SEASONAL LENGTH:WEIGHT RELATIONSHIPS OF THE INVERTEBRATE SPECIES CAUGHT BY FISHERIES AND OCEANS CANADA MARITIMES REGION ECOSYSTEM SURVEYS FROM 2001-2017

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ABSTRACT

Noble, V.R., and Clark, D. S., 2019. Seasonal length:weight relationships of the invertebrate species caught by Fisheries and Oceans Canada Maritimes Region Ecosystem Surveys from 2001-2017. Can. Data Rep. Fish. Aquat. Sci.1293: iv + 21 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 throughout 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. Invertebrate 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 an invertebrate. This report presents the regression coefficients of invertebrate species caught and measured during 2001-2017 in the Maritimes Region.

RÉSUMÉ

Noble, V.R., and Clark, D. S., 2019. Seasonal length:weight relationships of the invertebrate species caught by Fisheries and Oceans Canada Maritimes Region Ecosystem Surveys from 2001-2017. Can. Data Rep. Fish. Aquat. Sci.1293: iv + 21 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 des 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 d'invertébrés sont un outil important pour faciliter le contrôle de la qualité de la collecte des 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 invertébré. Ce rapport présente les coefficients de régression pour les espèces d'invertébrés capturés et mesurés de 2001 à 2017 dans la région des Maritimes.

BACKGROUND

Fisheries and Oceans Canada (DFO) has conducted annual summer ecosystem survey 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).

