SEASONAL LENGTH:WEIGHT RELATIONSHIPS OF GRENADIERS, CHIMAERAS AND ATLANTIC HERRING CAUGHT BY FISHERIES AND OCEANS CANADA MARITIMES REGION ECOSYSTEM SURVEYS USING DIFFERENT MEASUREMENT TECHNIQUES AT-SEA

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2019

Canadian Data Report of
Fisheries and Aquatic Sciences 1291

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Cat. No. Fs97-13/1291E ISBN 978-0-660-30469-4 ISSN 1488-5395

Correct citation for this publication:

Noble, V.R., and Clark, D. S., 2019. Seasonal length:weight relationships of Grenadiers, Chimaeras, and Atlantic Herring caught by Fisheries and Oceans Canada's Maritimes Region Ecosystem Surveys, using different measurement techniques at sea. Can. Data Rep. Fish. Aquat. Sci.1291: iv + 14 p.

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ABSTRACT

Noble, V.R., and Clark, D. S., 2019. Seasonal length:weight relationships of Grenadiers, Chimaeras, and Atlantic Herring caught by Fisheries and Oceans Canada's Maritimes Region Ecosystem Surveys, using different measurement techniques at sea. Can. Data Rep. Fish. Aquat. Sci.1291: iv + 14 p.

Fisheries and Oceans Canada Maritimes Region has conducted annual ecosystem surveys of the Scotian Shelf, Bay of Fundy and Georges Bank since 1970. These surveys are the primary data source for monitoring trends in fish and invertebrate species distribution, abundance, and biological condition in the Maritimes Region. Since 2014, all catch and biological data are entered at sea using the Ecosystem Survey Entry software system, which was developed to aid in the automation of the data entry process. An error message is generated during data entry if the observed weight of a specimen at-length differs from the predicted weight-at-length by more than 25%. This is intended to reduce data entry errors due to typographic errors, incorrect measurement and/or units used. Fish species Length:Weight Relationships (LWR) are an important tool to aid in data collection quality control at sea. We use regression coefficients, intercept (*a)* and slope (*b)*, calculated from previous years seasonal surveys to predict the weight from the length of a fish. This report examines fish species that have been measured differently throughout the time period (2001-2014 or 2001-2017 for deep water species) and estimates (LWR) coefficients for the differing methods. Moving forward, Atlantic Herring will be measured by total length in millimeter. Grenadier and Chimaera species will be measured using pre-anal fin length to the nearest millimeter.

RÉSUMÉ

Noble, V.R., and Clark, D. S., 2019. Seasonal length:weight relationships of Grenadiers, Chimaeras, and Atlantic Herring caught by Fisheries and Oceans Canada's Maritimes Region Ecosystem Surveys, using different measurement techniques at sea. Can. Data Rep. Fish. Aquat. Sci.1291: iv + 14 p.

Depuis 1970, le personnel de la région des Maritimes de Pêches et Océans Canada effectue chaque année des relevés de l'écosystème de la plate-forme Néo-Écossaise, de la baie de Fundy et du banc de Georges. Ces relevés constituent la principale source de données pour la surveillance des tendances en ce qui a trait à la répartition des espèces de poissons et d'invertébrés, à leur abondance et aux conditions biologiques dans la région des Maritimes. Depuis 2014, les données liées aux captures et les données biologiques sont toutes saisies en mer à l'aide du logiciel Ecosystem Survey Entry, qui a été mis au point pour faciliter l'automatisation du processus de saisie des données. Un message d'erreur est généré lors de la saisie de données si le poids observé d'un spécimen par rapport à sa taille diffère de plus de 25 % de celui prévu. Cette mesure vise à réduire les erreurs de saisie de données dues à des erreurs typographiques, à des mesures incorrectes ou aux unités utilisées. Les rapports longueur/poids des espèces de poissons sont un outil important pour faciliter le contrôle de la qualité de la collecte de données en mer. Nous utilisons les coefficients de régression, ordonnée à l'origine (*a)* et pente (*b)*, calculés à partir des relevés saisonniers des années précédentes pour prédire le poids en fonction de la longueur d'un poisson. Ce rapport porte sur les espèces de poissons qui ont été mesurées différemment au cours de la période en question (2001-2014 ou 2001-2017 pour les espèces d'eau profonde) et les coefficients estimés des rapports longueur/poids selon les différentes méthodes. À l'avenir, le hareng de l'Atlantique sera mesuré en utilisant la longueur totale en millimètres. Et les espèces de grenadiers et de chimères seront mesurées au millimètre près en utilisant la longueur jusqu'à la nageoire préanale.

BACKGROUND

Fisheries and Oceans Canada (DFO) has conducted annual summer ecosystem surveys of the Scotian Shelf and Bay of Fundy since 1970 (Figure 1) in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX. The March (winter) 4VsW survey, with spatial coverage selected to provide indices of abundance for 4VsW cod, was conducted from 1986-2010 and covered most of NAFO Divisions 4VsW (Figure 2). The Maritimes Region of DFO has also conducted a winter Ecosystem Survey on Georges Bank in the NAFO Division 5Z using a standardized protocol since 1987 (Figure 1). These surveys are the primary data source for monitoring trends in fish and invertebrate species distribution, abundance, and biological condition in the Maritimes Region (e.g., DFO 2017, 2018).

