COMPARISON OF TWO INDEXED GILL-NETTING PROTOCOLS FOR FISH COMMUNITY SURVEYS IN NORTHERN LAKES

by

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Thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science (M.Sc.) in Biology

Faculty of Graduate Studies

Laurentian University

Sudbury, Ontario

THESIS DEFENCE COMMITTEE/COMITÉ DE SOUTENANCE DE THÈSE
Laurentian Université/Université Laurentienne

Faculty of Graduate Studies/Faculté des études supérieures

Title of Thesis Titre de la thèse	COMPARISON OF TWO INDEXED GILL-NETTING PROTOCOLS FOR FISH COMMUNITY SURVEYS IN NORTHERN LAKES
Name of Candidate Nom du candidat	Brekke, Lorraine
Degree Diplôme	Master of Science
Department/Program Département/Programme	Biology
Date of Defence Date de la soutenance	January 18, 2017

APPROVED/APPROUVÉ

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ACCESSIBILITY CLAUSE AND PERMISSION TO USE

Abstract

1) I compared the performance of two standard fish community assessment protocols, the NORDIC protocol and the Broad-scale Fish Community Monitoring (BsM) protocol (the latter consisting of two gear types). I utilized fish catch and attribute data collected from 21 Boreal Shield lakes (17 in Ontario, 4 in NWT) surveyed using both protocols, in a pairwise design. Fish community composition (species richness, diversity, and evenness), relative abundance (number and biomass per 100 m of net), and body size distributions were compared between NORDIC and BsM surveys, and among the three gill net gears - NORDIC (NRD), North American Standard (NA1), and Ontario Small Mesh Standard (ON2). The NORDIC protocol dedicates a higher proportion of total sampling effort to small-mesh gear compared to the BsM protocol, and the ranking of gears according to proportion of small mesh effort is ON2 > NRD > NA1. NORDIC surveys used 38% greater effort (total length of net deployed per area of lake) than BsM surveys over the 21 lakes examined.

2) Principal components analysis (PCA) of species relative abundances showed significant differences between surveys in community compositions, as well as a separation of communities between Ontario and NWT lakes. NORDIC surveys detected 19% more species per survey, with the additional species primarily belonging to small-bodied taxa (e.g., Cyprinidae, Gasterosteidae, Cottidae). Paired-comparisons of gears indicated that NA1 gangs (highest proportion of large mesh) yielded fewer species, lower diversity, and higher evenness at standardized levels of effort compared to NRD and ON2 gangs, but there were no significant differences between NRD and ON2 gangs.

3) NORDIC surveys tended to provide higher numeric catch per unit effort (NPUE) and lower biomass per unit effort (BPUE) estimates compared to BsM surveys for the whole

community, but differences between surveys were stronger and more consistent for small-bodied species than large-bodied species. For most small-bodied species, both NPUE and BPUE were significantly higher in NORDIC than BsM surveys. In gear comparisons, differences generally followed mesh size compositions for both NPUE and BPUE; NA1 gear tended to provide higher estimates for large-bodied species, and lower estimates for small-bodied species compared to NRD and ON2 gears. NRD and ON2 gear provided comparable NPUE and BPUE estimates for small-bodied species, but NRD gear tended to provide higher estimates for large-bodied species.

4) Biomass size distributions of all captured fish differed significantly between surveys in most Ontario lakes, but not in most NWT lakes. Significant differences between the surveys were more consistent across lakes for large-bodied piscivores than for other taxa. Size distributions from NORDIC surveys generally had lower medians and higher CVs than distributions from BsM surveys. Both NRD and ON2 gears yielded size distributions that tended to be more multi-modal than distributions from NA1 gear. In gear comparisons, size distribution medians were NA1 > NRD > ON2, whereas size distribution CVs were NRD=ON2 > NA1.

5) Differences in fish community metrics between the surveys were not related to the physical characteristics of the survey lakes (area, depth, water clarity), with the exception that BPUE differences were weakly but significantly related to lake maximum depth. Differences between surveys appeared to be less distinct in NWT lakes than in Ontario lakes, presumably due to differences in fish community composition between regions.

6) Overall, BsM surveys tended to under-represent small-bodied fish and over-represent large-bodied fish relative to NORDIC surveys. Differences between survey results could likely be reduced by increasing the total sampling effort, and/or the relative amount of ON2 effort in BsM surveys.

Acknowledgements

I could not have done this without the love and support of my husband, Kris. Thank you.

Thank you to my supervisors, Dr. Tom Johnston and Dr. John Gunn for the endless support on this project. Thank you to Dr. Tom Johnston for the support, assistance with SAS, editing and advice regarding the project. Thank you to my committee members, Dr. Nigel Lester and Ed Snucins for your support, advice and patience with this project. Thank you to all who assisted in the data collection for this project (Pete Cott, Julian Morse, Lee Haslam, Nigel Lester, Sarah Elsasser, Morag McPherson, Sarah Olivier, Rick Walbourne, John Gunn, Corrie Gibson, Martin and Nesta Sawdon, Paul Blanchfield, Lee Hrenchuk, AJ Chapelsky, Matt Guzzo, and many others), and data acquisition (Dr. Tom Johnston, Dr. Nigel Lester, Evelyn Sim, Lee Haslam, Andrew Corston, Trevor Middell, and Noni Paulette). Thank you to Lauren Seabrook for Saturdays. And thank you to my family and friends for the support and encouragement.

This project was funded by the NWT Cumulative Impact Monitoring Program, and the Ontario Ministry of Natural Resources and Forestry.

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Introduction

Many fish species are managed as renewable resources, and quantifying their abundance and distribution is essential to effective fisheries management (Gibbs *et al.* 1998; Lester *et al.* 2003; Hubert & Fabrizio 2007; Al-Chokhachy *et al.* 2009). Assessments typically focus on the status of particular fish stocks or populations (Hubert & Fabrizio 2007), but may also target the fish community as a whole to examine species composition (Rahel 1990), predator-prey relationships (Bertolo & Magnan 2005), and trophic interactions (Van Den Avyle *et al.* 1995).

Subsistence, recreational, and commercial fisheries provide enormous social and economic benefits to Canadians. In 2010, recreational anglers contributed $8.3 billion to the Canadian economy (Fisheries and Oceans Canada 2012) and in 2012, marine and freshwater commercial fisheries in Canada generated $2.12 billion and $67 million, respectively (Fisheries and Oceans Canada 2013). The value of these fisheries underscores the need for effective assessment and management practices. Fisheries management decisions require reliable estimates of abundance (Hubert & Fabrizio 2007) and considerable effort has been directed at the development of assessment techniques (Appelberg 2000; Morgan 2002; Sandstrom *et al.* 2011).

Quantitative surveys of fish populations and communities pose several challenges compared to surveys of other biota. Fish live in an environment in which they are often highly mobile (both horizontally and vertically), and not easily visible (Zale *et al.* 2012). The most common assessment methods therefore require the capture and handling of fish. Methods that generate absolute abundance estimates (e.g., mark-recapture methods) are generally much more costly in time and expense and are therefore less frequently used than methods that provide relative abundance estimates (e.g., catch-per-unit-effort methods) (Hayes *et al.* 2007). Currently-used assessment methods vary according to the species and habitats being sampled and may be designed to target individual populations or the broader fish community. Regardless of the methods employed, there is a need for standardization to ensure robust and statistically sound spatio-temporal comparisons (Appelberg *et al.* 1995; Bonar *et al.* 2009) and to account for variation in the data generated (Hubert & Fabrizio 2007).

Sampling methods involving the capture of fish can be categorized according to how the gear is used. Active methods move the gear through the water to capture the fish (e.g., trawls, seines), whereas passive methods use stationary gears and rely on the fish encountering the gear and becoming caught (e.g., gill nets, trap nets) (Hayes *et al.* 2012). Angling methods can have both active (e.g., trolling) and passive (e.g., longlining) approaches (Hayes *et al.* 2012; Hubert *et al.* 2012). In general, the quantity of habitat sampled can usually be estimated when using active gears, but not when using passive gears (Hayes *et al.* 2012).

Passive net gears can be further categorized into entanglement gears (e.g., gill nets, trammel nets) and entrapment gears (e.g., trap nets, hoop nets, cod pots) (Hubert *et al.* 2012). Entanglement gears allow fish to become wedged or entangled in fine mesh and are commonly used as a lethal sampling technique (Lester *et al.* 2009; Hubert *et al.* 2012). Entrapment gear generally consists of thicker and coarser net mesh forming an enclosure into which fish can enter but cannot readily escape (Hubert *et al.* 2012). As the fish inside the enclosure can move about freely, these gears can be used for non-lethal sampling (Hubert *et al.* 2012). Each sampling gear has advantages and disadvantages with respect to cost, ease of deployment, the types of habitats in which it can be used, the species and life stages it can effectively sample, and the types of data it can provide (Hayes *et al.* 2012; Hubert *et al.* 2012).

Gill nets have many advantages over other passive gear types. They are relatively inexpensive to manufacture, lightweight, compact, easy to deploy in a wide range of depths and substrate conditions (Hubert *et al.* 2012), and can be customized to capture a narrow or broad size range of fishes by altering the mesh size composition (Jensen 1986; Walker *et al.* 2013). Among their disadvantages, gill nets are less useful for non-lethal sampling, for sampling in strong currents of rivers and streams, or for sampling species that are less mobile or less likely to entangle themselves when contacting the net (Hubert *et al.* 2012). The advantages of gill nets generally outweigh their disadvantages under many circumstances and they have become the standard capture gear for many survey and assessment programs, particularly in boreal lakes.

The probability of a fish being captured in a gill net (P_{cap}) is a product of the probability of a fish encountering the net (P_{enc}) and the probability of the fish becoming wedged or entangled in the net (P_{hold}) following encounter (Hubert *et al.* 2012). P_{enc} is linked to a variety of ecological and environmental factors that influence movement patterns of fishes (Hubert *et al.* 2012), whereas P_{hold} is more strongly linked to the characteristics of the gear (e.g., mesh size, twine size, hang ratio) and the morphology (Hubert *et al.* 2012) and behaviour of the fish (Hubert & Fabrizio 2007). Both P_{enc} and P_{hold} have strong species-specific components. Therefore, P_{cap} can vary considerably among different fish species within an ecosystem (Choat *et al.* 1993; Hubert & Fabrizio 2007). This has implications for how gill net survey data can be analyzed and interpreted.

Gill nets provide estimates of relative abundance, expressed as catch-per-unit-effort (CPUE), and the number or biomass of fish captured per unit of gear per unit of time (Hubert *et al.* 2012). Gill net surveys cannot provide estimates of absolute abundance (the number or biomass of fish per unit of habitat) on their own. However, gill net CPUE can be calibrated to absolute estimates of abundance (Lester *et al.* 1991; Portt *et al.* 2006; Walker *et al.* 2013). This is done by conducting standardized gill net surveys in conjunction with a program to estimate absolute abundance, such as a mark-recapture study, on a series of ecosystems across a gradient of abundance (Lester *et al.* 1991). The slope of the relationship between CPUE and abundance is termed catchability, q (Hubert & Fabrizio 2007). Catchability can vary considerably among species because of interspecific differences in encounter and entrapment probabilities (P_{enc} and P_{hold}). Therefore, CPUE estimates of different species caught in the same gear are not directly comparable (Hubert & Fabrizio 2007).

Many fish assessment programs have utilized gill nets as their primary sampling gear. These programs have standardized protocols with respect to the configuration of the gill net gear, the temporal and spatial distribution of gear deployment, and the overall sampling effort. Historically, fish assessment programs were usually designed to focus on only one or a few species per ecosystem, typically those most important to the fishery (Morgan 2002; Pikitch *et al.* 2004; Hubert & Fabrizio 2007; Kwak & Peterson 2007). Though such species-specific protocols served fisheries management objectives well, they provided relatively little information on other components of the fish community or the ecosystem (Kwak & Peterson 2007).

In recent decades fisheries managers in Ontario have focussed a great deal of effort and resources into the goal of creating a better assessment protocol. Prior to 1990, a standardized protocol for inland lakes (i.e., outside of the Laurentian Great Lakes) did not exist. Beginning in 1990 a number of standardized assessment protocols were developed and implemented, including Fall Walleye Index Netting (FWIN), Spring Littoral Index Netting (SLIN), and Summer Profundal Index Netting (SPIN) (Kerr 2010). All of these protocols used multi-mesh gill nets and were designed primarily for stock assessment of key target species. By the early 2000s, resource management priorities were shifting in Ontario; protection and preservation of biodiversity were gaining in importance (Kerr

2010). Fish assessment programs were expected to continue assessing the status of key target species, but it was important to also assess the status of the fish community as a whole (Ontario Ministry of Natural Resources 1992). This change necessitated using index gill nets with a greater diversity of mesh sizes, and distributing the sampling effort over the entire waterbody. The NORDIC Index Netting (NORDIC) protocol was developed in Scandinavia for assessing fish community structure in small- to moderate-sized lakes (Jensen 1986; Appelberg *et al.* 1995; Appelberg 2000) and was adopted for use on Ontario lakes in the early 2000s (Morgan & Snucins 2005). It has since been used for surveys on approximately 300 Ontario lakes, primarily small- to moderate-sized (< 1000 ha) lakes of the Boreal Shield. However, the NORDIC protocol did not gain as wide acceptance in Ontario as it did in Europe. Instead, the Broad-scale Fish Community Monitoring (BsM) protocol, was developed by the Ontario Ministry of Natural Resources in 2007 (Sandstrom *et al.* 2011). The BsM protocol was designed to approximate the NORDIC protocol while incorporating sampling gear that was similar to what was already in use in North America (Lester *et al.* 2009; Miranda & Boxrucker 2009; Pope *et al.* 2009). By 2011, the BsM protocol had been used to survey over 800 lakes across Ontario by (N. Lester, MNRF, Peterborough, *pers. comm.*) and it is now considered the Ontario fish community survey standard.

NORDIC and BsM protocols have many similarities, but also some key differences (Table 1) that may lead to differences in the interpretations of fish population and community structure. In terms of gear structure, the most striking difference is that the NORDIC protocol uses a single standard gill net gang (NRD), while the BsM protocol uses two standard gill net gangs, a longer gang composed of larger meshes (North American standard, NA1) and a shorter gang composed of smaller meshes (Ontario standard, ON2) (Table 1). The two-gang design of the BsM protocol allows surveys to be more adaptable as the relative proportions of small and large mesh gear deployed can be easily adjusted, if desired (Sandstrom *et al.* 2011). The NRD, NA1, and ON2 gangs are all multimesh, clear monofilament construction with a 2:1 hang ratio (Morgan & Snucins 2005; Sandstrom *et al.* 2011). The NRD gang consists of 12 mesh panels, each a different mesh size (Morgan & Snucins 2005). The NA1 and ON2 gangs collectively have 13 panels, however the gangs share a panel of common mesh size (38 mm), therefore there are 12 panels of distinct mesh size between the two gangs (Sandstrom *et al.* 2011). Mesh sizes are arranged non-sequentially in all three gears, and the mesh sizes of NA1 and ON2 gangs collectively span a range that is similar to the NRD gang, but are shifted slightly towards larger meshes (Table 1, Figure 1). NA1 gangs are constructed of thicker monofilament than ON2 and NRD gangs (Table 1, Figure 1), and both NA1 and ON2 gangs are 20% taller and have heavier float and sink lines compared to NRD gangs (Table 1). Another important difference is the unit of sampling effort (i.e., a net set). The NORDIC protocol deploys a single gang at each sampling site (Morgan & Snucins 2005), whereas the BsM protocol usually deploys two connected gangs, termed a strap, unless sensitive species are present (Sandstrom *et al.* 2011). The gangs in a strap are connected to each other by a rope spanner that leaves a 2-3 m gap between them (Sandstrom *et al.* 2011). The effective sampling lengths of the three gears are a 30 m gang for NRD gear (Morgan & Snucins 2005), a 49.6 m strap for NA1 gear, and a 25 m strap for ON2 gear (Sandstrom *et al.* 2011). The NORDIC protocol deploys each gang for a 12 hour period, while the BsM protocol deploys each strap for an 18 hour period. While there are differences between the gears in the length of daylight that the gears fish, both protocols deploy the gears over two crepuscular periods (Morgan & Snucins 2005; Sandstrom *et al.* 2011).

Another difference between BsM and NORDIC protocols is the relative proportion of effort per mesh size across depth strata and among lakes. As the NORDIC protocol uses a single standard gear, the relative amount of effort per mesh size stays constant under all conditions (Morgan & Snucins 2005). Until 2013, the BsM protocol required that NA1 gear was assigned to all depth strata in a lake while ON2 gear was only assigned to depth strata above 20 m (Sandstrom *et al.* 2011)[1]. This leads to variation across lakes and surveys in the relative amounts of NA1 and ON2 effort assigned, and therefore variation in the relative amounts of effort directed towards large and small fishes. The relative amounts of NA1 and ON2 effort in a BsM survey vary more with lake maximum depth than with lake area. The ON2 effort in a survey, expressed as a proportion of total sampling effort, is highest in lakes of 12-20 m maximum depth (Figure 2). The proportion of total effort as ON2 sets is fairly consistent across the full range of surface areas, except in very shallow lakes (Figure 2).

Another significant difference between the two protocols is the total number of net sets that is recommended per survey for lakes of various surface areas (Figure 3). The NORDIC and BsM protocols use roughly the same number of net sets for small (50 ha), shallow (0-6 m) lakes, and both surveys use progressively more net sets as lake area increases. However, the difference in total number of recommended net sets between surveys generally becomes greater as lake surface area increases and is greatest in deep lakes (Figure 3). There are several other important differences in deployment methods between the protocols (Table 1). NRD gangs are set at random angles with respect to the shoreline and are not anchored (Morgan & Snucins 2005), whereas both NA1 and ON2 gears are set perpendicular to shore and are anchored (Sandstrom *et al.* 2011). The recommended set duration for NRD gear is 12 hours (Morgan & Snucins 2005), whereas the recommended set duration for NA1 and ON2 gears is 18 hours (Sandstrom *et al.* 2011).

[1] The BsM protocol was modified in 2013 to include the deployment of the ON2 strap in all depth strata, including below 20 m, and some changes were made to the biological samples required (Sandstrom *et al.* 2013). These changes occurred after the dataset was compiled for this thesis and will be considered in the Discussion.

Table 1: Comparison of NORDIC and BsM gears and protocols.

		Gear (gill net gang*)		
	Component	**NRD**	**ON2**	**NA1**
Structural Comparison of Gill nets	Length (m)	30	12.5	24.8
	Height (m)	1.5	1.8	1.8
	Mesh Area (m^2)	45	22.5	44.6
	Gangs per Strap*	1	2	2
	Number of Panels	12	5	8
	Range of Mesh Sizes (mm, stretched)	10 - 110	13 - 38	38 - 127
	Range of Twine Diameters (mm)	0.10 - 0.23	0.10 - 0.15	0.28 - 0.40
	Float Line	6 g/m	10 mm	13 mm
	Lead Line	9.9 g/m	74.7 g/m	135.2 g/m
Deployment Comparisons of Gill nets	Maximum Depth Deployed (m)	>75	20	>75
	Orientation of Nets to Shoreline	Random	Perpendicular	Perpendicular
	Recommended Set Duration (hr)	12	18	18
	Anchors Used	No	Yes	Yes

* Gang is defined as one contiguous gill net comprised of multiple panels of varying mesh size. In the NORDIC protocol, one effort = deployment of one gang; in the BsM Protocol, one effort = deployment of two gangs linked together as a strap.

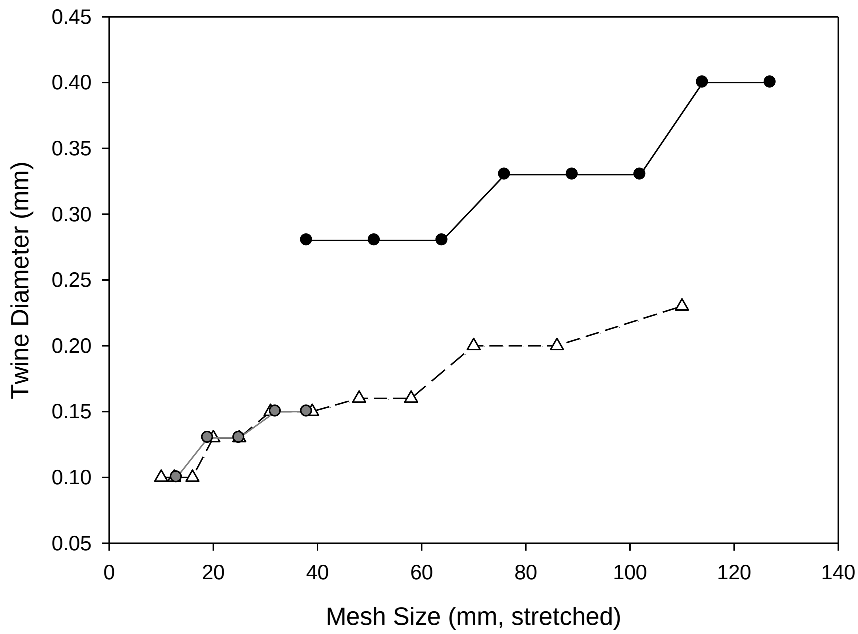


Figure 1: Comparison of twine diameter at various stretched mesh sizes among NA1 (black circles), ON2 (grey circles) and NRD (white triangles) gill net gears.

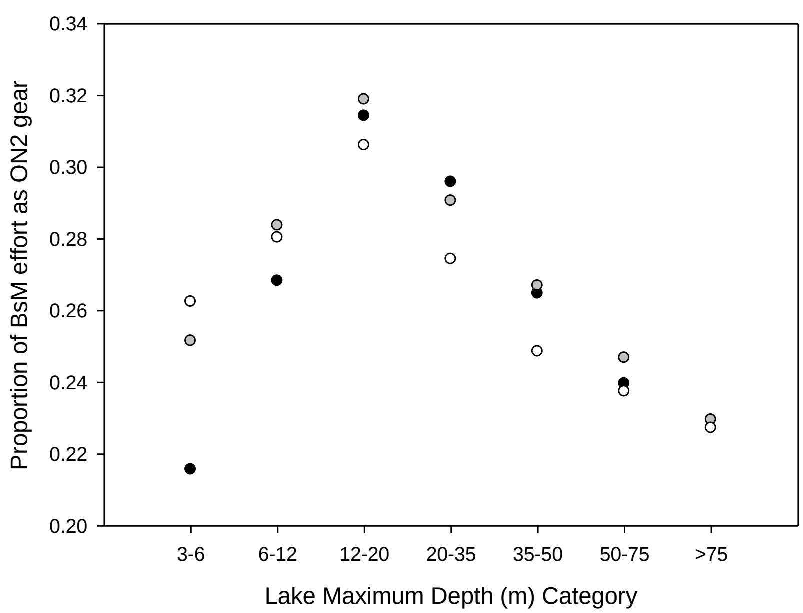


Figure 2: Proportion of total metres of gill net gear deployed that is composed of ON2 gear for BsM surveys of lakes of varying maximum depth. Data obtained from Tables 4 and 5 in Sandstrom *et al.* (2011). Symbols represent lakes with surface areas of 100 ha (black circles), 500 ha (grey circles) and 5000 ha (white circles).

In spite of these differences there are several similarities in deployment requirements between the protocols. Both protocols require overnight net sets that include the two crepuscular periods and recommend sampling during the summer stratified period, when epilimnetic temperatures are warm (> 15 ˚C for NORDIC, > 18 ˚C for BsM) (Morgan & Snucins 2005; Sandstrom *et al.* 2011). Each protocol samples the entire lake using a depth-stratified approach with total sampling effort determined by lake area and maximum depth, and use similar depth strata (Morgan & Snucins 2005; Sandstrom *et al.* 2011). The NORDIC protocol divides lakes into seven depth strata: 0-6 m, 6-12 m, 12-20 m, 20-35 m, 35-50 m, 50-75 m and > 75 m (Morgan & Snucins 2005). The BsM protocol use these same depth strata, with the exception that the 0-6 m stratum is divided into two strata (0-3 m and 3-6 m) (Sandstrom *et al.* 2011).

Understanding and quantifying how fish sampling protocols may affect our interpretations of fish community structure is very important to fisheries science and management especially when making comparisons across sampling programs. It is likely that differences in the NORDIC and BsM protocols as outlined above will lead to differences in the data they generate, and there is a need for comparative studies to quantify these differences. This will facilitate development of defensible approaches to combining and using data from both types of surveys in future. Because the BsM protocol uses two distinct gear types, NA1 and ON2 nets, comparisons can and should be made at two levels – between the two protocols (NORDIC vs BsM), and among the three gears (NRD vs NA1 vs ON2). This is the approach I have taken in the current study.

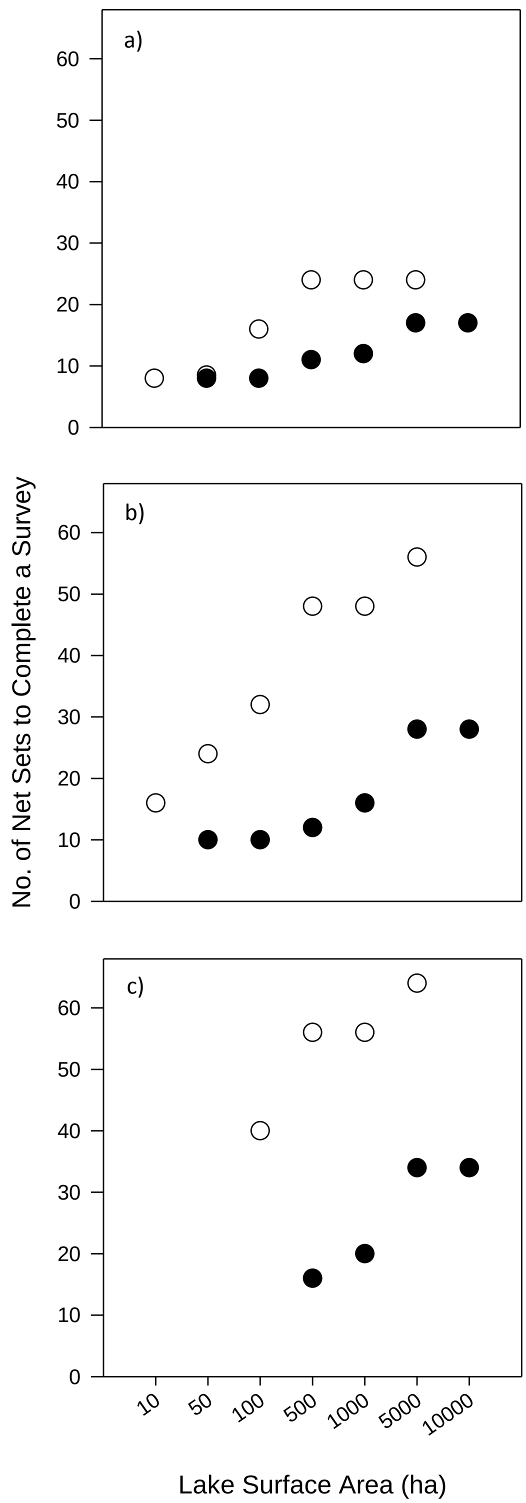


Figure 3: Total number of nets deployed by NORDIC (white circles) and BsM (black circles) surveys in relation to lake surface area, for lakes with maximum depths of a) 0-6 m, b) 20-35 m, and c) 50-75 m.

Objectives, Hypotheses and Predictions

The objective of this study was to compare and contrast interpretations of fish abundance and community structure in boreal lakes from two widely-used, standardized gill net survey protocols. I hypothesized that fish community surveys using the NORDIC and Broad-scale Fish Community Monitoring (BsM) protocols would yield different interpretations of fish community structure and abundance in boreal lakes because of various differences in sampling gear structure and deployment methods. I also hypothesized that these differences would be independent of the physical characteristics of the lakes.

My study used data obtained by applying both protocols to the same lakes in a paired-comparisons design. Comparisons were made between the two protocols, as well as among the three gear types (NRD, NA1, and ON2 gill nets). Gear comparisons were also conducted in separate depth strata, above and below 20 m depth, to account for spatial variation in NA1 and ON2 deployment. Though the NORDIC and BsM protocols differ in various ways, outlined above, I worked from the assumption that differences in mesh sizes would be the primary factor leading to differences in the data generated. My primary research predictions corresponded to differences in three particular fish community attributes:

Prediction 1 - species richness and diversity: As NORDIC surveys utilize a higher proportion of small mesh sizes, and because much of the biodiversity in aquatic communities is found in small-bodied fishes, I predicted that NORDIC surveys would yield higher estimates of both species richness and diversity than BsM surveys. Similarly, because NRD gear contains a higher diversity of mesh sizes than either NA1 or ON2 gears, I predicted that species richness estimates from the three gears would be NRD > ON2 > NA1 at standardized levels of effort.

Prediction 2 - relative abundance: As NORDIC surveys have a higher proportion of effort dedicated to small mesh sizes, and because small-bodied fishes tend to be more numerically abundant but lower in biomass, I predicted that NORDIC surveys would yield higher estimates of numerical relative abundance, but lower estimates of biomass relative abundance than BsM surveys at the community level (all species combined) at standardized levels of effort. Similarly, following the same abundance versus mesh size argument, I predicted that numeric relative abundances at the community level determined by the three gears would be NRD>ON2>NA1 and biomass relative abundances at the community level determined by the three gears would be NA1 > NRD > ON2, at standardized levels of effort. Finally, I predicted that these results would vary at the individual species level according to the species' relative susceptibilities to the different gears.

Prediction 3 - size composition: As NORDIC and BsM surveys differ in the proportions of effort dedicated to various mesh sizes, I predicted they would also yield different size distributions of captured fish with similar variance but different shapes; the mode will be skewed left (smaller modal size) for NORDIC relative to BsM surveys. And because of differences in the diversity of mesh sizes among gears, modal sizes will be NA1 > NRD > ON2, and variance in body size will be NRD > NA1 > ON2.

Methods

Study lakes and data collection

Data were acquired for 21 Boreal Shield lakes that had been surveyed by both the NORDIC and BsM protocols. Survey data for all lakes were obtained from the Ontario Ministry of Natural Resources and Forestry, and the Cooperative Freshwater Ecology

Unit of Laurentian University (Sudbury, ON)(Appendix VIII). Seventeen of these lakes were in northeastern Ontario, within approximately 275 km of Sudbury, and four lakes were in the Northwest Territories, approximately 30 km northeast of Yellowknife (Figure 4). Study lakes ranged from 140 to 2050 ha in area, 19.8 to 91.5 m in maximum depth, and 2 to 14 m in Secchi depth (Table 2). NORDIC surveys were completed between 2000 and 2012, with the majority conducted from 2002 to 2008, whereas the BsM surveys were completed between 2008 and 2012 (Figure 5). A single survey was conducted for each protocol on each lake with one exception. NORDIC surveys were carried out in both 2003 and 2004 on McFarlane Lake and data from the two surveys were pooled for subsequent analyses. A brief summary of the species richness, fork length and round weight attributes found in these two McFarlane Lake surveys is provided in Appendix II. The temporal span between NORDIC and BsM surveys ranged from one to 10 years, with a mean temporal span of 4.7 years.

