Fisheries and Oceans Canada
Canada

Pêches et Océans
Canada

Ecosystems and
Oceans Science

Sciences des écosystèmes
et des océans

**Canadian Science Advisory Secretariat (CSAS)**

**Research Document 2024/014**

**Central and Arctic Region**

# Fishery-Independent Gillnet Study (FIGS) Sampling Protocol Used for Multi-Species Ecology Study in Great Slave Lake, Northwest Territories, Canada

Xinhua Zhu[1], Deanna Leonard[2], Kimberly L. Howland[1], Melanie VanGerwen-Toyne[1],
Colin Gallagher[1], Theresa J. Carmichael[1], and Ross F. Tallman[1]

[1]Freshwater Institute
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB R3T 2N6

[2]Fisheries and Oceans Canada
5204-50th Avenue
Yellowknife, NT X1A 1E2

February 2024

## Foreword

**Published by:**

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-70114-1 Cat. No. Fs70-5/2023-014E-PDF

**Correct citation for this publication:**

Zhu, X., Leonard, D., Howland, K.J., VanGerwen-Toyne, M., Gallagher, C., Carmichael, T.J., and Tallman, R.F. 2024. Fishery-Independent Gillnet Study (FIGS) Sampling Protocol Used for Multi-Species Ecology Study in Great Slave Lake, Northwest Territories, Canada. CSAS Res. Doc. 2024/014. iv + 27 p.

***Aussi disponible en français :***

*Zhu, X., Leonard, D., Howland, K.J., VanGerwen-Toyne, M., Gallagher, C., Carmichael, T.J., et Tallman, R.F. 2024. Protocole d'échantillonnage de l'étude au filet maillant indépendante des pêches (EFMIP) utilisé pour étudier l'écologie plurispécifique dans le Grand lac des Esclaves, Territoires du Nord-Ouest, Canada. Secr. can. des avis sci. du MPO. Doc. de rech. 2024/014. iv + 31 p.*

## TABLE OF CONTENTS

# ABSTRACT

Gillnets are among the most widely-used devices to capture fish for both scientific research and commercial purposes. The basic advantages of multimesh gillnets include facilitating the ability to catch a wide range of sizes and species, the flexibilities of installation in various combination of mesh-sized panels, and ease of operation. There are few detailed sampling protocols specifying the mesh size and gillnet dimension, sampling schedule, sample collection, and data quality assurance for fishery-independent scientific exploration using multimesh gillnets. The objective of this document is to outline a standard multimesh gillnet sampling protocol for a fishery-independent gillnet study (FIGS), which aims to quantitatively investigate species richness, species-specific abundance and biomass indices, analogous to catch per unit effort (CPUEs), population structure, and multi-species community dynamics in Great Slave Lake (GSL), a large northern boreal lake situated in the Northwest Territories, Canada.

To conduct FIGS, an index gillnet comprised ten different mesh-sized panels, ranging between 13–140 mm (½–5½”) knot-to-knot stretched, which followed a geometric progression mesh size factor of r = 1.31. The height of the panels was 3.7 m (12’) and 1.8 m (6’) for pelagic and benthic sets, respectively. The lengths of the panels varied in groups of mesh sizes in order to reduce the catch/mortality of small-sized fishes in small mesh size panels: 11 m (36’) for smaller mesh-size panels (13–38 mm; ½–1½”) and 22 m (72’) for larger mesh-size panels (51–140 mm; 2–5½”). Associated with proportions of area-specific grid numbers and depth-specific strata, the selection of sampling grid, type and number of gillnet, and order of deployment was made following a depth stratified random sampling strategy.

Regardless, the multimesh gillnet design used for FIGS can be applied as a standard tool to monitor fish population status, fish community association, capture efficiency, and to potentially support quantitative fisheries stock assessment in large lakes. By applying this protocol to routine monitoring and assessment, it provides an important step towards delivering reliable, robust, and representative estimates of fisheries production and improves the interpretability and reliability of biological reference points into integrated fisheries management plans (IFMP), fish stock provisions, and ecosystem based fisheries management (EBFM) in particular for Arctic great lakes.

# INTRODUCTION

Unlike mineral resources, fisheries production is characterized as a self-renewable natural resource if it is properly managed (Cadima 2003). To assess the renewability, fisheries scientists are inspired to collect a vast array of fishery-related information on spatiotemporal dynamics of both fish population demographics and fisheries itself (Hamley 1975, Jensen 1986, Bonar et al. 2009). Associated with time series of abundance indices of the exploited fish populations, commonly termed as catch per unit effort (CPUE), one attempts to disseminate trend analysis of fisheries stock production in the past and current status, answering questions about how a set of biological parameters can better represent the stock status or population dynamics, spatiotemporal changes in population size, as well as management options to achieve sustainability. Given a set of management scenarios, stock assessment researchers also attempt to make predictions about how a unit of stock will respond to current and future management choices (Hilborn and Walters 1992). Therefore, creation and accumulation of a set of large-scale, long-term, fishery information is essential to develop reliable, robust, and cost-effective sampling designs that are standardized, representative, optimal with respect to the quantity and structure of catch, and replicated over relevant spatial and temporal scales (Andrew and Mapstone 1987, Bonar et al. 2009).

Creation and accumulation of time series CPUE of fish populations are essentially derived from fishery-independent survey (FIS), fishery-dependent survey (FDS), or some combination of FIS and FDS data (Hilborn and Walters 1992). FIS data are generally gathered using research vessels and standard gears, and typically consist of a relatively large sample size (both spatially and temporally). It is usually favoured by many fisheries scientists because of standard designs, random sampling and fewer biases (Hilborn and Walters 1992, Bonar et al. 2009). In freshwater ecosystems, gillnets have been commonly used both for scientific research and commercial purposes (Hamley 1975, Jensen 1995, Beauchamp et al. 2009, Winfield et al. 2009). Associated with mesh-sized selectivity of gillnets, FIS datasets have been used to test specific hypotheses about the design and deployment of sampling gears (Andrew and Mapstone 1987), to test the effects of biotic and abiotic variables on the performance of sampling gears (Zhu et al. 2017), and to test spatial and temporal variation in production of organisms across hierarchical scales (Bobori and Salvarina 2010). In particular, the fishery-independent gillnet study (FIGS) has generally been preferred to estimate abundance (Olin et al. 2004, Griffiths et al. 2007, Bobori and Salvarina 2010), biomass (Holmgren 1999, Bobori and Salvarina 2010, Jurvelius et al. 2011), and age-composition (Boy and Crivelli 1988) of exploited fish populations, and results have supported the review of the success or failure of fisheries management actions (Finstad et al. 2005, Bonar et al. 2009), to assess fish community diversity (Holmgren 1999, Olin et al. 2002, Rotherham et al. 2007), and to improve communications among fisheries professionals and the general public (Hamley 1975, Jensen 1995, Olin et al. 2009).

FISs, however, can be confronted with certain challenges because it is relatively more expensive to conduct and it may not be implemented every year, resulting in limited sample sizes and temporal discontinuity. FDS is an alternative to FIS, used to collect fisheries related information such as catch, fishing effort and harvest statistics for some target or bycatch species through logbook data, and landing records collected by commercial fishers. FDS data can be incorporated into stock assessments only if underlying biases are properly identified and corrected. If biases remain uncorrected or are themselves subject to trends, resolving temporal trends in population abundance will be nearly impossible. Biases in FDS data have been implicated in several of the world's most dramatic fisheries crashes (Namibian Hake

[*Merluccious capensis*], Northern Cod [*Gadus morhua*]), and may result in biased abundance estimates in other populations (Pennington and Stromme 1998).

Despite the dominant use of gillnets for scientific monitoring and commercial and subsistence fisheries in GSL, there is a paucity of information regarding how these boreal fisheries resources can be routinely monitored by implementing either FIS or FDS. GSL is a large (28,568 km$^2$) and deep (maximum depth 614 m) sub-Arctic boreal lake in the Northwest Territories, Canada. The GSL fisheries have been long targeted for Lake Whitefish (*Coregonus clupeaformis)* and Lake Trout (*Salvelinus namaycush)*, and by-catch of Inconnu (*Stenodus leucichthys)*. Over the course of GSL fisheries, there have been several discrete FIS or FID surveys , but inconsistent in their approaches to survey design so far (Rawson 1949, Bond and Turnbull 1973, Bond 1975, Hamley 1975, Moshenko and Low 1978, Day 2002). Due to the lack of standardized experimental gillnet-based sampling protocols, those FIGS activities were substantially limited by individual research objectives. The overarching objective of this working document is to apply theory of gillnet selectivity to create a standard FIGS framework. In association with large-scale, long-term and cost-effective sampling strategies, it aims to address quantitatively monitoring the stock status of fish population productivity, effects of fishing on fish populations, fish community diversity and its association with changing hydroclimate, as well as fisheries ecosystem integrity. The study will ultimately facilitate a better understanding of how GSL fisheries production and aquatic ecosystems interact with underlying biological, ecological and cumulative anthropogenic modifications in large sub-polar and Arctic freshwater systems.

# STRUCTURING AN INDEX GILLNET

## GILLNET SELECTIVITY

Gillnets are a highly species- and size-selective and passive gear; species and size composition can differ among respective mesh-sized panels can differ from those of another (Hamley and Regier 1973, Hamley 1975, Finstad et al. 2005, Carol and García-Berhou 2007). The difference in catches of fish caught in the mesh-specific gear is referred to as relative selectivity (Hovgård and Lassen 2000). Its capture efficiency of a specific mesh size, or that of a combination of various mesh sizes in a series of panels (gang), is the sum of the relative efficiency of each mesh to the size-class of its catch (Hamley 1975). The relative selectivity of a mesh-sized fishing gear is also related to the physical characteristics parameters, such as twine color, material, and hanging ratios of the net as well as the morphology and behavior of the fish species (Hamley 1975). By incorporating these specifics of gillnet configuration, sampling schedule and data quality control measure, a standardized protocol of FIGS can help better understand the additive attributes of selectivity and effects of species on estimated population composition.

Estimation of gillnet selectivity has long been an interest of a large number of fisheries researchers. Baranov (1948) perhaps was the first who fully appreciated and intensively investigated the probability of gillnet selection as a mechanical process. The Baranov's principle of geometric similarity interpreted that gillnet capture depends only on the relative geometry of the mesh sizes and the morphology of harvested fish species. In terms of the principle, the ratio of any combination of fish lengths to respective mesh sizes is constant if the gear selection solely depends on the relative geometry of the fish and meshes. Given that all fish of the same species (within a reasonable size range) are also geometrically similar, all different mesh sizes from a set of multi-mesh gillnet are equally efficient for the length class of fish they capture most efficiently (Hamley 1975, Jensen 1986). As variance in selectivity curves increases with mesh size, the overall selectivity or pooled efficiency of all mesh sizes are accounted for in the total catch of all length classes of representative fish under the same probability of encountering the nets (Regier and Robson 1966, Jensen 1986, Appelberg et al. 1995, Holst et al. 1996, Carol and García-Berthou 2007, Fukuwaka et al. 2008).

