted by ADF&G in the early 1980s for Alaska Power Authority's Susitna River hydroelectric project) on fishes of the Susitna River basin. They listed 19 documented species of anadromous and resident freshwater fish in the Susitna River drainage. Other sources document 4 additional species in the study area (see Table 3). According to HDR (2011), 2 additional undocumented species, Pacific lamprey (*Lampetra tridentata*) and Alaska blackfish (*Dallia pectoralis*) may also occur in the Susitna River drainage.

Table 3.–List of fish species previously found in the study area.

Common name	Scientific name	Common name	Scientific name
Arctic lamprey[a]	*Lampetra camtschatica*	coho salmon[a]	*Oncorhynchus kisutch*
longnose sucker[a]	*Catostomus catostomus*	sockeye salmon[a]	*Oncorhynchus nerka*
northern pike[a]	*Esox lucius*	Chinook salmon[a]	*Oncorhynchus tshawytscha*
eulachon[a]	*Thaleichthys pacificus*	Arctic char[b]	*Salvelinus alpinus*
Bering cisco[a]	*Coregonus laurettae*	Dolly Varden[a]	*Salvelinus malma*
humpback whitefish[a]	*Coregonus pidschian*	lake trout[a]	*Salvelinus namaycush*
round whitefish[a]	*Prosopium cylindraceum*	burbot[a]	*Lota lota*
pygmy whitefish[c]	*Prosopium coulterii*	threespine stickleback[a]	*Gasterosteus aculeatus*
Arctic grayling[a]	*Thymallus arcticus*	ninespine stickleback[d]	*Pungitius pungitius*
rainbow trout[a]	*Oncorhynchus mykiss*	sculpin[a]	Cottidae sp.
pink salmon[a]	*Oncorhynchus gorbuscha*	slimy sculpin[e]	*Cottus cognatus*
chum salmon[a]	*Oncorhynchus keta*	prickly sculpin[f]	*Cottus asper*

[a] HDR 2011.

[b] Havens 1988. See also: unpublished manuscript by Jack Dean, Fishery Biologist (retired), 2001, titled *Arctic char in Southcentral Alaska: a status report*, obtained from ARLIS Library, Anchorage. Arctic char are reported from Big, Flat, Never-Never, and Sara lakes (Fish Creek drainage near Wasilla) and Benka Lake (Susitna River drainage near Talkeetna).

[c] Pygmy whitefish were previously found in Lake George, Knik River drainage (M. Wiedmer and J. Buckwalter, Habitat Biologists, ADF&G, Anchorage, unpublished data, 2005; see also Wiedmer et al. 2010).

[d] Rich and Buckwalter (2003) documented ninespine stickleback in the Meadow Creek (Fish Creek tributary) drainage near Wasilla. Ninespine stickleback were also documented in the lower Susitna River and Little Susitna River drainages in unpublished field data prepared by Lynn Noel, ENTRIX Inc., for the Northern Rail Extension EIS and submitted to ADF&G under Fish Resource Permit No. 08-188 in 2008.

[e] McPhail and Lindsey (1970) reported slimy sculpin occur in the Susitna River. Rich and Buckwalter (2003) confirmed slimy sculpin occur in the Susitna River drainage and documented slimy sculpin in the Little Susitna River and Meadow Creek (Fish Creek, near Wasilla) drainages.

[f] Havens (1988) documented prickly sculpin in Big Lake (Fish Creek drainage near Wasilla). Mecklenburg et al. (2002), Morrow (1980), and McPhail and Lindsey (1970) report Seward, Alaska as the northern/western limit for prickly sculpin.

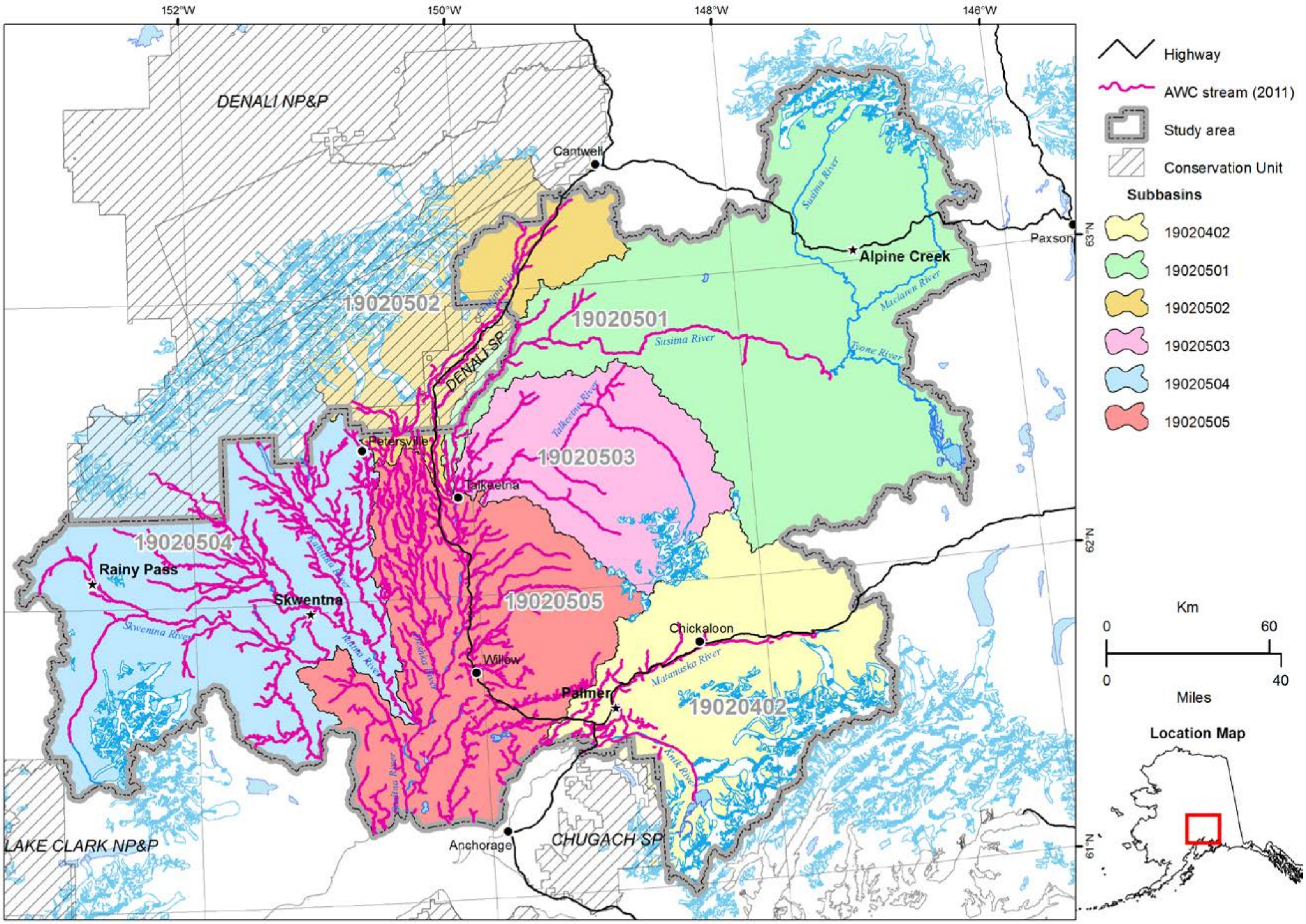

Figure 1.–Study area map.

OBJECTIVES

The overall goal of the AFFI program is to provide information needed for management of the habitats that support Alaska's freshwater fishes. This project contributed to that goal by achieving the following objectives:

Objective 1: To maximize the spatial increase of mapped anadromous fish habitat depicted in the AWC by completing a baseline inventory of fish (with emphasis on anadromous fish) assemblages in the Susitna River, Matanuska River, and Knik River basins.

- Task 1: Locate fish-collection reaches to maximize the spatial increase of specified anadromous fish habitat in targeted streams while minimizing the number of study sites per stream. At each reach, record GPS (Global Positioning System) coordinates and the occurrence and type of barriers to fish passage.
- Task 2: Sample each reach using standardized fish collection techniques and sufficient sampling effort to document the presence of all common fish species occurring in the reach at the time of sampling.
- Task 3: Record the species, life stage, number, and fork or total length of all fish collected, and record the species, life stage, and (estimated) number of visually observed (but not collected) fish from each fish-collection reach. Describe the fish collection effort and extent of area sampled.
- Task 4: For each water body in which anadromous fish are observed, submit a nomination form to the AWC, providing sufficient information to achieve the intended result (i.e., addition, deletion, correction, or backup information).

Objective 2: To record characteristics of aquatic and riparian habitats at each study site such that sufficient information is documented to: (a) identify well supported and adequate habitat protection stipulations for permitting of local low level disturbances; or (b) identify specific further sampling needs necessary to design adequate habitat protection stipulations or mitigation for permitting moderate or greater level disturbances.

- Task 1: Record a suite of standard aquatic habitat parameters at each study site.
- Task 2: Characterize the dominant riparian vegetation communities at each study site.

Objective 3: For nonwadeable streams (Intermediate and Mainstem target streams)—To develop stopping rules to guide fish-inventory field crews in estimating when a sufficient length of stream has been sampled to meet Objective 1, Task 2.

- Task 1: At each nonwadeable stream, record fish observations separately for a minimum of 10 spatially sequential subreaches (or as many as can be sampled in 1 day), each equivalent in length to 10 wetted channel widths. Sample additional subreaches as necessary until no new fish species are recorded from 6 consecutive subreaches.
- Task 2: Based on field data collected at nonwadeable target streams, develop appropriate stopping rules for single-pass electrofishing in nonwadeable Alaskan rivers.

Objective 4: To identify locations of spawning Chinook salmon aggregations in Upper Susitna River Subbasin tributaries upstream of Devils Canyon by aerial reconnaissance.

METHODS

In 2011 we followed the methods of Buckwalter et al. (2010) as modified by Buckwalter et al. (2012). In 2003 we used a different approach to select target streams, and some fish-collection and aquatic habitat measurement procedures varied slightly from the 2011 protocol. In 2003 we deployed just 1 team of 3 to wadeable target streams; whereas, in 2011 we deployed 3 teams of 2, with 1 team sampling wadeable streams and the other 2 teams sampling nonwadeable streams and rivers.

FIELDWORK DATES AND BASES

On August 1, 2003, we conducted a 1-day aerial (helicopter) reconnaissance to locate spawning Chinook salmon in selected upper Susitna River tributaries between Devils Canyon and Jay Creek. The main 21 field sampling days in 2003 occurred during August 4–30. We based at Talkeetna during August 4–7 and 18–20, at Gracious House Lodge (Mile 82 Denali highway) during August 13–16, and at Skwentna Airstrip during August 18–30.

In 2011, the main 21 field sampling days with the full crew and helicopter support occurred during August 3–24. We based at Alpine Creek Lodge (Mile 68 Denali Highway) during August 3–16, at Palmer Airport during August 18–24, and at Puntilla Strip during August 15–17 (Headwaters-Team only).

In advance of the main August 2011 trip, we sampled several mainstem target streams that were accessible by jet boat. Three jet boat trips were conducted: 1) June 30 (Knik River; day trip); 2) July 12–14 (Yentna, Skwentna, and Kahiltna rivers); and 3) July 19–21 (mainstem Susitna River). On July 27–28, we also conducted a 2-day aerial reconnaissance trip to identify spawning Chinook salmon aggregations in Upper Susitna River Subbasin tributaries upstream of Devils Canyon (see Objective 4).

In 2011, we also conducted several short sampling trips following the main August trip. During September 12–13, a team returned to the Yentna River Subbasin by helicopter to sample remaining wadeable target streams. And from September 14–23 we conducted several day trips to wadeable sites in the Knik River drainage near Palmer, Alaska, focusing on streams crossed by East Knik River Road and ATV trails in the Knik River Public Use Area.

By conducting the core of our fieldwork during August, we believed we would maximize our chances of observing a variety of anadromous fishes, especially stream rearing species and life stages, at the upstream limits of their range, to achieve Objective 1. We presumed that anadromous fishes rearing in headwater streams (i.e., mainly age-0 and age-1 coho and Chinook salmon) would be at or near their maximum upstream distribution in the study area during August, after emerging and dispersing from their natal habitats, but prior to the onset of rapidly cooling waters in the fall, when they likely begin moving to their winter habitats. And, according to Sam Ivey (personal communication, Fishery Biologist, ADF&G Div. of Sport Fish, Palmer, June 16, 2011), the end of July is typically the best time to find adult Chinook salmon on spawning grounds in the Upper Susitna area, so we targeted this period for the 2-day aerial survey trip.

TARGET STREAMS

In 2003 we selected as target streams all streams having non-AWC-listed segments having an estimated gradient of ≤ 10% and exceeding the minimum length criterion established for each survey area. The minimum length criterion was 7.9 km for the Yentna River basin, 9.0 km for the Skwentna River basin, 5.6 km for the Lake Creek basin, 2.6 km for the Talkeetna area (including streams in the Talkeetna River basin and Lower Susitna River Subbasin), and 12 km for upper Susitna River tributaries between Fog Creek and the Tyone River. We also added several individual streams requested by fish-habitat permitting biologists to the set of target streams.

In 2011, according to the methods of Buckwalter et al. (2010), we defined 3 stream size classes based on upstream drainage (catchment) area. *Headwaters* drain at least 50 km^2, *Intermediate Streams* drain at least 200 km^2, and *Mainstems* drain at least 1500 km^2. From these 3 classes, we selected a prioritized set of target streams, as described below.

Headwaters Target Streams

According to the methods of Buckwalter et al. (2010), we identified and ranked all non-AWC-listed *Headwaters* target streams in the study area. A set of 160 *Headwaters* target streams remained after we removed from consideration any candidate streams that were: 1) already listed in the AWC; 2) located entirely within a conservation unit; 3) streams we had already surveyed in 2003; or 4) located upstream of known fish migration barriers (e.g., waterfalls and glaciers).

Intermediate Target Streams

Using the same methods and criteria described above for selecting and ranking *Headwaters* target streams, we selected as target streams and ranked all 41 qualifying *Intermediate* streams in the study area.

Mainstem Target Streams

We selected as target streams all 11 *Mainstem* rivers in the study area, including the Knik, Deshka, Skwentna, Yentna, Kahiltna, Susitna, Maclaren, Tyone, Chulitna, Talkeetna, and Matanuska rivers. Eight of these rivers were already listed in the AWC at the point where the drainage area first exceeded 1500 km^2, and 3 were not. We included the 8 AWC-listed *Mainstem* target streams to add additional anadromous species and life stages to the AWC, and to document the complete fish assemblage occurring in these streams.

FISH-COLLECTION REACHES

At each *Headwaters* and *Intermediate* target stream sampled in 2011, and target streams sampled in 2003, the crew leader selected a fish-collection reach location during slow, low level helicopter reconnaissance according to the methods of Buckwalter et al. (2010). For the *Mainstem* target streams, fish-collection reach locations were selected in the office prior to fieldwork according to the methods of Buckwalter et al. (2010) for Jet-Boat Team fish-collection reaches. We selected 1 reach on each of the 11 *Mainstem* target streams listed above. Moreover, to sample fish assemblages representing the middle and lower reaches of the largest *Mainstem* target streams, which we presumed would likely result in the addition to the AWC of new anadromous species/life stages, we identified 3 additional *Mainstem* reaches to be sampled in the Susitna River and 1 additional reach in the lower Yentna River.

Reach Length

For *Headwaters* target streams sampled in 2011 and all target streams sampled in 2003, we sampled a standard reach length of 40 channel widths (CW), with a minimum reach length of

150 m and a maximum of 300 m. We previously demonstrated that a reach length of 40 CW is likely sufficient to detect within 1 species of the estimated true species richness 90% of the time in western Alaska (middle Kuskokwim and eastern Norton Sound drainages) headwaters streams (unpublished data, Daniel Reed, ADF&G biometrician, July 2010, Nome Alaska). And a 40 CW reach is consistent with the findings of other studies in wadeable coldwater streams (e.g., Patton et al. 2000, Reynolds et al. 2003, Temple and Pearsons 2007).

Analysis of prior (2007–2010) AFFI fish collections indicated that single-pass electrofishing in a 40 CW reach typically underestimates true species richness in nonwadeable streams of Western and Interior Alaska (Buckwalter et al. 2012). Therefore, to better ensure that all common species of the extant fish assemblage were detected in nonwadeable streams, in 2011 we sampled a minimum reach length of 120 CW (or as much as we could sample in one day), and we continued to collect data (as described under Objective 3 Task 1) to develop and assess regional sampling sufficiency recommendations for Alaskan nonwadeable streams (see the *Objective 3—Sampling Sufficiency* section under the *Data Analysis* heading, below).

WAYPOINTS AND STATIONS

At each study site, we marked a waypoint[4] at the habitat transect using a handheld, consumer grade GPS receiver (Garmin GPSMAP 60CSx). We referred to this point location as the Station. If fish sampling was attempted, we also marked additional GPS waypoints at the upstream and downstream ends of the fish-collection reach. If a fish-collection reach was established in the absence of a habitat transect (e.g., when we aerially observed an aggregation of adult fish spread throughout a stream segment), we referred to the upstream terminus of the fish-collection reach as the Station. We also established a Station at sites with no habitat transect and no fish-collection reach, such as: target streams lacking a suitable landing zone; target streams deemed unlikely to support anadromous fish use; target streams deemed to be inaccessible or nonwadeable; waterfalls or other definite migratory barriers (Appendix B3); or other features of interest.

FISH-COLLECTION METHODS

According to protocols of Buckwalter et al. (2012), and as detailed in Appendix A1 (wadeable streams) and Appendix A2 (nonwadeable streams), we sampled the fish assemblage in each reach by single-pass electrofishing, supplemented occasionally with other methods (i.e., visual observations, angling, dip net, beach seine, and minnow trap). Table 4 lists variables associated with fish-collection events and fish catch that were recorded at each study site.

In 2011, on behalf of the University of Alaska Museum, Fairbanks, we retained (fixed in 10% formalin solution) 182 individually tagged whole fish specimens from 26 sites, along with (right side, pectoral or pelvic) fin clips (in 95% ethanol) from 149 fish from 24 sites (Appendix I1).

In 2011, we retained up to 12 specimens of optionally-anadromous fishes >250 mm fork length from each site where they were collected, including 14 humpback whitefish collected from 4 sites and 23 Dolly Varden collected from 9 sites (Appendix I2). We froze the whole fish the same day they were collected, then thawed them in the fall of 2011, took fin clips for genetic analysis (see Appendices I1 and I3), recorded biological and meristic data (Appendix J), and extracted the sagittal otolith pair. After removing any soft tissue from the otoliths, we put each

[4] To minimize GPS error when marking waypoints, we used the waypoint-averaging mode (10 s).

pair of dry otoliths in a uniquely labeled glass sample vial and sent them to the USFWS in Fairbanks (c/o Randy Brown, Fishery Biologist) to be tested for periods of saltwater residency. If otolith-chemistry tests provide evidence of saltwater residency, we will also nominate for inclusion in the AWC the water bodies where these specimens were found, along with the downstream route to saltwater.

In 2011, on behalf of the USFWS Conservation Genetics Laboratory, Anchorage we retained (in vials with silica beads) for genetic analysis (right side, pelvic) fin clips from 97 Dolly Varden from 21 sites (Appendix I3).

AQUATIC AND RIPARIAN HABITAT ASSESSMENT

At each site where fish collection was attempted, we established a habitat transect and measured a suite of habitat variables describing water quality, channel dimensions, streamflow, and riparian vegetation according to the methods of Buckwalter et al. (2010) as modified by Buckwalter et al. (2012). Table 4 lists the variables that were typically recorded at each habitat transect, along with any associated instruments, measurement units and precision (continuous variables), and domain (list of possible values of categorical variables).

In 2003 the following methods differed from those used in 2011:

- In 2003 we used a Horiba U-10 water quality checker to measure water temperature, pH, conductivity, dissolved oxygen, and turbidity. In 2011 we used a YSI 556 meter and a Lamotte 2020e turbidimeter to measure these variables. The YSI 556 was set to display ambient conductivity (without temperature compensation), which is preferred for adjusting electrofisher output settings; however, the U-10 used an automatic temperature conversion function to calculate conductivity at 25°C, using a temperature coefficient of 2%/°C. Therefore, we converted the 2003 temperature compensated conductivity values reported by the U-10 to ambient conductivity values as:

  $L_t = L_{25}(1 + 0.02[t - 25])$, where:

  L_t = ambient conductivity at t

  L_{25} = conductivity at 25°C (value displayed on U-10)

  t = water temperature at time of measurement (°C)

- In 2003 we did not record substrate embeddedness, channel entrenchment ratio, or thalweg velocity.
- We measured channel width and thalweg depth at the ordinary high water level (OHW) in 2003 and at the bankfull level in 2011.

Table 4.–List of variables to be collected during fieldwork.

Variable name	Equipment	Units/Domain	Precision	Comment
Geographic information				
Project Code and Station ID	-	text	-	5-digit alphanumeric—see Waypoints and Visits heading in text.
Station location Upper end of reach Lower end of reach	consumer-grade GPS unit (e.g. Garmin GPSmap 60CSx or 76S)	decimal degrees: latitude (DD.DDDDD); longitude (-DDD.DDDDD)	0.00001 degrees	
Geodetic datum		Text	-	Default is WGS84.
Water-body name	Water-body name from USGS topo map	text	-	
Geographic comments	-	text	-	Describes location of study site in relation to adjacent long-term or permanent geographic features
Observers	-	list of field staff	-	
Date/time	field notebook computer	mm/dd/yyyy hh:mm:ss	1 s	Value input automatically from computer's clock when data entry is begun
Camera counter	-	sequential integers	-	List of photo filenames (last 3 digits only) associated with each station
Visit comments	-	text	-	Physical and biological conditions at the station during the visit—focus on ephemeral conditions, such as weather or stream conditions, or the dynamics of riparian conditions, that may help explain other recorded observations
Wildlife comments	-	text	-	Anecdotal wildlife observations, particularly those that relate to fish.
Water quality				
Water temperature	YSI 556 meter (2011)	°C	0.01 °C	Sample thalweg
pH	Horiba U-10 water quality checker (2003)	pH units	0.01 pH units	Sample thalweg
Dissolved oxygen		mg/L	0.01 mg/L	Sample thalweg
Conductivity		µS/cm	1 µS/cm	Ambient conductivity (not temperature corrected). Sample thalweg
Turbidity	LaMotte 2020e turbidimeter	NTU	1 NTU	Sample thalweg
Water color	-	see Appendix B4	-	

-continued-

Table 4.–Page 2 of 4.

Variable name	Equipment	Units/Domain	Precision	Comment
Channel morphology				
Channel width (wetted and bankfull [BF, 2011]/OHW [2003])	30-m fiberglass tape	m	0.1 m	In wadeable channels < 30 m wide
	laser range finder (Bushnell Yardage Pro)	m	1 m	In nonwadeable channels, or where width > 30 m
Thalweg depth (wetted and BF [2011]/OHW [2003])	handheld sonar (HawkEye Digital Sonar) and clinometer (to find the BF level)	m	0.1 m	For nonwadeable channels
	graduated rod	m	0.01 m	All teams—wadeable channels
Stream gradient	clinometer (Sokkia 5x magnifying abney level with clinometer, or Suunto PM-5)	%	0.1%	Water surface angle between consistent channel features near habitat transect.
Substrate composition	-	see Appendix B4	-	3 most dominant substrate classes within scoured portion of streambed in a 5 CW (<100 m) section centered on habitat transect.
Embeddedness category (not measured in 2003)	Visual estimate	see Appendix B4	-	Estimated embeddedness of gravel, cobble, and boulder particles in, or as near to as possible, the thalweg in a 5 CW (<100 m) section centered on the habitat transect.
Entrenchment ratio category (not measured in 2003)	Visual estimate or laser range finder (floodprone width), and see channel width (BF)	1.0–1.4=entrenched; 1.41–2.2=moderately-entrenched; >2.2=slightly-entrenched	-	Entrenchment ratio (Rosgen 1994) = flood-prone width ÷ BF width. Flood-prone width is the width of the floodplain measured at a water level of twice the thalweg BF depth.
Stream type	see Channel width, Thalweg depth and Stream gradient	Rosgen (1994) stream types, plus the following: Lake/Pond; Slough; Beaver pond complex; Wetland; or No defined channel	-	To be determined in the office following fieldwork based on BF width and BF depth (width-to-depth ratio), gradient, entrenchment ratio, dominant substrate, and estimated sinuosity values.
Streamflow				
Stream stage	-	See Appendix B4	-	Water level relative to BF stage.
48-hour precipitation	-	none/trace, moderate, heavy	-	

-continued-

Table 4.–Page 3 of 4.

Variable name	Equipment	Units/Domain	Precision	Comment
Streamflow (continued)				
Thalweg velocity (not measured in 2003)	Transparent velocity-head rod (TVHR)	Head depth (mm)→mean water column velocity (m/s)	1 mm (0.1 m/s)	Wadeable streams, depth <0.9 m
	Whole orange, fiberglass tape, stopwatch	m/s	0.1 m/s	Wadeable streams (alternate). Timed orange float through a 6-m length.
	consumer-grade GPS unit (Garmin GPSmap 60CSx or 76S)	m/s	0.1 m/s	Nonwadeable streams—maximum sustained GPS velocity of boat drifting in thalweg.
Meter type	-	TVHR, orange, or GPS	-	
Riparian vegetation communities				
Riparian vegetation composition	-	Viereck et al. (1992) vegetation communities	-	Dominant vegetation community recorded in 8 zones (4 zones on each bank): 0-5 m (from OHW); 5-10 m; 10-20 m; 20-30 m
Canopy height	graduated rod (< 1.5 m); clinometer & range finder (> 1.5 m)	m	0.1 m (< 1.5 m); 0.5 m (>1.5 m)	Recorded for each of the 8 zones described above
Disturbance	-	Disturbance classes (Appendix B6)	-	
Fish-collection events				
Channel	-	main-, side-, or off-channel	-	Channel type of fish-collection event
Fish-collection method	-	backpack electrofisher, boat electrofisher, visual observations (ground, boat, or helicopter), dipnet, angling, none	-	
Waveform	electrofisher setting	DC-pulsed; DC-unpulsed	-	
Voltage		V	1 V	(LR-24 only)
Range		Low or High	-	(GPP 2.5 only)
Percent of range		0–100 %	Continuous	(GPP 2.5 only)
Frequency		pulses per second (pps)	1 pps	
Duty cycle		%	1%	(LR-24 only)
Current	electrofisher output meter	A	0.01 A (LR-24); 0.1 A (GPP 2.5)	Peak current (LR-24); average current (GPP 2.5)
Power	electrofisher output meter	W	1 W	Peak power (LR-24 only)
Electrofisher on-time	electrofisher timer	s	1 s	
Efficiency	-	excellent, good, fair, poor	-	Perceived electrofishing efficiency, relative to optimal conditions.

-continued-

Table 4.–Page 4 of 4.

Variable name	Equipment	Units/Domain	Precision	Comment
Catch				
Reach length	GPS (trip computer mode, or track)	m	1 m	Indicate actual length of fish-collection reach, measured by GPS.
Species	-	list of Alaskan freshwater fish species	-	
Life stage	-	see Appendix B1	-	
Life history	-	anadromous, freshwater-resident, marine, unknown, N/A	-	
Suspect spawning	-	yes, no	-	
Barrier	-	see Appendix B3	-	
Fork length	fish measuring board	mm	1 mm	
Sex	-	male, female, blank (if sex was not determined)	-	
Anomalies	-	see Appendix B2	-	
Retained	-	Checkbox (Y/N)	-	Indicate each individual fish retained.
Tag No.	-	10-digit alphanumeric text	-	For retained specimens, indicate the tag number affixed to each fish.
Vial No.	-	10-digit alphanumeric text	-	If a tissue sample was taken, indicate the vial number.
Photo No.	Digital camera	3-digit positive integer	1	For each fish photographed, indicate the photo number (last 3 digits of the photo filename) for each photo taken. May use comma or hyphen to separate non-sequential photo numbers or indicate a range of photo numbers.
Individual fish comments	-	text	-	Comments pertaining to an individual fish (e.g., sampling injuries or mortalities, unusual features or behavior)
Additional counts	-	integer--no. of fish	1 fish	
Estimated	-	yes, no	-	Indicates whether the no. of additional fish recorded above was an estimate or a direct count
Species-life-stage comments	-	text	-	Comments pertaining to an entire group of fish of the same species and life stage

DATA ANALYSIS

Stream-Size Groups

We grouped the reaches sampled based on drainage area (km^2) upstream of the habitat transect to compare fish occurrence and distributions of habitat variables across stream sizes as follows: wadeable (Small) streams, ≤100 km^2; nonwadeable streams, >100 km^2. For most of the data summaries and tables in the Results section and appendices, we further subdivided the nonwadeable streams into Medium (100–500 km^2) and Large (>500 km^2) streams.

Graphical Summaries of Frequency Distributions

We created a variety of graphs (Appendix G1) to display frequency distributions of categorical variables. We created side-by-side box plots[5] to graphically display the distributions of selected numeric habitat variables and visualize how distributions of each variable differ within stream-size (Appendix G2) and species-occurrence (Appendix G4) groups. Likewise, we created frequency histograms to visualize how fish fork length distributions varied between species and among stream-size groups (Appendix G3). We derived catch per unit effort (CPUE) for Species A as the total number of fish of Species A collected divided by the total electrofisher on time (hours) at sites where Species A was collected and created box plots summarizing CPUE for each species, within stream-size groups (Appendix G5).

We created frequency histograms (Appendix J) to display meristics data from Dolly Varden and humpback whitefish specimens retained for an otolith-chemistry study (see Appendix I2).

Supplemental Data Analyses

When we examined side-by-side plots of numeric variables grouped by stream size (Appendix G2 and Appendix G3) and species occurrence (species found vs. not found, Appendix G4), it appeared there were some variables having distributions that differed among groups. So we ran 2-tailed randomization tests (Manley 1997) to test for differences in medians of numeric variables between stream-size groups (Small vs. Medium, Small vs. Large, and Medium vs. Large streams; 100,000 simulations each—Appendix H1 and Appendix H2) and species-occurrence groups (100,000 simulations for wadeable streams and 10,000 simulations for nonwadeable streams, Appendix H3). For most species, the sample sizes (i.e., number of reaches where the species was found or not found) in nonwadeable streams were not adequate to further subdivide the nonwadeable streams into Medium and Large sub-groups, so we did not subdivide the nonwadeable streams for Appendix G4 and Appendix H3.

We also examined the data for evidence that pairs of fish species either tended to be associated or that they demonstrated a tendency to not occur at the same sites within stream-size groups (wadeable or nonwadeable reaches). We constructed contingency tables (2x2) for each pair of species to test the null hypothesis that the occurrence of species A at a site was independent of the occurrence of species B at a site. Fisher's Exact Test was used to evaluate the null hypothesis for each pair of species because contingency table cell counts were frequently small (<5) and expected values for cell counts were frequently < 1.0 (Agresti 1990). Regardless of the significance of test results, nominal positive or negative association between each pair of species was determined by examining marginal values for each contingency table.

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[5] The box plots in this report display the median (50th percentile) as a black dot (●), and the 1st (25th percentile) and 3rd (75th percentile) quartiles as the lower and upper ends of the box. The ends of the whiskers represent the lowest value still within 1.5 IQR (interquartile range, i.e., the difference between the 3rd and 1st quartiles) of the 1st quartile, and the highest value still within 1.5 IQR of the 3rd quartile. Outliers (values beyond 1.5 IQR) are represented as open circles.

Objective 3—Sampling Sufficiency

True species richness (*TSR*) was estimated for each nonwadeable fish-collection reach where sampling sufficiency data were collected, and compared to observed species richness (*SR*), the total number of species found in a reach. For a site *i*, where data were collected over a series of n_i subreaches, *TSR* and *SR* were compared at the conclusion of each subreach beginning with the 4th subreach and continuing to the n_ith subreach.

A Horvitz-Thompson estimator (Cochran 1977) was used to estimate *TSR*. For each observed species *s* in *SR* in the sample of n_i subreaches for site *i*, the probability that this species was detected in one subreach was estimated:

$$\hat{p}_{s,i} = \frac{n_{s,i}}{n_i} \qquad (1)$$

where $n_{s,i}$ is the number of subreaches n_i where species *s* was detected. We then calculated the probability that the species would not have been detected by sampling n_i subreaches:

$$1 - \hat{p}_s = \left(1 - \hat{p}_{s,i}\right)^{n_i} \qquad (2)$$

from which we can directly calculate $\hat{p}_s$, and estimate the probability that the species can be detected at site *i* with n_i sampled subreaches. The Horvitz-Thompson estimate of *TSR* was calculated as a sum across all detected species:

$$TSR_{H-T} = \sum_{j=1}^{SR} \frac{1}{\hat{p}_s}. \qquad (3)$$

The analytical formulae presented in Cochran (1977) for estimating the sampling variance of the Horvitz-Thompson estimator when p_s is estimated (not known with certainty) are not stable for small sample sizes. We are in the process of evaluating a bootstrap approach (Efron and Tibshirani 1993) for estimating variance using the type of data collected in this project.

To evaluate stopping rules for sampling sufficiency for nonwadable streams and rivers, we combined data from this experiment with our 2008 results from the lower Yukon River (Buckwalter et al. 2010), 2007 results from the upper Kuskokwim River and 2009 results from the middle Kuskokwim River (Kirsch et al. *In prep*), 2009 results from eastern Norton Sound (Kirsch et al. 2011) and 2010 results from the upper Koyukuk River and Chandalar River (Buckwalter et al. 2012). Two types of stopping rules were evaluated: fixed and adaptive.

Fixed stopping rules were evaluated for stream sampling where data are recorded after completion of sampling of the entire reach. Stopping rules of 80, 100, 120, and 140 wetted widths (8, 10, 12, and 14 subreaches) were considered.

The estimate TSR_{H-T} rounded to the nearest integer was used to indicate total species richness for each reach sampled. Observed *SR* at each stopping point was subtracted from the estimate of species richness for the entire reach to estimate the number of species undetected. The proportion of reaches, along with cumulative proportions, where an estimated 0, 1, 2, …5 or more species were missed was calculated. Only those reaches where 9 or more subreaches were sampled were used to estimate the number of undetected species per reach when evaluating stopping sampling at 8 subreaches. Those reaches where 11 or more subreaches were sampled were used to estimate undetected species when evaluating stopping at 10 subreaches, and to provide an additional evaluation for stopping at 8. Reaches with 13 or more subreaches sampled were used to evaluate stopping at 12 subreaches, and to provide additional evaluations for stopping at 10 and 8 subreaches. Reaches with 15 or more subreaches sampled were used to evaluate stopping at 14 subreaches, and to provide additional evaluations for stopping a 12, 10 and 8 subreaches.

Adaptive stopping rules were evaluated for stream sampling where data are recorded after completion of sampling of each subreach (10 wetted widths), and the series of data recorded for all subreaches is used to determine if additional sampling is necessary at that reach after sampling a minimum number of subreaches. Adaptive stopping rules had two criteria. First, a minimum number of subreaches were required to be sampled before sampling could be terminated. Minimums evaluated were 6, 8, 10, 12, and 14 subreaches. Second, sampling would be continued unless no new species were detected in the last 4 or 6 subreaches sampled. Adaptive stopping rules were evaluated using methods similar to those described above for fixed stopping rules. Observed species richness at a stopping point was subtracted from the estimated true species richness for the entire reach to estimate the number of species undetected.

Using data tabulated for fixed stopping rules described above, contingency table analyses (Agresti 1990) were used to look for evidence of differences between regions in application of stopping decision rules. Three contingency tables were analyzed based on the following data sources: all reaches with 9+ subreaches sampled using a stopping rule of 8 subreaches; all reaches with 11+ subreaches sampled using a stopping rule of 10; and all reaches with 13+ subreaches sampled using a stopping rule of 12 subreaches. Data were categorized into 5 geographic areas (upper + middle Kuskokwim, middle Yukon, eastern Norton Sound, upper Koyukuk and Chandalar and Susitna + Matanuska + Knik streams) by estimated number of species not detected (1 or fewer vs. 2 or more). We tested the null hypothesis that the distribution of numbers of species missed was independent of geographic area. Rejection of the null hypothesis would be evidence that different stopping rules need to be considered for the different geographic areas in the data set.

To check whether drainage area matters in application of stopping rules for nonwadeable streams, the Kolmogorov-Smirnov (KS) test (Conover 1980) was used to look for differences in drainage area between reaches where 1 or fewer vs. 2 or more species were undetected. The data examined were from 105 reaches with 9+ subreaches sampled. For each reach, the difference between estimated TSR and observed species richness after sampling 8 subreaches was calculated and rounded to the nearest integer. Reaches were then categorized as reaches where 0 or 1 species were missed or as reaches where 2 or more species were missed. The cumulative distribution of drainage area was compared between these two categories of reaches using the KS test. Detection of significant differences between distributions would be evidence that different stopping rules need to be considered for different drainage areas.

RESULTS

As a result of the 114 AWC nominations generated by these projects (60 in 2003 and 54 in 2011), a total stream distance of 830 km of previously unlisted anadromous fish habitat was added to the AWC (Figure 3 and Appendix E). Additional anadromous species or life stages were documented in 18 previously cataloged streams. Station reports and digital photos are available on the AFFI interactive mapping website at http://www.adfg.alaska.gov/index.cfm?adfg=ffinventory.interactive, and are also included in Appendix J of this report. We created maps to display study site locations and species found (Appendix C) and fish distribution, by species (Appendix D).

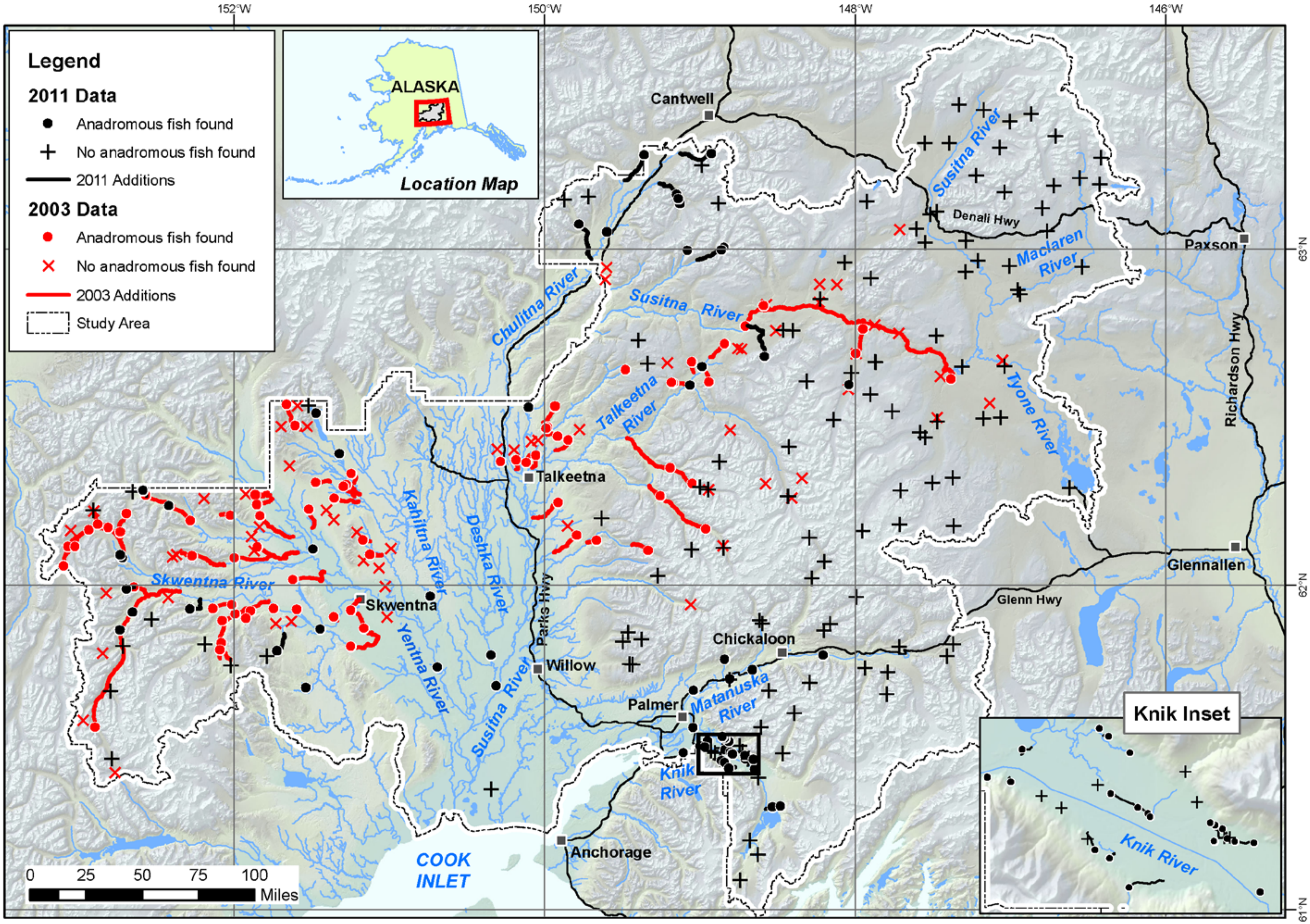

Figure 2.–Map of new or extended AWC water bodies resulting from ADF&G inventories in 2003 and 2011.

We attempted to collect fish at a total of 275 sites (105 in 2003 and 170 in 2011). Single-pass electrofishing was the primary fish-collection method at 242 (88%) of them. Of the 242 electrofished sites, 152 were in Small streams, 63 in Medium streams, and 27 in Large streams. Of the remaining 33 sites where fish collection was attempted, 30 were sampled primarily by minnow traps (6.35 cm mesh) baited with cured salmon roe, and 3 were sampled primarily by dipnet. At 44 additional sites, we observed fish, but made no attempt to collect them (e.g., visual observations of adult salmon).

At an additional 38 sites, we marked a waypoint, took photos, and created a station record in the database, but did not attempt to collect or observe fish—28 of these sites represented waterfalls, 6 represented target streams that we flew by but did not sample (typically no suitable landing zone, or stream was unsafe to sample), and 4 represented other features of interest (i.e., Station ID FSS1103G01 Devils Canyon flyby, Station ID FSS1113C08 mining camp along the Skwentna River, Station ID FSS1117A02 “Hotel Rocks” on the Chickaloon River, and Station ID FSS1101F04 ATV trail crossing a Knik River tributary).

We found at least 1 fish at 223 (92%) of the 242 electrofished sites, including representatives of 19 species and 7 families (Table 5). 11 of the 19 species were members of the salmonid family (Salmonidae—including salmon, trout, char, whitefishes, and grayling). Salmonidae was the dominant family across all 3 stream sizes, occurring at 100% of sites in Large streams and 86% of sites in Medium and Small streams sampled by electrofisher. Occurring at 92% of the electrofished sites in Large streams, 57% in Medium streams, and 50% in Small streams, Cottidae (sculpins) was the second most dominant family. We found at least 1 anadromous fish at 76 (31%) of the 242 electrofished sites.

We found 13 fish species in Small streams, 13 in Medium streams, and 16 in Large streams. In Small streams, Dolly Varden (85 sites, 56%) and slimy sculpin (75 sites, 49%) occurred at the greatest number of electrofished sites. In Small streams, we found no longnose sucker, northern pike, humpback whitefish, pygmy whitefish, or chum salmon, and only 1 Small stream had lamprey. In Medium streams, slimy sculpin (35 sites, 56%) and Dolly Varden (29 sites, 46%) occurred most frequently. And in Large streams, slimy sculpin (21 sites, 78%) and Arctic grayling (19 sites, 70%) were most ubiquitous. We found lampreys, northern pike, humpback whitefish, pygmy whitefish, pink salmon, chum salmon, and sticklebacks (threespine and ninespine) at only <5% of the electrofished sites, and, with the exception of sticklebacks, these less common species were found almost exclusively in nonwadeable streams. We found no fish at 20 electrofished sites in Small streams and at 6 in Medium streams (Table 5).