NORDIC and BsM survey data had been generated following procedures outlined in Morgan and Snucins (2005) and Sandstrom *et al.* (2011), respectively. An individual overnight net set within a survey was treated as one sampling effort. For each effort, all captured fish were identified to species and counted. Collection of attribute data (fork length and/or total length, round weight, sex and maturity) was completed for a random subsample of each species. As a result, there were two data sets. The first was a summation of each species captured in each effort (the catch count data set), and the second was the attribute data from the subsamples of fish measured from each effort (the attribute data set).

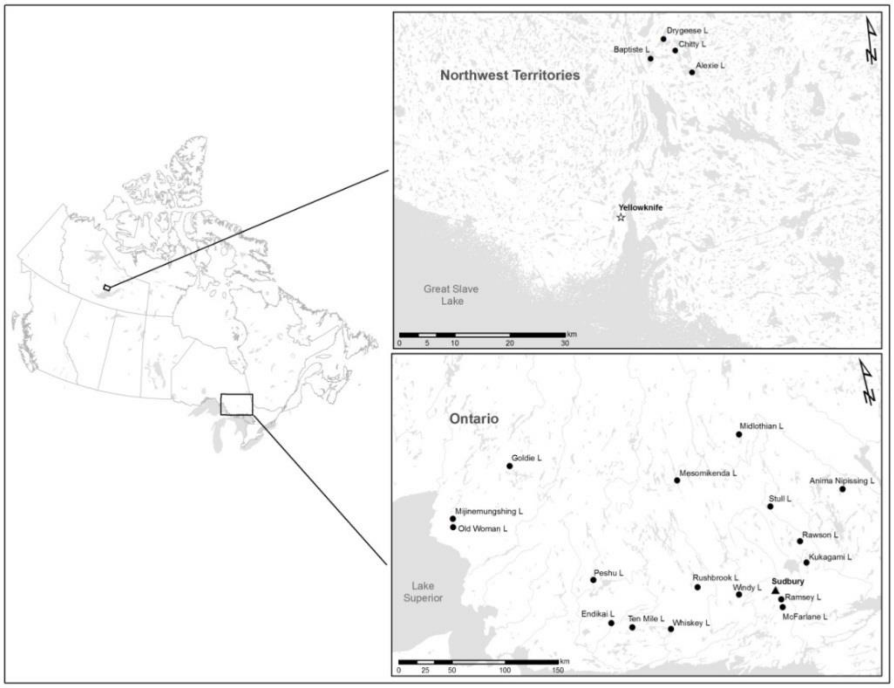


Figure 4: Location of study lakes used for the comparison of the NORDIC and BsM surveys (n=21 lakes, 17 in Ontario and four in Northwest Territories).

Several data scrubbing and culling steps were performed on the two data sets prior to conducting statistical analyses. Data for any species that was considered transient (i.e., not native or naturalized) in the study lakes were deleted. This included rainbow trout (*Oncorhynchus mykiss*) and splake (*Salvelinus namaycush* x *S. fontinalis* hybrid) which are commonly stocked for recreational fisheries. These species were found in few lakes, and were reported in low abundances. To detect possible discrepancies in species identification between surveys, scatter plots of the total number of individuals of each species caught by the two surveys (number caught by NORDIC versus number caught by BsM) for each lake were produced.

Table 2: Geographical and limnological features of study lakes that were surveyed by both the NORDIC and BsM protocols. Survey dates are provided in Appendix III.

Lake	Latitude	Longitude	Area (ha)	Z_{mean} (m)	Z_{max} (m)	Secchi (m)	Year Surveyed BsM	Year Surveyed NORDIC
Alexie*	62°40'34 N	114°09'38 W	420	11.7	32	6	2011	2008
Anima Nipissing	47°15'34 N	79°54'23 W	2050	13.7	66	2	2009	2012
Baptiste*	62°42'13 N	114°13'14 W	365	11.7	32	6	2011	2008
Chitty*	62°42'48 N	114°07'54 W	305	6.9	20	6	2011	2008
Drygeese*	62°44'10 N	114°10'11 W	547	14.5	35	6	2011	2008
Endikai	46°35'21 N	83°01'48 W	592	29.0	48	6	2009	2008
Goldie	48°02'40 N	83°53'43 W	1227	3.2	22	5	2012	2011
Kukagami	46°43'59 N	80°32'59 W	1700	13.2	55	8	2010	2003
McFarlane	46°25'00 N	80°57'23 W	141	7.3	20	2	2010	2003/2004
Mesomikenda	47°38'53 N	81°52'44 W	1706	13.6	71	5	2010	2012
Midlothian	47°54'35 N	80°59'54 W	367	8.2	32	5	2011	2008
Mijinemungshing	47°41'35 N	84°42'38 W	589	7.5	34	4	2010	2003
Old Woman	47°37'21 N	84°43'27 W	261	15.9	46	6	2008	2004
Peshu	46°58'18 N	83°08'27 W	389	18.0	51	6	2011	2008
Ramsey	46°28'57 N	80°57'01W	874	9.3	21	4	2011	2005
Rawson	46°55'12 N	80°34'01 W	159	5.6	26	5	2010	2003
Rushbrook	46°44'04 N	81°54'47 W	174	7.3	20	5	2010	2002
Stull	47°15'42 N	80°49'22 W	257	7.5	34	5	2012	2009
Ten Mile	46°31'10 N	82°47'16 W	960	31.2	117	11	2011	2003
Whiskey	46°26'22 N	82°20'08 W	917	22.5	55	14	2009	2002
Windy	46°35'57 N	81°26'20 W	1111	10.7	66	5	2009	2006

* located in Northwest Territories, Canada. Otherwise, lakes are located in Ontario, Canada.

Species with high abundance in one survey but zero abundance in the other were identified. For these cases, if the particular species' presence could not be confirmed from earlier lake surveys (from the Aquatic Habitat Inventory Program database, OMNRF) it was assumed to be a misidentification, and the species' data were re-assigned to the most physically similar species that had been identified in both the NORDIC and BsM surveys and in the historic survey.

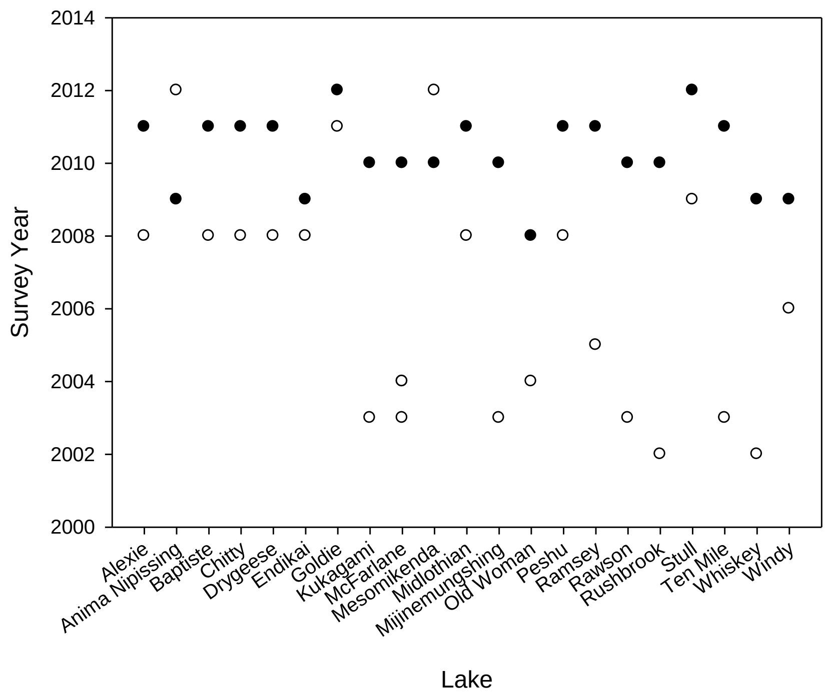


Figure 5: Years that study lakes were surveyed using the NORDIC (white) and BsM (black) protocols.

This happened in only two instances: River Chub (*Nocomis micropogon*) was re-assigned to Creek Chub (*Semotilus atramaculatus*) in Old Woman Lake, and Eastern Silvery Minnow (*Hybognathus regius*) was re-assigned to Common Shiner (*Luxilus cornutus*) in Mijminemungshing Lake.

Discrepancies between catch count and attribute data sets were detected and treated as follows. In cases where the number of fish with attribute data exceeded the catch count for a specific species in a given effort, the catch count was adjusted upwards to match; in cases where the catch count datum was greater than zero but attribute data were lacking for a particular species in a particular effort, species-specific mean attribute values (total length, round weight) were assigned, as calculated across all efforts using the same gear within the same lake. For analyses of size composition of catches, round weight was used because it was considered more representative of ecological function than length when making interspecific or community-level comparisons (see below). However, round weight was recorded less consistently than length for both surveys. Where round weight was not recorded it was estimated from length using fitted lake- and species-specific round weight versus length power functions, generated from attribute data of the current study.

Lake physical data were required both for area-weighted calculations, and for analyzing relationships between protocol differences and lake characteristics. These data were obtained from the Ontario Ministry of Natural Resources and Forestry, the Department of Fisheries and Oceans Canada, and the Cooperative Freshwater Ecology Unit. Lake bathymetric (depth contour) maps were digitized to generate hypsographic curves, and from these the proportion of lake area contained within each sampled depth stratum was calculated. Additional lake physical data acquired included surface area, mean depth, and maximum depth, to represent ecosystem size, and Secchi depth to represent water clarity and system productivity.

Statistical analysis approach

Standardization of effort, where required, was carried out with respect to gill net length. Though the gill net gears differed in both length and height (Table 1), it was assumed that the effects of height differences on catch were negligible as a high proportion of fish captured in benthic gill nets tend to be caught closer to the lead line than the float line. Therefore, data were standardized to 100 m of gill net deployed by multiplying catches in each effort by 100 / 30 for NRD gear, by 100 / 49.6 for NA1 gear, and by 100 / 25 for ON2 gear. Corrections were not applied for net selectivity.

Effect sizes were calculated for all comparisons, and expressed as percentages from the perspective of the BsM protocol or gear (mean difference between protocols or gears divided by the BsM (or NA1 or ON2) mean and multiplied by 100). In comparisons between NA1 and ON2 gears, the mean difference was divided by the ON2 mean. All effect sizes were calculated and expressed as untransformed values. Where a percentage could not be calculated (e.g., value of 0 for denominator), only the mean difference was reported.

All statistical analyses were performed using SAS/STAT® software procedures (SAS Institute Inc 2013). Analyses were divided into three sections, corresponding to the three primary predictions of the study, and dependent variables were calculated to represent the fish community as a whole (all species combined), as well as selected individual species. Within each section, analyses generally followed a tiered structure. For each dependent variable comparisons were made between the entire NORDIC and BsM surveys, and then among the NRD, NA1 and ON2 sampling gears at various spatial scales, according to where they were deployed (Table 3). However, not all contrasts were explored for every dependent variable. The primary statistical approach was a paired-comparisons design, using either paired-comparison's *t* test for normal data or Wilcoxon's Signed Rank test for non-normal data (UNIVARIATE procedure). For some of these comparisons, the difference variable was regressed against combinations of lake physical characteristics (GLMSELECT procedure). The regression models were ranked by Akaike's Information Criterion adjusted for small sample size (AICc) (Anderson 2008) in order to test the assumption that observed differences between methods were independent of environmental conditions.

Table 3: Primary statistical analyses conducted for each dependent variable.

Contrast	Spatial Scale	Analysis
NORDIC vs BsM surveys	Whole Lake	Differences between surveys tested by paired-comparisons or Signed Rank tests
NORDIC vs BsM surveys	Whole Lake	Differences between surveys regressed against combinations of lake physical characteristics, and models ranked by AICc
NRD vs NA1 gears	Strata > 20 m deep	Differences between gears tested by paired-comparisons or Signed Rank tests
NRD vs NA1 gears	Strata < 20 m deep	Differences between gears tested by paired-comparisons or Signed Rank tests
NRD vs ON2 gears	Strata < 20 m deep	Differences between gears tested by paired-comparisons or Signed Rank tests
NA1 vs ON2 gears	Strata < 20 m deep	Differences between gears tested by paired-comparisons or Signed Rank tests

Species richness and diversity

Community structure was first compared through principal components analysis (PCA) (PRINCOMP procedure), using data pooled across all lakes and efforts; numeric catches per 100 m net per night (see *Relative Abundance*, below) for each species, transformed as log (x + 1) were used as the input variables. Principal components that accounted for a high proportion of the observed variation were used as dependent variables in subsequent paired-comparison analyses between NORDIC and BsM surveys.

Community structure was also compared between complete NORDIC and BsM surveys, without standardization for effort, to assess the differences in reported species richness (total number of species detected), Shannon's diversity (combines species richness with species abundance) and evenness (equality of relative abundances of each species captured). Shannon's diversity and evenness were calculated as outlined below. All subsequent analyses were standardized for sampling effort.

Species richness is a unique variable in my analysis because its value increases asymptotically with sampling effort. I modelled the species richness versus sample size relationship (rarefaction curve) and estimated species richness from the fitted relationship at specified levels of effort (Colwell *et al.* 2004). *EstimateS*, a freeware program designed for this purpose (Colwell 2011), was used to estimate species richness, and Shannon mean Diversity. Species richness was estimated as:

$$\tilde{S}_{\text{sample}}(T+t^{*}) = S_{obs} + \hat{Q}_0\left[1-\left(1-\frac{Q_1}{Q_1+T\hat{Q}_0}\right)^{t^{*}}\right]$$

$$\approx\; S_{obs} + \hat{Q}_0\left[1-exp\left(\frac{-t^{*}Q_1}{Q_1+T\hat{Q}_0}\right)\right]$$

where $S_{sample}(T+t^{*})$ is the estimated number of species expected, from an enlarged set of $T+t^{*}$ sampling units, where $t^{*}>0$ from the sampled community, T is an independent sampling unit (e.g., gill net gang or strap), t is a random set of sampling units from T, S_{obs} is the number of species observed in the reference sample (e.g., survey), Q_1 is the number of species that are detected in the survey once (i.e., unique species), and Q_0 is the number of species within the community that are not identified within any T sampling unit (Colwell *et al.* 2012).

Shannon mean diversity was also calculated in *EstimateS* using the Magurran (2013) equation

$$H' = -\sum_{i=1}^{n} p_i ln p_i$$

where p_i is the proportion of individuals represented by species *i*, and *n* is the number of species. The mean among runs is provided in the *EstimateS* output. In addition to the species richness and Shannon mean diversity index generated by *EstimateS*, evenness values associated with Shannon mean diversity were calculated and compared. Evenness was calculated using the equation found in Kwak and Peterson (2007)

$$J' = \frac{H'}{H'_{max}} = \frac{H'}{\log_e s}$$

where J' is evenness, H'_{max} is the maximum possible Shannon's index value, and *s* is the number of species.

For the subset of catch count data used in a particular comparison (Table 3), *EstimateS* resampled the gill net efforts 10 000 times without replacement at each level of effort. The effort axes for the rarefaction curves generated were converted from number of net sets for each gear type to length of net set, to enable comparisons at standardized length of net deployed. A standard effort of 250 m of net was used to provide a species richness estimate as close as possible to the asymptote without extrapolating beyond the total effort used by any particular survey in the comparison. Generally, sampling effort was much lower in the > 20 m depth stratum. In comparisons involving this stratum, the number of lakes used as replicates was reduced to those lakes that deployed nine or more net sets below 20 m; this reduced the sample size from 16 lakes to six lakes.

Relative abundance

Relative abundance was estimated as catch-per-unit-effort (CPUE) in two ways; as numerical CPUE (NPUE, number of fish captured per 100 m of mesh), and as biomass CPUE (BPUE, kg of fish captured per 100 m of mesh). NPUE was calculated as the sum of the number of individuals captured (from the catch count data set) for each species in the effort. BPUE was calculated as the summed products of number of individuals captured (from the catch count data set) and their mean round weight (from the attribute data set) for each species in the effort. As fish in the attribute data set represented a subsample of the total fish captured in the catch count data set, this calculation required the assumption that the fish measured for attribute data were a random subsample for each species in each effort. After standardizing to 100 m of mesh effort, area-weighted means of NPUE and BPUE were calculated at the desired spatial scale as:

$$Area - weighted\ CPUE\ =\ \sum_{i=1}^{n} CPUE_i\ PA_i$$

where $CPUE_i$ is the mean NPUE or BPUE of all efforts in the ith depth stratum, and PA_i is the proportional surface area represented by the ith depth stratum, for a lake or portion of a lake composed of n depth strata. Data were transformed as log (x + 1) prior to statistical analyses.

Size distributions

Body size distributions of the captured fish were assessed with respect to biomass. As with BPUE estimation (above), this analysis required the assumption that the fish measured for attribute data were a random subsample of the total fish captured for each species in each effort. Each fish from the attribute data set was categorized based on its round weight into one of 40 arithmetic size bins spanning 100 g each (0-100 g, 100-200 g,

…, 3900-4000 g), or the largest size bin (> 4000 g). Once a fish was categorized, its round weight was multiplied by the species-specific processing ratio (total catch / number processed for attribute data) for its effort, and converted to a BPUE value (per 100 m of mesh, described above). These individual BPUEs were then summed across all fish belonging to a given size bin for a given effort. The resultant BPUE sums contained in each of the 41 size bins represented the size frequency distribution for each effort. Means of these frequency distributions (i.e., mean BPUEs for each size bin across efforts) were determined across all efforts within each stratum. These stratum mean distributions were then used to calculate area-weighted mean distributions as the summed products of stratum means and stratum proportional areas for each size bin (as described for relative abundance indices, above). Finally, area-weighted mean distributions were normalized to percentages (i.e., sum of all bins = 100) prior to making contrasts between methods or gears.

Comparisons of distributions between methods or gears were carried out in two steps. First, differences in the overall shape and position of size distributions were made on a lake by lake basis using the Kolmogorov-Smirnov two-sample test (NPAR1WAY procedure). Secondly, medians and coefficients of variation (CVs) of the size distributions were compared using the standard approach summarized in Table 3. The arithmetic size bin structure was effective for analyses of the fish community as a whole and large-bodied species but was too coarse for small-bodied species (most fell into the smallest size bin). Accordingly, analyses at the individual species level were carried out primarily on large-bodied species.

Results

Survey summary

The total length of gill net deployed per survey was consistently higher for NORDIC surveys in the 21 study lakes, with the exception of Anima Nipissing Lake (Figure 6a). The mean ratio of total effort (metres of net) to lake area (ha) was 3.25 (range 0.8 - 7.5) for NORDIC surveys, and 2.36 (range 0.8 - 6.0) for BsM surveys. For both surveys, the effort to lake area ratio was highest in the smallest lake and declined with increasing lake area. The distribution of effort among mesh sizes was also quite distinct between surveys (Figure 6b). Mesh sizes in the 10-30 mm (stretched mesh) categories made up 50% of the NORDIC survey effort, but only 23% of BsM survey effort (Figure 6b).

A total of 43 native and naturalized species were reported from the surveys of the 21 lakes (Table 4; Appendix IV). Eleven of these species were detected by one or both of the surveys in 10 or more lakes (Table 4); subsequent tests on individual species focused on these common species. The number of lakes where each species was detected was similar between surveys (usually ± 1 lake), with the exception of species from smaller-bodied families such as minnows (Cyprinidae), sticklebacks (Gasterosteidae), and sculpins (Cottidae). Northern Redbelly Dace (*Chrosomus eos*), Sand Shiner (*Notropis stramineus*), Blacknose Dace (*Rhinichthys atratulus*), Longnose Dace (*Rhinichthys cataractae*), Brook Stickleback (*Culaea inconstans*), Iowa Darter (*Etheostoma exile*) and Spoonhead Sculpin (*Cottus ricei*) were caught only in NORDIC surveys, whereas Round Whitefish (*Prosopium cylindraceum*) and Mimic Shiner (*Notropis volucellus*) were caught only in BsM surveys (Table 4).

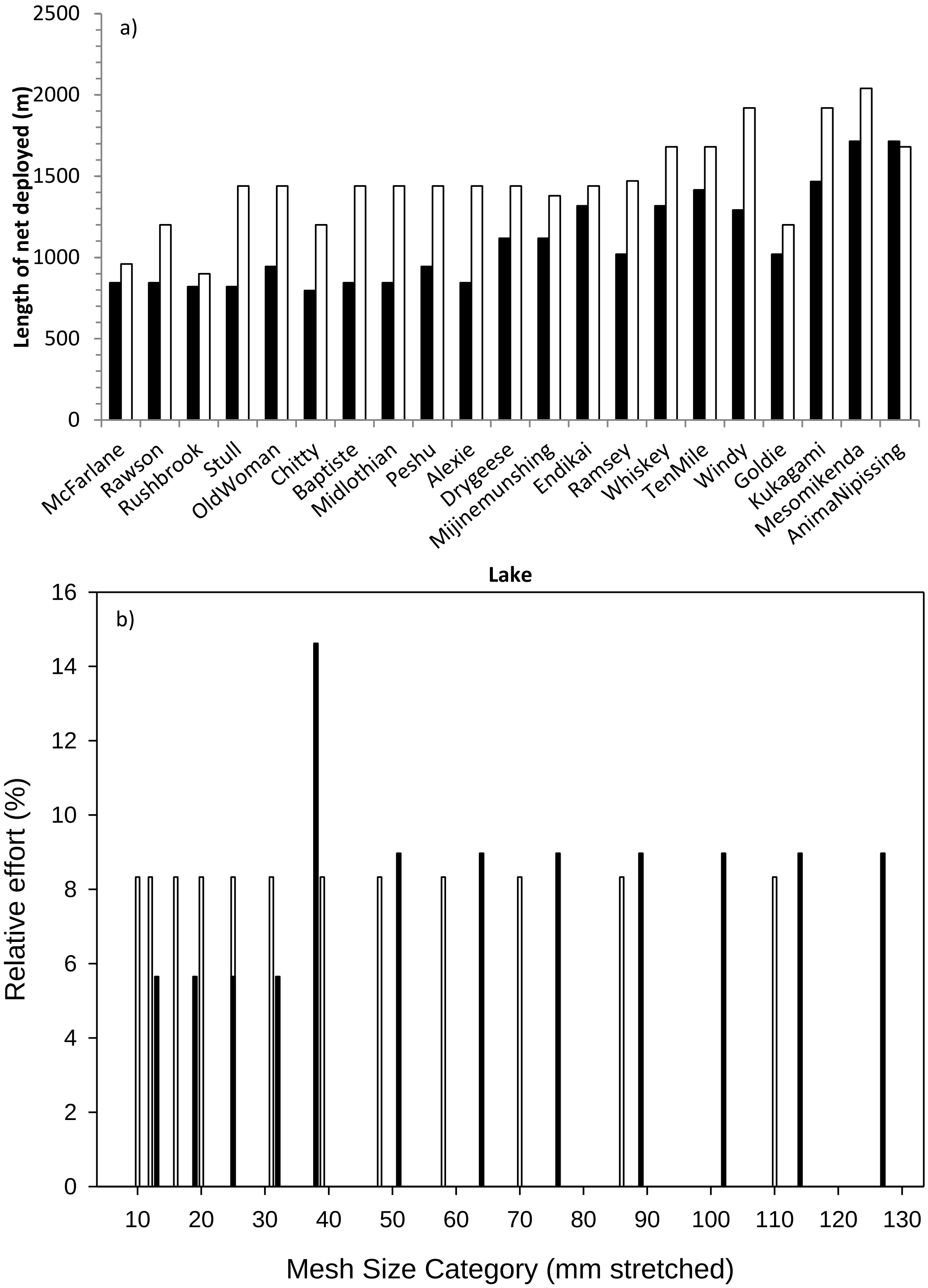


Figure 6: Comparison of NORDIC (white bars) and BsM (black bars) surveys for the 21 study lakes in terms of a) total metres of net deployed per survey in each lake, and b) mean percentages of total length of net deployed in 10-mm mesh size categories. Lakes in Figure 6a are ordered by surface area (ha) from smallest to largest.

Table 4: Common and scientific names and codes of the 42 fish species sampled in this study, and the number of lakes (out of 21 in total) where they were detected by each survey.

		Number of lakes where detected by survey	
Species	**Code**	**NORDIC**	**BsM**
Family Salmonidae			
Cisco (*Coregonus artedi*)	CISC	11	10
Lake Whitefish (*Coregonus clupeaformis*)	LKWH	13	12
Round Whitefish (*Prosopium cylindraceum*)	RNWH	0	1
Brook Trout (*Salvelinus fontinalis*)	BKTR	3	2
Lake Trout (*Salvelinus namaycush*)	LKTR	18	19
Family Osmeridae			
Rainbow Smelt (*Osmerus mordax*)	RNSM	5	3
Family Esocidae			
Northern Pike (*Esox lucius*)	NRPK	13	13
Family Catostomidae			
Longnose Sucker (*Catostomus catostomus*)	LNSC	3	2
White Sucker (*Catostomus commersoni*)	WHSC	17	17
Shorthead Redhorse (*Moxostoma macrolepidotum*)	SHRH	1	1
Family Cyprinidae			
Northern Redbelly Dace (*Chrosomus eos*)	NRBD	1	0
Lake Chub (*Couesius plumbeus*)	LKCH	10	10
Common Shiner (*Luxilus cornutus*)	CMSH	11	9
Northern Pearl Dace (*Margariscus nachtriebi*)	PRDC	1	2
Golden Shiner (*Notemigonus crysoleucas*)	GLSH	4	4
Emerald Shiner (*Notropis atherinoides*)	EMSH	2	1
Blackchin Shiner (*Notropis heterodon*)	BCSH	1	1
Blacknose Shiner (*Notropis heterolepis*)	BNSH	5	2
Spotttail Shiner (*Notropis hudsonius*)	SPSH	3	3
Sand Shiner (*Notropis stramineus*)	SNSH	1	0
Mimic Shiner (*Notropis volucellus*)	MMSH	0	1
Bluntnose Minnow (*Pimephales notatus*)	BNMN	5	3
Fathead Minnow (*Pimephales promelas*)	FHMN	1	1

		Number of lakes where detected by survey	
Species	**Code**	**NORDIC**	**BsM**
Blacknose Dace (*Rhinichthys atratulus*)	BNDC	1	0
Longnose Dace (*Rhinichthys cataractae*)	LNDC	1	0
Creek Chub (*Semotilus atromaculatus*)	CRCH	3	2
Family Ictaluridae			
Brown Bullhead (*Ameiurus nebulosus*)	BRBH	4	4
Family Gadidae			
Burbot (*Lota lota*)	BURB	15	13
Family Gasterosteidae			
Brook Stickleback (*Culaea inconstans*)	BRST	3	0
Ninespine Stickleback (*Pungitius pungitius*)	NSST	5	3
Family Percopsidae			
Trout Perch (*Percopsis omiscomaycus*)	TRPR	8	9
Family Centrarchidae			
Rock Bass (*Ambloplites rupestris*)	RCBS	6	5
Pumpkinseed (*Lepomis gibbosus*)	PMSD	4	3
Smallmouth Bass (*Micropterus dolomieu*)	SMBS	10	10
Largemouth Bass (*Micropterus salmoides*)	LMBS	1	1
Family Percidae			
Iowa Darter (*Etheostoma exile*)	IWDR	2	0
Yellow Perch (*Perca flavescens*)	YLPR	14	14
Logperch (*Percina caprodes*)	LGPR	4	4
Walleye (*Sander vitreus*)	WALL	10	10
Family Cottidae			
Slimy Sculpin (*Cottus cognatus*)	SLSC	13	3
Spoonhead Sculpin (*Cottus ricei*)	SHSC	4	0
Deepwater Sculpin (*Myoxocephalus thompsonii*)	DWSC	4	4

Species richness – survey comparison

For the PCA of individual species CPUE, the first four principal components accounted for 53.7% of the observed variation. The first component (23.7%) was positively weighted towards coolwater fish species and negatively weighted towards coldwater fish species. The second component (13.1%) was positively weighted towards minnows, and negatively weighted towards predatory fish, and the third component (10.4%) was positively weighted towards coldwater species and negatively weighted towards coolwater species (Table 5). Forage fishes and benthivores tended to contribute strongly to the first component while predatory fish did not. Among the predatory fish, centrarchids (Smallmouth Bass and Rock Bass) contributed the most strongly. Yellow Perch contributed strongly to the first three components and Common Shiner contributed strongly to the first two (Table 5). The three principal components differed between the NORDIC and BsM surveys, but only the difference in the first principal component was found to be statistically significant (paired-comparison $t = 2.42$, $n = 21$, $p = 0.03$). When the mean first and second principal components for each lake were plotted for both surveys, the NWT lakes (Alexie, Baptiste, Chitty and Drygeese) tended to group separately from Ontario lakes, and show greater similarity between surveys than Ontario lakes (Figure 7).

Species richness, diversity and evenness comparisons were first made between full surveys without standardization for effort. Generally, NORDIC surveys detected more species than BsM surveys for most lakes (Figure 8). NORDIC surveys also reported higher diversity and evenness values. However, only the species richness comparison was statistically significant (Table 6). NORDIC surveys reported an average of 1.8 more species (19.3%) than the BsM surveys. Of the species that were reported in the NORDIC surveys but not in the BsM surveys, 75% were small-bodied fish.

Table 5: Selected large absolute eigenvalues in each of the first three principal components for the PCA of individual species CPUE.

PC	Species	Eigenvalues
PC1	Yellow Perch	0.7474
	White Sucker	0.3659
	Common Shiner	0.285
	Lake Whitefish	-0.2459
PC2	Common Shiner	0.5583
	Lake Chub	0.3365
	Walleye	-0.2492
	Smallmouth Bass	-0.2556
	Yellow Perch	-0.3535
PC3	Lake Whitefish	0.3939
	Yellow Perch	-0.2334
	Smallmouth Bass	-0.3319
	Rock Bass	-0.6628

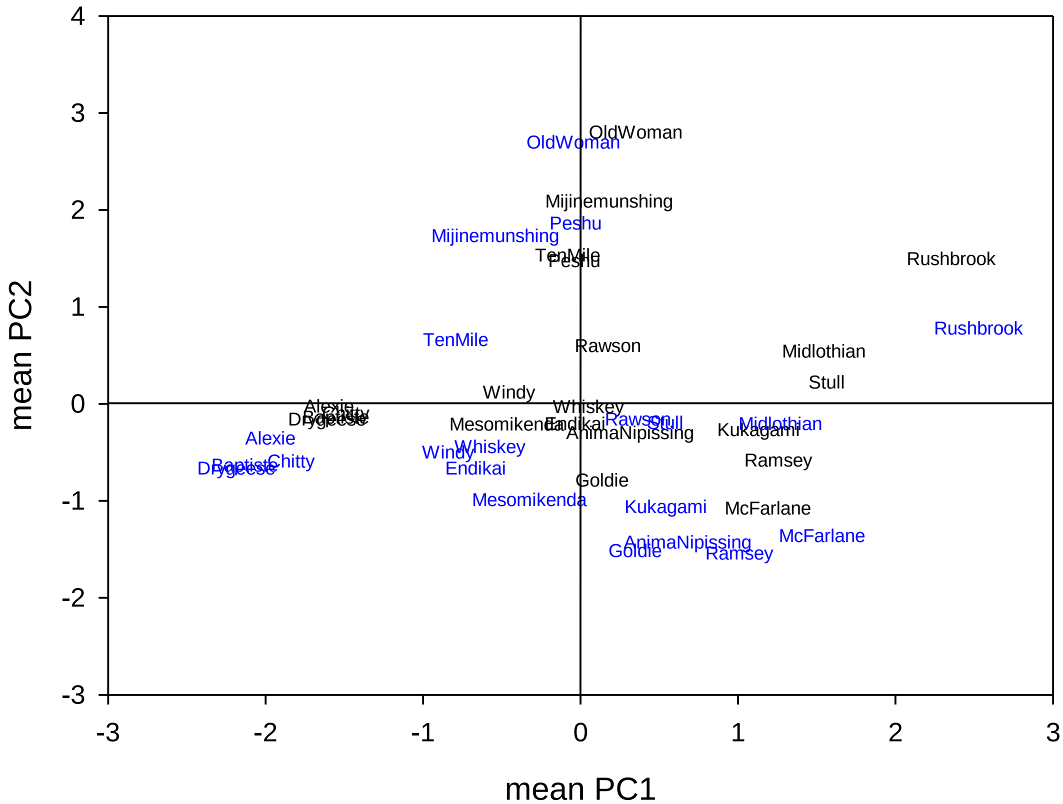


Figure 7: Plot of the first (PC1) and second (PC2) mean principal components of fish species CPUEs reported by BsM (black) and NORDIC (blue) surveys in 21 lakes (lake names plotted). BsM PC1 values were increased by 0.25 and NORDIC PC1 values were decreased by 0.25 to enhance the legibility of the figure.