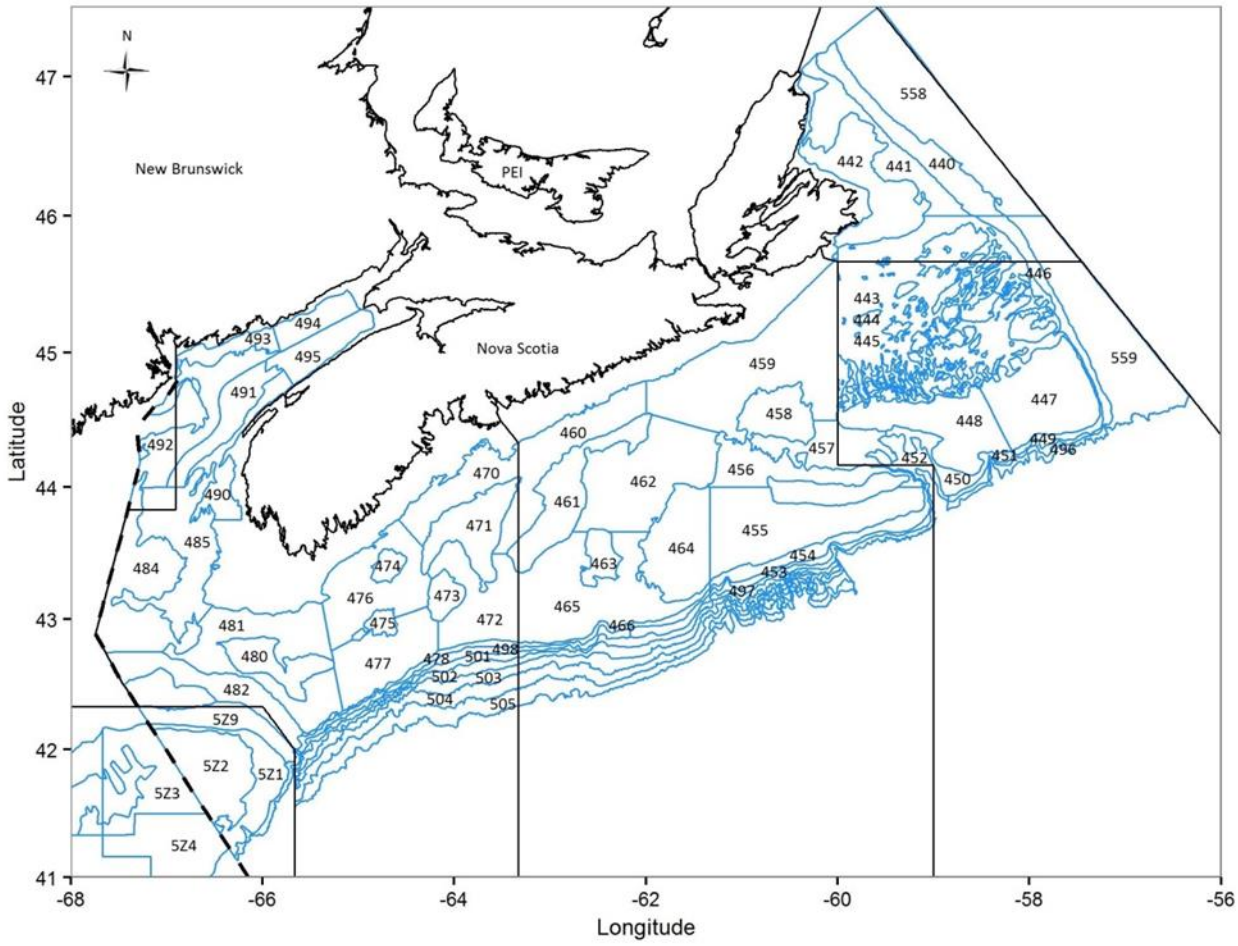

Figure 1. Ecosystem Survey strata areas surveyed off the Scotian Shelf, Bay of Fundy and Georges Bank.

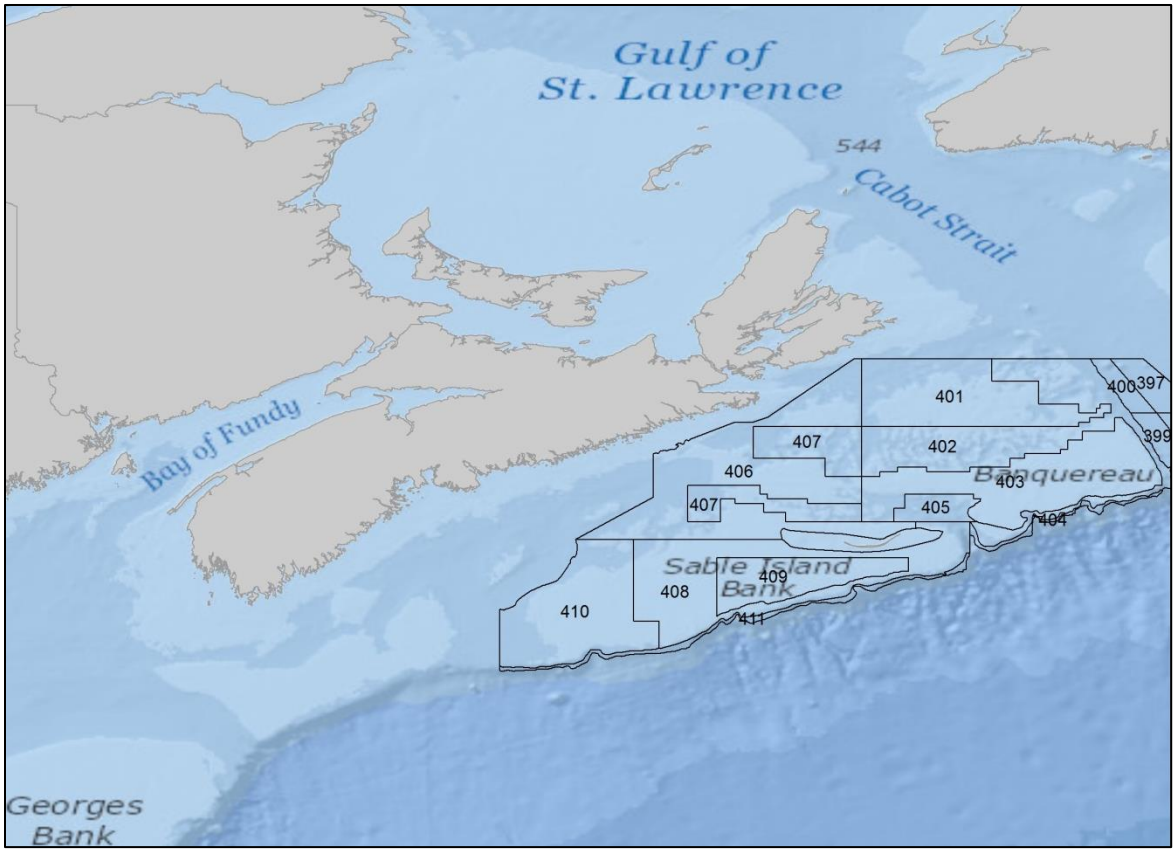

Figure 2. Ecosystem Survey strata areas surveyed off the Scotian Shelf during the March (winter) 4VsW survey.

The Ecosystem Survey Entry software system (ESE; Ecosystem Surveys Entry User Guide 14, January 2017) was developed for the Maritimes Region Ecosystem Surveys, to aid in the automation of the data entry process while at sea. Length:Weight Relationships (LWR) differ between species of fish depending on body shape, and within a species depending on condition of the individual fish. Individual fish within the population can vary in body condition seasonally, yearly and between the sexes. Using linear regressions of the LWR, we determine the regression coefficients, (*b*) slope and (*a*) intercept, for each fish species caught in the DFO summer 4VWX (strata 440-503), winter Georges Bank (strata area 5Z), and March (winter) 4VsW (strata 396-411) Ecosystem Surveys (See Figures 1 and 2). We created a regression coefficients table for each species depending on survey season, summer (4VWX survey) and winter (Georges Bank and 4VsW combined), that can easily be entered into the ESE before these two yearly surveys are conducted. These coefficients are used to predict the weight of a fish from its length. The ESE will return an error message if the weight-at-length differs from the predicted weight-at-length by more than a given percentage (25% is frequently used). This is intended to reduce human error during the data entry process, and improve data reliability.