Appendix F1 summarizes occurrence (number of electrofished sites) of fish species by stream size and life stage. Round whitefish, Arctic grayling, rainbow trout, Chinook salmon, Dolly Varden, and slimy sculpin were the only species for which both juveniles and adults were reported from all 3 stream-size groups. Only adult Pacific lamprey, pink salmon, and chum salmon life stages were found (no other life stages were found for these species). No juvenile coho or sockeye salmon were found in Large streams. Adult round whitefish and burbot were found only in nonwadeable streams.

Appendix G1 shows frequency distributions of dominant riparian vegetation communities (*sensu* Viereck et al. 1992). Shrub communities dominated the riparian zone within 30 m of the edge of the stream in Small and Medium streams. In Small streams, tall, closed willow scrub (IIB1a) was the most prevalent riparian vegetation community. In Medium streams, IIB1a, along with tall, closed alder-willow scrub (IIB1d) were co-dominant. In Large streams, IIB1d and IIB1a were dominant within 5 m of the stream, and closed, mixed spruce - paper birch forest (IC1a) and closed white spruce forest (IA1j) were co-dominant in the zone from 20 to 30 m from the stream, with the zones in between showing a transition from shrub to forest types.

Appendix G1 also shows frequency distributions of water-color, dominant substrate, embeddedness, and Rosgen (1994) stream types. The water color category we identified most frequently in Small (66%) and Medium (51%) streams was "Clear". However, most Large streams we sampled had a "Glacial, high turbidity" color (49%), followed by “Clear” (46%).

Cobble was most frequently the dominant substrate class in Small (43%) and Medium (58%) streams; however, in Large streams, gravel most frequently (35%) occurred as the dominant substrate type.

Substrate embeddedness was most frequently rated low or negligible in Small (67%) and Medium (60% streams), but was rated moderate to very high in 52% of Large streams.

In the reaches we sampled, the most prevalent level-I Rosgen (1994) stream type across all stream sizes was C, followed by B in Small and Large streams and D in Medium streams.

Average CPUE (total number of fish collected while electrofishing/total electrofisher on-time) was 84 fish/h in Small streams, 45 fish/h in Medium streams, and 44 fish/h in Large streams. When calculated separately for each species, CPUE was greatest for most species in Small streams, with a few exceptions (Appendix G5).

Supplemental Data Analyses

In Appendix G2, side-by-side box plots show distributions of selected numeric habitat variables, grouped by stream size. For each variable, Appendix H1 lists up to 3 *p*-values from randomization tests for a difference in the medians for each pair of stream-size groups. Low ($\leq$0.05) *p*-values suggest the medians differ among stream-size groups.

Median pH, turbidity, conductivity, thalweg velocity, and channel width and depth all tended to increase from Small to Large streams. For pH, Medium streams did not differ significantly from Large streams. Randomization tests suggested that Medium streams had a significantly higher median elevation and dissolved oxygen than Large or Small streams and a significantly higher stream gradient than Large streams. Water temperature was the only numeric habitat variable showing no significant difference in medians between stream-size groups.

Frequency histograms of fish fork lengths (mm), along with the number of species found per electrofished reach, grouped by stream size, are shown in Appendix G3. For each species, and for the number of species found, Appendix H2 lists up to 3 *p*-values from randomization tests for a difference in the medians for each pair of stream-size groups. Low ($\leq$0.05) *p*-values suggest the medians differ among stream-size groups.

The number of species found per site ranged from 0 to 11 (Appendix G3). Randomization tests suggested that Large streams had a significantly higher median number of species per site (mean = 5.1, median = 5) than Medium (mean = 2.1, median = 2) or Small (mean = 1.9, median = 2) streams (Appendix H2).

Randomization tests also showed some apparently significant differences in median fish fork length between stream sizes (Appendix G3 and Appendix H2):

- The median length of Arctic grayling in our catch appeared to be significantly lower in Small (121 mm, *n*=160) vs. Medium (250 mm, *n*=195) and Large (220 mm, *n*=175) streams.
- The median length of juvenile coho salmon in our catch appeared to be significantly lower in Small (52 mm, *n*=569) vs. Medium (59 mm, *n*=27) streams, with Large streams in between (54.5 mm, *n*=24), but note the small sample sizes in Large and Medium streams.
- The median length of rainbow trout in our catch appeared to be significantly lower in Small (52 mm, *n*=73) vs. Medium (145 mm, *n*=59) and Medium vs. Large (165.5 mm, *n*=12) streams, but note the small sample size in Large streams.
- The median length of juvenile Chinook salmon in our catch appeared to be significantly greater in Large (59 mm, *n*=147) vs. Medium (50 mm, *n*=93) and Small (49 mm, *n*=164) streams.
- The median length of Dolly Varden in our catch appeared to be significantly lower in Small (94 mm, *n*=717) vs. Medium (120 mm, *n*=373) and Medium vs. Large (144 mm, *n*=81) streams.

In Appendix G4, paired box plots show distributions of selected numeric habitat variables from groups of sites where a given fish species was found versus not found, grouped by stream size. Appendix H3 lists *p*-values from randomization tests to detect a significant difference in the median values for these populations. Low (≤0.05) *p*-values suggest the medians differ.

Appendix H4 lists *p*-values from contingency table analyses for apparent relationships (association or avoidance) between fish species found at electrofished sites, grouped by stream size. Low (≤0.05) *p*-values suggest that, either an interspecific relationship occurs, or the given species may have similar (or differing) habitat preferences.

Fish-Distribution Patterns

Our inspection of species occurrence maps (Appendix D), paired boxed plots of habitat variables (Appendix G4), results of tests for a difference in the median of habitat variables between groups of sites where each species was found versus not found (Appendix H3), and results of contingency table analyses for co-occurrence of fishes (Appendix H4), suggested the following fish-distribution patterns occurred in the study area during summer:

We found **Arctic-Alaskan-brook lamprey** (the ammocoetes of these 2 sister species could not be distinguished) at only 4 sites (3 Large and 1 Small stream) located in the Lower Susitna River and Yentna River subbasins (Table 5, Appendix D1). Adult specimens collected from the Deshka River (site FSS1108D01) keyed out as Arctic lamprey[a]. Although the sample size was very low, Large streams where Arctic/Alaskan-brook lamprey were found appeared to have greater median *catchment area, wetted width,* and *thalweg depth*, and lesser *elevation* and *dissolved oxygen* than where Arctic/Alaskan-brook lamprey were not found. We also did not find

[a] Six adult lamprey specimens from this site were euthanized in MS-222, fixed in 10% formalin on site, and subsequently keyed out (according to the *Key to Adults of Petromyzontidae of Alaska* in Mecklenburg et al 2002) as *L. camtschatica* by Joe Buckwalter and Raye Ann Neustel. Diagnostic characteristics indicative of *L. camtschatica* included: 2 cusps on supraoral bar; posterial teeth present; 3 pairs of lateral tooth plates; 8 cusps on infraoral bar, and; cusps on tongue teeth well developed, pointed. All the adults and ammocoetes we collected from the Deshka River also had distinct silvery sides. The specimens were sent to the UA Museum in Fairbanks c/o Andres Lopez.

any Arctic/Alaskan-brook lamprey where *water temperature* was <10.84 °C, *stream gradient* was >0.25%, or *conductivity* was >81 µS/cm. Contingency table analyses suggested that pink salmon, northern pike, and threespine stickleback tended to co-occur with Arctic/Alaskan-brook lamprey in Large streams (Appendix H4).

We collected a single adult **Pacific lamprey**[a] in the Deshka River just below the ADF&G weir at site FSS1108D01 (Table 5 and Appendix D2). The AWC does not contain any specified Pacific lamprey waters within the study area; however, listing a new species in the AWC requires more than a single specimen. The sample size was insufficient to infer any habitat associations; however, the Deshka River was unique in being one of just two *clear* Large streams in the study area (the other Large clear stream was the Tyone River in the Upper Susitna Subbasin), and also had the highest *water temperature* (17.9 °C) of any site sampled in the study area.

We found **longnose sucker** at 13 Large and 5 Medium streams in the Lower Susitna River, Upper Susitna River, and Yentna River subbasins (Table 5 and Appendix D3). Both Large and Medium streams where longnose sucker were found appeared to have lower median *stream gradient* than where longnose sucker were not found (Appendix H3). Median *dissolved oxygen* also appeared to be lower in Medium streams where longnose sucker were found. And median w*etted width*, *thalweg depth,* and *catchment* area appeared to be greater in Large streams where longnose sucker were found. Contingency table analyses suggested that round whitefish tended to co-occur with longnose sucker in Medium and Large streams, as did humpback whitefish in Large streams. In Medium streams, Arctic grayling and burbot also tended to co-occur, and Dolly Varden tended not to co-occur, with longnose sucker (Appendix H4).

We found **northern pike** in 3 Large streams in the Yentna River and Lower Susitna River subbasins (Table 5 and Appendix D4). Although the sample size was very low, median *elevation* and *dissolved oxygen* appeared to be lower at these sites than at sites where no northern pike were found. We found no northern pike where *stream gradient* was >0.5%, *thalweg velocity* >1.8 m/s, or *conductivity* >106 µS/cm. Contingency table analyses demonstrate co-occurrence of northern pike with threespine stickleback, pink salmon, and Arctic or Alaskan-brook lamprey in Large streams (Appendix H4).

We found **humpback whitefish** in 5 Large streams, including 4 sites in the Upper Susitna River subbasin and 1 site in the Yentna River subbasin (Table 5 and Appendix D5). From randomization tests, median *dissolved oxygen* appeared to be higher at sites where humpback whitefish were found than where they were not found (Appendix H3). We found no humpback whitefish where *water temperature* was greater than 10.84 °C, *stream gradient* >0.6%, or *conductivity* >101 µS/cm. Contingency table analyses suggested that longnose sucker tended to co-occur with humpback whitefish in Large streams (Appendix H4).

We collected a single **pygmy whitefish**[b] from Lake Fork Knik River, a Medium stream located in the Matanuska River subbasin (Table 5, Appendix D6). The sample size was insufficient to infer habitat associations; however, the site where we collected this specimen was located about 6 km upstream of the outlet of Inner Lake George, where 6 pygmy whitefish were collected in

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[a] This Pacific lamprey specimen was fixed in 10% formalin and subsequently keyed out (according to the *Key to Adults of Petromyzontidae of Alaska* in Mecklenburg et al 2002) as *L. tridentata* by Joe Buckwalter and Raye Ann Neustel. The key diagnostic characteristic indicative of *L. tridentata* was the presence of 3 cusps on the supraoral bar. A photo of this specimen showing the dentition is included in the station report for site FSS1108D01 (see Appendix J). The specimen was sent to the UA Museum in Fairbanks c/o Andres Lopez.

[b] This pygmy whitefish specimen was fixed in 10% formalin and sent to the UA Museum in Fairbanks c/o Andres Lopez.

June 2005 (M. Wiedmer and J. Buckwalter, Habitat Biologists, ADF&G, Anchorage, unpublished data).

We found **round whitefish** in 12 Large, 10 Medium, and 4 Small streams scattered throughout the study area, but not in the Matanuska River Subbasin (Table 5, Appendix D7). In Small and Medium streams where we found round whitefish, the median *catchment area* appeared to be greater than where none were found. In Medium streams where we found round whitefish, median *dissolved oxygen* and *stream gradient* appeared to be lesser, and *thalweg depth*, *elevation*, *water temperature*, and *conductivity* greater, compared to Medium streams where we found no round whitefish. With one exception, we found no round whitefish where *stream gradient* exceeded 1%. Contingency table analyses suggested that longnose sucker tended to co-occur with round whitefish in Medium and Large streams. In Small and Medium streams, Arctic grayling and burbot tended to co-occur with round whitefish. Also, Dolly Varden tended not to co-occur with round whitefish in Medium streams (Appendix H4).

We found **Arctic grayling** in 19 Large, 25 Medium, and 25 Small streams dispersed across the study area, but most prevalent in the Upper Susitna subbasin (Table 5, Appendix D8). Across all 3 stream-size groups, median *elevation* appeared to be greater in streams where Arctic grayling were found than in streams where Arctic grayling were not found. And both Small and Medium streams where Arctic grayling were found appeared to have greater median *catchment area,* and lower *dissolved oxygen*, *thalweg velocity*, *turbidity,* and *stream gradient* (Appendix H3). Median *water temperature* also appeared to be greater in Medium streams where Arctic grayling were found. Contingency table analyses suggested that Dolly Varden tended not to co-occur with Arctic grayling across all stream sizes. In Small and Medium streams, burbot, slimy sculpin, and round whitefish tended to co-occur with Arctic grayling. Also, coho and Chinook salmon tended not to co-occur with Arctic grayling in Small streams, as did sockeye salmon in Large streams (Appendix H4).

We found adult **pink salmon** in 6 Large, 1 Medium, and 1 Small streams while electrofishing (Table 5), and in one more Small stream by visual observation (Appendix D9). We found pink salmon dispersed throughout the study area at lower elevations; however, we did not find pink salmon in the Talkeetna River or Upper Susitna River subbasins. In Large streams where we found pink salmon, median *elevation* and *dissolved oxygen* appeared to be lower, and *wetted width* and *thalweg depth* greater, than in Large streams where we did not find pink salmon (Appendix H3). We did not find pink salmon in any streams above an elevation of 430 m. In Large streams, Arctic-Alaskan brook lamprey, northern pike, sockeye salmon, and threespine stickleback tended to co-occur with pink salmon, and Arctic grayling tended not to co-occur with pink salmon (Appendix H4).

We found adult **chum salmon** in 1 Medium stream while electrofishing (Table 5), and in 1 more Medium and 2 Small streams by visual observation (Appendix D10). We found chum salmon only in the Yentna River and Matanuska subbasins (although we had few sites in the Susitna lowlands, where chum salmon were likely more prevalent). We also did not find chum salmon in any streams having a *catchment area* greater than 136 km^2, or *elevation* greater than 536 m.

We found **coho salmon** (mostly juveniles) in 3 Large, 2 Medium, and 35 Small streams while electrofishing (Table 5), plus 17 more Small, 2 Medium, and 2 Large streams by other sampling methods (minnow traps, visual observations, dip net; Appendix D11). We found coho salmon widely dispersed throughout the study area, but not in the Upper Susitna River subbasin. In

Small streams where we found coho salmon, median *catchment area, elevation, wetted width, thalweg depth,* and *pH* appeared to be lower, and *water temperature* higher, than in Small streams where we did not find coho salmon. And in Large streams where we found coho salmon, *thalweg velocity* appeared greater than in Large streams where we found no coho salmon (Appendix H3). In Small streams, contingency table analyses suggested that *Chinook salmon*, and to a lesser extent *rainbow trout*, tended to co-occur with coho salmon, and *Arctic grayling* tended not to co-occur with coho salmon. And in Large streams, *Dolly Varden* tended to co-occur with coho salmon (Appendix H4).

We found **rainbow trout** in 6 Large, 3 Medium, and 14 Small streams while electrofishing (Table 5); rainbow trout were not found by non-electrofishing methods in any additional streams. We found rainbow trout widely dispersed throughout the study area, but not in the Upper Susitna River subbasin. In Small streams where we found rainbow trout, median *catchment area, elevation, turbidity, wetted width and thalweg depth* appeared to be lower and *water temperature* higher, than in Small streams where we did not find rainbow trout. No relationships between rainbow trout presence and habitat variables were identified in Medium streams. In Large streams where rainbow trout were found, median catchment area and thalweg depth appeared to be higher than in Large streams where rainbow trout were not found (Appendix H3). Contingency table analyses suggested that in Small streams rainbow trout tended to co-occur with *coho salmon,* and not co-occur with *Dolly Varden* (Appendix H4).

We found **sockeye salmon** (mostly adults) in 7 Large, 4 Medium and 13 Small streams while electrofishing (Table 5), plus 30 more Small, 13 Medium, and 10 Large streams by other sampling methods (minnow traps, visual observations, dip net; Appendix D13). We found sockeye salmon widely dispersed throughout the study area, but not in the Upper Susitna River subbasin. In Small streams where we found sockeye salmon, median *elevation* and *water temperature* appeared to be lower than in Small streams where we did not find sockeye salmon. In Medium streams where we found sockeye salmon, median *catchment area* and *elevation* appeared to be lower than in Medium streams where we did not find sockeye salmon. In Large streams where we found sockeye salmon, median *elevation* appeared to be lower, and *catchment area, turbidity, wetted width* and *thalweg depth* higher than in Large streams where sockeye salmon were not found (Appendix H3). Contingency table analyses suggested that in Small streams sockeye salmon tended to co-occur with *threespine stickleback*, and in Large streams with *pink salmon* and *Dolly Varden*, but not co-occur with *Arctic grayling* (Appendix H4).

We found **Chinook salmon** (mostly juveniles) in 10 Large, 7 Medium and 24 Small streams while electrofishing (Table 5), plus 3 more Small, 6 Medium, and 5 Large streams by other sampling methods (minnow traps, visual observations, dip net; Appendix D14). We found Chinook salmon widely dispersed throughout the study area including several individuals in the Upper Susitna River subbasin, although none above its confluence with the Tyone River. In Small streams where Chinook salmon were found, median *elevation* appeared to be lower, and *dissolved oxygen* and *wetted width* higher than in Small streams where Chinook salmon were not found. In Medium streams where Chinook salmon were found, median *elevation* appeared to be lower than in Medium streams where Chinook salmon were not found. Median *elevation* appeared to be lower, while *conductivity* and *stream gradient* higher in Large streams where Chinook salmon were found compared to where they were not found (Appendix H3). Contingency table analyses suggested that Chinook salmon tended to co-occur with *coho salmon* and not co-occur with *Arctic grayling* in Small streams (Appendix H4).

We found **Dolly Varden** in 7 Large, 29 Medium, and 85 Small streams while electrofishing (Table 5), plus 10 more Small and 1 Medium streams by other sampling methods (minnow traps, visual observations, dip net; Appendix D15). We found Dolly Varden widely dispersed throughout the study area. In Small streams where Dolly Varden were found, median *water temperature* appeared to be lower, and *pH*, *dissolved oxygen* and *stream gradient* higher than in Small streams where Dolly Varden were not found. In Medium streams where Dolly Varden were found, median *catchment area*, *elevation* and *water temperature* appeared to be lower, while *dissolved oxygen* and *thalweg velocity* higher than in streams where Dolly Varden were not found. *Water temperature* appeared to be lower, while *pH* and *dissolved oxygen* higher in Large streams where Dolly Varden were found when compared to Large streams where Dolly Varden were not found (Appendix H3). Contingency table analyses suggested that Dolly Varden tended not to co-occur with *Arctic grayling*, *rainbow trout* and *slimy sculpin* in Small streams; *longnose sucker*, *round whitefish*, *Arctic Grayling*, *burbot* and *slimy sculpin* in Medium streams; and *Arctic grayling* in Large streams. Dolly Varden did however tend to co-occur with *coho* and *sockeye salmon* in Large streams (Appendix H4).

We found **burbot** in 11 Large, 6 Medium and 3 Small streams while electrofishing (Table 5); burbot were not found by non-electrofishing methods in any additional streams. Burbot were commonly found in the Upper Susitna River subbasin upstream of the Tyone River confluence and within the lower Yetna River and its tributaries, however to a lesser degree elsewhere within the study area. In Medium streams where burbot were found, median *dissolved oxygen*, *stream gradient* and *thalweg velocity* appeared to be lower than in Medium streams where burbot were not found. In Large streams where burbot were found, median *elevation*, *dissolved oxygen* and *stream gradient* appeared to be lower, and *catchment area*, *wetted width* and *thalweg depth* higher than in Large streams where burbot were not found (Appendix H3). Contingency table analyses suggested that burbot tended not to co-occur with *round whitefish* and *Arctic grayling* in Small streams. In Medium streams, burbot tended to not co-occur with *longnose sucker*, *round whitefish* and *Arctic grayling*, while they did tend to co-occur with *Dolly Varden* (Appendix H4).

We found **threespine stickleback** in 3 Large and 7 Small streams while electrofishing (Table 5), plus 3 more Small streams by other sampling methods (minnow traps, visual observations, dip net; Appendix D17). Threespine stickleback distribution across the study area was limited, and confined for the most part to lower elevations streams in the Susitna, Matanuska and Knik river flats with gradients at or below .5%. In Small streams where threespine stickleback were found, median *elevation* appeared to be lower than in Small streams where they were not found. In Large streams where threespine stickleback were found, median *elevation* and *dissolved oxygen* appeared to be lower than in Large streams where they were not found (Appendix H3). Contingency table analyses suggest that threespine stickleback tended to co-occur with *sockeye salmon* in Small streams, and *Arctic lamprey*, *northern pike* and *pink salmon* in Large streams (Appendix H4).

We found **ninespine stickleback** in 1 Large and 2 Small streams while electrofishing (Table 5); ninespine stickleback were not found by non-electrofishing methods in any additional streams. Ninespine stickleback were very limited in distribution only being found in 3 low elevation streams in the Lower Susitna River subbasin and the Yetna River subbasin. Due to low sample size (*n*=3), no further distributional analyses were conducted.

We found **slimy sculpin** in 21 Large, 35 Medium and 75 Small streams while electrofishing (Table 5); slimy sculpin were not found by non-electrofishing methods in any additional streams.

We found slimy sculpin widely dispersed throughout the study area, particularly in the Upper Susitna River subbasin where they were found at nearly every sample site (52 of 63 [83%]; Appendix D19). In Small streams where slimy sculpin were found, median *pH*, *dissolved oxygen*, *turbidity*, *stream gradient* and *thalweg velocity* appeared to be lower, and *water temperature* higher than in Small streams where slimy sculpin were not found. In Medium streams where slimy sculpin were found, median *pH*, *dissolved oxygen*, *turbidity*, *stream gradient* and *thalweg velocity* appeared lower, and *catchment area*, *elevation* and *water temperature* higher than in Medium streams where slimy sculpin were not found. No relationships between slimy sculpin presence and habitat variables were identified in Large streams (Appendix H3). Contingency table analyses suggested that slimy sculpin tended to co-occur with *Arctic grayling* and not co-occur with *Dolly Varden* in Small streams. In Medium streams, slimy sculpin tended to co-occur with *round whitefish* and *Arctic grayling*, and not co-occur with *Dolly Varden* (Appendix H4).

Table 5.–Occurrence (number of electrofished sites) of fish species by stream size.

			Stream size			
Family	Scientific name	Common name	Small (*n*=152)	Medium (*n*=63)	Large (*n*=27)	Total (*n*=242)
Petromyzontidae	*Lampetra camtschatica*	Arctic lamprey	0	0	1	1
	Lampetra tridentata	Pacific lamprey	0	0	1	1
	L. camtschatica or *alaskense*	Arctic or Alaskan-brook lamprey	1	0	2	3
Catostomidae	*Catostomus catostomus*	longnose sucker	0	5	13	18
Esocidae	*Esox lucius*	northern pike	0	0	3	3
Salmonidae	*Coregonus pidschian*	humpback whitefish	0	0	5	5
	Prosopium coulteri	pygmy whitefish	0	1	0	1
	Prosopium cylindraceum	round whitefish	4	10	12	26
	Coregoninae	whitefish-unspecified	0	1	4	5
	Thymallus arcticus	Arctic grayling	25	25	19	69
	Oncorhynchus gorbuscha	pink salmon	1	1	6	8
	O. keta	chum salmon	0	1	0	1
	O. kisutch	coho salmon	35	2	3	40
	O. mykiss	rainbow trout	14	3	6	23
	O. nerka	sockeye salmon	13	4	7	24
	O. tshawytscha	Chinook salmon	24	7	10	41
	Salvelinus malma	Dolly Varden	85	29	7	121
Gadidae	*Lota lota*	burbot	3	6	11	20
Gasterosteidae	*Gasterosteus aculeatus*	threespine stickleback	7	0	3	10
	Pungitius pungitius	ninespine stickleback	2	0	1	3
Cottidae	*Cottus cognatus*	slimy sculpin	75	35	21	131
	Cottidae	sculpin-unspecified	1	1	4	6
-	-	no fish found	20	6	0	26

Objective 3—Sampling Sufficiency

Estimates of total species richness, $TSR_{H\text{-}T}$ (Cochran 1977), were calculated for 45 reaches sampled in nonwadeable streams during the 2011 field season (Table 6).

Table 6.–Summary of sampling sufficiency data analysis for reaches sampled in nonwadeable streams in Susitna River, Matanuska River, and Knik River drainages in 2011.

Reach ID	Subreaches Sampled	SR[a]	Subreach when SR first observed	$TSR_{H\text{-}T}$[b]	$TSR_{H\text{-}T}$ minus SR
FSS1101a01	15	3	8	3.01	0.01
FSS1101B01	12	1	2	1.00	0.00
FSS1102A01	16	5	16	6.11	1.11
FSS1102B01	15	3	10	3.55	0.55
FSS1102D01	12	8	11	11.27	3.27
FSS1103A01	15	4	10	4.17	0.17
FSS1103B01	16	5	11	5.01	0.01
FSS1103D01	10	5	4	6.16	1.16
FSS1104A01	8	5	4	5.14	0.14
FSS1104B01	13	2	3	2.00	0.00
FSS1104D01	12	3	11	3.80	0.80
FSS1105A01	12	4	5	4.01	0.01
FSS1105B01	13	2	1	2.04	0.04
FSS1106A01	6	5	1	5.05	0.05
FSS1106b01	17	5	11	5.70	0.70
FSS1106D01	7	7	1	7.25	0.25
FSS1107A01	5	5	4	5.58	0.58
FSS1107B01	8	6	6	7.12	1.12
FSS1107D01	6	8	1	8.62	0.62
FSS1108A01	12	3	3	3.00	0.00
FSS1108B01	14	1	1	1.00	0.00
FSS1108D01	5	10	4	11.96	1.96
FSS1109A01	15	8	11	9.41	1.41
FSS1109b01	13	3	7	4.09	1.09
FSS1110A01	16	5	12	5.69	0.69
FSS1110B01	16	3	7	4.66	1.66
FSS1111A01	22	3	6	3.05	0.05
FSS1111B01	17	5	15	5.78	0.78
FSS1112A01	12	1	1	1.00	0.00
FSS1112B01	19	3	9	3.15	0.15
FSS1113A01	12	5	12	5.54	0.54
FSS1113B01	28	5	12	5.71	0.71
FSS1114A01	12	7	11	8.09	1.09
FSS1114B01	12	3	7	3.54	0.54
FSS1115A01	10	2	3	2.66	0.66
FSS1115B01	12	0	1	-	NA
FSS1116b01	13	1	13	1.55	0.55
FSS1117A01	15	1	3	1.00	0.00
FSS1117b01	24	1	1	1.00	0.00
FSS1118A01	32	2	32	2.57	0.57
FSS1118b01	22	1	2	1	0
FSS1119A01	17	4	17	4.69	0.69
FSS1119B01	18	0	0	-	NA
FSS1120A01	12	2	2	2.54	0.54
FSS1120B01	18	1	1	1.00	0.00

Note: "-" indicates that no fish were observed at a given site and therefore no estimate of true species richness ($TSR_{H\text{-}T}$) could be calculated.

[a] Observed species richness–the total number of species found in a reach.

[b] Horvitz-Thompson estimate (Cochran 1977) of the true species richness in a reach.

Total species richness appeared likely to have been achieved in 21 of the 45 reaches sampled, including 2 reaches where 0 species were detected when 12 and 18 subreaches were sampled. In the other 19 reaches, 1 to 7 species were observed in 6 to 24 subreaches sampled.

In 21 of the 45 reaches sampled, estimates of $TSR_{H\text{-}T}$ suggested that the estimated number of species missed during sampling was between 0.50 and 1.50. In these 21 reaches, the number of subreaches sampled varied from 5 to 32, and the number of species detected varied from 1 to 8.

In two reaches, the estimated number of species missed was between 1.50 and 2.50. Three species were observed in 16 subreaches sampled in one case, with 10 species observed in 5 subreaches sampled in the other.

In one reach, the estimated number of species missed was between 2.50 and 5.50. Eight species were observed in 12 subreaches sampled.

To evaluate both fixed and adaptive stopping rules for nonwadeable streams in Alaska, these 2011 results were combined with 4 other data sets collected during 2007–2010 (Buckwalter et al. 2010, Buckwalter et al. 2010, Kirsch et al. 2011, Kirsch et al. *In prep*). When examining the distributions of the estimated numbers of species undetected using fixed stopping rules, we detected no significant evidence to indicate that different stopping rules were necessary for the different geographic areas. No differences between geographic areas were detected using reaches with 9+ subreaches sampled and a stopping rule of 8 ($\chi^2 = 1.64$, $p = 0.80$), with 11+ subreaches sampled and a stopping rule of 10 ($\chi^2 = 5.34$, $p = 0.25$), or with 13+ subreaches sampled and a stopping rule of 12 ($\chi^2 = 4.31$, $p = 0.37$).

When using the KS test to compare the distributions between reaches where 1 or fewer vs. 2 or more species were undetected, we found significant evidence that reaches should be stratified by drainage area (D = 0.401, $p = 0.001$). After stratifying sampled reaches into those draining up to 300 km^2 and those draining greater than 300 km^2, we detected no evidence that further stratification was required. As a result, we evaluated stopping rules for nonwadeable streams for reaches in 2 strata: reaches draining ≤ 300 $km^{2;}$ and reaches draining > 300 km^2.

When evaluating fixed stopping rules for nonwadeable streams in Alaska draining ≤ 300 km^2, we found that a minimum of 120 stream widths (12 subreaches) should be sampled per reach to provide an estimated 90% probability of failing to detect no more than 1 of the species occurring in each reach (Table 7). Sampling 100 stream widths provides only a 80% chance of failing to detect no more than 1 species, based on estimates of species richness from reaches where 130+ stream widths were sampled. Sampling 80 stream widths provides only a 73% chance of failing to detect no more than 1 species, based on estimates of species richness from reaches where 130+ stream widths were sampled.

When evaluating fixed stopping rules for nonwadeable streams in Alaska draining > 300 km^2, we found that sampling a minimum of 120 stream widths (12 subreaches) would provide an estimated 73% probability of failing to detect no more than 1 of the species occurring in each reach (Table 8). We were not able to identify a sampling intensity that would provide our target 90% chance of failing to detect no more than 1 species. Our data indicate that the required sampling effort would be in excess of 140 stream widths (14 subreaches).

Table 7.–Estimated number of undetected species per reach for nonwadeable reaches draining 0–300 sq. km, when sampling is stopped after 80, 100, 120, and 140 stream widths.

Source data[a]	Estimated # of undetected species	Stopping after 80 stream widths %	Stopping after 80 stream widths cumulative %	Stopping after 100 stream widths %	Stopping after 100 stream widths cumulative %	Stopping after 120 stream widths %	Stopping after 120 stream widths cumulative %	Stopping after 140 stream widths %	Stopping after 140 stream widths cumulative %
Reaches where 90+ stream widths (9+ subreaches) were sampled (n=51)	0	56.9%	56.9%						
	1	25.5%	82.4%						
	2	13.7%	96.1%						
	3	3.9%	100.0%						
	4	0.0%	100.0%						
	5	0.0%	100.0%						
Reaches where 110+ stream widths (11+ subreaches) were sampled (n=39)	0	56.4%	56.4%	56.4%	56.4%				
	1	23.1%	79.5%	28.2%	84.6%				
	2	15.4%	94.9%	15.4%	100.0%				
	3	5.1%	100.0%	0.0%	100.0%				
	4	0.0%	100.0%	0.0%	100.0%				
	5	0.0%	100.0%	0.0%	100.0%				
Reaches where 130+ stream widths (13+ subreaches) were sampled (n=26)	0	57.7%	57.7%	57.7%	57.7%	57.7%	57.7%		
	1	15.4%	73.1%	23.1%	80.8%	34.6%	92.3%		
	2	19.2%	92.3%	19.2%	100.0%	7.7%	100.0%		
	3	7.7%	100.0%	0.0%	100.0%	0.0%	100.0%		
	4	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%		
	5	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%		
Reaches where 150+ stream widths (15+ subreaches) were sampled (n=18)	0	55.6%	55.6%	55.6%	55.6%	55.6%	55.6%	55.6%	55.6%
	1	5.6%	61.1%	16.7%	72.2%	33.3%	88.9%	33.3%	88.9%
	2	27.8%	88.9%	27.8%	100.0%	11.1%	100.0%	11.1%	100.0%
	3	11.1%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
	4	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%

[a] Streams included in this analysis were located in the Susitna River, Matanuska River, and Knick River basins (this study) and the upper Koyukuk River and Chandalar River basins, portions of the Kuskokwim River, lower Yukon River, and eastern Norton Sound basins (sampled during 2007–2010; see Buckwalter et al. 2010, Buckwalter et al. 2012, Kirsch et al. 2011, Kirsch et al. *In prep*).

Table 8.–Estimated number of undetected species per reach for nonwadeable reaches draining >300 sq. km, when sampling is stopped after 80, 100, 120, and 140 stream widths.

Source data[a]	Estimated # of undetected species	Stopping after 80 stream widths		Stopping after 100 stream widths		Stopping after 120 stream widths		Stopping after 140 stream widths	
		%	cumulative %	%	cumulative %	%	cumulative %	%	cumulative %
Reaches where 90+ stream widths (9+ subreaches) were sampled (n=54)	0	24.1%	24.1%						
	1	24.1%	48.1%						
	2	38.9%	87.0%						
	3	9.3%	96.3%						
	4	0.0%	96.3%						
	5+	3.7%	100.0%						
Reaches where 110+ stream widths (11+ subreaches) were sampled (n=42)	0	26.2%	26.2%	35.7%	35.7%				
	1	9.5%	35.7%	21.4%	57.1%				
	2	47.6%	83.3%	33.3%	90.5%				
	3	11.9%	95.2%	4.8%	95.2%				
	4	0.0%	95.2%	4.8%	100.0%				
	5+	4.8%	100.0%	0.0%	100.0%				
Reaches where 130+ stream widths (13+ subreaches) were sampled (n=26)	0	23.1%	23.1%	38.5%	38.5%	38.5%	38.5%		
	1	7.7%	30.8%	11.5%	50.0%	34.6%	73.1%		
	2	53.8%	84.6%	38.5%	88.5%	23.1%	96.2%		
	3	11.5%	96.2%	7.7%	96.2%	3.8%	100.0%		
	4	0.0%	96.2%	3.8%	100.0%	0.0%	100.0%		
	5	3.8%	100.0%	0.0%	100.0%	0.0%	100.0%		
Reaches where 150+ stream widths (15+ subreaches) were sampled (n=18)	0	11.1%	11.1%	33.3%	33.3%	33.3%	33.3%	33.3%	33.3%
	1	11.1%	22.2%	11.1%	44.4%	38.9%	72.2%	38.9%	72.2%
	2	66.7%	88.9%	50.0%	94.4%	22.2%	94.4%	27.8%	100.0%
	3	11.1%	100.0%	5.6%	100.0%	5.6%	100.0%	0.0%	100.0%
	4	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%

[a] Streams included in this analysis were located in the Susitna River, Matanuska River, and Knick River basins (this study) and the upper Koyukuk River and Chandalar River basins, portions of the Kuskokwim River, lower Yukon River, and eastern Norton Sound basins (sampled during 2007–2010; see Buckwalter et al. 2010, Buckwalter et al. 2012, Kirsch et al. 2011, Kirsch et al. *In prep*).

When considering adaptive stopping rules for nonwadeable streams in Alaska draining ≤ 300 km^2, we found that sampling a minimum of 8 subreaches and stopping only after no new species are detected in the last 4 or 6 subreaches provides an estimated 86% probability that no more than one species will be undetected in that reach (Table 9). Sampling a minimum of 10 or 12 subreaches with adaptive stopping rules provided probabilities of 88% to 90% that no more than one species will be undetected.

When considering adaptive stopping rules for nonwadeable streams in Alaska draining > 300 km^2, we found that sampling a minimum of 12 subreaches and stopping only after no new species are detected in the last 4 or 6 subreaches provides a 69% to 74% probability that no more than one species will be undetected in that reach (Table 10). We were not able to identify an adaptive strategy that would provide our target 90% chance of failing to detect no more than 1 species.

Table 9.–Estimated number of undetected species per reach, for reaches draining 0–300 sq. km, when sampling is stopped after sampling a minimum number of subreaches and finding no new species in the last 4 or 6 subreaches.

Minimum number of subreaches sampled	Estimated # of undetected species	Stop after no new species in last 4 subreaches		Stop after no new species in last 6 subreaches	
		%	cumulative %	%	cumulative %
6	0	49.1%	49.1%	54.3%	54.3%
	1	20.0%	69.1%	23.9%	78.3%
	2	18.2%	87.3%	17.4%	95.7%
	3	10.9%	98.2%	4.3%	100.0%
	4	1.8%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=57		*n*=46	
8	0	57.1%	57.1%	60.5%	60.5%
	1	28.6%	85.7%	25.6%	86.0%
	2	10.2%	95.9%	11.6%	97.7%
	3	4.1%	100.0%	2.3%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=49		*n*=43	
10	0	53.8%	53.8%	55.9%	55.9%
	1	35.9%	89.7%	32.4%	88.2%
	2	10.3%	100.0%	11.8%	100.0%
	3	0.0%	100.0%	0.0%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=39		*n*=34	
12	0	55.6%	55.6%	56.0%	56.0%
	1	33.3%	88.9%	32.0%	88.0%
	2	11.1%	100.0%	12.0%	100.0%
	3	0.0%	100.0%	0.0%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=27		*n*=25	

Note: Source data were those reaches where at least 1 additional subreach was sampled after the minimum number of subreaches was met. Streams included in this analysis were located in the Susitna River, Matanuska River, and Knick River basins (this study) and the upper Koyukuk River and Chandalar River basins, portions of the Kuskokwim River, lower Yukon River, and eastern Norton Sound basins (sampled during 2007–2010; see Buckwalter et al. 2010, Buckwalter et al. 2012, Kirsch et al. 2011, Kirsch et al. *In prep*).

Table 10.–Estimated number of undetected species per reach, for reaches draining >300 sq. km, when sampling is stopped after sampling a minimum number of subreaches and finding no new species in the last 4 or 6 subreaches.

Minimum number of subreaches sampled	Estimated # of undetected species	Stop after no new species in last 4 subreaches		Stop after no new species in last 6 subreaches	
		%	cumulative %	%	cumulative %
6	0	25.5%	25.5%	28.2%	28.2%
	1	23.6%	49.1%	23.1%	51.3%
	2	34.5%	83.6%	38.5%	89.7%
	3	10.9%	94.5%	5.1%	94.9%
	4	3.6%	98.2%	5.1%	100.0%
	5+	1.8%	100.0%	0.0%	100.0%
		n=55		n=39	
8	0	26.0%	26.0%	29.7%	29.7%
	1	24.0%	50.0%	24.3%	54.1%
	2	38.0%	88.0%	37.8%	91.9%
	3	12.0%	100.0%	8.1%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=50		n=37	
10	0	40.0%	40.0%	48.0%	48.0%
	1	14.3%	54.3%	8.0%	56.0%
	2	40.0%	94.3%	40.0%	96.0%
	3	5.7%	100.0%	4.0%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=35		n=25	
12	0	43.5%	43.5%	50.0%	50.0%
	1	30.4%	73.9%	18.8%	68.8%
	2	21.7%	95.7%	25.0%	93.8%
	3	4.3%	100.0%	6.3%	100.0%
	4	0.0%	100.0%	0.0%	100.0%
	5	0.0%	100.0%	0.0%	100.0%
		n=23		n=16	

Note: Source data were those reaches where at least 1 additional subreach was sampled after the minimum number of subreaches was met. Streams included in this analysis were located in the Susitna River, Matanuska River, and Knick River basins (this study) and the upper Koyukuk River and Chandalar River basins, portions of the Kuskokwim River, lower Yukon River, and eastern Norton Sound basins (sampled during 2007–2010; see Buckwalter et al. 2010, Buckwalter et al. 2012, Kirsch et al. 2011, Kirsch et al. *In prep*).

DISCUSSION

By completing a systematic inventory of stream fish assemblages, we substantially increased AWC coverage in the study area. We also provided a snapshot of baseline conditions (i.e., fish assemblage composition and aquatic and riparian habitat characteristics) at many streams for which there was little or no prior information. Station reports listing all collected data for each site is included in Appendix K (2003) and Appendix L (2011).

Overall, fish occurrence in this study was generally consistent with prior studies. As expected for coldwater streams, salmonids and sculpins dominated our catch. And, as expected for high latitude and high elevation streams, species richness was very low. We typically found a greater number of fish species in Large (median of 5 species) streams than in Medium or Small streams (median of 2 species).

We detected a total of 19 fish species including 18 of 23 previously documented species (Table 3) and 1 (Pacific lamprey) that was expected to be present but not explicitly documented in the study area. We failed to find 5 previously documented species (eulachon, Bering cisco, Arctic char, lake trout and prickly sculpin) 2 of which (Arctic char and lake trout) were previously reported only from lakes—since we only sampled streams, it is not surprising that we did not find these 2 species. The remaining 3 previously documented species that we failed to find (eulachon, Bering cisco and prickly sculpin) are likely either especially rare or sparsely distributed across the study area, and therefore comparatively less likely to be found using rapid sampling techniques.

In general, it is usually best to use multiple gear types to get a more representative sample of the fish assemblage. However, study objectives, logistical constraints, and project budgets affect gear selection choices. Since our main objective entailed sampling fish assemblages in a large number of remote streams in a short amount of time, we decided to rely primarily on a single fish-collection gear type, single-pass electrofishing, for this project because: 1) electrofishing is considered to be the single most effective (Barbour et al. 1999, Simon and Sanders 1999, Flotemersch and Blocksom 2005) and widely applicable (Hughes et al. 2002) method in streams and rivers; 2) electrofishing typically captures more species with less size selectivity than other gear types (Hendricks et al. 1980); 3) electrofishing is a relatively safe method for biologists, and captures fishes with minimal mortality or injury to the fishes (Curry et al. 2009); 4) long reaches can be sampled relatively quickly using electrofishing (Curry et al. 2009); 5) electrofishing equipment is compact and portable; and 6) electrofishing is recommended as a standard fish sampling method for coldwater fishes in streams and rivers (Bonar et al. 2009).

We standardized our fish-collection effort by adopting: a systematic protocol to identify study site locations; electrofishing reach length as a multiple of channel width; and electrofishing protocols with guidelines for standardizing power output (Appendix A). Use of a standardized fish-collection protocol was not absolutely necessary to accomplish the objectives of this project, but will facilitate comparisons of fish assemblages between locations, and over time. Furthermore, standardized fish-occurrence data may be useful in developing regional models to predict fish presence. The backpack electrofishing power standardization table (Appendix A3) we prepared from data collected during this project will allow us to further reduce variability in applied power.

Since electrofishing tends to be size selective (although less so than other methods), with larger fish being more vulnerable to capture (reviewed by Reynolds [1996]), smaller fish species and life stages are likely underrepresented in our catch. Furthermore, large fish were more likely to be observed and counted than smaller species. Smaller fish were only likely to be observed if mobilized toward the anode; however, large fish and their carcasses were usually easy to observe and count, even if they remained beyond the electrical field. Therefore, our results should not be used to infer absolute or relative abundance of fishes without correcting for differences in detectability between different types of fish and habitats.