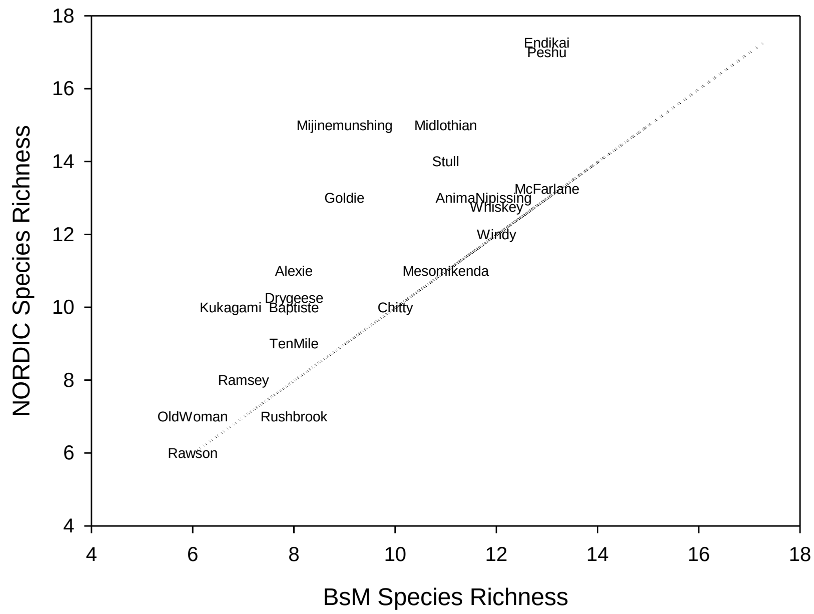


Figure 8: Species richness from BsM vs NORDIC surveys for 21 Boreal Shield lakes (lake names plotted). Line indicates 1:1 agreement between the surveys.

Table 6: Comparison of species richness (N_{spc}), Shannon mean diversity index (H') and evenness (J') between the BsM and NORDIC surveys in their entirety. Test statistics are paired-comparisons t. Significant differences ($p < 0.05$) are indicated *.

Comparison	Variable	n	Trend	Statistic	p-value
NORDIC vs BsM Surveys	N_{spc}	21	NORDIC>BsM	t = 4.60	< 0.001*
	H'	21	NORDIC>BsM	t = 1.50	0.15
	J'	21	NORDIC>BsM	t = 0.032	0.97

Eight linear regression models were tested to determine the influence of lake physical characteristics on the reported differences in species richness between NORDIC and BsM surveys. The highest ranked model was the intercept term, and the next best model accounted for only 0.8% of the variation in the survey differences (Table 7). Akaike weights (w_i) were very low for models other than the intercept model (Table 7) indicating that all combinations of the lake physical characteristics examined were poor predictors of the observed differences in species richness between BsM and NORDIC surveys.

Table 7: AIC_c rankings of linear models relating differences in reported species richness between NORDIC and BsM surveys to maximum depth (maxDepth, m), Secchi depth (Secchi, m), and surface area (SA, ha) of 21 Boreal Shield lakes.

Rank	Model Structure (Effects)	n	AIC_c	Δ_i	exp ($-0.5\Delta_i$)	w_i	r^2
1	Intercept	21	50.52	0.00	1.00	0.51	
2	maxDepth (+)	21	53.08	2.56	0.28	0.14	0.0086
3	Secchi (+)	21	53.23	2.71	0.26	0.13	0.0016
4	SA (+)	21	53.25	2.74	0.25	0.13	0.0004
5	SA (-), maxDepth (+)	21	56.14	5.62	0.06	0.03	0.0065
6	maxDepth (+), Secchi (-)	21	56.17	5.65	0.06	0.03	0.0086
7	SA (+), Secchi (+)	21	56.31	5.80	0.06	0.03	0.0018
8	SA(-), maxDepth (+), Secchi (-)	21	59.63	9.12	0.01	0.01	0.0102

Species richness - gear comparisons - > 20 m and < 20 m depths

For gear comparisons, species richness and Shannon mean diversity index values were estimated at a standard level of effort of 250 m of net. Differences were greatest in the NRD vs NA1, and NA1 vs ON2 comparisons. The NRD gear reported 84% higher species richness than the NA1 gear (mean difference of 3.8 species) above 20 m depth, and 80% higher species richness (mean difference of 1.3 species) below 20 m depth

(Table 8). The NRD gear also yielded greater Shannon mean diversity and evenness values both above and below 20m, but these differences were statistically significant only in the above 20 m comparisons (Table 8). In comparisons of NRD and ON2 gears, the former provided greater estimated species richness, Shannon mean diversity and evenness values but, none of these differences were statistically significant (Table 8). Finally, in comparisons between NA1 and ON2 gears, ON2 gear reported significantly greater species richness by 75% (mean difference of 3.9 species), and significantly lower evenness values by 21% (mean difference of 0.18) (Table 8). Species richness and diversity rarefaction curves for each lake are summarized in Appendices V and VI.

Table 8: Comparisons of species richness (N_{spc}), Shannon mean diversity index (H') and evenness (J') among the NA1, ON2 and NRD gears. Test statistics are paired-comparisons t or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

Comparison	Variable	n	Trend	Statistic	p-value
Below 20 m Depth					
	N_{spc}	6	NRD>NA1	t = 2.70	0.043*
NRD vs NA1	H'	6	NRD>NA1	t = 2.54	0.052
	J'	5	NRD<NA1	t = -1.24	0.28
Above 20 m Depth					
	N_{spc}	20	NRD>NA1	S = 95	< 0.001*
NRD vs NA1	H'	20	NRD>NA1	t = 2.28	0.03*
	J'	20	NRD<NA1	t = -2.74	0.01*
	N_{spc}	20	NRD>ON2	t = 1.33	0.20
NRD vs ON2	H'	20	NRD>ON2	t = 2.12	0.05
	J'	20	NRD>ON2	t = 1.98	0.06
	N_{spc}	20	NA1<ON2	t = 7.46	< 0.001*
NA1 vs ON2	H'	20	NA1<ON2	t = 0.92	0.37
	J'	20	NA1>ON2	t = -3.34	0.004*

Relative abundance (NPUE and BPUE) – survey comparison

For whole survey comparisons, NORDIC surveys tended to yield higher numeric relative abundance estimates (NPUE) (24%, mean difference of 17.3 fish / 100 m) but lower biomass relative abundance estimates (BPUE) than BsM surveys (Figure 9). The difference in NPUE was statistically significant whereas the difference in BPUE was not (Table 9). Individual species NPUE estimates ranged from 0.02 to 140 fish/100 m for the BsM survey and 0.01 to 163 fish/100 m for the NORDIC survey. Overall, a higher percentage of mean NPUE was attributed to small-bodied fish species and families in NORDIC surveys than in BsM surveys (Figure 10).

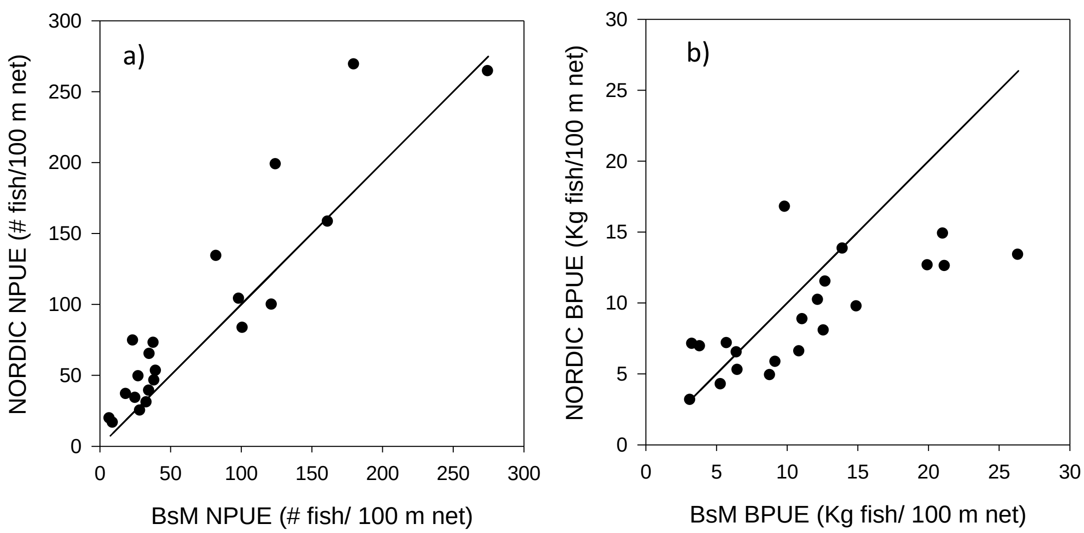


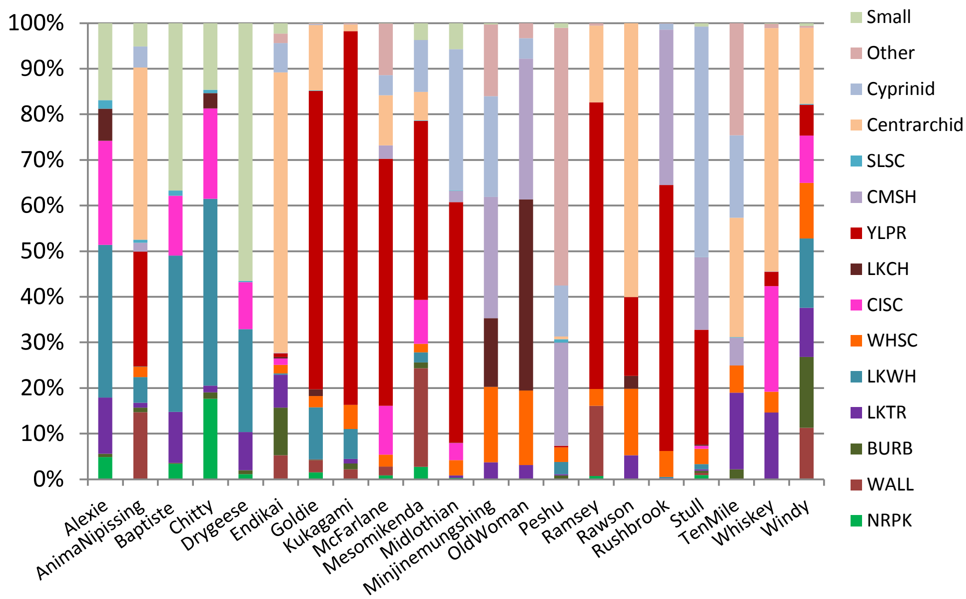
Figure 9: Scatter plots of NORDIC survey vs BsM survey estimates of fish relative abundances expressed as a) numeric catch-per-unit-effort (NPUE), and b) biomass catch-per-unit-effort (BPUE) for fish communities (all species combined) in 21 Boreal Shield lakes. Solid line indicates 1:1 agreement between estimates.

Table 9: Results of tests between NORDIC and BsM survey numeric catch-per-unit-effort (NPUE) and biomass catch-per-unit-effort (BPUE) for fish communities (all species combined) and selected individual species in boreal lakes. Test statistics are paired-comparison *t* or Wilcoxon's signed rank S. Significant differences (p< 0.05) are indicated *.

		NPUE (number per 100 m of net)			BPUE (kg per 100 m of net)		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NRD>BsM	S = 92.5	< 0.001*	NRD<BsM	t = -0.18	0.86
Large-Bodied Fish							
Northern Pike	14	NRD<BsM	S = -26.5	0.10	NRD<BsM	S = -37.5	0.017*
Walleye	10	NRD<BsM	t = -0.40	0.69	NRD<BsM	t = -1.35	0.21
Burbot	15	NRD>BsM	S = 20	0.28	NRD>BsM	t = 0.90	0.38
Lake Trout	19	NRD<BsM	t = -1.47	0.16	NRD<BsM	t = -2.21	0.04*
Lake Whitefish	13	NRD<BsM	t = -1.10	0.29	NRD<BsM	t = -1.76	0.10
White Sucker	17	NRD>BsM	t = 0.12	0.91	NRD>BsM	t = 0.76	0.46
Small-Bodied Fish							
Cisco	11	NRD>BsM	t = 2.45	0.034*	NRD>BsM	t = 1.73	0.11
Yellow Perch	14	NRD>BsM	t = 4.73	< 0.001*	NRD>BsM	t = 5.38	< 0.001*
Lake Chub	13	NRD>BsM	S = 15.5	0.31	NRD>BsM	S = 17.5	0.24
Common Shiner	11	NRD>BsM	t = 2.42	0.036*	NRD>BsM	t = 2.66	0.02*
Slimy Sculpin	13	NRD>BsM	t = 2.92	0.013*	NRD>BsM	S = 42.5	0.001*

When analyses were conducted for individual fish species, results differed between large-bodied and small-bodied species. For large-bodied species, BsM surveys yielded higher NPUE and BPUE estimates than NORDIC surveys for four of the six species examined. However, these trends were only statistically significant in the cases of BPUE comparisons for two species, Northern Pike and Lake Trout (Table 9).

a) NORDIC



b) BsM

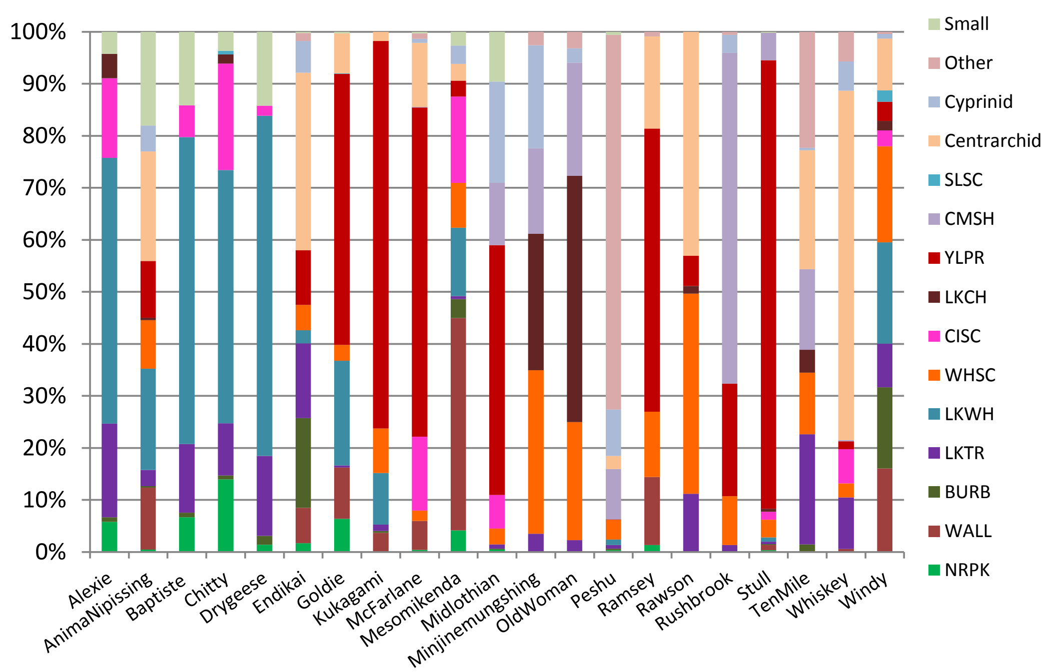


Figure 10: Percent composition of NPUE estimates attributable to individual fish species or groups for a) NORDIC, and b) BsM surveys on 21 Boreal Shield lakes. Group categories (first four) in the legend do not include individual species listed below; Small = Gasterosteidae, Percopsidae, Cottidae and Percidae, Other = Salmonidae, Osmeridae, Catastomidae and Ictaluridae.   Species codes are listed in Table 4.

NORDIC surveys yielded 51% (mean difference 0.77 kg/100 m) and 35.6% (mean difference 0.96 kg/100 m) lower BPUE than BsM surveys for Northern Pike and Lake Trout, respectively. NORDIC surveys yielded consistently higher NPUE and BPUE than BsM surveys for each of the small-bodied fish species, and these trends were statistically significant for four of five species in the NPUE comparisons, and three of five species in the BPUE comparisons (Table 9). In the BPUE comparisons, NORDIC surveys yielded 48.5 % (mean difference 0.16 kg/100 m) more Yellow Perch, 42.1% (mean difference 0.01 kg /100 m) more Common Shiner, and 2500% (mean difference 0.001 kg/ 100 m) more Slimy Sculpin than BsM surveys.

Eight linear regression models were tested to determine the influence of lake physical characteristics on the reported differences in NPUE and BPUE estimates between NORDIC and BsM surveys for all species combined. For NPUE, the highest ranked model had just the intercept term, and the next best model accounted for only 1% of the observed variation in the dependent variable (NORDIC-BsM). Similarly, Akaike weights (w_i) were very low for models other than the intercept, indicating that the physical characteristics of the lakes are highly unlikely to describe the differences observed (Table 10). In contrast, for BPUE, differences between NORDIC and BsM survey estimates were positively related to lake maximum depth, and this model received the strongest support (Table 11). In general, lake physical characteristics accounted for a higher percentage of variance in BPUE differences than NPUE differences (cf. r^2 values, Tables 10 and 11).

Table 10: AIC_c rankings of linear models relating differences in reported numeric-catch-per-unit effort (NPUE) between NORDIC and BsM surveys to maximum depth (maxDepth, m), Secchi depth (Secchi, m), and surface area (SA, ha) of 21 Boreal Shield lakes.

Rank	Model Structure (Effects)	n	AIC_c	Δ_i	exp $(-0.5\Delta_i)$	w_i	r^2
1	Intercept	21	-0.01	0.00	1	0.51	
2	maxDepth (+)	21	2.60	2.62	0.27	0.14	0.01
3	Secchi (-)	21	2.72	2.73	0.26	0.13	0.0007
4	SA (+)	21	2.72	2.73	0.26	0.13	0.0006
5	maxDepth (+), Secchi (-)	21	5.58	5.60	0.06	0.03	0.01
6	SA (-), maxDepth (+)	21	5.68	5.70	0.06	0.03	0.01
7	SA (+), Secchi (-)	21	5.79	5.80	0.05	0.03	0.0014
8	SA (-), maxDepth (+), Secchi (-)	21	9.05	9.06	0.01	0.01	0.01

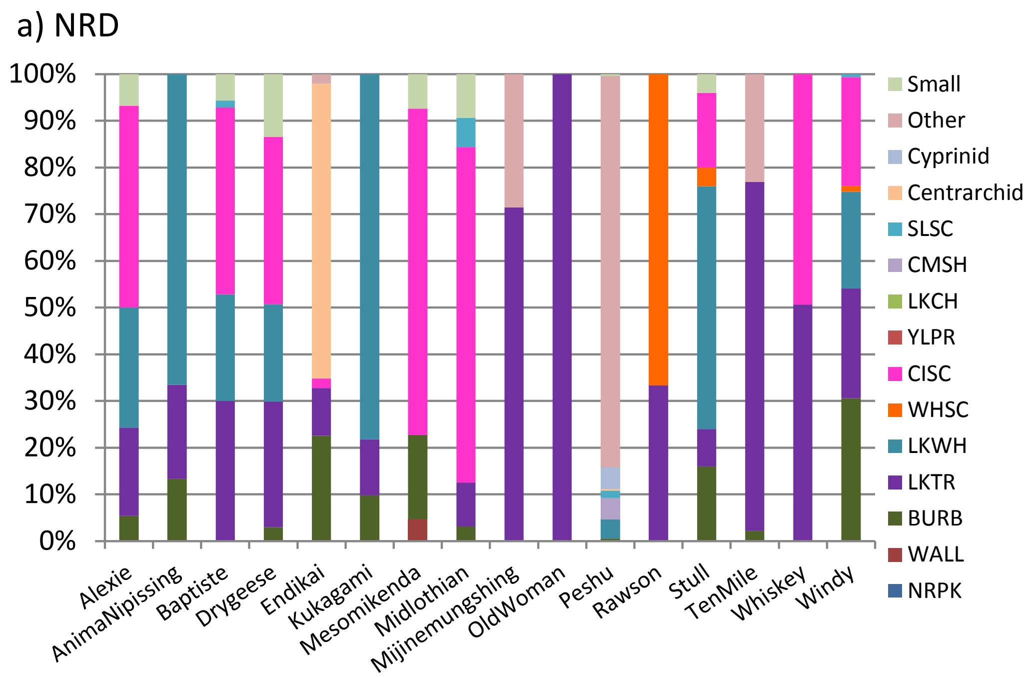
Table 11: AIC_c rankings of linear models relating differences in reported biomass-catch-per-unit effort (BPUE) between NORDIC and BsM surveys to maximum depth (maxDepth, m), Secchi depth (Secchi, m), and surface area (SA, ha) of 21 Boreal Shield lakes.

Rank	Model Structure (Effects)	n	AIC_c	Δ_i	exp $(-0.5\Delta_i)$	w_i	r^2
1	maxDepth (+)	21	19.94	0.00	1	0.31	0.15
2	Intercept	21	20.60	0.67	0.72	0.22	
3	Secchi (+)	21	21.16	1.22	0.54	0.17	0.10
4	SA (-), maxDepth (+)	21	22.33	2.39	0.30	0.09	0.18
5	maxDepth (+), Secchi (+)	21	22.48	2.55	0.28	0.09	0.17
6	SA (+)	21	23.25	3.31	0.19	0.06	0.005
7	SA (+), Secchi (+)	21	24.19	4.25	0.12	0.04	0.10
8	SA (-), maxDepth (+), Secchi (+)	21	25.53	5.59	0.06	0.02	0.19

Relative abundance (NPUE and BPUE) – gear comparisons - > 20 m and < 20 m depths

NRD and NA1 gears were compared both below 20 m and above 20 m depth. Below 20 m depth, mean NPUE estimates ranged from 0.05 to 21.5 fish/100 m for NA1 gear and from 0.13 to 57.3 fish/100 m for NRD gear. Above 20 m depth, mean NPUE estimates ranged from 0.07 to 25.0 fish/100 m for NA1 gear, 0.02 to 205 fish/100 m for NRD gear and 0.13 to 269 fish/100 m for ON2 gear. The taxonomic composition of these estimates differed among gears. Below 20 m depth, NA1 NPUE was dominated primarily by Lake Trout and Lake Whitefish whereas NRD NPUE was more diverse and had higher proportions of Cisco (Figure 11). Above 20 m depth, differences among gears were most pronounced with respect to White Sucker, Yellow Perch, and a variety of small-bodied species (Figure 12).

For comparisons of NPUE between NRD and NA1 gears, NRD tended to yield higher NPUE for all species combined, and this trend was statistically significant above 20 m depth (Figure 13a, b; Table 12). Above 20 m depth, NPUE was 339% (81.8 fish / 100 m) higher for NRD gear than NA1 gear. When analyses were broken down into NPUE for individual species, the results varied with respect to fish body size. For all large-bodied species except Burbot, NRD gear tended to yield lower NPUE than NA1 gear, but this trend was only statistically significant for Northern Pike above 20 m, and Lake Trout below 20 m (Table 12). However, for all small-bodied species, NRD gear tended to yield higher NPUE than NA1 gear, and these trends were statistically significant for all species examined both above and below 20 m (Table 12). The magnitude of these differences were substantial; compared to NA1 gear NRD gear yielded on average 539% (4.3 fish/100 m) more Cisco, 2820% (52.5 fish/ 100 m) more Yellow Perch, and 1936% (22.5 fish/100 m) more Common Shiner above 20 m, and yielded 592% (5.45 fish/100 m) more Cisco below 20 m.



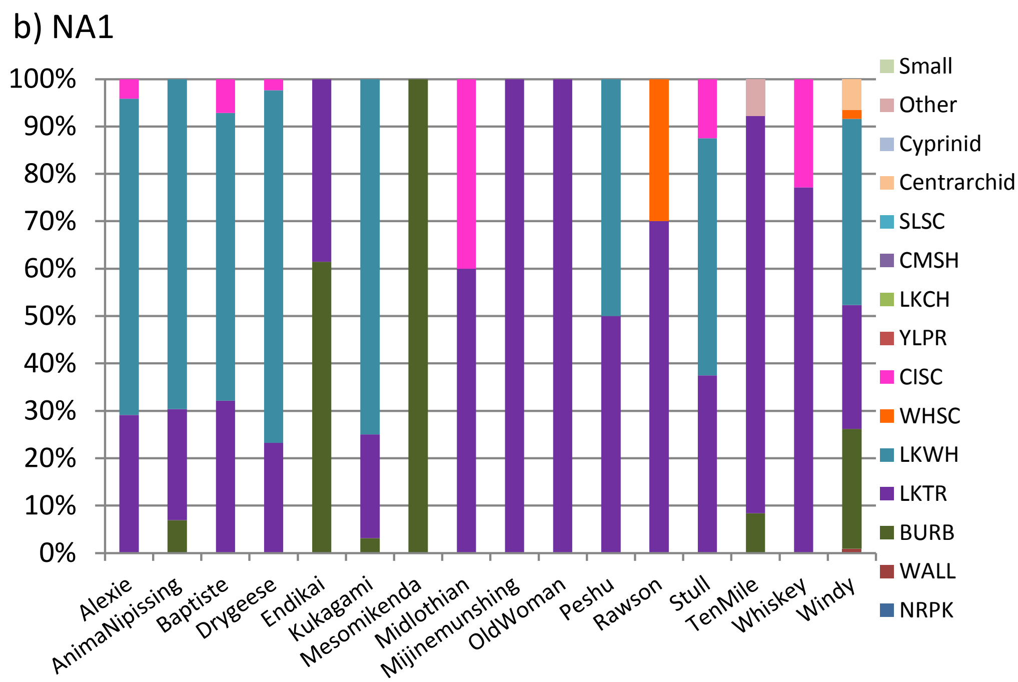


Figure 11: Percent composition of NPUE estimates attributable to individual fish species or groups for a) NRD, and b) NA1 gears set below 20 m on 16 Boreal Shield lakes. Group categories (first four) in the legend do not include individual species listed below; Small = Gasterosteidae, Percopsidae, Cottidae and Percidae, Other = Salmonidae, Osmeridae, Catastomidae and Ictaluridae. Species codes are listed in Table 4.

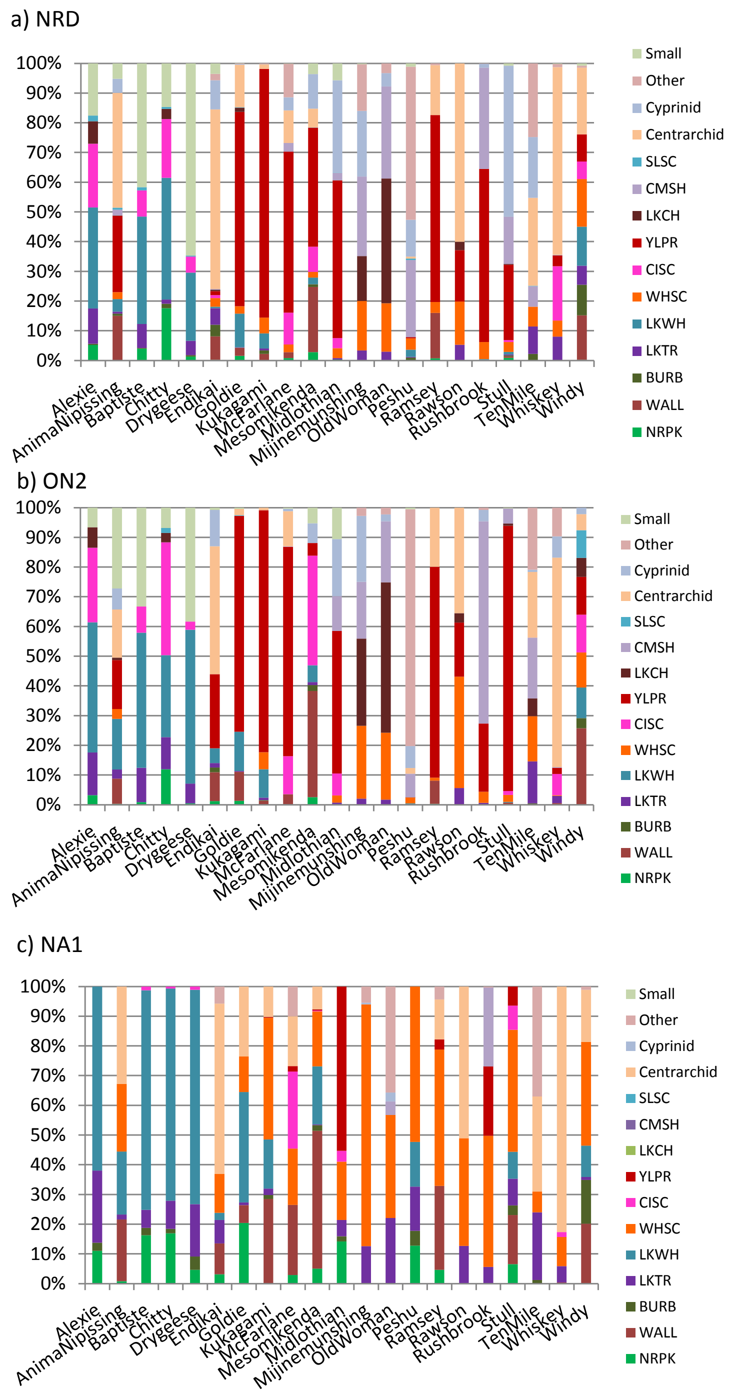


Figure 12: Percent composition of NPUE estimates attributable to individual fish species or groups for a) NRD, b) ON2, and c) NA1 gears set above 20 m on 21 Boreal Shield lakes. Group categories (first four) in the legend do not include individual species listed below; Small = Gasterosteidae, Percopsidae, Cottidae and Percidae, Other = Salmonidae, Osmeridae, Catastomidae and Ictaluridae. Species codes are listed in Table 4.