Numerically, gillnet selectivity can be delineated as a multiplicative process of the probability that a fish will approach a net (encounter), the probability that an approaching fish will contact the mesh rather than detect and avoid it (contact), and the probability that a fish contacts the mesh is retained (retention) (Radomski et al. 2020). Here, encounter probabilities have been assumed to be independent or power functions of fish sizes (Rudstam et al. 1984). Many researchers have presumed that retention probabilities are a function of the relative size of fish and mesh, given that the most vulnerable-sized fish for various meshes will be retained with equal probability. In fact, the mesh construction, twine thickness and hanging ratios may affect fish contact probability with the gillnet (Hamley 1975). Incorporated with this multiplicative process, direct or indirect methods can be used to disseminate gillnet selectivity curves and model parameters (Hamley 1975, Jensen and Hesthagen 1996, Kurkilahti et al. 1998, Radomski et al. 2020). If abundance and size distribution of a fish population are known, the proportion of fish caught by each mesh-size panel can be directly used as estimates of the panel's selectivity (Hamley 1975). In a direct method, the catchability of a set of gillnets varies with mesh size dependent on ecological and ethological differences between fish of different size and changes in net geometry (Jesen and Hesthagen 1996, Lobyrev and Hoffman 2018).

Given the extensive data demands by use of the direct methods, many investigators have used indirect methods to estimate relative selectivity in a way to correct estimates of the size selectivity of gillnet. Indirect estimates of gillnet selectivity are based on comparisons of size distribution of fish taken by different mesh sizes of the gear, requiring assumption about equal heights of the selectivity curves for all mesh sizes of the gillnet (Hamley 1975). Indirect methods have advantages in that the essential data are easily obtained when fishing with standard nets and statistical tools are readily available. These estimates are likely biased because overestimates on the left and underestimates on the right of the selectivity curve were identified by Hamley and Regier (1973). Millar and Holst (1997) developed a statistical approach for estimating gillnet retention curves indirectly by using generalized linear modeling, maximum likelihood and Poisson-distributed errors, termed the SELECT (share each length-class's catch total) method. Radomski et al. (2020) combined indirect and direct methods to estimate absolute selectivity, which allowed the prediction of CPUE and described how fish of a specified size were distributed among different mesh sizes of a gillnet.

## MESH SIZE

In terms of the principles of gillnet selectivity, net geometry is a set of important parameters to define the numbers of panels and panel-specific mesh size range when configuring a standard set of index gillnet. Selection of numbers of panels and the range of mesh sizes can allow us to ensure that the capture efficiency of a set of standard gillnet can facilitate both a wide spectrum of species richness and the body sizes within a fish population. Among those panels selected, however, at least one panel of the net should be similar mesh size that is used for commercial or subsistence fisheries so that catches of fish samples by the experimental gillnet can mimic the capture efficiency between the standard and commercial gillnets (Bonar et al. 2009).

Determination of number of panels, mesh size range, and mesh size of each panel will be a critical reference to construct a standard set of index gillnet. Two types of numeric progression, arithmetic or geometric, are applied to specify these values. An arithmetic progression or arithmetic sequence is a sequence of numbers such that the difference or interval between the consecutive mesh-sized panels after the first panel is added by a constant value. A geometric progression, or geometric sequence, is a sequence of numbers where mesh size of panel after the first panel is found by multiplying the previous one by a fixed, non-zero number called the *common ratio*. Arithmetic progressions have frequently been employed because it is easy to specify the consecutive panels by adding an equal increment of stretched mesh sizes. Numerous freshwater fisheries studies have been based on data collected using gillnets structured by use of arithmetic progression (Rawson 1949, Bond and Turnbull 1973, Bond 1975, Moshenko and Low 1978, Power 1978, Roberge et al. 1985, Day 2002, Askey et al. 2007, Jones and Yunker 2011).

Compared with arithmetic progressions, some research has indicated that catch efficiency of geometric series gillnets tend to underestimate the degree of overlap between the size distributions of the fish and that intermediate mesh sizes should be removed to reduce redundant sampling (Lyons et al. 2013). For general sampling purposes, a standard gang in which mesh size increased in a certain geometric progression would be more efficient than those with mesh sizes in the usual arithmetic progression (Regier and Robson 1966, Jensen 1986, Rotherham et al. 2007). The NORDIC index net (Appelberg 2000), comprised of 12 different mesh-sized panels ranging from 5 to 55 mm, is generally used for monitoring programs in many Scandinavian countries (Appelberg et al. 1995, Kurkilakti et al. 1998, Holgren 1999, Holmgren and Appelberg 2000, Olin et al. 2009). Lauridsen et al. (2008) added two large-meshed panels to the NORDIC index net to compare the methods estimating CPUE in two stratified eutrophic Danish lakes. Their results suggested that it is of key importance to include pelagic nets when comparing spatial distribution of fish assemblages and abundances among deep lakes as well as when evaluating the effects of major changes in key environmental factors such as nutrient loading and hydroclimate.

In addition to consideration of the numeric progression, selection of mesh size seems to be dependent on the actual objectives of activities. In most European lakes, small to intermediate sizes of cyprinids dominate the fish community, making it appropriate to design an experimental gillnet with mesh sizes ranging from 5 to 55 mm (Appelberg 2000). Peltonen et al. (1999) compared the CPUE of small-bodied fish such as Roach (*Rutilus rutilus*) and Smelt (*Osmerus eperlanus*) with virtual population analysis (VPA), hydroacoustics, and gillnets in Lake Vesijärvi in southern Finland. In Coregonid-dominated GSL, gillnets with a wide range of mesh sizes were used for both commercial exploration and experimental studies (Rawson 1949, Zhu et al. 2017). Bond and Turnbull (1973) and Bond (1975) first employed a five-panel gillnet, ranging from 38 to 140 mm knot to knot stretched, to examine Lake Whitefish biological characteristics. Moshenko and Low (1978) and Roberge et al. (1985) used a similar design but added two extra panels consisting of 114 and 140 mm for their Lake Whitefish reproduction study. Day (2002) modified these experimental gillnet designs by use of arithmetic interval of 13 mm increment between mesh sizes 114 and 140 mm to explore how a reduction of the commercial mesh size of gillnet may influence capture efficiency and biological characteristics of Lake Whitefish in GSL. To target Lake Whitefish for commercial and subsistence fisheries, several mesh sizes of commercial gillnets varying from 102 to 140 mm were examined (Read and Taptuna 2003). Combined with the fish species richness and size composition of dominant fish populations, we propose that the minimum and maximum mesh sizes will be 13 and 140 mm selected for assembling a standard gillnet set.

## MULTI-MESH GEAR DIMENSION

Gear dimension of multi-mesh experimental gillnet mainly refers to its influence of capture efficiency relative to fish species diversity and size composition of important fish populations in the studied fisheries ecosystem. There are major differences among multi-mesh gillnet configurations used in research projects such as the minimum (5–76 mm) and maximum mesh sizes (52–253 mm), the number of panels (5–14), and the geometric/mesh size factor (1.03–1.27, Table 1). Individual panel dimensions vary by numerous factors including differences in the size distribution of fish species caught in different sized panels (depending on the amount of overlap In similar sized panels), the actual versus estimated values for mesh size given by net and twine suppliers often differ, and the availability of mesh size-specific panels in the market often fluctuates.

By incorporating the mesh sizes of experimental gillnets used in European countries, the Laurentian Great Lakes, and GSL, we determined that a gang of 10 different mesh sizes between 13 and 140 mm (½–5½”) knot to knot stretched following a geometric/mesh size factor of 1.31 would be most appropriate for our FIGS. Two general mesh-sized panel groups, small (13–38 mm; ½–1½”) and large (51–140 mm; 2–5½”), were organized. To diminish the excess loss (mortality) of small-sized or juvenile fishes, each small mesh-sized panel length was reduced by half compared to large panels: 11 m or 36 ft versus 22 m or 72 ft (Table 2). To avoid two consecutive mesh-sized panels attached adjacently, all panels were tied together in a random sequence for all benthic and pelagic gillnets. A two-meter space was added between individual panels to clearly indicate the changes in the mesh-sized panels and restrict herding effects between nets (Hovgård and Lassen 2000). As a result, the total length of a complete gang of gillnets was 183 m (600 ft). This design helps to minimize the effects of the interactions between catch saturation and panel size (Hamley 1975). In order to sample representative fish through thermal stratified water columns, two types of standard gillnets were proposed for the FIGS: bottom (benthic) and upper (pelagic) sets. Between both gillnet types, all lengths of the respective panels are the same but the panel heights of both are different in 1.83 m for benthic and 3.66m for pelagic gillnets, to allow pelagic nets to sample fish from a wider range of depths in the water column.

# PRIOR TO FIELD SURVEY

## PREPARING A PUBLIC INFORMATION NOTICE

Prior to field survey, it is essential to prepare a public information notice and post at public community centers to inform the members of the Aboriginal communities in the geographic areas that you intend to sample. Public information notices can be posted on loading docks, community centers, libraries, and public gathering places. A typical information sheet or contact letter should identify who is conducting the sampling and provide immediate contact information in the form of email and/or phone number. It should also include an overview of the study, why it will be conducted, and for how long it will be ongoing.

In addition to the public posting, there are two public engagement platforms, the Aboriginal Aquatic Resource and Oceans Management (AAROM) program and the Great Slave Lake Advisory Committee (GSLAC), for DFO to interact with Indigenous organizations. AAROM is a DFO program that supports 31 Indigenous AAROM departments to build and maintain scientific and technical capacity in fisheries, aquatic resources, and oceans management. It facilitates advancing ongoing co-development, co-design, and co-delivery with Indigenous partners, and moves towards greater co-management of aquatic resources and the ocean environment to meet the needs of their member communities. GSLAC is another advisory platform for DFO staff to communicate Indigenous community concerns, community-based contribution, engagement and involvement, as well as to provide updates on scientific activities during the implementation of the FIGS program.

Around GSL, there are three Aboriginal governments that actively participate in AAROM and GSLAC activities and provide their financial, employment, and logistic supports of the FIGS. Dehcho First Nations (DFN) coordinates the AAROM program to engage the First Nations members from Katlodeeche First Nation (KFN) and West Point First Nation (WPFN). An

Akaitcho Territories Government (ATG) AAROM coordinator contracts Aboriginal communities from the Deninu Ku'e First Nation (DKFN) in Fort Resolution of South Slave Region, Dettah and N'dilo First Nations (DNFN) in the North Slave Region, and Yellowknife Dene as well as Lutselk'e First Nation (LFN) in the East Arm. The Northwest Territories Metis Nations (NWTMN) AAROM coordinator contracts Indigenous communities in Hay River Metis Council (HRMC) and Fort Resolution Metis Council (FRMC) to support annual FIGS activities. Through this effective community-based engagement, these Indigenous government and community members can directly be involved in monitoring, priority-setting, proposal review, logistic support, survey design, field operation, and results update processes (Brunet et al. 2016). Additionally, we also provide opportunities for employment for Indigenous youth to develop skills and bridge traditional knowledge with environmental research and fisheries management (Cohen et al. 2021). Ultimately, the participation of Indigenous community members in the FIGS has greatly enhanced local engagement and environmental literacy.

## LICENCE AND GUIDANCE FOR COLLECTING AND HANDLING FISH FOR SCIENTIFIC PURPOSES

In accordance with Section 52 of the *Fisheries (General) Regulations of the Fisheries Act*, a license to fish for Scientific, Experimental, Educational, Public Display, or Aquatic Invasive Species control purposes, should be obtained for i) activities involving fishing, catching, or attempting to catch fish; ii) activities where the potential exists for the incidental capture of fish; iii) sampling or possessing fish caught in a subsistence fishery; and iv) collecting data on marine mammals from aircraft at an altitude of less than 305 m (~ 1000 ft), by vessels, by 'land' vehicles, or by foot at a distance of less than 100 m.