Over time, some fish species have been measured using different techniques. For all species, the protocol followed when surveys began was to measure length as fork length. For grenadiers and chimaeras length measurement used has switched to pre-anal fin length, following recommendations in the literature (Atkinson 1981). Pre-anal fin length will be the measurement moving forward for chimaeras and grenadiers as it helps to avoid measurement error when tails have been damaged during capture. The standard protocol for herring biologists at DFO is to

pinch the caudal fin together and record total length in millimeters. Herring length is now recorded in this manner on the regional survey.

QUANTITATIVE METHODS

Fish LWR were calculated using the exponential relationship: $W = a \times L^{b}$ (Ricker 1968), where W is total weight (g) and L is length (cm or mm). Regression coefficients, intercept (*a*) and slope (*b*), were estimated using linear regression through logarithmic transformation; log (W) = log (*a*) + *b*·log (L). The slope (*b*) of the LWR represents the body condition of the sample population and is affected by factors such as age, sex, season, spawning state, food availability, temperature, and fishing gear used (Ricker 1973).

Here we use species LWR as an important tool to aid in data collection quality control at sea. We use regression coefficients, *a* and *b*, calculated from previous years survey results to predict the weight from the length of the fish. At sea, if the weight of that fish differs from the predicted weight for that length by more than a specified percentage (error) the ESE will generate an error message to prompt a measurement re-evaluation.

More generally, fish biologists will use the LWR to predict the weight from the length of a fish, which is then used for computing the biomass of a sample of fish from the length-frequency of that sample. One can also compare LWR from fisheries independent surveys to targeted catches from the fisheries.

A log transformed LW linear regression was conducted for individual species in summer and winter seasons using available data from DFO's Summer (June – Aug 4VWX 5YZ) and Winter (Feb-Apr 4VsWX and 5Z) between 2001 and 2014 (or 2017 when sample size was small) to determine each species regression coefficients by season (see Noble and Clark 2019). For those species where the length measurement method has changed, conversion factors between length types are needed over the duration of the Maritimes Region Ecosystem Surveys to ensure data can be compared among years.

In the past, Atlantic Herring have been measured in both centimeters and millimeters, and the grenadiers and chimaeras have been measured in either pre-anal fin or total length depending on the year in either centimeters or millimeters. A log transformed LW regression was performed for both measurements of a species separately when two measurements or units were included in past data. The *a* and *b* coefficients for the regression that fit the survey data best (based on r^2) for each measurement type was recorded. Based on the defined sampling requirements for these species, the associated *a* and *b* coefficients were selected to be entered into the ESE for future surveys. Moving forward, Atlantic Herring will be measured by total length in millimeters using the pinched caudal fin length. The grenadier and chimaera species will be measured to pre-anal fin length (as tails are fragile and easily damaged during capture) in millimeters. Grenadiers and chimaeras are found in deeper water and are generally only captured during the summer 4VWX survey which allows for more time to survey in deeper strata.

In order to standardize length measurements for views of the data in the Oracle database, Length Length Relationships (LLR) were examined using a linear regression model on grenadier and chimaera species that had individual fish measured in both pre-anal fin length (PAFL) and total length (TL). During the summer survey of 2010 aboard the *CCGS Alfred Needler*, Longnose and Knifenose chimaeras length measurements were taken for individual chimaera in centimeters for both PAFL and TL. In the summer in 2016 and 2017, individual Marlin-Spike Grenadier were measured in both PAFL in millimeters and TL in centimeters. In the summer of 2017, individual Roundnose Grenadier were measured in both PAFL in

millimeters and TL in centimeters. In the summer of 2010 and 2017, Roughhead Grenadier were measured in both PAFL and TL, but sample size was small. The *a* (intercept) and *b* (slope) coefficients of the regression line for each species will be used for the standardization between the two measurements as follows:

$$TL_{(cm)} = b \times PAFL_{(cm)} + a \text{ or } PAFL_{(cm)} = \frac{(TL(cm) - a)}{b}.$$

Pre-anal fin length is a more reliable measure of length for these species, since tails are often broken during capture. LWR relationships between pre-anal fin length and total weight should be more consistent and result in fewer spurious errors between observed and predicted weight during data collection.

For older data, where total length was recorded, the LLR conversion can be used to provide a consistent data series. Since damage to tails was not recorded during past surveys, the predicted pre-anal fin length from the LLR should be compared with the predicted length from the LWR. Where the LLR provides a much smaller length, it may be advisable to use the LWR to derive a predicted pre-anal fin length, since the total length recorded may be unreliable as a result of truncation to the tail.

RESULTS

Length:weight regressions (LWR) coefficients, intercept (*a*) and slope (*b*), measurement unit, species code, maximum length, survey source, and LWR goodness of fit (r^2) for species caught using mixed measurement techniques in Maritimes Region ecosystem surveys from 2001-2017 are included in the following table (Table 1). The Length: length regression (LLR) coefficients: intercept (*a*) and slope (*b*) in pre-anal fin length (PAFL) and total length (TL) (cm), species code, and goodness of fit (r^2) for species caught in Maritimes Region ecosystem surveys are included in Table 2 below.

Figures show the seasonal length:weight relationship of the differing measurement techniques for each species. The solid line in the plots represents the length:weight regression for each species caught between 2001-2017. The dashed line represents 25% error bounds of the LWR. Finally, figures also show the length:length relationships of grenadier and chimaera species measured by pre-anal length and total length.

ACKNOWLEDGEMENTS

The authors would like to thank Daphne Themelis for her earlier work on the Length Weight Relationships of fish species and R Script. Also, many thanks to Daphne Themelis and Samantha Fulton for their edits to earlier drafts of the document that have improved the documents.

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TABLES

Table 1. Length: weight regressions (LWR) coefficients intercept (a) and slope (b), measurement unit, species code, maximum length, survey source, and LWR goodness of fit (r^2) for species caught in Maritimes Region ecosystem surveys from 2001-2017.