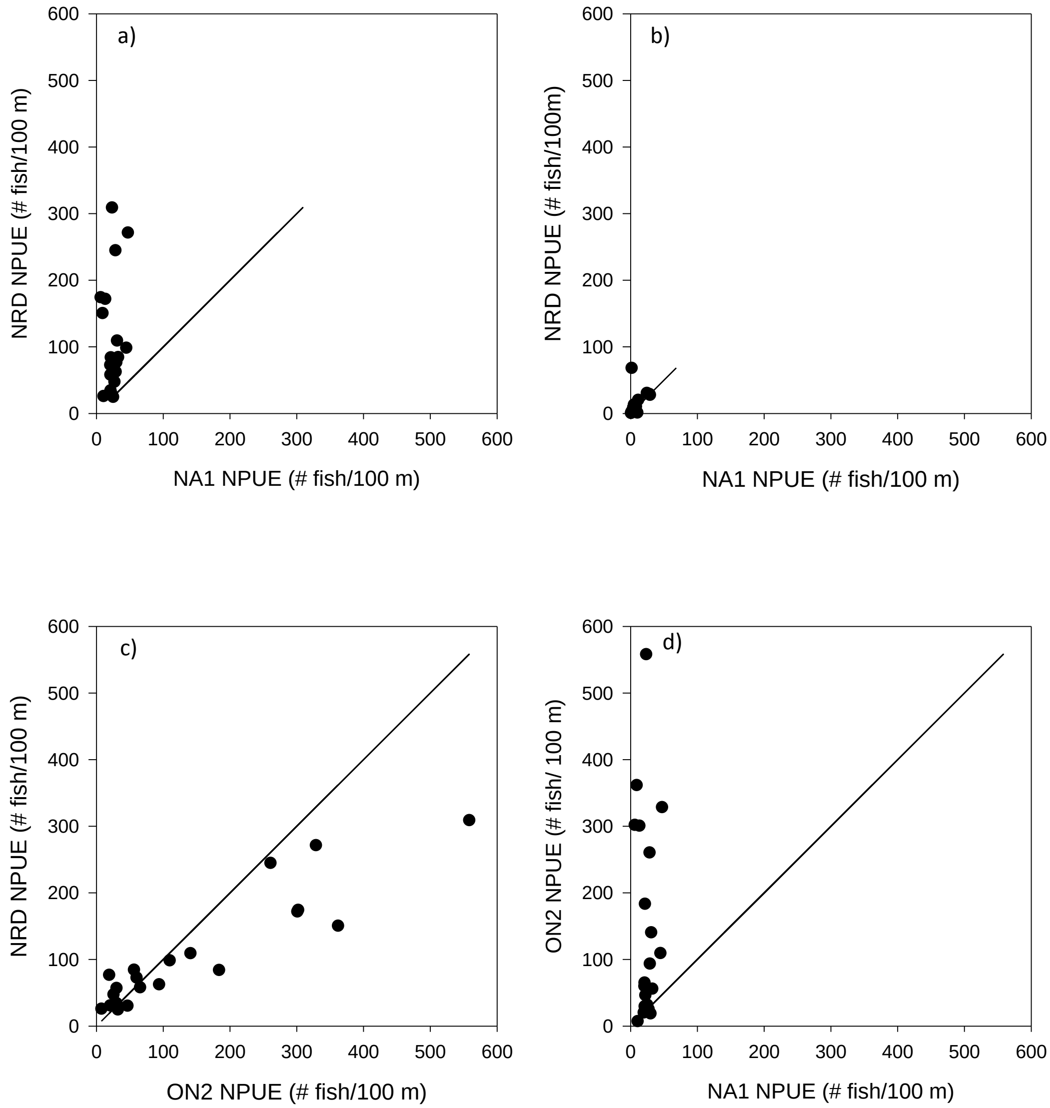


Figure 13: Scatter plots comparing NRD, NA1, and ON2 gear estimates of numeric catch-per-unit-effort (NPUE, fish per 100 m of net) for fish communities (all species combined) in 21 Boreal Shield lakes. Comparisons are a) NRD vs NA1, above 20 m depth (n=21), b) NRD vs NA1, below 20 m depth (n=16), c) NRD vs ON2, above 20 m depth (n=21), and d) NA1 vs ON2, above 20 m depth (n=21). Reference line indicates 1:1 agreement between the gears.

Table 12: Results of tests between NRD and NA1 gill net numeric catch-per-unit-effort (NPUE, number per 100 m of net) for fish communities (all species combined) and selected individual species in boreal lakes, above and below 20 m depth. Test statistics are paired-comparison *t* or Wilcoxon's signed rank S (n = number of lakes). Significant differences (p < 0.05) are indicated *.

		NPUE (number per 100 m of net) above 20 m depth				NPUE (number per 100 m of net) below 20 m depth		
Species	**n**	**Trend**	**Statistic**	**p-value**	**n**	**Trend**	**Statistic**	**p-value**
All	21	NRD>NA1	S = 112.5	<0.001*	16	NRD>NA1	S = 24	0.23
Large-bodied species								
Northern Pike	14	NRD<NA1	t = -3.29	0.006*		.	.	.
Walleye	10	NRD<NA1	t = -1.19	0.26		.	.	.
Burbot	15	NRD>NA1	t = 1.18	0.26	11	NRD>NA1	t = 1.64	0.13
Lake Trout	19	NRD<NA1	t = -0.35	0.73	15	NRD<NA1	S = -45	0.0084*
Lake Whitefish	13	NRD<NA1	t = -1.10	0.29	8	NRD<NA1	t = -0.90	0.40
White Sucker	17	NRD<NA1	t = -1.23	0.24		.	.	.
Small-bodied species								
Cisco	11	NRD>NA1	t = 3.78	0.0036*	9	NRD>NA1	t = 4.58	0.0018*
Yellow Perch	14	NRD>NA1	t = 6.04	<0.001*		.	.	.
Lake Chub	13	NRD>NA1	S = 28	0.002*		.	.	.
Common Shiner	11	NRD>NA1	S = 33	0.001*		.	.	.
Slimy Sculpin	13	NRD>NA1	t = 4.06	0.002*		.	.	.

NRD gear yielded lower BPUE than NA1 gear for all species combined (Figure 14), and this trend was statistically significant above 20 m depth (Table 13). On average, NRD BPUE was 37% (6.2 kg/100 m) lower than NA1 BPUE, above 20 m. When analyses were broken down into BPUE for individual species the results varied with respect to fish body size. For all large-bodied species except Burbot, NRD gear tended to yield lower BPUE than NA1 gear. This trend was significant for four of six species examined above

20 m depth (Table 13). For all small-bodied fish species examined, NRD gear yielded significantly higher BPUE than NA1 gear, except for Cisco above 20 m depth (Table 13).

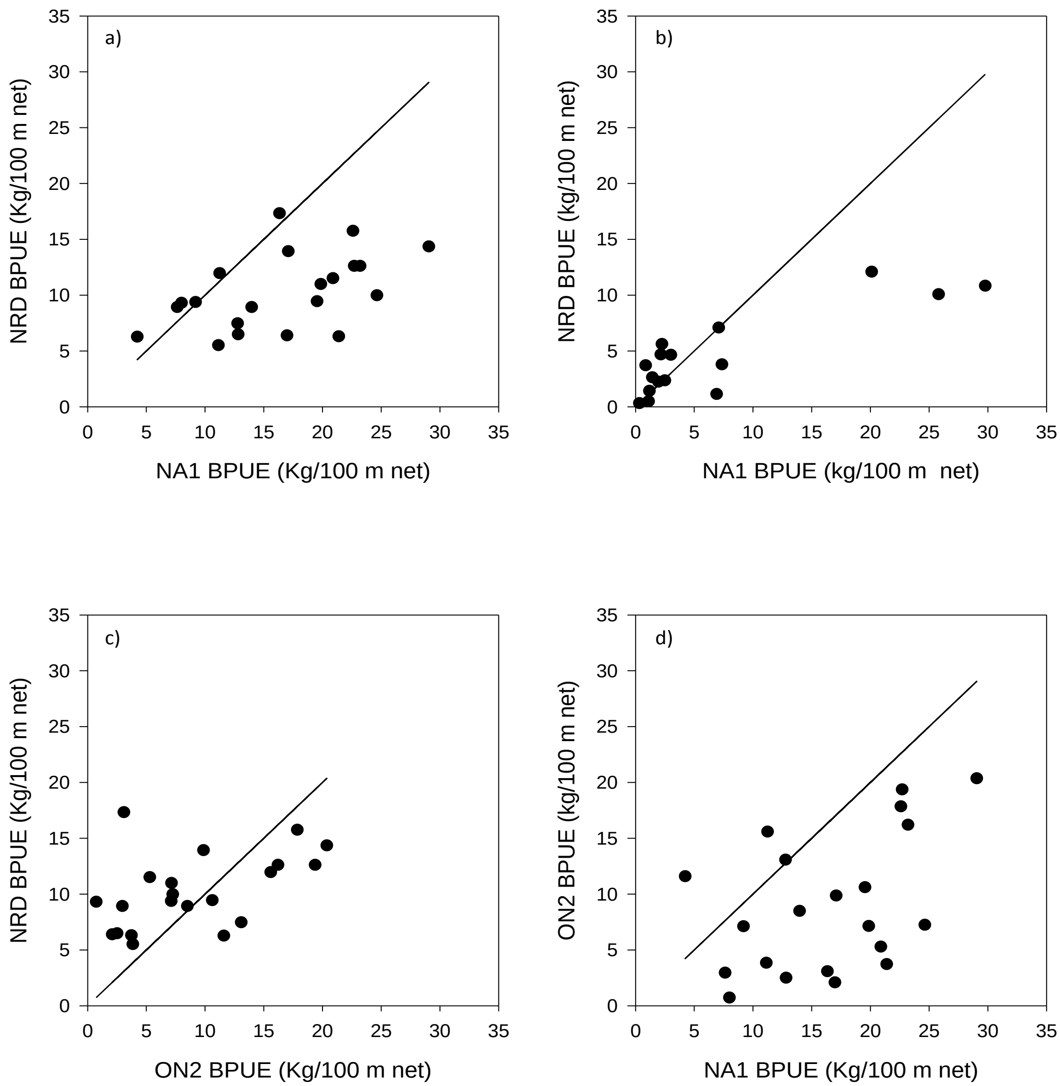


Figure 14: Scatter plots comparing NRD, NA1, and ON2 gear estimates of biomass catch-per-unit-effort (BPUE, Kg of fish per 100 m of net) for fish communities (all species combined) in 21 Boreal Shield lakes. Comparisons are a) NRD vs NA1, above 20 m depth (n=21), b) NRD vs NA1, below 20 m depth (n=16), c) NRD vs ON2, above 20 m depth (n=21), and d) NA1 vs ON2, above 20 m depth (n=21).

Table 13: Results of tests between NRD and NA1 gill net biomass catch-per-unit-effort (BPUE, kg of fish per 100 m of net) for fish communities (all species combined) and selected individual species in boreal lakes, above and below 20 m depth. Test statistics are paired-comparison *t* or Wilcoxon's signed rank S (n = number of lakes). Significant differences (p < 0.05) are indicated*.

		BPUE (kg per 100 m of net) above 20 m depth				BPUE (kg per 100 m of net) below 20 m depth		
Species	**n**	**Trend**	**Statistic**	**p-value**	**n**	**Trend**	**Statistic**	**p-value**
All	21	NRD<NA1	t = -4.99	< 0.001*	16	NRD<NA1	S = -12	0.56
Large-bodied species								
Northern Pike	14	NRD<NA1	S = -52	< 0.001*		.	.	.
Walleye	10	NRD<NA1	S = -28	0.002*		.	.	.
Burbot	15	NRD>NA1	t = 0.67	0.51	11	NRD>NA1	t = 1.78	0.11
Lake Trout	19	NRD<NA1	t = -1.88	0.077	15	NRD<NA1	t = -1.38	0.19
Lake Whitefish	13	NRD<NA1	t = -2.63	0.022*	8	NRD<NA1	S = -8	0.31
White Sucker	17	NRD<NA1	S = -70	< 0.001*		.	.	.
Small-bodied species								
Cisco	11	NRD>NA1	S = 19	0.10	9	NRD>NA1	t = 3.35	0.010*
Yellow Perch	14	NRD>NA1	S = 53	< 0.001*		.	.	.
Lake Chub	13	NRD>NA1	S = 28	0.002*		.	.	.
Common Shiner	11	NRD>NA1	S = 33	0.001*		.	.	.
Slimy Sculpin	13	NRD>NA1	S = 39	< 0.001*		.	.	.

Above 20 m depth, NRD gear yielded lower BPUE than NA1 gear by 71% (1.9 kg/100 m) for Northern Pike, 62% (2.1 kg/100 m) for Walleye, 39% (2.4 kg/100 m) for Lake Whitefish and 53% (3.1 kg/100 m) for White Sucker. Also above 20 m depth, NRD gear yielded higher BPUE than NA1 gear by 518% (0.45 kg/100 m) for Yellow Perch, by 0.05 kg/100 m for Lake Chub (BPUE = 0 for NA1), by 1198% (0.33 kg/100 m) for Common Shiner, and by 0.001 kg/100 m (BPUE = 0 for NA1) for Slimy Sculpin. Below 20 m depth, NRD gear yielded higher BPUE than NA1 gear by 336% (0.15 kg/100 m) for Cisco.

In comparisons of NRD and ON2 gears above 20 m depth, there was a trend of higher NPUE for NRD for all species combined (Figure 13c), but this was not statistically significant (Table 14). For individual species, NRD gear yielded significantly higher NPUE than ON2 gear for two of the six large-bodied species, but none of the small-bodied species (Table 14). On average, NRD gear gave higher NPUE estimates than ON2 gear for Northern Pike and Burbot, by 68% (0.41 fish/100 m) and 295% (0.65 fish/100 m), respectively. Slightly different patterns emerged when these two gears were compared based on BPUE above 20 m depth (Figure 14c; Table 14). There was not a significant difference in BPUE between NRD and ON2 when all species were combined, but NRD had higher BPUE than ON2 for three of six large-bodied, and one of five small-bodied species examined (Table 14). The NRD gear yielded higher BPUE than ON2 gear by 115% (0.69 kg/100 m) for Walleye, by 312% (0.31 kg/100 m) for Burbot, by 200% (1.8 kg/100 m) for White Sucker, and by 626% (0.0009 kg/100 m) for Slimy Sculpin.

Not surprisingly, comparisons of NA1 and ON2 gears provided the strongest contrasts in CPUE. In comparisons of NA1 and ON2 gears above 20 m depth, NA1 had lower NPUE for all species combined (Figure 13d) by 83% (120 fish/100 m) and this difference was statistically significant (Table 15). For individual species the results diverged sharply between large-bodied and small-bodied species (Table 15). NA1 gear had significantly higher NPUE than ON2 gear for three of the six large-bodied species examined, and significantly lower NPUE than ON2 for four of the five small-bodied species examined (Table 15). NA1 gear yielded higher NPUE than ON2 gear by 184% (1.1 fish/100 m) for Northern Pike, by 100% (0.22 fish/100 m) for Burbot, and by 36% (4.2 fish/100 m) for White Sucker. NA1 gear yielded lower NPUE than ON2 gear by 95% (9.5 fish/100 m) for Cisco, 97% (74.3 fish/100 m) for Yellow Perch, by 18.4 fish/100 m (NPUE = 0 for NA1) for Lake Chub, and by 97% (39.9 fish/100 m) for Common Shiner.

Table 14: Results of tests between NRD and ON2 gill net numeric (NPUE, number per 100 m of net) and biomass catch-per-unit-effort (BPUE, kg of fish per 100 m of net) for fish communities (all species combined) and selected individual species above 20 m depth. Test statistics are paired-comparison *t* or Wilcoxon's signed rank S (n = number of lakes). Significant differences (p < 0.05) are indicated *.

		NPUE (number per 100 m of net) above 20 m depth			BPUE (kg per 100 m of net) above 20 m depth		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NRD>ON2	t = 0.43	0.67	NRD>ON2	t = 1.09	0.29
Large-Bodied Fish							
Northern Pike	14	NRD>ON2	t = 3.06	0.009*	NRD>ON2	S = 15.5	0.36
Walleye	10	NRD>ON2	t = 0.77	0.46	NRD>ON2	t = 4.35	0.002*
Burbot	15	NRD>ON2	t = 3.23	0.006*	NRD>ON2	t = 2.98	0.01*
Lake Trout	19	NRD<ON2	t = -0.28	0.78	NRD>ON2	S = -31	0.22
Lake Whitefish	13	NRD>ON2	t = 1.82	0.087	NRD>ON2	t = -1.03	0.32
White Sucker	17	NRD>ON2	t = 1.82	0.087	NRD>ON2	t = 3.66	0.002*
Small-Bodied Fish							
Cisco	11	NRD<ON2	t = -1.78	0.11	NRD<ON2	S = -12	0.32
Yellow Perch	14	NRD>ON2	t = 0.49	0.63	NRD<ON2	S = -3.5	0.86
Lake Chub	13	NRD<ON2	t = -1.13	0.28	NRD<ON2	S = -9.5	0.54
Common Shiner	11	NRD<ON2	t = -1.39	0.19	NRD<ON2	S = -5	0.70
Slimy Sculpin	13	NRD>ON2	S = 25	0.094	NRD>ON2	t = 2.56	0.025*

Table 15: Results of tests between NA1 and ON2 gill net numeric (NPUE, number per 100 m of net) and biomass catch-per-unit-effort (BPUE, kg of fish per 100 m of net) for fish communities (all species combined) and selected individual species above 20 m depth. Test statistics are paired-comparison *t* or Wilcoxon's signed rank S (n = number of lakes). Significant differences (p < 0.05) are indicated *.

		NPUE (number per 100 m of net) above 20 m depth			BPUE (kg per 100 m of net) above 20 m depth		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NA1<ON2	S = -88	< 0.001*	NA1>ON2	t = 5.14	< 0.001*
Large-bodied species							
Northern Pike	14	NA1>ON2	S = 46	< 0.001*	NA1>ON2	t = 3.43	0.0044*
Walleye	10	NA1>ON2	t = 2.01	0.075	NA1>ON2	S= 28	0.002*
Burbot	15	NA1>ON2	t = 2.41	0.03*	NA1>ON2	t = 2.41	0.03*
Lake Trout	19	NA1>ON2	t = 0.045	0.96	NA1<ON2	t = -0.58	0.57
Lake Whitefish	13	NA1>ON2	t = 0.89	0.39	NA1>ON2	S = 27	0.03*
White Sucker	17	NA1>ON2	S = 45	0.035*	NA1>ON2	t = 4.95	< 0.001*
Small-bodied species							
Cisco	11	NA1<ON2	t = -4.15	0.002*	NA1<ON2	S = -27	0.0039*
Yellow Perch	14	NA1<ON2	t = -4.28	< 0.001*	NA1<ON2	S = -52	< 0.001*
Lake Chub	13	NA1<ON2	S = -28	0.002*	NA1<ON2	S = -28	0.002*
Common Shiner	11	NA1<ON2	t = -3.83	0.0033*	NA1<ON2	S = -23	0.0039*
Slimy Sculpin	13	NA1<ON2	S = -3	0.25	NA1<ON2	S = -3	0.25

Patterns were similar when NA1 and ON2 gear were compared with respect to BPUE, except for the case of all species combined. Above 20 m depth, NA1 had significantly higher BPUE for all species combined (Figure 14d; Table 15) by 82% (7.4 kg/100 m). For large-bodied species, NA1 gear had significantly higher BPUE estimates than ON2 gear for five of the six species examined (Table 15). NA1 gear yielded higher BPUE than ON2 gear by 247% (1.9 kg/100 m) for Northern Pike, by 469% (2.8 kg/100 m) for Walleye, by 218% (0.2 kg/100 m) for Burbot, by 36% (1.6 kg/100 m) for Lake

Whitefish, and by 548% (4.9 kg/100 m) for White Sucker. For small-bodied fish species, NA1 gear yielded significantly lower BPUE estimates than ON2 gear for four of the five species examined (Table 15). NA1 gear yielded lower BPUE than ON2 gear by 65% (0.45kg/100 m) for Cisco, by 85% (0.53 kg/100 m) for Yellow Perch, by 0.08 kg/100 m (BPUE = 0 for NA1) for Lake Chub, and by 1569% (0.44 kg/100 m) for Common Shiner.

Biomass distributions – survey comparison

Biomass size distributions were first compared between full surveys. For both surveys, the greatest mean percentage of captured biomass was in the 0-100 g bin, 12.31% and 8.23% for NORDIC and BsM surveys, respectively (Figure 15). The overall trend was that NORDIC survey distributions had a higher proportion of the total mass in smaller size classes and BsM survey distributions had a higher proportion in larger size classes (Figure 15). The overall shape and position of the biomass distributions for all species combined were significantly different between NORDIC and BsM surveys for 16 of the 21 lakes (Kolmogorov-Smirnov two-sample tests, $p < 0.05$). Three of the five lakes where the biomass distributions were not found to be significantly different were the NWT lakes Alexie, Baptiste and Drygeese. Results of the Kolmogorov-Smirnov tests of whole communities and individual species for each lake are summarized in Appendix VII, Table 26.

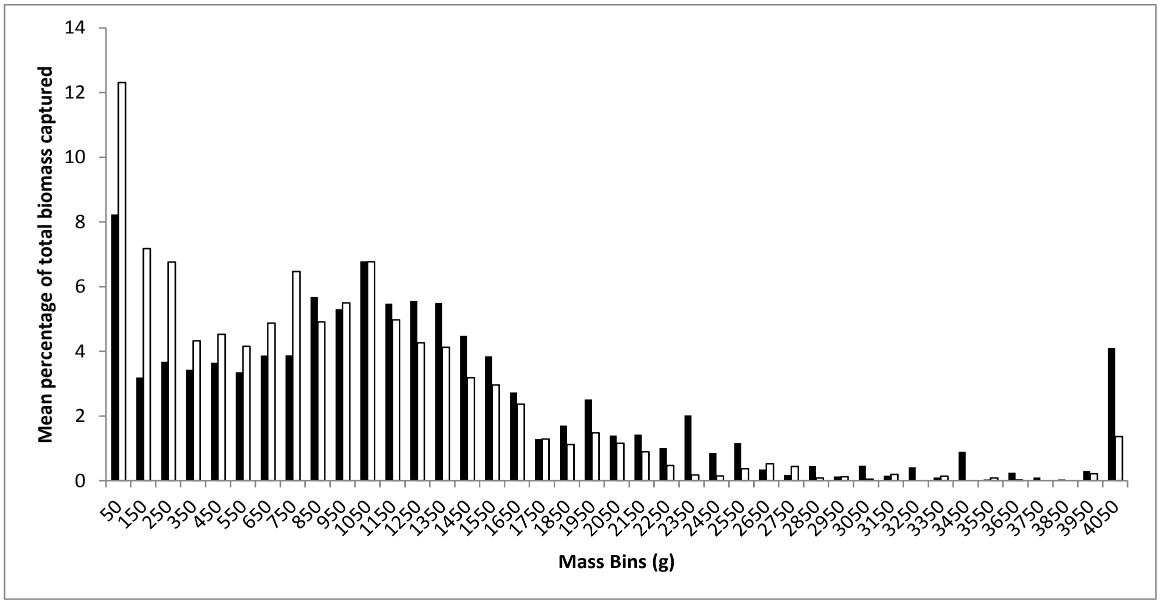


Figure 15: Comparison of mean (n = 21 lakes) biomass distributions of captured fish between NORDIC (white bars) and BsM (black bars) surveys.

When biomass distributions for individual species were compared within each lake, the majority of comparisons resulted in significant differences between the two surveys (Figure 16). However, significant differences were rare for small-bodied species. For example, significant differences between NORDIC and BsM surveys in biomass size distributions were not found in any of the lakes where comparisons could be made for Yellow Perch, and were found in only three of 10 lakes where comparisons could be made for Cisco (Figure 16).

Comparison of NORDIC and BsM Survey Biomass Distributions - Kolmogorov-Smirnov Test																					
	Alexie*	Anima Nipissing	Baptiste*	Chitty*	Drygeese*	Endikai	Goldie	Kukagami	McFarlane	Mesomikenda	Midlothian	Mijinemungshing	Old Woman	Peshu	Ramsey	Rawson	Rushbrook	Stull	Ten Mile	Whiskey	Windy
ALL	NS	s	NS	S	NS	S	S	S	S	S	S	S	NS	S	S	S	S	S	S	S	NS
NRPK	S		S	S	S	S	NS		S	S	S			S	S			S			
WALL		NS				S	S	S	NS	S					S			S		S	S
BURB	S	S	S	S	S	S		S		S	S			S				S	S		S
LKTR	S	S	NS	S	NS	NS	S	S			S	S	NS	S		S	S	S	S	S	S
LKWH	NS	NS	NS	NS	S	S	S	S		S				S				NS			S
WHSC		S				S	S	S	S	NS	S	S	S	S	S	S	NS	S	S	S	S
CISC	NS		NS	S	NS				S	NS	NS							NS		S	NS
YLPR		NS				NS	NS	NS	NS	NS	NS			NS	NS	NS	NS	NS		NS	NS

Figure 16: Results of Kolmogorov-Smirnov two-sample tests, comparing the biomass distributions of fish captured in NORDIC and BsM surveys, across 21 boreal lakes, for all species (entire fish community) and eight common species (codes defined in Table 4). Black squares denote comparisons that could not be made, grey squares denote non-significant (NS) statistical results, and white squares denote statistically significant (S) results.

For all species combined, NORDIC surveys yielded size distributions with a 35% lower median, and an 18% higher CV; both of these differences were statistically significant (Table 16). When analyses of medians and CVs were conducted for individual fish species, similar trends were observed but relatively few tests were statistically significant (Table 16). Medians of biomass distributions for NORDIC surveys compared to BsM surveys were 50% lower for Walleye and 11% lower for White Sucker, and CVs of biomass distributions for NORDIC surveys compared to BsM surveys were 101% higher for Burbot and 22% higher for Lake Whitefish.

Table 16: Results of comparisons between NORDIC and BsM survey biomass size distribution medians and CVs for fish communities (all species combined) and selected individual species in boreal lakes. Test statistics are paired-comparisons *t* or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

		Median of biomass distribution			**CV of biomass distribution**		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NRD<BsM	S = -95	< 0.001*	NRD>BSM	t = 2.91	0.0087*
Large-bodied species							
Northern Pike	14	NRD<BsM	t = -2.03	0.064	NRD>BSM	t = 1.01	0.331
Walleye	10	NRD<BsM	S = -28	0.002*	NRD>BSM	t = 0.14	0.89
Burbot	15	NRD>BSM	t = 0.33	0.75	NRD>BSM	S = 38	0.0061*
Lake Trout	19	NRD<BsM	t = -1.34	0.20	NRD>BSM	t = 1.17	0.26
Lake Whitefish	13	NRD<BsM	S = -9.5	0.31	NRD>BSM	t = 3.50	0.0044*
White Sucker	17	NRD<BsM	t = -2.26	0.038*	NRD>BSM	t = 0.96	0.35
Small-bodied species							
Cisco	4	NRD<BsM	S = -2.0	0.50	NRD>BSM	t = 0.15	0.89
Yellow Perch	6	-	-	-	NRD>BSM	t = 0.62	0.56

Eight linear regression models were tested to determine the influence of lake physical characteristics on the reported difference in median size of entire community biomass distributions between NORDIC and BsM surveys. The highest ranked model was the intercept term (Table 17). None of the models accounted for any significant portion of the variation of the dependent variable (NORDIC-BsM).

Table 17: AIC_c rankings of linear models relating difference in median size of biomass distributions of entire fish communities between NORDIC and BsM surveys to maximum depth (maxDepth, m), Secchi depth (Secchi, m), and surface area (SA, ha).

Rank	MODEL STRUCTURE (Effects)	n	AIC_c	Δ_i	exp ($-0.5\Delta_i$)	w_i	r^2
1	Intercept	21	271.17	0.00	1.00	1.03	
2	SA (+)	21	273.80	2.63	0.27	0.28	0.0054
3	maxDepth (+)	21	273.82	2.65	0.27	0.27	0.0044
4	Secchi (+)	21	273.89	2.72	0.26	0.26	0.0011
5	SA (+), maxDepth (+)	21	276.87	5.70	0.06	0.06	0.0064
6	SA (+), Secchi (+)	21	276.87	5.70	0.06	0.06	0.0062
7	maxDepth (+), Secchi (+)	21	276.91	5.74	0.06	0.06	0.0044
8	SA (+), maxDepth (+), Secchi (+)	21	280.36	9.20	0.01	0.01	0.0066

Biomass distributions - Gear Comparisons - > 20 m and < 20 m depths

Below 20 m depth, size distributions from NA1 gear had a higher proportion of total biomass in the larger size classes than distributions from NRD gear (Figure 17). The overall shape and position of the biomass distributions for all species combined, as well as most individual species in all lakes, except for Cisco, were significantly different between NRD and NA1 gears for all lakes (Kolmogorov-Smirnov two-sample test, $p < 0.05$, Figure 18a). The results of the Kolmogorov-Smirnov tests of whole communities and individual species below 20 m depth for each lake can be found in Appendix VII, Table 27.

Above 20 m, the general trend was that body size distributions were skewed most strongly to the right (larger size classes) for NA1 gear, most strongly to the left (smaller size classes) for ON2 gear, and intermediate for NRD gear (Figure 19). The mean size distribution generated by the NRD gear was bimodal with the largest peak in the smallest size bin, and a secondary, smaller peak in the 1000-1100 g mass bin (Figure 19).