Although our FIGS seldom includes live fish because most fish are enmeshed in the net which is set in water for an average of 24 hours, in association with other related research projects, it is possible to collect and handle live fishes in the field. Activities requiring animal use protocols include the following: 1) holding (even for very short periods of time) of all living vertebrates, including those that are or have been genetically modified, for research, display, teaching, or testing; 2) all activities that involve physical tagging or chemical restraint and/or the taking of measurements or tissue samples; 3) all tagging/identification activities including insertion/attachment of transmitters on fish or mammals; 4) all lethal field sampling for research, teaching or testing purposes; and 5) dosing of animals and/or their habitats with toxic or hazardous chemicals, including studies administering non-lethal concentrations or doses of analgesics or other pharmaceuticals. Under these situations, a live fish handling protocol has been applied for people to catch, handle, and release fish (CCAC 2005). To reduce the naturally high mortality rates of juvenile or small-sized fishes, we reduced the length of small mesh sized panels (13–38 mm) by 50% in our standard gillnet set.

As an FIS field survey, we may unintentionally catch some fish species that have been registered as Species of Concern, Threatened, Endangered, or Extirpated in terms of the *Species at Risk Act*. Four fishes; Bull Trout (*Salvelinus confluentus,* Special Concern), Dolly Vardon (*Salvelinus malma malma,* Special Concern), Northern Wolffish (*Anarhichas denticulatus,* Threatened) and Shortjaw Cisco (*Coregonus zenithicus,* Threatened), were listed as Species at Risk in the Northwest Territories (GNWT 2020). Among these species, Shortjaw Cisco is present throughout the GSL and adjacent waters (COSEWIC 2003, Murray and Reist 2003, COSEWIC 2012, GNWT 2020). Therefore, a *Species at Risk Act* (SARA) scientific or educational permit is required to address the possible capture of Shortjaw Cisco. If approved, a SARA scientific or educational permit(s) will be issued in conjunction with an approved license to fish for scientific purposes.

## EQUIPMENT CALIBRATION AND FIELD PREPARATION

An equipment list for the FIGS is included in Appendix A. This includes equipment required for vessel preparation, safety and outdoor protective gear, scientific sampling equipment used in the vessel and on land, and more. Crews are expected to have all the necessary navigational aids such as GPS and maps when on the vessel. It is also expected that each person have a personal flotation device, and all necessary safety equipment close at hand.

Prior to the field season, equipment must be cleaned, maintained, stored properly during winter, inventoried and ordered for next season if needed, and calibrated prior to storage if needed. Throughout the field season, it is the responsibility of DFO employees and crew members to ensure all equipment is in a working and maintained state, as well as to calibrate necessary equipment prior to field operation.

To keep accurate and complete records of sampling details, three kinds of datasheets are designed for the FIGS: field sheets, catch forms, and fish sample forms. All forms and instructional materials should be printed and reviewed prior to the start of fieldwork to ensure staff and community members are well trained. The field sheet is to be used while sampling on the vessel. It includes information such as sampling location and depth, samplers, net type, environmental data, fish species and abundances caught, and more. The catch form and fish sample form are to be filled out on land during fish sample processing. These include biological information on fish caught as well as the net type/mesh they were caught in, and more. Datasheets may be updated as needed in order to include necessary data and to reflect possible changes in the study.

# FIELD ACTIVITIES

## SAFETY AND COMMUNICATION

All safety equipment should be accessible and personal flotation devices must be worn while on the water. Safety of field crews must override all other activities and everybody participating in the FIGS should be aware of their rights and obligations according to the *Occupational Health and Safety Act*. A designated person should know where the field crew is on any given day and how to contact them. The crew should report to this person at the end of the day to inform about the day, any issues encountered, and the plan for the next day. If the plan changes unexpectedly, the crew should inform the designated person.

On the sampling vessel, all persons should be able to swim. The field personnel should be equipped with a device for communication such as a satellite or cell phone, a megaphone, or whistle to alert people on land. A handheld GPS, a first-aid kit, and a personal flotation device are prepared for each person when onboarding the vessel.

## SPATIOTEMPORAL SAMPLING DESIGN

In order to maximize spatial representation when sampling, it is critically important for researchers to take the heterogeneity of both spatial and vertical (depth) variables into account during survey design. Spatially, in the main basin ($112^{o}$ 30’–$116^{o}$ 50’W, $60^{o}$ 50’–$62^{o}$ 25 ’N) of GSL, fisheries have been managed by use of six management areas since 1972 (Figure 1; Read and Taptuna 2003). Over the main basin of GSL, we designed a total of 245 discrete grids equalling 86.49 $km^2$ (an area of 10’ W x 5’ N) each. Each grid has two geographic attributes: coordinating within the respective fisheries management area and depth. Across the individual management areas, spatial coverage is much greater in areas II (23%) and IV (28%), compared to areas IE (14%), III (14%), V (14%), and IW (7%) (Table 3). The main basin of GSL has a maximum depth of approximately 165 m and a mean depth of 42 m (Rawson 1950, Read and Taptuna 2003). Because a typical benthic gillnet is 1.8 m deep, the FIGS is limited to sampling locations beyond 2 m deep. Over the depth range of 2–165 m, depth strata sampled were divided into four categories: < 10 m, 10.1–20 m, 20.1–40 m, and > 40 m. Of the 245 grids in GSL (Figure 1), most are in waters where depths are > 40 m (38%), followed by grids with depths of 20.1–40 m (29%) and 10.1–20 m (21%), with the least number of grids at a depth ≤ 10 m (12%; Table 1). A majority of grids are located at depths of 20.1–80 m (60%), while only 7% of grids are deeper than 80 m. Grids at depths ≤ 20m account for 33% of the total number of grids.

When implementing the FIGS, we assumed that there are no evident seasonal migrations between the management areas and connecting tributaries, as well as no diel movement over different depths of the water columns, which could affect whole lake CPUE estimates. The first assumption appears to be violated on GSL based on the study by Roberge et al. (1985), who investigated the fall spawning runs of Lake Whitefish into Little Buffalo River and found some of the larger and older Lake Whitefish utilized habitats in the river and lake year-round. Tagging results confirmed the maximum inter-boundary movement distance was 70 km for the post-spawning stock (Roberge et al. 1985). Moreover, diel movement behavior of fish is subjected to many factors such as light intensity, thermal stratification, and predator-prey interactions. During June and September, there exists an evident thermocline down to approximately 15 m (Rawson 1950, Blanken et al. 2000). To address these CPUE differences due to the diel and seasonal movements, we standardized FIGS timelines in summer months, explored a depth-stratified random sampling strategy, and limited soak time to a total of 18–30 hours per set.

The number of sets will impact the statistical power or sensitivity of a diagnostic test which relates to the accuracy and precision of a gillnet selectivity study (Eng 2003). When comparing model deviance on gillnet selectivity, for example, Carol and García-Berthou (2007) indicated there was significant dependence on both fish species captured and number of sets, stating that species that were captured at higher proportions had larger model deviances than species that were more rarely captured. When determining the appropriate number of sets, several related variables, such as surface area, grid depth, desired precision of the estimates, habitat heterogeneity, and spatial coverage, should be taken into consideration. The higher the desired precision and the larger and deeper the lake, the more sampling effort is required. To improve the precision of CPUE estimates, a depth stratified random sampling strategy is employed for all types of gillnets. The number of gillnets used at each sampling occasion is determined both by the minimum sampling time and effort needed to catch fish species as well as the desired precision of the mean value (Nyberg and Degerman 1988). The selection of a sampling grid requires consideration of three factors, the percentage of sampling grids to the total number of grids by management area; the percentage of sampling grids per depth stratum; and finally, a list of targeted grid numbers by depth stratum obtained. Using a random number generator, every year we randomly selected a maximum of 50 grids, proportional to the individual depth strata, to represent the spatial distribution of fish abundance during summer from June to August.

## NET TYPES AND SETTING STRATEGIES

Four net setting strategies were included for our FIGS in GSL: benthic, pelagic, mid-water pelagic, and Inconnu nets.

1. Benthic (bottom) set (B): a gang of benthic gillnet is set on the bottom of the lake using sideline line and anchors. It consists of 10 different mesh size panels with panel depth of 1.83 m and a total area of 300 m2 (Figure 2, Table 2). Benthic gillnet is set at every selected sampling grid except a grid depth between 10 m and 20 m.

2. Pelagic set (P): a gang of pelagic gillnet is suspended in the water column with a 5-m sideline (the distance from the water surface to the top of the net) tied to buoy between panels to increase buoyance. Panel lengths are similar to those of benthic gillnets and the panel depth of 3.66 m is specified, resulting in a total area of 600 m2 (Table 2). Pelagic gillnet is used at sampling grids that are 10 m and deeper.
3. Mid-water pelagic set (MP): a gang of pelagic gillnet is suspended with a specified length of sideline tied to buoys and attached to the headline between panels. The specified length of sideline for mid-water pelagic gillnet is 20 m (MP1) for grid depths < 40 m and 30 m (MP2) for grid depths > 40 m.
4. Inconnu set (I): To mimic commercial catch, an Inconnu net (I), single panel gillnet 50 m long, 10 m in height, and 133 mm mesh size stretched, is deployed side by side with standard gillnet. VanGerwen-Toyne et al. (2013) reported that no Inconnu were caught in the offshore waters deeper than 23.5 m. So, two Inconnu nets were set in each grid < 40 m to give a buffer for possible differences in catch.

Five depth strata have been specified at which the type and number of nets deployed differs. Figure 3 provides details on the setting strategy and the type of net to deploy by each depth strata:

1. < 10 m (< 33 ft): benthic (B) and Inconnu (I) nets;
2. 10.1–20 m (33–66 ft): pelagic (P) and Inconnu (I) nets;
3. 20.1–40 m (66–131 ft): pelagic (P), benthic (B), and Inconnu (I) nets;
4. 40.1–60 m (131–197 ft): pelagic (P), benthic (B), and mid-water (MP1) nets;
5. > 60 m (> 197 ft): pelagic (P), benthic (B), and mid-water (MP2) nets.

## FIELD OPERATION OF GILLNET

If multiple sets of gillnets are deployed at the same sampling grid, nets will be set in a order of pelagic, mid-water pelagic, benthic, and Inconnu nets to avoid possible tangling due to strong wind and water current. It can also reduce mixture of catch by mesh size panels and types of gillnets.

Once a net is deployed, effects of soak and setting duration are often concerned with issues of efficiency, fish mortality, and size and species selectivity by both researchers and fishers (Hamley 1975, Jensen 1986, Askey et al. 2007). Kennedy (1951) summarized commercial fisheries data including net length, fishing duration, and location in summer and found that greater catch rates occurred in nets that were cleared daily over those that were cleared every two days, when targeting Lake Whitefish and Lake Trout in GSL. Net setting for a relatively short duration may prevent dead fish from decomposing and decrease the probability of the catch being scavenged (Erzini et al. 1997). Other research shows that fish catch decreases with soak time because longer soak times result in more opportunities for fish to escape from the net (Prchalova et al. 2011). In addition to soak and setting time, spatiotemporal variation in the limnological environment, fish composition and size-dependent behaviour, as well as fisheries activities, will inevitably influence the capture efficiency of a given mesh size panel. In most usual circumstances, our standard method for the FIGS makes sure that nets are set between 8:00 am and 10:00 and retrieved within approximately 24 hours (between 18 and 30 hours). If unusual conditions are encountered, which lead to a setting duration of < 18 hours or > 30 hours, the records of fish samples will be excluded from accounting for CPUE, and therefore, all nets will need to be re-set. Biological data, however, may still be valuable to collect if invalid. If the survey is in conjunction with commercial fishing events, extra care must be taken to ensure that the index nets are not mixed with commercial gillnetting.