Larger fish, and species with high vertebral counts and fine scales, such as trout, salmon, and char, are more likely to be injured by electrofishing (reviewed by Reynolds [1996]). However, in order to collect all the common fish species present, we needed to electrofish with sufficient power to capture even the smallest fish, and those having low vertebral counts or large scales. Therefore, we acknowledge that some fish were likely injured or killed as a direct or indirect result of our selecting electrofishing power output settings necessary to capture members of the entire fish assemblage. However, since our sampling efforts were restricted to single-pass electrofishing in 1–2 fish collection reaches (representing a very small fraction of a given target stream's length) per target stream, this project was not expected to significantly affect fish populations. For example, Kocovsky et al. (1997) found no population level effects in salmonids after 8 years of electrofishing in 3 Colorado streams. Furthermore, we carefully chose electrofisher output settings (Appendix A1) to minimize trauma to fish, and generally ceased electrofishing in the immediate vicinity of any observed large (> 300 mm) salmonids.

OBJECTIVE 3—SAMPLING SUFFICIENCY

Our objective was to develop stopping rules for single-pass electrofishing in nonwadeable Alaskan streams to guide fish-inventory field crews in estimating when a sufficient length of stream has been sampled to document the presence of all common fish species occurring in the reach at the time of sampling. Other investigators have recommended reach lengths of 30–40 (Maret and Ott 2003) to 85 stream widths (Hughes et al. 2002) when electrofishing for coldwater fish in nonwadeable streams. Analysis of our prior (2007–2010) AFFI fish collections in nonwadeable streams of western Alaska indicated that a 40 CW reach typically underestimates true species richness (Buckwalter et al. 2012).

Our analyses of data collected during 2007–2011 indicated that a recommended minimum reach length for nonwadeable streams in Alaska should not be independent of the drainage area of a reach. While a reach length equivalent to 120 wetted widths appears to be adequate to provide a 90% chance that the number of undetected species is no greater than 1 per reach for reaches draining ≤ 300 km^2, we have no similar recommendation for streams draining >300 km^2 other than to suggest the minimum exceeds 14 wetted widths. Similarly, when considering adaptive stopping rules, we have no good recommendations for reaches draining >300 km^2.

The drainage area breakpoint indicated by our use of the KS test (300 km^2) is a result of an ad hoc analysis of a relatively small data set, so may not be ecologically ideal points for stratifying reaches based on drainage area. However, this stratification will serve to guide future sampling recommendations and investigations of sampling sufficiency until preferable points are identified. The ad hoc analysis clearly indicates that drainage areas of reaches need be considered when evaluating sampling sufficiency.

It is critical to note that all of our tabled results of observed species and estimated TSR are germane only to species that occur in streams during the summer and that are consistently vulnerable to the sampling gear we typically use, namely single-pass, pulsed-DC electrofishing.

All of Alaska's freshwater fishes can be effectively sampled using electrofishing, but capture efficiency varies among species and between habitats. Many factors, acting alone or cumulatively, affect electrofishing efficiency. Some examples follow: 1) Electrofishing is size selective—with all else being equal, smaller fish are less vulnerable; 2) Electrofishing is primarily a shallow water (< 2 m) activity—species that remain in deep water are less vulnerable; 3) Larval lamprey characteristically dwell in substrates, so they are likely less vulnerable to our electrofishing effort, which focuses on species that remain in the water column or on the stream bottom; 4) Northern pike may be able to detect an electrical field when they are still outside the effective radius for electrofishing and thus avoid capture (Novotny and Priegel 1974); 5). Sculpins tend to remain on the stream bottom, so they can be difficult to see or collect, especially in deeper or more turbid water. Thus, some fish species and life stages may occur in sampled reaches, but are less likely to be detected due to their size, physiology, or habitat preferences. As a result, our estimated TSR may be lower than the true species richness that could have been measured more accurately using a combination of gear types and alternate methods to target the variety of fishes in each unique habitat type.

Additional data from nonwadeable streams collected at the subreach level from different geographic areas would be highly desirable to further evaluate sampling sufficiency stopping rules and consistency between geographic areas. More data collected at the subreach level is also necessary for wadeable streams. Data necessary to evaluate potential stopping rules for field sampling needs to be in excess of the amount necessary to adequately sample for species richness. An additional, nontrivial, advantage of sampling at the subreach level is that the more detailed data provide the opportunity to estimate total species richness for a reach, allowing an ongoing assessment of quality control.

RECOMMENDATIONS

1. We recommend that additional sampling effort is undertaken in the Upper Susitna River subbasin, above Devils Canyon, such that a more complete picture of **Chinook salmon** distribution and habitat use is achieved.
2. Based on prior AFFI findings, additional **Chinook salmon rearing areas** may be found in the lower reaches of small (less than 50 km^2 upstream drainage) non-natal tributaries to large rivers supporting Chinook salmon that are <610 m above sea level and have moderate (0.5–1.5%) gradient. Small tributaries such as those described above were not targeted, due to their drainage area, during this project, but may indeed provide important rearing habitat for Chinook salmon across this study area.
3. We recommend that additional **Chinook salmon spawning** sites be located and added to the AWC in the vicinity of streams where we found juveniles, particularly within the Upper Susitna River subbasin.
4. More fish-collection data at the subreach level is needed from both wadeable and nonwadeable streams to test and refine sampling sufficiency (reach length) recommendations. A minimum of ten 10 CW subreaches should be sampled, with additional subreaches sampled as necessary until no new species are collected in the last 6 consecutive subreaches. More data from nonwadeable streams draining at least 1500 km^2 and wadeable streams is especially needed. Observations are also needed from other Alaskan regions (i.e., Southcentral, Southwest, Southeast, and North Slope).
5. We recommend that our electrofisher power standardization table be updated annually as our skills improve to ensure the highest level of efficiency possible while limiting fish injury and mortality.
6. Develop a rapid lake fish sampling protocol to be implemented, where appropriate, into the AFFI program to more fully describe freshwater fish distribution throughout Alaska.

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APPENDIX A. FIELD PROTOCOLS

The objective is to detect all the common fish species found in the reach. Fish collection should be completed within 30 minutes with a cumulative electrofishing time of *at least* 300 s. The procedure to collect fish with a backpack electrofisher (Smith-Root LR-24) is presented below.

Procedures to collect fish at wadeable sites. (adapted from McCormick and Hughes 1998).

1. Establish the habitat transect (Station) in a straight, representative, non-pool (preferably glide or run) channel unit, mark the first GPS waypoint at the Station, and complete habitat characterization and data entry.
2. Measure wetted channel width (CW, to the nearest 0.1 m) at the station. The minimum fish-collection reach length is 40 CW, or 150 m, whichever is greater. The maximum reach length for wadeable streams is 300 m.
3. The 2-person electrofishing team will typically begin electrofishing at the station and work their way upstream the predetermined reach length while collecting fish. If the downstream end of the reach does not coincide with the Station, the team will mark a second GPS waypoint at the downstream end of the reach. A handheld, consumer grade GPS unit in trip computer mode, range finder, hip chain, or other similarly accurate method, will be used to measure the reach length as they work their way upstream. At the upstream end of the reach, the team will mark a third GPS waypoint. If walking upstream from the Station is not practicable (e.g., due to dense riparian vegetation), the team may walk downstream, staying near a bank, the required total reach length, then begin electrofishing and work their way back up to the Station. In this case, the team will measure the curvilinear length of the channel while walking downstream on the bank, but will avoid walking in the channel or otherwise startling fish. The location of the fish collection reach in relation to the station location should be noted in the database.
4. Both crewmembers must wear leak free chest waders with wading belt snugly fastened, wading shoes that fit properly, electrically insulated gloves, and polarized sunglasses (preferably with amber lenses). A hat with a brim may also be helpful in reducing glare.
5. Make sure the electrofisher battery is securely fastened in. Check electrical connections (battery, anode, cathode). Replace the battery cover securely.
6. Try on the backpack unit, and make any adjustments to the suspension system to achieve a comfortable fit, with the unit snug against the operator's back and resting above the hip bones. If necessary, untangle and route the cathode (rat tail) and anode cables.
7. With both electrodes out of the water and clear of each other and both operators, turn the unit on and confirm the system is ready. Reset the timer to zero.
8. To use a smooth-DC waveform (preferred):
    a. Set the waveform to smooth DC, and select the initial voltage setting according to the ambient (not temperature-compensated) water conductivity—Appendix A3.

-continued-

   b. Ensure that all non-target organisms are clear of the water, and begin fishing when both crewmembers are ready.

   c. Closely observe the fishes’ response and attempt to maximize capture prone responses (i.e, taxis or forced swimming) and minimize responses associated with elevated trauma (i.e., immobilization, bruising, spinal deformities, or recovery period exceeding 15 seconds). Try to capture fish before they approach near to the electrodes, and remove fish quickly from the electric field.

   d. If fish exhibit symptoms of trauma, decrease the voltage by 50 V, press the Enter key, and try again. If fish are unresponsive, increase the voltage by 50 V, press the Enter key and try again.

   e. If fish are still not showing capture prone responses, or if it is necessary to extend battery life, switch to a pulsed-DC waveform.

9. To use a pulsed-DC waveform:

   a. Select initial voltage setting according to the ambient (not temperature-compensated) water conductivity—see Appendix A3.

   b. Set initial pulse frequency to 30 pulses-per-second (pps).

   c. Set duty cycle to achieve a pulse width of 2 ms, according to the following table:

Frequency	Duty cycle (%)	
(pps)	2 ms	4 ms
30	6	12
35	7	14
40	8	16
45	9	18
50	10	20
60	12	24

   d. If electrofishing is unsuccessful:

      i. Increase the voltage by 50 V, press the enter key and try again. Stop increasing voltage when fish exhibit a forced response (twitch).

      ii. If fish twitch, but are not showing taxis (induced movement of the fish toward the anode), increase the duty cycle to achieve a pulse width of 4 ms, according to the table in Step 9.c. Press the Enter key and try again. If necessary, repeat this step, increasing duty cycle by 10% increments until fish show taxis. If the duty cycle is increased to maximum, and taxis is still not achieved, proceed to Step iii.

      iii. Increase the frequency by 10 pps, and press the Enter key. Adjust the duty cycle to achieve a pulse width of 2 ms for the new frequency setting (see Step 9.c), and try again. Repeat Step ii after each frequency increase. Avoid frequencies >60 pps.

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10. Beginning at the downstream end of the sampling reach, the electrofishing team will fish in an upstream direction, zigzagging across the channel from bank to bank in order to sample all habitat types. Depress the switch and sweep the anode slowly from side to side in the water. Electrofish intermittently to avoid herding fish, especially in glides or long pools. After electrofishing continuously for up to 5 s, quietly advance upstream approximately 2–4 m before resuming electrofishing. Alternatively, it can be effective to intentionally herd fish out of open water into shallow water or confined areas, where they are less likely to escape.

11. Attempt to sample the variety of habitats (deep and shallow, fast and slow, complex and simple, warmer and colder) present throughout the reach. Be sure to sample available cover (e.g., large substrate elements, large wood, debris piles, undercut banks, aquatic macrophytic beds, overhanging vegetation). Move the anode near confined cover with the power off, then depress the switch and slowly sweep the anode away from the cover to draw fish out into open. Do not attempt to sample in or near pools greater than waist deep, or where velocity is too fast to safely wade. Always move slowly and carefully to avoid startling fish and to minimize risk of falling.

12. The netter follows downstream of the electrofisher operator, collecting fish with a dip net with a non-conductive (e.g. fiberglass or wood) handle and placing them into a 5-gallon bucket with stream water for later processing. Try to net all fish seen. When this is not feasible (e.g., in highly productive systems), try to collect a representative sample of the fish assemblage (e.g., not just large game fish). Pay special attention to netting small and benthic fish, as well as fish that respond differently to the electric field—not just the big fish that move to the surface. Particularly when visibility is obscured by turbidity, debris, or vegetation, the netter should keep the dip net in the water downstream of the anode. The dip net opening should be near vertical, perpendicular to the current, with the dip net frame in contact with the substrate. The distance between the anode and the dip net is related to the current velocity: the faster the current, the greater the distance between the anode and dip net. In fast water, the net should remain several meters downstream of the anode.

13. Refresh the water in the bucket periodically to minimize physiological stress prior to measuring fish. If fish in the live well begin to show signs of excessive stress (e.g., rapid gill ventilation, gaping, gulping air, loss of equilibrium, excessive mucus), stop electrofishing and process them (Appendix A4). Also process large fish (> 300 mm) immediately and record species, life stage, life history, length, sex, and external anomalies in a notebook for future transfer to the database.

14. Record in the database the final, or most successful, electrofisher output settings (waveform, voltage, frequency, duty cycle, electrofisher on-time, and typical peak current and power), sampling efficiency (poor, fair, good, excellent), and distance sampled, along with fish observations, including fish collected while electrofishing, as well as any additional fish observed within the reach, but not collected. If conditions prevent safe or effective electrofishing within a reach, the conditions, and their effect on sampling efficiency, should be noted in the Sampling Event tab in the database, and the length of stream that was actually sampled should be noted in Sampling Event comments.

The objective is to detect all the common fish species found in the reach. The procedure to sample with a generator powered boat electrofisher unit (Smith-Root GPP 2.5) is presented below.

Procedures to collect fish by boat electrofishing. (adapted from McCormick and Hughes 2000)

Onshore at launch site

1. Check generator oil and fill tank with gas (wipe up any spillage).
2. Attach electrodes to boat, and connect their cables to the corresponding outlet on the control box. If the fishing site is distant, keep electrodes and anode poles in boat.
3. Connect generator and pulsator (control box).
4. Confirm that all gear for the day is in the boat.
5. Put on a life jacket. Wear polarized sunglasses to aid vision.

At sample reach

1. Establish the habitat transect (Station) in a straight, representative, non-pool (preferably glide or run) channel unit, mark the first GPS waypoint at the Station, and complete habitat characterization and data entry.
2. Measure wetted channel width (CW, in meters) at the station—multiply by 10—this is the length of a single subreach. The minimum fish-collection reach length is 10 subreaches, plus any additional subreaches necessary until no new species are detected in the last 6 consecutive subreaches (or as much as can be sampled in a day). Record fish observations and electrofisher settings separately for each subreach under a unique sampling event code.
3. Check all electrical connections and suspend the electrodes in the water. The wetted surface area of the cathode(s) should be greater than that of the anode(s). Fill live well and put on dry electrically insulated gloves. Verify that all electrical switches are off, that all non-target organisms are clear of the water or 2 boat lengths away, and that both crewmembers are clear of the water and electrodes and ready to begin electrofishing. Reset the timer on the electrofisher control box to zero at the start of each subreach.
4. If ambient conductivity is <300 µS/cm, set the Range dial to High. If ambient conductivity is >300 µS/cm, set the Range dial to Low. Switch the Mode dial to DC (**Caution! The position of this switch should not be changed when the foot switch is engaged!**) and select an initial frequency of 30 pulses-per-second (pps) and an initial Percent of Range (POR) setting of 10%.
5. Start the generator and depress the foot pedal to begin electrofishing. Increase POR as needed to elicit a capture prone response [i.e, taxis (induced movement of the fish toward the anode) or forced swimming] from fish, while minimizing responses associated with elevated trauma (i.e., immobilization, branding, spinal deformities, or recovery period exceeding 15 seconds).

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Note: Where water conductivity is high (>300 µS/cm), avoid using POR settings in excess of 60%, which will simply increase duty cycle, but not peak voltage, and may overload the generator (Martinez and Kolz 2009). If the generator sounds labored, decrease POR and/or switch from High to Low range.

6. If fish taxis cannot be achieved, increase frequency to 60 pps, return the POR dial to 10%, and repeat Step 5.
7. Select the riverbank for fishing (river left for odd numbered target streams, river right for even), and stay along the selected bank through the entire reach, to the degree it is safely navigable. Position the boat so the bow is angled downstream and toward the bank. While drifting downstream, use oars (cataraft) to maneuver laterally in the channel to avoid obstacles and position the anode(s) into habitats providing cover for fish. Most effort should occur near the bank, where most fish are expected to occur, and at depths less than 3 m wherever possible. However, all habitat types should be sampled, zigzag between the thalweg and the bank to allocate some sampling effort to a variety of habitats throughout the channel.

   With electrical current off, maneuver the boat so the anode(s) approach near to fish cover elements (e.g., large substrate elements, large wood, debris piles, undercut banks, aquatic macrophyte beds, overhanging vegetation), then begin electrofishing as the boat is slowly backed away from the cover. Electrofish intermittently to avoid herding fish, especially in glides or long pools. After electrofishing continuously for a duration of up to 10 s, drift quietly for 5–10 m before resuming electrofishing. Alternatively, it can be effective to intentionally herd fish out of open water into shallow water or confined areas, where they are less likely to escape. Do not place the boat in danger in order to fish particular habitats. Cut the generator and stow the gear before negotiating hazards.
8. The netter uses a dip net with non-conductive (e.g. fiberglass or wood) handle to retrieve fish, which are then deposited into a live well for later processing. Try to capture fish before they approach near to the electrodes, and remove fish quickly from the electric field. Try to net all fish seen. When this is not feasible (e.g., in highly productive systems), try to collect a representative sample of the fish assemblage (e.g., not just large game fish). Pay special attention to netting small and benthic fish, as well as fish that respond differently to the electric field—not just the big fish that move to the surface. If benthic fish are being missed, hold the net behind the anode just above the bottom so some are collected.
9. Change the water in the live well periodically to minimize stress prior to processing. If fish in the live well begin to show signs of excessive stress (e.g., rapid gill ventilation, gaping, gulping air, loss of equilibrium, excessive mucus), stop electrofishing, tie off or land the boat on shore, and process them. This should only be necessary on very warm days, in long reaches, or if very large numbers of fish are collected. Electrofishing may also need to cease at times to immediately process and release large fish. If fish are processed and released prior to the end of a reach (or between subreaches), be sure to release them upriver, or preferably near the opposite bank, to reduce the likelihood of recapturing them.

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10. Using a GPS unit in trip computer mode to monitor distance traveled, continue sampling downstream to the end of the subreach. At the end of the subreach, process the fish according to Appendix A4.

11. Record in the database the final, or most successful, electrofisher output settings (mode, range, POR, pulse frequency, current, electrofisher on-time, and duty cycle and power, if known), sampling efficiency (poor, fair, good, excellent), and reach length sampled, along with fish observations, including fish collected while electrofishing, as well as any additional fish observed within the reach, but not collected. If conditions prevent safe or effective electrofishing within a reach, the conditions, and their effect on sampling efficiency, should be noted in the Sampling Event tab in the database, and the length of stream that was actually sampled should be noted.

12. Be sure the station visit information is completely entered before leaving the site.

Appendix A3.–Recommended target voltage for standardized backpack electrofishing (constant power transfer) for predominantly juvenile salmonids in cold waters at various ambient water conductivities.

Ambient conductivity (µS/cm)	Target voltage		Ambient conductivity (µS/cm)	Target voltage	
	pulsed DC[a]	Smooth DC		pulsed DC	Smooth DC
20	1155	490	170	306	130
30	834	354	180	299	127
40	674	286	190	294	125
50	577	245	200	289	123
60	513	218	210	284	121
70	467	199	220	280	119
80	433	184	230	276	117
90	406	173	240	273	116
100	385	163	250	269	115
110	367	156	260	266	113
120	353	150	270	264	112
130	340	145	280	261	111
140	330	140	290	259	110
150	321	136	300	257	109
160	313	133			

Note: Target voltage values were calculated for a Smith-Root LR-24 backpack electrofisher fitted with a standard Smith-Root rat-tail cathode (a 10-ft length of braided, 3/16 in stainless steel cable with the connected end insulated with a 6 ft length of neoprene) and a single anode pole having a standard Smith-Root 11 inch diameter 3/8 in stainless steel anode ring, and are optimized for capturing juvenile salmonids in cold, wadeable flowing waters with predominantly rocky substrates. These target voltages may not be optimal for electrofishing systems having a different internal resistance (i.e., different electrofishing system, electrode type, or if electrodes are heavily corroded), if targeting different fish species/life stages, or when electrofishing in nonwadeable waters or over predominantly fine substrates.

We prepared this power standardization table based on the power transfer theory for electrofishing (Kolz 1989), using water ambient conductivity measurements and metered electrofisher output values (peak voltage and current) selected while electrofishing to maximize capture prone responses (taxis and forced swimming) and minimize responses associated with elevated trauma (immobilization, branding, spinal deformities, or recovery period exceeding 15 seconds) in target fish. We assumed fish conductivity = 100 µS/cm.

This table provides a starting voltage setting for standardized backpack electrofishing. While electrofishing, always monitor the response of target and non-target organisms, and fine tune electrofisher operations and settings as recommended in the user's manual to achieve the desired response.

[a] 30 pulses per second, 12% duty cycle (4 mS pulse width)

Appendix A4.–Procedure to process collected fish.

1. Anesthetize collected fish with CO_2:
    a. Add 2 buffered CO_2 producing tablets (e.g. Alka Seltzer) to a bucket containing about 4 L of stream water.
    b. Place a batch of fish in the bucket (Note: only a few fish should be anesthetized at a time to avoid prolonged sedation).
    c. Leave fish in the bucket until the desired level of sedation is achieved (about 2 to 5 minutes). Determining CO_2 dosage in the field can be difficult, because, by the time the fish have responded to the sedation, the concentration of CO_2 may be too high. If the concentration is too high (onset of sedation is rapid), the fish should be moved to native water or processed immediately.
2. Remove 1 fish at a time from the sedation bucket and place on a length measuring tube (FL $\leq$ 250 mm) or board (FL $\geq$ 250 mm).
3. Identify all collected fish to species (Appendix B5), life stage (Appendix B1), and life history (anadromous, resident, marine/estuarine, unknown) and measure fork length to the nearest mm. Refer primarily to Pollard et al. 1997 to identify unknown salmoninae (salmon, trout, or char) and to Mecklenburg et al. 2002 for all other species. Also refer to photos of known specimens for confirmation. Check each fish for external anomalies (Appendix B2). Document any definite fish passage barriers (Appendix B3) found in or adjacent to the reach. Immediately after identification and measurement, place fish in a second bucket of fresh stream water for recovery.
4. Take a representative photo of each anadromous species and life stage, as well as of any rare or unusual fish, fish with anomalies, or fish where ID was uncertain. Record the photo number(s) associated with each fish in the database.
5. Take a fin clip from each Dolly Varden to be retained (see below) and from additional species requested by UAF. Follow the appropriate instructions for taking fin clips (USFWS instructions for Dolly Varden, UAF instructions for other species). Record the fin clip vial number in the database.
6. Retain the following specimens:
    a. <u>Species unknown</u>: up to 5 (from each site) individual fish of each species and life stage that cannot be confidently identified in the field;
    b. <u>UAF Museum</u>: requested voucher specimens (see UAF instructions);
    c. <u>Juvenile coho salmon</u>: up to 5 from each site;
    d. <u>Optionally-anadromous fishes for otolith study</u>: up to 12 large (> 300 mm, except for Dolly Varden, which may be any size) individuals from each study site where they are collected of each of the following species: Dolly Varden; humpback and broad whitefish; sheefish; and least and Bering cisco.

    Euthanize (by a blow to the head, or an overdose of CO_2) all specimens to be retained. Tag any retained fish with a unique tag number, and record the tag number in the database. For UAF, each fish must be individually tagged. For all other retained specimens, fish of the same species and life stage that were all collected from the same reach may be retained as a

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group with a single unique tag for the group. Any juvenile coho salmon and specimens retained for the otolith study must be frozen. All other specimens should be stored in 10% formalin solution. For specimens >200 mm, make an incision through the belly wall before placing in formalin. Keep specimens cool (e.g., in fresh stream water) until they can be put in formalin or frozen. ***CAUTION! MINIMIZE THE CHANCE OF ATTRACTING WILDLIFE BY KEEPING RETAINED FISH INSIDE A COVERED COOLER OR HEAVY DUTY PLASTIC BAG. NEVER LEAVE SPECIMENS UNATTENDED IN THE FIELD.***

7. While 1 crewmember processes fish, the other will enter fish observations into the appropriate fields in the database.
8. Release fish to still water in the fish collection reach. If additional contiguous fish collection will be conducted, release fish downstream (Headwaters Team) or upstream (Cataraft Teams), and/or along the opposite bank, to avoid their recapture.
9. Record the species, life stage, life history, and count, along with any comments indicating average size, behavior, anomalies, etc., of any additional fish that were observed, but not collected (e.g., visually observed adults).

APPENDIX B. LOOKUP TABLES

Appendix B1.–Fish life-stage classes and threshold fork-length values.

Descriptions of fish life-stage classes.

Code	Name	Description
FXE	fixed egg	Eggs adhering to or buried within a substrate.
PLE	planktonic egg	Non-adherent, buoyant or nearly so, eggs drifting with currents.
FXA	alevin	Pre-emergent sac-fry within the interstices of the substrate.
PLL	planktonic larvae	Hatched juveniles drifting with currents and with no, or poorly, developed volitional swimming capabilities.
JUV	juvenile	Sexually immature free-swimming fish.
SMT	smolt	Juvenile anadromous fish on first emigration from fresh to marine water.
JOA	juvenile/adult	Free swimming fish whose sexual maturity is not determined.
ADT	adult	Fish at, or approaching sexual maturity.
ASP	adult spawning	Adults observed in the act of spawning.
KLT	kelt	Post-spawning iteroparous anadromous fish in freshwater prior to return to marine water.
CAR	carcass	Post-spawning adult carcass.
NAP	not applicable	No fish observed or general information record only.
NRD	not recorded	Life stage not recorded.

Fork-length threshold values (mm) used to assign fish to selected life-stage classes.

	Life stage		
Species	Juvenile	Juvenile-or-adult	Adult
lamprey-unspecified	-	-	-
longnose sucker	<188	188–348	>348
northern pike	<330	330–448	>448
Alaska blackfish	<42	42–113	>113
broad whitefish	<343	343–448	>448
humpback whitefish	<280	280–363	>363
least cisco	<199	199–318	>318
round whitefish	<199	199–318	>318
inconnu (sheefish)	<586	586–648	>648
Arctic grayling	<190	190–328	>328
pink salmon	-	-	-
chum salmon	-	-	-
coho salmon	-	-	-
sockeye salmon	-	-	-
Chinook salmon	-	-	-
Dolly Varden	<83	83–	-
burbot	<280	280–498	>498
slimy sculpin	<51	51–68	>68

Note: A hyphen or missing value indicates that we assigned individual fish to the indicated life stage based only on examination of morphological indicators of sexual maturity, not based on fork-length threshold values.

Appendix B2.–Fish-anomaly classes.

Code	Name	Description
AB	Absent	Absent eye, fin, tail.
BK	Blackening	Tail or whole body with darkened pigmentation.
BL	Blisters	In mouth, just under skin.
BS	Extensive black spot	Small black cysts (dots) all over the fins and body.
CO	Copepod	A parasitic infection characterized by a worm-like copepod embedded in the flesh of the fish; body extends out and leaves a sore/discoloration at base, may be in mouth gills, fins, or anywhere on body.
CY	Cysts	Fluid-filled swellings; may be either small or large dots.
DE	Deformities	Skeletal anomalies of the head, spine, and body shape; amphibians may have extra tails, limbs, and toes.
EF	Eroded fins	Appear as reductions or substantial fraying of fin surface area.
EG	Eroded gills	Gill filaments eroded from tip.
EX	Exophthalmia	Bulging of the eye.
FA	Fin anomalies	Abnormal thickenings or irregularities of rays
FU	Fungus	May appear as filamentous or "fuzzy" growth on the fins, eyes, or body.
GR	Grubs	White or yellow worms embedded in muscle or fins.
HM	Hemorrhaging	Red spots on mouth, body, fins, fin bases, eyes, and gills.
IC	Ich	White spots on the fins, skin or gills.
LE	Lesions	Open sores or exposed tissue; raised, granular, or warty outgrowths.
LI	Lice	Scale-like, mobile arthropods.
MU	Mucus	Thick and excessive on skin or gill, or as long cast from vent.
NO	None	No anomalies present.
OT	Other	Anomalies or parasites not specified.
SA	Scale anomalies	Missing patches, abnormal thickenings, granular skin
SO	Shortened operculum	Leaves a portion of the gill chamber uncovered
TU	Tumors	Areas of irregular cell growth which are firm and cannot be easily broken open when pinched. (Masses caused by parasites can usually be opened easily.)
WR	Leeches	Annelid worms which have anterior and posterior suckers. They may attach anywhere on the body.

Source: McCormick and Hughes 1998.

Appendix B3.–Fish-passage barrier classes.

Code	Name	Description
EBD	Ephemerally Fixed, Beaver Dam	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a beaver dam. Used where the location of the barrier to movement is known within 100 m.
EDJ	Ephemerally Fixed, Debris Jam	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a debris jam. This category is restricted to small scale (?10 m) features that do not dramatically alter the overall channel type. Larger mass-wasting created barriers fall in the EGD category. Used where the location of the ultimate barrier to movement is known within 100 m.
EGD	Ephemerally Fixed, Hydro-Geomorphically Dynamic	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by current hydrological or geomorphic conditions but where evidence indicates that these landscape-scale conditions are in flux over brief (decades) geologic time. Used in areas of recent or ongoing geomorphic alteration (e.g., glacial advance or retreat, mass wasting, tectonic movements, dynamic channel formation). Used where the location of the barrier to movement is within 100 m.
ELF	Ephemerally Fixed, Low Flow	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by low streamflow, but where evidence indicates that at higher streamflow, fish could ascend further up the channel. Used where the location of the barrier to movement is known within 100 m.
EOT	Ephemerally Fixed, Other	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a non-permanent barrier other than those listed immediately above. Used where the location of the ultimate barrier to movement is known within 100 m.
ESS	Ephemerally Fixed, Spring Source	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling or on-site analysis, to be blocked by the emergence of ground water from an unconfined substrate. Compare to GSL. Used where the location of the barrier to movement is known within 100 m.
GLK	Geologically Fixed, Lake Shore	Where the upstream movements of a given species appear, based on sufficient sampling or on-site analysis, to be limited by the perimeter of a geologically-stable lake shore. Used where the location of the barrier to movement is known within 100 m.
GOT	Geologically Fixed, Other	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling or on site analysis, to be blocked by a geologically fixed barrier other than those listed immediately above. Used where the location of the ultimate barrier to movement is known within 100 m.
GSL	Geologically Fixed, Stream Limit	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling or on-site analysis, to be limited to the presence of surface water, and where that presence of surface water appears to be fixed in space and stable in time (compare to ELF). Spring-fed headwall pools are examples. Used where the location of the barrier to movement is known within 100 m.

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Appendix B3.–Page 2 of 2.

Code	Name	Description
GWG	Geologically Fixed, Waterfall/High Gradient	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling or on-site analysis, to be blocked by a waterfall, cascade, or other similar geologically fixed barrier. Used where the location of the barrier to movement is known within 100 m.
HCU	Human, Culvert	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a culvert through a road bed, a railroad bed, a runway, or through any other type of fill. This code includes culverts of all materials (e.g., metal, plastic, wood) and shapes (e.g., round, arched, bottomless) Used where the location of the barrier to movement is known within 100 m.
HDB	Human, Debris	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by debris placed or deposited in the stream as the direct result of human activities but where that material was not intentionally placed to impound, filter, or divert streamflow. Examples include woody debris from logging activities, and debris flows from failed road prisms. Used where the location of the barrier to movement is known within 100 m.
HDM	Human, Dam	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a dam, weir, head gate, or other cross channel structure that impounds, filters, or diverts streamflow. This code includes structures of all materials (e.g., earth, concrete, rip rap, metal, wood). Used where the location of the barrier to movement is known within 100 m.
HOT	Human, Other	Where the upstream movements of a given species appear, based on sufficient upstream and downstream sampling, to be blocked by a human-created structure other than those listed immediately above. Used where the location of the barrier to movement is known within 100 m.
NAP	Not applicable	No fish observed. See downstream stations.
NON	None	No barrier exists at survey station.
SBU	Specific Barrier Unknown	Where a given species is collected at a downstream station and not at an upstream station but where no specific barrier is known between the 2 stations. Used where the distributional limits are not known within 100 m.
UNK	Unknown	No information exists upstream of a sample station. Often where a species is collected at a station and no additional sampling or survey occurs upstream.

Appendix B4.–Water color, substrate, and stream-stage classes.

Water-color classes.

Code	Description	Definition
CLR	Clear	Transparent water, or nearly so.
FER	Ferric	Rust- (orange) stained.
GHT	Glacial, High Turbidity	High turbidity waters (visibility ≤ 30 cm (12 in) typical of streams originating directly from glaciers (e.g., Matanuska River).
GLT	Glacial, Low Turbidity	Low turbidity waters (visibility > 30 cm) typical of systems with large lakes (settling basins) below glacial discharge (e.g., Kenai River). These waters are frequently turquoise-colored.
HUM	Humic	Tea-colored water (tannic)
MUD	Muddy	Dark water with high suspended particulate load.

Substrate classes.

Code	Name	Intermediate-axis dimensions
BED	Bedrock	> 4,096 mm. Solid rock—few or no discrete particles
BLD	Boulder	256–4,096 mm
CBL	Cobble	64–256 mm
GRV	Gravel	2–64 mm
SND	Sand	0.0625–2 mm
SCL	Silt/Clay	≤ 0.0625 mm
ORG	Organic	Incompletely-decomposed organic material

Source: adapted (Bedrock and Organic classes added) from Cummins (1962), which is based on the Wentworth (1922) scale.

Stream-stage classes.

Code	Description
DNC	Dry, no defined channel
DDC	Dry, defined channel
LDF	Low, intermittent surface flow
LCF	Low, continuous surface flow
MED	Medium
HIH	High
WNC	Wet, no defined channel

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Embeddedness classes.

Code	Level of embeddedness[a]	Description
NEG	Negligible	Gravel, cobble, and boulder particles have <5% of their height covered by fine sediment[b].
LOW	Low	Gravel, cobble, and boulder particles have 5-25% of their height covered by fine sediment.
MOD	Moderate	Gravel, cobble, and boulder particles have 25-50% of their height covered by fine sediment.
HIH	High	Gravel, cobble, and boulder particles have 50-75% of their height covered by fine sediment.
VHI	Very high	Gravel, cobble, and boulder particles have >75% of their height covered by fine sediment.

Note: If the dominant substrate type is sand, silt, or clay, the level of embeddedness will be rated as Very high. If the dominant substrate type is bedrock, the level of embeddedness will be rated as Negligible.

Source: modified from Bain (1999), which was adapted from Platts et al. 1983.

[a] Embeddedness (*sensu* Armantrout 1998): Degree that gravel and larger sizes of particles (boulders, cobble, or rubble) are surrounded or covered by fine sediment (e.g., less than 2 mm).

[b] <2 mm, i.e., sand, silt, or clay.

Appendix B5.–Fish species codes.

Code	Common name	Scientific name
ACI	sturgeon-unspecified	*Acipenser* sp.
ATG	green sturgeon	*Acipenser medirostris*
ATW	white sturgeon	*Acipenser transmontanus*
CAC	Arctic char	*Salvelinus alpinus*
CBT	brook trout	*Salvelinus fontinalis*
CDV	Dolly Varden	*Salvelinus malma*
CHR	char-unspecified	*Salvelinus* sp.
CLK	lake trout	*Salvelinus namaycush*
DAL	Alaska blackfish	*Dallia pectoralis*
ERC	trout-perch	*Percopsis omiscomaycus*
FAR	Arctic flounder	*Pleuronectes glacialis*
FLN	righteye flounders-unspecified	Pleuronectidae
FST	starry flounder	*Platichthys stellatus*
GAD	cod-unspecified	Gadidae
GAR	Arctic cod	*Boreogadus saida*
GBR	burbot	*Lota lota*
GPA	Pacific cod	*Gadus macrocephalus*
GRA	Arctic grayling	*Thymallus arcticus*
GSA	saffron cod	*Eleginus gracilis*
HAM	American shad	*Alosa sapidissima*
HER	herrings-unspecified	Clupeidae
HPA	Pacific herring	*Clupea pallasii*
IDA	salmonid, unspecified	Salmonidae
KNS	ninespine stickleback	*Pungitius pungitius*
KSB	stickleback-unspecified	Gasterosteidae
KTS	threespine stickleback	*Gasterosteus aculeatus*
LAC	Arctic-Alaskan brook lamprey paired species	*L. camtschatica / L. alaskense*
LAK	Alaskan brook lamprey	*Lampetra alaskense*
LAR	Arctic lamprey	*Lampetra camtschatica*
LMO	Atlantic salmon	*Salmo salar*
LMP	lamprey-unspecified	*Lampetra* sp.
LPC	Pacific lamprey	*Lampetra tridentata*
LRV	American river lamprey	*Lampetra ayresii*
LWB	western brook lamprey	*Lampetra richardsoni*
MIN	lake chub	*Couesius plumbeus*
NOS	longnose sucker	*Catostomus catostomus*
OEU	eulachon	*Thaleichthys pacificus*
OLS	longfin smelt	*Spirinchus thaleichthys*
OPS	pond smelt	*Hypomesus olidus*
ORM	rainbow smelt	*Osmerus mordax*
OSM	smelt-unspecified	Osmeridae
OSS	surf smelt	*Hypomesus pretiosus*
PIK	northern pike	*Esox lucius*
SAM	Pacific salmon-unspecified	semelparous *Oncorhynchus sp.*
SCK	Chinook salmon	*Oncorhynchus tshawytscha*
SCM	chum salmon	*Oncorhynchus keta*
SCO	coho salmon	*Oncorhynchus kisutch*
SPI	pink salmon	*Oncorhynchus gorbuscha*
SSE	sockeye salmon	*Oncorhynchus nerka*
TCT	cutthroat trout	*Oncorhynchus clarkii*
TRB	rainbow trout	*Oncorhynchus mykiss*
TRT	trout-unspecified	iteroparous *Oncorhynchus sp.*
UCR	coastrange sculpin	*Cottus aleuticus*
UFH	fourhorn sculpin	*Myoxocephalus quadricornis*
ULP	sculpin-unspecified	Cottidae
UPR	prickly sculpin	*Cottus asper*
UPS	Pacific staghorn sculpin	*Leptocottus armatus*
USH	sharpnose sculpin	*Clinocottus acuticeps*
USL	slimy sculpin	*Cottus cognatus*
WAK	Alaska whitefish	*Coregonus nelsonii*
WAR	Arctic cisco	*Coregonus autumnalis*
WBC	Bering cisco	*Coregonus laurettae*
WBD	broad whitefish	*Coregonus nasus*
WHB	humpback whitefish	*Coregonus pidschian*
WHC	humpback whitefish complex	*C. clupeaformis / C. nelsonii / C. pidschian*
WHF	whitefish-unspecified	Coregoninae
WIN	inconnu (sheefish)	*Stenodus leucichthys*
WLC	least cisco	*Coregonus sardinella*
WLK	lake whitefish	*Coregonus clupeaformis*
WPG	pygmy whitefish	*Prosopium coulteri*
WRN	round whitefish	*Prosopium cylindraceum*
YMA	shiner perch	*Cymatogaster aggregata*
YYP	yellow perch	*Perca flavescens*
QQQ	other species not listed	-
VVV	no collection effort	-
XXX	no fish collected or observed	-
ZZZ	general fish observation, no species information	-

Appendix B6.–Vegetation disturbance classes.

Code	Description
A	Anthropogenic Disturbance
AA	Unique
AA1	Timber Harvest
AA1a	0-1 year post-harvest
AA1b	1-5 year post-harvest
AA1c	10-20 year post-harvest
AA1d	20+ year post-harvest
AA2	Construction
AA2a	0-1 year post-construction
AA2b	1-5 year post-construction
AA2c	10-20 year post-construction
AA2d	20+ year post-construction
AA3	Enhancement/Restoration
AA3a	Bank Stabilization
AA3b	Riparian Thinning
AA3c	Fisheries Related
AA3d	Rip-Rap
AB	Repeated Seasonal
AB1	Foot Traffic
AB1a	Anglers
AB1b	Non-anglers
AB2	Vehicle Traffic
AB2a	Non-Recreational (road vehicle)
AB2b	Recreational (ATV, snowmachine)
AC	Permanent
AC1	Pervious Surfaces
AC1a	Urban/Commercial Landscaping
AC1b	Agricultural
AC1c	Gravel
AC1d	Other
AC2	Impervious Surfaces
AC2a	Parking Area
AC2b	Paved Trail/Walkway
AC2c	Concrete Wall/Abutment
N	Natural Disturbance
NA	Water/Flood
NA1	Slumping/Undercutting
NA1a	Wood Inputs
NA1b	Sediment Inputs
NA2	Sediment deposition from tributary
NB	Windthrow
NC	Glacial Retreat
ND	Fire
NE	Mass Wasting
NE1	Avalanche
NE2	Landslide
NE3	Debris Torrent
NE4	Natural Tree Mortality

Link to Appendix C:

APPENDIX C. STUDY-SITE MAPS

FDS 14-04 – FULL PDF FILE DOWNLOAD (93,185 kb)

Sections:

FDS14-04 – Text, Appendices A, B, E. F, G, H, I, and J

Appendix D – Occurrence Maps

Appendix K – 2003 Station Reports and Photos

Appendix L – 2011 Station Reports and Photos

Link to Appendix D:

APPENDIX D. SPECIES-OCCURRENCE MAPS

FDS 14-04 – FULL PDF FILE DOWNLOAD (93,185 kb)

Sections:

FDS14-04 – Text, Appendices A, B, E. F, G, H, I, and J

Appendix C – Occurrence Maps

Appendix K – 2003 Station Reports and Photos

Appendix L – 2011 Station Reports and Photos

APPENDIX E. SUMMARIES OF ANADROMOUS WATERS CATALOG NOMINATIONS

Appendix E1.–Summary of Anadromous Waters Catalog (AWC) nominations, 2003.