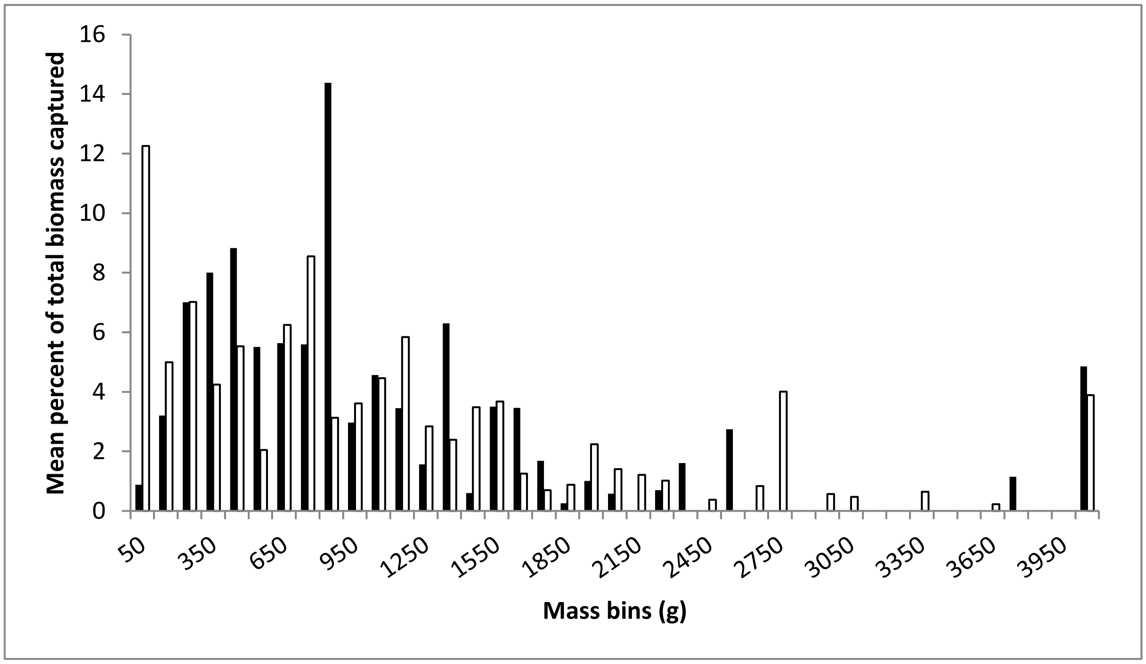


Figure 17: Comparisons of mean (n = 21 lakes) biomass distributions between NA1 (black bars) and NRD (white bars) gear below 20 m depth.

Similarly, the mean size distribution for the ON2 gear was multimodal with the largest peak in the smallest size bin, and one or two much smaller peaks in larger size bins (Figure 19). Each of the gears caught a relatively small proportion of very large fish (> 4000 g, Figure 19). Interestingly, fish > 1 kg in size made up almost 40% of the mean biomass in ON2 gear (Figure 19). Given that the largest mesh size in the ON2 gang is only 38 mm it is likely that a high proportion of the biomass is captured by tangling rather than wedging. The overall shapes and positions of the biomass distributions for the whole fish communities differed significantly between gears for 17 of the 21 lakes (Kolmogorov-Smirnov two-sample test, $p < 0.05$, Figure 18 b,c,d). Two of the NWT lakes (Alexie and Baptiste) were consistently found to have non-significant statistical differences in the shape and position of their biomass distributions above 20 m, regardless of the gear comparison being made (Figure 18).

A. Comparison of NRD and NA1 Gear - Kolmogorov-Smirnov Test - Below 20m Depth

	Alexie*	Anima Nipissing	Chitty*	Baptiste*	Drygeese*	Endikai	Goldie	Kukagami	McFarlane	Mesomikenda	Midlothian	Mijinemungshing	Old Woman	Peshu	Ramsey	Rawson	Rushbrook	Stull	Ten Mile	Whiskey	Windy
ALL	S	S		S	S	S		S		S	S	S	S	S		S		S	S	S	S
NR PK																					
WALL																					
BURB		S				S		S		S									S		S
LKTR	S	S		S	S	S		S			S	S	S			S		S	S	S	S
LKWH	S	S		S	S			S						S				S			S
CISC	NS			NS	S						NS							NS		S	
YL PR																					

B. Comparison of NRD and NA1 Gear - Kolmogorov-Smirnov Test - Above 20 m Depth

	Alexie*	Anima Nipissing	Baptiste*	Chitty*	Drygeese*	Endikai	Goldie	Kukagami	McFarlane	Mesomikenda	Midlothian	Mijinemungshing	Old Woman	Peshu	Ramsey	Rawson	Rushbrook	Stull	Ten Mile	Whiskey	Windy
ALL	NS	S	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	NS	S	S
NR PK	S	S	S	S	S	S	S		S	S	S			S	S						
WALL		S				S	S	S	S	S					S			S		S	S
BURB	S	S	S	S	S			S		S	S			S					S		S
LKTR	S		S	S	S	S	S	S		S	S	S	S	S		S	S	S	NS	S	S
LKWH	NS	S	S	NS	S	S	S	S		S				S				S			S
WHSC		NS				S	S	S	S	S	S	S	S	S	NS	S	NS	S	NS	S	S
CISC		NS	NS	NS	NS				S	NS	NS									S	
YL PR		NS						NS	NS	S	S				S		NS				

C. Comparison of NRD and ON2 Gear - Kolmogorov-Smirnov Test - Above 20 m Depth

	Alexie*	Anima Nipissing	Baptiste*	Chitty*	Drygeese*	Endikai	Goldie	Kukagami	McFarlane	Mesomikenda	Midlothian	Mijinemungshing	Old Woman	Peshu	Ramsey	Rawson	Rushbrook	Stull	Ten Mile	Whiskey	Windy
ALL	NS	S	NS	S	S	S	S	S	S	S	S	S	NS	S	S	S	NS	S	S	S	S
NR PK	S	S	S	S	S	S	S		S	S					S						
WALL		S				S	S	S	S	S					S			S		S	S
BURB		S				S		S			S			S					S		S
LKTR	S		S	S	S	S	S	S			S	S	S			S	S	S	S	S	
LKWH	NS	S	S	S	S	S	S	S		S				S				S			S
WHSC								S		S	S	S	S	S	S	S	S	S	S	S	S
CISC	NS	NS	NS	S	NS				S	NS	NS									S	NS
YL PR		NS				NS	NS	NS	NS	NS	NS			NS	S	NS	NS	NS		NS	NS

D. Comparison of NA1 and ON2 Gear - Kolmogorov-Smirnov Test - Above 20 m Depth

	Alexie*	Anima Nipissing	Baptiste*	Chitty*	Drygeese*	Endikai	Goldie	Kukagami	McFarlane	Mesomikenda	Midlothian	Mijinemungshing	Old Woman	Peshu	Ramsey	Rawson	Rushbrook	Stull	Ten Mile	Whiskey	Windy
ALL	NS	S	NS	S	NS	S	S	S	S	S	S	S	S	S	S	S	S	S	NS	S	S
NR PK	S	S	S	S	S	S	S		S	S					S			S			
WALL		S				S	S	S	S	S					S			S		S	S
BURB		S						S			S			S					S		S
LKTR	S	S	S	S	S	S	S	S			S	S	S			S	S	S	NS	S	
LKWH	NS	S	NS	NS	NS	S	NS	S		S				S				NS			S
WHSC								S		S	S	S	S	S	S	S	S	S	S	S	S
CISC		NS	NS	S	NS				NS	NS	NS									S	
YL PR		NS						NS	NS	S	S				S		NS				

Figure 18: Results of Kolmogorov-Smirnov two-sample tests, comparing biomass distributions of a) NRD vs NA1 gear below 20 m depth, b) NRD vs NA1 gear above 20 m depth, c) NRD vs ON2 gear above 20 m depth, and d) NA1 vs ON2 gear above 20 m depth in each of 21 boreal lakes, for all species combined and eight commonly-sampled individual species. White (S) = significant, Grey (NS) = not significant, Black = no test made.

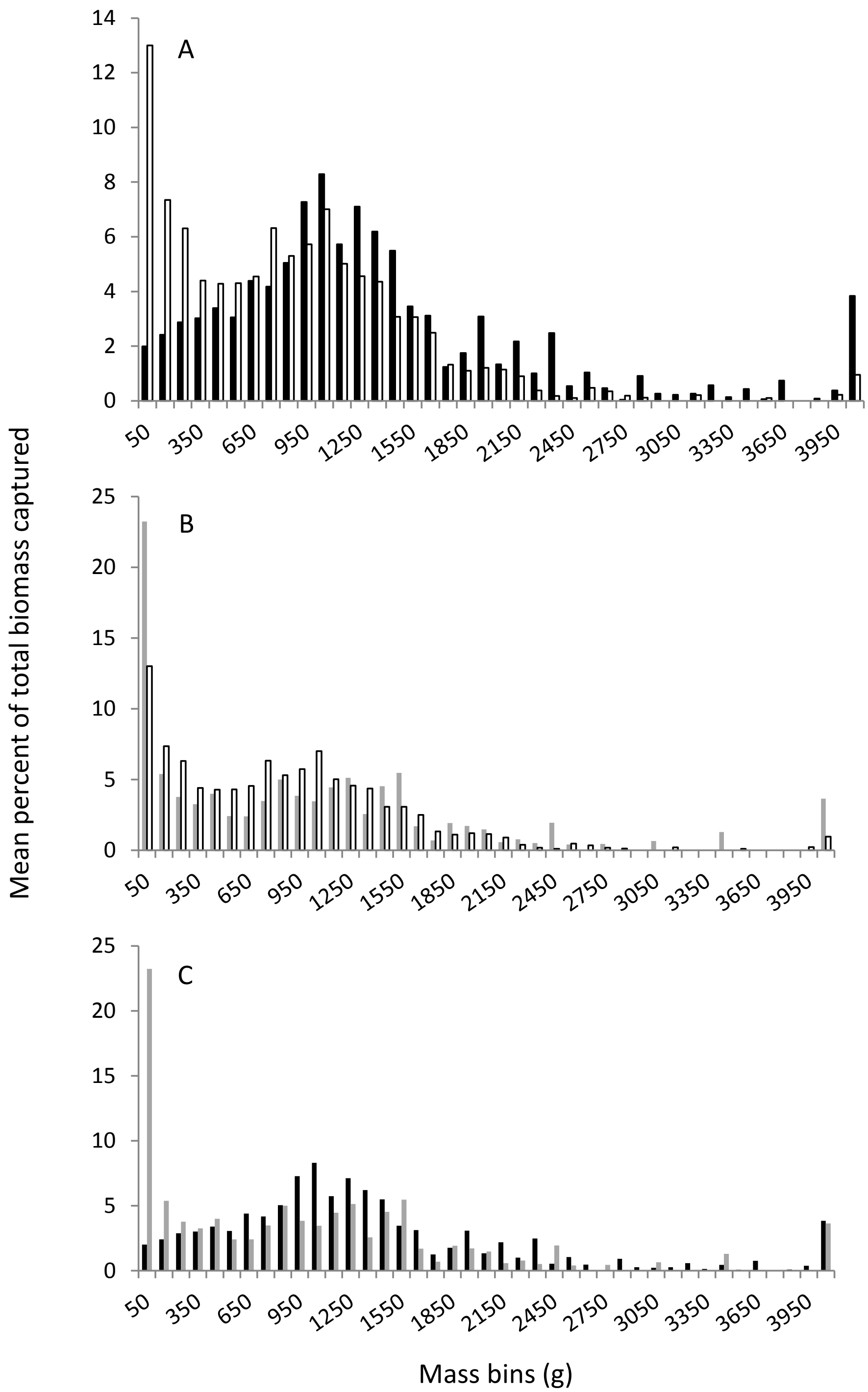


Figure 19: Comparisons of mean (n = 21 lakes) biomass distributions above 20 m depth for a) NA1 (black) and NRD (white) gears, b) NRD (white) and ON2 (grey) gears, and c) NA1 (black) and ON2 (grey) gears.

When comparisons were made for size distributions of individual species, some species-specific patterns emerged. Biomass distributions for all Northern Pike, Walleye and Burbot populations, and most Lake Trout populations were significantly different, regardless of the gear comparison being made (Figure 18). In contrast, significant differences between gears were less consistent among populations of other species (Figure 18). For benthivore populations, Lake Whitefish and White Sucker, significant differences were evident in about three-quarters of comparisons, and for forage fish populations, Cisco and Yellow Perch, significant differences were only evident in less than a quarter of the comparisons (Figure 18). Results of Kolmogorov-Smirnov two-sample tests between the various gears for whole communities and individual fish species in each lake are summarized in Appendix VII, Tables 27-30.

Biomass size distributions were compared further through analysis of distribution medians and CVs. For comparisons of NRD and NA1 gears below 20 m depth, NRD gear tended to generate size distributions with both higher median and CV, though this trend was only statistically significant for the CV of all species combined (Table 18). Trends between NRD and NA1 gears were generally stronger above 20 m depth due to larger sample sizes. Above 20 m depth the NRD gear yielded a lower median size in all comparisons, and this was statistically significant for all species combined, and three of six large-bodied species (Table 19). The NRD gear also yielded a higher CV in most comparisons, and this was also statistically significant for all species combined, and three of six large-bodied species (Table 19).

Table 18: Results of tests between NRD and NA1 gear biomass distribution medians and coefficients of variation (CV) for fish communities (all species combined) and selected individual species in boreal lakes, below 20 m depth. Test statistics are paired-comparisons *t* or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

		Median of biomass distributions			CV of biomass distributions		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	16	NRD<NA1	S = -9	0.63	NRD>NA1	t = 3.22	0.0057*
Burbot	6	NRD>NA1	t = 0	1	NRD>NA1	t = 2.10	0.09
Lake Trout	14	NRD>NA1	S = 6.5	0.68	NRD>NA1	t = 1.39	0.19
Lake Whitefish	8	NRD<NA1	t = -1.93	0.095	NRD>NA1	t = 1.87	0.10
White Sucker	2	NRD>NA1	t = 0.75	0.59	NRD<NA1	t = -4.01	0.16
Cisco	6	-	-	-	NRD>NA1	S = 0.5	1

Table 19: Results of tests between NRD and NA1 gear biomass distribution medians and coefficients of variation for fish communities (all species combined) and selected individual species in boreal lakes, above 20 m depth. Test statistics are paired-comparisons *t* or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

		Median of biomass distributions			CV of biomass distributions		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NRD<NA1	S = -95	< 0.001*	NRD>NA1	t = 4.69	< 0.001*
Northern Pike	12	NRD<NA1	t = -1.79	0.10	NRD>NA1	t = 1.19	0.26
Walleye	10	NRD<NA1	t = -27.5	0.002*	NRD>NA1	t = 2.02	0.074
Burbot	11	NRD<NA1	t = 1.54	0.16	NRD>NA1	t = 2.41	0.037*
Lake Trout	18	NRD<NA1	t = 1.94	0.069	NRD>NA1	S = 35.5	0.13
Lake Whitefish	12	NRD<NA1	t = -2.60	0.025*	NRD>NA1	t = 3.19	0.0087*
White Sucker	17	NRD<NA1	S = -31	0.014*	NRD>NA1	t = 2.93	0.0098*
Cisco	8	NRD<NA1	S = -0.5	1	NRD>NA1	S = 1.5	0.50
Yellow Perch	7	NRD<NA1	S = -0.5	1	NRD<NA1	t = -0.44	0.68

Trends between body size distributions generated by NRD and ON2 gears above 20 m depth are summarized in Table 20. For medians, trends varied among comparisons, and were only statistically significant for two of the six large-bodied species examined; for both Walleye and White Sucker the NRD gear yielded a greater median body size than the ON2 gear (Table 20). Similarly, for CVs, trends varied among comparisons and were only statistically significant for three of the six large-bodied species examined; for Northern Pike, Burbot and Lake Trout the NRD gear yielded a greater CV of body size than the ON2 gear (Table 20).

Table 20: Results of tests between NRD and ON2 gear biomass distribution medians and coefficients of variation (CV) for fish communities (all species combined) and selected individual species in boreal lakes, above 20 m depth. Test statistics are paired-comparisons t or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

		Median of biomass distributions			CV of biomass distributions		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NRD>ON2	t = 0.301	0.77	NRD<ON2	t = -0.35	0.73
Northern Pike	10	NRD<ON2	t = -1.34	0.21	NRD>ON2	t = 3.27	0.0097*
Walleye	10	NRD>ON2	S = 20.5	0.037*	NRD>ON2	t = 0.87	0.41
Burbot	7	NRD>ON2	t = 0	1	NRD>ON2	t = 9.99	< 0.001*
Lake Trout	15	NRD<ON2	t = -0.91	0.38	NRD>ON2	t = 3.79	0.002*
Lake Whitefish	12	NRD<ON2	S = -7.5	0.48	NRD>ON2	t = 0.98	0.35
White Sucker	13	NRD>ON2	t = 4.88	< 0.001*	NRD>ON2	t = 0.44	0.67
Cisco	10	NRD<ON2	S = -1.5	0.5	NRD<ON2	S = 0	1
Yellow Perch	14	-	-	-	NRD>ON2	S = 6.5	0.13

Trends between body size distributions generated by NA1 and ON2 gears above 20 m depth are summarized in Table 21. For all species combined, size distributions from NA1 gear exhibited significantly higher medians and lower CVs than distributions from ON2 gear (Table 21). Trends were more variable for individual species. For medians, only two significant trends were detected; NA1 gear yielded size distributions with significantly higher medians than ON2 gear for Walleye and White Sucker (Table 21). Similarly, for CVs, only two significant trends were evident; NA1 gear yielded size distributions with significantly higher CVs than ON2 gear for Northern Pike and Lake Trout (Table 21).

Table 21: Results of tests between NA1 and ON2 gear biomass distribution medians and coefficients of variation (CV) for fish communities (all species combined) and selected individual species in boreal lakes, above 20 m depth. Test statistics are paired-comparisons *t* or Wilcoxon's signed rank S. Significant differences ($p < 0.05$) are indicated *.

		Median of biomass distributions			**CV of biomass distributions**		
Species	**n**	**Trend**	**Statistic**	**p-value**	**Trend**	**Statistic**	**p-value**
All	21	NA1>ON2	t = 3.93	< 0.001*	NA1<ON2	t = -4.73	< 0.001*
Northern Pike	11	NA1>ON2	t = 0.84	0.42	NA1>ON2	t = 3.61	0.0048*
Walleye	10	NA1>ON2	S = 27.5	0.002*	NA1<ON2	S = -11.5	0.27
Burbot	6	NA1>ON2	t = 2.37	0.064	NA1>ON2	t = 1.69	0.15
Lake Trout	16	NA1>ON2	S = 11	0.55	NA1>ON2	S = 42	0.015*
Lake Whitefish	12	NA1<ON2	S = -1.5	0.81	NA1<ON2	t = -0.39	0.70
White Sucker	13	NA1>ON2	t = 6.13	< 0.001*	NA1<ON2	t = -1.36	0.20
Cisco	8	NA1<ON2	S = -0.50	1	NA1<ON2	S = -3	0.25
Yellow Perch	7	NA1>ON2	S = 0.50	1	NA1>ON2	t = 2.32	0.060

Discussion

The objective of this study was to compare and contrast interpretations of fish community structure in boreal lakes from two widely-used, standardized gill net survey protocols and their component gears. To my knowledge, this is the first study to compare the NORDIC and BsM protocols in a well-replicated, paired-comparison design. My primary research predictions corresponded to differences in three particular fish community attributes – species composition, relative abundance, and size composition. I found significant differences in all three of these attributes, both between the full surveys and among the three gear types, and for the most part, the patterns that I observed tended to reflect my expectations based on differences between the survey protocols and gears.

Species Composition

I predicted that NORDIC surveys would yield higher estimates of both species richness and diversity than BsM surveys, and that species richness estimates from the three gears would be NRD > ON2 > NA1 at standardized levels of effort. These predictions were largely supported by my results, with a few exceptions.

Using Principal Components Analysis (PCA) I found significant differences in species composition between NORDIC and BsM surveys, and the principal component with the strongest influence was weighted towards abundances of forage fish and benthivore species. NORDIC surveys detected significantly more species (mean = 1.8) than BsM surveys across the 21 study lakes, and in most cases, the fish species reported in a NORDIC survey that were not reported in the corresponding BsM survey were small-bodied fish species. The observed differences in species richness at the survey level could be due, in part, to the lower total sampling effort of BsM surveys, as well as the restricted depth distribution of small-mesh gear in BsM surveys. However, it is likely that the overall lower proportion of small-mesh gear in the BsM surveys was the primary factor. When the three gears were compared at standardized levels of effort, I found that both NRD and ON2 gears detected ≥ 75% more species and also generated higher biodiversity estimates than NA1 gear. While the NA1 gear is relatively ineffective at catching small-bodied fish species, the ON2 and NRD gears can capture both large- and small-bodied fish species through a combination of wedging and tangling (see below). I had also predicted that NRD gear would yield greater species richness and diversity estimates than ON2 gear, due to the wider diversity of mesh sizes in the former. However, this prediction was not supported by the data.

Relative Abundance

I predicted that NORDIC surveys would yield higher estimates of numerical relative abundance (NPUE), but lower estimates of biomass relative abundance (BPUE) than BsM surveys at the community level, and that numeric relative abundances at the community level determined by the three gears would be NRD>ON2>NA1 and biomass relative abundances at the community level determined by the three gears would be NA1 > NRD > ON2. I also predicted that these results would vary at the individual species level according to the species' relative susceptibilities to the different gears.

I found that NORDIC surveys, and gears with larger proportions of small mesh, did indeed tend to yield higher NPUE estimates at the community level, but trends with respect to BPUE were less consistent. As predicted, the nature and strength of the trends varied among fish species; survey differences in both NPUE and BPUE were stronger and more consistent for small-bodied than large-bodied fish species. For small-bodied species, both NPUE and BPUE were usually higher in NORDIC than BsM surveys. This interactive effect of body size extended to the gear comparisons. For both NPUE and BPUE, I found that the gears generally ranked as ON2 = NRD > NA1 for small-bodied species, but ranked as NA1 > NRD > ON2 for most large-bodied species. Of particular note at the individual species level, I found that Lake Trout NPUE and BPUE in the BsM surveys and NA1 gear, was equal to or greater than in NORDIC surveys and in NRD gear, despite the fact that NRD gill nets have long been considered the gear of choice for lake trout sampling (J. Gunn, Laurentian University, pers. comm.).

Size composition

I predicted that NORDIC and BsM surveys would yield different size distributions of captured fish with similar variance but with the mode skewed towards smaller size classes for NORDIC relative to BsM surveys. I also predicted that among size distributions generated by the three gears I would see rankings of NA1 > NRD > ON2 for modal size, and NRD > NA1 > ON2 for variance in size. My results generally supported these predictions, but some interesting exceptions emerged.

When I examined and compared size distributions on a lake-by-lake basis, I found that community (all species combined) size distributions differed significantly between surveys in most Ontario lakes, but not in most NWT lakes. Furthermore, when size distributions were examined for individual species, significant differences between the surveys were more consistent for large-bodied piscivores than for other fish species. When analyses were conducted for the combined data set of 21 lakes, size distributions from NORDIC surveys generally had lower medians than distributions from BsM surveys, as predicted. But, contrary to my predictions, the variance in body sizes was higher from NORDIC surveys than from BsM surveys. When comparing size distributions generated by the three gears, I found that both NRD and ON2 gears yielded distributions that tended to be more multi-modal than distributions from NA1 gear. Size distribution medians were NA1 > NRD > ON2, whereas size distribution CVs were generally NRD=ON2> NA1.

Protocol and gear effects

The overall differences in fish community metrics that I observed were probably the net effect of a variety of differences between NORDIC and BsM protocols and gears that influenced the quantity and quality of fish captured. Capture probability for gill nets is a function of encounter and retention rates. Both NORDIC and BsM protocols employ benthic gill nets, randomly distributed about the lake, therefore, it seems likely that encounter rates (standardized to length of gear) would be similar for both. A key difference is that gear is deployed perpendicular to shore in BsM surveys, but at random orientations in NORDIC surveys. Though this may influence encounter rates, I was unable to find any previous studies that have quantified this effect. However, it seems more probable that differences in the fish captured would be related more to retention rates than to encounter rates. Upon encounter and contact, fish are retained in the net through two processes – wedging and tangling. Wedging occurs when a fish becomes lodged after passage of its head but not its mid-body through the mesh, whereas tangling involves more superficial retention on teeth, maxillae, spines, or other external features (Millner 1985). The relative importance of these two processes depends on both the characteristics of the gear, and the morphology and behaviour of the fish.

Gill net structure influences the selectivity of retention in terms of the size, species, and numbers of fish that are captured (Appelberg 2000; McClanahan & Mangi 2004; Hayes *et al.* 2007). This selectivity is driven by various net characteristics including mesh size, twine attributes, hanging ratio, and net anchorage (Hamley 1975), and of these, mesh size is believed to be one of the more influential factors (Holst *et al.* 1998). I worked from the assumption that differences in mesh sizes was the primary factor leading to differences in the data generated in this study. In boreal lakes, large-mesh gear captures almost exclusively large-bodied fish, whereas small-mesh gear primarily captures small-bodied fish by wedging, but also large-bodied fish by tangling. My analysis of body size distributions indicated that large fish are captured in the ON2 gear, the gear that is exclusively small-mesh. As the largest mesh in ON2 gear is only 38 mm, any captured fish exceeding 1 kg in size were probably tangled. While the BsM gear, NA1 and ON2 combined, has a wider range of mesh sizes, the NORDIC gear has a higher proportion of small mesh. Thus, it is not surprising that species richness and relative abundance (NPUE and BPUE) estimates for small-bodied fish were higher in NORDIC surveys, or that NORDIC surveys had a higher proportion of their biomass distribution in the smaller size categories. Small-bodied fish species comprise a large proportion of the aquatic biodiversity in boreal lakes and therefore a higher proportion of small mesh would be advantageous to detecting a greater number of species within a survey, or better characterizing the forage fish community. My results suggest that NRD and ON2 gears would serve this function equally well.

Twine characteristics have also been shown to influence selectivity of gill nets (Hamley 1975; Millner 1985; Yokota *et al.* 2001; Grati *et al.* 2015). The visibility of the twine can influence fish avoidance behaviour, and the flexibility and texture of the twine can influence how well a net holds fish following contact. Both depend on the composition and thickness of the twine. In terms of twine composition, it is well known that monofilament gill nets tend to catch more fish than those made of earlier materials, such as multi-filament nylon (Henderson & Nepszy 1992). All gill nets used in the current study were made of clear monofilament, but they differed in twine diameter for larger mesh sizes (≥ 38 mm); NA1 twine is 50-80% thicker than NRD twine at equivalent mesh sizes. Smaller diameter twine is considered more efficient for capturing fish, as it is less visible and reflects less of the pressure wave created by an advancing fish (Millner 1985). Small diameter twine is also more flexible, and this may influence both size and species selectivity of the mesh (Hamley 1975; Millner 1985). There is some evidence that as twine diameter decreases the proportion of fish captured by tangling increases, and the proportion captured by wedging decreases (Hamley 1975; Grati *et al.* 2015). Tangling is considered a less efficient capture method than wedging because the probability of escape is higher in the former (Potter & Pawson 1991; Yokota *et al.* 2001). Overall, for larger mesh sizes, the thicker twine of the NA1 gear may be more visible and cause greater avoidance, and be less efficient at tangling but better at wedging, compared to NRD gear. This may have contributed to some of the differences that I observed. However, the net effect of these differences, and their importance relative to other gear effects cannot be determined in the present study.

Fish capture and retention in gill nets following contact also depends on the tautness of the mesh when the gear is set, which is influenced both by the hanging ratio of the mesh on the lead and float lines, and the amount of weight holding the gear in position. A greater number of fish, across a wider size range may be caught in more loosely hung nets (Hamley 1975). Hanging ratios were identical for all gears used in the current study. However, NA1 and ON2 gears have much heavier lead lines compared to NRD gear, and the former are anchored in place whereas the latter is not. Therefore, mesh panels of NRD gangs are believed to be more supple within the water column and entangle fish more readily.

A final consideration in terms of gear effects is the phenomenon of saturation – the tendency for the effectiveness of gear to change over time as progressively more fish are caught. Reported saturation effects are usually negative, that is, capture rate declines as catch increases (Hamley 1975; Holst *et al.* 1998; Rotherham *et al.* 2006). This is probably because nets become more visible as the number of captured fish increases, causing avoidance (Hamley 1975; Holst *et al.* 1998; Olin *et al.* 2004), and/or because captured fish distort the adjacent mesh pattern making the panels less effective (Olin *et al.* 2004). While this does not appear to influence species richness or size distributions, it can lead to underestimation of relative abundance (Olin *et al.* 2004; Prchalova *et al.* 2013). Alternatively, in some circumstances, fish captured in a gill net may actually attract other fish and increase their susceptibility to capture. For example, piscivorous fishes may be attracted to smaller fish held in the net, and become entangled trying to engulf them. It is unknown how saturation or baiting effects vary among the three gear types used in the current study, and how they may have influenced my results.

Environmental effects

It is recognized that environmental conditions can influence the performance of sampling gears, including gill nets (Hansson & Rudstam 1995; Holst *et al.* 1998; Linløkken & Haugen 2006; Deceliere-Vergès *et al.* 2009; Achleitner *et al.* 2012). Less is known about how environmental conditions may differentially influence sampling methods (i.e., method x environment interaction). Numerous environmental factors could have influenced the relative performance of the two protocols and three gears that I examined in this study. These could be physical, chemical or biological in nature, and spatial or temporal in scale. I tested for potential interactive effects of several physical variables in a subset of my analyses. I found that differences in fish community metrics between the NORDIC and BsM surveys were not generally related to the area, depth, or water clarity of my study lakes, with the exception that BPUE differences were weakly but significantly related to lake maximum depth.

I tested for the possible effects of ecosystem size, represented by area and depth, on differences between NORDIC and BsM surveys because BsM effort changes qualitatively with increasing lake size. Specifically, the relative proportions of NA1 and ON2 effort varied with lake size, particularly depth, because only NA1 gear was deployed below 20 m depth. The observed trend between the relative difference in BPUE estimates of the surveys and lake maximum depth was most likely a result of this stratification of effort. The BsM protocol was modified starting in 2013 to include ON2 sets below 20 m depth (Sandstrom *et al.* 2013) and it is expected that this will reduce the effect of lake depth on relative differences in BPUE between NORDIC and BsM surveys.

I did not detect any significant effect of water clarity, inferred from Secchi depth, on the relative performances of the protocols or gears. I tested for this effect due to the possible differential influence of water clarity on gear visibility and avoidance behaviour. A number of studies have identified that water clarity can affect CPUE and gear selectivity (Hansson & Rudstam 1995; Deceliere-Vergès *et al.* 2009). However, potentially confounding this effect is the role of lake productivity; lakes with higher water clarity also tend to be lakes of lower productivity (i.e., more oligotrophic) with lower standing stocks of fish. My expectation was that any differences in gear avoidance between surveys due to water clarity would diminish as water clarity decreased. Secchi depths ranged from 2.2 to 13.7 m across my 21 study lakes, a seemingly wide range in clarity. The lack of any strong effect suggests little difference in avoidance behaviour towards the gears, possibly because much of the soak time was overnight. It is possible that water clarity effects, if they exist, would be stronger and easier to detect in daytime sampling.

Fish community effects

Some of the variation that I observed between surveys and gears was probably due to temporal differences in the fish community. That is, on each lake, the fish community differed in some respects between the time when the NORDIC survey was conducted and the time when the BsM survey was conducted. These temporal effects could be short- or long-term. In the short-term, seasonal changes in water temperature, dissolved oxygen, photoperiod, and prey resources can affect spatial distributions and movements of fish (Pope & Willis 1996). In this study, all surveys were carried out during the summer stratified period, and this presumably minimized the seasonal variation effect. In the longer-term, fish communities change over years and decades in various ways including species introductions and extirpations, cascading effects (e.g., shifts in forage fish abundance following shifts in predator abundance), and changes in fisheries harvest. The time between NORDIC and BsM surveys in this study was quite variable (range 1 – 10 years), with BsM surveys generally conducted more recently. However, the magnitudes and directions of any community shifts over these time periods are impossible to quantify, and it is unlikely that these would follow any systematic pattern across the 21 study lakes. Thus, any temporal variation in fish community structure would simply add to the random variation observed, and would make my tests more conservative but probably not bias my results.