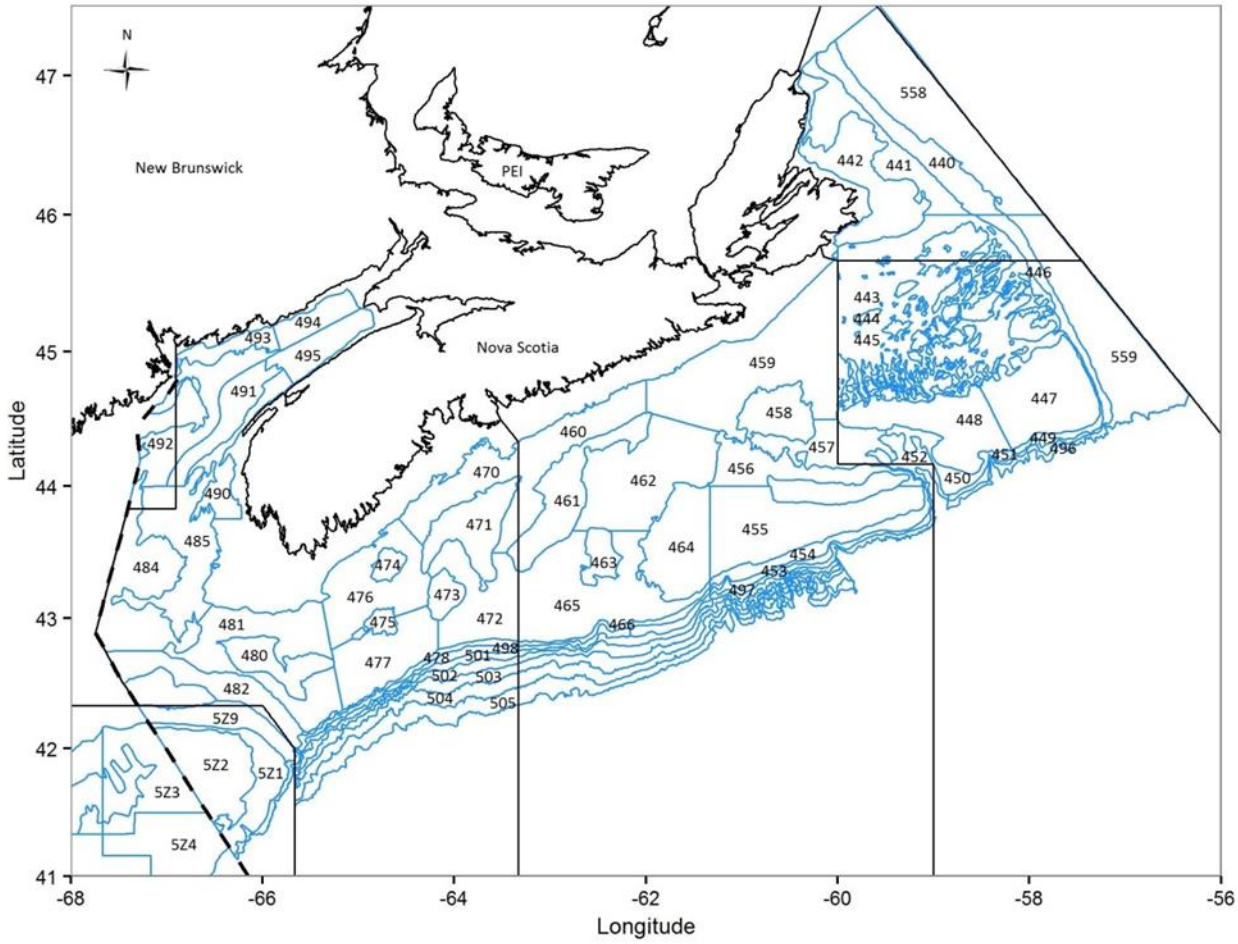

Figure 1. Ecosystem Survey strata areas surveyed off the Scotian Shelf, Bay of Fundy and Georges Bank.

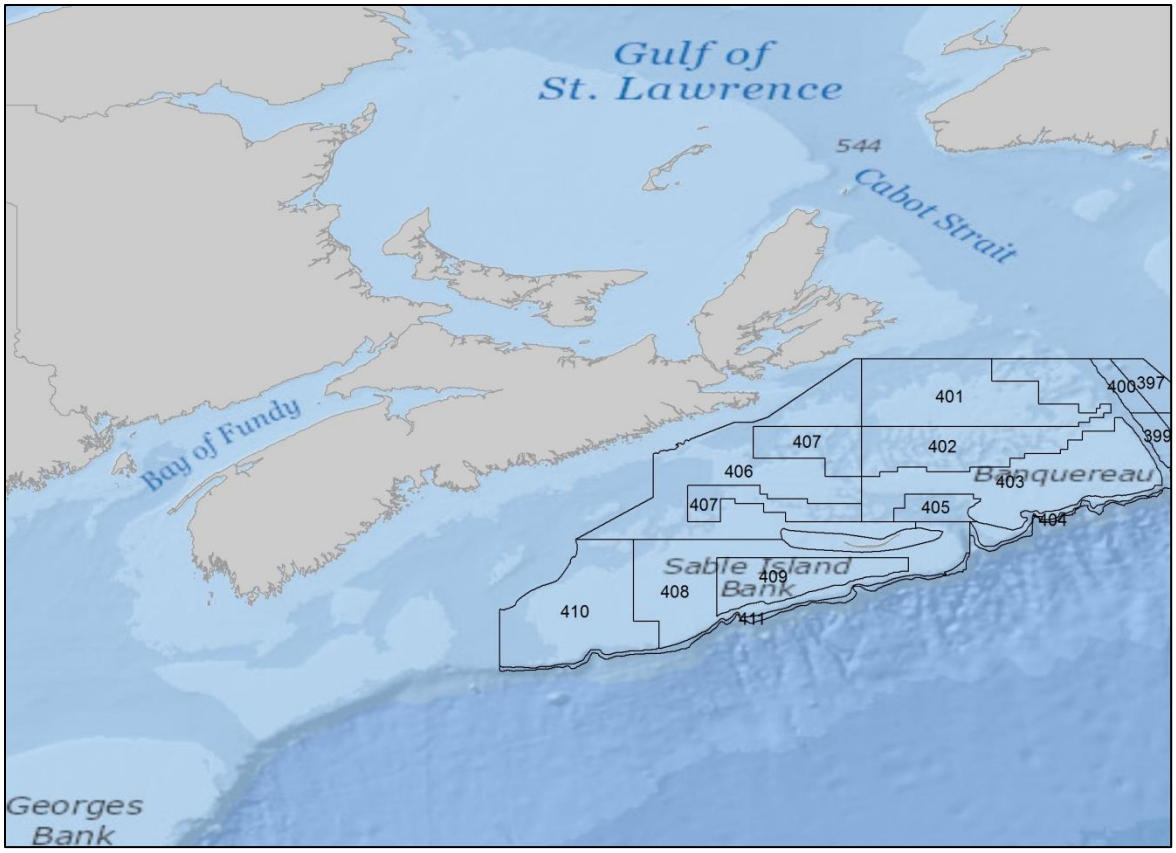

Figure 2. Ecosystem Survey strata areas surveyed off the Scotian Shelf during the March (winter) 4VsW survey.