AWC nom. no.	Station ID (FSS03…)	AWC stream code (247-41-10200…)	Quad	New/Extend waterbody?	New species/ activity[a]	Backup species/ activity[a]
04-022	04A08	-2370-3023	Talkeetna B-1	N	-	Sp
04-023	11A05	-2370-3015	Talkeetna B-1	N	-	COr
04-024	05A01	-2969	Talkeetna Mts D-4	N	Kr	Kp
04-025	USU02	N/A	Talkeetna Mts D-4	Y[b]	Kp	
04-026	21A07	-2053-3170-4054	Talkeetna B-3	Y	COr	
04-027	21A05	-2053-3205-4050-5010	Tyonek D-4	Y	COr, Sr	
04-028	21A03	-2053-3170-4027-5033	Talkeetna A-3	Y	COr	
04-029	20A11	-2053-3205-4089-5255-6020	Tyonek D-6	Y	Ss	
04-030	21A02	-2053-3170-4027-5025	Talkeetna A-3	Y	Kr, COr	
04-031	20A10	-2053-3229	Talkeetna B-6	Y	COr, Ssr	
04-032	20A08 20A12	-2053-3205-4099-5012	Tyonek D-6	Y	COr, Sp	
04-033	20A06	-2053-3205-4120	Tyonek D-8	Y	Kr	
04-034	20A03	-2053-3205-4089-5119	Tyonek D-6	Y	Sp	
04-035	20A04	-2053-3205-4089-5255-6011	Tyonek D-6	Y	Ss	
04-036	20A02 20A01	-2053-3205-4089-5111	Tyonek D-6	Y	Kr, Ss	
04-037	19A10 19A05	-2053-3205-4112-5060	Talkeetna A-6	Y	Sp	
04-038	19A09	-2053-3205-4112-5054	Talkeetna A-6	Y	Sp	
04-039	19A04	-2053-3205-4112-5155-6015	Mc Grath A-1	Y	Kr, Sr	
04-040	19A03	-2053-3205-4112-5255	Mc Grath A-1	Y	Ssr	
04-041	18A02	-2053-3205	Tyonek C-8	Y	Sp	
04-042	17A05	-2053-3205-4009-5006	Tyonek D-4	Y	COr	
04-043	16A05	-2053-3205-4077	Tyonek D-5	Y	CHp, Ps, Sp	
04-044	16A04	-2053-3205-4064-5105-6035	Tyonek D-5	Y	CHs	
04-045	16A02 16A01	-2053-3205-4009	Tyonek D-4	Y	COr, Kp, Ss	
04-046	15A05	-2053-3225	Talkeetna A-5	Y	Ss	
04-047	15A04	-2053-3219	Talkeetna A-4	Y	COr	
04-048	15A02	-2053-3229-4009-5011	Talkeetna A-4	Y	COr	
04-049	15A01	-2053-3229-4009-5105	Talkeetna A-4	Y	COr	
04-050	14A06	-2053-3229-4050	Talkeetna A-5	Y	Sp	
04-051	14A04	-2053-3229-4002-5033	Talkeetna A-4	Y	COr	
04-052	14A03	-2053-3043	Talkeetna A-4	Y	COr	
04-053	14A02	-2053-3249-4103	Talkeetna B-4	Y	Kr, COr, Pp	
04-054	13A05	-2053-3220-4030-5040-6405	Talkeetna A-4	Y	COr	
04-055	13A02	-2053-3170-4045-5011	Talkeetna B-3	Y	COr, Kr	
04-056	13A01	-2053-3170-4045-5201	Talkeetna B-3	Y	COr	
04-057	12A07	-2053-3170-4045-5028-6025	Talkeetna B-3	Y	COr	

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Appendix E1.–Page 2 of 2.

AWC nom. no.	Station ID (FSS03…)	AWC stream code (247-41-10200…)	Quad	New/Extend waterbody?	New species/ activity[a]	Backup species/ activity[a]
04-058	12A06	-2053-3170-4047	Talkeetna B-3	Y	COr	
04-059	12A02 12A01	-2053-3170-4067	Talkeetna B-4	Y	COr, Kr, CHp, Ss	
04-060	11A06	-2381-3004	Talkeetna B-1	Y	COr	
04-061	11A04	-2361	Talkeetna B-1	Y[b]	COr	
04-062	09A05	-2300-3011-4016	Talkeetna Mts B-6	Y	COr	
04-063	09A04	-2230-3144-4520	Talkeetna Mts A-6	Y	COr	
04-064	09A03	-2200-3310	Talkeetna Mts A-6	Y	COr	
04-065	09A02	-2200	Talkeetna Mts A-5	Y	Kr	
04-066	07A06	-2810	Talkeetna Mts C-2	Y	Kr	
04-067	06A05	-2880	Talkeetna Mts C-1	Y	Kr	
04-068	04A07 04A05	-2370-3041-4049-5056	Talkeetna Mts B-6	Y	COrp, Krp	
04-069	04A06 04A04	-2370-3041-4049	Talkeetna Mts C-6	Y	COpr	
04-070	04A03	-2370-3041-4080	Talkeetna Mts C-6	N	COsr	
04-071	04A02	-2370-3041	Talkeetna Mts C-5	Y	Kr	
04-072	03A07 03A06	-2370-3297	Talkeetna Mts C-5	Y	Kp, Sp	
04-073	03A05	-2370-3301	Talkeetna Mts C-5	Y	Kr, COr	
04-074	03A04	-2370-3301-4034	Talkeetna Mts C-4	Y	COr	
04-075	03A03	-2370-3301	Talkeetna Mts C-4	Y	Sp	
04-076	02A06	-2370-3041-4050	Talkeetna Mts B-6	Y	Kr	
04-077	02A05	-2370-3041-4010-5056-6306-7055	Talkeetna Mts B-6	Y	COr	
04-078	01A04 01A05	-2370-3180	Talkeetna Mts B-5	Y	Sp, Kp	
04-079	01A03 SHE01	-2370-3090	Talkeetna Mts A-4	Y	Sp, Kp	
04-080	20A05	-2053-3205-4089-5130	Tyonek D-6	Y	Ss	
04-081	19A07	-2053-3205-4112-5054	Talkeetna A-6	N	Sr	

[a] AWC species codes: CH = chum salmon; CO = coho salmon; K = Chinook salmon; P = pink salmon; S = sockeye salmon. AWC activity codes: p = present; r = rearing; s = spawning.

[b] This nomination did not result in a revision to the AWC. An addition to the AWC requires observation of ***at least two anadromous fish*** of the same species and life stage.

Appendix E2.–Summary of Anadromous Waters Catalog (AWC) nominations, 2011.

AWC nom. no.	Station ID (FSS11…)	AWC stream code (247…)	Quad	New/ Extend waterbody?	New species/ activity[a]	Backup species/ activity[a]
11-484	01F01	-50-10200-2081	Anchorage C-6	N	Sr	
11-485	01G04	-41-10200-2810	Talkeetna Mts C-3	Y	Kp	
11-486	02D01	-41-10200-2053	Talkeetna A-3	N	Sp	Kpr, Pp
11-487	02F03 02F02 02F01	-50-10200-2121	Anchorage B-5	Y	COr, Kr	
11-488	02F07 02F06	-50-10200-2155-3004	Anchorage B-5	Y	Ss	
11-489	03D01	-41-10200-2053-3205	Tyonek D-4	N		Kp, Pp, Sp
11-490	03F04 03F06	-50-10200	Anchorage B-5	N	Sr	Ss
11-491	03F05	-50-10200	Anchorage B-5	N		Ss
11-492	04D01	-41-10200-2053-3150	Tyonek D-2	N		Kp, Sp
11-493	06D01	-41-10200	Talkeetna C-1	N	Kr	Kp
11-494	08D01	-41-10200-2081	Tyonek D-1	N	ALpr, PCp	Kpr, Pp
11-495	09A01	-41-10200-2381	Healy A-6	N	Kr, Pp	COp
11-496	11A01	-41-10200-2381-3239-4502	Healy B-5	Y	Krs	
11-497	14A01	-41-10200-2370	Talkeetna Mts C-5	N	Krs	COp, Sp
11-498	15A01	-50-10200-2160	Anchorage A-5	N	*AWC correction: remove Upper Lake George*	
11-499	19A01	-50-10220	Anchorage D-4	N		Ss, COp
11-564	10B01	-41-10200-2381-3235	Healy A-6	Y	Sp	
11-565	11B01	-41-10200-2381-3260	Healy A-5	Y	Krs	
11-566	11B02	-41-10200-2381-3260-4100	Healy A-5	Y	COp	
11-567	16C04	-50-10220-2110	Anchorage C-5	Y	Kr, COr	
11-568	17C05	-50-10220-2105	Anchorage D-5	N	Kr	
11-569	21C04	-50-10220-2085	Anchorage C-6	N	Ps, Ss	Kr, CHs, COr
11-570	26C02	-41-10200-2053-3229-4200	Talkeetna B-6	Y	COrs, Ss	
11-571	26C03	-41-10200-2053-3229-4127	Talkeetna A-5	Y	Kr	
11-572	27C03	-41-10200-2053-3205-4067	Tyonek D-5	Y	Kr, COr	
11-573	27C05	-41-10200-2053-3205-4053-5046	Tyonek C-5	Y	Kr, COr	
11-574	27C06	-41-10200-2053-3205-4053-5046	Tyonek C-5	Y	COr	Kr, CHs, COr
11-575	28C01	-50-10200-2074	Anchorage C-6	Y	Sr, COr	
11-576	28C02	-50-10200-2078-0010	Anchorage C-6	Y	COr	
11-577	28C06	-50-10200-2120	Anchorage B-5	Y	COrs, Ss	
11-578	28C08	-50-10200-2140	Anchorage B-5	N	COs, DVs	
11-579	28C09	-50-10200-2071-3023	Anchorage C-6	N	Ss	
11-580	29C01	-50-10200-2050	Anchorage B-6	Y	COrs, Kpr	

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AWC nom. no.	Station ID (FSS11…)	AWC stream code (247…)	Quad	New/ Extend waterbody?	New species/ activity	Backup species/ activity
11-581	14C03	-41-10200-2053-3170-4088	Talkeetna C-3	N		Ss
11-582	04C01	-41-10200-2696-3020	Talkeetna Mts B-3	Y	Kr	
11-583	06C04	-41-10200-2370-3301	Talkeetna Mts C-4	N		Ksr, COr, Sp
11-584	08C04	-41-10200-2381	Healy B-4	Y	Kr, COr	
11-585	09C01 11C09	-41-10200-2585	Healy A-4	Y	Kr	
11-586	09C03	-41-10200-2381-3260-4100	Healy A-5	Y	Kr, COr	
11-587	11C04	-41-10200-2585-3223	Talkeetna Mts D-5	Y	Kr	
11-588	13C04	-41-10200-2053-3205-4220	Tyonek D-8	Y	Kr, Sr	
11-589	13C05	-41-10200-2053-3205-4165	Tyonek D-8	Y	Kr, COr, Spr	
11-590	13C06	-41-10200-2053-3205-4120	Tyonek D-8	Y	Kr	
11-591	14C08	-41-10200-2053-3205-4105	Tyonek D-7	Y	Sr	
11-592	14C09	-41-10200-2053-3205-4112-5045	Talkeetna A-6	N	Sr, Kr	Kp, Ss
11-593	15C01	-41-10200-2053-3205-4112-5045-0010	Talkeetna A-6	N		Ss
11-623	28C07	-50-10200-2126	Anchorage B-5	Y	Sr, COr	
11-700	19A02	-50-10220-2139	Anchorage C-5	Y	Ss	
11-701	21A03 21A04 21A06	-50-10200-2081-3041	Anchorage C-5	N	COr, Srs	
11-702	21B01 16C03	-50-10200-2160-3051	Anchorage B-4	Y	Sp	
11-703	21B02 02F04 03F03 21A01	-50-10200-2155	Anchorage B-5	Y	COpr, Srs	
11-709	07D01	-41-10200	Tyonek C-1	N		Sp, Pp
11-710	05D01	-41-10200-2053	Tyonek C-2	N	Sp	Pp
11-711	03F01	-50-10200	Anchorage B-5	N	Sr	

[a] AWC species codes: AL = Arctic lamprey; CH = chum salmon; CO = coho salmon; DV = Dolly Varden; K = Chinook salmon; P = pink salmon; PC = Pacific lamprey; S = sockeye salmon.

AWC activity codes: p = present; r = rearing; s = spawning.

APPENDIX F. OCCURRENCE OF FISH SPECIES AND LIFE STAGES BY STREAM SIZE

Appendix F1.–Occurrence (no. of electrofished sites) of fish species and life stages by stream size.

Scientific name	Common name	Life stage	Stream size: Small (n=152)	Medium (n=63)	Large (n=27)	Total (n=242)
Lampetra camtschatica	Arctic lamprey	juvenile	0	0	1	1
		juvenile/adult	0	0	1	1
		adult	0	0	1	1
Lampetra tridentata	Pacific lamprey	adult	0	0	1	1
Lampetra sp.	lamprey-unspecified	juvenile	1	0	2	3
		juvenile/adult	0	0	2	2
		adult	0	0	1	1
Catostomus catostomus	longnose sucker	juvenile	0	2	6	8
		juvenile/adult	0	4	11	15
		adult	0	3	11	14
Esox lucius	northern pike	juvenile/adult	0	0	2	2
		adult	0	0	1	1
Coregonus pidschian	humpback whitefish	juvenile	0	0	2	2
		juvenile/adult	0	0	3	3
		adult	0	0	4	4
Prosopium coulteri	pygmy whitefish	juvenile/adult	0	1	0	1
Prosopium cylindraceum	round whitefish	juvenile	1	4	7	12
		juvenile/adult	3	10	10	23
		adult	0	6	6	12
Coregoninae	whitefish-unspecified	juvenile	0	0	2	2
		adult	0	1	2	3
Thymallus arcticus	Arctic grayling	juvenile	22	20	16	58
		juvenile/adult	16	16	12	44
		adult	6	6	8	20
Oncorhynchus gorbuscha	pink salmon	adult	1	0	6	7
		adult spawning	0	1	0	1
		carcass	0	0	1	1
O. keta	chum salmon	adult spawning	0	1	0	1
O. kisutch	coho salmon	juvenile	35	1	0	36
		adult	1	0	3	4
		adult spawning	2	1	0	3
O. mykiss	rainbow trout	juvenile	10	2	0	12
		juvenile/adult	7	2	4	13
		adult	1	2	3	6
O. nerka	sockeye salmon	juvenile	10	1	0	11
		adult	1	2	7	10
		adult spawning	4	1	1	6
		carcass	2	0	0	2
O. tshawytscha	Chinook salmon	juvenile	24	7	8	39
		adult	1	1	5	7
		adult spawning	0	2	1	3
		carcass	1	1	0	2

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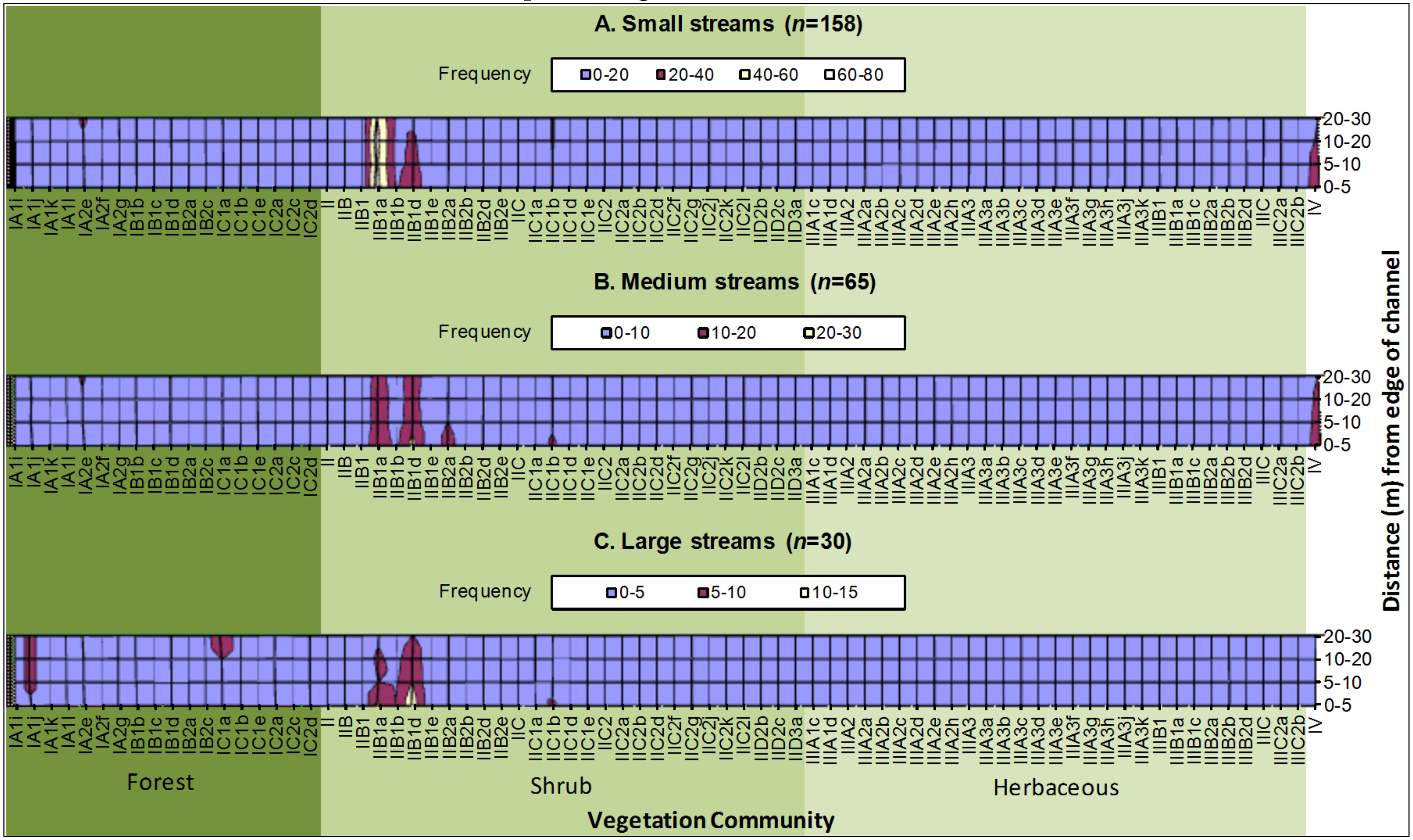
Appendix F1.–Page 2 of 2.

Scientific name	Common name	Life stage	Stream size Small (n=152)	Medium (n=63)	Large (n=27)	Total (n=242)
Salvelinus malma	Dolly Varden	Juvenile	59	18	2	79
		juvenile/adult	65	27	7	99
		adult	20	7	2	29
Lota lota	burbot	juvenile	3	4	9	16
		juvenile/adult	0	4	5	9
		adult	0	0	1	1
Gasterosteus aculeatus	threespine stickleback	juvenile	1	0	2	3
		juvenile/adult	4	0	1	5
		adult	1	0	2	3
Pungitius pungitius	ninespine stickleback	juvenile	1	0	0	1
		juvenile/adult	1	0	0	1
		adult	1	0	0	1
Cottus cognatus	slimy sculpin	juvenile	43	18	16	77
		juvenile/adult	61	27	20	108
		adult	40	22	14	76
Cottidae	sculpin-unspecified	juvenile	0	0	1	1
		juvenile/adult	2	0	4	6
		adult	0	2	2	4
no fish found	N/A	N/A	39	33	12	84

APPENDIX G. GRAPHICAL SUMMARIES OF FISH AND HABITAT VARIABLES

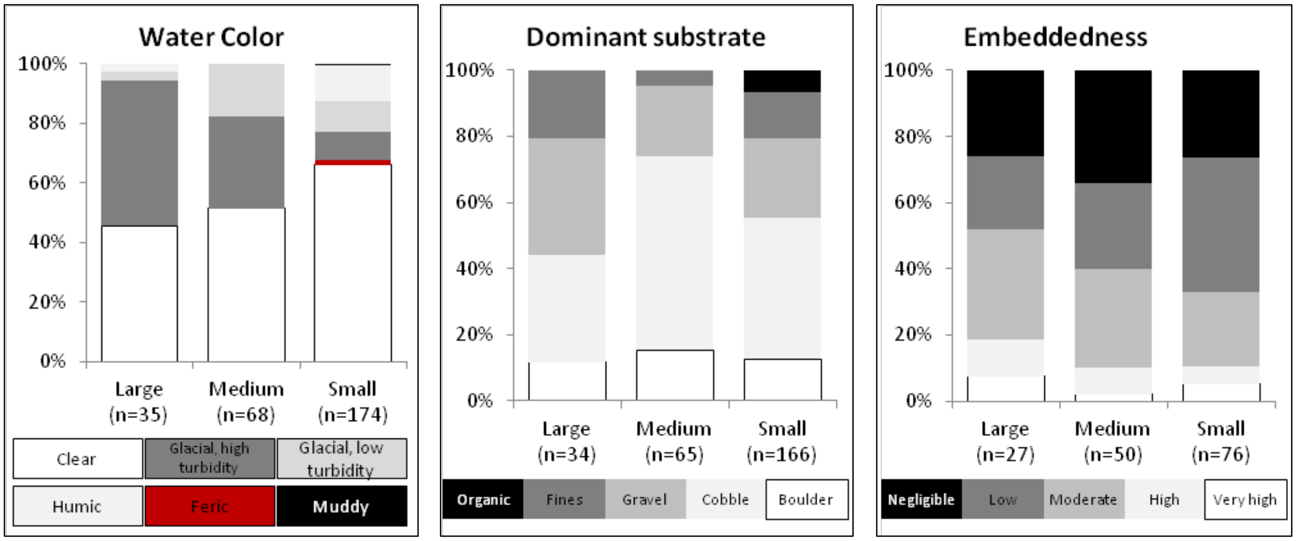
Appendix G1.–Distributions of categorical habitat variables.

Occurrence of dominant riparian vegetation communities at fish-collection reaches.

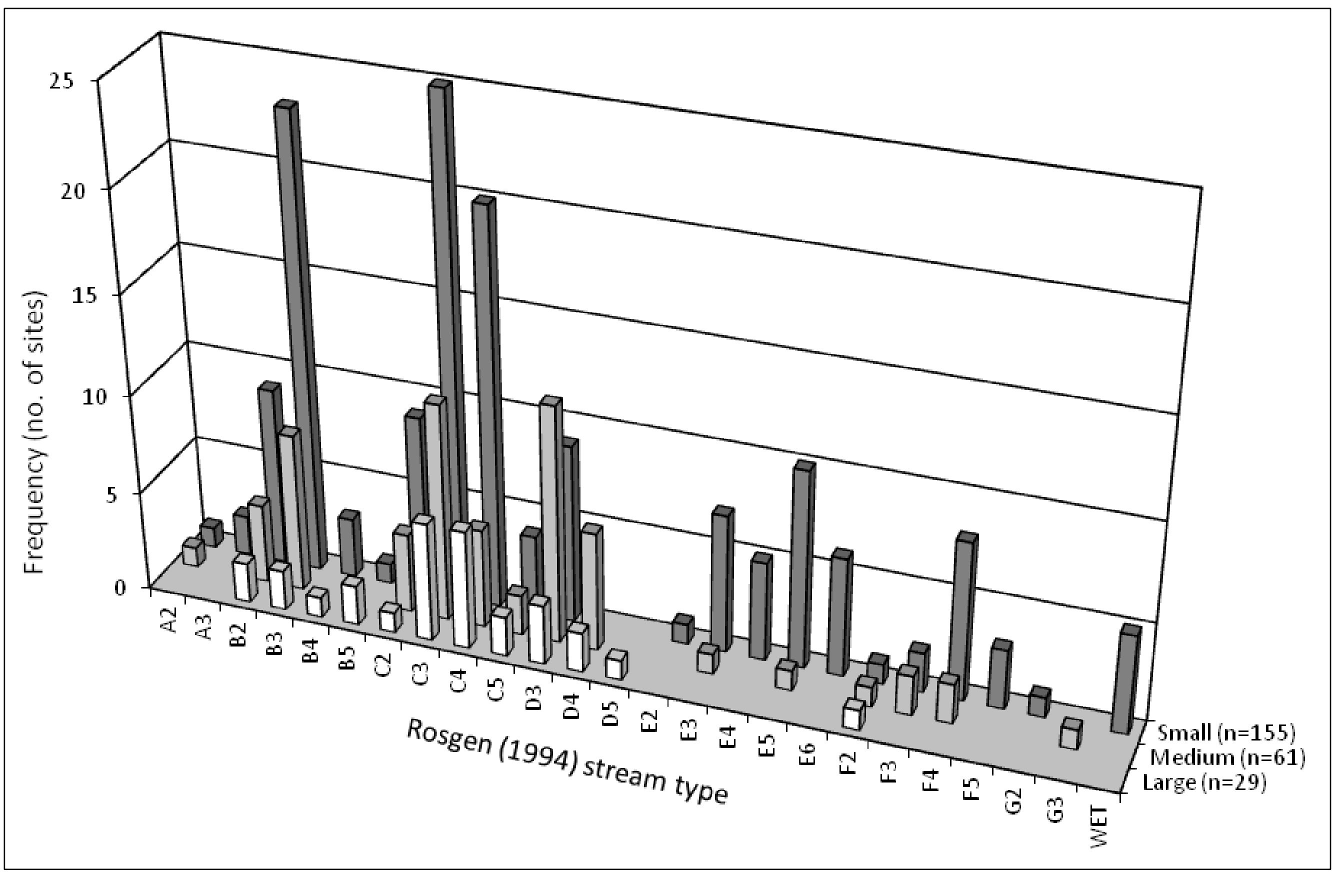


Note: Level-IV vegetation communities (Viereck et al. 1992) we observed are shown along the *x*-axis. Along the *y*-axis, vegetation communities are grouped into 4 zones according to their distance (m) from the edge of the stream channel. The count of each vegetation community type is represented by shading. Vegetation communities along both stream banks are included—so, for each site, there are 2 vegetation community counts per zone.

Occurrence of water color, substrate, embeddedness, and Rosgen stream types

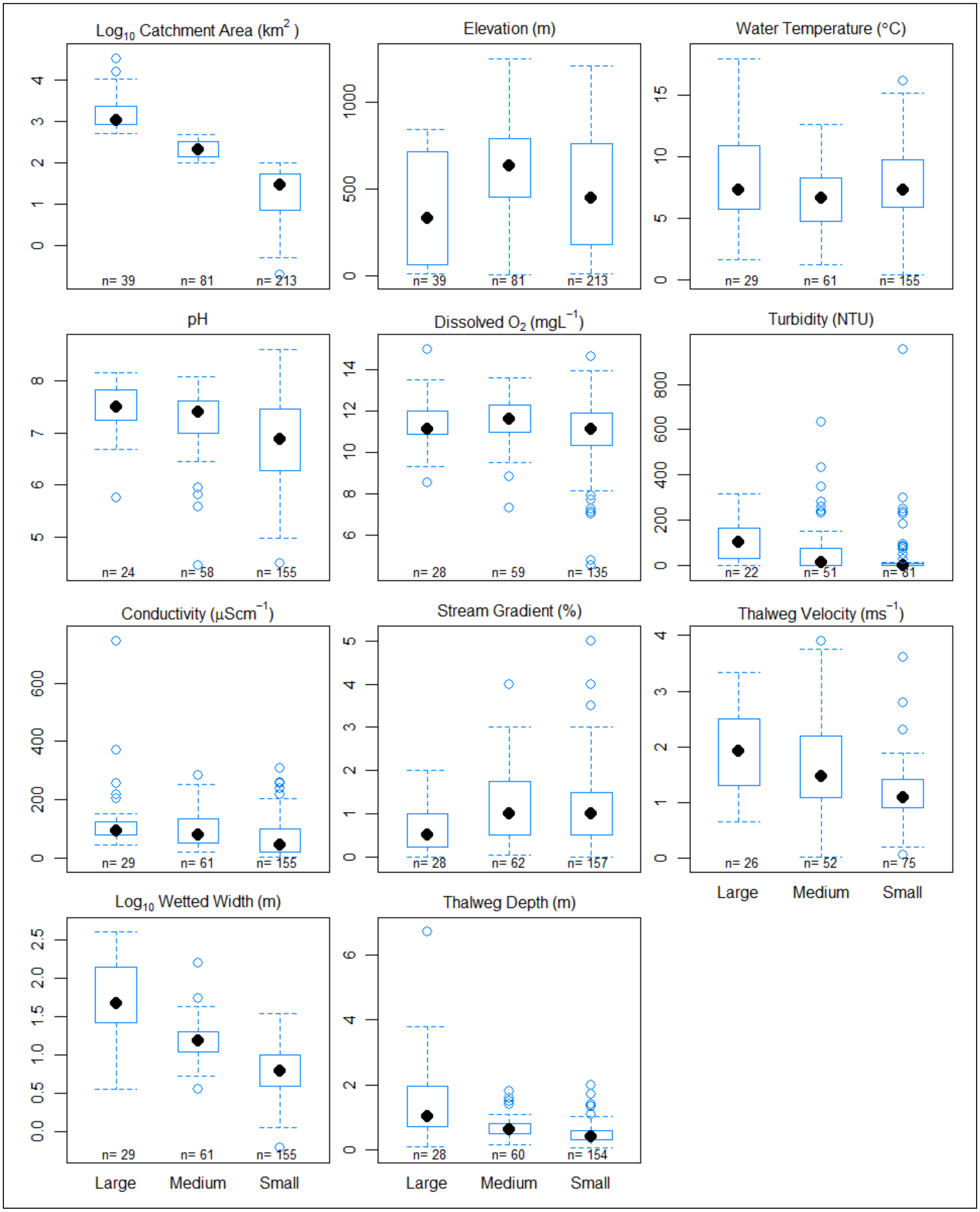


Note: Variables grouped along the *x*-axis by stream size.



Note: Rosgen (1994) stream types (*y*-axis) by stream size (*x*-axis). Bar height (*z*-axis) represents the number of sites.
Note: Graphical display of frequency distributions created using R statistical language (R Core Team 2012).

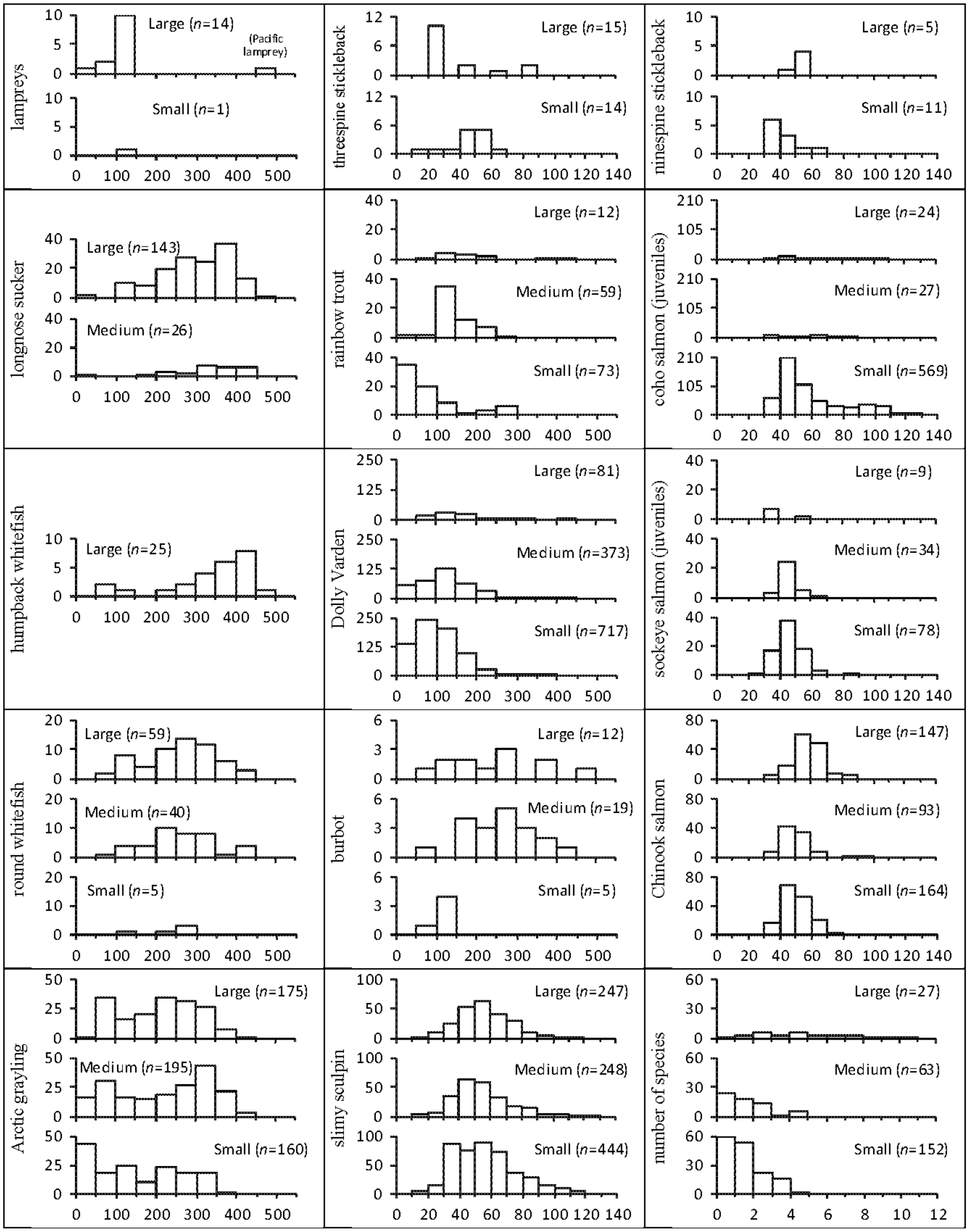
Appendix G2.–Box plots of selected numeric habitat variable distributions, grouped by stream size.



Note: Stream-size categories are based on drainage area (km^2) upstream of each site (i.e., catchment area): Small streams, ≤100 km^2; Medium streams, 100–500 km^2; Large streams, >500 km^2.

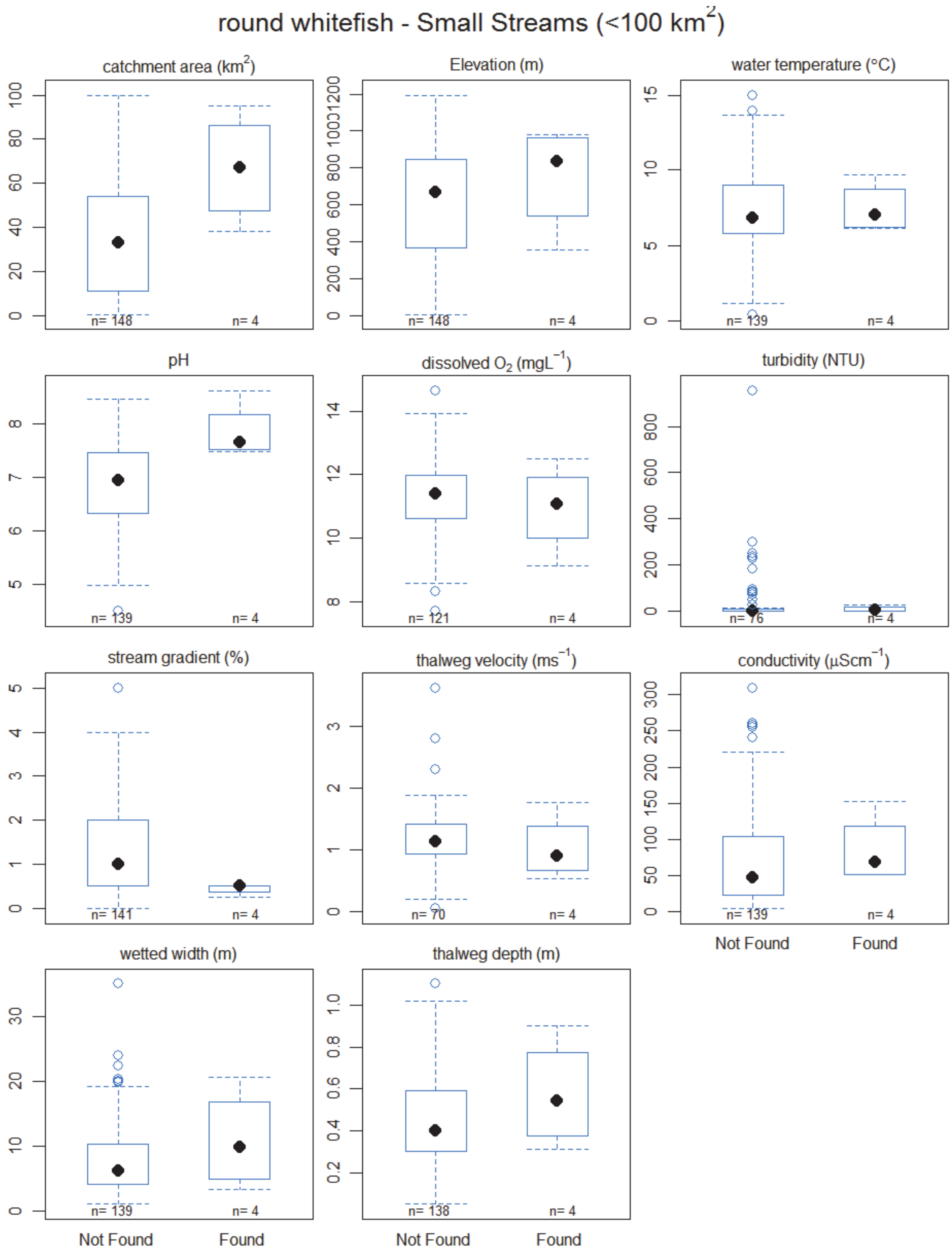
Note: Box plots created through R

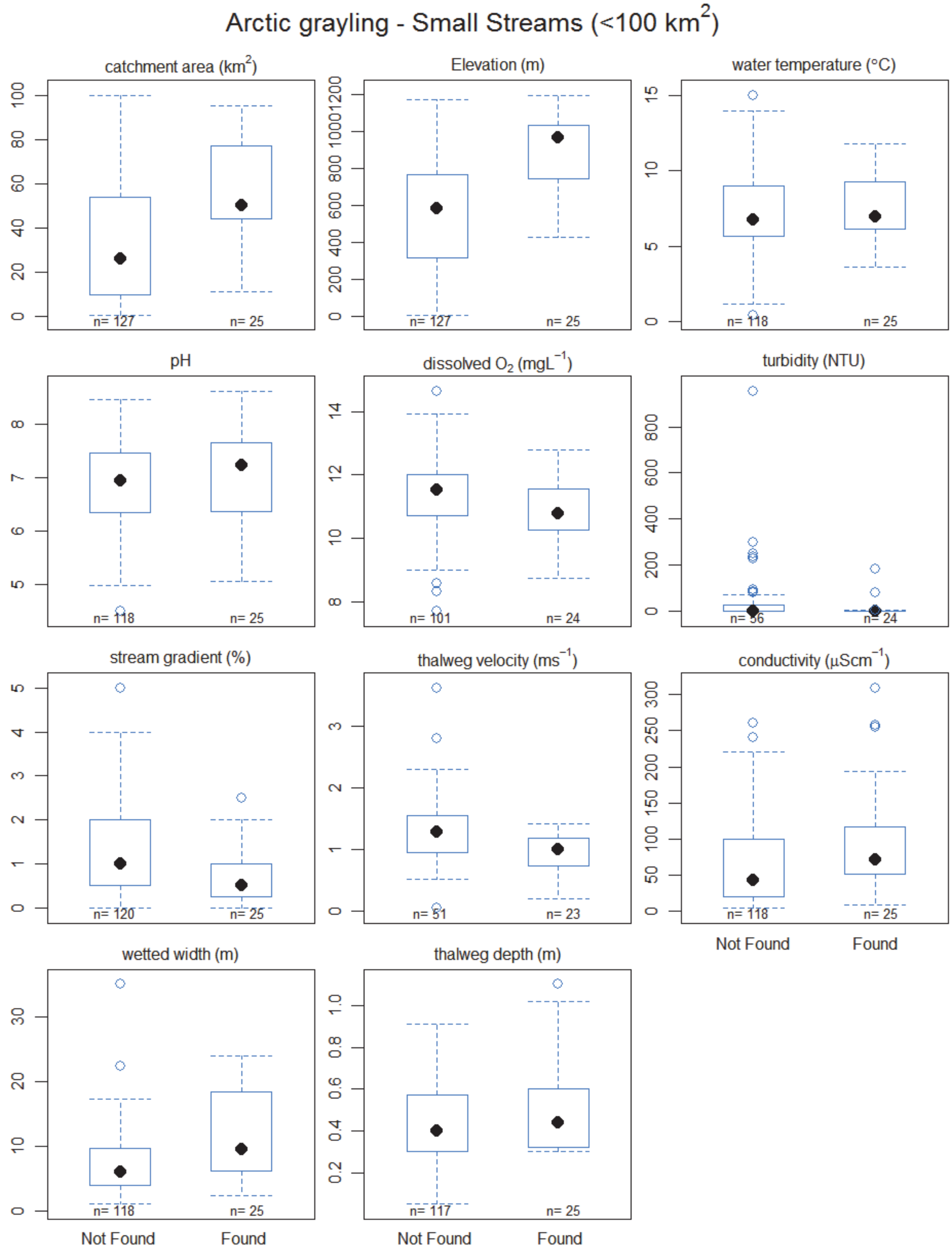
Appendix G3.–Frequency histograms of fork lengths of measured fish, and the number of species found per site, grouped by stream size.