The magnitude of the difference in survey or gear comparisons may also depend on characteristics of the fish community. I found that differences between surveys and gears in some of my analyses were less pronounced in NWT lakes than in Ontario lakes. This trend may be due, in part, to the relatively short time between NORDIC and BsM surveys for NWT lakes (3 years) that presumably minimized temporal variation effects. However, I feel that this trend primarily arises from differences in fish community composition between regions. Compared to the survey lakes in Ontario, the NWT lakes have fewer species, including some key Ontario species such as Yellow Perch and White Sucker, and have relatively high predator abundances and low forage fish abundances. Consequently, fish communities of NWT lakes tend to be simpler and skewed towards large-bodied fishes. Because the major differences in community interpretations between NORDIC and BsM surveys probably arise from the higher proportional effort of small mesh in the former, I feel that differences between the surveys are probably less evident where catches in small mesh are lower.

Conclusions and recommendations

My study demonstrates that interpretations of fish community structure, relative abundance and biomass distributions will differ between surveys conducted following the NORDIC and BsM protocols. In short, the NORDIC protocol dedicates relatively more effort to gear that is small-mesh, thin twine, and loosely anchored compared to the BsM protocol. The net effect of these differences is that the NORDIC protocol is more selective towards small-bodied fish, and because of this tends to detect more species, whereas the BsM protocol is more selective towards large-bodied fish. However, the two protocols may provide more similar results for some comparisons in lightly-exploited, predator-rich systems. When the NORDIC gear is compared against the BsM component gears, NA1 and ON2, it is apparent that ON2 gear performs very similarly to NRD gear in many respects, and it is likely that the increase in ON2 effort in BsM surveys initiated in

2013 (Sandstrom *et al.* 2013) will lead to greater similarities in survey results between the protocols.

What recommendations can be made to fish researchers and managers planning to carry out fish community surveys of boreal lakes in future? Choosing a survey to conduct a research or monitoring program is always an exercise in compromise. Choices must be made based on study objectives, spatial and temporal scope, data requirements, the types of communities of interest, and budget constraints. Both the NORDIC and BsM protocols were designed to survey entire fish communities; neither was designed to target rare species. Because much of fish species diversity is found in small-bodied species, a NORDIC survey would be recommended where biodiversity assessment is the primary objective, and because most species of interest to fishers are large-bodied, a BsM survey would be recommended for fisheries management objectives. If both are important, I would recommend a BsM survey with supplemental ON2 effort. Availability of historic data for comparison will also be a consideration for some studies; researchers may prefer to use previously used methods to maintain consistency. The NORDIC protocol remains the most widely used standard for fish community surveys in Europe, whereas the BsM protocol, and NA1 gear in particular, is gaining in popularity in North America. The BsM protocol has been the Ontario standard for fish community assessments since 2008 and is recommended in the NWT by the Cumulative Impact Monitoring Program. Finally, cost must be considered. A quick comparison of the costs to conduct both surveys on small, medium and large lakes indicated that regardless of lake size, the NORDIC survey was more expensive to conduct (Appendix I). The largest contributor to the difference in cost is the shorter lifespan of the NRD gear.

Based on my findings, I make the following recommendations for future research on these, and other, fish community survey methods. First, conversion factors should be developed to ‘translate’ results from NORDIC to BsM (or vice versa, as required) to bridge between data sets generated by the different protocols and gears. This will extend the usefulness of the data across spatial and temporal scales. Second, it would be informative to compare the gears using an experimental design that better controls for temporal effects. This could be achieved through a study using an interspersed survey design, where the various gears are deployed within the same survey period for each lake. Third, paired-comparisons should be made between results from the first cycle of Ontario BsM surveys (2008-2012, the data used in the current study) and results from the same lakes during the second cycle (2013-2017). Such a comparison could be used to assess how the protocol change in ON2 depth deployment from 2013 onwards influenced community metrics. Finally, further comparisons of the two protocols on lightly-exploited lakes with climax predator populations would help to confirm if the similarity between protocols observed on NWT lakes was particular to that region, or common to other climax fish populations.

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Appendix I – Cost Comparison

I compared the costs of conducting each survey on eight small, medium and large lakes. The data set analysed (n = 21 lakes) was used to define lake size (Figure 20: small, < 200 ha; medium, 200-800 ha; large, > 800 ha), and to determine the mean number of nets deployed per day and the mean number of days per survey for each size of lake (Table 22). These calculations were rounded to the nearest whole number and were included in the summation of costs to conduct each survey. Financial considerations included the cost of gear to conduct a survey (NRD nets, NA1 and ON2 straps), floats, anchors and salary. Supplies (e.g., fuel), food, lodging, transportation, and overtime wages were not included in the calculations. I assumed mean lifespans of 2-3 lake surveys for NORDIC and ON2 gears, and 6-8 lake surveys for NA1 gear (A. Corston, MNRF, pers. comm.). To account for the differences in expected lifespan of the gears, costs were weighted by the frequency of replacement within an 8 lake survey program.

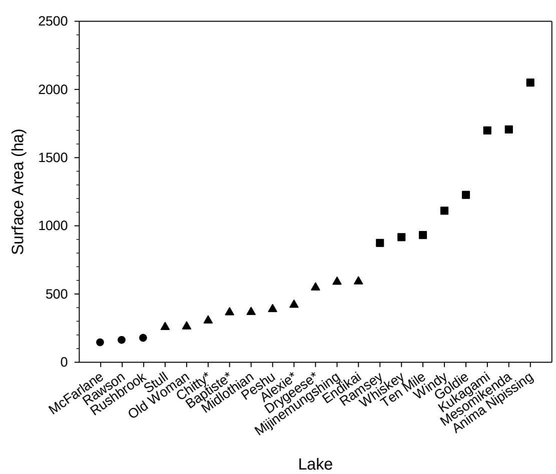


Figure 20: Classification of lake size based on surface area (ha). All lakes are located in Ontario, Canada, except for four lakes (indicated by *) located in the Northwest Territories, Canada. Circles denote small lakes (< 200 ha), triangles denote medium-sized lakes (200-800 ha), and boxes denote large lakes (> 800 ha).

Costs of the nets, floats and anchors were obtained from *Lakefish Net and Twine,* a fishing equipment retailer in Winnipeg, MB. In order to complete the cost estimates, the following assumptions were made: a four person team would conduct each survey, deploying, retrieving and processing the mean number of nets per day identified for each protocol (Table 22); each person was paid $20.00/hr, 8 hrs/day.

Table 22: Mean surface area (ha), number of days and number of nets deployed per day to complete NORDIC and BsM surveys in lakes of this study (n=21).

Lake Size		Mean Surface	Mean days/survey		Mean nets/day	
Classification	n	Area (ha)	BsM	NORDIC	BsM	NORDIC
Small	3	158	4.0	4.7	5.4	7.3
Medium	10	409	4.7	5.7	5.3	8.3
Large	8	1315	5.5	6.6	6.7	9.0

The gear is the single largest contributor to the discrepancy in costs between the surveys, with the NRD gear costing roughly 75% more than the NA1 and ON2 gears combined, regardless of the size of the lake that is surveyed (Table 23). NORDIC surveys also require more time to complete. On average, NORDIC surveys require 15% more time to conduct than BsM surveys (Figure 21), and 25-35% more nets are deployed each day. A logical financial consequence of setting a greater number of nets per day is increased costs associated with overtime, however these costs are not considered in this comparison.

Table 23: Comparison of costs to conduct BsM and NORDIC surveys on 8 small, medium and large sized lakes.

		BsM		NORDIC	
Item	**Lifespan Weighting**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**
Small Lake (<200 ha)					
NRD nets	2.67	-	-	7	16,240.00
NA1 nets	1	6	1,188.00	-	-
ON2 nets	2.67	6	2,944.00	-	-
Anchors		12	299.88	-	-
Buoys		12	108.00	14	126.00
People		4	2,560.00	4	3,200.00
Total			7,099.88		19,566.00
Medium Lake (200-600 ha)					
NRD nets	4	-	-	8	27,840.00
NA1 nets	1.14	6	1,357.71	-	-
ON2 nets	4	6	4,416.00	-	-
Anchors		12	299.88	-	-
Buoys		12	108.00	16	144.00
People		4	3,200.00	4	3,840.00
Total			9,381.59		31,824.00
Large Lake (>600 ha)					
NRD nets	4	-	-	9	31,320.00
NA1 nets	1.33	8	2,112.00	-	-
ON2 nets	4	8	5,888.00	-	-
Anchors		16	399.84	-	-
Buoys		16	144.00	18	162.00
People		4	3,840.00	4	4,480.00
Total			12,383.84		35,962.00

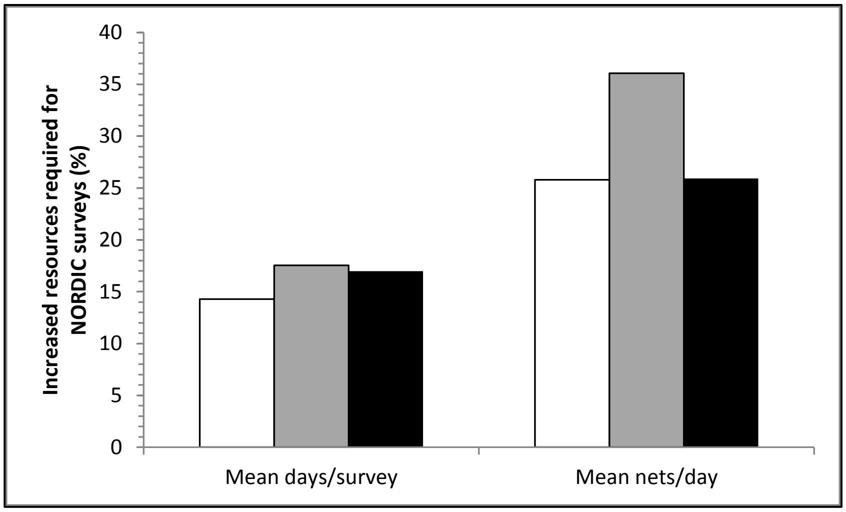


Figure 21: Mean additional effort required to conduct NORDIC surveys relative to BsM surveys for small (white), medium (grey) and large (black) lakes.

Appendix II – Brief Description of McFarlane Lake NORDIC surveys

McFarlane Lake was surveyed using the NORDIC protocol in 2003 and 2004. In both years, 32 NORDIC nets were deployed. In 2003, the survey was conducted from July 20th to 23rd, and twelve fish species were detected ranging in fork length from 36 to 565 mm and in round weight from 0.5 to 2400 g (Figure 22). Mean fork length was 157 mm (n=601) and mean round weight was 13 g (n=583).

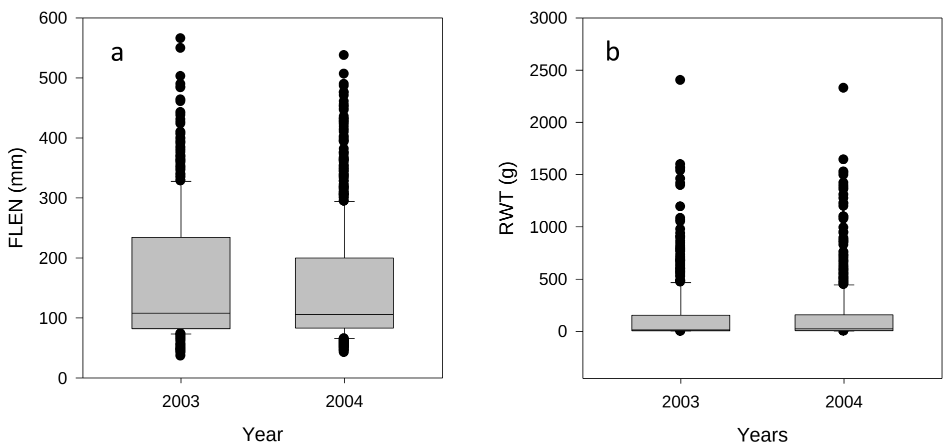


Figure 22: Box plots of (a) fork length (FLEN, mm), and (b) round weight (RWT, g) for all fish captured in the 2003 and 2004 NORDIC surveys of McFarlane Lake.

In 2004, the survey was conducted from August 17th to 20th. One additional species, Emerald Shiner (*Notropis atherinoides*), was captured in addition to all species that were captured in 2003. Fish captured ranged in fork length from 42 to 537 mm, and in round weight from 0.9 to 2324 g (Figure 22). Mean fork length was 152 mm (n=1000) and mean round weight was 143 g (n=841).

Appendix III – Survey Dates

Table 24: Dates that the NORDIC and BsM surveys were conducted on each of the study lakes.

	NORDIC		BsM	
Lake	**Year**	**Dates**	**Year**	**Dates**
Alexie*	2008	Aug 18-23	2011	Aug 19-23
Anima Nipissing	2012	Sept 4-9	2009	July 6-14
Baptiste*	2008	Aug 23-28	2011	Aug 16-19
Chitty*	2008	Aug 18-22	2011	Aug 20-23
Drygeese*	2008	Aug 23-27	2011	Aug 16-20
Endikai	2008	July 14-19	2009	Aug 19-24
Goldie	2011	July 23-28	2012	July 8-12
Kukagami	2003	Aug 18-21, 25-29	2010	Aug 4-9
McFarlane	2003	July 20-24	2010	July 26-29
McFarlane	2004	Aug 17-21	-	-
Mesomikenda	2012	June 25-30, July 2	2010	June 9-12
Midlothian	2008	June 22-27	2011	July 5-8
Mijinemungshing	2003	July 13-18	2008	July 12-16
Old Woman	2004	Aug 3-7	2008	Sept 2-6
Peshu	2008	July 21-26	2011	July 18-22
Ramsey	2005	July 6-8, 11-14	2011	June 13-17
Rawson	2003	Aug 18-22	2010	July 25-28
Rushbrook	2002	Aug 26-29	2010	June 27-30
Stull	2009	Sept 21-25	2012	Sept 18-20
Ten Mile	2003	July 2-9	2011	July 5-10
Whiskey	2002	July 2-5, 8-12	2009	Sept 8-11
Windy	2006	July 4-7	2009	June 23-27, 29-30

* denotes NWT lake

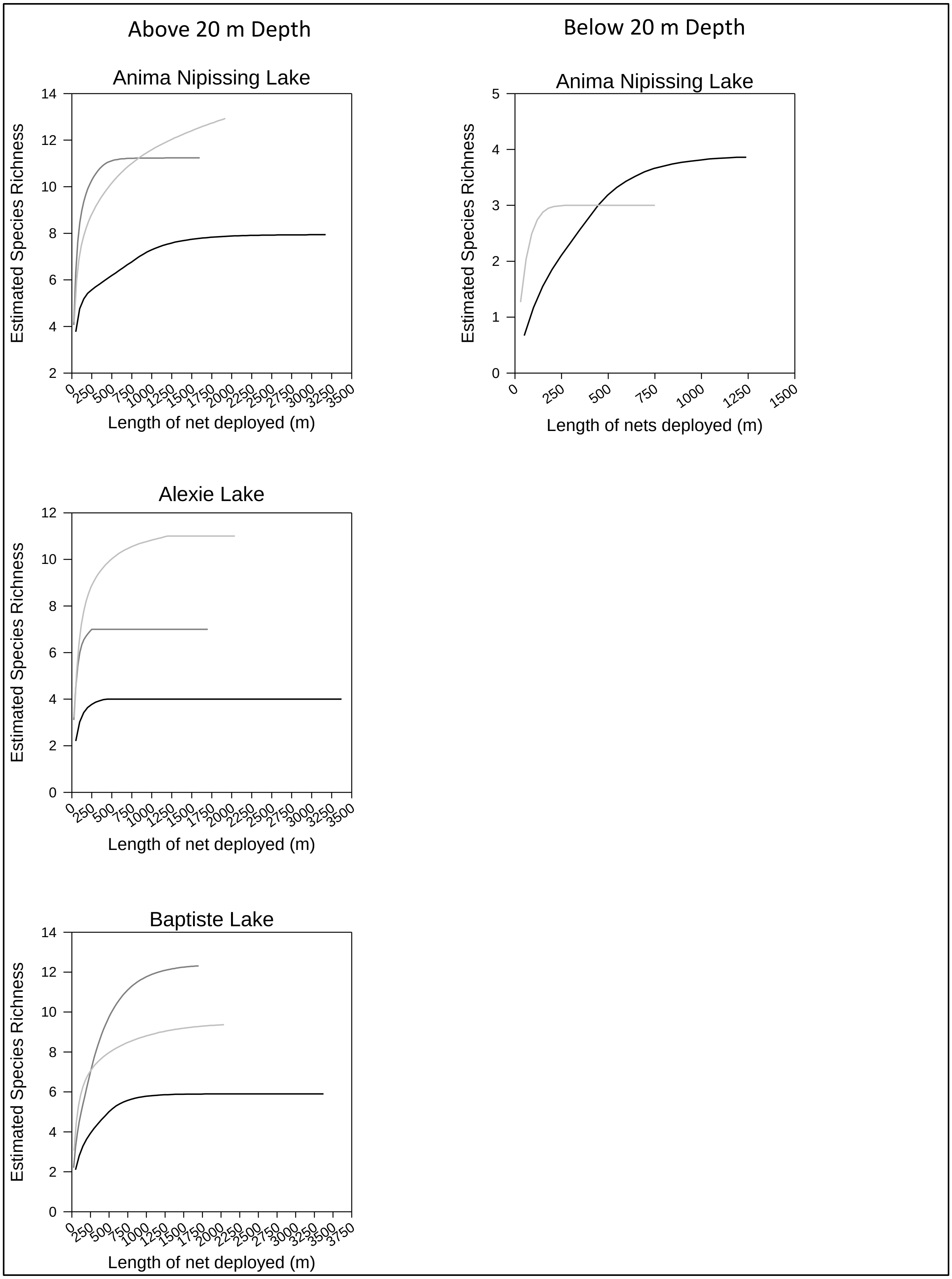
Appendix IV – Species Detected in each Lake

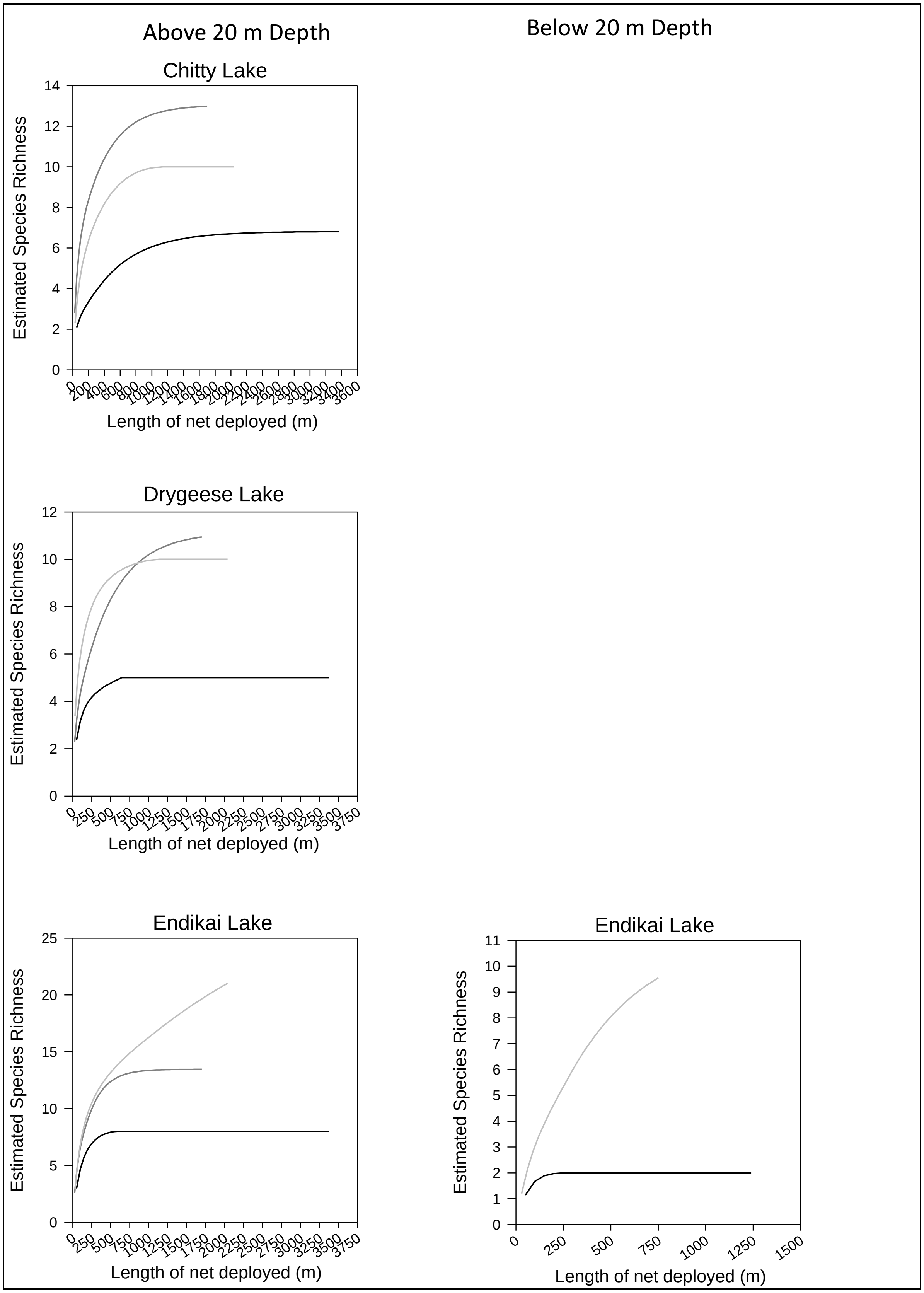
Table 25: Species detected in each study lake. Species codes are listed in Table 4.

Lake	Alexie	AnimaNipissing	Baptiste	Chitty	Drygeese	Endikai	Goldie	Kukagami	McFalane	Mesomikenda	Midlothian	Mijinemungshing	OldWoman	Peshu	Ramsey	Rawson	Rushbrook	Stull	TenMile	Whiskey	Windy
CISC	x		x	x	x	x			x	x	x							x		x	x
LKWH	x	x	x	x	x	x	x	x		x	x			x			x	x			x
RNWH																	x				
BRTR												x	x							x	
LKTR	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x
RNSM						x						x		x						x	
NRPK	x	x	x	x	x	x	x		x	x	x			x	x			x			x
LNSC														x			x		x		x
WHSC		x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SHRH						x															
NRBD																			x		
LKCH	x	x		x		x	x				x	x	x	x		x		x	x		x
CMSH		x				x			x		x	x	x	x			x	x	x	x	
PRDC								x									x				x
GLSH												x		x			x			x	
EMSH									x										x		
BCSH		x										x									
BNSH											x	x		x				x			
SPSH									x	x	x										
SNSH												x									
MMSH						x															
BNMN		x				x						x		x					x	x	
FHMN												x									
BNDC												x									
LNDC													x								
CRCH						x						x	x								
BRBH								x	x						x		x			x	x
BURB	x	x	x	x	x	x	x	x		x	x			x				x	x	x	x
BRST												x		x						x	
NSST	x		x	x	x		x														
TRPR	x		x	x	x		x			x	x			x				x			
RCBS		x				x		x							x				x	x	
PMSD									x					x	x	x					
SMBS		x				x	x	x	x	x					x	x				x	x
LMBS									x												
IWDR											x			x							
YLPR		x				x	x	x	x	x	x			x	x	x	x	x		x	x
LGPR		x				x			x		x										
WALL		x				x	x	x	x	x					x			x		x	x
SLSC	x	x	x	x	x		x			x	x							x	x	x	x
SHSC	x		x		x																x
DWSC	x		x	x	x																

Appendix V - Estimated Species Richness Rarefaction Curves

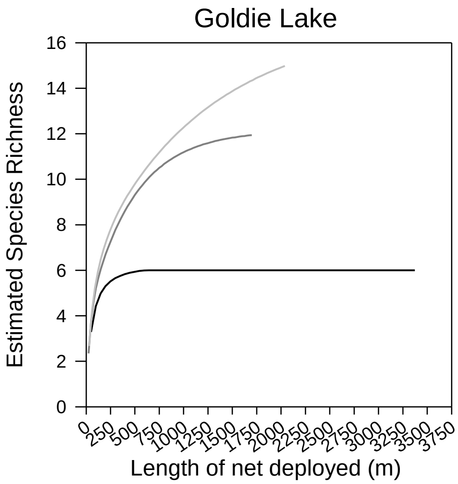
Species richness vs sampling effort relationships (rarefaction curves) were generated using *EstimateS*. The black line represents NA1 gear, the dark grey line represents ON2 gear and the light grey line represents NRD gear. In all panels, the x-axis is the total length of net that was deployed by each gear. As each of the gears are different lengths, and species richness increases with increased sampling, a maximum length of net was chosen at which all gears could be compared in subsequent statistical analyses.

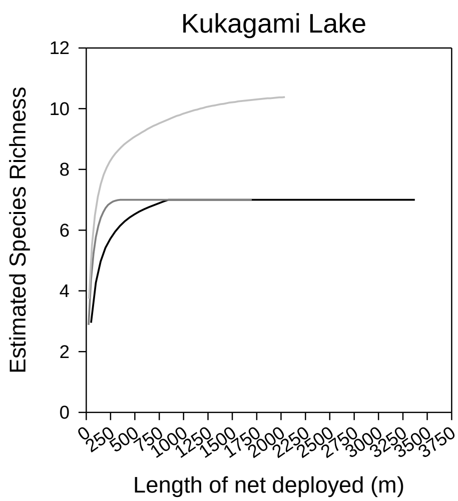

Above 20 m Depth
Below 20 m Depth
Anima Nipissing Lake
Estimated Species Richness
Length of net deployed (m)
Anima Nipissing Lake
Estimated Species Richness
Length of nets deployed (m)
Alexie Lake
Estimated Species Richness
Length of net deployed (m)
Baptiste Lake
Estimated Species Richness
Length of net deployed (m)

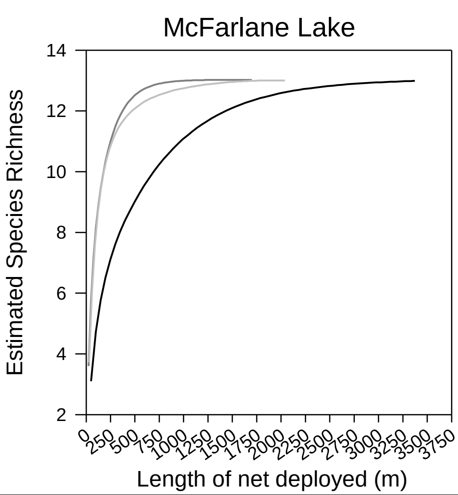

Above 20 m Depth
Below 20 m Depth
Chitty Lake
Estimated Species Richness
Length of net deployed (m)
Drygeese Lake
Estimated Species Richness
Length of net deployed (m)
Endikai Lake
Estimated Species Richness
Length of net deployed (m)
Endikai Lake
Estimated Species Richness
Length of net deployed (m)

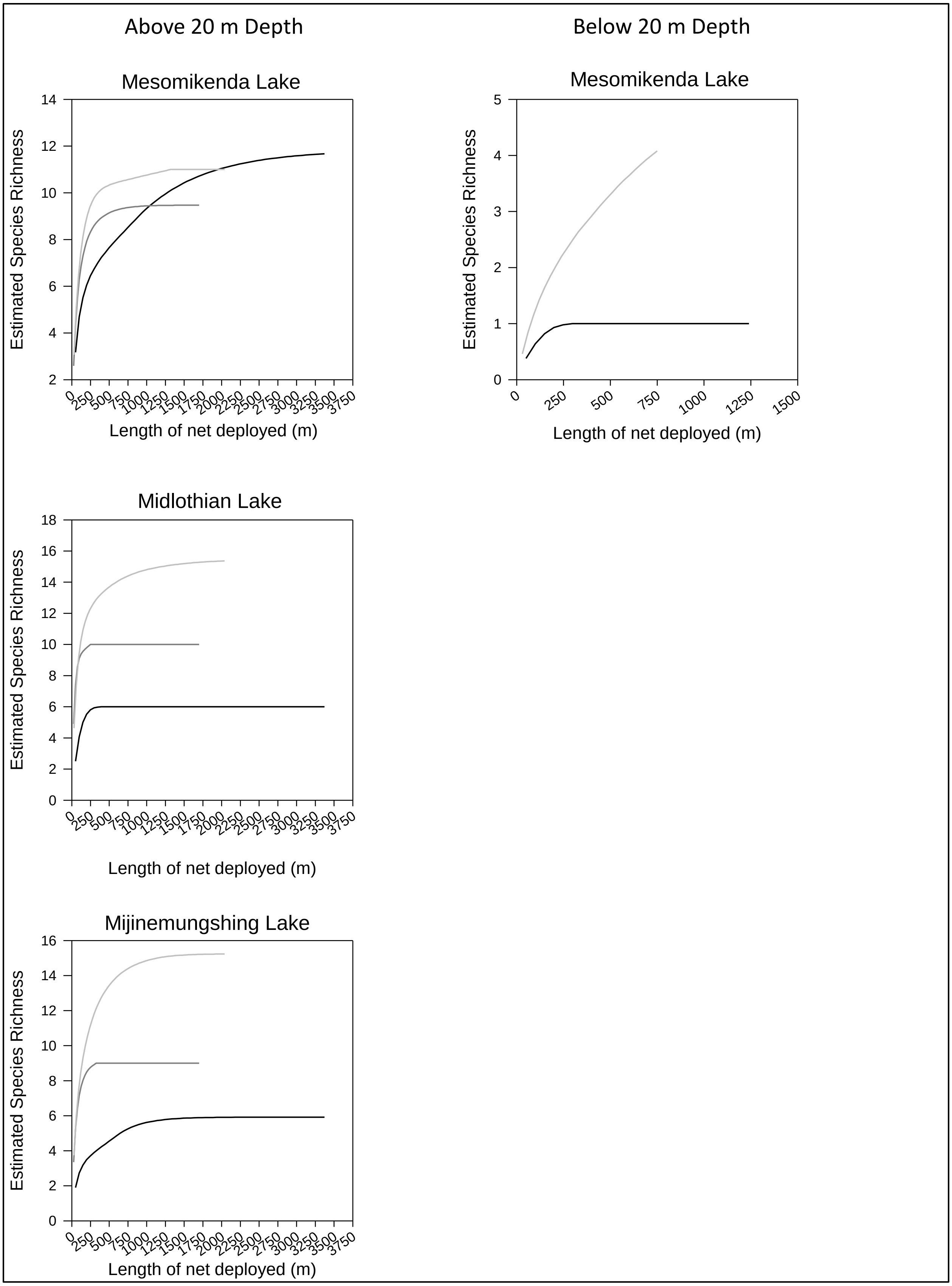
Above 20 m Depth

Below 20 m Depth





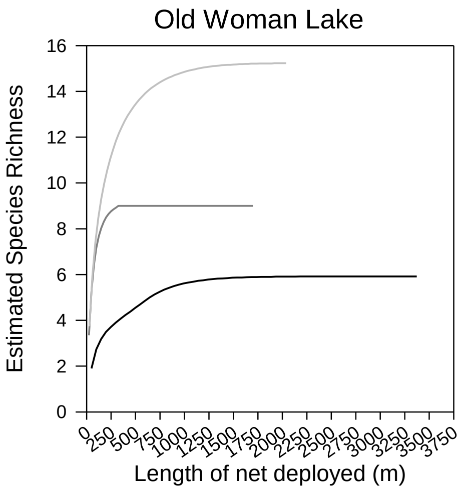


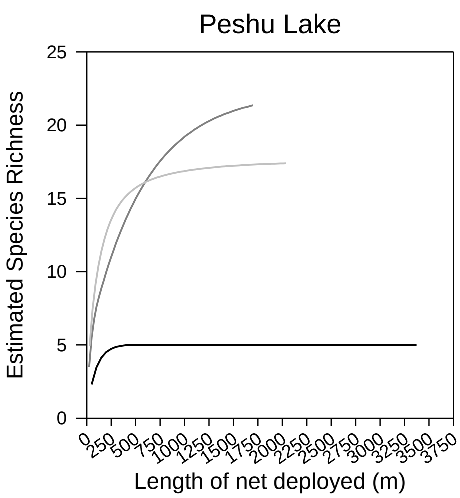


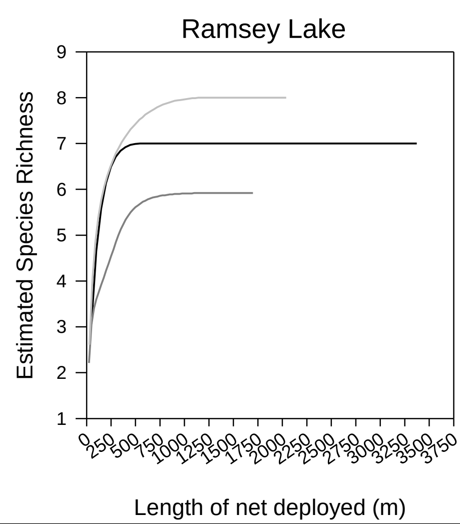
Above 20 m Depth
Below 20 m Depth
Mesomikenda Lake
Midlothian Lake
Mijinemungshing Lake
Estimated Species Richness
Length of net deployed (m)
0 250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000 3250 3500 3750
0 250 500 750 1000 1250 1500