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.

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 2017 to determine each species regression coefficients by season. For simplicity, we first pooled seasons together to see how the log transformed LW linear regression fit the data. If the regression model had an r^2 of >0.9 and/or sample size was limited, separate regressions by season were not necessary for that species, for the purpose of at-sea ESE error checking.

When there were body size differences between sexes and/or seasons for a species apparent in the LWR plots, and sufficient data were available, a log transformed LW linear regression for the subset of data from the summer season and for the winter season were produced separately. The intercept (*a)* and slope (*b)* coefficients for the regression that fit the survey data best (based on r^2) for that season and/or sex were chosen to be the coefficients that will be entered into the ESE for future surveys. Crustacean species LWR were calculated based on sex of the species and not just survey season, as survey season alone did not fit the data well due to sexual dimorphism of these species (For example, see American Lobster in Figure 3 below). The number of observed weights that differed from predicted by >25% for a given length was greatly reduced when the data were separated by season and sex. In some cases, the imprecision of weight measurements of smaller individuals, where the precision of the scales is similar to the weight of the specimen, results in variation in the LWR that skews the regressions. In these cases, small individuals of the species were removed for the regression analysis. There were four specific cases: 1) Male and female Atlantic Rock Crab in the Winter, carapace lengths greater than 30mm were used for the regression analysis. 2) Female Snow Crab in the winter season, carapace lengths greater than 20mm were used for the

regression analysis. 3) *Hyas Coaractatus,* carapace lengths greater than 20mm were used for the regression analyses. 4) Toad Crab in the winter season, carapace lengths greater than 20 mm were used for both sexes.

A table was created for each season to simplify the input of the table into the ESE for each survey season. Figures examining LWR of each species are also included in this document (see below). Species that had a sample size of <10 were included in the table, but the corresponding figures are not included due to low precision of the LWR coefficients and small sample sizes.

RESULTS

Length:Weight Regression coefficients, intercept (a) and slope (b), for each invertebrate species and sex (when appropriate) in the Maritimes Region from 2001-2017 are included in the following tables (Table 1, Table 2). Other information that is included in the tables are species code, what survey the coefficients will be used for in the future, measurement units, maximum length of fish caught during the survey analysis period, the fit of the regression line (r^2), and the surveys used in the analysis.

Figures show the seasonal Length:Weight Relationship of invertebrate species, separated by sex for the sexually dimorphic species. The solid line in the plots represents the Length:Weight regression for each species caught 2001-2017. The dashed line represents 25% error bounds of the LWR.

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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Table 1. Length:Weight Regression coefficients, intercept (a) and slope (b), for each species in the Maritimes Region from 2001-2017. Other information that is included is species code used by the Maritimes Region (see Appendix for corresponding species names), what survey the coefficients will be used for, measurement units, maximum length of invertebrate caught during that survey period and the fit of the regression line (r^2). The a and b coefficients that will be used for at sea survey quality control are starred (*).

Common Name	Future Sampling Requirement	Species Code	Length Weight a	Length Weight b	Max. Length	Length Units	Weight Units	Surveys pooled for analysis	n	r^2
Brachyuran Crabs	All*	2510	0.00101	2.529	91	mm	g	All combined	4	0.98
Toad Crab, Unidentified	All*	2520	0.00252	2.619	71	mm	g	All combined	21	0.99
Porcupine Crab	All*	2528	0.00030	3.128	134	mm	g	Summer	6	0.94
Munida Iris	All*	2555	0.00465	2.544	26	mm	g	All combined	8	0.70
Munida Valida	All*	2556	0.09600	1.376	28	mm	g	All combined	4	0.97
Sea Scallop	All	4321	0.00005	3.209	166	mm	g	All combined	3049	0.95
Sea Scallop	Winter*	4321	0.00006	3.158	166	mm	g	Winter/Georges	2368	0.94
Sea Scallop	Summer*	4321	0.00004	3.229	165	mm	g	summer	681	0.97
Iceland Scallop	All	4322	0.00008	3.118	115	mm	g	All combined	433	0.94
Iceland Scallop	Winter*	4322	0.00010	3.081	96	mm	g	Winter/Georges	77	0.87
Iceland Scallop	Summer*	4322	0.00007	3.158	115	cm	g	summer	356	0.95
Cephalopoda C.	All*	4500	1.61361	1.536	16	cm	g	All combined	9	0.91
Shortfin Squid	Summer*	4511	0.02973	2.856	28	cm	g	summer	7315	0.95
Shortfin Squid	Winter*	4511	0.12318	2.383	26	cm	g	Winter/Georges	473	0.92
Shortfin Squid	All	4511	0.05230	2.659	28	cm	g	All combined	7788	0.94
Longfin Squid	Summer*	4512	0.17432	2.256	24	cm	g	Summer	289	0.95
Longfin Squid	Winter*	4512	0.14885	2.351	27	cm	g	Winter/Georges	763	0.96
Longfin Squid	All	4512	0.15110	2.338	27	cm	g	All combined	1052	0.96
Loligo sp.	All*	4541	0.25346	2.209	19	cm	g	All combined	7	0.98
Mastigoteuthis sp.	All*	4584	0.20170	2.139	15	cm	g	All combined	9	0.94
Atlantic Rock Crab	Winter (*ovigerous females only)	2513	0.00079	2.678	115	mm	g	Winter (*ovigerous females only)	157	0.97