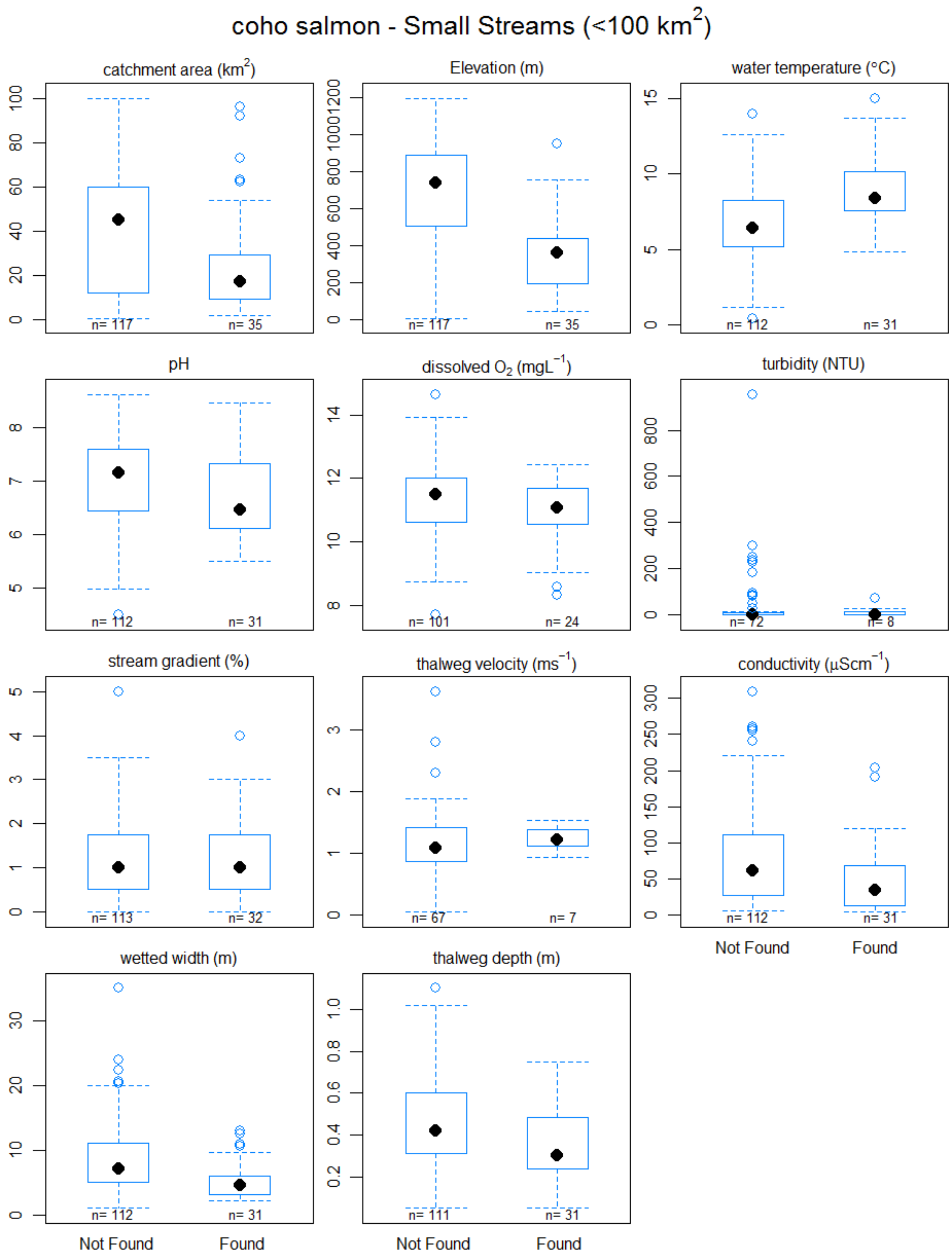


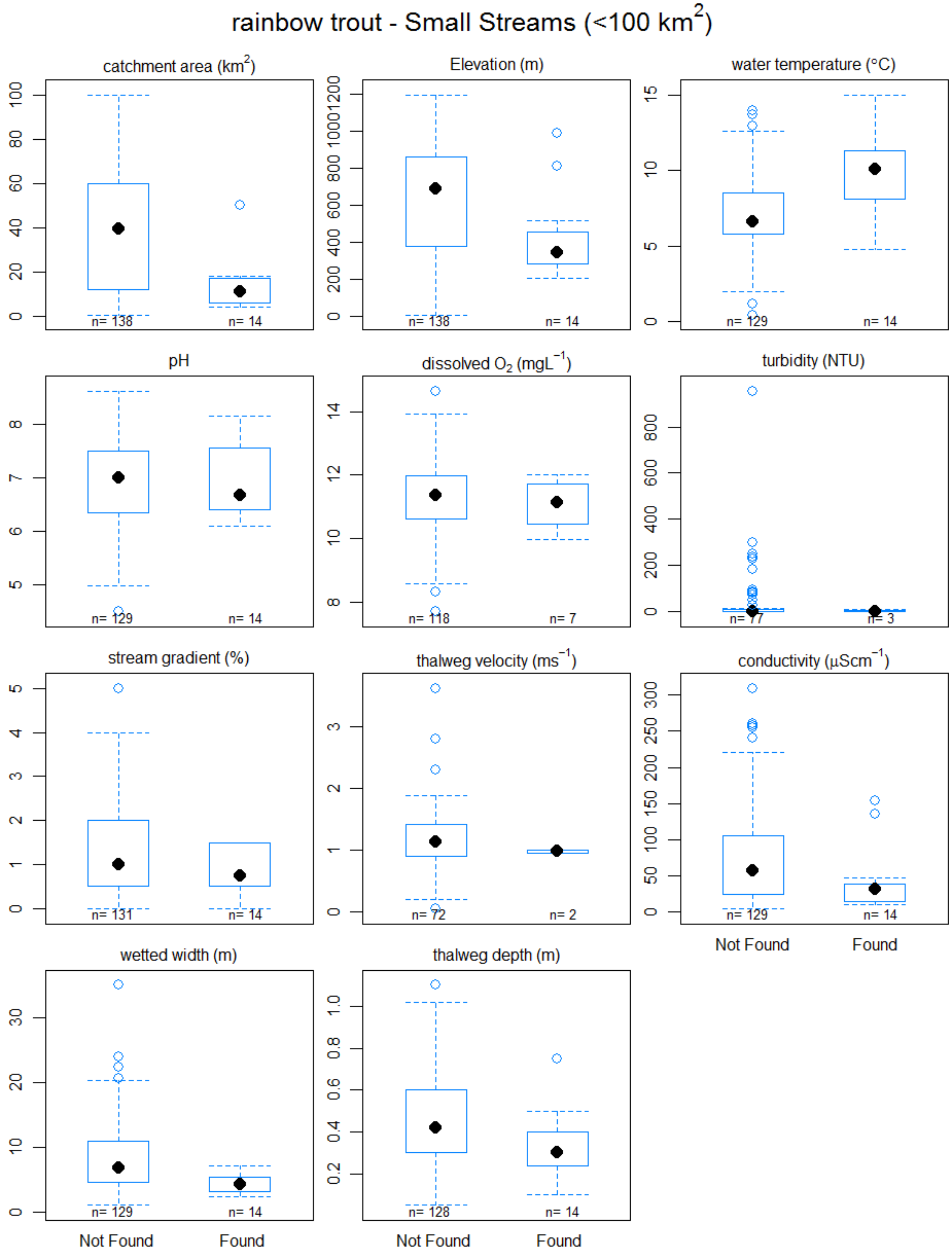
Note: x-axis shows fish fork length (mm); y-axis shows frequency (number of fish measured). Stream-size categories are based on drainage area (km^2) upstream of each site (i.e., catchment area): Small streams, ≤100 km^2; Medium streams, 100–500 km^2; Large streams, >500 km^2. Individual fish lengths from all sites within each stream-size category were pooled.

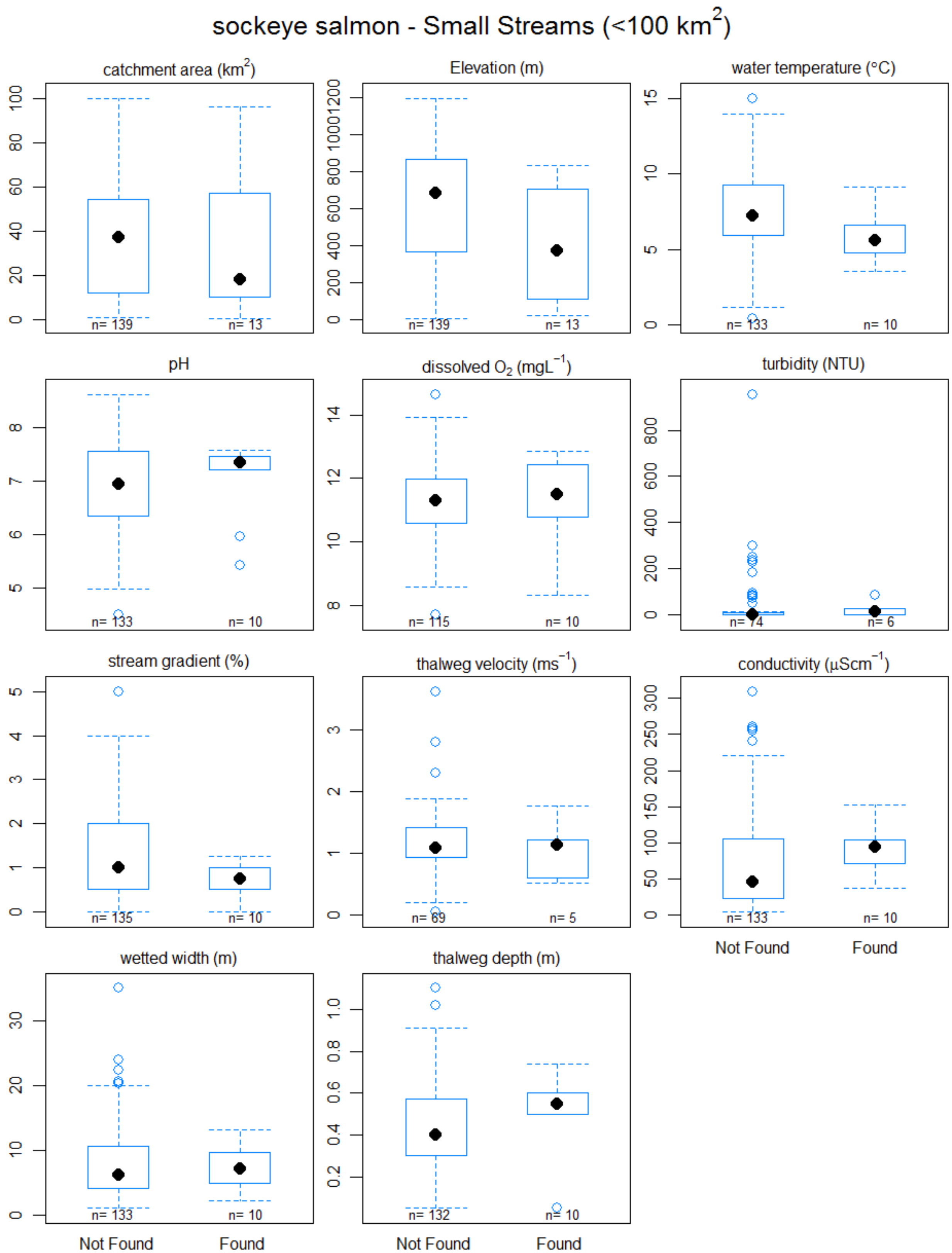
Appendix G4.–Paired box plots of continuous habitat variable distributions grouped by stream size and species occurrence.

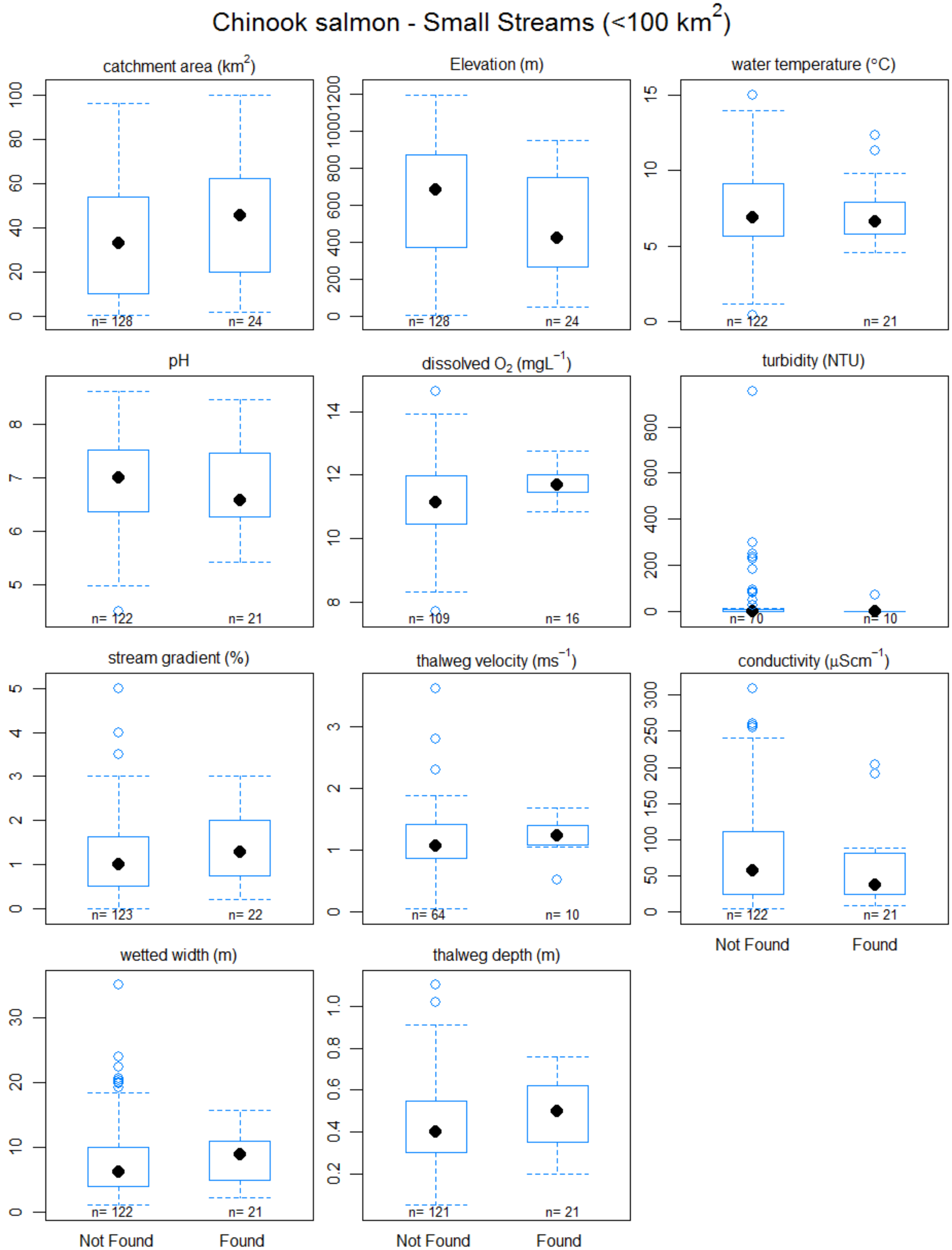


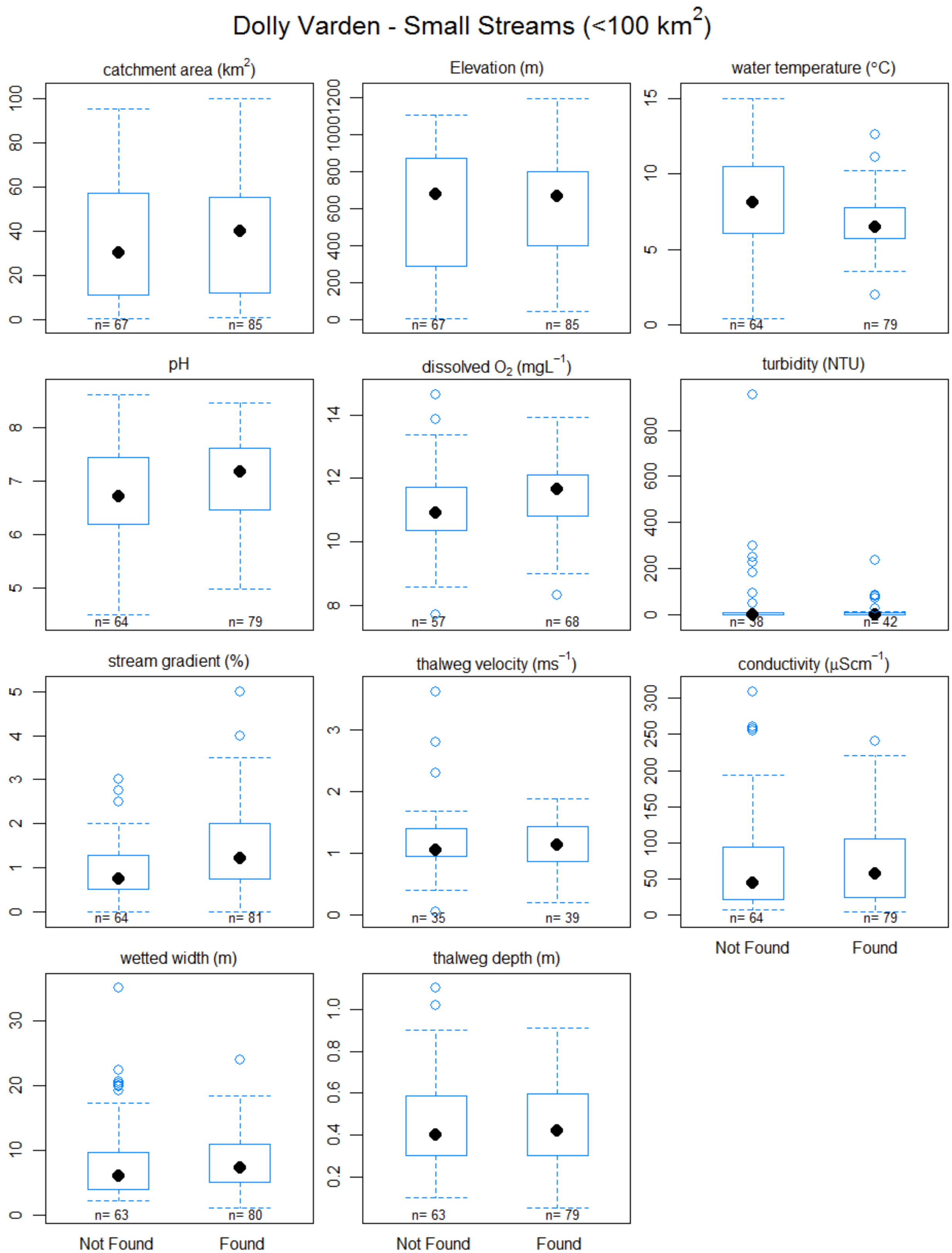

Arctic grayling - Small Streams (<100 km²)
catchment area (km²)
Elevation (m)
water temperature (°C)
pH
dissolved O₂ (mgL⁻¹)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms⁻¹)
conductivity (µScm⁻¹)
wetted width (m)
thalweg depth (m)
n= 127
n= 25
n= 127
n= 25
n= 118
n= 25
n= 118
n= 25
n= 101
n= 24
n= 56
n= 24
n= 120
n= 25
n= 51
n= 23
n= 118
n= 25
n= 118
n= 25
n= 117
n= 25
Not Found
Found

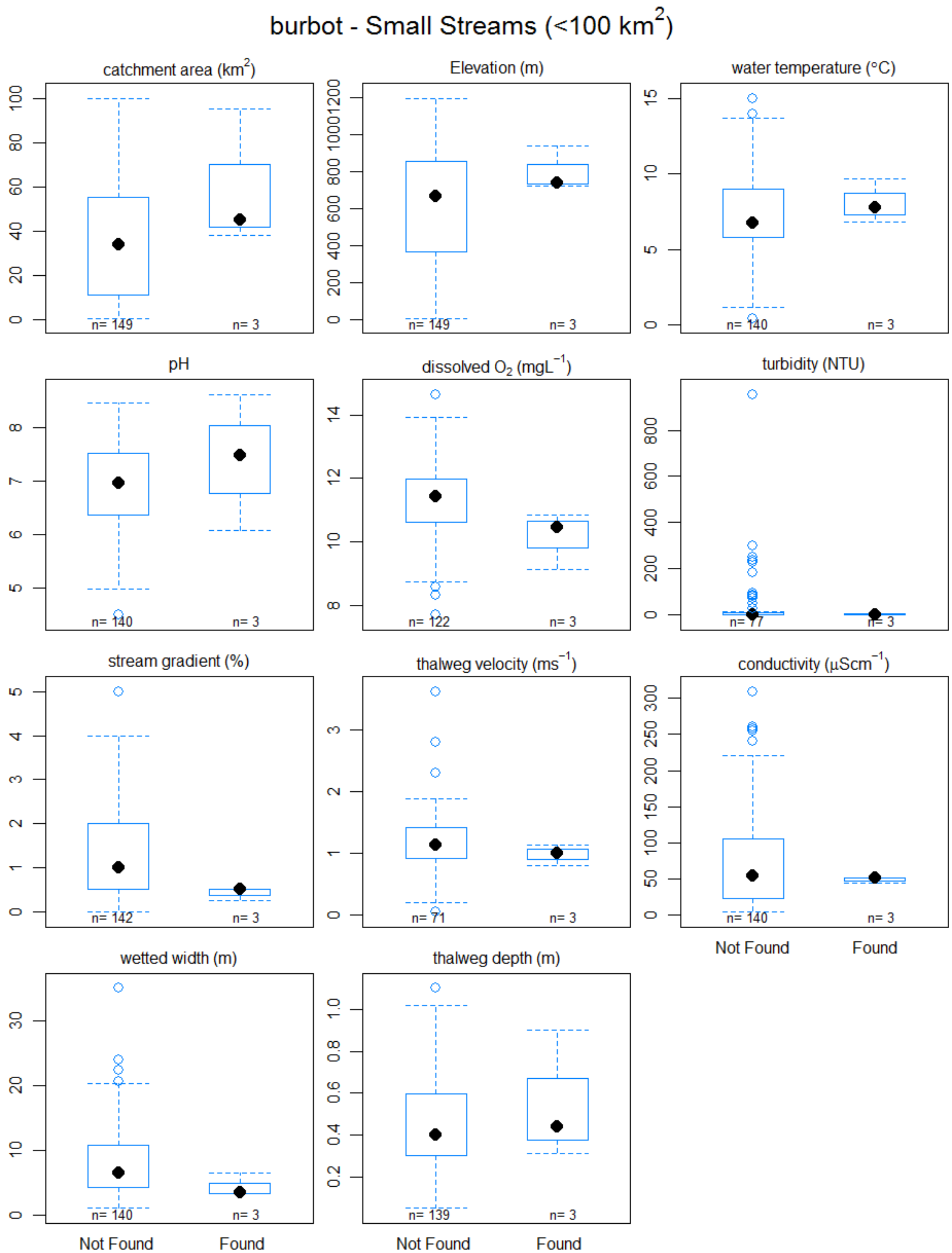

coho salmon - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
n= 117
n= 35
n= 117
n= 35
n= 112
n= 31
n= 112
n= 31
n= 101
n= 24
n= 72
n= 8
n= 113
n= 32
n= 67
n= 7
n= 112
n= 31
n= 112
n= 31
n= 111
n= 31
Not Found
Found

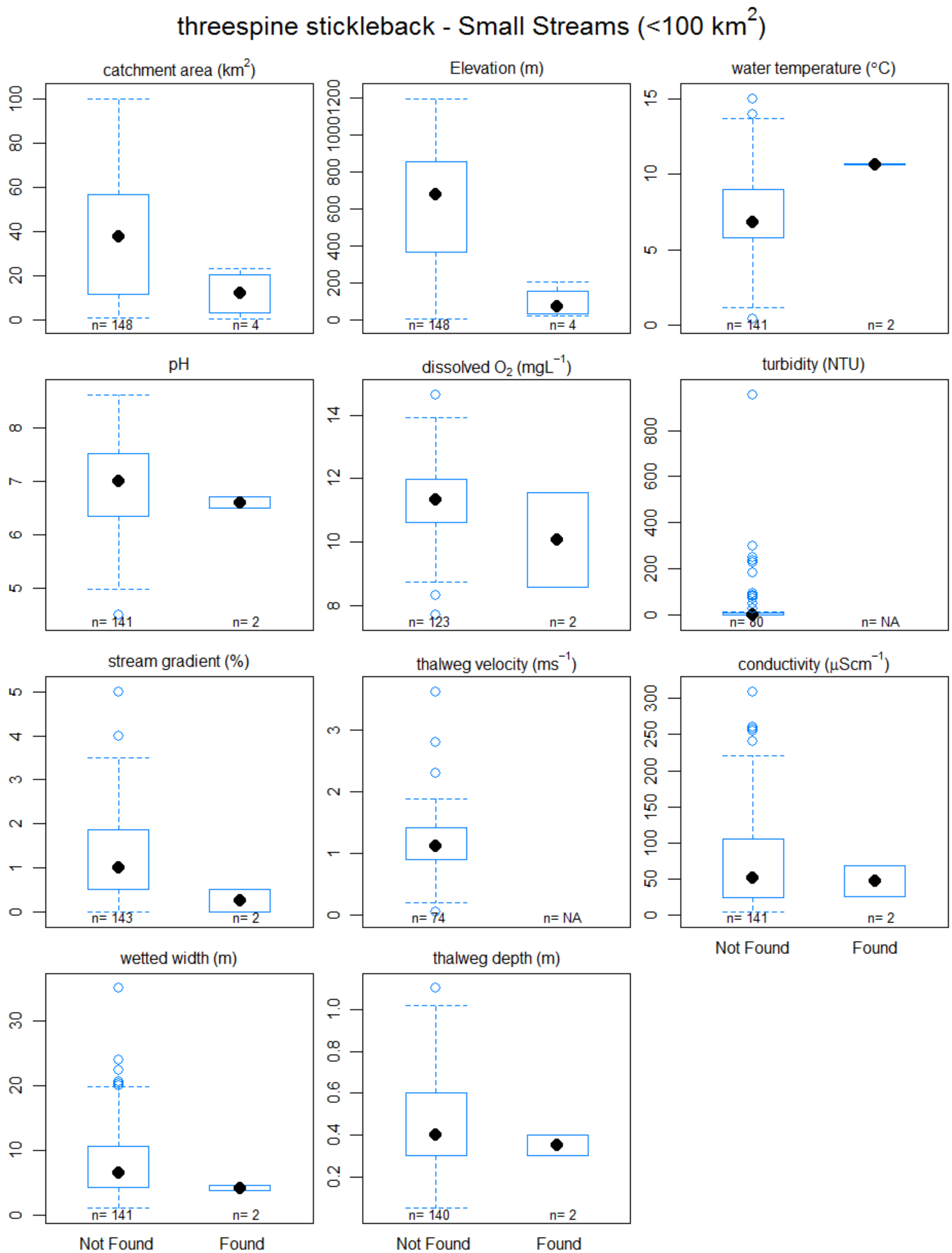

rainbow trout - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
n= 138
n= 14
n= 129
n= 118
n= 7
n= 77
n= 3
n= 131
n= 72
n= 2
n= 128
Not Found
Found


sockeye salmon - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 139
n= 13
n= 133
n= 10
n= 115
n= 74
n= 6
n= 135
n= 69
n= 5
n= 132
Not Found
Found

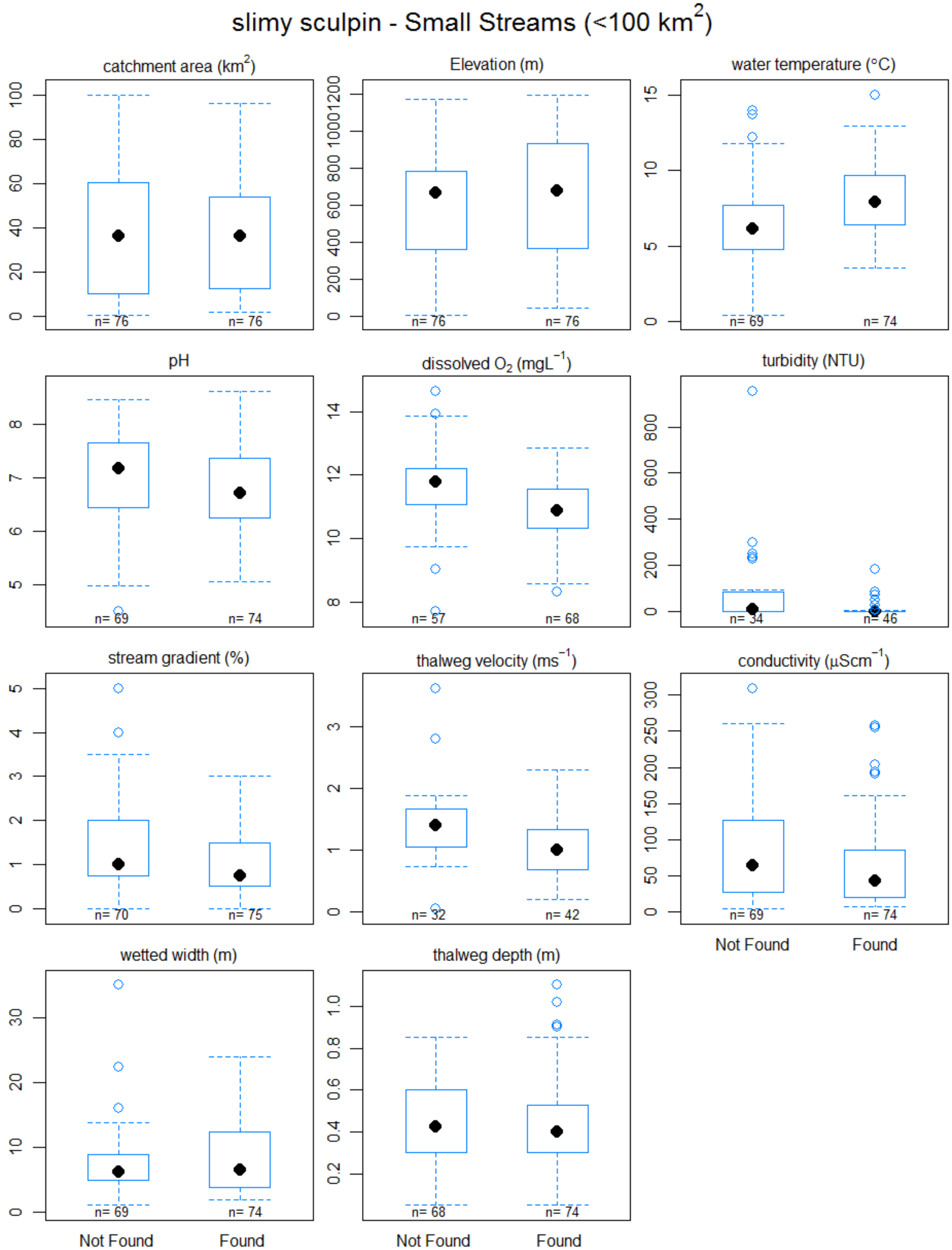

Chinook salmon - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 128
n= 24
n= 128
n= 24
n= 122
n= 21
n= 122
n= 21
n= 109
n= 16
n= 70
n= 10
n= 123
n= 22
n= 64
n= 10
n= 122
n= 21
n= 122
n= 21
n= 121
n= 21
Not Found
Found

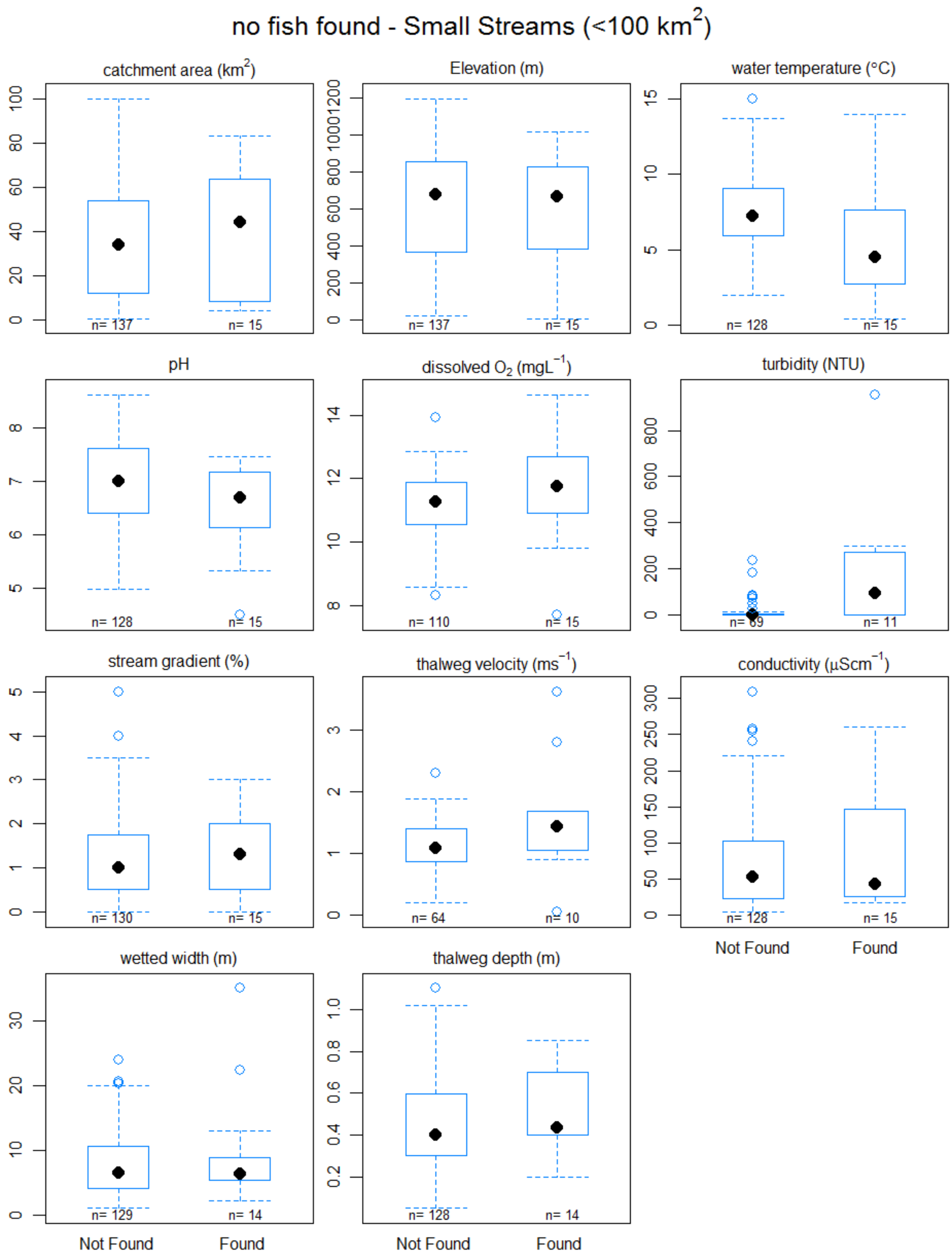

Dolly Varden - Small Streams (<100 km2)
catchment area (km2)
n= 67
n= 85
Elevation (m)
n= 67
n= 85
water temperature (°C)
n= 64
n= 79
pH
n= 64
n= 79
dissolved O2 (mgL-1)
n= 57
n= 68
turbidity (NTU)
n= 38
n= 42
stream gradient (%)
n= 64
n= 81
thalweg velocity (ms-1)
n= 35
n= 39
conductivity (µScm-1)
n= 64
n= 79
Not Found
Found
wetted width (m)
n= 63
n= 80
thalweg depth (m)
n= 63
n= 79
Not Found
Found
Not Found
Found

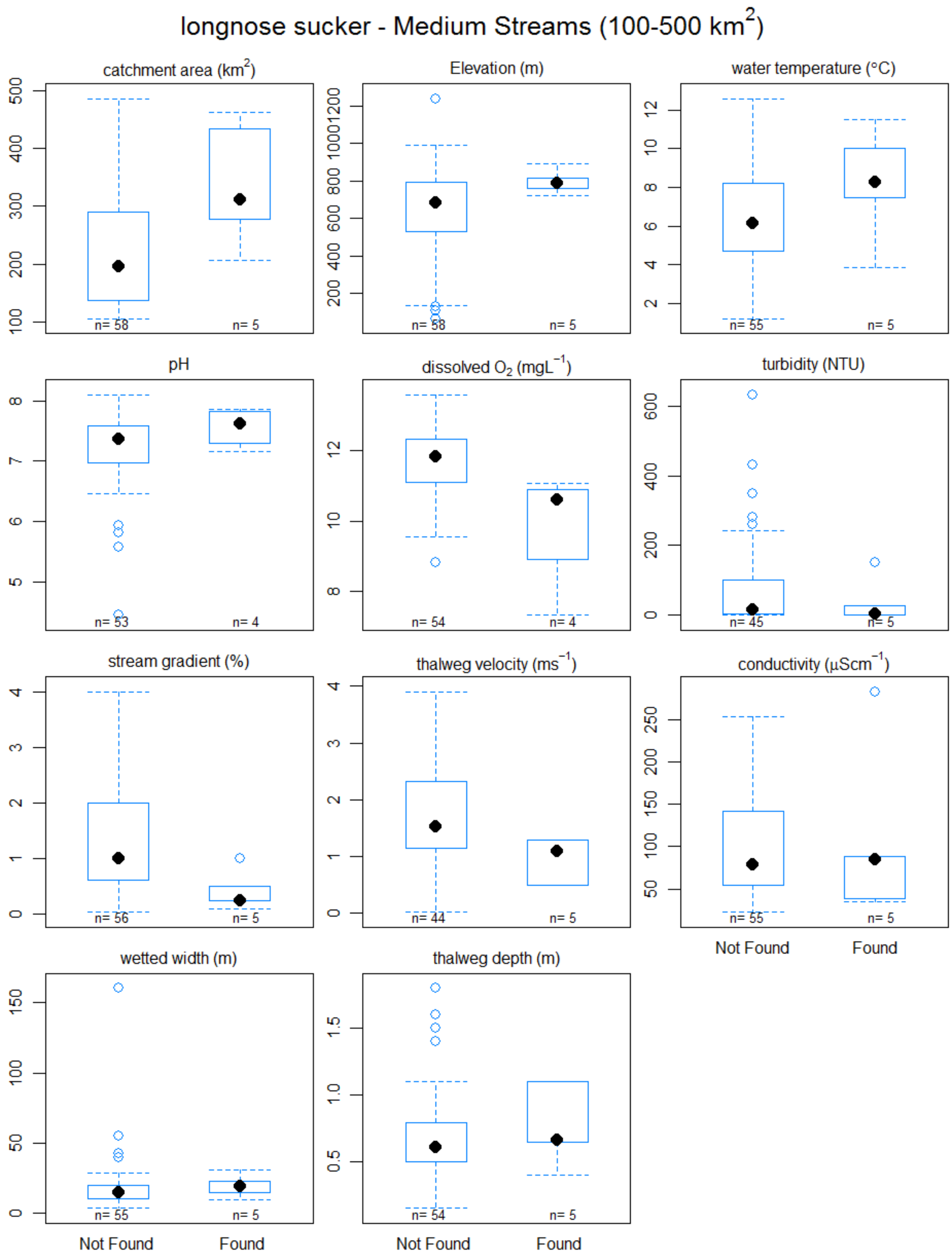

burbot - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 149
n= 3
n= 140
n= 122
n= 77
n= 142
n= 71
n= 139
Not Found
Found

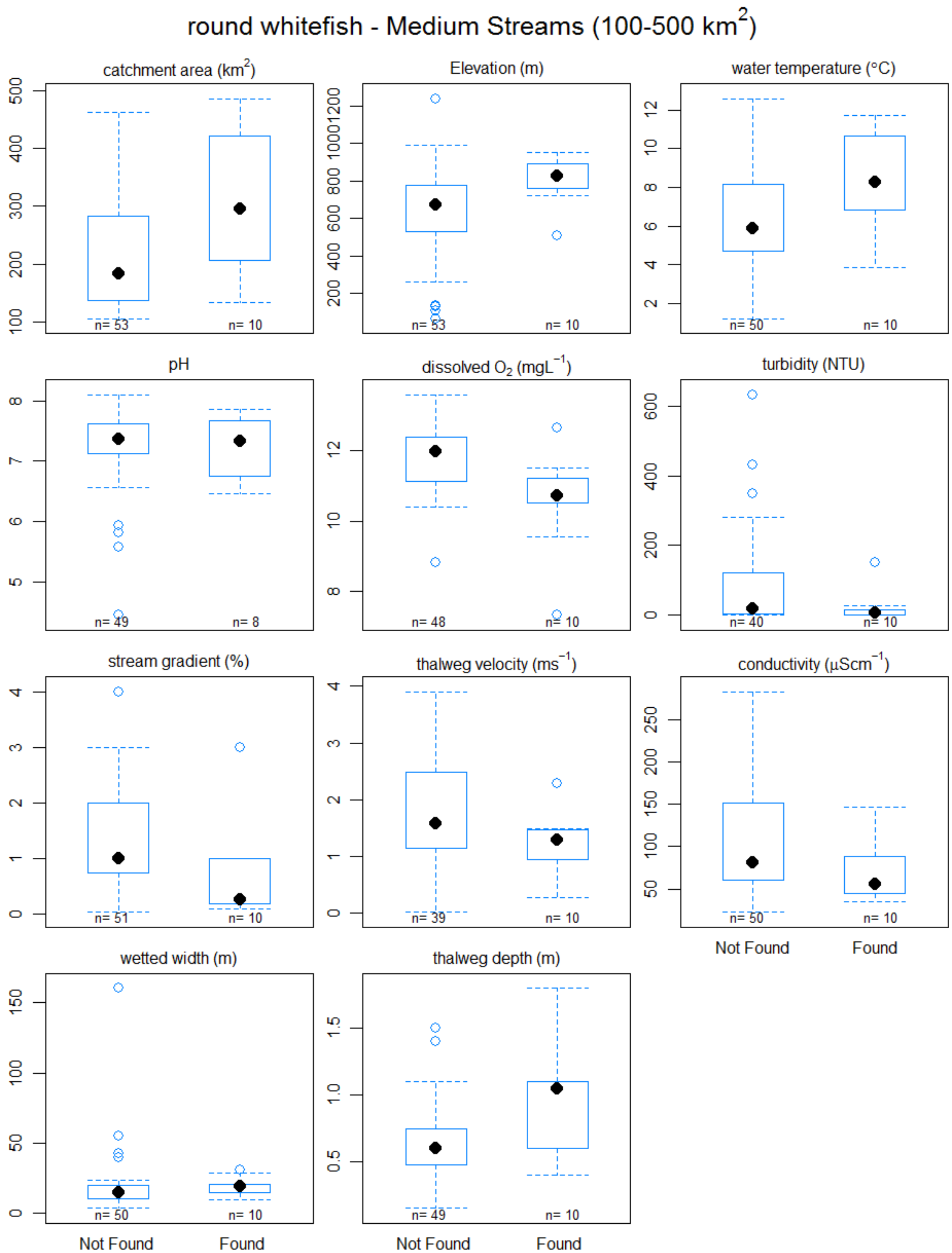


threespine stickleback - Small Streams (<100 km²)
catchment area (km²)
n= 148
n= 4
Elevation (m)
n= 148
n= 4
water temperature (°C)
n= 141
n= 2
pH
n= 141
n= 2
dissolved O₂ (mgL⁻¹)
n= 123
n= 2
turbidity (NTU)
n= 80
n= NA
stream gradient (%)
n= 143
n= 2
thalweg velocity (ms⁻¹)
n= 74
n= NA
conductivity (µScm⁻¹)
n= 141
n= 2
wetted width (m)
n= 141
n= 2
thalweg depth (m)
n= 140
n= 2
Not Found
Found

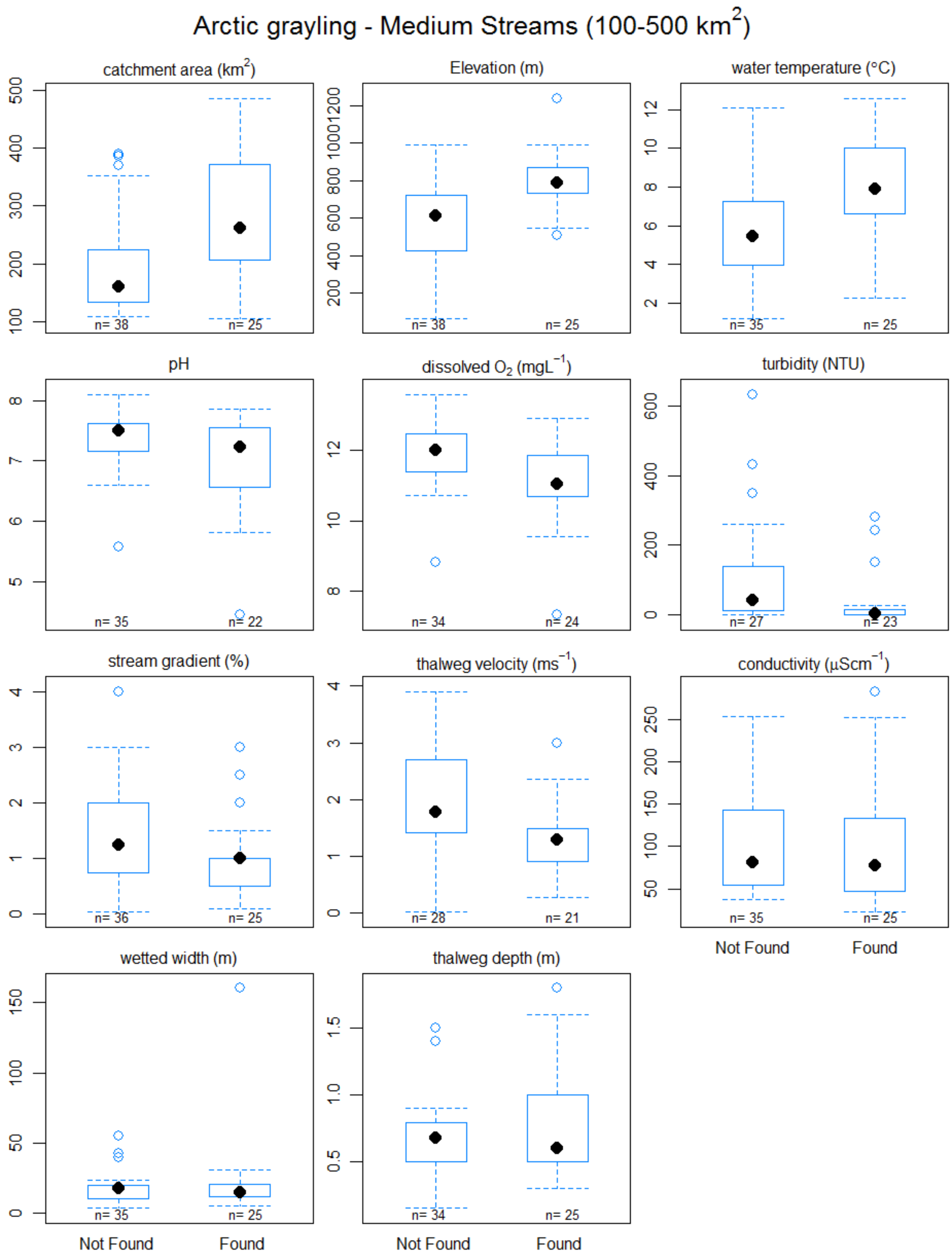

slimy sculpin - Small Streams (<100 km²)
catchment area (km²)
Elevation (m)
water temperature (°C)
pH
dissolved O₂ (mgL⁻¹)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms⁻¹)
conductivity (µScm⁻¹)
wetted width (m)
thalweg depth (m)
n= 76
n= 76
n= 76
n= 76
n= 69
n= 74
n= 69
n= 74
n= 57
n= 68
n= 34
n= 46
n= 70
n= 75
n= 32
n= 42
n= 69
n= 74
n= 69
n= 74
n= 68
n= 74
Not Found
Found