Above 20 m Depth

Below 20 m Depth

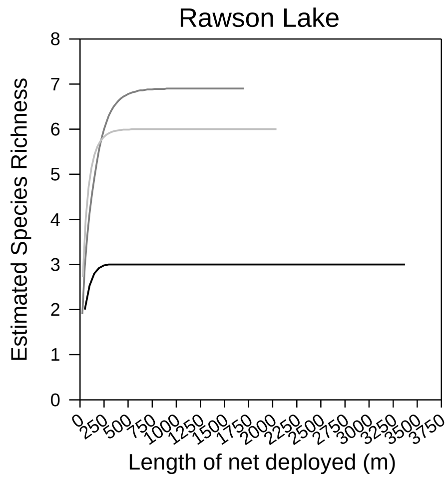


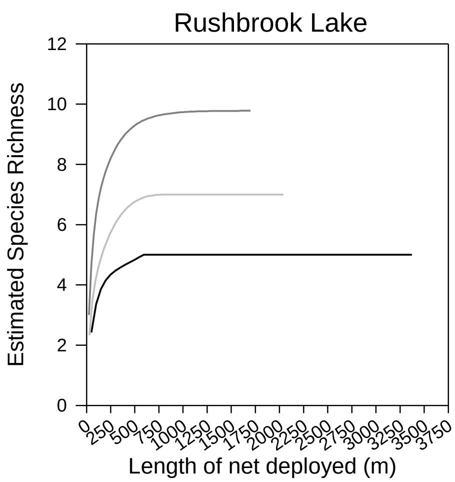


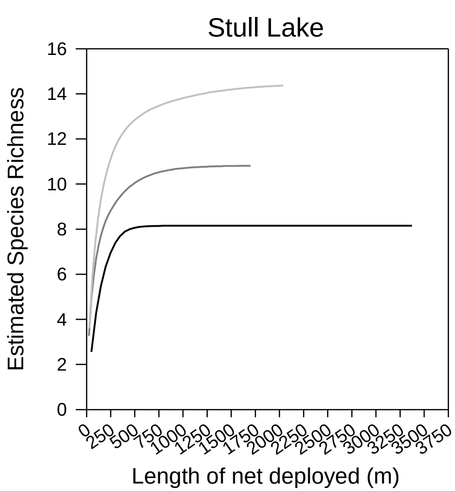


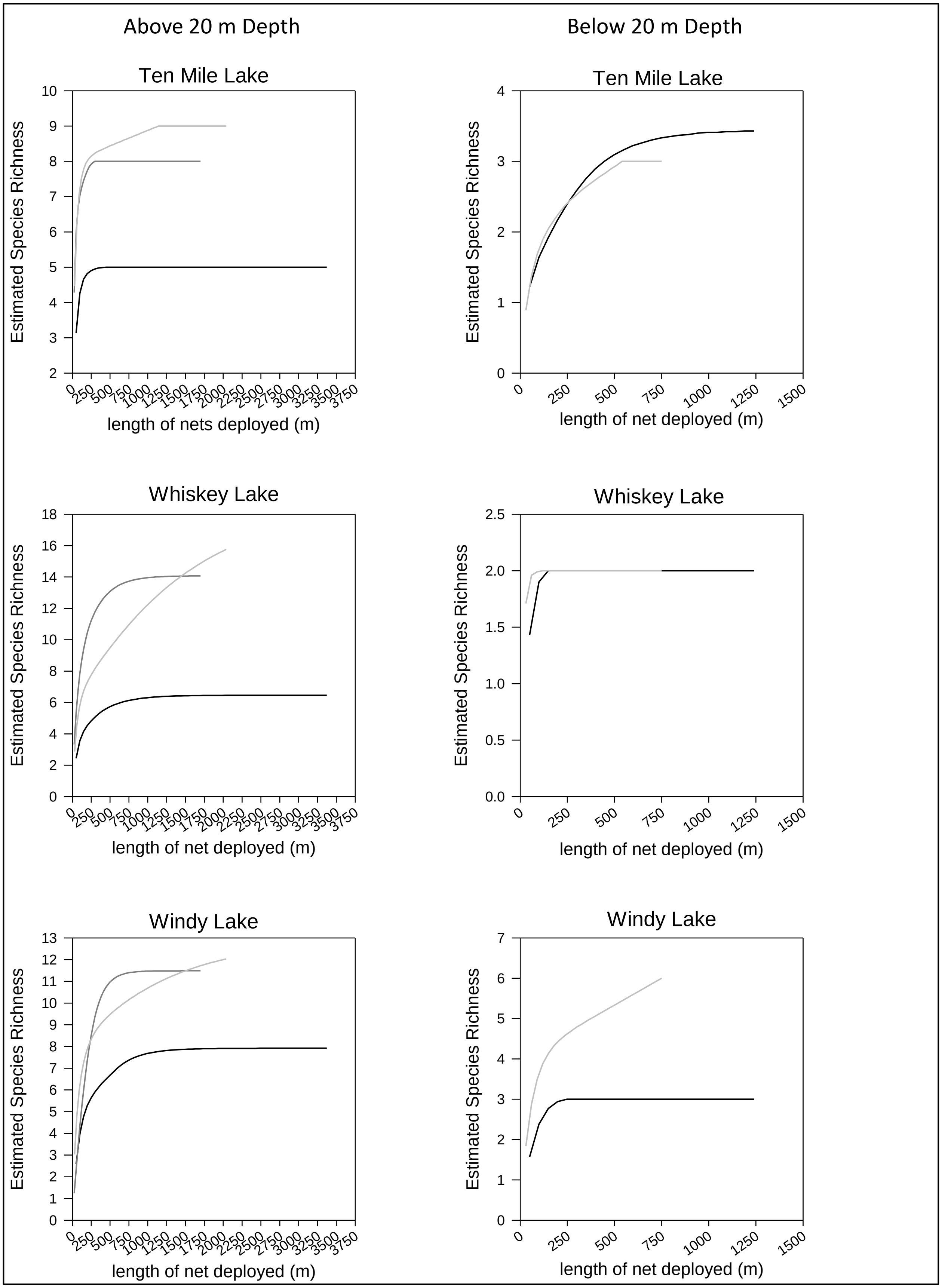
Above 20 m Depth

Below 20 m Depth



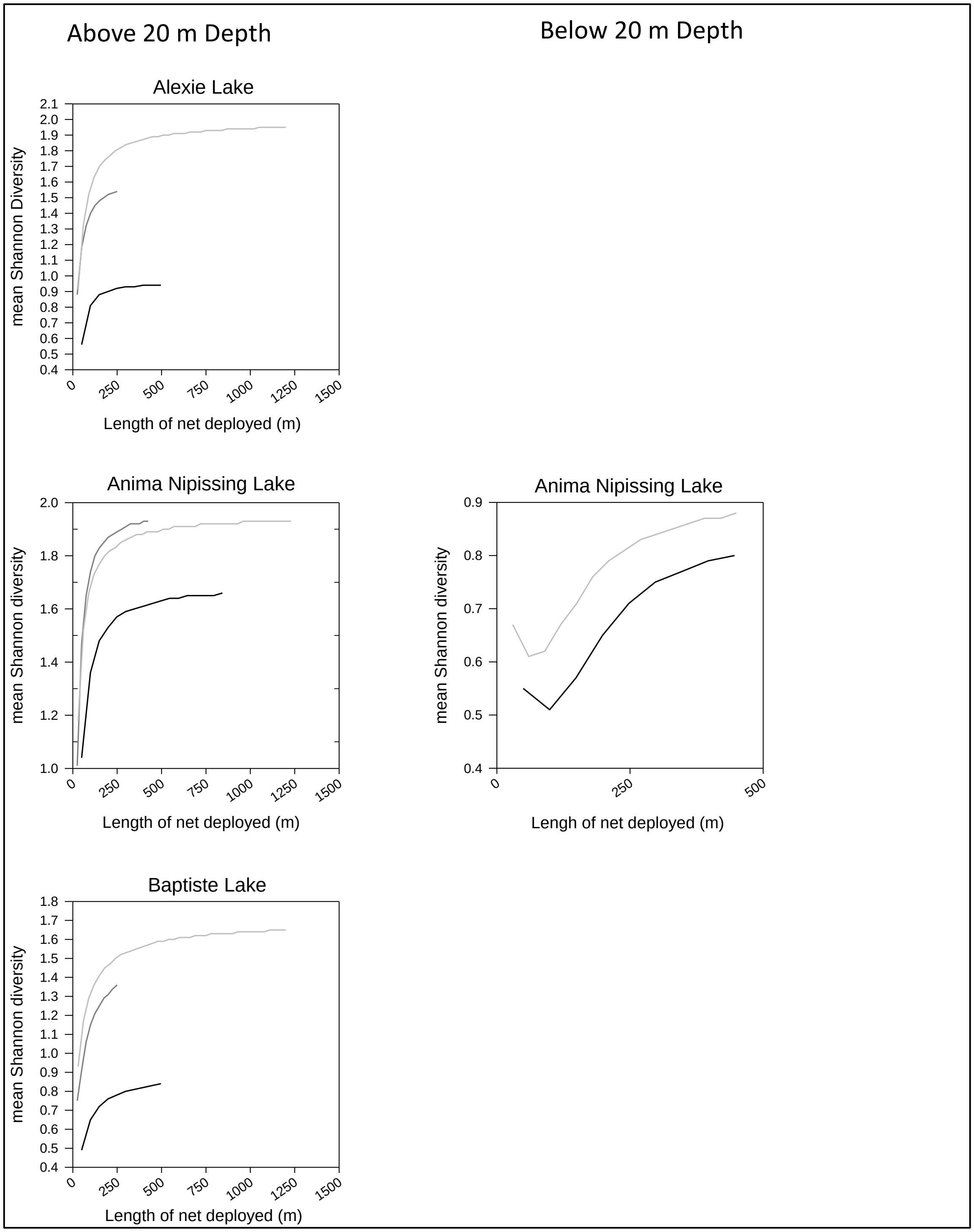


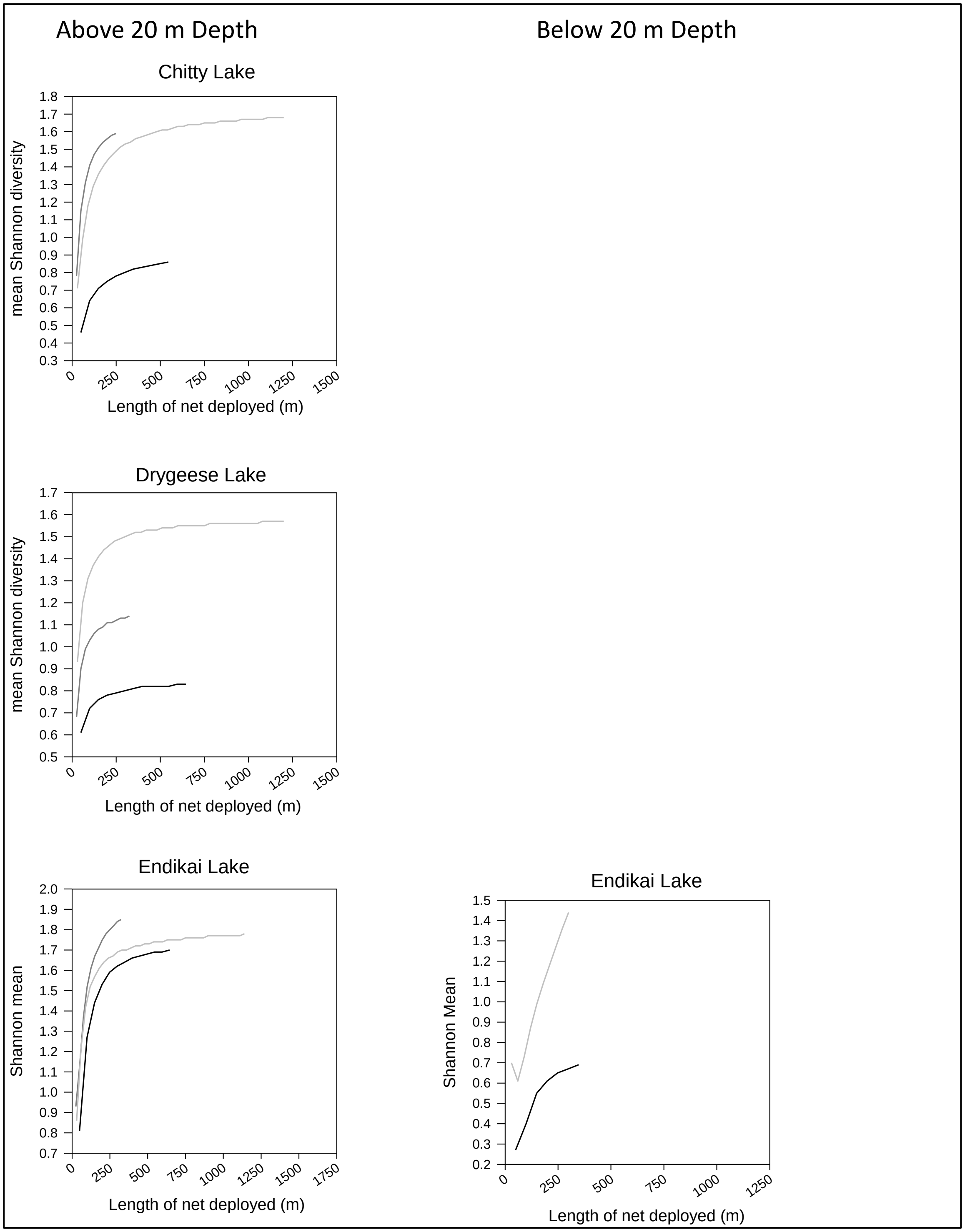



Above 20 m Depth
Below 20 m Depth
Ten Mile Lake
Estimated Species Richness
length of nets deployed (m)
Ten Mile Lake
Estimated Species Richness
length of net deployed (m)
Whiskey Lake
Estimated Species Richness
length of net deployed (m)
Whiskey Lake
Estimated Species Richness
length of net deployed (m)
Windy Lake
Estimated Species Richness
length of net deployed (m)
Windy Lake
Estimated Species Richness
length of net deployed (m)

Appendix VI – Estimated Species Diversity Rarefaction Curves

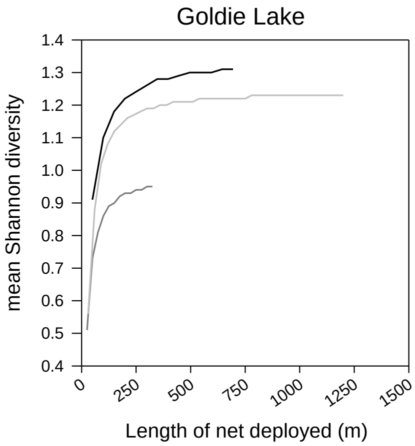
Estimated Shannon mean Diversity vs sampling effort relationships (rarefaction curves) were generated using *EstimateS*. The black line represents NA1 gear, the dark grey line represents ON2 gear and the light grey line represents NRD gear. In all panels, the x-axis is the total length of net that was deployed by each gear. As each of the gears are different lengths, a maximum length of net was chosen at which all gears could be compared in subsequent analyses.

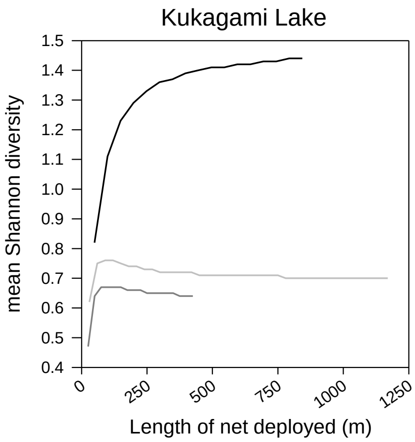

Above 20 m Depth
Below 20 m Depth
Alexie Lake
mean Shannon Diversity
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
250
500
750
1000
1250
1500
Length of net deployed (m)
Anima Nipissing Lake
mean Shannon diversity
2.0
1.8
1.6
1.4
1.2
1.0
0
250
500
750
1000
1250
1500
Length of net deployed (m)
Anima Nipissing Lake
mean Shannon diversity
0.9
0.8
0.7
0.6
0.5
0.4
0
250
500
Lengh of net deployed (m)
Baptiste Lake
mean Shannon diversity
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
250
500
750
1000
1250
1500
Length of net deployed (m)

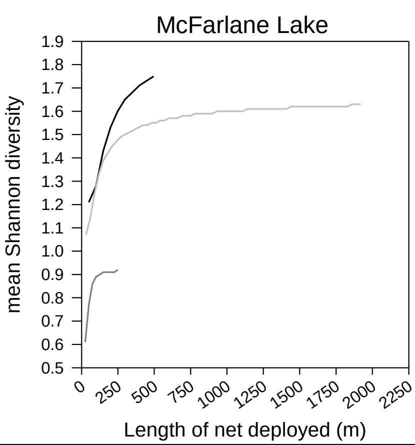

Above 20 m Depth
Below 20 m Depth
Chitty Lake
mean Shannon diversity
Length of net deployed (m)
Drygeese Lake
mean Shannon diversity
Length of net deployed (m)
Endikai Lake
Shannon mean
Length of net deployed (m)
Endikai Lake
Shannon Mean
Length of net deployed (m)

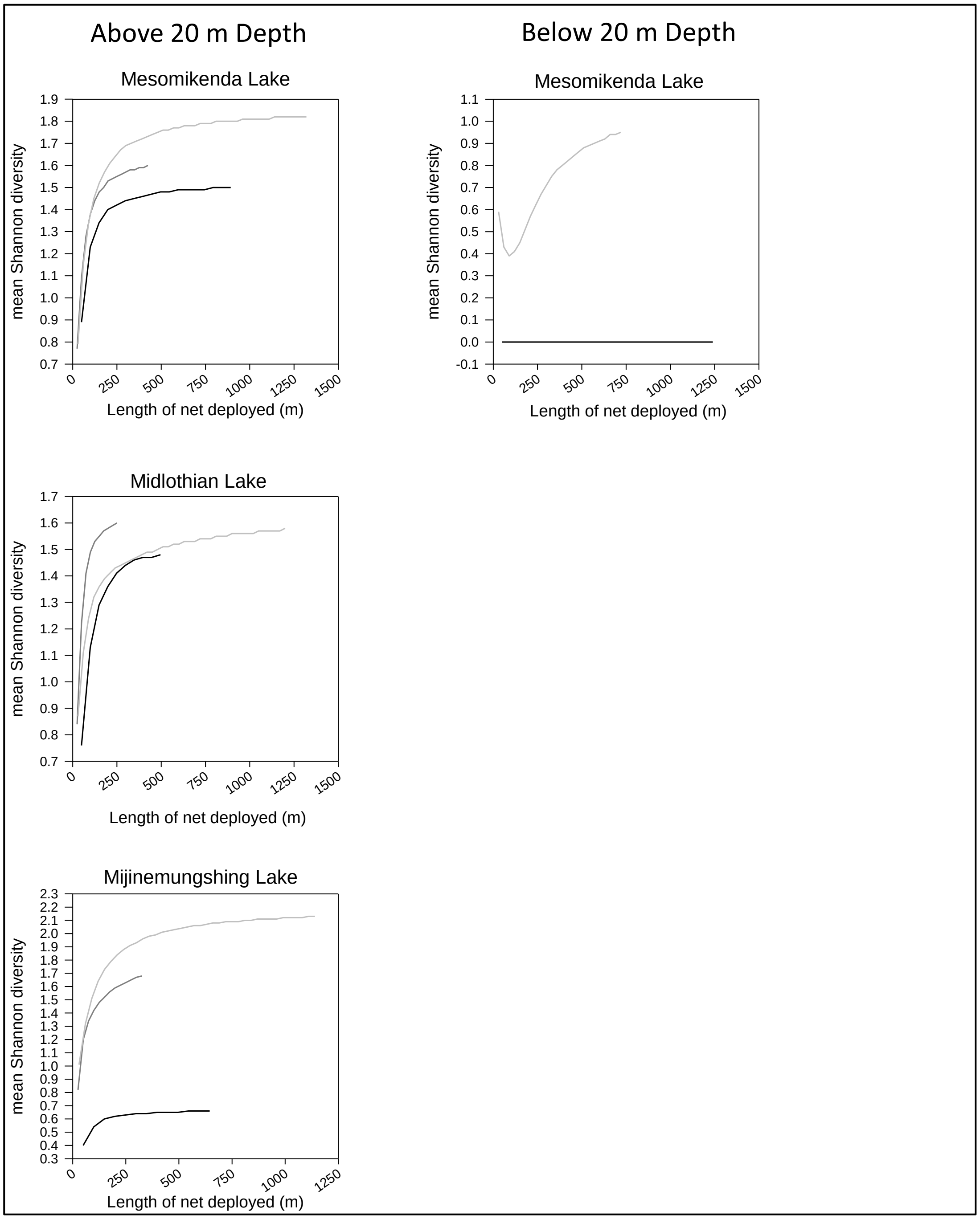
Above 20 m Depth

Below 20 m Depth





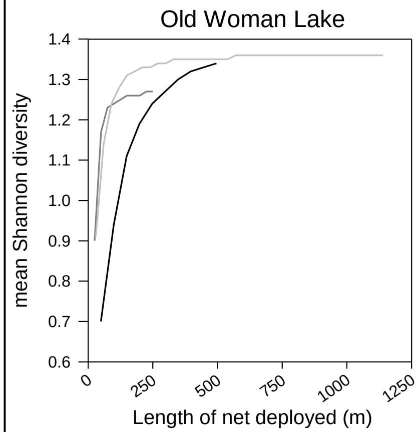


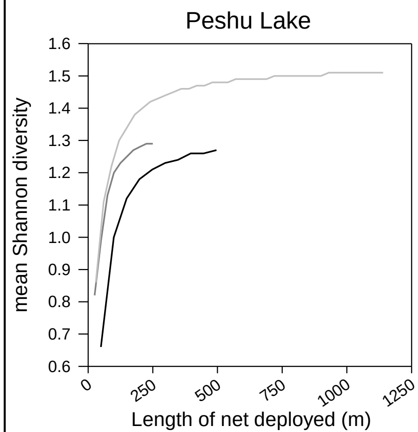


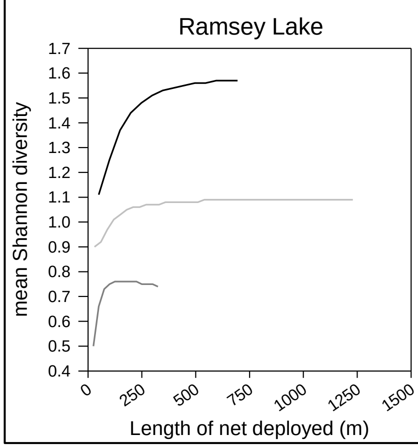
Above 20 m Depth
Below 20 m Depth
Mesomikenda Lake
Mesomikenda Lake
Midlothian Lake
Mijinemungshing Lake
mean Shannon diversity
Length of net deployed (m)

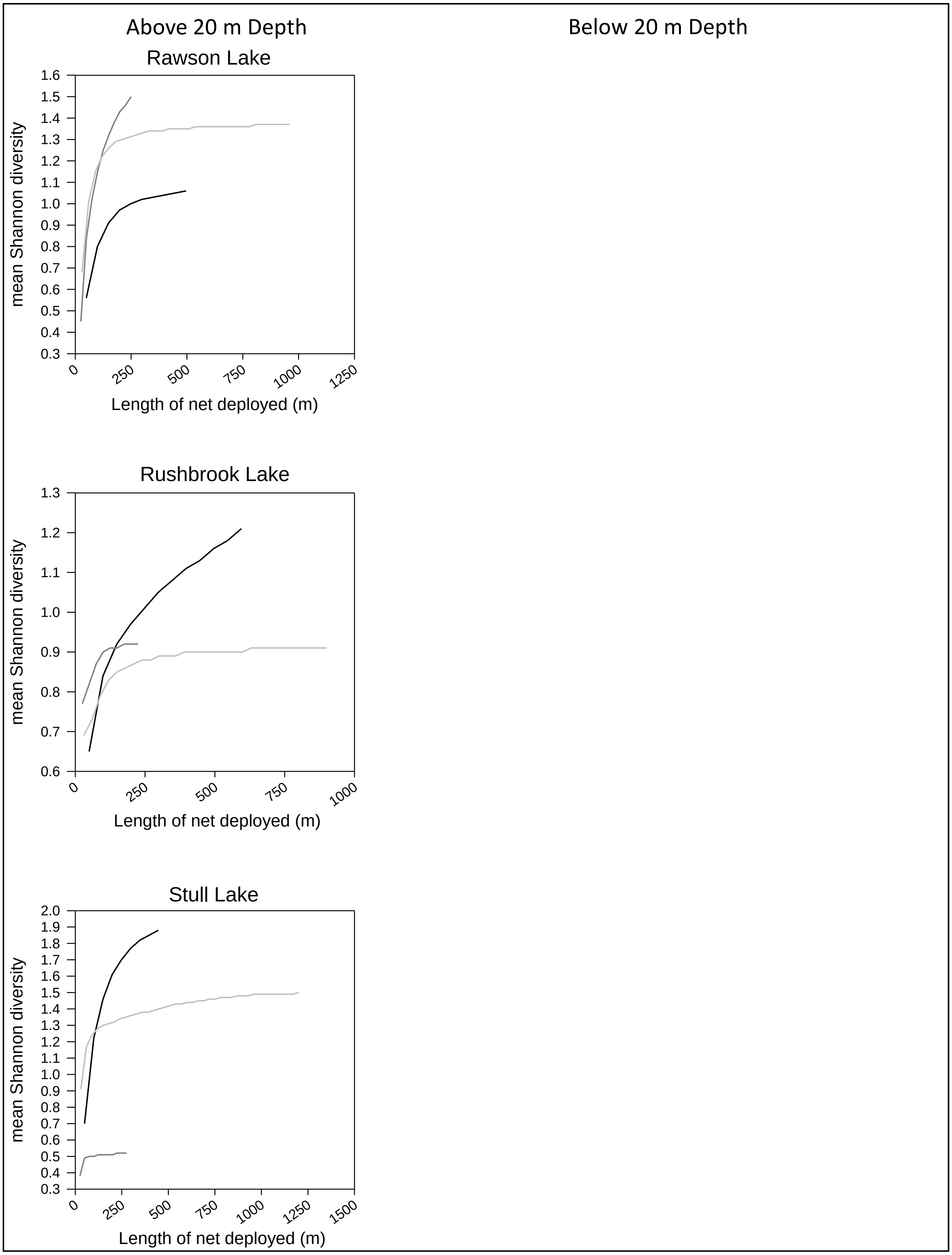
Above 20 m Depth

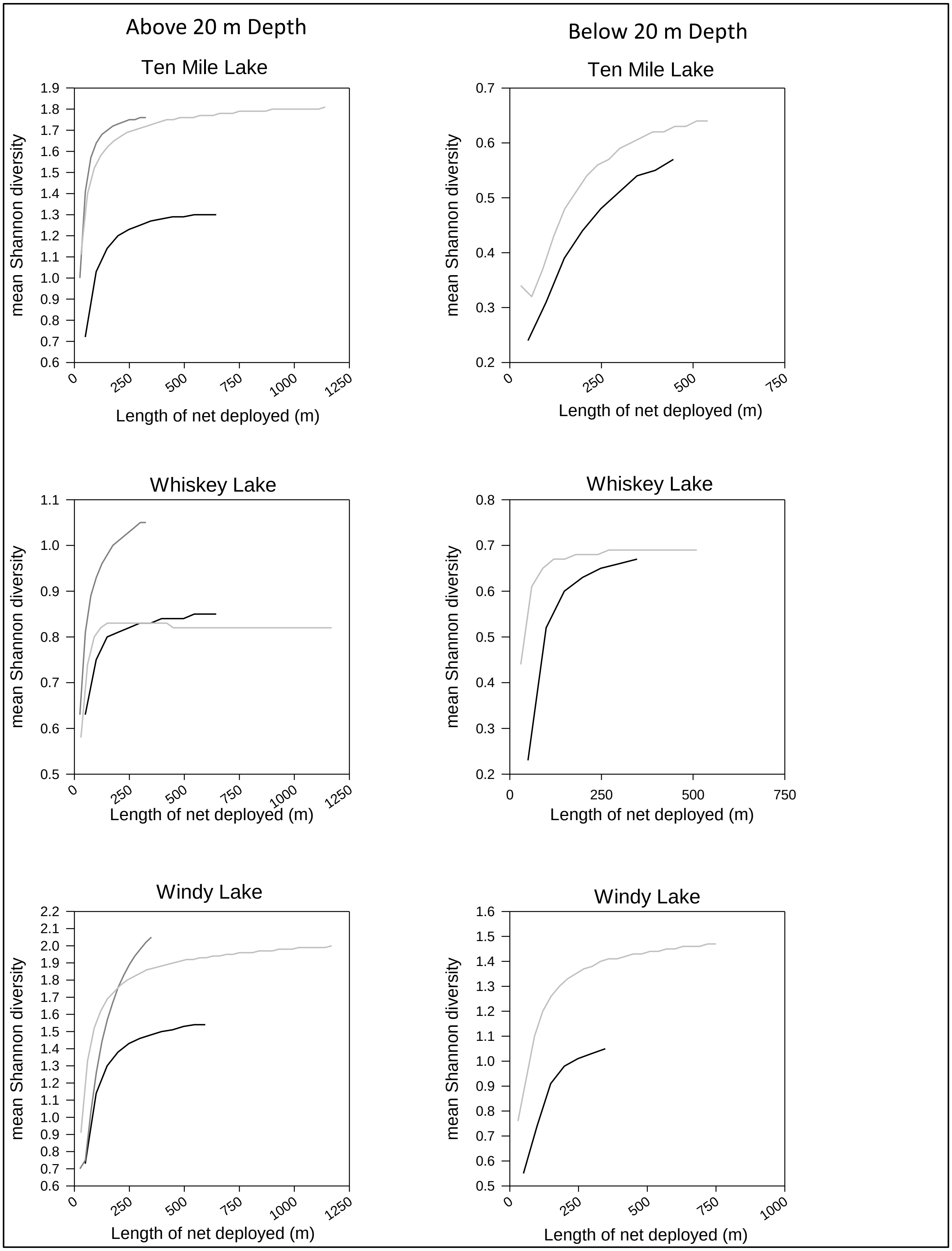
Below 20 m Depth








Above 20 m Depth
Below 20 m Depth
Rawson Lake
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
mean Shannon diversity
0
250
500
750
1000
1250
Length of net deployed (m)
Rushbrook Lake
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
mean Shannon diversity
0
250
500
750
1000
Length of net deployed (m)
Stull Lake
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
mean Shannon diversity
0
250
500
750
1000
1250
1500
Length of net deployed (m)


Above 20 m Depth
Below 20 m Depth
Ten Mile Lake
Ten Mile Lake
Whiskey Lake
Whiskey Lake
Windy Lake
Windy Lake
mean Shannon diversity
Length of net deployed (m)

Appendix VII - Kolmogorov-Smirnov Two-Sample Tests of Biomass Size Distributions

1. Number in parentheses beside species name indicates number of lakes where one or both protocols reported that species.
2. * denotes that the species was found by only one of the gears and a comparison could not be made.