## INFORMATION TO RECORD

For ease of understanding and reproducibility, all field observation activities should explicitly define the context of each required observation, method of operation, and metric measurement unit.

The context of required field observation encompasses the schedule of the field collection, sampling grid, weather conditions, and operation procedures during field operations. The schedule of field operation includes date and time at which the field survey occurs and what specific action is taken. Sampling grids are to be chosen prior to the field survey; however, exact position of sampling grids may differ slightly due to on-site geography, weather, and limnological conditions. Grid-specific position should be recorded as latitude-longitude coordinates by real-time GPS reading. A set of weather parameters, including air temperature and pressure, cloudiness, wind direction and speed, precipitation, and wave height are documented to reflect real-time environmental conditions during field observations. These can be collected from Canadian Weather and Marine Forecasts and Warnings for Canada. Other site-based environmental information, including grid depth, gear depth (from the lake surface to the middle of net), and thermocline depth, is also gathered on record sheets. Limnological parameters including depth-specific water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* are then obtained using a multiparameter water quality sonde/meter (YSI or Hydrolab). Along the water depth profile, limnological observations are taken every 1 m within 10 m deep sites, every 2 m within depths of 10–20 m, and every 5 m beyond 20 m deep.

In addition to collection of environmental parameters, biological production is sampled by means of different kinds of gears. Before gillnetting, two vertical tows of zooplankton samples are performed from one meter above the bottom to the surface water by means of a standard plankton net (50 cm diameter, 1.5 m long, and 118 µm mesh size). If feasible, two additional tows will be required through each thermal layer, epilimnion, metalimnion and hypolimnion, to account for thermal stratification of species composition and production of zooplankton. Three replicates of mud samples are retrieved using a standard PONAR dredge (9” x 9” stainless box). For setting gillnets, gear type and setting method will be chosen in terms of grid depth. When lifting the gillnets, all fish are collected by mesh-sized panels. Grid ID, date and times, as well as coordinates for setting and lifting nets, and panel-specific catch are collected separately. When back on land, fish samples are processed, identified to species, enumerated, weighed to grams, and totaled by sets of gillnets, mesh-sized panels, and sampling grids. If the SARA species Shortjaw Cisco is caught, a minimum of 20 individuals are bagged, labeled, and frozen for future examination. All unknown fish samples are fully frozen for further checks.

## EFFECTIVE SAMPLE SIZE

In order to accommodate good representation of fish population attributes, the conventional fisheries assessment models require the specification of an effective sample size (ESS) as a weighting component for multinomial composition datasets (Quinn and Deriso 1999, Francis 2011). Usually, ESS is smaller than the actual sample size (ASS) of fish collected for age or length composition, and a theoretic parameter to simulate the variability in size or age composition from a simple random sample of fish sizes or ages (Pennington and Volstad 1994, Folmer and Pennington 2000). Considering a dataset covering inter-annual or -spatial variation, the negative log-likelihood is used to estimate ESS (Quinn and Deriso 1999):

$$-\ln L = \sum_{y=1}^{Y} n_y \sum_{a=2}^{A} p_{a,y} \, ln\hat{p}_{a,y}$$

Where $n_y$ is the sample size in year $y$ of $Y$ years, $p_{a,y}$ is the observed proportion of fish of age $a$ from $A$ ages obtained from sampling, and $\hat{p}_{a,y}$ is the predicted proportion obtained from a model. The underlying assumption is that fish have been sampled at random from the population and that ages or lengths observed more often in the sampling and estimated with more precision. Therefore, the multinomial variance of a proportion is inversely related to the sample size of fish taken for age or length composition. As sample size increases, the variance or uncertainty in the observed proportion decreases (Hulson et al. 2011). In fact, the sampling methods and the behaviour of fish usually cause overdispersion of the true uncertainty in the estimated proportions (Coggins and Quinn 1998). FDS is more complicated than simple random sampling, whilst fish samples from a set of highly-selective gillnets are remarkably truncated by certain size or age-class distributions (Regier and Robson 1966, Jensen 1995, Kurkilahti et al. 1998). In addition, fish tend to school with similar size or age groups, impacted by strong cohort recruitment events. Thus, positive intra-class correlations mean that treating the samples as random will result in erroneously small uncertainty in the length or age distribution (Pennington and Volstad 1994).

To determine ESS, Truesdell et al. (2017) outlined four types of schematic methods for relating ESS to actual sample size in catch-at-age or catch-at-size models: i) constant as annual maximum number of observations, ii) up to a maximum value as a threshold sample is reached, iii) multiplicative proportionality to annual observations, and iv) additive relationship to asymptotic number of observations. Methods i) and ii) are termed ad-hoc approaches, and methods iii) and iv) are iterative approaches. The choice of ESS estimation method and sampling intensity can impact assessment model results, either assuming constant ESS when inter-annual variation in sampling levels is substantial or assuming that ESS is related to sampling intensity (Truesdell et al. 2017).

In fisheries monitoring practices, ASS is better than ESS for describing biological length-age frequency composition, trends to be related to life history processes, field sampling intensity at large, and exploitation history of a fish stock. For instance, fish longevity and growth rate can influence the degree to which fish of a particular length overlap in age, which in turn should influence the accuracy and precision of population parameter estimates, like size-specific growth and mortality (Coggins et al. 2013). For small-sized fishes (maximum length less than 300 mm), 300–400 individuals are often an appropriate ASS for describing length frequency distribution and smaller sample sizes may be suitable for small fishes. Many large fishes (maximum length greater than 1,000 mm), are highly migratory species with wider spatial distribution and multiple habitat uses. Small ASS for large-sized fishes often fails to capture the true length distribution of the whole population or of the total catch within a limited spatiotemporal range (Schultz et al. 2016). The catch contributions of the youngest or oldest ages due to gear catchability or spatial behavior of fish were biased in the slope of the catch curve with only a single or few sub-samples, leading to an inaccurate estimate of the growth and total mortality rate (Goodyear 1995, Hulson et al. 2011).

The determination of ASS largely depends on the availability of fish from field sampling intensity and exploitation history of fisheries. In association with field sampling intensity, Brouwer and Griffiths (2005) proposed an ASS rule that ten fish per 20 mm length be randomly sampled. We examined biological samples from GSL FIGS during 2011–2020, and found that the species-specific sample sizes differed from those in general fisheries surveys (Table 4). Collected from multimesh gillnets in FIS, ASS varied from 113 (Goldeye) to 460 (Inconnu). Three small-sized species (average size < 300 mm), Least Cisco, Cisco, and Shortjaw Cisco, had relatively narrow length ranges of 98–470 mm and minimum sample sizes less than 185 mm. Three medium-sized fishes, Lake Whitefish, Longnose Sucker, and Walleye (*Stizostedion vitreum vitreum)*, spanned a length range of 102 to 602 mm, resulting in a minimum ASS of 250 fish to be sampled. For large-sized fishes, the smallest and largest fish were 153–948 mm for Burbot, 137–952 mm for Lake Trout, 248–1,010 mm for Northern Pike and 172–1,091 mm for Inconnu, which required minimum ASS of 398, 408, 381, and 460 individuals, respectively. Thus, the required minimum ASS was significantly related to average length of fish ($n = 13$, $r = 0.89$, $p < 0.001$), meaning that more samples are required for larger body-sized fish species through implementation of FIGS. To associate with the relative abundance of some fish species, we suggest conducting biological measurements of the 1st 10 Cisco and Least Cisco, the 1st 20 Lake Whitefish, and all other fishes caught by each FIS gillnet set.

Minimum ASSs for commercial fishes are largely related to minimum mesh sizes of gillnets used for fisheries. Compared with biological measurements from FIS, small-sized fish through implementation of FDS, like fish plant sampling programs, are considerably under-represented because of the selectivity of commercial gillnets (Table 4). The average length values of three medium-sized fishes were 426, 513, and 505 mm, and minimum ASSs were estimated at 222, 95, and 156 individuals for Lake Whitefish, Longnose Sucker, and Walleye, respectively. Correspondingly, the average length values of four large-sized commercial fishes were 699, 758, 650, and 770 mm, while minimum ASSs were estimated at 234, 448, 409, and 227 individuals for Burbot, Inconnu, Lake Trout, and Northern Pike, respectively. Given that the same mesh sizes of gillnets were used, the selection of constant ASS is in consensus with Scenario A outlined by Truesdell et al. (2017). However, over the exploitation history in GSL, the minimum mesh size of commercial gillnets has been modified from 140 mm in 1944 to 133 mm in 1977 and 127 mm in 1997 (Zhu et al. 2015a,b). Thus, adaptive modification of minimum ASS as outlined in Scenario B will be practically needed when size ranges of fish species are related to the alteration of mesh sizes of commercial gillnet.

## BIOLOGICAL MEASUREMENTS AND SAMPLING

For fish population biology studies, measurements of morphometric characteristics have been a key component of both FIS and FDS programs. In general, the biological characteristics of a fish population covers both descriptive, like sex, maturity and stomach content, and quantitative parameters like length, weight, and age attributes (Table 4). Fork length is measured from the tip of the snout to the fork in the caudal fin. Total length is measured from the tip of the snout to the tip of the caudal fin (caudal fin is compressed slightly vertically from maximum measurement). Both fork and total lengths are read to the closest mm. Round weight is the weight of fish with guts recorded to the nearest gram, while dressed weight is without guts. Round and dressed weights are used to calculate conversion factors for use with FDS fish samples. Fish sample processing also involves the collection of stomachs, scales, fins and fin clips, and otoliths for particular studies. Stomach contents of fish are used for studying feeding habits of fish and muscle samples will be collected for stable isotope analysis of trophic ecology. When mature, the whole gonad tissue will be frozen for determining fecundity in the lab.

Three kinds of calcified tissues are commonly used for age determination of fish. A total of 10 scales, 3 fins, and 2 otoliths per fish are collected (Zymonas and McMahon 2009, Zhu et al. 2015b). Scales from salmonids are removed from the left side within an area lying between the lateral line and the dorsal fin and just below the anterior insertion of the dorsal fin. Scales from spiny-rayed fishes such as Walleye are to be taken below the lateral line near the tip of the left pectoral fin when depressed. At least 10 scales per fish are removed to ensure an adequate number of usable scales. Prior to removing scales excess mucous is scraped away. Scales should be removed by pulling scales from the fish using forceps. Do not use a knife as this damages the scale and impairs scale reading for age estimation. Ensure tools and work stations are wiped clean between every fish sample in order to minimize contamination with other samples.

Fins or rays of pelvic, anal, dorsal or pectoral fins offer an ageing structure for species where scales or otoliths may not be available or reliable. For example, one cannot cut and open the head from fish that are intended to be commercially sold, and therefore otoliths cannot be collected. In lieu of otoliths, pectoral fin rays are the preferred aging structures for salmonids such as Lake Whitefish (Mills and Beamish 1980, Read and Taptuna 2003, Mills and Chalanchuk 2004, Zhu et al. 2017), Inconnu (Howland et al. 2004), and Bull Trout (Zymonas and McMahon 2009). Compared to scales, fin ray sampling is easily performed with simple cutting tools and does not necessarily involve sacrificing the fish.