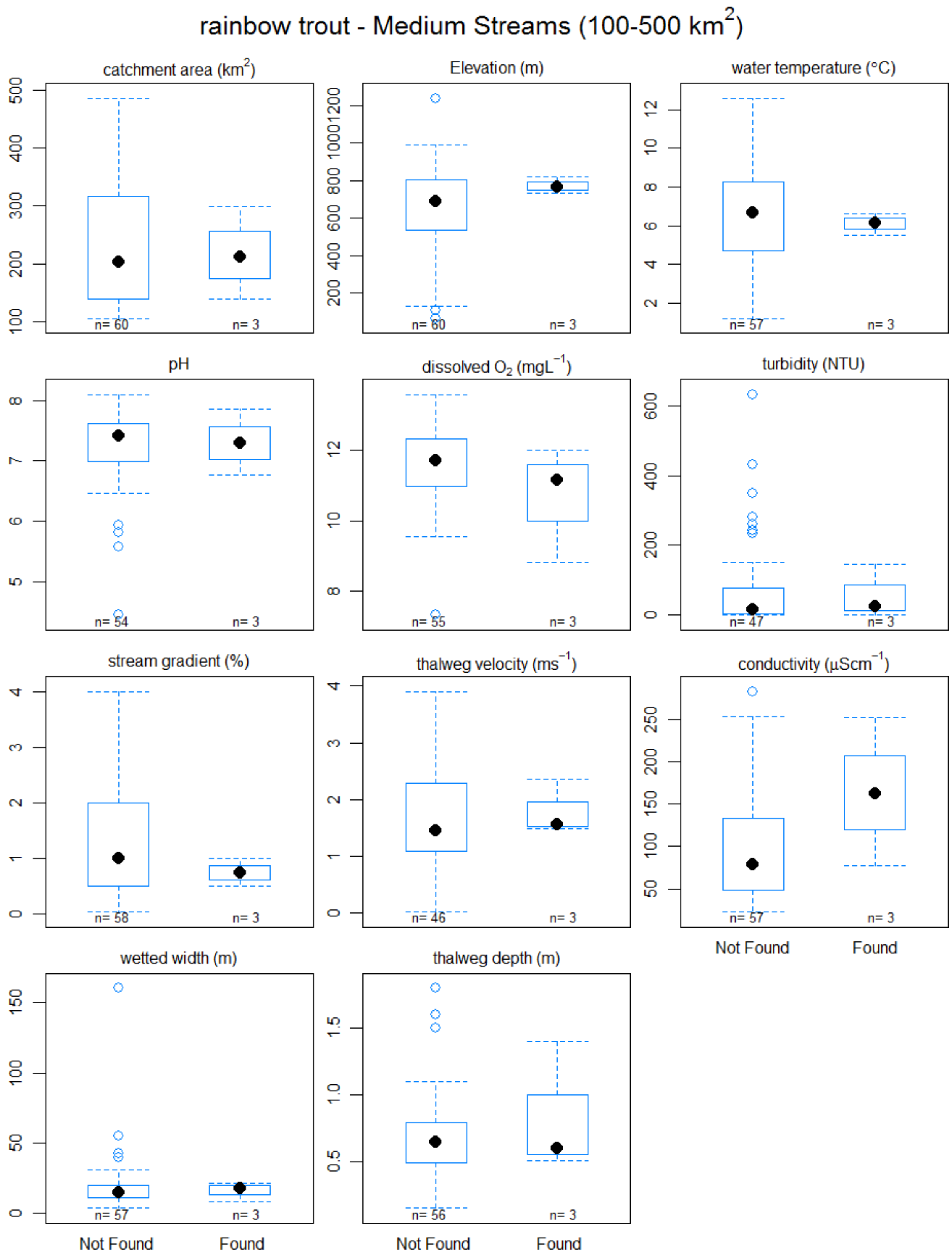

no fish found - Small Streams (<100 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 137
n= 15
n= 128
n= 110
n= 69
n= 11
n= 130
n= 64
n= 10
n= 129
n= 14
Not Found
Found

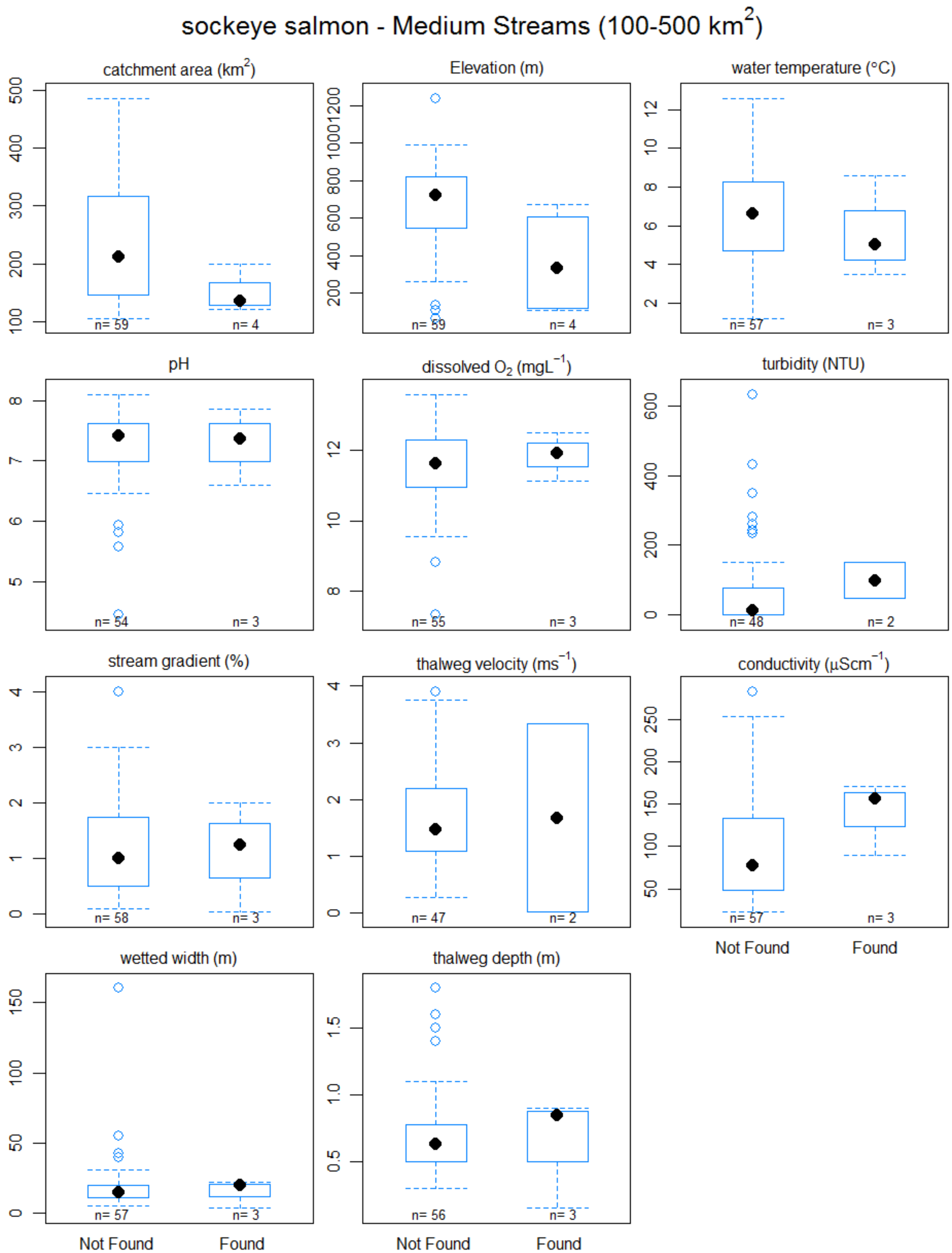

longnose sucker - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (μScm−1)
wetted width (m)
thalweg depth (m)
n= 58
n= 5
n= 55
n= 53
n= 4
n= 54
n= 45
n= 56
n= 44
n= 55
Not Found
Found



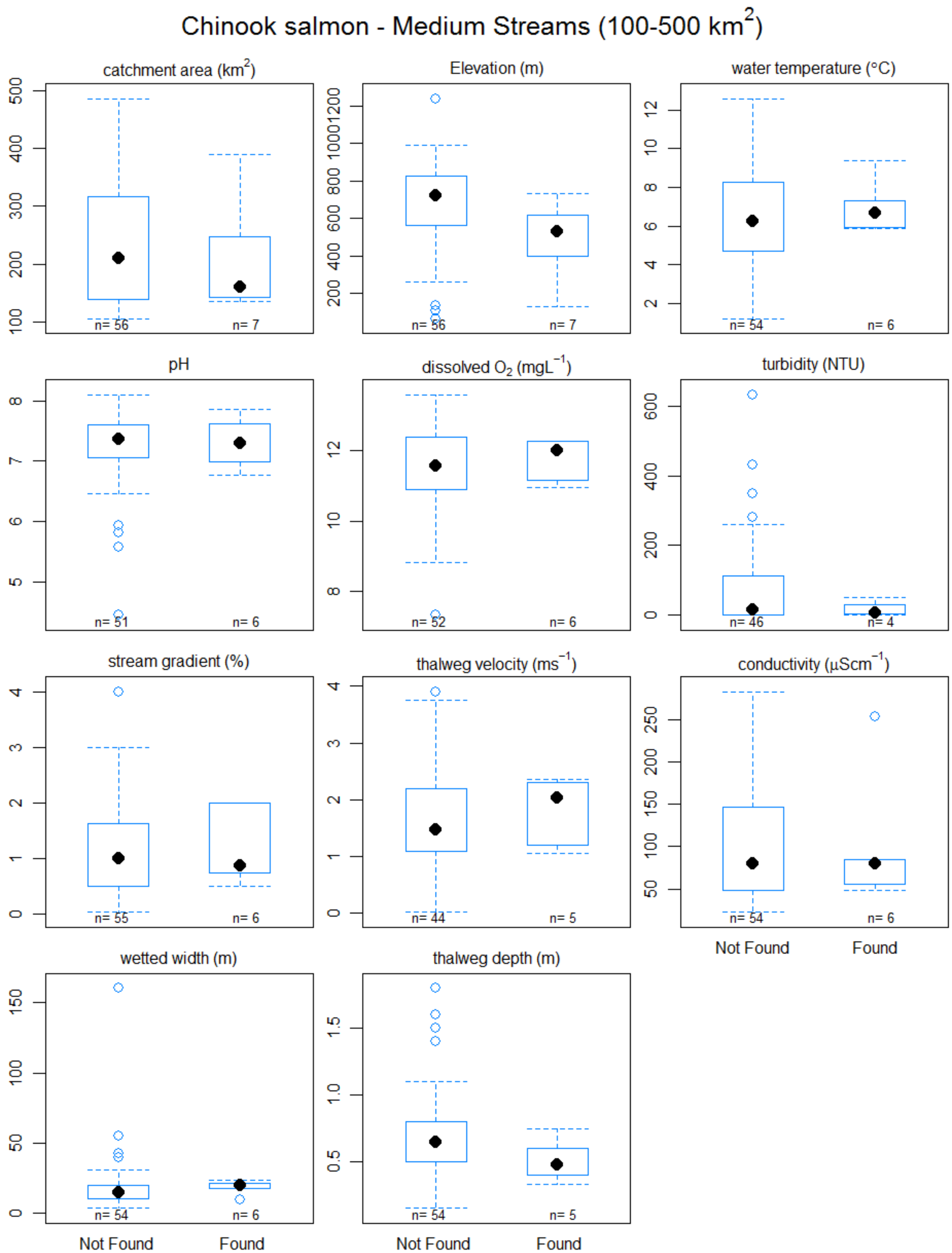
round whitefish - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found

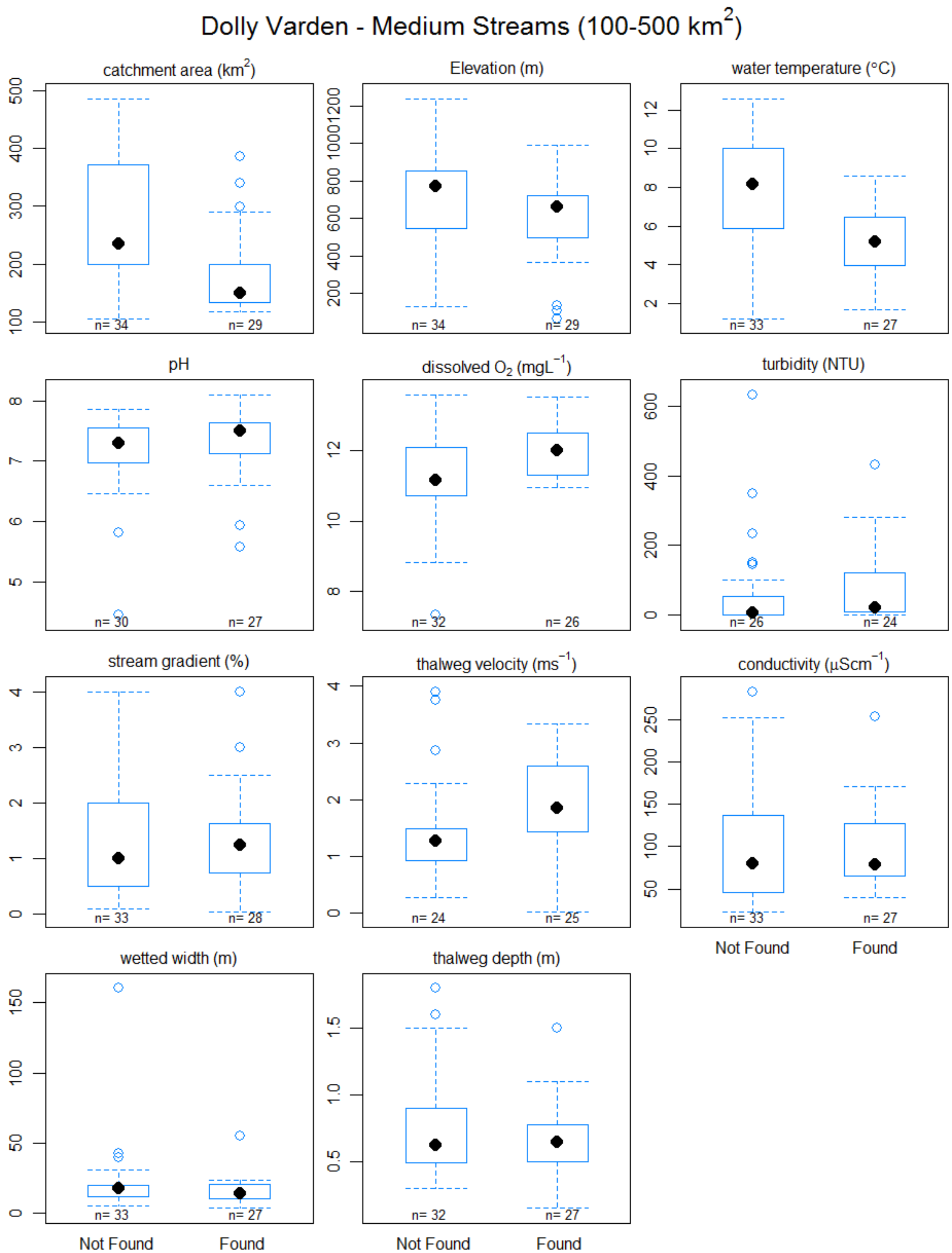

Arctic grayling - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
n= 38
n= 25
n= 38
n= 25
n= 35
n= 25
n= 35
n= 22
n= 34
n= 24
n= 27
n= 23
n= 36
n= 25
n= 28
n= 21
n= 35
n= 25
n= 35
n= 25
n= 34
n= 25
Not Found
Found


rainbow trout - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 60
n= 3
n= 57
n= 54
n= 55
n= 47
n= 58
n= 46
n= 56
Not Found
Found

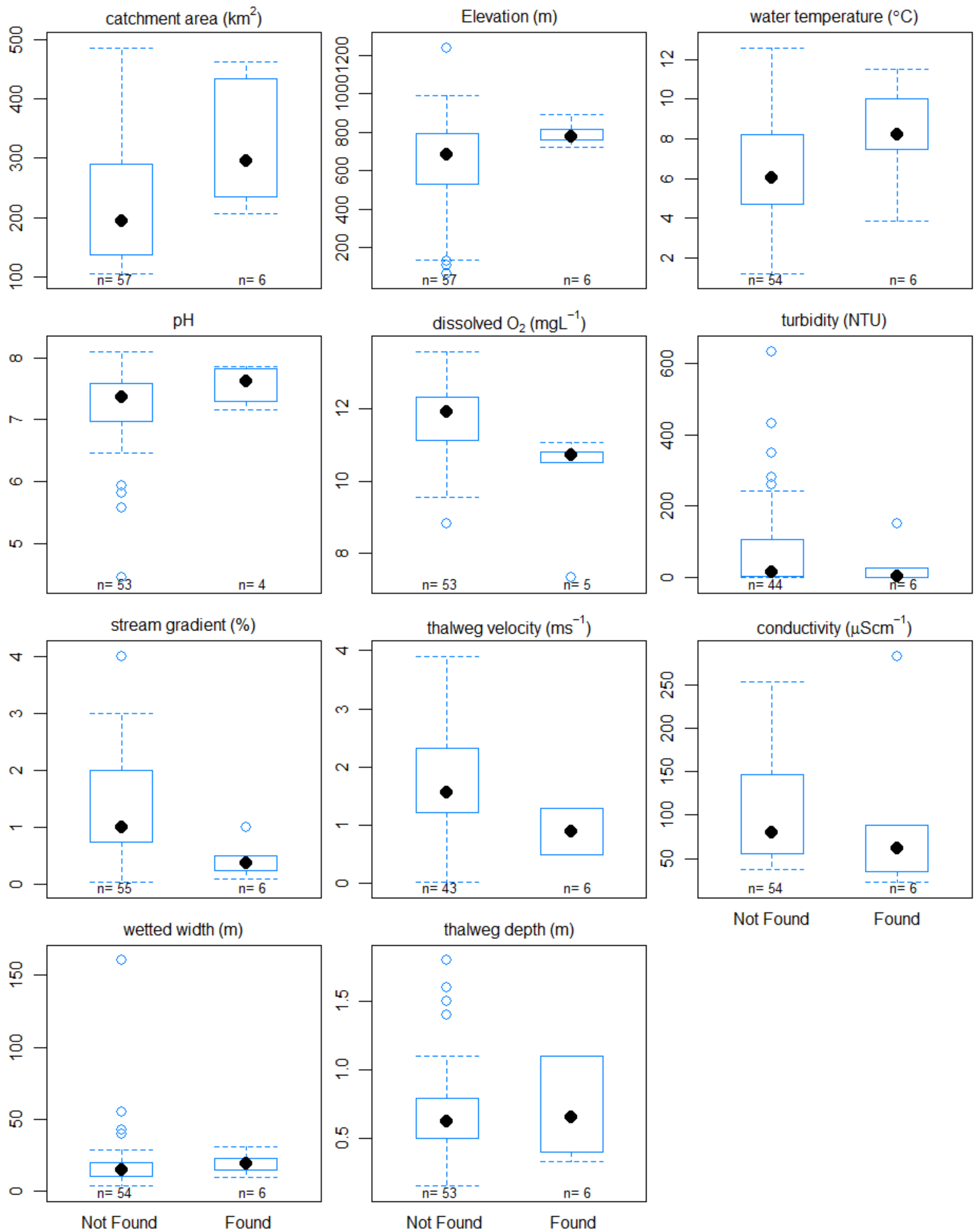


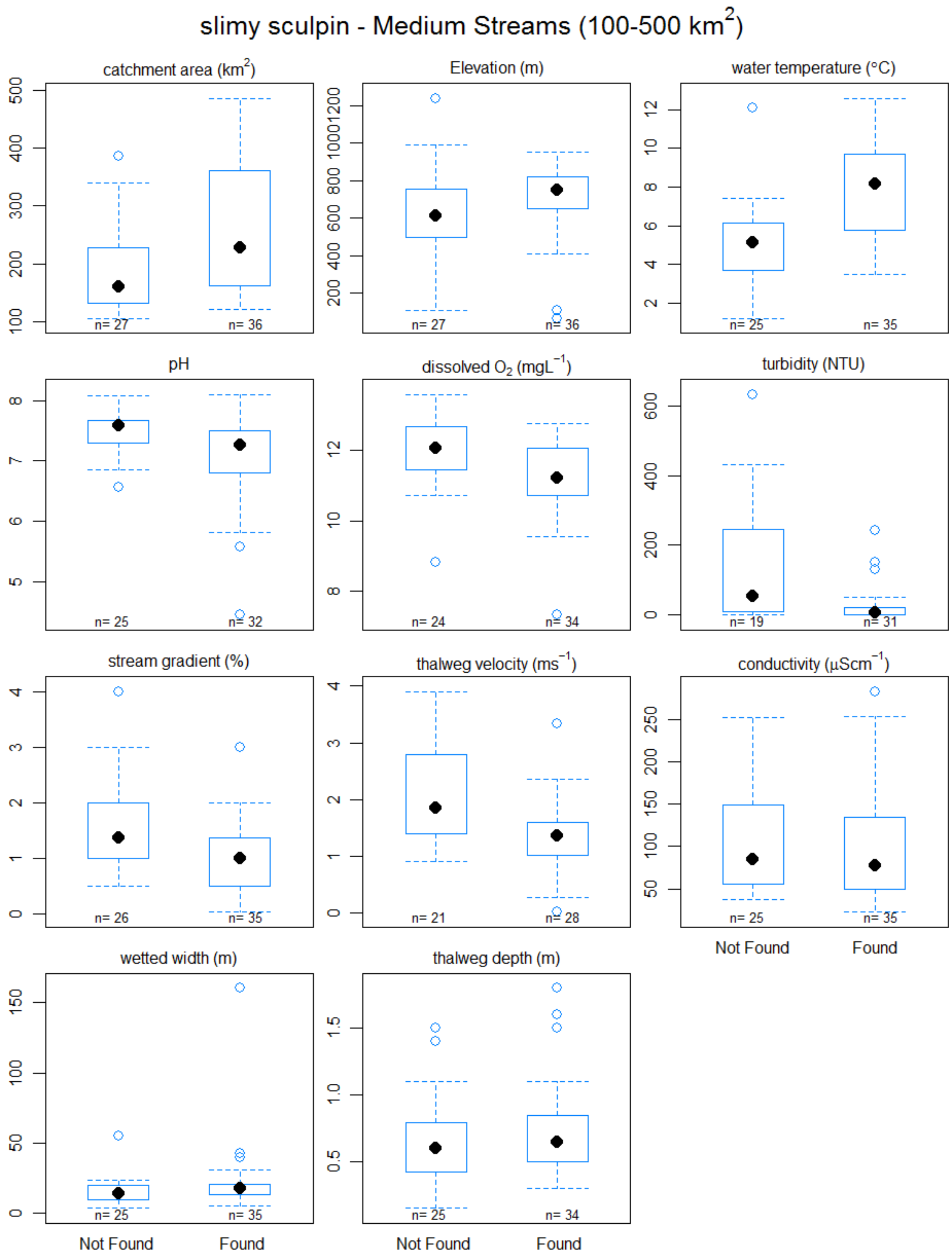
sockeye salmon - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 59
n= 4
n= 57
n= 3
n= 54
n= 55
n= 48
n= 2
n= 58
n= 47
n= 56
Not Found
Found

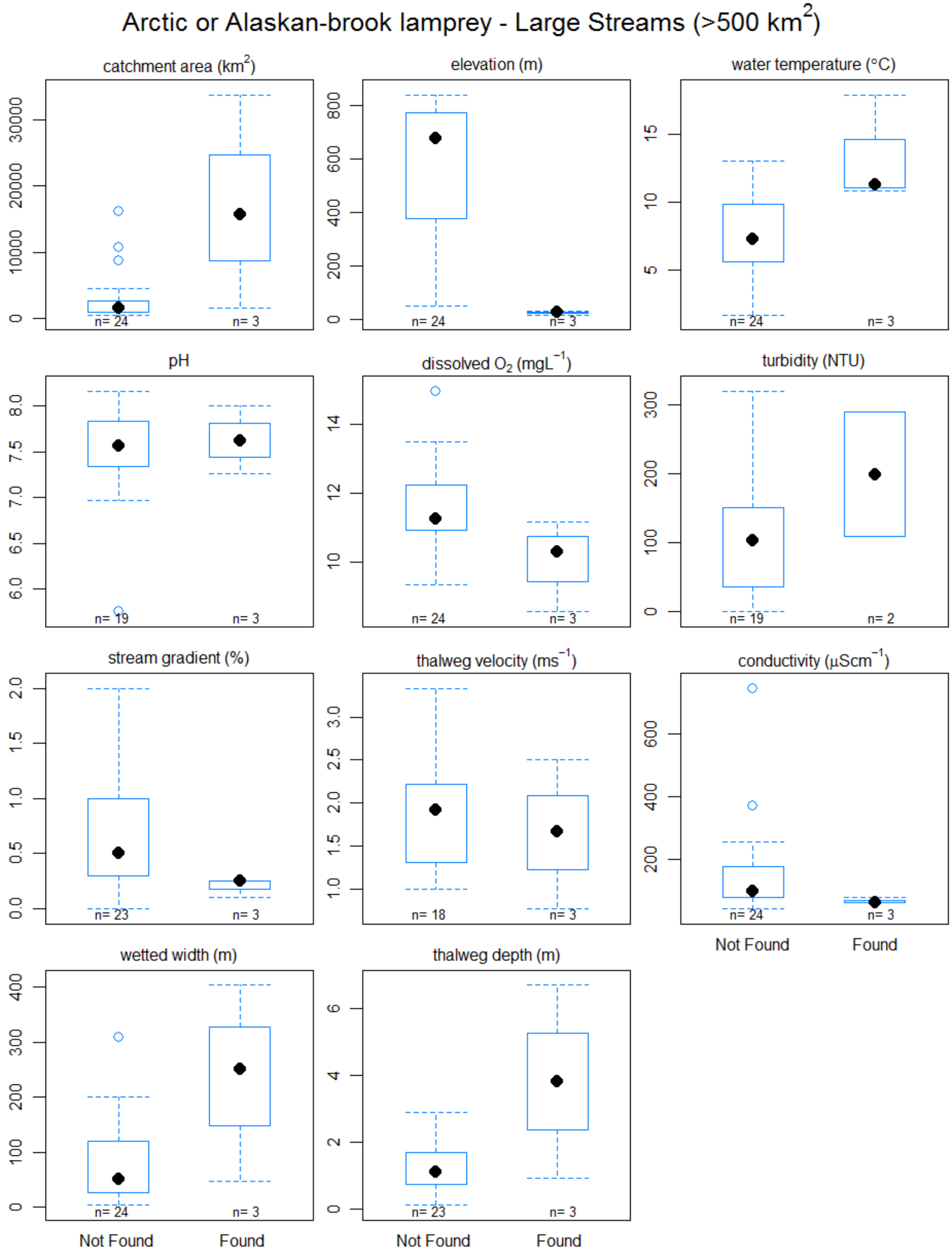

Chinook salmon - Medium Streams (100-500 km^2)
catchment area (km^2)
Elevation (m)
water temperature (°C)
pH
dissolved O_2 (mgL^{-1})
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms^{-1})
conductivity (µScm^{-1})
wetted width (m)
thalweg depth (m)
Not Found
Found

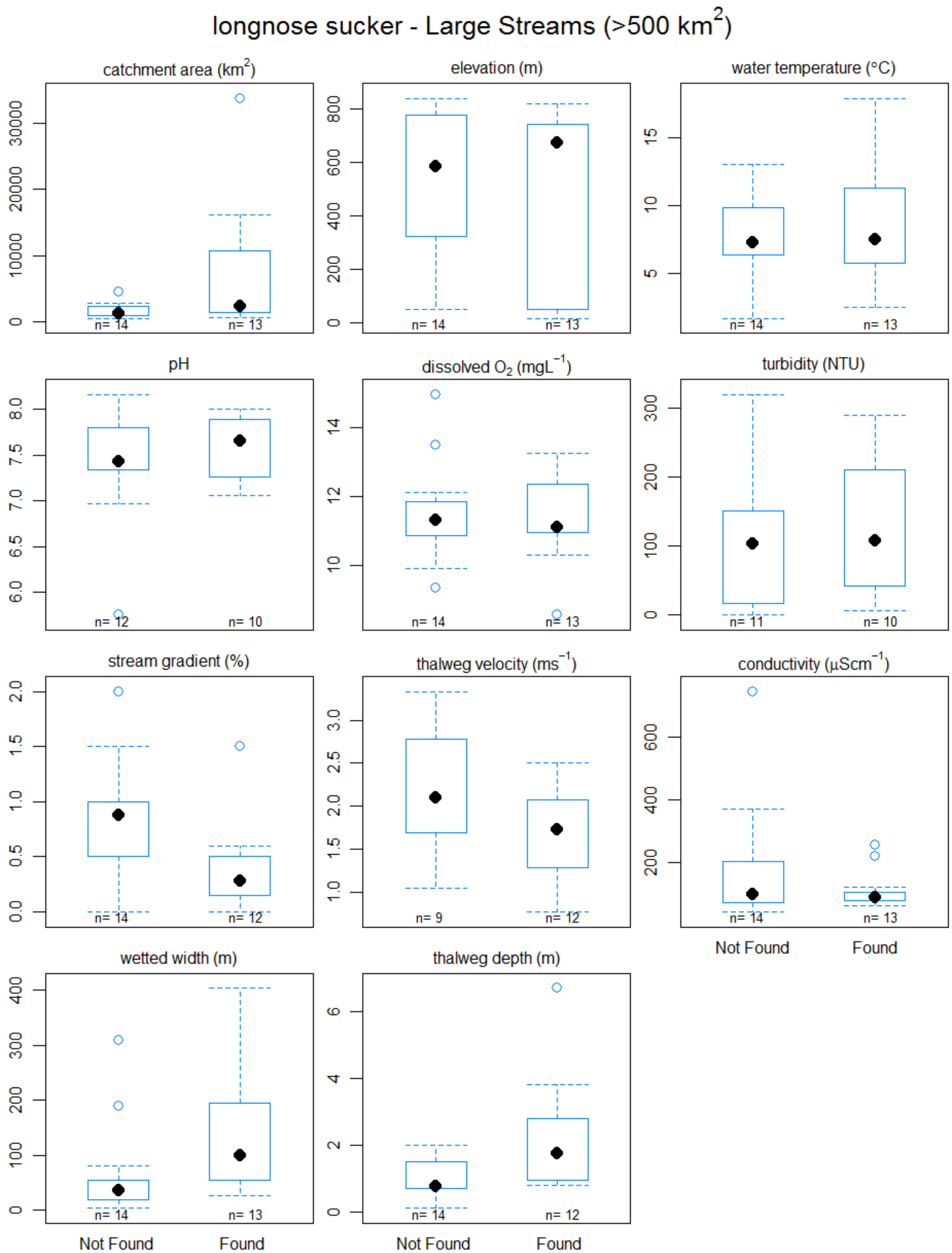

Dolly Varden - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 34
n= 29
n= 34
n= 29
n= 33
n= 27
n= 30
n= 27
n= 32
n= 26
n= 26
n= 24
n= 33
n= 28
n= 24
n= 25
n= 33
n= 27
n= 33
n= 27
n= 32
n= 27
Not Found
Found
Not Found
Found
Not Found
Found

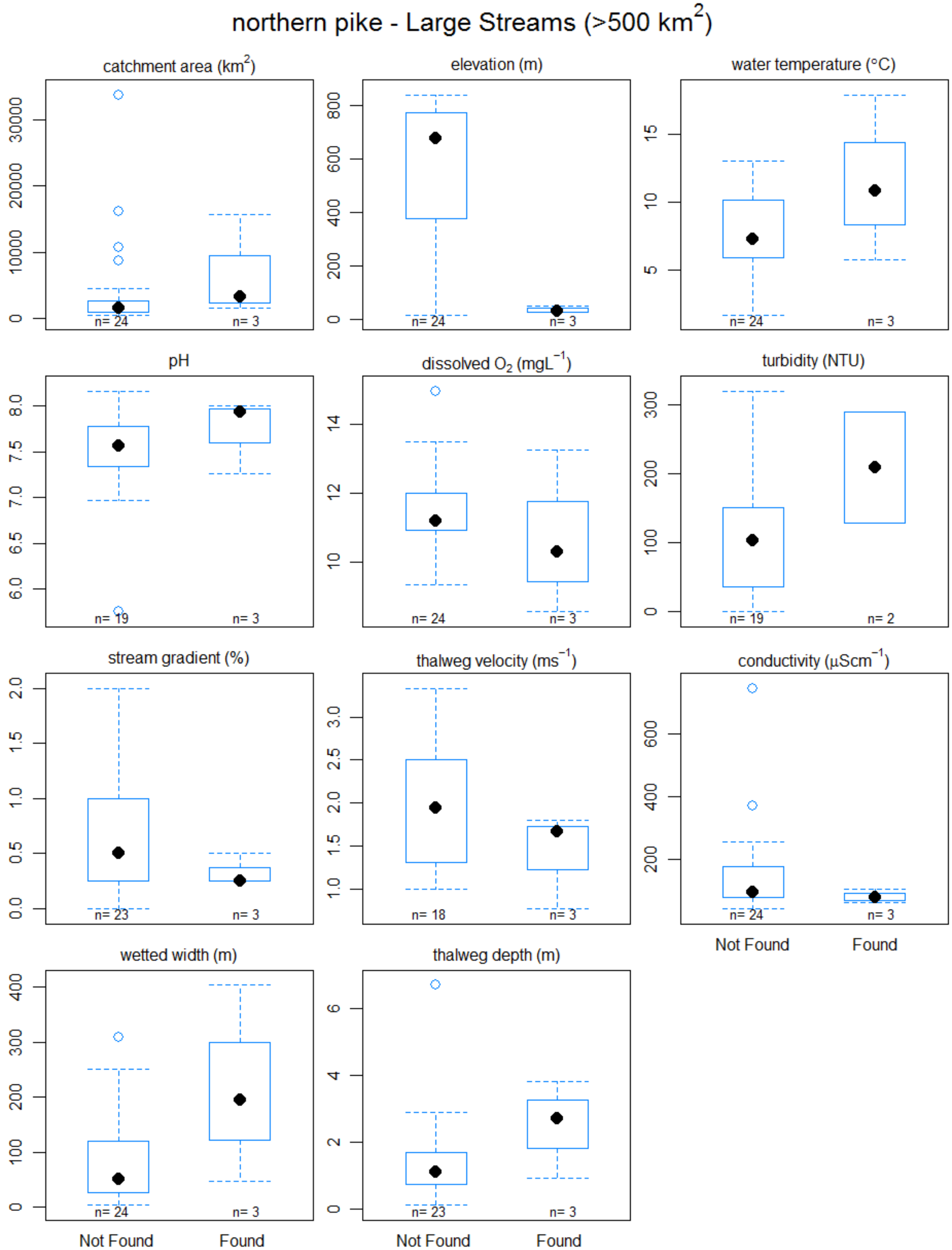
burbot - Medium Streams (100-500 km^2)

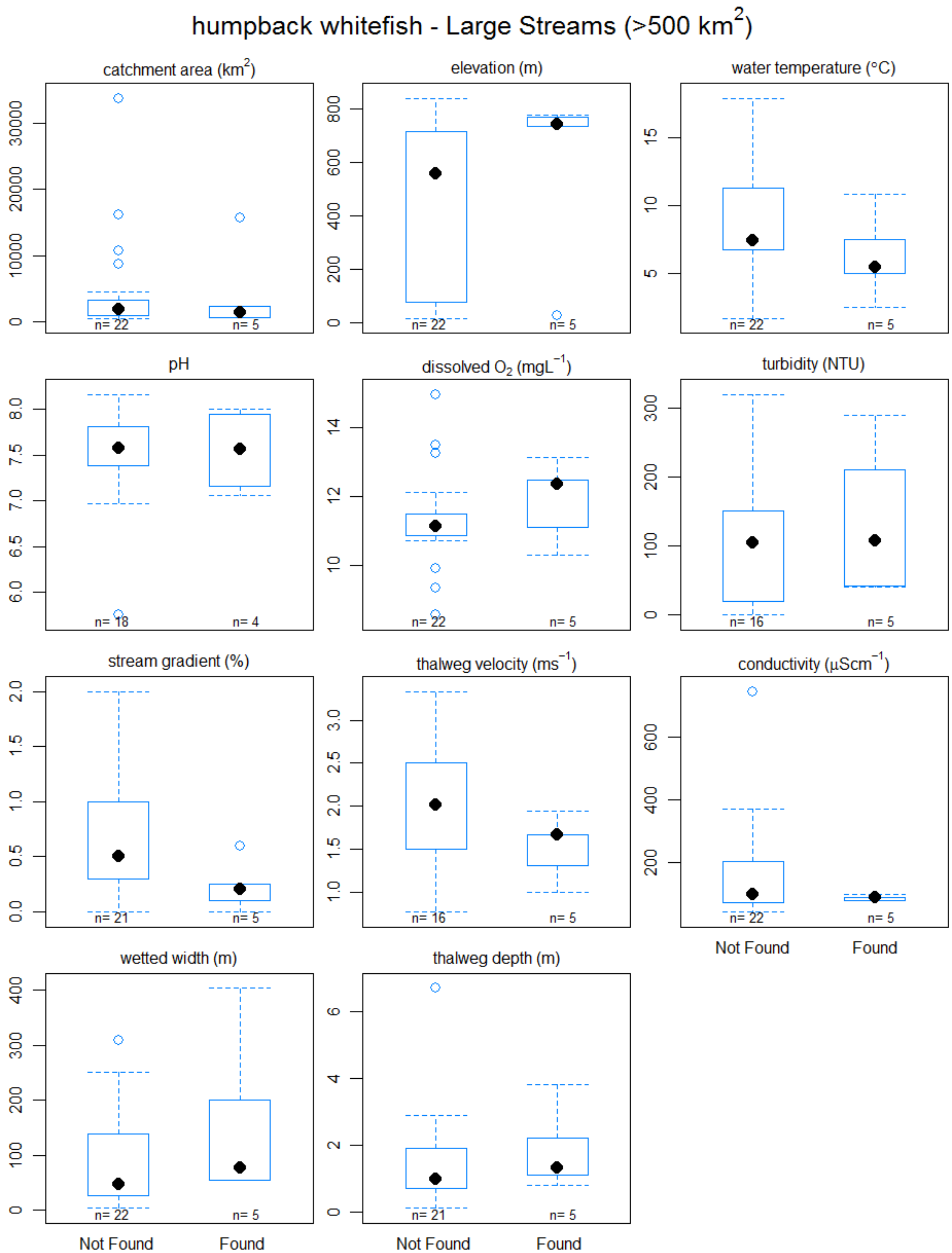


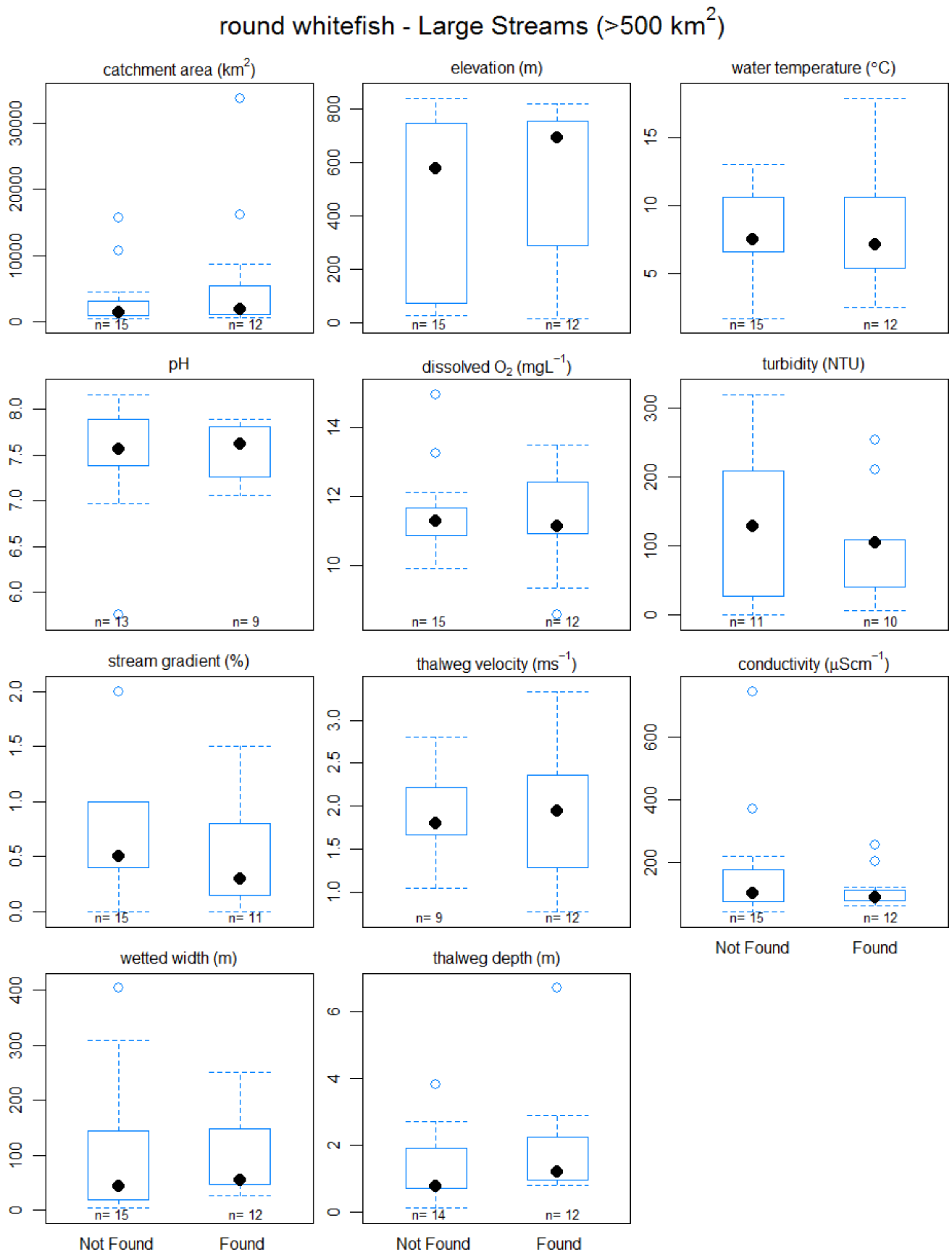

slimy sculpin - Medium Streams (100-500 km2)
catchment area (km2)
Elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 27
n= 36
n= 27
n= 36
n= 25
n= 35
n= 25
n= 32
n= 24
n= 34
n= 19
n= 31
n= 26
n= 35
n= 21
n= 28
n= 25
n= 35
n= 25
n= 35
n= 25
n= 34
Not Found
Found