Common Name	Survey Season	Species Code	Length Weight *a*	Length Weight *b*	Max. Length	Length Unit	Weight Unit	Data Source	n	r^2
HERRING (ATLANTIC)	Winter	60	0.000003	3.121	319	mm	g	Georges 2016-1017	181	0.97
HERRING (ATLANTIC)	Summer	60	0.000002	3.210	346	mm	g	Summer (mm) 2016-2017	5465	0.96
HERRING (ATLANTIC)	Not Used	60	0.01075	2.928	29	cm	g	All Surveys (cm)	414	0.96
LONGNOSE CHIMAERA	Summer/ Winter	247	0.00063	2.406	460	mm	g	Pre-anal fin Length (cm x10)	40	0.83
LONGNOSE CHIMAERA	Not Used	247	0.16065	2.406	46	cm	g	Pre-anal fin Length	40	0.84
LONGNOSE CHIMAERA	Not Used	247	0.00170	3.030	104	cm	g	Total Length	50	0.86
KNIFENOSE CHIMAERA	Summer/Winter	248	0.00038	2.506	800	mm	g	Pre-anal fin Length (cm x10)	14	0.78
KNIFENOSE CHIMAERA	Not Used	248	0.12040	2.506	80	cm	g	Pre-anal fin Length	14	0.78
KNIFENOSE CHIMAERA	Not Used	248	0.00081	3.216	144	cm	g	Total Length	34	0.92
MARLIN-SPIKE GRENADIER	Summer/ Winter	410	0.00065	2.843	82	mm	g	Pre-anal fin Length (2016-2017)	116	0.91
MARLIN-SPIKEGRENADIER	Not Used	410	0.79056	2.394	10	cm	g	Pre-anal fin Length (2015-2017)	132	0.89
MARLIN-SPIKE GRENADIER	Not Used	410	0.00200	3.112	41	cm	g	Total Length	11	0.93
ROUGHHEAD GRENADIER	Summer/ Winter	411	0.000005	3.499	410	mm	g	Pre-anal fin Length (cm x10)	6	0.90
ROUGHHEAD GRENADIER	Not Used	411	0.01564	3.499	41	cm	g	Pre-anal fin Length	6	0.92
ROUGHHEAD GRENADIER	Not Used	411	0.00126	3.372	84	cm	g	Total Length	16	0.99
ROUGHNOSE GRENADIER	Not Used	412	0.00057	3.542	52	cm	g	Summer(2001-2017)	8	0.97
ROUNDNOSE GRENADIER	Summer/Winter	414	0.00018	3.033	233	mm	g	Pre-anal fin Length (mm)	133	0.98

Table 2. Length: length regression (LLR) coefficients: intercept (a), slope (b) in pre-anal fin length (PAFL) and total length (TL) (cm), species code, and goodness of fit (r^2) for species caught in Maritimes Region ecosystem surveys.

Species	Species Code	Intercept (a)	Slope (b)	n	r^2	Equation	Conversion Equation (PAFL to TL)
MARLIN-SPIKE GRENADIER	410	1.770067	4.453725	116	0.9320	TL= a + bPAFL	TL(cm)=1.770067 + 4.453725 x PAFL(cm)
ROUNDNOSE GRENADIER	414	-2.188077	4.345336	133	0.9094	TL= a + bPAFL	TL(cm)= -2.188077 + 4.345336 x PAFL(cm)
KNIFENOSE CHIMAERA	248	28.39702	1.421523	23	0.9138	TL= a + bPAFL	TL(cm)=28.39702 + 1.421523 x PAFL(cm)
LONGNOSE CHIMAERA	247	26.63213	1.469462	38	0.7796	TL= a + bPAFL	TL(cm)=26.63213 + 1.469462 x PAFL(cm)
ROUGHHEAD GRENADIER	411	18.59875	1.831639	748	0.9567	TL= a + bPAFL	TL(cm)= 18.59875+ 1.831639 x PAFL(cm)
*ROUGHHEAD GRENADIER	411	-2.3455	5.2320	6	0.993	TL= a + bPAFL	*TL(cm)=5.2320 + 2.3455 x PAFL(cm)

* Roughhead Grenadier converted using Atkinson (1991) due to small sample size.