Table 2. Length:Weight Regression coefficients, intercept (a) and slope (b), for each species and sex (where appropriate) in the Maritimes Region from 2001-2017. Other information that is included is species code used by the Maritimes Region (see Appendix for corresponding species names), what survey the coefficients will be used for, measurement units, maximum length of invertebrate caught during that survey period and the fit of the regression line (r^2).

Common Name	Future Sampling Requirement	Species Code	Length Weight Male a	Length Weight Male b	Length Weight Female a	Length Weight Female b	Length Weight Unspecified a	Length Weight Unspecified b	Max. Length	Length Units	Weight Units	Surveys pooled for analysis	n	r^2
Jonah Crab	Summer	2511	0.00024	2.882	0.00033	2.810	0.00033	2.810	171	mm	g	summer	760, 401	0.95, 0.93
Jonah Crab	Winter	2511	0.00060	2.674	0.00076	2.635	0.00076	2.635	180	mm	g	winter/ georges	390, 152	0.97, 0.98
Atlantic Rock Crab	Summer	2513	0.00014	3.000	0.00032	2.820	0.00032	2.820	142	mm	g	summer	860, 517	0.97, 0.95
Atlantic Rock Crab	Winter	2513	0.00033	2.814	0.00045	2.748	0.00045	2.748	155	mm	g	winter/ georges	999, 257	0.95, 0.96
Hyas Coarctatus	Summer	2521	0.00090	2.873	0.00032	2.521	0.00032	2.521	88	mm	g	summer	376, 466	0.98, 0.96
Hyas Coarctatus	Winter	2521	0.00094	2.855	0.00078	2.919	0.00078	2.919	83	mm	g	winter/ georges	185, 121	0.97, 0.95
Northern Stone Crab	Summer	2523	0.00042	2.975	0.00068	2.864	0.00068	2.864	148	mm	g	summer	153, 506	0.94, 0.93
Northern Stone Crab	Winter	2523	0.00060	2.925	0.00039	3.013	0.00039	3.013	136	mm	g	winter/ georges	18, 90	0.95, 0.93
Snow Crab	Summer	2526	0.00051	2.919	0.00066	2.837	0.00066	2.837	144	mm	g	summer	6187, 3265	0.98, 0.96
Snow Crab	Winter	2526	0.00047	2.939	0.00040	2.961	0.00040	2.961	146	mm	g	winter/ georges	1946, 1115	0.98, 0.96
Toad Crab	Summer	2527	0.00155	2.740	0.00201	2.651	0.00201	2.651	88	mm	g	summer	527, 492	0.98, 0.95
Toad Crab	Winter	2527	0.00129	2.782	0.00237	2.591	0.00237	2.591	90	mm	g	winter/ georges	69, 37	0.95, 0.90
Red Deep Sea Crab	Summer	2532	0.00015	3.134	0.00021	3.045	0.00021	3.045	143	mm	g	summer	154, 216	0.96, 0.95
Red Deep Sea Crab	Winter	2532	0.00012	3.195	0.00042	2.867	0.00042	2.867	102	mm	g	winter/ georges	13, 12	0.97, 0.90
American Lobster	Summer	2550	0.00062	3.058	0.00147	2.864	0.00147	2.864	212	mm	g	summer	2704, 3920	0.99, 0.98
American Lobster	Winter	2550	0.00062	3.056	0.00202	2.801	0.00202	2.801	225	mm	g	winter/ georges	327, 1196	0.98, 0.97