Scale envelopes are used for storing ageing materials including scales, fin rays, and otoliths, however, otoliths may be stored in cryovials for ease of analysis. On the envelope or cryovial, species name, fish sample ID, and net lift date must be clearly recorded for sample differentiation. If some ageing structures cannot be taken from a fish, “No scale”, “No Fin ray”, or “No otolith” will be recorded on the scale envelope. The next envelope in sequence is used for the following fish.

Sex and maturity are classified using the description provided by Murua et al. (2003) and Brown-Peterson et al. (2011). When a spawning season approaches, fish are either classified as immature, pre-spawning, or post-spawning. Once spawning season begins, fish can be categorized as immature, pre-spawning, spawning, or spent. After spawning, fish are identified as either immature or spent. Occasionally there are some late spawners which could still be coded as pre-spawning. When spawning is complete, it is somewhat difficult to determine gonad condition by visual check and only sex is recorded. For young fish whose sex cannot be distinguished, both sex and maturity are recorded as ‘unknown’. In the FIGS, maturity is classified and coded as either Immature (I), Mature (M), Running Ripe (RR), Spent (S), Resting (R) or Unknown (U). Maturity can be recorded either alphabetically or numerically but should be consistently recorded using either coding to reduce confusion (Table 5).

## CONCLUSION

Gillnets are an inherently selective and flexible gear that are commonly used for scientific research and commercial fisheries purposes. Despite the dominant uses, there is a paucity of information regarding how fisheries resources can be routinely monitored by means of a set of standardized multimesh nets for fishery-independent multispecies studies. We constructed a standard set of gillnets comprising 10 different mesh size panels following a geometric progression for quantitative collection of fish samples distributed in different thermal layers of Great Slave Lake. It is important to develop a depth-stratified random sampling protocol for a large-scale, long-term and cost-effective fisheries monitoring program, like FIGS. Through implementation of FIGS, we expect to produce reliable estimates of species-specific relative abundance, analogous to CPUE, age and size composition, selectivity and efficiency of combination of mesh sizes, as well as sex ratios and size-dependent maturity. The incorporation of fishery-dependent statistics including harvest, fishing effort, and age or size composition from commercial, recreational, and Aboriginal fisheries can contribute to estimating the population demographic parameters like year-class or cohort-specific strength, growth, or mortality parameters. Meanwhile, the resulting dataset can be used to examine the stock status of fish population productivity, effects of fishing on fish populations, fish community diversity and its association with changing hydroclimate, as well as fisheries ecosystem integrity. Ultimately, it will facilitate a better understanding of how GSL fisheries production and the aquatic ecosystem will interact with underlying biological, ecological, and cumulative anthropogenic modifications in the Arctic.

## ACKNOWLEDGEMENTS

During the project design, community consultation, and field investigation, many people from the Department of Fisheries and Oceans (DFO) Great Slave Lake Working Group, Great Slave Lake Advisory Committee (GSLAC), and a number of Indigenous governments including the Dehcho First Nations (DFN), Northwest Territories Metis Nations (NWTMN), and the Akaitcho Territory Government (ATG), contributed their invaluable insights, suggestions, and traditional ecological knowledge. In particular, Larry Dow, Ellen Lea, George Low, Diane Giroux, Trevor Beck, Rosy Bjornson, Shawn Buckley, Peter Sabourin, Alex Richardson, Muhammad Janjua, Andrew Chapelsky, Chris Day, Fred Taptuna, Taylor Connolly, David Boguski, Brendan Malley, Justin Shead and Kevin Hedges, provided many invaluable comments and editing help. This project was funded by the Northwest Territories Cumulative Impacts Monitoring Program (NWT-CIMP; 2011–2016), the DFO Aboriginal Fisheries Strategy (AFS) and Aboriginal Aquatic Resource and Oceans Management (AAROM).

## REFERENCES CITED

Andrew, N.L., and Mapstone, B.D. 1987. Sampling and the description of spatial pattern in marine ecology. Ann. Rev. Oceanog. Mar. Biol. 25: 39–90.

Appelberg, M. 2000. Swedish standard methods for sampling freshwater fish with multi-mesh gillnets. Report of the National Board of Fisheries. 33 p.

Appelberg, M., Berger, H.M., Hesthagen, T., Kleiven, E., Kurkilahti, M., Raitaniemi, J., and Rask, M. 1995. Development and intercalibration of methods in NORDIC freshwater fish monitoring. Water, Air, and Soil Pollut.: Focus 85: 401–406.

Askey, P.J., Post, J.R., Parkinson, E.A., Rivot, E., Paul, A.J., and Biro, P.A. 2007. Estimation of gillnet efficiency and selectivity across multiple sampling units: A hierarchical Bayesian analysis using mark-recapture data. Fish. Res. 83: 162–174.

Baranov, F.I. 1948. Theory and assessment of fishing gear. Ch. 7, Theory of fishing with gillnets. Pishchepromizdat, Moscow. (Translation from Russian by Ontario Department of Lands and Forests, Maple, ON) 45 p.

Baremore, I.E., Bethea, D.M., and Andrews, K.I. 2012. Gillnet selectivity for juvenile Blacktip Sharks (*Carcharhinus limbatus*). Fish. Bull. 110: 230–241.

Beauchamp, D.A., Parrish, D.L., and Whaley, R.A. 2009. Coldwater fish in large standing waters. *In* Standard methods for sampling North American freshwater fishes. Edited by S.A. Bonar, W.A. Hubert, and D.W. Willis. American Fisheries Society, Bethesda, ML. pp. 97–117.

Blanken, P.D., Rouse, W.R., Culf, A.D., Spence, C., Boudreau, L.D., Jasper, J.D., Kochtubajda, B., Schertzer, W.M., Marsh, P., and Verseghy, D. 2000. Eddy covariance measurements of evaporation from Great Slave Lake, Northwest Territories, Canada. Water Resour. Res. 36(4): 1069–1077.

Bobori, D.C., and Salvarina, I. 2010. Seasonal variation of fish abundance and biomass in gillnet catches of an East Mediterranean lake: Lake Doirani. J. Environ. Biol. 31: 995–1000.

Bonar, S.A., Contreras-Balderas, S., and Iles, A.C. 2009. An introduction to standardized sampling. *In* Standard methods for sampling North American freshwater fishes. Edited by S.A. Bonar, W.A. Hubert, and D.W. Willis. American Fisheries Society, ML. pp. 1–12.

Bond, W.A. 1975. Results of an experimental gill netting program at the west end of Great Slave Lake, N.W.T. during summer, 1974. Can. Fish. Mar. Serv. Data Rep. Ser. CEN/D 75-7: viii + 83 p.

Bond, W.A., and Turnbull, T.D. 1973. Fishery investigations at Great Slave Lake, Northwest Territories 1972. Department of Environment and Fish. Mar. Serv. Tech. Rep. Ser. CEN/T-73-7: 78 p.

Boy, V., and Crivelli, A.J. 1988. Simultaneous determination of gillnet selectivity and population age-class distribution for two cyprinids. Fish. Res. 6: 337–345.

Brouwer, S.L., and Griffiths, M.H. 2005. Influences of sample design on estimates of growth and mortality in *Argyrozona argyrozona* (Pisces: Sparidae). Fish. Res. 74: 44–54.

Brown-Peterson, N.J., Wyanski, D.M., Saboriso-Rey, F., Macewicz, B.J., and Lowerre-Barbieri, S.K. 2011. A standardized terminology for describing reproductive development in fishes. Mar. Coast. Fish.: Dynam. Manage., and Ecosyst. Sci. 3: 52–70.

Brunet, N.D., Hickey, G.H., and Humphries, M.M. 2016. Local participation and partnership development in Canada's Arctic research: challenges and opportunities in an age of empowerment and self-determination. Polar Rec. 52: 345–359.

Cadima, E.L. 2003. Fish stock assessment manual. FAO Fish. Tech. Paper. No. 393. Rome, FAO. 161 p.

Carol, J., and García-Berhou, E. 2007. Gillnet selectivity and its relationship with body shape for eight freshwater fish species. J. Appl. Ichthyol. 23: 654–660.

CCAC (Canadian Council on Animal Care). 2005. Guidelines on the care and use of fish in research, teaching and testing. Canadian Council on Animal Care, Ottawa, ON. iv + 87 p.

Coggins, L.G., Jr., and Quinn, II, T.J. 1998. A simulation study of the effects of ageing error and sample size on sustained yield estimates. *In* Fishery Stock Assessment Models. Edited by F. Funk, T.J. Quinn II, J. Heifetz, J.N. Ianelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.I. Zhang. Proceedings of the International Symposium on Fishery Stock Assessment Models for the 21st Century, October 8-11, 1997, Anchorage, AK. pp. 955–975.

Coggins Jr., L.G., Gwinn, D.C., and Allen, M.S. 2013. Evaluation of age-length key sample sizes required to estimate fish total mortality and growth. Tran. Am. Fish. Soc. 142: 832–840.

Cohen, A., Matthew, M., Neville, K.J., and Wrightson, K. 2021. Colonialism in community-based monitoring: knowledge systems, finance, and power in Canada. Annals Am. Ass. Geogr. 111: 1988–2004.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2003. COSEWIC assessment and update status report on the Shortjaw Cisco *Coregonus zenithicus*. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. viii + 19 p.

COSEWIC. 2012. COSEWIC assessment and status report on the Bull Trout *Salvelinus confluentus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. iv + 103 p.

Day, A.C. 2002. Predicted impact of reducing gillnet mesh size on the efficiency of Great Slave Lake commercial Lake Whitefish, *Coregonus clupeaformis* (Mitchill) fishery, Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 2440: vii + 45 p.

Eng, J. 2003. Sample size estimation: how many individuals should be studied? Radiology 227: 309–313.

Erzini, K., Monteiro, C.C., Ribeiro, J., Santos, M.N., Gaspar, M., Monteiro, P., and Borges, T.C. 1997. An experimental study of gill net and trammel net 'ghost fishing' off the Algarve (southern Portugal). Mar. Ecol. Prog. Ser. 158: 257–265.

Fabi, G., and Grati, F. 2008. Selectivity of gill nets for *Solea solea* (Osteichthyes: Soleidae) in the Adriatic Sea Sci. Mar. 72(2): 253–263

Finstad, A.G., Jansen, P.A., and Langeland, A. 2005. Gillnet selectivity and size and age structure of an alpine Arctic Char (*Salvelinus alpinus*) population. Can. J. Fish. Aquat. Sci. 57: 1718–1727.

Folmer, O., and Pennington, M. 2000. A statistical evaluation of the design and precision of the shrimp trawl survey off West Greenland. Fish. Res. 49: 165–178.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68(6): 1124–1138.

Fukuwaka, M., Azumaya, T., Dacis, N.D., and Nagasawa, T. 2008. Bias in size composition of Chum Salmon (*Oncorhynchus keta*) caught by a gillnet with a geometric series of mesh sizes, and its correction using gear intercalibration. ICES J. Mar. Sci. 65: 930–936.

Goodyear, C.P. 1995. Mean size at age: an evaluation of sampling strategies with simulated red grouper data. Trans. Am. Fish. Soc. 124: 746–755.

Government of the Northwest Territories (GNWT). 2020. Species at Risk in the Northwest Territories: a guide to species in the Northwest Territories currently listed, or considered for listing, under federal and territorial species at risk legislation. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 116 p.