LENGTH:WEIGHT RELATIONSHIP PLOTS

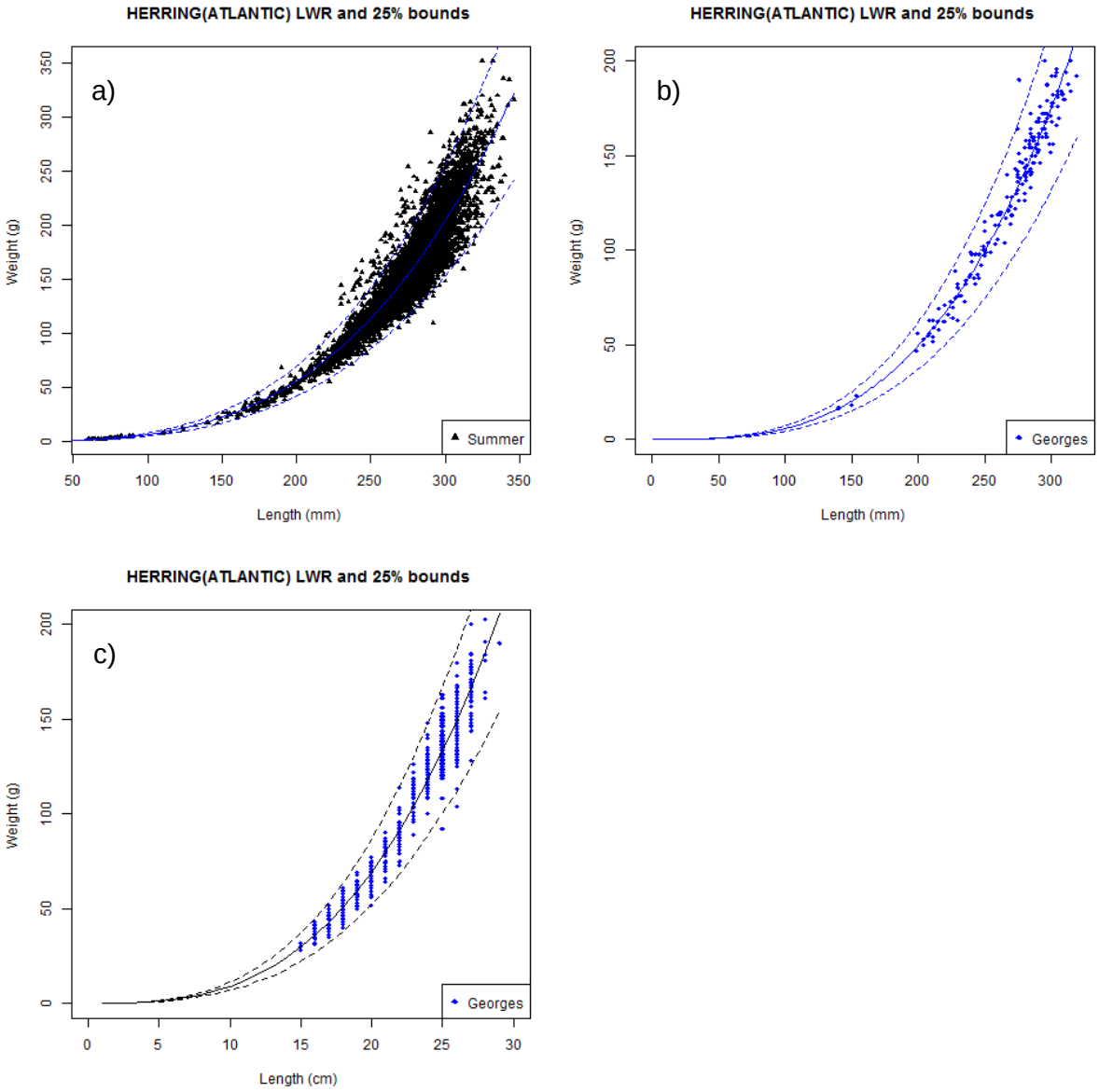

Figure 3. Length-weight relationships (LWR) for Atlantic herring (2016-2017). In each panel, Blue solid line represents LWR of herring in survey and the coefficients of the LWR to predict LWR of herring in future surveys. Dashed lines represent 25% error bounds. (a–-Summer RV survey (mm); b – Georges Bank survey (mm), c– Georges Bank survey (cm)).

Pre-anal fin length vs. total length measurements (2001-2017):

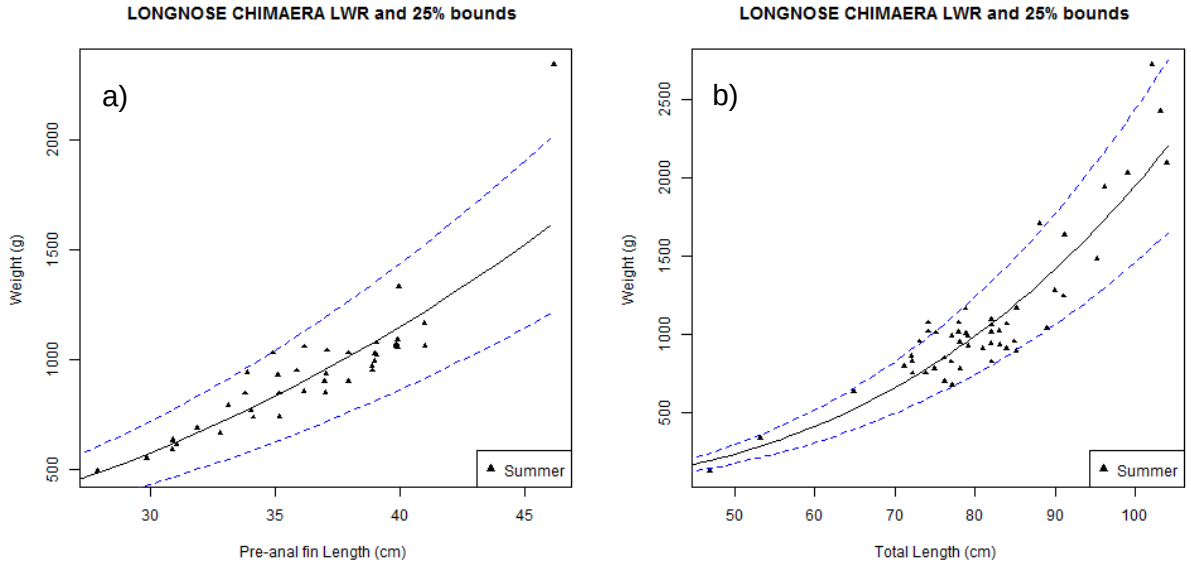

Figure 4 a) Solid line represents LWR of Longnose Chimaera measured by pre-anal fin length (cm) in 2010. b) Black line represents LWR of Longnose Chimaera measured by total length in surveys since 2010. Dashed lines represent 25% error bounds.

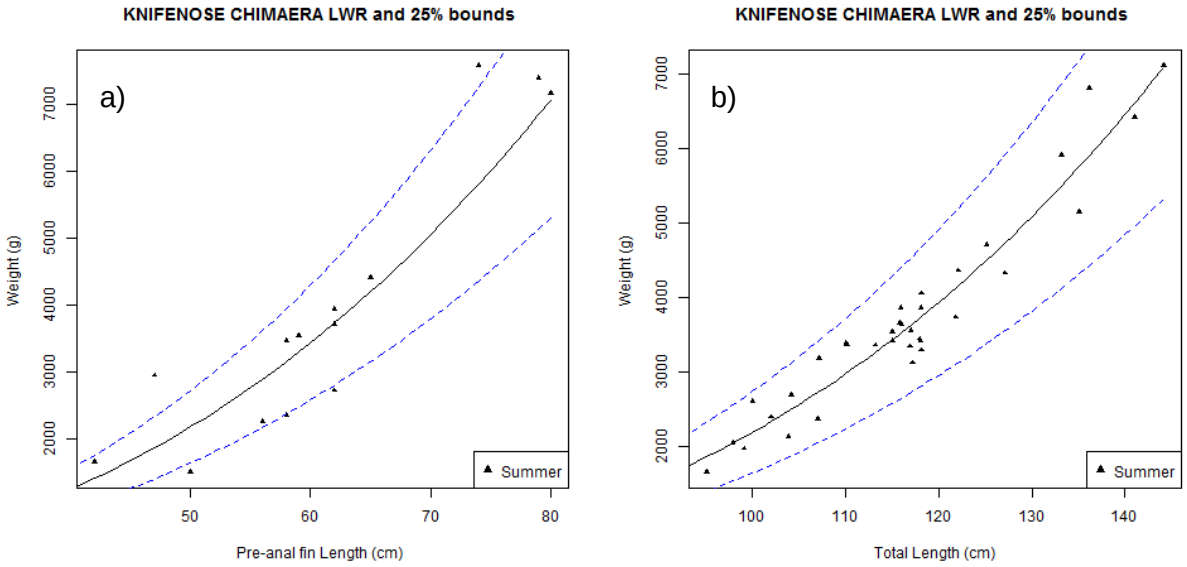

Figure 5 a) Black line represents LWR of Knifenose Chimaera measured by pre-anal fin length (cm) in 2010. b) Black line represents LWR of Knifenose Chimaera measured by total length in surveys since 2010. Dashed lines represent 25% error bounds.