LENGTH:WEIGHT RELATIONSHIP PLOTS

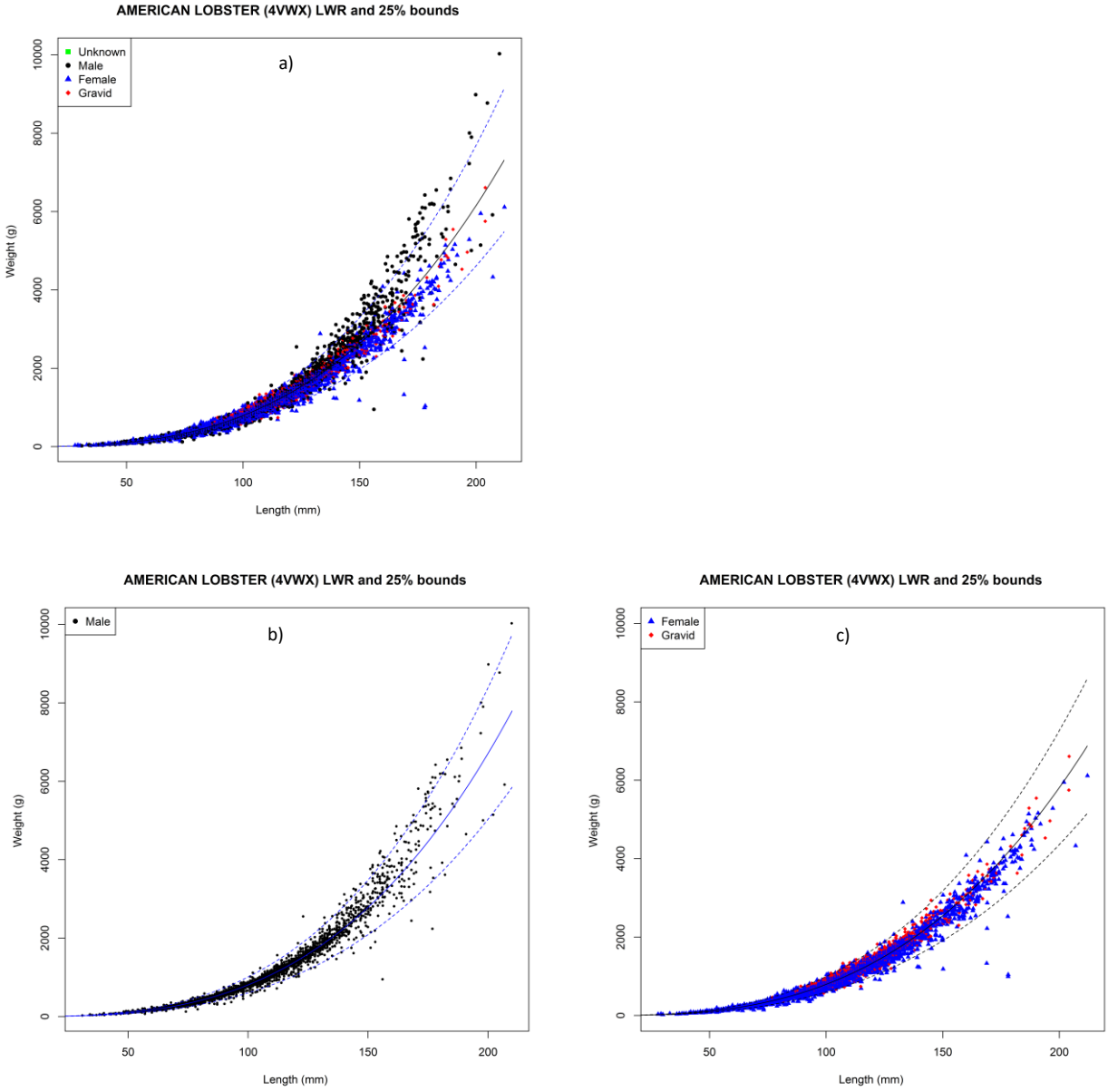

Figure 3. LWR of Lobsters caught in the summer surveys in 2001-2017 for a) All lobsters combined b) male lobsters and c) female lobsters. Solid line represents the LWR and the blue dashed lines represent 25% bounds (error).