Griffiths, S.P., Kuhnert, P.M., Venables, W.N., and Blaber, S.J.M. 2007. Estimating abundance of pelagic fishes using gillnet catch data in data-limited fisheries: a Bayesian approach. Can. J. Fish. Aquat. Sci. 64: 1019–1033.

Hamley, J.M. 1975. Review of gillnet selectivity. Can. J. Fish. Aquat. Sci. 32(11): 1943–1969.

Hamley, J.M., and Regier, H.A. 1973. Direct estimates of gillnet selectivity to Walleye (*Stizostedion vitreum vitreum*). J. Fish. Res. Bd. Can. 30(6): 817–830.

Hilborn, R., and Walters, C.J. 1992. Quantitative fisheries stock assessment., choice, dynamics and uncertainty. Kluwer Academic Publishers, BS. 570 p.

Holmgren, K. 1999. Between-year variation in community structure and biomass-size distribution of benthic lake fish communities. J. Fish. Biol. 55: 535–552.

Holmgren, K., and Appelberg, M. 2000. Size structure of benthic freshwater fish communities in relation to environmental gradients. J. Fish. Biol. 57: 1312–1330.

Hovgård, H., and Lassen, H. 2000. Manual on estimation of selectivity for gillnet and loneline gears in abundance surveys. FAO Fish. Tech. Pap. No. 397. Rome, FAO. 84 p.

Howland, K.L., Gendron, M., Tonn, W.M., and Tallman, R.F. 2004. Age determination of a long-lived coregonid from the Canadian North: comparison of otoliths, fin rays and scales in inconnu (*Stenodus leucichthys*). Annales Zoologici Fennici 41: 205–214.

Hulson, P.J.F., Hanselman, D.H., and Quinn II, T.J. 2011. Effects of process and observation errors on effective sample size of fishery and survey age and length composition using variance ratio and likelihood methods. ICES J. Mar. Sci. 68(7): 1548–1557.

Jensen, J.W. 1986. Gillnet selectivity and the efficiency of alternative combinations of the mesh sizes for some freshwater fish. J. Fish. Biol. 28: 637–646.

Jensen, J.W. 1995. Evaluating catches of salmonids taken by gillnets. J. Fish. Biol. 46: 862–871.

Jensen, J.W. and Hesthagen, T. 1996. Direct estimates of the selectivity of a multimesh and a series of single gillnets for Brown Trout. J. Fish Biol. 49: 33–40.

Jones, N.E., and Yunker, G.B. 2011. Development of a riverine index netting protocol: comparisons of net orientation, height, panel order, and line diameter. N. Am. J. Fish. Manage. 31: 23–31.

Jurvelius, J., Kolari, I., and Leskela, A. 2011. Quality and status of fish stocks in lakes: gillnetting, seining, trawling and hydroacoustics as sampling methods. Hydrobiologia 660: 29–36.

Kurkilahti, M., Appelberg, M., Bergstrand, E., and Enderlein, O. 1998. An indirect estimate of bimodal gillnet selectivity of smelt. J. Fish. Biol. 52: 243–254.

Kennedy, W.A. 1951. The relationship of fishing effort by gill nets to the interval between lifts. J. Fish. Res. Bd. Can. 8(4): 264–274.

Lauridsen, T.L., Landkildehus, F., Jeppesen, E., Jorgensen, T.B., and Sondergaard, M. 2008. A comparison of methods for calculating catch per unit effort (CPUE) of gill net catches in lakes. Fish. Res. 93: 204–211.

Lobyrev, F. and Hoffman, M.J. 2018. A morphological and geometric method for estimating the selectivity of gill nets. Rev. Fish Biol. Fish. 28: 909–924.

Low, G., Stewart, D.B., Day, A.C. and Taptuna, W.E.F. 1999. Comparison of fish harvests from the east arm of Great Slave Lake, N.W.T., by itinerant sport anglers in 1986 and 1994. Can. Tech. Rep. Fish. Aquat. Sci. 2263: iv + 32 p.

Lyons, K., Jarvis, E.T., Jorgensenc, S.J., Weng, K., O'Sullivanc, J., Winkler, C., and Lowea, C.G. 2013. The degree and result of gillnet fishery interactions with juvenile white sharks in southern California assessed by fishery-independent and -dependent methods. Fish. Res. 147: 370–380.

Millar, R.B., and Holst, R. 1997. Estimation of gillnet and hook selectivity using log-linear methods. ICES J. Mar. Sci. 54: 471–477.

Mills, K.H., and Beamish, R.J. 1980. Comparison of fin-ray and scale age determinations for Lake Whitefish (*Coregonus clupeaformis*) and their implications for estimates of growth and animal survival. Can. J. Fish. Aquat. Sci. 37: 534–544.

Mills, K.H., and Chalanchuk, S.M. 2004. The fin-ray method of aging Lake Whitefish. Annales Zoologici Fennici 41: 215–223.

Moshenko, R.W., and Low, G. 1978. An experimental gillnetting program on Great Slave Lake, Northwest Territories, 1977. Fish. Mar. Serv. Data Rep. No. FS 97-13/102, vi + 51 p.

Murray, L., and Reist, J.D. 2003. Status report on the Shortjaw Cisco (*Coregonus zenithicus*) in central and western Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. 2638: vii + 56 p.

Murua, H., Kraus, G., Saborido-Rey, F., Witthames, P.R., Thorsen, A., and Junquera, S. 2003. Procedures to estimates fecundity of marine fish species in relation to their reproductive strategy. J. Northwest Atl. Fish. Sci. 33: 33–54.

Nyberg, P., and Degerman, E. 1988. Standardized test fishing with survey nets. Inform. Institute for Freshwater Research, Drottningholm (7). 22 p. (In Swedish with English summary).

Olin, M., Malinen, T., and Ruuhijarvi, J. 2009. Gillnet catch in estimating the density and structure of fish community-comparison of gillnet and trawl samples in a eutrophic lake. Fish. Res. 96: 88–94.

Olin, M., Kurkilahi, M., Peitola, P., and Ruuhijarvi, J. 2004. The effects of fish accumulation on the catchability of multimesh gillnet. Fish. Res. 68: 135–147.

Olin, M., Rask, M., Ruuhijarvi, J., Kurkilahti, M., Ala-Opas, P., and Ylonen, O. 2002. Fish community structure in mesotrophic and eutrophic lakes of southern Finland: the relative abundance of percids and cyprinids along a trophic gradient. J. Fish. Biol. 60: 593–612.

Peltonen, H., Ruuhijarvi, J., Malinen, T., and Horppila, J. 1999. Estimation of Roach (*Rutilus rutilus* (L)) and Smelt (*Osmerus eperlanus* (L)) stocks with virtual population analysis, hydroacoustics and gillnet CPUE. Fish. Res. 44: 25–36.

Pennington, M., and Volstad, J.H. 1994. Assessing the effect of intra-haul correlation and variable density on estimates of population characteristics from marine surveys. Biometrics, 50: 725–732.

Pennington, M., and Strùmme, T. 1998. Surveys as a research tool for managing dynamic stocks. Fish. Res. 37: 97–106.

Power, G. 1978. Fish population structure in Arctic lakes. J. Fish. Res. Bd. Can. 35: 53–59.

Prchalova, M., Mrkvicka, T., Peterka, J., Cech, M., Berec, L., and Kubecka, J. 2011. A model of gillnet catch in relation to the catchable biomass, saturation, soak time and sampling period. Fish. Res. 107: 201–209.

Quinn, T.J., and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York, NY. 560 p.

Radomski, P., Anderson, C.S., Bruesewitz, A.E., Carlson, A.J., and Borkholder, B.D. 2020. An assessment model for a standard gill net incorporating direct and indirect selectivity applied to Walleye. N. Am. J. Fish. Manag. 40: 105–124.

Rawson, D.S. 1949. Estimating the fish production of Great Slave Lake. Trans. Am. Fish. Soc. 77: 81–92.

Rawson, D.S. 1950. The physical limnology of Great Slave Lake. J. Fish. Res. Board Can. 8: 3–66.

Read, C.J., and Taptuna, W.E.F. 2003. Data from the commercial fishery for Lake Whitefish, *Coregonus clupeaformis* (Mitchill), on Great Slave Lake, Northwest Territories, 1999/00 to 2001/02. Can. Data Report of Fish. Aquat. Sci. No. 1111: v + 54 p.

Regier, H.A., and Robson, D.S. 1966. Selectivity of gill nets, especially to Lake Whitefish. Can. J. Fish. Aquat. Sci. 23(3): 423–454.

Roberge, M.M., Low, G., and Read, C.J. 1985. Data from an experimental gillnetting program on Great Slave Lake, Northwest Territories, 1980–81. Can. Data Rep. Fish. Aquat. Sci. 537: vii + 156 p.

Rotherham, D., Underwood, A.J., Chapman, M.G., and Gray, C.A. 2007. A strategy for developing scientific sampling tools for fishery-independent surveys of estuarine fish in New South Wales, Australia. ICES J. Mar. Sci. 64: 1512–1516.

Rudstam, L.G., Magnuson, J.J., and Tonn, W.M. 1984. Size selectivity of passive fishing gear: a correction for encounter probability applied to gill nets. Can. J. Fish. Aquat. Sci. 41: 1252–1255.

Schultz, L.D., Mayfield, M.P., and Whitlock, S.L. 2016. Sample sizes needed to describe length-frequency of small-bodied fishes: an example using larval Pacific Lamprey. J. Fish Wildl. Manag. 7(2): 315–322.

Truesdell, S.B., Bence, J.R., Syslo, J.M., and Ebener, M.P. 2017. Estimating multinomal effective sample size in catch-at-age and catch-at-size models. Fish. Res. 192: 66–83.

VanGerwen-Toyne, M., Day, A.C., Taptuna, F., Leonard, D., Frame, S., and Tallman, R. 2013. Information in support of assessment of Buffalo River Inconnu, (*Stenodus leucichthys*), Great Slave Lake, Northwest Territories, 1945–2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/069. vii + 81 p.

Winfield, I.J., Fletcher, J.M., James, J.B., and Bean, C.W. 2009. Assessment of fish populations in still waters using hydroacoustics and survey gill netting: experiences with Arctic charr (*Salvelinus alpinus*) in the UK. Fish. Res. 96: 30–38.

Zymonas, N.D., and McMahon, T.E. 2009. Comparison of pelvic fin rays, scales and otoliths for estimating age and growth of Bull Trout, *Salvelinus confluentus*. Fish. Manage. Ecol. 16: 155–164.

Zhu, X., Day, A.C., Taptuna, W.E.F., Carmichael, T.J., and Tallman, R.F. 2015a. Hierarchical modeling of spatiotemporal dynamics of biological characteristics of Lake Whitefish, *Coregonus clupeaformis* (Mitchill), in Great Slave Lake, Northwest Territories, 1972–2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/038. v + 56 p.

Zhu, X., Wastle, R.J., Howland, K.L., Leonard, D.J., Mann, S., Carmichael, T.J., and Tallman, R.F. 2015b. A comparison of three anatomical structures for estimating age in a slow-growing subarctic population of Lake Whitefish. N. Am. J. Fish. Manag. 35: 262–270.

Zhu, X., Chapelsky, A., Carmichael, T.J., Leonard, D.L., Lea, E., Tallman, R.F., Evans, M., Podemski, C., and Low, G. 2017. Establishment of ecological baseline metrics for integrated ecomonitoring and assessment of cumulative impacts on Great Slave Lake fisheries ecosystem. Can. Tech. Rpt. Fish. Aquat. Sci. 3223: ix + 58 p.