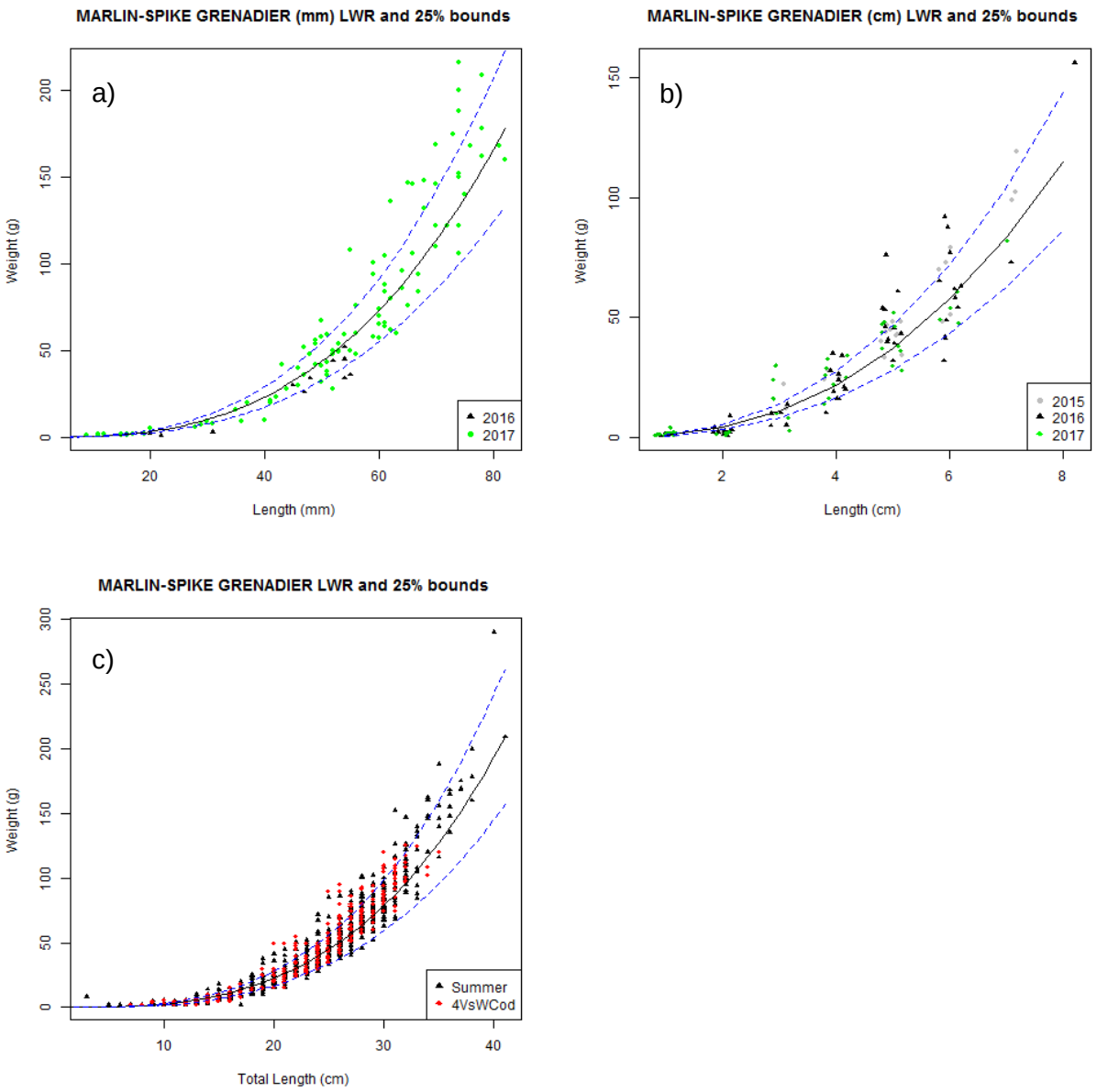

Figure 6 a) Black line represents LWR of Marlin-spike Grenadier measured by pre-anal fin length in millimetres in all surveys in 2016 and 2017 and the coefficients of the LWR will be used to predict the weight of Marlin-spike Grenadier measured by pre-anal fin length in future surveys. b) Black line represents LWR of Marlin-spike Grenadier measured by pre-anal fin length in centimeters in all surveys in 2015, 2016, and 2017. c) Black line represents LWR of Marlin-spike Grenadier measured by total length in centimeters in all surveys. Blue dashed lines represent 25% error bounds.