All Three Surveys (pooled from 2001-2017):

The following figures consist of a solid blue line that represents the LWR of each species pooled of all the surveys between 2001-2017. These plots illustrate why separating species by season is useful for obtaining more precise *a* and *b* coefficients. The blue dashed lines represent 25% error.

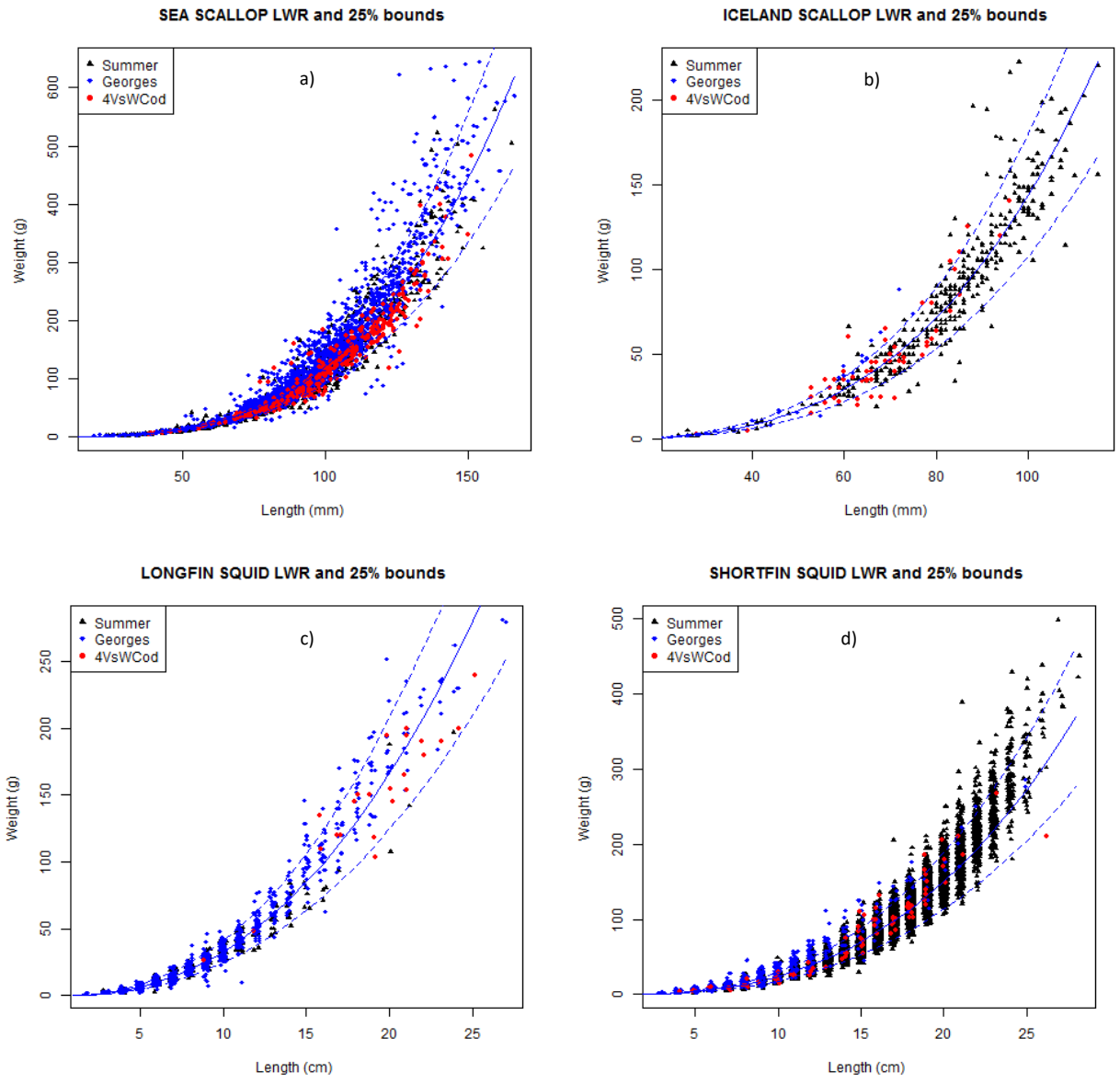

Figure 4. Solid line represents LWR of all Sea Scallop (a), Iceland Scallop (b), Longfin Squid (c) and Shortfin Squid (d) pooled in all three surveys combined.

Summer Survey (2001-2017):

The following figures consist of a solid blue line that represents the LWR of each species during the summer 4VWX survey between 2001-2017. The blue dashed lines represent 25% error.