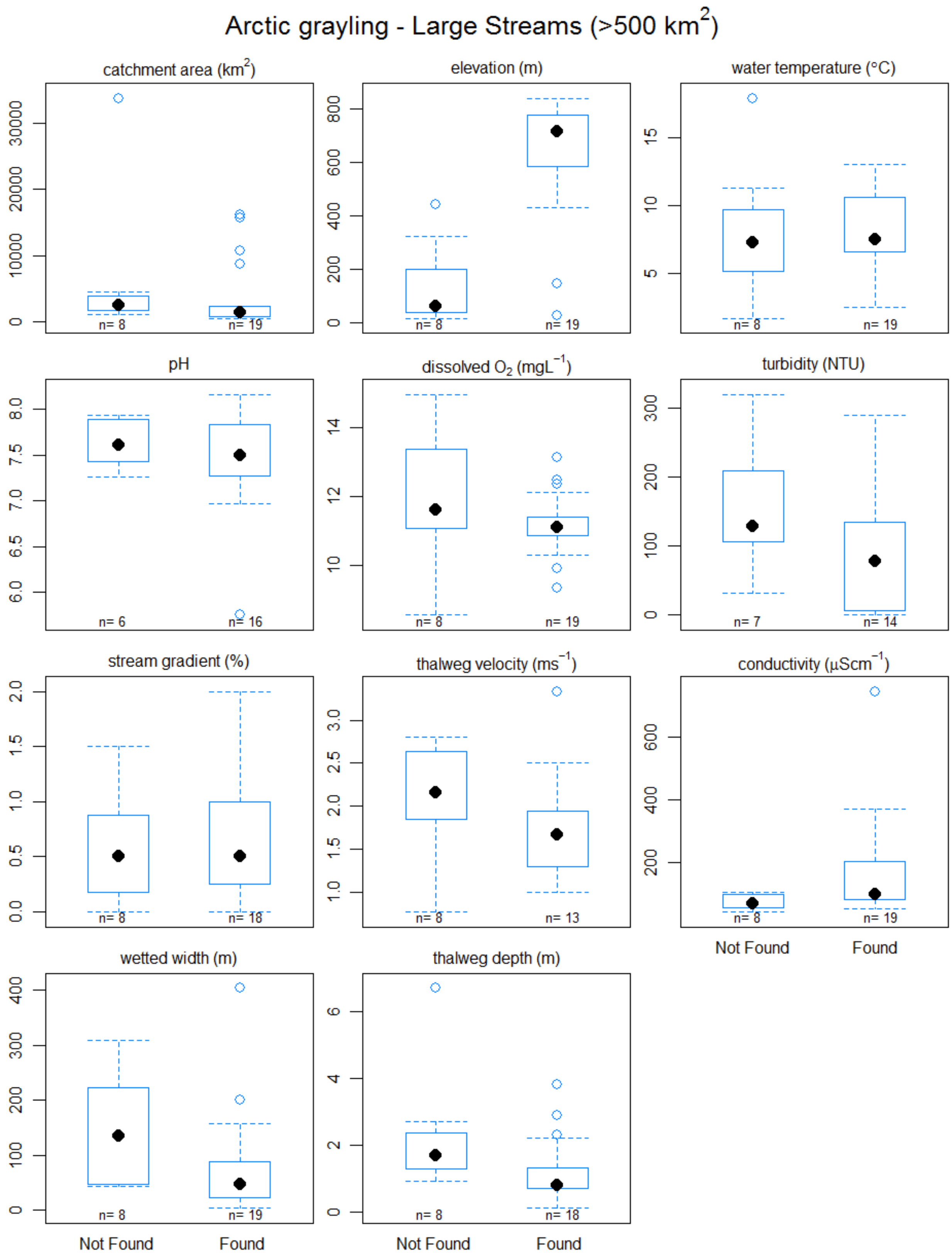

Arctic or Alaskan-brook lamprey - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 24
n= 3
n= 19
n= 2
n= 23
n= 18
Not Found
Found

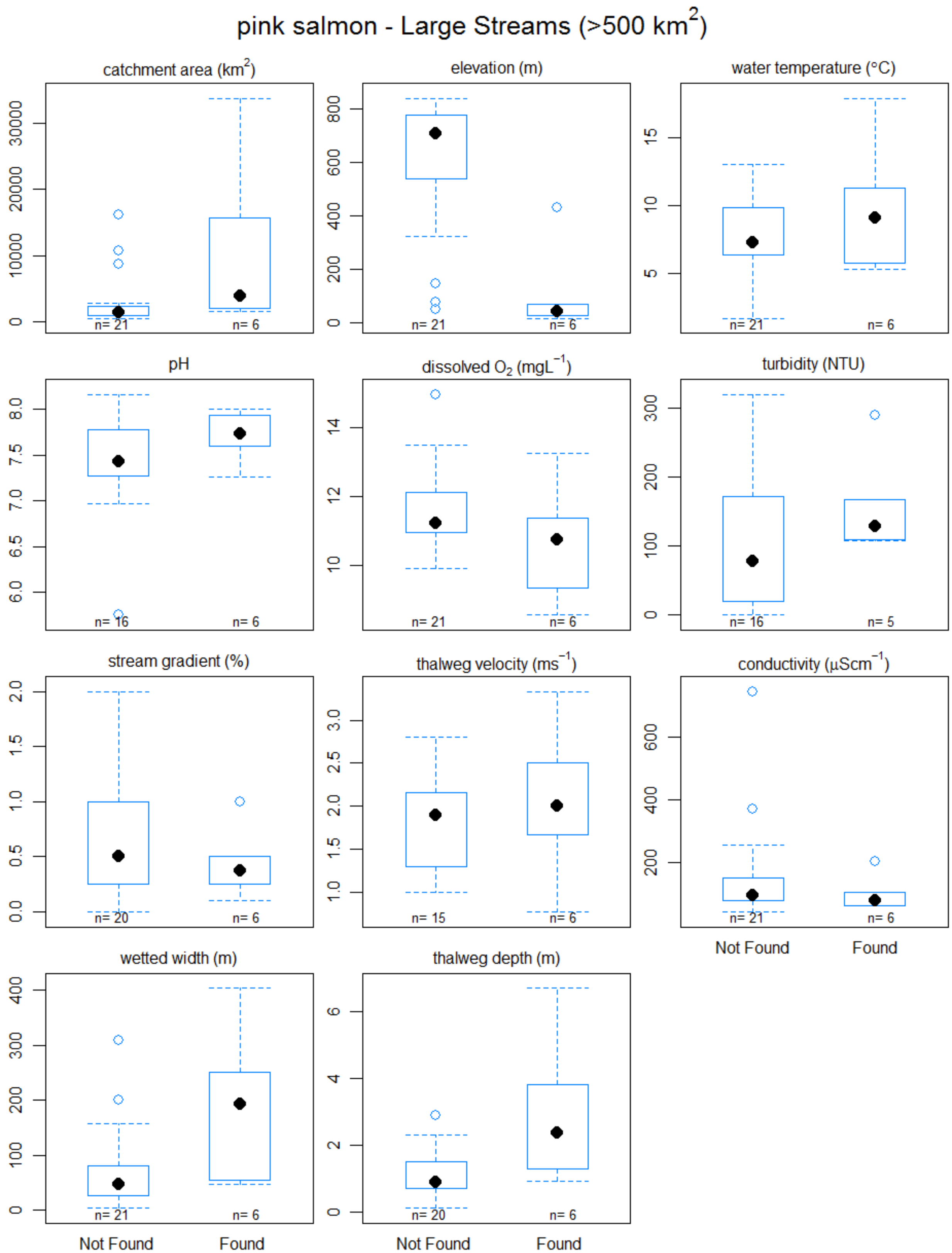

longnose sucker - Large Streams (>500 km²)
catchment area (km²)
0
10000
20000
30000
n= 14
n= 13
elevation (m)
0
200
400
600
800
n= 14
n= 13
water temperature (°C)
5
10
15
n= 14
n= 13
pH
6.0
6.5
7.0
7.5
8.0
n= 12
n= 10
dissolved O₂ (mgL⁻¹)
10
12
14
n= 14
n= 13
turbidity (NTU)
0
100
200
300
n= 11
n= 10
stream gradient (%)
0.0
0.5
1.0
1.5
2.0
n= 14
n= 12
thalweg velocity (ms⁻¹)
1.0
1.5
2.0
2.5
3.0
n= 9
n= 12
conductivity (µScm⁻¹)
200
400
600
n= 14
n= 13
Not Found
Found
wetted width (m)
0
100
200
300
400
n= 14
n= 13
Not Found
Found
thalweg depth (m)
0
2
4
6
n= 14
n= 12
Not Found
Found

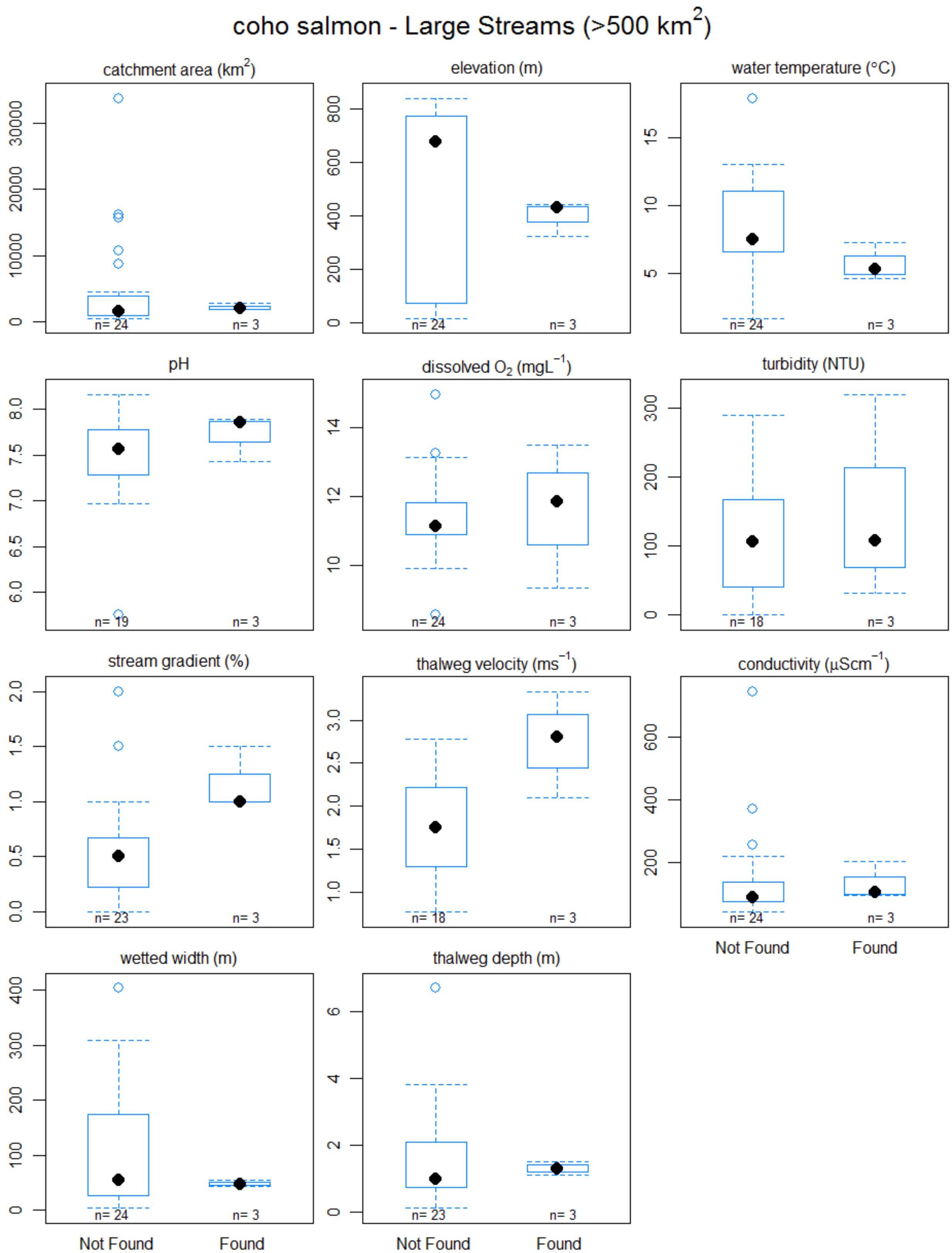

northern pike - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found
n= 24
n= 3
n= 19
n= 2
n= 23
n= 18


humpback whitefish - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found
n= 22
n= 5
n= 18
n= 4
n= 16
n= 21

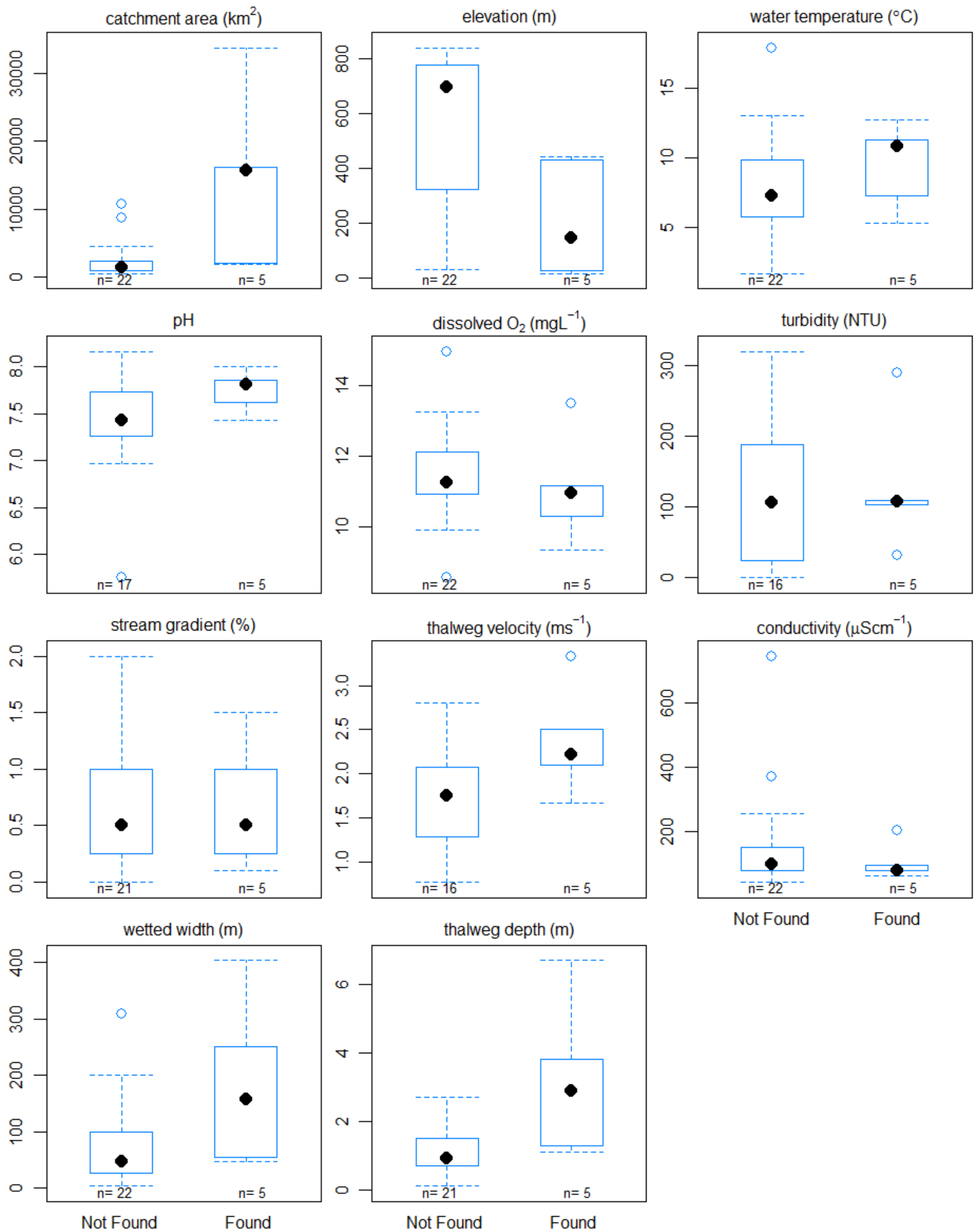

round whitefish - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
Not Found
Found

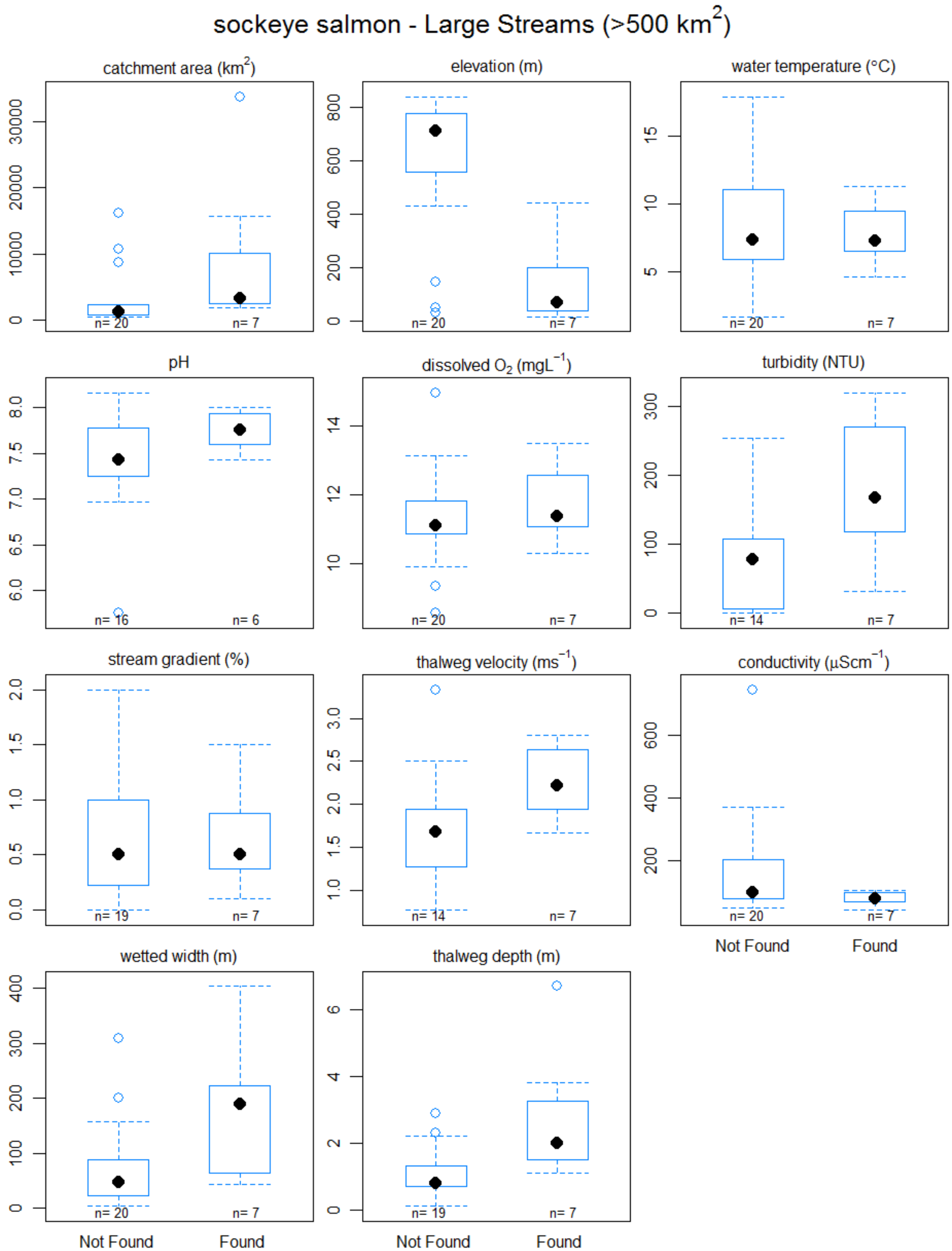

Arctic grayling - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found
n= 8
n= 19
n= 6
n= 16
n= 7
n= 14
n= 18
n= 13

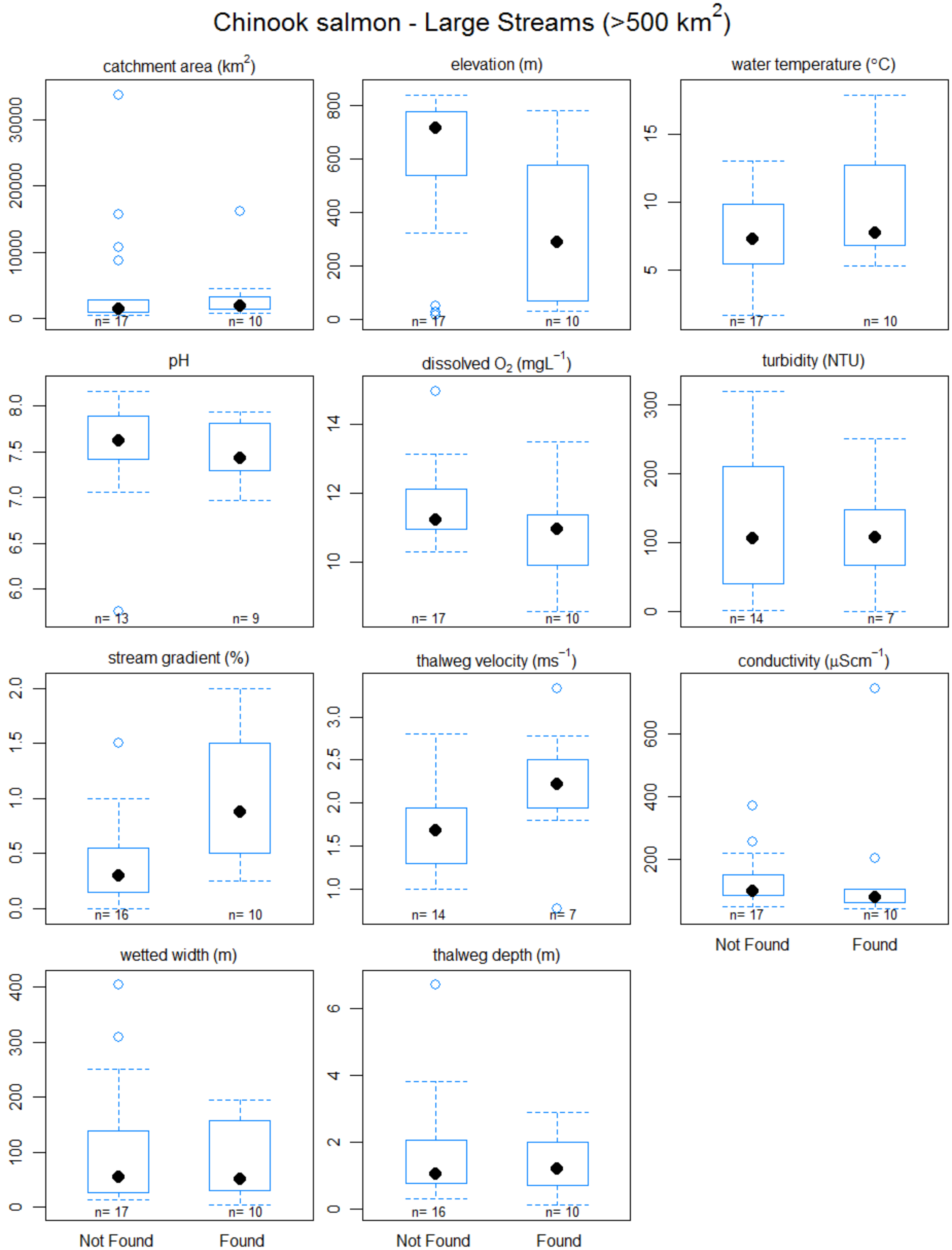

pink salmon - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 21
n= 6
n= 16
n= 5
n= 20
n= 15
Not Found
Found

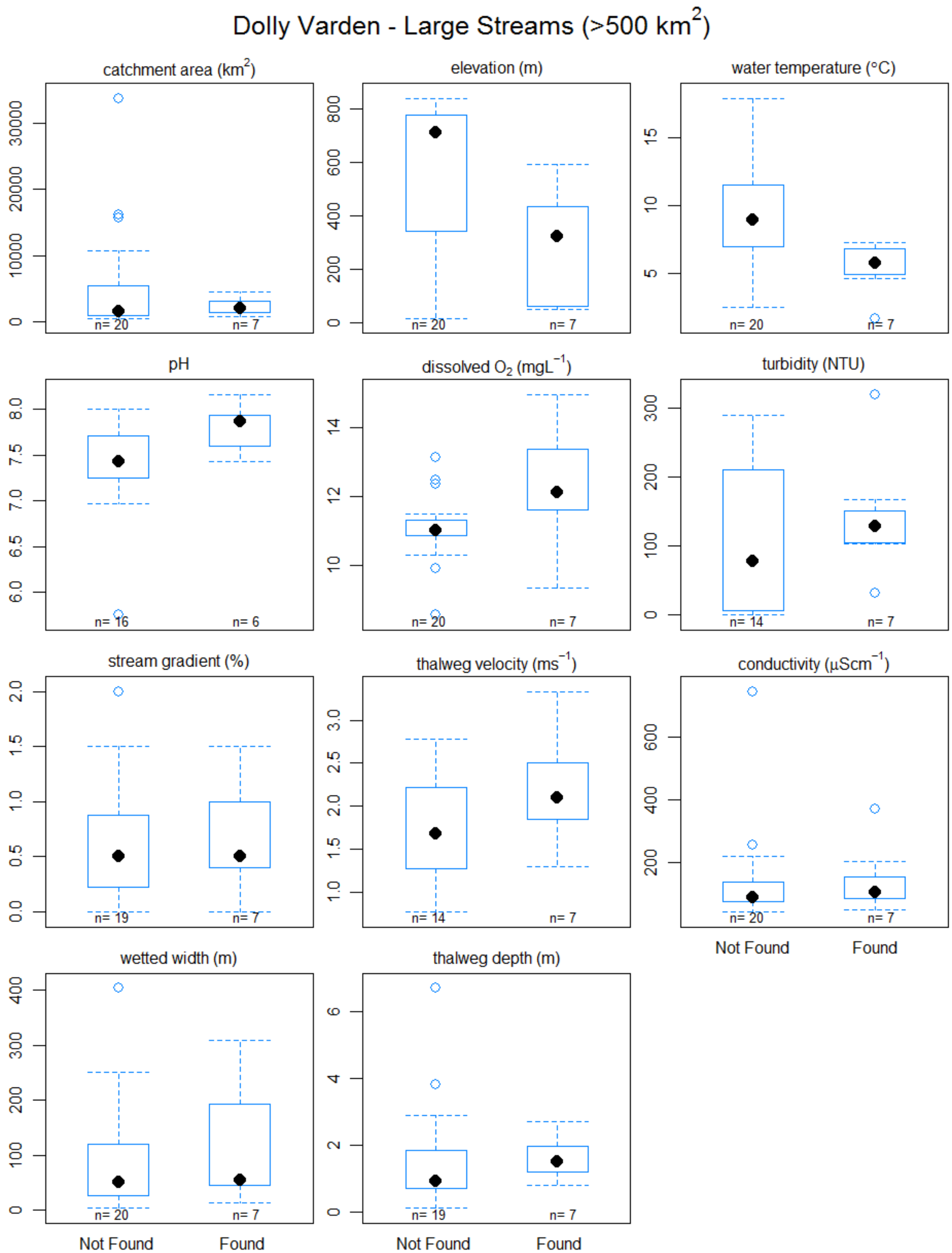

coho salmon - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
n= 24
n= 3
n= 19
n= 18
n= 23
Not Found
Found

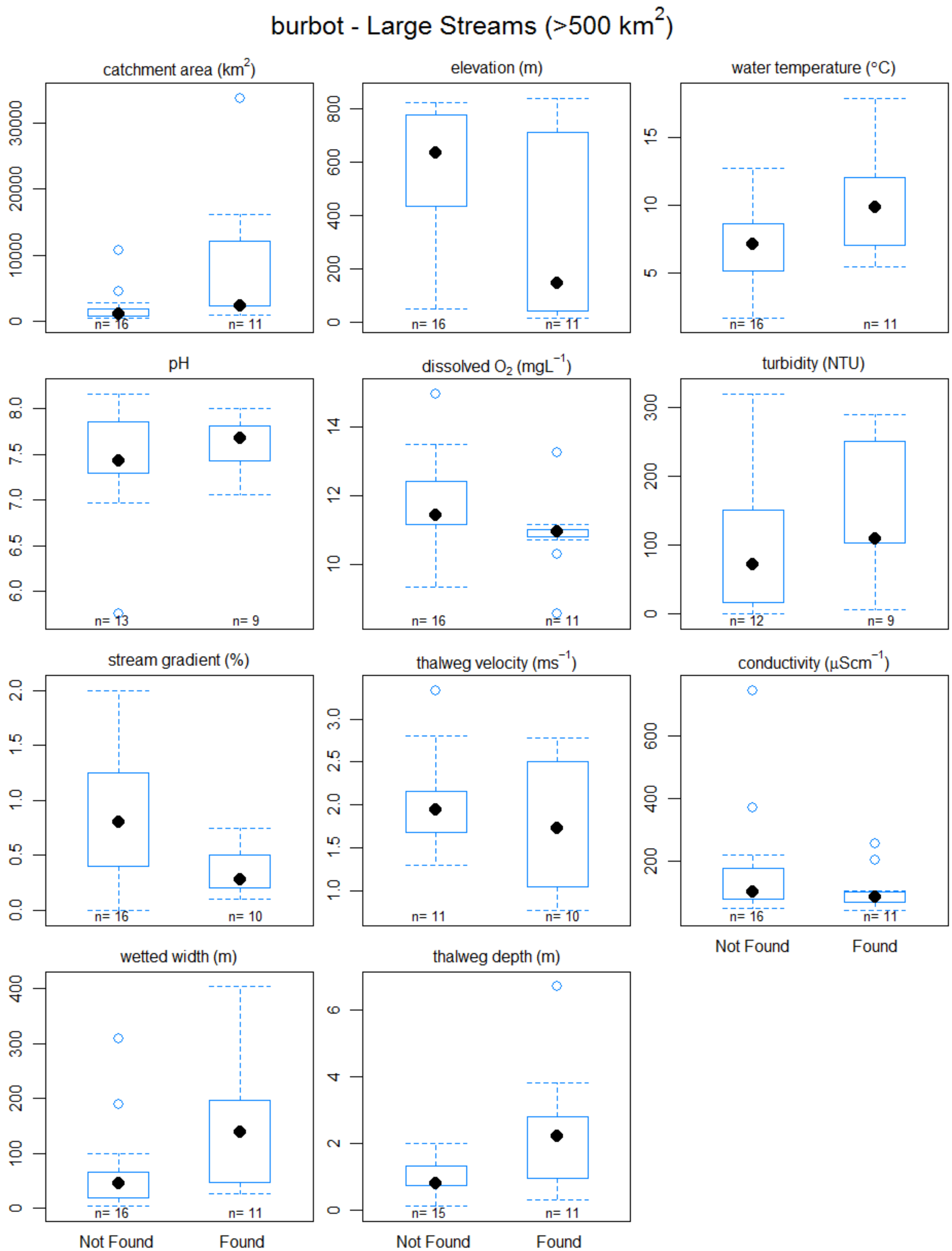
rainbow trout - Large Streams (>500 km²)

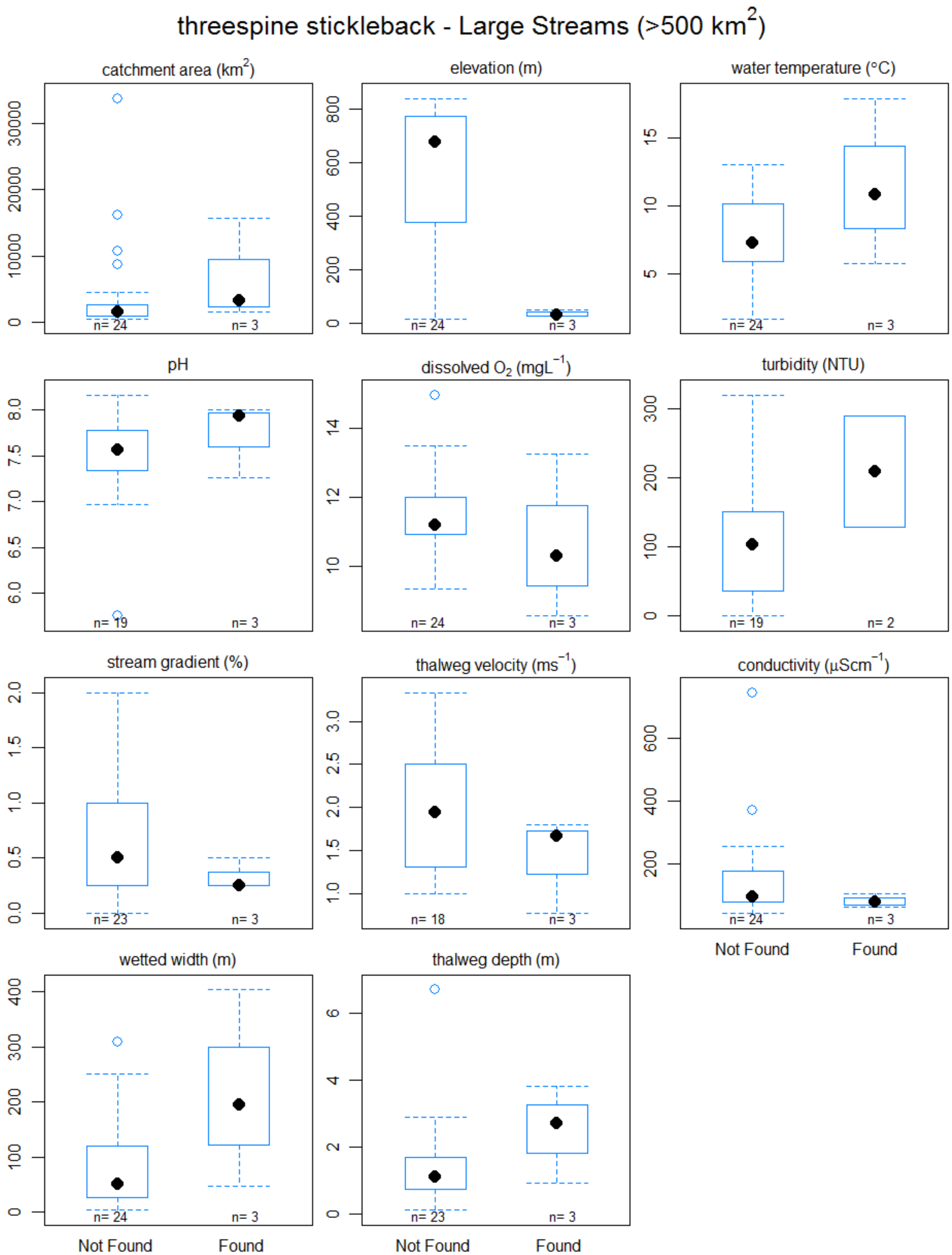


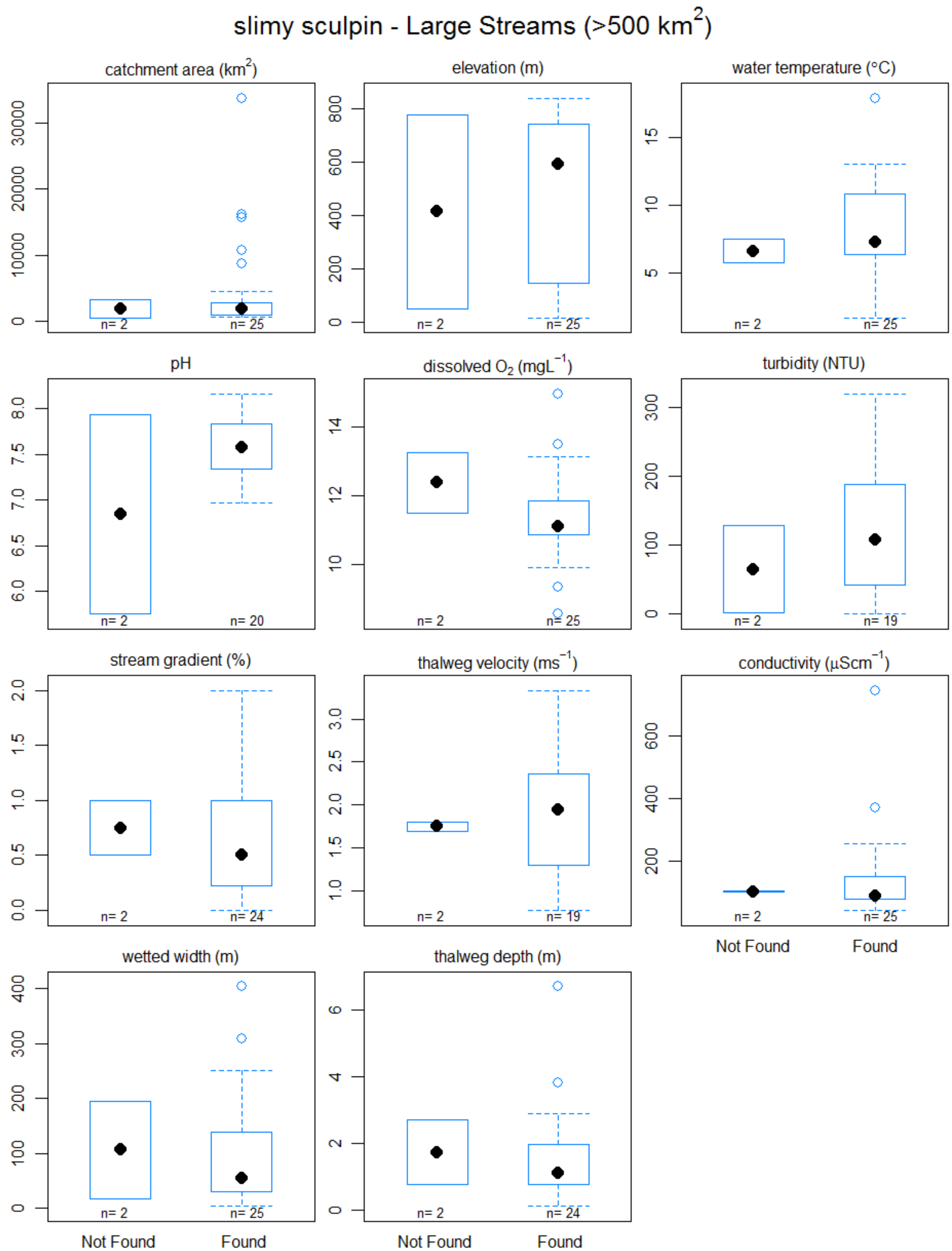

sockeye salmon - Large Streams (>500 km2)
catchment area (km2)
n= 20
n= 7
elevation (m)
n= 20
n= 7
water temperature (°C)
n= 20
n= 7
pH
n= 16
n= 6
dissolved O2 (mgL-1)
n= 20
n= 7
turbidity (NTU)
n= 14
n= 7
stream gradient (%)
n= 19
n= 7
thalweg velocity (ms-1)
n= 14
n= 7
conductivity (µScm-1)
n= 20
n= 7
Not Found
Found
wetted width (m)
n= 20
n= 7
Not Found
Found
thalweg depth (m)
n= 19
n= 7
Not Found
Found


Chinook salmon - Large Streams (>500 km²)
catchment area (km²)
elevation (m)
water temperature (°C)
pH
dissolved O₂ (mgL⁻¹)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms⁻¹)
conductivity (µScm⁻¹)
wetted width (m)
thalweg depth (m)
Not Found
Found
n= 17
n= 10
n= 13
n= 9
n= 14
n= 7
n= 16

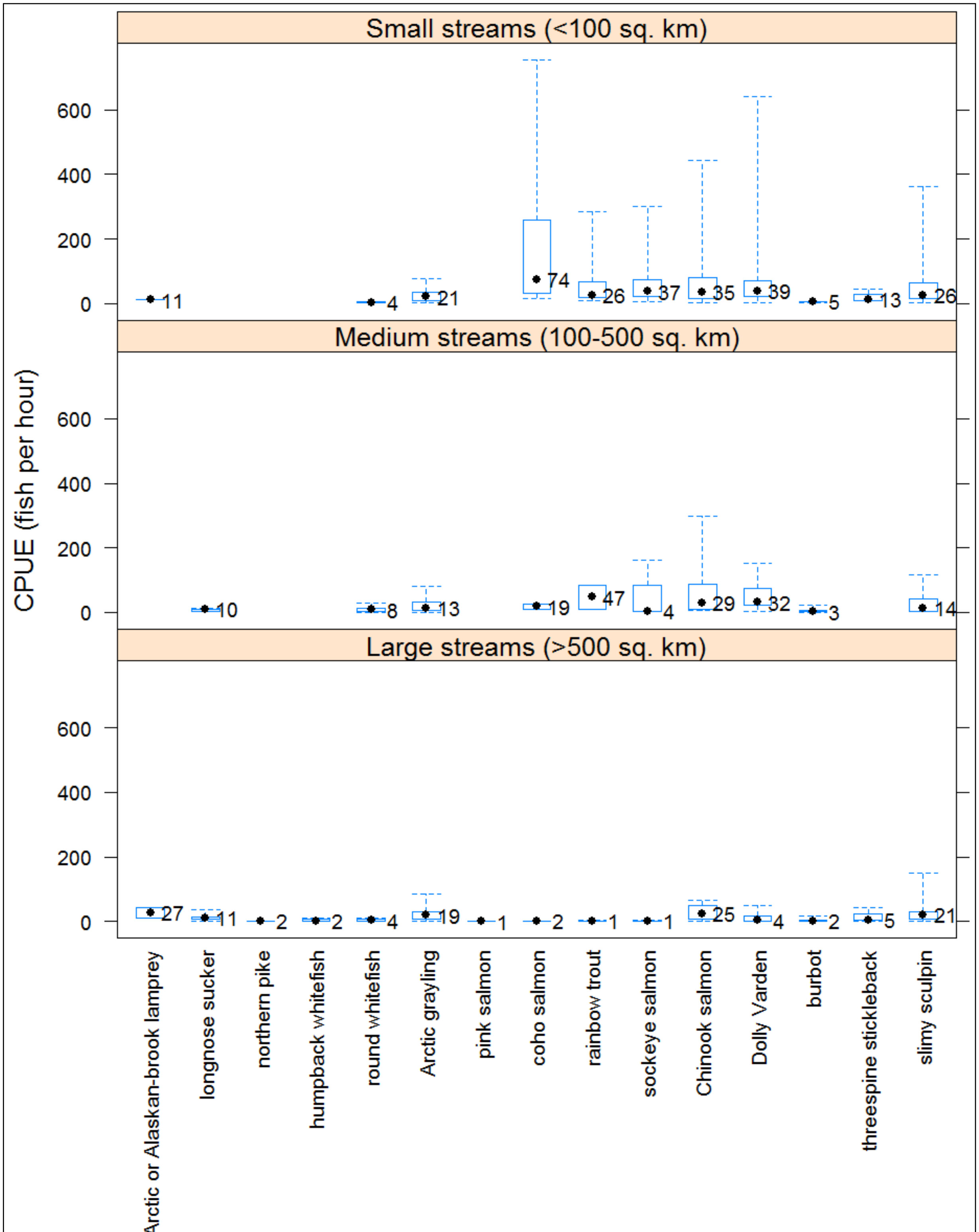

Dolly Varden - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (μScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found


burbot - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL-1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms-1)
conductivity (µScm-1)
wetted width (m)
thalweg depth (m)
Not Found
Found
n= 16
n= 11
n= 13
n= 9
n= 12
n= 10
n= 15


threespine stickleback - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
Not Found
Found


slimy sculpin - Large Streams (>500 km2)
catchment area (km2)
elevation (m)
water temperature (°C)
pH
dissolved O2 (mgL−1)
turbidity (NTU)
stream gradient (%)
thalweg velocity (ms−1)
conductivity (µScm−1)
wetted width (m)
thalweg depth (m)
Not Found
Found

Appendix G5.–Box plots of electrofishing catch per unit effort, grouped by stream size.