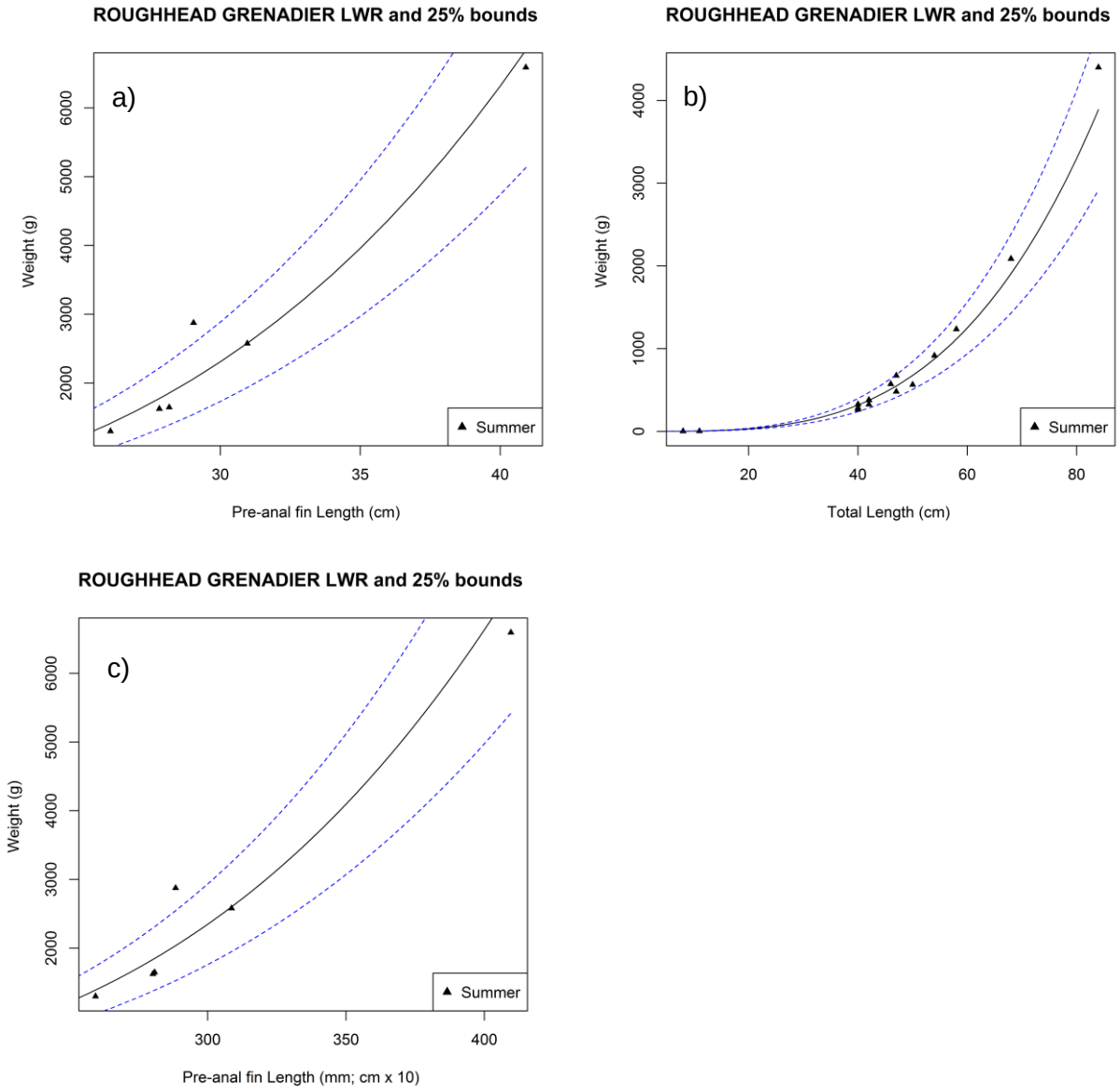

Figure 7 a) Black line represents LWR of Roughhead Grenadier measured by pre-anal fin length (cm) in 2010 and 2011 surveys. b) Black line represents LWR of Roughhead Grenadier measured by total length in all surveys. c) Black line represents LWR of Roughhead Grenadier measured by pre-anal fin length, converted from centimeters to millimetres, in all surveys and the coefficients of the LWR will be used to predict the weight of Roughhead Grenadier measured by pre-anal fin length in future surveys. Blue dashed lines represent 25% error bounds.

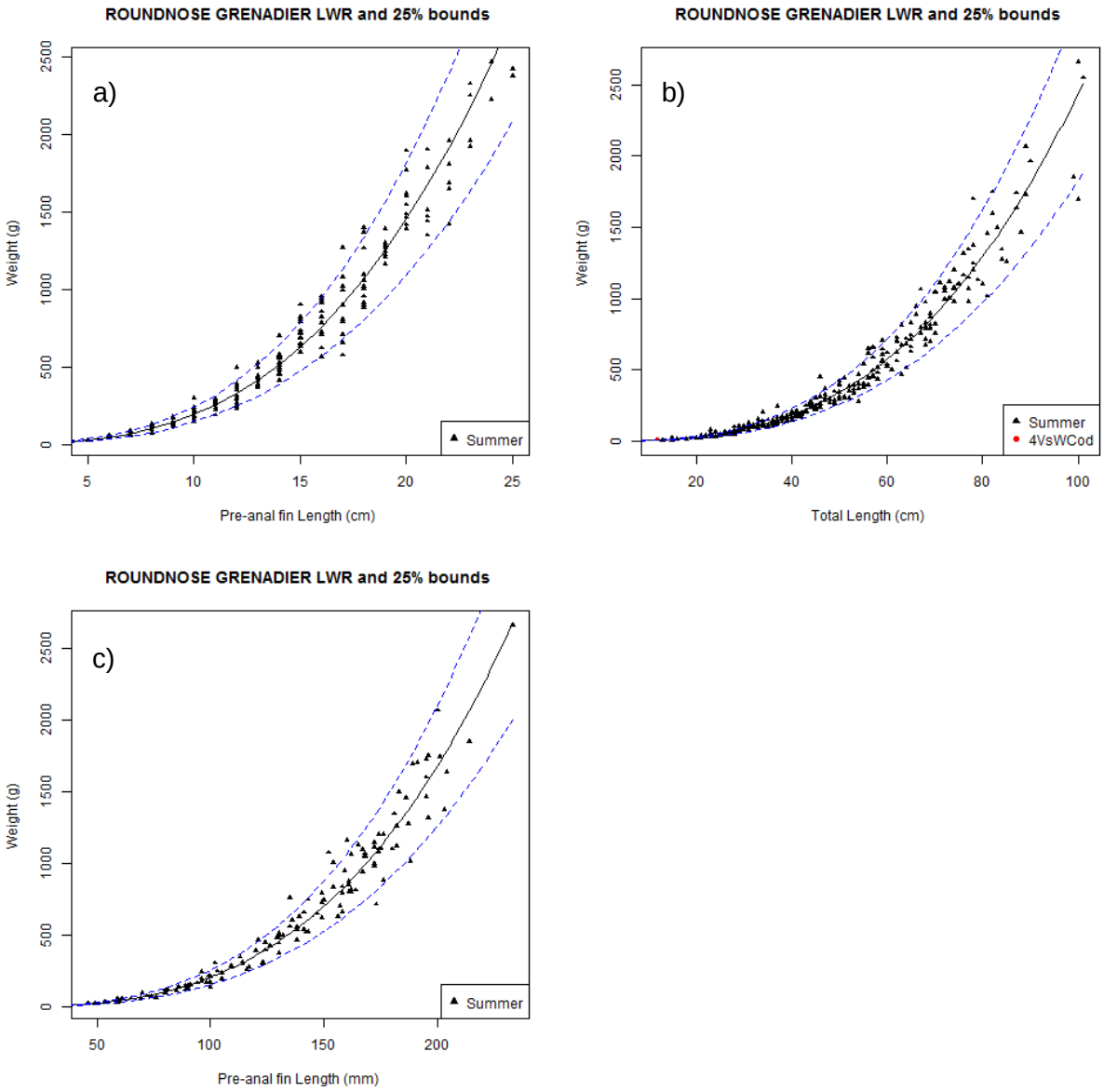

Figure 8 a) Black line represents LWR of Roundnose Grenadier measured by pre-anal fin length (cm) in 2010 and 2011 surveys. b) Black line represents LWR of Roundnose Grenadier measured by total length in all surveys. c) Black line represents LWR of Roundnose Grenadier measured by pre-anal fin length (mm) in the 2017 summer survey and the coefficients of the LWR will be used to predict the weight of Roundnose Grenadier measured by pre-anal fin length in future surveys. Blue dashed lines represent 25% error bounds.