Table 26: Kolmogorov-Smirnov two-sample test results comparing biomass distributions between NORDIC and BsM Surveys for whole communities (All) and individual species. Species codes are listed in Table 4.

	All (21)			NRPK (14)			WALL (10)			BURB (15)		
Lake	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**
Alexie*	87/90	0.57	0.90	93/95	3.29	<.0001				100/98	4.24	<.0001
Anima Nipissing	87/89	1.96	0.00				92/95	1.34	0.06	100/98	4.67	<.0001
Baptiste*	88/87	0.85	0.46	96/95	2.33	<.0001				99/100	7.05	<.0001
Chitty*	85/90	1.67	0.01	90/89	3.11	<.0001				99/99	2.91	<.0001
Drygeese*	89/88	1.17	0.13	97/94	5.02	<.0001				99/98	2.23	<.0001
Endikai	92/88	2.27	<.0001	97/100	7.02	<.0001	96/96	4.40	<.0001	99/96	2.27	<.0001
Goldie	87/89	1.64	0.01	93/96	1.21	0.11	94/96	3.05	<.0001			
Kukagami	88/86	1.82	0.00				89/95	4.14	<.0001	99/94	3.40	<.0001
McFarlane	93/90	2.89	<.0001	99/95	5.50	<.0001	93/96	0.99	0.28			
Mesomikenda	87/91	1.75	0.00	95/95	1.52	0.02	89/93	2.06	0.00	96/97	3.37	<.0001
Midlothian	85/90	2.25	<.0001	97/97	1.79	0.00				99/99	7.04	<.0001
Mijinemungshing	84/90	2.33	<.0001									
Old Woman	93/91	0.40	1.00									
Peshu	91/90	2.80	<.0001	99/99	7.04	<.0001				98/94	2.36	<.0001
Ramsey	87/92	1.73	0.00	95/96	6.11	<.0001	95/97	3.10	<.0001			
Rawson	92/91	1.65	0.01									
Rushbrook	88/93	2.07	0.00									
Stull	90/90	2.31	<.0001	98/95	5.24	<.0001	97/97	4.02	<.0001	98/94	6.50	<.0001
Ten Mile	94/91	1.48	0.02							98/98	4.07	<.0001
Whiskey	88/92	1.87	0.00				98/100	6.17	<.0001			
Windy	91/87	1.01	0.26				94/94	1.52	0.02	98/95	1.41	0.04

	LKTR (19)			LKWH (13)			WHSC (17)			CISC (11)		
Lake	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**	**(%BsM/%NRD)**	**Statistic (KSa)**	**p**
Alexie*	94/91	2.36	<.0001	92/92	0.52	0.95				100/100	0.00	1.00
Anima Nipissing	95/96	2.22	0.00	92/96	1.28	0.08	92/93	1.74	0.00			
Baptiste*	92/90	1.05	0.22	92/92	1.25	0.09				100/100	0.00	1.00
Chitty*	92/99	5.40	<.0001	92/93	0.98	0.30				99/100	3.85	<.0001
Drygeese*	91/91	1.11	0.17	88/90	1.47	0.03				100/99	1.00	0.27
Endikai	96/95	1.21	0.11	99/99	3.27	<.0001	96/93	2.36	<.0001			
Goldie	98/98	2.29	<.0001	94/95	1.87	0.00	95/96	1.89	0.00			
Kukagami	92/89	3.33	<.0001	94/94	1.53	0.02	91/93	1.86	0.00			
McFarlane							95/91	1.80	0.00	99/97	5.99	<.0001
Mesomikenda				94/97	3.53	<.0001	91/96	1.28	0.07	100/100	0.00	1.00
Midlothian	94/92	4.84	<.0001				96/95	1.48	0.03	100/100	0.00	1.00
Mijinemungshing	89/90	4.67	<.0001				92/95	3.07	<.0001			
Old Woman	95/93	0.97	0.31				96/95	1.58	0.01			
Peshu	97/98	5.97	<.0001	98/96	2.92	<.0001	94/94	1.68	0.01			
Ramsey							88/93	1.58	0.01			
Rawson	96/97	3.64	<.0001				91/93	1.38	0.05			
Rushbrook	95/99	4.10	<.0001				94/92	0.89	0.41			
Stull	97/95	2.33	<.0001	98/96	1.00	0.27	94/94	3.28	<.0001	100/100	0.00	1.00
Ten Mile	89/89	1.57	0.01				97/97	1.44	0.03			
Whiskey	94/92	3.16	<.0001				94/93	2.87	<.0001	99/98	1.76	0.00
Windy	99/92	5.63	<.0001	97/95	1.84	0.00	95/92	2.13	0.00	100/100	0.00	1.00

Table 26: Continued

	YLPR (14)		
Lake	**(%BsM/%NRD**	**Statistic (KSa)**	**p**
Alexie*			
Anima Nipissing	100/100	0.00	1.00
Baptiste*			
Chitty*			
Drygeese*			
Endikai	100/100	0.00	1.00
Goldie	100/100	0.00	1.00
Kukagami	100/99	0.07	1.00
McFarlane	100/100	0.00	1.00
Mesomikenda	100/100	0.00	1.00
Midlothian	99/100	0.57	0.90
Mijinemungshing			
Old Woman			
Peshu	100/100	0.00	1.00
Ramsey	99/99	1.14	0.15
Rawson	100/100	0.00	1.00
Rushbrook	99/98	0.51	0.96
Stull	99/100	0.14	1.00
Ten Mile			
Whiskey	100/99	0.71	0.69
Windy	100/100	0.00	1.00

Table 27: Kolmogorov-Smirnov two-sample test results comparing biomass distributions between NA1 and NRD gears below 20 m depth for whole communities (All) and individual species. Species codes are listed in Table 4.

	All (16)			NRPK (-)			WALL (-)			BURB (11)		
Lake	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**
Alexie*	94/92	1.74	**0.00**	-	-	-	-	-	-			
Anima Nipissing	96/96	3.03	**<.0001**	-	-	-	-	-	-	100/99	7.05	**<.0001**
Baptiste*	94/93	1.63	**0.01**	-	-	-	-	-	-	*	*	*
Chitty*	-	-	-	-	-	-	-	-	-	-	-	-
Drygeese*	93/93	1.61	**0.01**	-	-	-	-	-	-			
Endikai	98/96	2.48	**<.0001**	-	-	-	-	-	-	99/98	2.01	**0.00**
Goldie	-	-	-	-	-	-	-	-	-	-	-	-
Kukagami	93/91	2.01	**0.00**	-	-	-	-	-	-	100/97	4.99	**<.0001**
McFarlane	-	-	-	-	-	-	-	-	-	-	-	-
Mesomikenda	97/99	3.04	**<.0001**	-	-	-	-	-	-	97/99	5.02	**<.0001**
Midlothian	98/98	4.71	**<.0001**	-	-	-	-	-	-			
Mijinemungshing	96/94	3.30	**<.0001**	-	-	-	-	-	-	*	*	*
Old Woman	99/99	4.62	**<.0001**	-	-	-	-	-	-	*	*	*
Peshu	99/97	2.43	**<.0001**	-	-	-	-	-	-			
Ramsey	-	-	-	-	-	-	-	-	-	-	-	-
Rawson	95/98	3.44	**<.0001**	-	-	-	-	-	-	*	*	*
Rushbrook	-	-	-	-	-	-	-	-	-	-	-	-
Stull	97/97	2.23	**<.0001**	-	-	-	-	-	-			
Ten Mile	95/95	2.54	**<.0001**	-	-	-	-	-	-	100/100	7.07	**<.0001**
Whiskey	95/93	1.92	**0.00**	-	-	-	-	-	-	*	*	*
Windy	92/94	3.11	**<.0001**	-	-	-	-	-	-	98/97	2.84	**<.0001**

	LKTR (15)			LKWH (8)			WHSC (3)			CISC (9)		
Lake	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**
Alexie*	96/97	1.76	**0.00**	96/96	1.88	**0.00**	*	*	*	100/100	0.00	1.00
Anima Nipissing	99/99	2.13	**0.00**	98/97	1.90	**0.00**	*	*	*	*	*	*
Baptiste*	96/94	2.23	**<.0001**	95/95	1.67	**0.01**	*	*	*	100/100	0.00	1.00
Chitty*	-	-	-	-	-	-	-	-	-	-	-	-
Drygeese*	96/93	3.40	**<.0001**	93/96	2.10	**0.00**	*	*	*	100/99	1.57	**0.01**
Endikai	97/98	3.19	**<.0001**	*	*	*	*	*	*			
Goldie	-	-	-	-	-	-	-	-	-	-	-	-
Kukagami	97/97	3.30	**<.0001**	95/95	2.61	**<.0001**	*	*	*	*	*	*
McFarlane	-	-	-	-	-	-	-	-	-	-	-	-
Mesomikenda	*	*	*	*	*	*	*	*	*			
Midlothian	99/98	6.02	**<.0001**	*	*	*	*	*	*	100/100	0.00	1.00
Mijinemungshing	96/94	3.30	**<.0001**	*	*	*	*	*	*	*	*	*
Old Woman	99/99	4.62	**<.0001**				*	*	*	*	*	*
Peshu				100/98	3.23	**<.0001**	*	*	*	*	*	*
Ramsey	-	-	-	-	-	-	-	-	-	-	-	-
Rawson	99/100	7.05	**<.0001**	*	*	*	98/99	6.66	**<.0001**	*	*	*
Rushbrook	-	-	-	-	-	-	-	-	-	-	-	-
Stull	99/99	4.41	**<.0001**	97/98	3.02	**<.0001**				100/100	0.00	1.00
Ten Mile	95/97	2.60	**<.0001**	*	*	*	*	*	*	*	*	*
Whiskey	97/93	2.15	**0.00**	*	*	*	*	*	*	99/99	2.42	**<.0001**
Windy	99/97	6.06	**<.0001**	97/95	2.11	**0.00**	99/100	7.05	**<.0001**			

Table 28: Kolmogorov-Smirnov two-sample test results comparing biomass distributions between NA1 and NRD gears above 20 m depth for whole communities (All) and individual species. Species codes are listed in Table 4.

	All (21)			NRPK (14)			WALL (10)			BURB (15)		
Lake	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**
Alexie*	89/90	0.64	0.80	93/96	3.24	**<.0001**	-	-	-	100/100	7.07	**<.0001**
Anima Nipissing	89/92	2.14	**0.00**				94/95	1.90	**0.00**			
Baptiste*	91/90	1.05	0.22	95/95	2.32	**<.0001**	-	-	**-**	99/100	7.05	**<.0001**
Chitty*	88/90	1.07	0.20	92/89	2.53	**<.0001**	-	-	**-**	99/99	2.91	**<.0001**
Drygeese*	90/89	1.99	**0.00**	96/94	4.71	**<.0001**	-	-	**-**	98/99	5.66	**<.0001**
Endikai	90/89	3.02	**<.0001**	98/100	7.04	**<.0001**	95/96	4.60	**<.0001**			
Goldie	86/89	1.90	**0.00**	93/96	1.73	**0.01**	96/96	4.33	**<.0001**			
Kukagami	86/91	2.76	**<.0001**	-	-	-	88/94	4.40	**<.0001**	99/96	3.05	**<.0001**
McFarlane	92/90	3.24	**<.0001**	99/95	5.50	**<.0001**	97/96	1.76	**0.00**	-	-	-
Mesomikenda	89/90	2.36	**<.0001**	97/95	1.53	**0.02**	90/92	3.10	**<.0001**	97/97	3.88	**<.0001**
Midlothian	90/91	3.45	**<.0001**	97/97	1.87	**0.00**	-	-	-	98/99	7.02	**<.0001**
Mijinemungshing	87/92	3.33	**<.0001**	-	-	-	-	-	-	-	-	-
Old Woman	93/92	2.90	**<.0001**	-	-	-	-	-	-	-	-	-
Peshu	91/95	4.36	**<.0001**	98/99	7.02	**<.0001**	-	-	-	99/95	2.49	**<.0001**
Ramsey	88/92	1.91	**0.00**	96/96	6.28	**<.0001**	95/98	3.65	**<.0001**	-	-	-
Rawson	90/91	2.05	**0.00**	-	-	-	-	-	.	-	-	-
Rushbrook	89/93	2.51	**<.0001**	-	-	-	-	-	-	-	-	-
Stull	93/90	3.19	**<.0001**	99/95	3.42	**<.0001**	97/97	4.16	**<.0001**	99/95	6.47	**<.0001**
Ten Mile	92/92	1.18	0.12	-	-	-	-	-	-	99/96	4.40	**<.0001**
Whiskey	87/90	2.47	**<.0001**	-	-	-	99/100	7.05	**<.0001**			
Windy	92/91	1.72	**0.01**				96/95	1.53	**0.02**	98/95	4.05	**<.0001**

	LKTR (19)			LKWH (13)			WHSC (17)			CISC (11)		
Lake	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**	**(%NA1/NRD)**	**Statistic (KSa)**	**P**
Alexie*	97/92	1.40	**0.04**	94/90	0.57	0.90	*	*	*			
Anima Nipissing	99/97	3.39	**<.0001**	96/96	1.95	**0.00**	92/93	1.67	**0.01**	*	*	*
Baptiste*	99/92	2.65	**<.0001**	94/92	1.71	**0.01**	*	*	*	100/100	0.00	1.00
Chitty*	95/99	4.76	**<.0001**	92/93	0.76	0.62	*	*	*	100/100	0.00	1.00
Drygeese*	94/94	2.70	**<.0001**	91/92	1.58	**0.01**	*	*	*	100/100	0.00	1.00
Endikai	98/96	2.34	**<.0001**	99/99	3.06	**<.0001**	94/94	2.04	**0.00**			
Goldie	99/98	2.84	**<.0001**	94/95	2.02	**0.00**	94/96	1.76	**0.00**	*	*	*
Kukagami	98/93	3.94	**<.0001**	95/97	2.89	**<.0001**	92/93	2.40	**<.0001**	*	*	*
McFarlane	*	*	*	*	*	*	95/91	1.80	**0.00**	99/97	6.06	**<.0001**
Mesomikenda				92/97	3.29	**<.0001**	91/96	1.28	0.07	100/100	0.00	1.00
Midlothian	96/93	5.36	**<.0001**	*	*	*	96/95	3.06	**<.0001**	100/100	0.00	1.00
Mijinemungshing	89/94	4.76	**<.0001**	*	*	*	93/95	4.07	**<.0001**	*	*	*
Old Woman	97/92	1.91	**0.00**	*	*	*	96/95	5.39	**<.0001**	*	*	*
Peshu	98/98	6.71	**<.0001**	98/97	1.82	**0.00**	94/94	1.68	**0.01**	*	*	*
Ramsey	*	*	*	*	*	*	90/93	1.33	0.06	*	*	*
Rawson	95/96	4.24	**<.0001**	*	*	*	94/93	1.44	**0.03**	*	*	*
Rushbrook	96/99	4.07	**<.0001**				91/92	0.96	0.32	*	*	*
Stull	98/97	2.38	**<.0001**	98/96	1.50	**0.02**	94/94	3.50	**<.0001**	100/100	0.00	1.00
Ten Mile	92/92	0.88	0.41	*	*	*	98/97	1.24	0.09	*	*	*
Whiskey	96/93	3.48	**<.0001**	*	*	*	95/93	2.95	**<.0001**	100/99	1.57	**0.01**
Windy	100/96	4.81	**<.0001**	97/95	2.42	**<.0001**	95/93	1.80	**0.00**			

Table 28: Continued

Lake	YLPR (14)		
	(%NA1/NRD)	Statistic (KSa)	P
Alexie*	*	*	*
Anima Nipissing			
Baptiste*	*	*	*
Chitty*	*	*	*
Drygeese*	*	*	*
Endikai			
Goldie			
Kukagami	100/99	0.07	1.00
McFarlane	100/100	0.00	1.00
Mesomikenda	100/100	0.00	1.00
Midlothian	99/100	2.07	**0.00**
Mijinemungshing	*	*	*
Old Woman	*	*	*
Peshu			
Ramsey	99/99	2.20	**0.00**
Rawson			
Rushbrook	99/98	0.36	1.00
Stull	99/100	3.06	**<.0001**
Ten Mile	*	*	*
Whiskey			
Windy			

Table 29: Kolmogorov-Smirnov two-sample test results comparing biomass distributions between NRD and ON2 gears above 20 m depth for whole communities (All) and individual species. Species codes are listed in Table 4.

	All (21)			NRPK (14)			WALL (10)			BURB (15)		
Lake	**(%NRD/ON2)**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**
Alexie*	90/90	0.82	0.51	96/99	2.33	**<.0001**	*	*	*			
Anima Nipissing	92/92	2.65	**<.0001**				95/98	2.90	**<.0001**			
Baptiste*	90/93	1.16	0.14	95/100	6.98	**<.0001**	*	*	*			
Chitty*	90/89	3.39	**<.0001**	89/96	4.13	**<.0001**	*	*	*			
Drygeese*	89/94	1.48	**0.02**	94/100	5.78	**<.0001**	*	*	*			
Endikai	89/98	3.35	**<.0001**	100/100	7.07	**<.0001**	96/100	6.93	**<.0001**	97/100	4.20	**<.0001**
Goldie	89/98	2.51	**<.0001**	96/99	3.06	**<.0001**	96/99	6.91	**<.0001**			
Kukagami	91/93	1.51	**0.02**	*	*	*	94/97	1.52	**0.02**	96/99	5.53	**<.0001**
McFarlane	90/96	2.16	**0.00**	95/100	6.10	**<.0001**	96/99	6.25	**<.0001**	*	*	*
Mesomikenda	90/95	1.49	**0.02**	95/98	2.56	**<.0001**	92/97	2.13	**0.00**	97/99	3.03	**<.0001**
Midlothian	91/95	2.43	**<.0001**				*	*	*	99/100	7.05	**<.0001**
Mijinemungshing	92/95	1.98	**0.00**	*	*	*	*	*	*	*	*	*
Old Woman	92/95	1.29	0.07	*	*	*	*	*	*	*	*	*
Peshu	95/99	2.48	**<.0001**				*	*	*	95/100	4.04	**<.0001**
Ramsey	92/97	2.37	**<.0001**	96/100	5.98	**<.0001**	98/98	3.07	**<.0001**	*	*	*
Rawson	91/95	1.75	**0.00**	*	*	*	*	*	*	*	*	*
Rushbrook	93/94	1.28	0.07	*	*	*	*	*	*	*	*	*
Stull	90/98	2.11	**0.00**	95/100	6.98	**<.0001**	97/99	3.69	**<.0001**			
Ten Mile	92/91	1.87	**0.00**	*	*	*	*	*	*	96/99	4.65	**<.0001**
Whiskey	90/95	2.62	**<.0001**	*	*	*	100/99	7.05	**<.0001**			
Windy	91/97	1.96	**0.00**				95/99	5.13	**<.0001**	95/100	5.00	**<.0001**

	LKTR (19)			LKWH (13)			WHSC (17)			CISC (11)		
Lake	**(%NRD/ON2)**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**	**(%NRD/ON2**	**Statistic (KSa)**	**P**
Alexie*	92/96	3.80	**<.0001**	91/90	0.94	0.34	*	*	*	100/100	0.00	1.00
Anima Nipissing	97/98	5.34	**<.0001**	96/96	1.80	**0.00**	93/98	4.61	**<.0001**	*	*	*
Baptiste*	92/96	1.94	**0.00**	92/95	1.59	**0.01**	*	*	*	100/100	0.00	1.00
Chitty*	99/97	5.85	**<.0001**	93/96	1.67	**0.01**	*	*	*	100/99	4.27	**<.0001**
Drygeese*	94/98	3.54	**<.0001**	92/94	1.73	**0.01**	*	*	*	100/100	0.00	1.00
Endikai	96/100	4.52	**<.0001**	99/99	3.98	**<.0001**						
Goldie	98/100	4.38	**<.0001**	95/98	1.82	**0.00**				*	*	*
Kukagami	93/97	3.93	**<.0001**	97/97	3.59	**<.0001**	93/99	3.26	**<.0001**	*	*	*
McFarlane	*	*	*	*	*	*				97/98	6.05	**<.0001**
Mesomikenda				97/98	5.13	**<.0001**				100/100	0.00	1.00
Midlothian	93/98	5.76	**<.0001**	*	*	*	95/99	4.91	**<.0001**	100/100	0.00	1.00
Mijinemungshing	94/97	4.67	**<.0001**	*	*	*	95/98	3.59	**<.0001**	*	*	*
Old Woman	92/97	2.14	**0.00**	*	*	*	95/98	2.54	**<.0001**	*	*	*
Peshu				97/100	3.83	**<.0001**	94/100	6.37	**<.0001**	*	*	*
Ramsey	*	*	*	*	*	*	93/100	3.13	**<.0001**	*	*	*
Rawson	96/99	3.27	**<.0001**	*	*	*	93/97	3.39	**<.0001**	*	*	*
Rushbrook	99/98	2.08	**0.00**				92/98	5.39	**<.0001**	*	*	*
Stull				96/100	5.91	**<.0001**	94/99	5.98	**<.0001**	100/100	0.00	1.00
Ten Mile	92/93	2.03	**0.00**	*	*	*	97/98	1.96	**0.00**	*	*	*
Whiskey	93/99	5.90	**<.0001**	*	*	*	93/99	6.48	**<.0001**	99/99	1.85	**0.00**
Windy				95/99	6.82	**<.0001**	93/100	6.94	**<.0001**	100/100	0.00	1.00

Table 29: Continued

	YLPR (14)		
Lake	(%NRD/ON2	Statistic (KSa)	P
Alexie*	*	*	*
Anima Nipissing	100/100	0.00	1.00
Baptiste*	*	*	*
Chitty*	*	*	*
Drygeese*	*	*	*
Endikai	100/100	0.00	1.00
Goldie	100/100	0.00	1.00
Kukagami	99/100	0.07	1.00
McFarlane	100/100	0.00	1.00
Mesomikenda	100/100	0.00	1.00
Midlothian	99/100	0.28	1.00
Mijinemungshing	*	*	*
Old Woman	*	*	*
Peshu	100/100	0.00	1.00
Ramsey	99/100	1.57	**0.01**
Rawson	100/100	0.00	1.00
Rushbrook	98/99	0.79	0.56
Stull	100/100	0.00	1.00
Ten Mile	*	*	*
Whiskey	99/100	0.71	0.69
Windy	100/100	0.00	1.00

Table 30 : Kolmogorov-Smirnov two-sample test results comparing biomass distributions between NA1 and ON2 gears above 20 m depth for whole communities (All) and individual species. Species codes are listed in Table 4.

	All (21)			NRPK (13)			WALL (10)			BURB (12)		
Lake	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P
Alexie*	89/90	1.17	0.13	93/99	3.87	**<.0001**	*	*	*			
Anima Nipissing	89/92	2.18	**0.00**	99/100	7.05	**<.0001**	94/98	4.41	**<.0001**	*	*	*
Baptiste*	91/93	0.84	0.48	95/100	6.98	**<.0001**	*	*	*			
Chitty*	88/89	2.61	**<.0001**	92/96	3.10	**<.0001**	*	*	*			
Drygeese*	90/94	1.08	0.19	96/100	4.37	**<.0001**	*	*	*			
Endikai	90/98	2.82	**<.0001**	98/100	7.04	**<.0001**	95/100	6.98	**<.0001**			
Goldie	86/98	2.03	**0.00**	93/99	4.77	**<.0001**	96/99	6.98	**<.0001**	*	*	*
Kukagami	86/93	2.86	**<.0001**	*	*	*	88/97	4.86	**<.0001**	99/99	3.62	**<.0001**
McFarlane	92/96	3.84	**<.0001**	99/100	2.21	**0.00**	97/99	6.49	**<.0001**	*	*	*
Mesomikenda	89/95	2.72	**<.0001**	97/98	2.59	**<.0001**	90/97	3.50	**<.0001**	97/99	6.28	**<.0001**
Midlothian	90/95	2.63	**<.0001**				*	*	*	98/100	7.04	**<.0001**
Mijinemungshing	87/95	3.60	**<.0001**	*	*	*	*	*	*	*	*	*
Old Woman	93/95	4.00	**<.0001**	*	*	*	*	*	*	*	*	*
Peshu	91/99	5.60	**<.0001**				*	*	*	99/100	4.42	**<.0001**
Ramsey	88/97	3.42	**<.0001**	96/100	7.00	**<.0001**	95/98	5.22	**<.0001**	*	*	*
Rawson	90/95	3.51	**<.0001**	*	*	*	*	*	*	*	*	*
Rushbrook	89/94	3.44	**<.0001**	*	*	*	*	*	*	*	*	*
Stull	93/98	3.52	**<.0001**	99/100	4.06	**<.0001**	97/99	5.05	**<.0001**			
Ten Mile	92/91	1.21	0.11	*	*	*	*	*	*	99/99	5.76	**<.0001**
Whiskey	87/95	1.63	**0.01**	*	*	*	99/99	7.04	**<.0001**	*	*	*
Windy	92/97	2.94	**<.0001**	*	*	*	96/99	6.04	**<.0001**	98/100	2.73	**<.0001**

	LKTR (19)			LKWH (12)			WHSC (17)			CISC (10)		
Lake	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P	(%NA1/ON2)	Statistic (KSa)	P
Alexie*	97/96	2.98	**<.0001**	94/91	0.89	0.40	*	*	*			
Anima Nipissing	99/98	6.16	**<.0001**	96/96	1.23	0.10	92/98	4.64	**<.0001**	*	*	*
Baptiste*	99/96	2.33	**<.0001**	94/95	0.61	0.85	*	*	*	100/100	0.00	1.00
Chitty*	95/97	3.71	**<.0001**	92/96	1.30	0.07	*	*	*	100/99	4.27	**<.0001**
Drygeese*	94/98	5.53	**<.0001**	91/94	1.04	0.23	*	*	*	100/100	0.00	1.00
Endikai	98/100	2.37	**<.0001**	99/99	1.92	**0.00**				*	*	*
Goldie	99/100	6.98	**<.0001**	94/98	1.11	0.17				*	*	*
Kukagami	98/97	2.11	**0.00**	95/97	5.28	**<.0001**	92/99	3.54	**<.0001**	*	*	*
McFarlane	*	*	*	*	*	*				99/98	0.70	0.71
Mesomikenda	100/100	7.07	**<.0001**	92/98	5.06	**<.0001**				100/100	0.00	1.00
Midlothian	96/98	1.90	**0.00**	*	*	*	96/99	6.84	**<.0001**	100/100	0.00	1.00
Mijinemungshing	89/97	2.91	**<.0001**	*	*	*	93/98	5.27	**<.0001**	*	*	*
Old Woman	97/97	3.09	**<.0001**	*	*	*	96/98	5.88	**<.0001**	*	*	*
Peshu				98/100	2.87	**<.0001**	94/100	6.96	**<.0001**	*	*	*
Ramsey	*	*	*	*	*	*	90/100	3.59	**<.0001**	*	*	*
Rawson	95/99	2.71	**<.0001**	*	*	*	94/97	4.15	**<.0001**	*	*	*
Rushbrook	96/98	3.48	**<.0001**	*	*	*	91/98	5.51	**<.0001**	*	*	*
Stull				98/100	6.68	**<.0001**	94/99	6.65	**<.0001**	100/100	0.00	1.00
Ten Mile	92/93	1.14	0.15	*	*	*	98/98	3.21	**<.0001**	*	*	*
Whiskey	96/99	4.36	**<.0001**	*	*	*	95/99	6.96	**<.0001**	100/99	3.42	**<.0001**
Windy				97/99	6.86	**<.0001**	95/100	6.98	**<.0001**			

Table 30: Continued

	YLPR (14)		
Lake	**(%NA1/ON2)**	**Statistic**	**P**
Alexie*	*	*	*
Anima Nipissing			
Baptiste*	*	*	*
Chitty*	*	*	*
Drygeese*	*	*	*
Endikai			
Goldie			
Kukagami	100/100	0.00	1.00
McFarlane	100/100	0.00	1.00
Mesomikenda	100/100	0.00	1.00
Midlothian	99/99	1.78	**0.00**
Mijinemungshing	*	*	*
Old Woman	*	*	*
Peshu			
Ramsey	99/100	3.78	**<.0001**
Rawson			
Rushbrook	99/99	0.99	0.28
Stull	99/100	3.06	**<.0001**
Ten Mile	*	*	*
Whiskey			
Windy			

Appendix VIII – Data Availability

Final data sets are available through the Cooperative Freshwater Ecology Unit, Laurentian University. Data for lakes of the Northwest Territories are also available through the Cumulative Impact Monitoring Program, Government of the Northwest Territories.