# TABLES AND FIGURES

*Table 1. Comparison of gillnet dimensions together with minimum mesh size, maximum mesh size, number of panels (n), and geometric/mesh size factor (r) for the consecutive panels of experimental gillnets.*

| Min mesh size (mm) | Max mesh size (mm) | Number of Panels (n) | Geometric/Mesh size factor (r) | Source |
|---|---|---|---|---|
| 5 | 55 | 12 | 1.24 | Appelberg et al. (1995), Holmgren (1999), Holmgren and Appelberg (2000), Kurkilahti et al. (1998), Olin et al. (2004), Olin et al. (2009) |
| 5 | 85 | 14 | 1.24 | Lauridsen et al. (2008) |
| 8 | 52 | 11 | 1.21 | Jensen (1995) |
| 12 | 60 | 8 | 1.26 | Peltonen et al. (1999) |
| 29 | 253 | 10 | 1.27 | Carol and García-Berhou (2007) |
| 48 | 157 | 10 | 1.14 | Fukuwaka et al. (2008) |
| 64 | 72 | 5 | 1.03 | Fabi and Grati (2008) |
| 76 | 203 | 7 | 1.18 | Baremore et al. (2012) |

*Table 2. Specification of estimated and marketable mesh size (knot to knot stretched), thread diameters, height, length and area of a set of both benthic (a) and pelagic gillnets (b) used in the fishery-independent gillnet study (FIGS) in Great Slave Lake (GSL).*

*a) Benthic gillnet*

| Panel | Estimated (mm) | Market (mm) | Diameter (mm) | Length (m) | Height (m) | Area ($m^2$) |
|---|---|---|---|---|---|---|
| 1 | 12.70 | 12.70 | 0.10 | 1.83 | 10.94 | 20.00 |
| 2 | 16.58 | 19.05 | 0.13 | 1.83 | 10.94 | 20.00 |
| 3 | 21.64 | 25.40 | 0.13 | 1.83 | 10.94 | 20.00 |
| 4 | 28.24 | 31.75 | 0.15 | 1.83 | 10.94 | 20.00 |
| 5 | 36.87 | 38.10 | 0.15 | 1.83 | 10.94 | 20.00 |
| 6 | 48.12 | 50.80 | 0.18 | 1.83 | 21.87 | 40.00 |
| 7 | 62.82 | 63.50 | 0.23 | 1.83 | 21.87 | 40.00 |
| 8 | 81.99 | 88.90 | 0.23 | 1.83 | 21.87 | 40.00 |
| 9 | 107.03 | 114.30 | 0.28 | 1.83 | 21.87 | 40.00 |
| 10 | 139.70 | 139.70 | 0.33 | 1.83 | 21.87 | 40.00 |

*b) Pelagic gillnet*

| Panel | Estimated (mm) | Market (mm) | Diameter (mm) | Length (m) | Height (m) | Area ($m^2$) |
|---|---|---|---|---|---|---|
| 1 | 12.70 | 12.70 | 0.10 | 3.66 | 10.94 | 40.00 |
| 2 | 16.58 | 19.05 | 0.13 | 3.66 | 10.94 | 40.00 |
| 3 | 21.64 | 25.40 | 0.13 | 3.66 | 10.94 | 40.00 |
| 4 | 28.24 | 31.75 | 0.15 | 3.66 | 10.94 | 40.00 |
| 5 | 36.87 | 38.10 | 0.15 | 3.66 | 10.94 | 40.00 |
| 6 | 48.12 | 50.80 | 0.18 | 3.66 | 21.87 | 80.00 |
| 7 | 62.82 | 63.50 | 0.23 | 3.66 | 21.87 | 80.00 |
| 8 | 81.99 | 88.90 | 0.23 | 3.66 | 21.87 | 80.00 |
| 9 | 107.03 | 114.30 | 0.28 | 3.66 | 21.87 | 80.00 |
| 10 | 139.70 | 139.70 | 0.33 | 3.66 | 21.87 | 80.00 |

*Table 3. Summary of management area-based grid numbers against six depth groups for the fishery-independent gillnet study (FIGS) in Great Slave Lake, including the total number of grids per management area and the percentage of the total number of grids that the area included.*

| **Depth Range (m)** | **Management Area** | | | | | | **Total Grids** | **Percent of Total** |
|---|---|---|---|---|---|---|---|---|
| | **IW** | **IE** | **II** | **III** | **IV** | **V** | | |
| **≤ 10 m** | 11 | 4 | 1 | 9 | 4 | 1 | 30 | 12 |
| **10.1 m–20 m** | 5 | 14 | 6 | 9 | 7 | 11 | 52 | 21 |
| **20.1 m–40 m** | 0 | 13 | 13 | 14 | 22 | 9 | 71 | 29 |
| **40.1 m–80 m** | 0 | 3 | 36 | 3 | 27 | 6 | 75 | 31 |
| **80.1 m–160 m** | 0 | 0 | 1 | 0 | 9 | 4 | 14 | 6 |
| **> 160 m** | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 1 |
| **Total Grids** | 16 | 34 | 57 | 35 | 69 | 34 | 245 | 100 |
| **Percent of Total** | 7 | 14 | 23 | 14 | 28 | 14 | 100 | - |

*Table 4. Biological measurements and sample size estimation suggested for the fishery-independent survey (FIS) and fishery-dependent survey (FDS) when implementing FIGS in Great Slave Lake (GSL).*

| **Biological Measurement** | **Burbot** | **Cisco** | **Goldeye** | **Inconnu** | **Lake Whitefish** | **Lake Trout** | **Least Cisco** | **Longnose Sucker** | **Northern Pike** | **Shortjaw Cisco** | **Walleye** | **White Sucker** | **Other Cisco** | **Other fish** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total length (mm)** | Yes | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Fork length (mm)** | - | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Round weight (g)** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Dressed weight (g)** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Sex** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Maturity** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Gonad weight (g)** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Otolith** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Scale** | - | Yes | - | - | Yes | - | Yes | Yes | Yes | Yes | Yes | Yes | Yes | - |
| **Pectoral fin ray*** | - | Yes | - | Yes | Yes | Yes | - | - | - | Yes | - | - | Yes | - |
| **Stomach frozen (with food)** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Freeze whole**** | - | Yes | - | - | - | - | Yes | - | - | Yes | - | - | Yes | Yes |
| **Picture** | - | Yes | - | - | Yes | Yes | Yes | - | - | Yes | - | - | Yes | Yes |
| **For fishery-independent survey** | | | | | | | | | | | | | | |
| **Min size (mm)** | 153 | 120 | 159 | 172 | 102 | 137 | 103 | 132 | 248 | 98 | 174 | 232 | 113 | - |
| **Max size (mm)** | 948 | 466 | 385 | 1,091 | 602 | 952 | 470 | 666 | 1,010 | 440 | 665 | 585 | 425 | - |
| **Average length (mm)** | 536 | 307 | 319 | 695 | 359 | 588 | 253 | 404 | 622 | 221 | 412 | 489 | 260 | - |
| **Sample size estimated** | 398 | 173 | 113 | 460 | 250 | 408 | 184 | 267 | 381 | 171 | 246 | 177 | 156 | - |
| **Sample size suggested** | All | 1st 10 fish | All | All | 1st 20 fish | All | 1st 10 fish | All | All | All | All | All | 1st 10 fish | - |
| **For fishery-dependent survey** | | | | | | | | | | | | | | |
| **Min size (mm)** | 440 | - | - | 231 | 226 | 165 | - | 440 | 615 | - | 340 | - | - | - |
| **Max size (mm)** | 908 | - | - | 1,126 | 669 | 982 | - | 630 | 1,068 | - | 652 | - | - | - |
| **Average length (mm)** | 699 | - | - | 758 | 426 | 650 | - | 513 | 770 | - | 505 | - | - | - |
| **Sample size estimated** | 234 | - | - | 448 | 222 | 409 | - | 95 | 227 | - | 156 | - | - | - |
| **Sample size suggested** | 250 | - | - | 450 | 250 | 450 | - | 100 | 250 | - | 200 | - | - | - |

* For Lake Trout, there are two options for biological sampling: frozen or processed in field. If frozen, provide sample number with biological information on scale envelope and put the envelope under left gill, and freeze flat.

** For Cisco group fish, a portion of fish sampled will be required to be frozen whole without cuts or damage for morphological and identification purposes.

*Table 5. Maturity classification of fish ovaries and corresponding histological descriptions by maturity stage and code. The general descriptions were referred to Murua et al. (2003) and Brown-Peterson et al. (2011). Each fish sampled was encoded by both the sex and maturity stage in a comparable 2-character format (i.e., F2 = mature female, M9 = spent male).*

| **Maturity Stage** | **Code** | **Female (F)** | **Code** | **Male (M)** |
|---|---|---|---|---|
| Unknown | 0 | • sex unknown | - | - |
| Immature | 1 | • never spawned<br>• gonad bumpy in texture<br>• hard and shaped like a long triangle<br>• up to full length of body cavity<br>• gonad skin firm<br>• eggs visible but tiny | 6 | • never spawned<br>• gonads long and thin<br>• tube-like shape<br>• up to full body length<br>• putty-like firmness |
| Mature | 2 | • current year spawner<br>• gonad fills body cavity<br>• small blood vessel visible<br>• eggs growing but not loose<br>• not expelled by pressure | 7 | • current year spawner<br>• gonads growing and more firm<br>• milt not expelled by pressure<br>• centers may feel juicy |
| Running/Ripe | 3 | • current year spawner<br>• gonads fill body cavity<br>• eggs full size and almost see-through<br>• eggs released by pressing stomach | 8 | • current year spawner<br>• gonads full size<br>• usually white<br>• milt expelled by slight pressure |
| Spent | 4 | • spawning complete<br>• gonad skin burst open and loose<br>• small eggs visible<br>• some loose full sized eggs found | 9 | • spawning complete<br>• loose with some milt<br>• blood vessels obvious<br>• gonads darker in color |
| Resting | 5 | • not spawning this year, but did in past<br>• gonads about half the size of the body cavity<br>• gonad skin is thin, loose, and almost see-through<br>• healed from spawning<br>• tiny eggs visible<br>• some full-size eggs may be found<br>• gonad loose or flappy | 10 | • not spawning this year but did in past<br>• gonads tube-shaped, less bulby<br>• healed from spawning<br>• no fluid in center (does not feel juicy)<br>• usually full length of body cavity<br>• usually dark and blotchy in color |