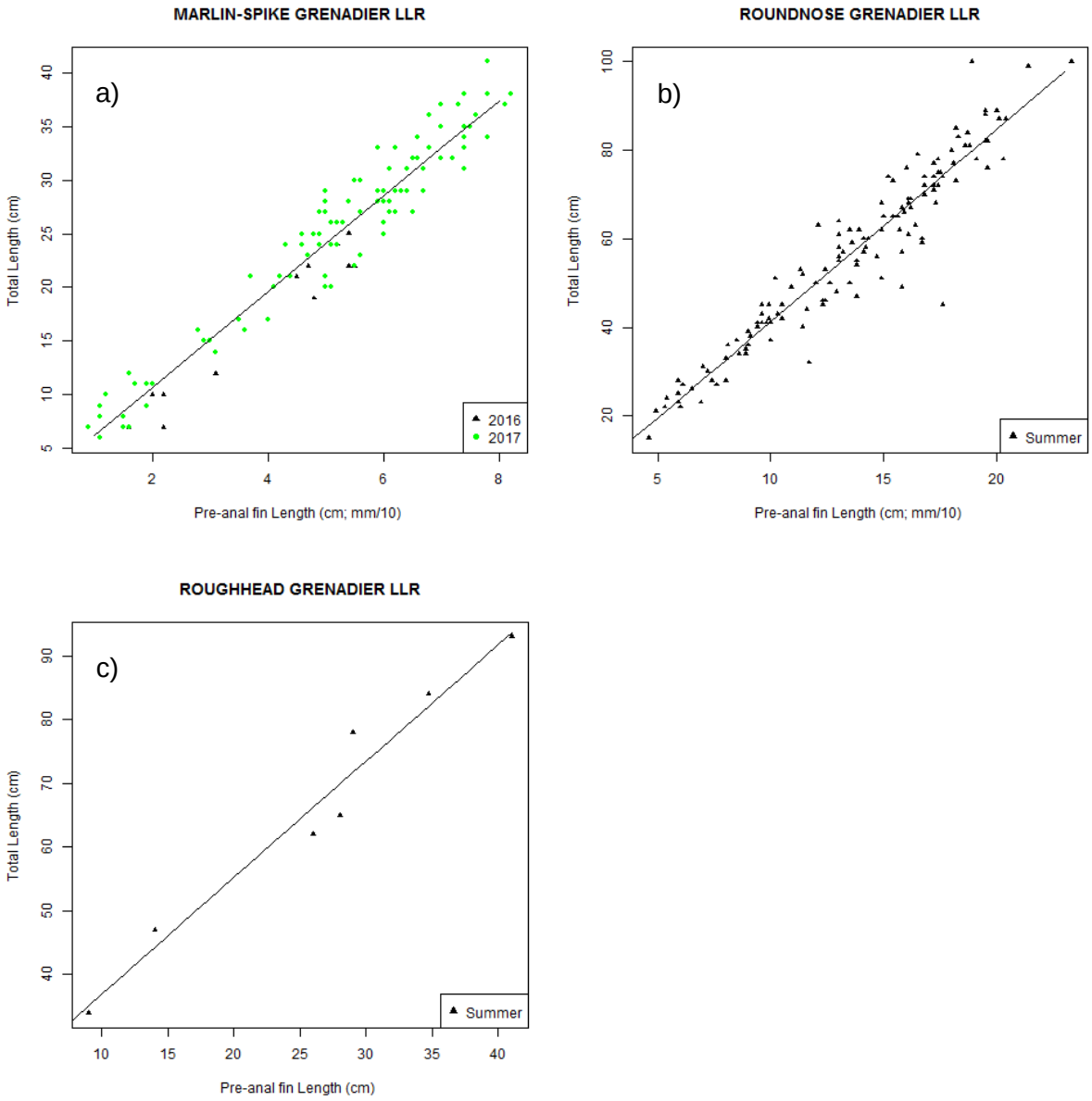

Figure 9. Length:Length Relationship Plots (TL= b x PAFL + a). a) Black line represents LLR of Marlin-Spike Grenadier measured by pre-anal fin length (in mm converted to cm) and total length in centimeters in all surveys. b) Black line represents LLR of Roundnose Grenadier measured by pre-anal fin length (in mm converted to cm) and total length in centimeters in 2017. c) Black line represents LLR of Roughhead Grenadier measured by pre-anal fin length and total length in centimeters in all surveys.

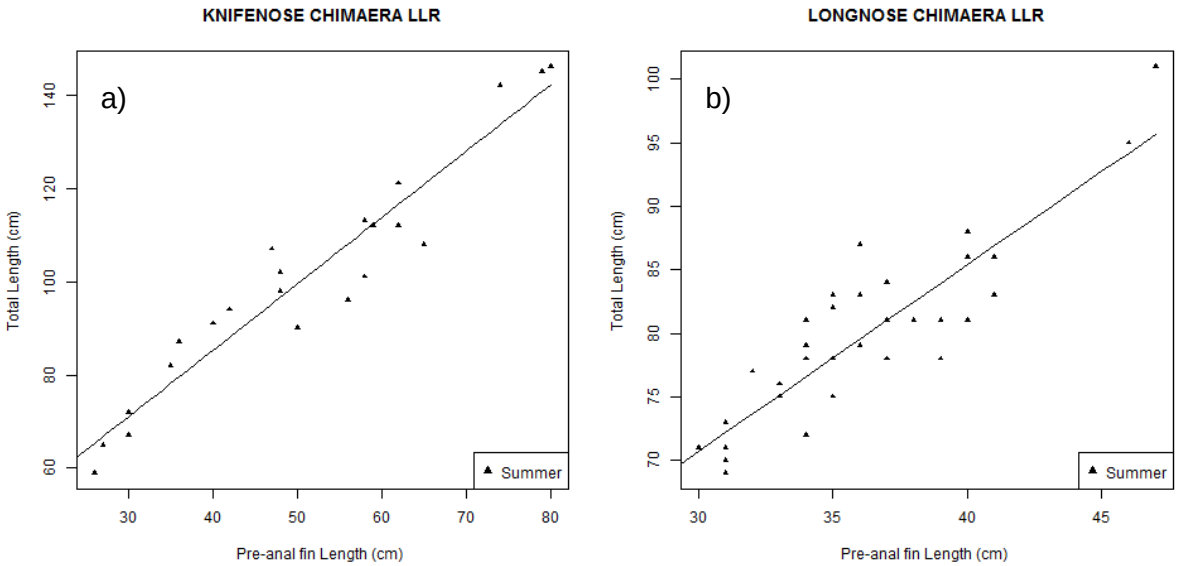

Figure10 a) Black line represents LLR of Knifenose Chimaera measured by pre-anal fin length and total length in centimeters in 2010. b) Black line represents LLR of Longnose Chimaera measured by pre-anal fin length and total length in centimeters in 2010.

APPENDIX

Appendix 1. Scientific names and codes of the groundfish species caught in the Maritimes Region.

Scientific Name	TSN Code	Rank	Common Name	RV Survey Code	Accepted Author
Clupea harengus	161722	Species	HERRING(ATLANTIC)	60	(Linnaeus, 1758)
Harriotta raleighana	161029	Species	LONGNOSE CHIMAERA	247	(Goode and Bean, 1895)
Rhinochimaera atlantica	161027	Species	KNIFENOSE CHIMAERA	248	(Holt and Byrne, 1909)
Nezumia bairdii	165395	Species	MARLIN-SPIKE GRENADIER	410	(Goode and Bean, 1877)
Macrourus berglax	165421	Species	ROUGHHEAD GRENADIER	411	(Lacepède, 1801)
Coryphaenoides rupestris	165350	Species	ROUNDNOSE GRENADIER	414	(Gunnerus, 1765)