Note: We derived a CPUE value (number of fish collected per hour of electrofisher on time) by species for each reach. Then we plotted the CPUE values grouped by species and stream size. Only CPUE values from reaches where the given species was found were included in the plots. Median CPUE is labeled on each box plot.

APPENDIX H. SUPPLEMENTAL DATA ANALYSIS

Appendix H1.–Table of *p*-values from randomization tests for differences in the median of selected numeric habitat variables between stream-size groups.

Stream-size pair	elevation	water temp.	pH	dissolved oxygen	turbidity	conductivity	stream gradient	thalweg velocity	channel width	thalweg depth
Large - Medium	**<0.001**	~	~	0.023	0.009	0.034	0.054	0.051	**<0.001**	**<0.001**
Large - Small	~	~	**0.001**	~	**<0.001**	**<0.001**	~	**<0.001**	**<0.001**	**<0.001**
Medium - Small	**0.005**	~	**<0.001**	0.028	**<0.001**	**0.002**	~	**<0.001**	**<0.001**	**<0.001**

Note: Low *p*-values (≤0.05) suggest the given habitat variable differs among the given stream-size groups. Very low p-values (≤0.005), in bold, strongly suggest a difference. Grey shading behind a *p*-value indicates the median for the larger stream-size group was less than the median for the smaller stream-size group. No shading indicates the median for the larger stream-size group was greater than for the smaller stream-size group. "~" indicates the *p*-value was > 0.05.

Appendix H 2.–Table of *p*-values from randomization tests for differences in the median of fish fork lengths, and number of species found, between stream-size groups.

Stream-size pair	longnose sucker	round whitefish	Arctic grayling	coho salmon	rainbow trout	sockeye salmon	Chinook salmon	Dolly Varden	slimy sculpin	no. of species
Large - Medium	~	~	~	~	0.020	-	**<0.001**	0.006	~	**<0.001**
Large - Small	-	-	**<0.001**	~	**0.002**	-	**<0.001**	**<0.001**	~	**<0.001**
Medium - Small	-	-	**<0.001**	0.036	**<0.001**	~	~	**<0.001**	~	**~**

Note: We only tested species that were found in at least 3 reaches, and of which we measured at least 10 fish, per stream-size group. A low *p*-value (≤0.05) suggests the median fish length differs between the given stream-size groups. A very low p-value (≤0.005), in bold, strongly suggests a difference. Grey shading behind a *p*-value indicates the median for the larger stream-size group was less than the median for the smaller stream-size group. No shading indicates the median for the larger stream-size group was greater than for the smaller stream-size group. "~" indicates the *p*-value was >0.05. "-" indicates less than 10 fish were measured for one of the stream-size groups.

Appendix H3.–Table of *p*-values from randomization tests for differences in the median of selected numeric habitat variables between groups of sites where each fish species was found versus not found, grouped by stream size.

Species	catchment area	elevation	water temp	pH	dissolved oxygen	turbidity	conductivity	stream gradient	thalweg velocity	wetted width	thalweg depth
Small (≤100 km²) streams											
round whitefish	0.033	~	~	~	~	~	~	~	~	~	~
Arctic grayling	**0.002**	**<0.001**	~	~	0.015	0.028	~	0.030	0.012	0.009	~
coho salmon	**<0.001**	**<0.001**	**0.002**	0.006	~	~	0.025	~	~	**<0.001**	**0.004**
rainbow trout	0.006	0.008	**<0.001**	~	~	0.033	~	~	~	0.010	0.010
sockeye salmon	~	0.040	0.018	~	~	~	~	~	~	~	~
Chinook salmon	~	0.023	~	~	0.049	~	~	~	~	0.049	~
Dolly Varden	~	~	**<0.001**	0.043	**0.002**	~	~	**0.001**	~	~	~
burbot	~	~	~	~	~	~	~	~	~	~	~
threespine stickleback	~	**<0.001**	-	-	-	-	-	-	-	-	-
slimy sculpin	~	~	**<0.001**	0.033	**<0.001**	**<0.001**	~	0.007	**0.001**	~	~
no fish found	~	~	**<0.001**	~	~	**<0.001**	~	~	0.036	~	~
Medium (100-500 km²) streams											
longnose sucker	~	~	~	~	0.011	~	~	**0.005**	~	~	~
round whitefish	0.025	**0.005**	0.027	~	**<0.001**	~	0.048	**<0.001**	~	~	**0.001**
Arctic grayling	**0.005**	**<0.001**	**0.003**	~	**<0.001**	**0.001**	~	0.046	0.006	~	~
rainbow trout	~	~	~	~	~	~	~	~	~	~	~
sockeye salmon	0.028	0.011	~	~	~	~	~	~	~	~	~
Chinook salmon	~	0.040	~	~	~	~	~	~	~	~	~
Dolly Varden	**0.002**	0.023	**<0.001**	~	0.010	~	~	~	**0.004**	~	~
burbot	~	~	~	~	0.010	~	~	0.006	0.006	~	~
slimy sculpin	0.017	0.009	**<0.001**	0.009	0.010	**0.002**	~	0.037	0.015	~	~
Large streams (>500 km²)											
Arctic/Alaskan-brook lamprey	0.016	**0.004**	~	~	0.032	-	~	~	~	0.027	0.009
longnose sucker	0.037	~	~	~	~	~	~	0.006	~	0.016	0.010
northern pike	~	0.011	~	~	0.047	-	~	~	~	~	~
humpback whitefish	~	~	~	~	0.052	~	~	~	~	~	~
round whitefish	~	~	~	~	~	~	~	~	~	~	~
Arctic grayling	~	**<0.001**	~	~	~	~	0.008	~	~	0.036	0.047
pink salmon	~	**<0.001**	~	~	0.024	~	~	~	~	0.010	0.012
coho salmon	~	~	~	~	~	~	~	~	0.008	~	~
rainbow trout	**0.001**	~	~	~	~	~	~	~	~	~	**<0.001**
sockeye salmon	0.024	**0.005**	~	~	~	0.039	~	~	~	0.023	0.025
Chinook salmon	~	0.037	~	~	~	~	0.050	0.016	~	~	~
Dolly Varden	~	~	0.006	0.012	0.029	~	~	~	~	~	~
burbot	0.018	0.026	~	~	0.010	~	~	**0.004**	~	0.020	**<0.001**
threespine stickleback	~	0.013	~	~	0.048	-	~	~	~	~	~
slimy sculpin	~	~	~	~	~	~	~	~	~	~	~

Note: Low *p*-values (≤0.05) suggest the given habitat variable differs between sites where the species was found versus not found. Very low p-values (≤0.005), in bold, strongly suggest a difference. Grey shading behind a *p*-value indicates the median for sites where the species was found was less than the median for sites where the species was not found. No shading behind a *p*-value indicates the median for sites where the species was found was greater. "~" indicates the *p*-value was >0.05. "-" indicates insufficient sample size (<3 reaches from where the species was found/not found).

Appendix H4.–Table of *p*-values from contingency table analyses for co-occurrence of selected species at electrofished sites.

Species[a]	LAC	NOS	PIK	WHB	WRN	GRA	SPI	SCO	TRB	SSE	SCK	CDV	GBR	KTS	USL
Small streams (≤100 km², *n* = 138 sites)															
n	1	0	0	0	4	25	1	35	14	13	24	85	3	4	76
WRN	-	-	-	-	N/A	0.019	-	~	~	~	~	~	**0.002**	~	~
GRA	-	-	-	-	0.019	N/A	-	**0.001**	~	~	0.008	**0.001**	**0.005**	~	0.007
SCO	-	-	-	-	~	**0.001**	-	N/A	0.046	~	**0.001**	~	~	~	~
TRB	-	-	-	-	~	~	-	0.046	N/A	~	~	**0.002**	~	~	~
SSE	-	-	-	-	~	~	-	~	~	N/A	~	~	~	0.044	~
SCK	-	-	-	-	~	0.008	-	**0.001**	~	~	N/A	~	~	~	~
CDV	-	-	-	-	~	**0.001**	-	~	**0.002**	~	~	N/A	~	~	**0.003**
GBR	-	-	-	-	**0.002**	**0.005**	-	~	~	~	~	~	N/A	~	~
KTS	-	-	-	-	~	~	-	~	~	0.044	~	~	~	N/A	~
USL	-	-	-	-	~	0.007	-	~	~	~	~	**0.003**	~	~	N/A
Medium streams (100–500 km², *n* = 57 sites)															
n	0	5	0	0	10	25	1	2	3	4	7	29	6	0	36
NOS	-	N/A	-	-	**0.002**	0.013	-	~	~	~	~	0.024	**<0.001**	-	~
WRN	-	**0.002**	-	-	N/A	**<0.001**	-	~	~	~	~	**<0.001**	0.007	-	0.009
GRA	-	0.013	-	-	**<0.001**	N/A	-	~	~	~	~	**<0.001**	**0.005**	-	**0.006**
SCO	-	~	-	-	~	~	-	N/A	~	~	~	~	~	-	~
TRB	-	~	-	-	~	~	-	~	N/A	~	~	~	~	-	~
SSE	-	~	-	-	~	~	-	~	~	N/A	~	~	~	-	~
SCK	-	~	-	-	~	~	-	~	~	~	N/A	~	~	-	~
CDV	-	0.024	-	-	**<0.001**	**<0.001**	-	~	~	~	~	N/A	0.010	-	0.028
GBR	-	**<0.001**	-	-	0.007	**0.005**	-	~	~	~	~	0.010	N/A	-	~
USL	-	~	-	-	0.009	**0.006**	-	~	~	~	~	0.028	~	-	N/A
Large streams (≥500 km², *n* = 27 sites)															
n	3	13	3	5	12	19	6	3	5	7	10	7	11	3	25
LAC	N/A	~	0.025	~	~	~	0.007	~	~	~	~	~	~	0.025	~
NOS	~	N/A	~	0.016	**0.002**	~	~	~	~	~	~	~	~	~	~
PIK	0.025	~	N/A	~	~	~	0.007	~	~	~	~	~	~	**<0.001**	~
WHB	~	0.016	~	N/A	~	~	~	~	~	~	~	~	~	~	~
WRN	~	**0.002**	~	~	N/A	~	~	~	~	~	~	~	~	~	~
GRA	~	~	~	~	~	N/A	0.044	~	~	**0.001**	~	0.011	~	~	~
SPI	0.007	~	0.007	~	~	0.044	N/A	~	~	0.024	~	~	~	0.007	~
SCO	~	~	~	~	~	~	~	N/A	~	~	~	0.012	~	~	~
TRB	~	~	~	~	~	~	~	~	N/A	~	~	~	~	~	~
SSE	~	~	~	~	~	**0.001**	0.024	~	~	N/A	~	0.050	~	~	~
SCK	~	~	~	~	~	~	~	~	~	~	N/A	~	~	~	~
CDV	~	~	~	~	~	0.011	~	0.012	~	0.050	~	N/A	~	~	~
GBR	~	~	~	~	~	~	~	~	~	~	~	~	N/A	~	~
KTS	0.025	~	**<0.001**	~	~	~	0.007	~	~	~	~	~	~	N/A	~
USL	~	~	~	~	~	~	~	~	~	~	~	~	~	~	N/A

[a] Species codes defined in Appendix B5.

Note: *p* values are based on Fisher's Exact Test. Low *p* values (≤0.05) suggest an interspecific relationship (either association or avoidance) occurs. Grey shading behind a *p* value indicates possible avoidance. No shading behind a *p* value indicates possible association. "~" indicates the *p* value was >0.05 (i.e., not significant). "-" indicates sample size (number of sites where the species was found) was ≤1.

APPENDIX I. DISPOSITION OF FISH VOUCHER SPECIMENS AND FIN CLIPS

Appendix I1.–Fish voucher specimens and fin clips sent to University of Alaska Museum, Fairbanks.

Species	Date collected	Station ID	Fish tag number	Fin-clip vial number	Fin clipped
Arctic lamprey	07/20/2011	FSS1107D01	157090[a]	-	-
		FSS1108D01	157095[b]	-	-
Pacific lamprey	07/20/2011	FSS1108D01	157095	-	-
longnose sucker	07/15/2011	FSS1105D01	05D01_2	05D01_2	rt. pelvic fin
			05D10	05D10	rt. pelvic fin
			05D11	05D11	rt. pelvic fin
	07/19/2011	FSS1106D01	157075	-	-
			157076	-	-
			157077	-	-
			157078	-	-
	08/04/2011	FSS1102A01	T000389	157005	rt. pectoral fin
	08/05/2011	FSS1103A01	T000392	157014	rt. pectoral fin
			T000394	157015	rt. pectoral fin
	08/06/2011	FSS1104A01	T000405	157026	rt. pectoral fin
			T000410	157030	rt. pectoral fin
			T000408	157032	rt. pectoral fin
	08/08/2011	FSS1106A01	T000432	157056	rt. pectoral fin
northern pike	07/20/2011	FSS1108D01	157092	-	-
humpback whitefish	07/15/2011	FSS1105D01	[cd]	05D01_3	rt. pelvic fin
	08/08/2011	FSS1106A01	T000406	157050	rt. pectoral fin
			T000425	157051	rt. pectoral fin
			T000417	157052	rt. pectoral fin
			T000431	157053	rt. pectoral fin
			T000415	157054	rt. pectoral fin
			T000416	157055	rt. pectoral fin
			06A01_1	-	-
			06A01_3	-	-
			[c]	157076	rt. pectoral fin
			[c]	06A01_4	rt. pectoral fin
			[c]	157078	rt. pectoral fin
			[c]	06A01_6	rt. pectoral fin
	08/09/2011	FSS1107A01	07A01_1	-	-
			07A01_2	-	-
			[c]	07A01_3	rt. pectoral fin
			[c]	07A01_4	rt. pectoral fin
			[c]	07A01_5	rt. pectoral fin
		FSS1107B01	[c]	157073	rt. pectoral fin
			[c]	157074	rt. pectoral fin
			[c]	157075	rt. pectoral fin
			[c]	157079	rt. pectoral fin
			[c]	157077	rt. pectoral fin
pygmy whitefish	08/17/2011	FSS1115A01	T000447	157072	rt. pectoral fin

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Appendix I1.–Page 2 of 4.

Species	Date collected	Station ID	Fish tag number	Fin-clip vial number	Fin clipped
round whitefish	07/19/2011	FSS1106D01	157079	-	-
			157080	-	-
	07/20/2011	FSS1107D01	157091	-	-
		FSS1108D01	157094	-	-
	08/04/2011	FSS1102A01	T000391	157004	rt. pectoral fin
		FSS1102B01	T000381	157002	rt. pectoral fin
			T000400	157003	rt. pectoral fin
		FSS1102C04	T000388	157012	rt. pectoral fin
	08/05/2011	FSS1103B01	T000403	157019	rt. pectoral fin
			T000411	157020	rt. pectoral fin
			T000377	157021	rt. pectoral fin
			T000379	157022	rt. pectoral fin
	08/06/2011	FSS1104A01	T000407	157027	rt. pectoral fin
			T000409	157033	rt. pectoral fin
			T000412	157034	rt. pectoral fin
whitefish-unspecified	08/06/2011	FSS1104A01	T000422	157036	rt. pectoral fin
Arctic grayling	07/15/2011	FSS1105D01	05D12	05D12	rt. pelvic fin
	07/19/2011	FSS1106D01	157081	-	-
	08/03/2011	FSS1101A01	T000360	156984	rt. pectoral fin
			T000361	156985	rt. pectoral fin
		FSS1101C01	T000356	156980	rt. pectoral fin
			T000357	156981	rt. pectoral fin
			T000358	156982	rt. pectoral fin
			T000359	156983	rt. pectoral fin
	08/04/2011	FSS1102B01	T000398	156998	rt. pectoral fin
			T000385	156999	rt. pectoral fin
			T000382	157000	rt. pectoral fin
			T000383	157001	rt. pectoral fin
		FSS1102C04	T000396	157006	rt. pectoral fin
			T000387	157009	rt. pectoral fin
			T000389	157010	rt. pectoral fin
			T000390	157011	rt. pectoral fin
	08/06/2011	FSS1104A01	T000413	157028	rt. pectoral fin
coho salmon	08/08/2011	FSS1106C04	T000442	157057	rt. pectoral fin
			T000438	157058	rt. pectoral fin
			T000441	157059	rt. pectoral fin
			T000444	157060	rt. pectoral fin
			T000435	157061	rt. pectoral fin
			T000440	157062	rt. pectoral fin
			T000436	157063	rt. pectoral fin
			T000439	157064	rt. pectoral fin
			T000443	157065	rt. pectoral fin
			T000437	157066	rt. pectoral fin

-continued-

Species	Date collected	Station ID	Fish tag number	Fin-clip vial number	Fin clipped
rainbow trout	07/15/2011	FSS1105D01	05D06	05D06	rt. pelvic fin
Chinook salmon	07/12/2011	FSS1102D01	02D01_3	02D01_3	rt. pelvic fin
			02D01_4	02D01_3	rt. pelvic fin
			02D01_5	02D01_3	rt. pelvic fin
	07/19/2011	FSS1106D01	157073	-	-
Dolly Varden	06/30/2011	FSS1101D01	T000083	-	-
			T000085	55515	rt. pelvic fin
			T000086	55504	rt. pelvic fin
			T000087	55507	rt. pelvic fin
			T000088	55501	rt. pelvic fin
			T000089	55497	rt. pelvic fin
			T000090	55508	rt. pelvic fin
			T000091	55511	rt. pelvic fin
			T000092	55513	rt. pelvic fin
			T000093	55500	rt. pelvic fin
			T000094	55496	rt. pelvic fin
	07/12/2011	FSS1102D01	T000095	55499	rt. pelvic fin
	07/13/2011	FSS1103D01	03D01-1	03D01-1	rt. pelvic fin
	08/06/2011	FSS1104B01	T000419	157037	rt. pectoral fin
			T000421	157038	rt. pectoral fin
			T000420	157039	rt. pectoral fin
			T000418	157040	rt. pectoral fin
		FSS1104C03	T000430	157041	rt. pectoral fin
			T000393	157042	rt. pectoral fin
			T000429	157043	rt. pectoral fin
			?[e]	157044	rt. pectoral fin
			?[e]	157045	rt. pectoral fin
			T000428	157046	rt. pectoral fin
			T000433	157047	rt. pectoral fin
			T000424	157048	rt. pectoral fin
			T000434[f]	157049	rt. pectoral fin
	08/14/2011	FSS1112A01	[g]	157071	rt. pectoral fin
burbot	07/15/2011	FSS1105D01	05D04	05D04	rt. pelvic fin
			05D05	05D05	rt. pelvic fin
	07/19/2011	FSS1106D01	157074	-	-
	07/20/2011	FSS1108D01	157093	-	-
	08/05/2011	FSS1103A01	T000452	157016	rt. pectoral fin
			T000376	157017	rt. pectoral fin
			T000453	157018	rt. pectoral fin
		FSS1103B01	T000414	157023	rt. pectoral fin
			T000454	157024	rt. pectoral fin
			T000404	157025	rt. pectoral fin
	08/06/2011	FSS1104A01	T000401	157029	rt. pectoral fin

-continued-

Species	Date collected	Station ID	Fish tag number	Fin-clip vial number	Fin clipped
burbot (cont.)	08/06/2011 (cont.)	FSS1104A01 (cont.)	T000402	157031	rt. pectoral fin
			T000423	157035	rt. pectoral fin
	08/08/2011	FSS1106B01	T000448	157067	rt. pectoral fin
	08/09/2011	FSS1107C01	T000449	157068	rt. pectoral fin
			T000450	157069	rt. pectoral fin
	08/12/2011	FSS1110A01	T000445	157070	rt. pectoral fin
threespine stickleback	07/12/2011	FSS1102D01	02D01_1	02D01_1	rt. pelvic fin
			02D01_2	02D01_2	rt. pelvic fin
	07/15/2011	FSS1105D01	05D01_1	05D01_1	rt. pelvic fin
slimy sculpin	06/30/2011	FSS1101D01	T000084	55514	rt. pelvic fin
	07/13/2011	FSS1103D01	03D01-2	03D01-2	rt. pelvic fin
	07/15/2011	FSS1105D01	05D07	05D07	rt. pelvic fin
			05D08	05D08	rt. pelvic fin
			05D09	05D09	rt. pelvic fin
			05D13	05D13	rt. pelvic fin
			05D14	05D13	rt. pelvic fin
			05D15	05D13	rt. pelvic fin
	07/19/2011	FSS1106D01	157082	-	-
			157083	-	-
			157084	-	-
			157085	-	-
			157086	-	-
			157087	-	-
			157088	-	-
			157089	-	-
	08/03/2011	FSS1101A01	T000365	156986	rt. pectoral fin
			T000366	156987	rt. pectoral fin
			T000367	156988	rt. pectoral fin
		FSS1101C01	T000368	156989	rt. pectoral fin
			T000371	156990	rt. pectoral fin
			T000372	156991	rt. pectoral fin
			T000373	156992	rt. pectoral fin
			T000374	156993	rt. pectoral fin
			T000375	156994	rt. pectoral fin
			T000396	156995	rt. pectoral fin
			T000397	156996	rt. pectoral fin
	08/04/2011	FSS1102C01	T000380	156997	rt. pectoral fin
		FSS1102C04	T000451	157007	rt. pectoral fin
			T000395	157008	rt. pectoral fin
			T000378	157013	rt. pectoral fin

Note: "-" indicates no fin clip was taken from the specimen. A total of 182 whole specimens and 149 fin clips were sent to the UAF Museum.

[a] Batch of 11 specimens in a bag with a single tag attached. No fin clips taken.

[b] Batch of 9 specimens in a bag with a single tag attached. No fin clips taken.

[c] Sagittal otoliths extracted and sent to Randy Brown (Fishery Biologist, USFWS, Fairbanks) for chemical analysis (see Appendix I2). Fish carcasses were destroyed.

[d] This row represents 2 fish collected at the same site. Fin clips from both fish were combined in vial 05D01_3.

[e] Fish tag number not recorded.

[f] In addition to the individual specimens listed, a small bag of Dolly Varden young-of-the-year collected from this site was sent to the UAF museum.

[g] Batch of 10 specimens in a bag labeled with the Station ID. Fin clips from all 10 specimens were combined in vial 157071.

Appendix I2.–Otoliths sent to USFWS, Fairbanks.

Species	Date collected	Station ID	Otolith vial number	Fin clip vial number[a]
Dolly Varden	08/13/2011	FSS1111C03	662	[b]
			663	[b]
	08/16/2011	FSS1114A01	648	[b]
			649	[b]
			650	[b]
			651	[b]
			652	[b]
			658	[b]
	08/19/2011	FSS1116C03	664	[b]
	08/21/2011	FSS1118A01	646	[b]
			659	[b]
	08/22/2011	FSS1119A01	665	[b]
	08/23/2011	FSS1120A01	647	[b]
			660	[b]
			661	[b]
	09/12/2011	FSS1126C02	653	[b]
			654	[b]
			655	[b]
			656	[b]
			657	[b]
	09/14/2011	FSS1128C08	644	[b]
			645	[b]
	09/19/2011	FSS1129C01	666	[b]
Humpback whitefish	07/14/2011	FSS1105D01	05D01_1	05D01_3
			05D01_2	05D01_3
	08/08/2011	FSS1106A01	06A01_2	157076
			06A01_4	06A01_4
			06A01_5	157078
			06A01_6	06A01_6
	08/09/2011	FSS1107A01	07A01_3	07A01_3
			07A01_4	07A01_4
			07A01_5	07A01_5
		FSS1107B01	07B01_1	157073
			07B01_2	157074
			07B01_3	157075
			07B01_4	157079
			07B01_5	157077

Note: Both sagittal otoliths were extracted from each optionally-anadromous fish specimen >250 mm long and sent to Randy Brown (Fishery Biologist, USFWS, Fairbanks) for chemical analysis to identify evidence of periods of possible saltwater residency.

[a] Fin clips from the Dolly Varden specimens were sent to the UAF Museum (see Appendix I1) for genetic analysis. Fin clips from the humpback whitefish specimens were sent to the USFWS Conservation Genetics Lab in Anchorage for genetic analysis (see Appendix I3).

[b] Dolly Varden fin clips from each site were combined into a single vial labeled with the last 5 digits of the Station ID.

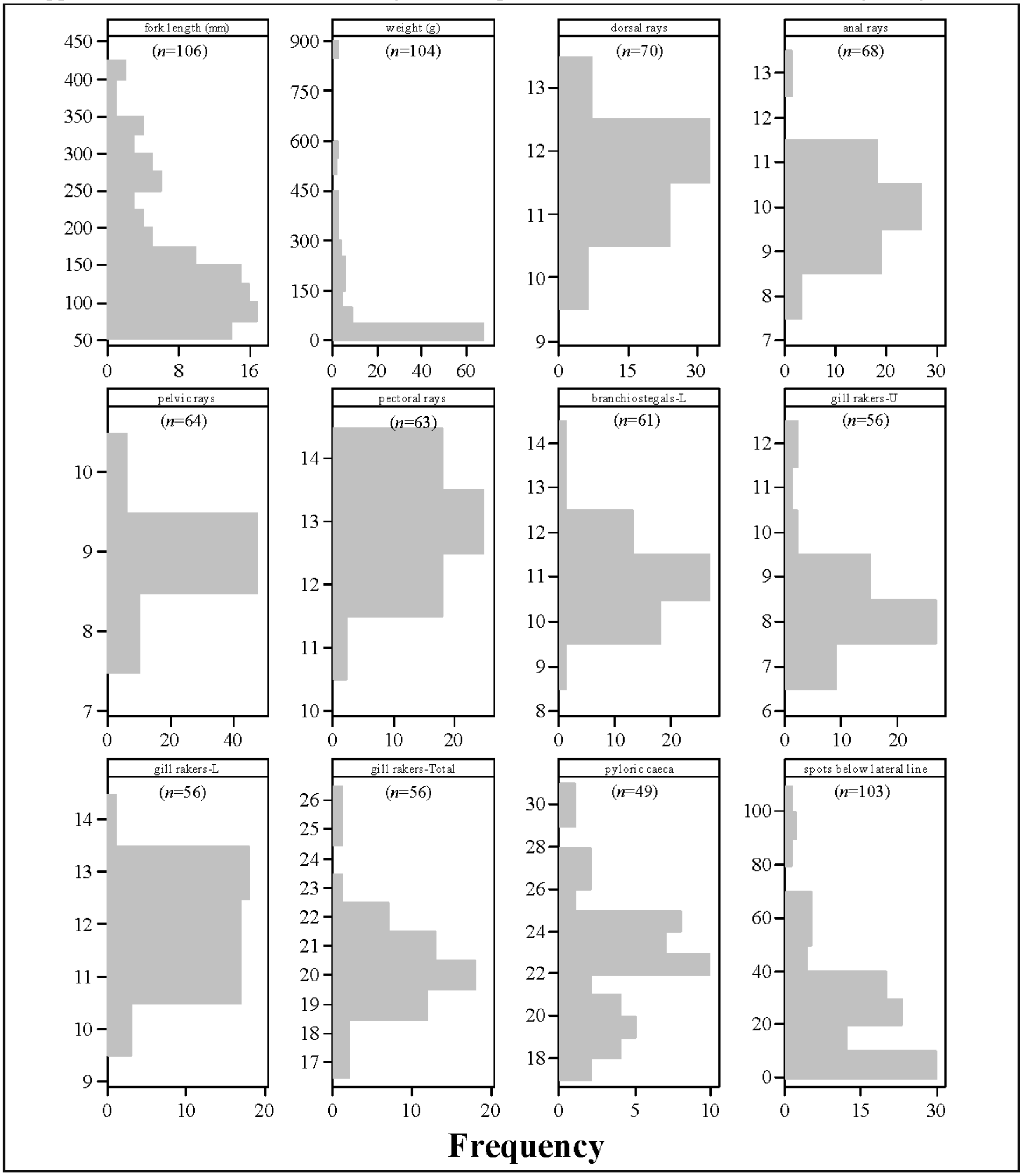
Appendix I3.–Dolly Varden fin clips sent to USFWS Conservation Genetics Lab, Anchorage.

Date collected	Station ID	Number of fish clipped	Fin-clip vial number
06/30/2011	FSS1101D01	10	01D01
08/06/2011	FSS1104B01	4	04B01
08/06/2011	FSS1104C03	7	04C03
08/07/2011	FSS1105C02	1	05C02
08/07/2011	FSS1105C03	1	05C03
08/08/2011	FSS1106C01	9	06C01
08/08/2011	FSS1106C02	12	06C02
08/09/2011	FSS1107C02	3	07C02
08/10/2011	FSS1108C03	12	08C03
08/13/2011	FSS1111C03	2	11C03
08/16/2011	FSS1114A01	6	14A01
08/19/2011	FSS1116C03	1	16C03
08/21/2011	FSS1118A01	2	18A01
08/22/2011	FSS1119A01	1	19A01
08/23/2011	FSS1120A01	3	20A01
08/24/2011	FSS1121B01	9	21B01
08/24/2011	FSS1121B03	1	21B03
09/12/2011	FSS1126C02	5	26C02
09/14/2011	FSS1128C08	2	28C08
09/19/2011	FSS1129C01	1	29C01
09/23/2011	FSS1103F02	5	03F02
Total		97	

Note: The right pelvic fin was clipped.

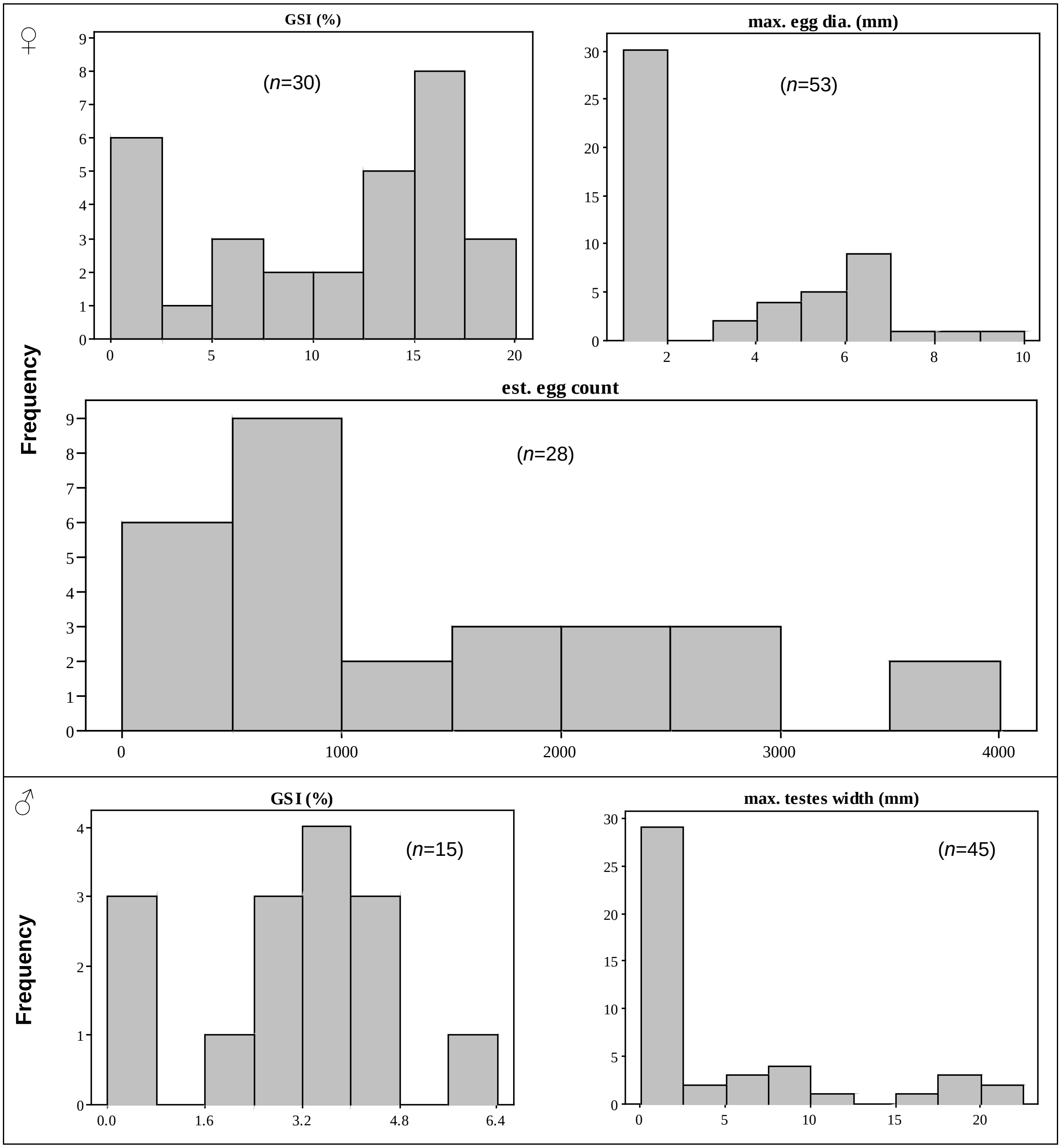
APPENDIX J. MERISTIC AND GONAD DATA FROM RETAINED DOLLY VARDEN AND HUMPBACK WHITEFISH SPECIMENS

Appendix J1.–Meristic data from Dolly Varden specimens retained for otolith-chemistry study.



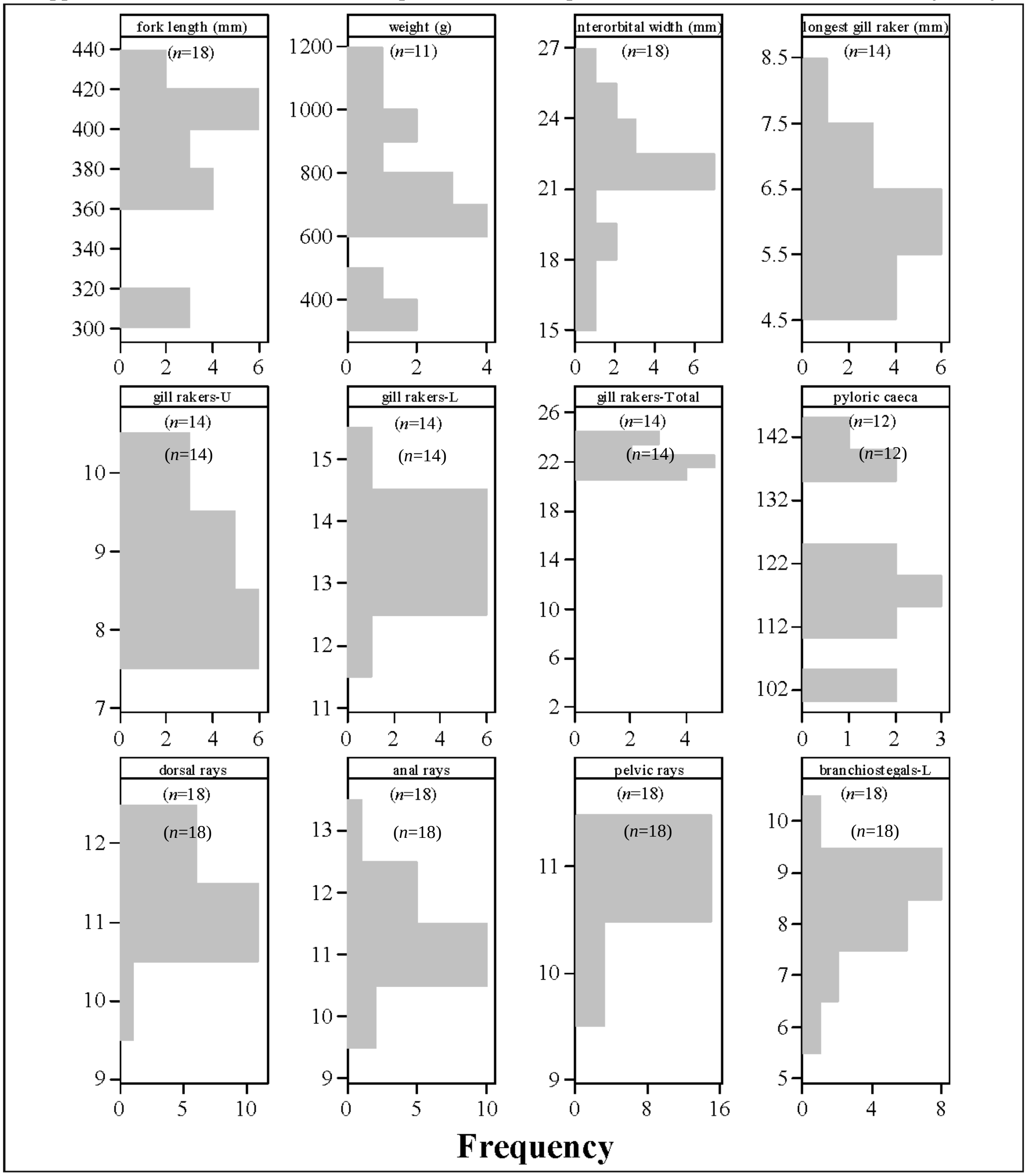
Note: Fish were previously frozen then thawed. Fin rays counted from fin on fish's left-side. Gill rakers counted from the 1st arch on the fish's right side. Rakers in the angle between the upper and lower limb were included with the lower-limb count.

Appendix J2.–Gonad data from Dolly Varden specimens retained for otolith-chemistry study.



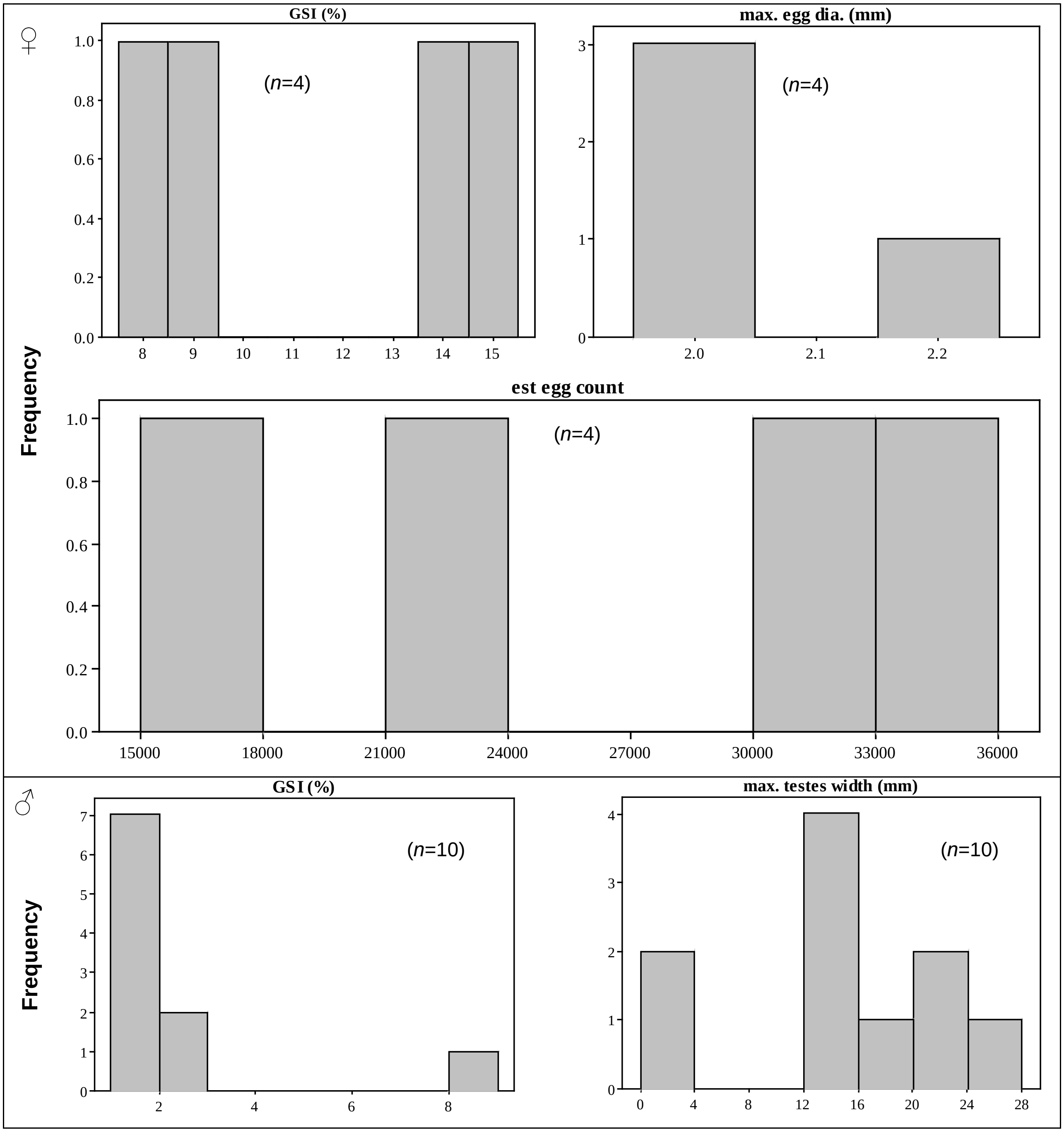
Notes: Fish were previously frozen, then thawed. Top panel shows gonad data for female, and bottom panel male, specimens. *GSI* (gonado-somatic index) is gonad mass as a percent of total body mass. Egg count was estimated as total ovary weight × no. of eggs counted from a sample taken from a transverse section through the center of an ovary ÷ ovary sample weight.

Appendix J3.–Meristic data from humpback whitefish specimens retained for otolith-chemistry study.



Note: Fish were previously frozen then thawed. Fin rays counted from fin on fish's left-side. Gill rakers counted from the 1st arch on the fish's right side. Rakers in the angle between the upper and lower limb were included with the lower-limb count.

Appendix J4.–Gonad data from humpback whitefish specimens retained for otolith-chemistry study.



Notes: Fish were previously frozen, then thawed. Top panel shows gonad data for female, and bottom panel male, specimens. *GSI* (gonado-somatic index) is gonad mass as a percent of total body mass. Egg count was estimated as total ovary weight × no. of eggs counted from a sample taken from a transverse section through the center of an ovary ÷ ovary sample weight.

Link to Appendix K:

APPENDIX K. 2003 STATION REPORTS AND PHOTOS

FDS 14-04 – FULL PDF FILE DOWNLOAD (93,185 kb)

Sections:

FDS14-04 – Text, Appendices A, B, E. F, G, H, I, and J

Appendix C – Occurrence Maps

Appendix D – 2003 Station Reports and Photos

Appendix L – 2011 Station Reports and Photos

Link to Appendix L:

APPENDIX L. 2011 STATION REPORTS AND PHOTOS

FDS 14-04 – FULL PDF FILE DOWNLOAD (93,185 kb)

Sections:

FDS14-04 – Text, Appendices A, B, E. F, G, H, I, and J

Appendix C – Occurrence Maps

Appendix D – 2003 Station Reports and Photos

Appendix K – 2011 Station Reports and Photos