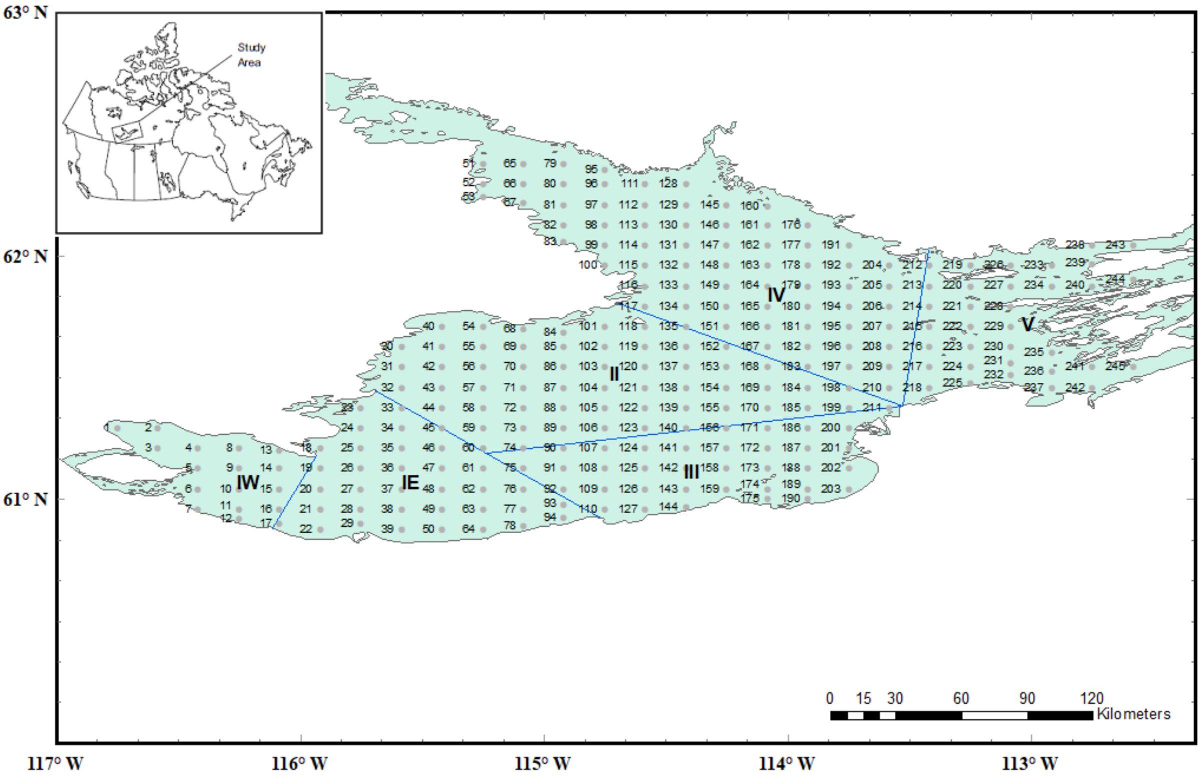

*Figure 1. Grid codes and fisheries management areas in the main basin of Great Slave Lake (GSL). GSL is divided into 6 management areas from I to V, with I split into east (E) and west (W) boundaries. The lake is further subdivided into 245 equal-sized grids for the purpose of the fishery-independent gillnet study (FIGS) program.*

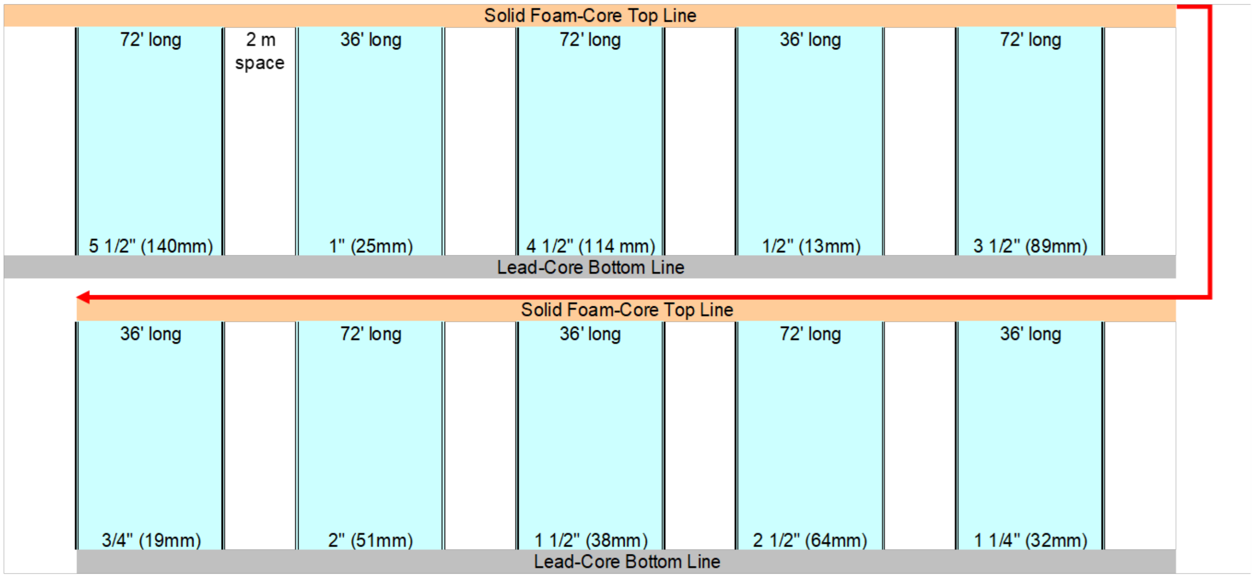

*Figure 2. Profiles of a gang of experimental gillnets used for the Great Slave Lake fisheries-independent gillnet studies indicating respective mesh sizes (mm), length (m) and random order. Panel depth varies between 1.8 m and 3.7 m for benthic (bottom) and pelagic (suspended) gillnets, respectively.*

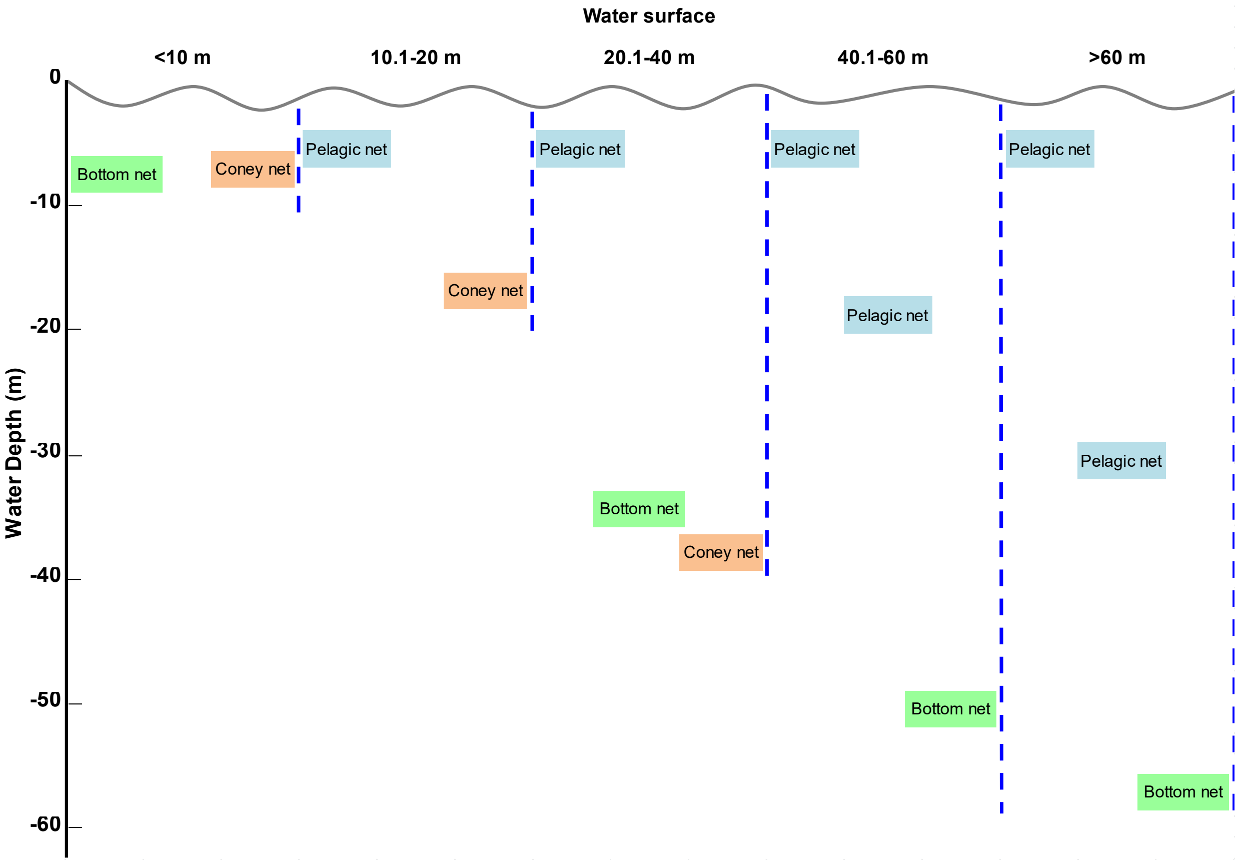

*Figure 3. Spatial profile of the net setting strategy for the fishery-independent gillnet study for Great Slave Lake in terms of depth-stratified contours. Broken vertical lines indicate the divisions of each depth stratum.*

# APPENDIX A. EQUIPMENT CHECKLIST

- **Vessel** – minimum length required 4.3 m, with 4.9 m preferred
- **Outboard motor** – minimum 9.9 hp, with 15 hp preferred
- **Motor repair kit** – includes:
    - spark plugs and spark plug wrench
    - large screwdriver and pliers
    - cotter and shear pins wire
    - lubricating oil (WD-40™)
    - manual pull cord
    - duct tape and electrical tape
    - a whistle
- **Gas** – plan on enough gas for the day's requirements
- **Spare gas line and spare oil filter** (just in case)
- **Paddles or oars** (three are better than two)
- **Bailing bucket** (or bilge pump)
- **Anchor/Throw line** – 65.0 m for the vessel's anchor and 15.0 m for the safety throw line
- The required number of approved **personal flotation devices** (e.g., life jackets, flotation jackets, or survival suits) and an **emergency flotation vessel** able to fit the crew in case of major disaster
- **First aid kit** for vessel and personal first aid kits for field crew
- **Satellite Phone** or a **SPOT** for use in emergencies and for checking in when no cell service
- **GPS unit** to navigate vessel to grid location and **personal GPS unit** for recording GPS coordinates of actual sampling and net setting locations and for emergency back-up
- **Rain suits**, **rubber boots** (or waders), **gloves**, **hat**, and a **change of warm clothes**
- The required number of **FIGS nets**, plus 1 spare net per mesh size (in case of damage) with attached bridles, all stored in **fish tubs**
- The required number of **marker buoys**, anchors, and **anchor-marker buoy lines** in a separate storage container for the nets with extra sideline/rope
- **Depth sounder** and **battery**
- **Watch**
- **YSI** dissolved oxygen meter with spare batteries, membranes, and KCl solution (calibration liquids and equipment kept on land)
- **Light meter and/or secchi disk on measured rope** to determine light penetration
- **Hand held thermometer**
- **Datasheets and necessary protocols** in a field binder
- **Fish sampling kit** (kept on land) – includes:
    - measuring board with built in ruler, have measuring tape on hand for larger fish

  - hand held spring scales with a weigh sock (ranging from 10 g, 25 g, 100 g, 1 kg, 3 kg, and 10 kg) or an electronic digital balance with a weigh pan (recommended to read to the nearest 0.01 g)
  - fillet knives (two are better than one)
  - scale envelopes and cryovials (many)
  - whirl-pak bags (many) and plastic bags (many)
  - vials or empty film canisters (many)
  - scissors (two are better than one)
  - forceps (two are better than one)
  - HB pencils (ten or more)
  - permanent waterproof felt tip markers (at least two of each: fine, medium and thick tips)

- **Landing net**
- **Camera with tripod**, construct a **mesh screen** with built in meter stick for comparable photos
- **Mesh bags** – each marked with the type of net and mesh size, to be used to store fish when transporting to shore. Use of labelled **Fish tubs** may be needed for large catches
- **Ice and shovel** – to ensure the freshness of the catch when transporting to shore and prior to sampling