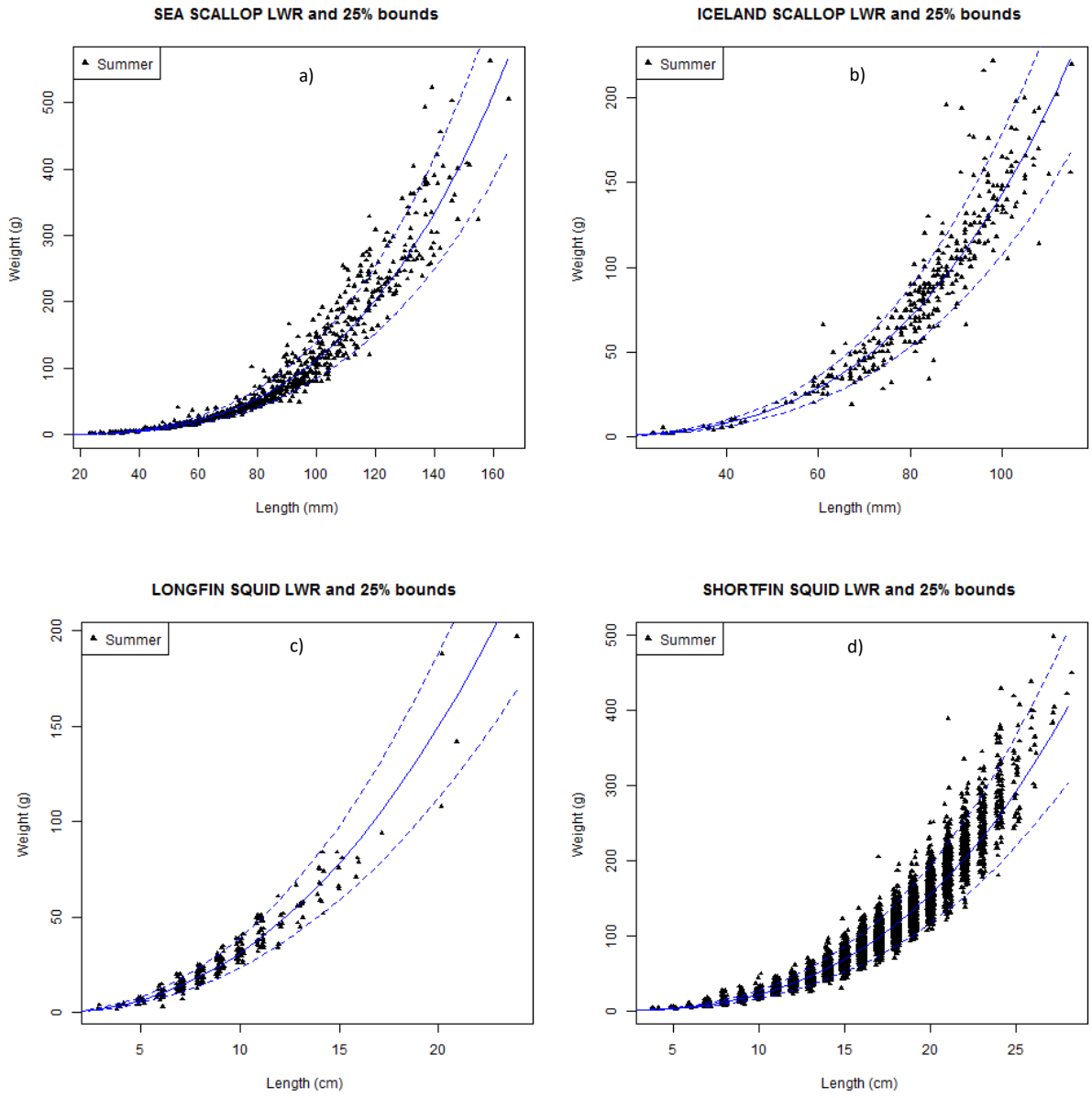

Figure 5. Solid line represents LWR of all Sea Scallop (a), Iceland Scallop (b), Longfin Squid (c) and Shortfin Squid (d) pooled in summer surveys.

Winter Surveys (Georges Bank & 4VsW; 2001-2017):
The following figures consist of a solid black line that represents the LWR of each species caught in Georges Bank and 4VsW surveys combined between 2001-2017.

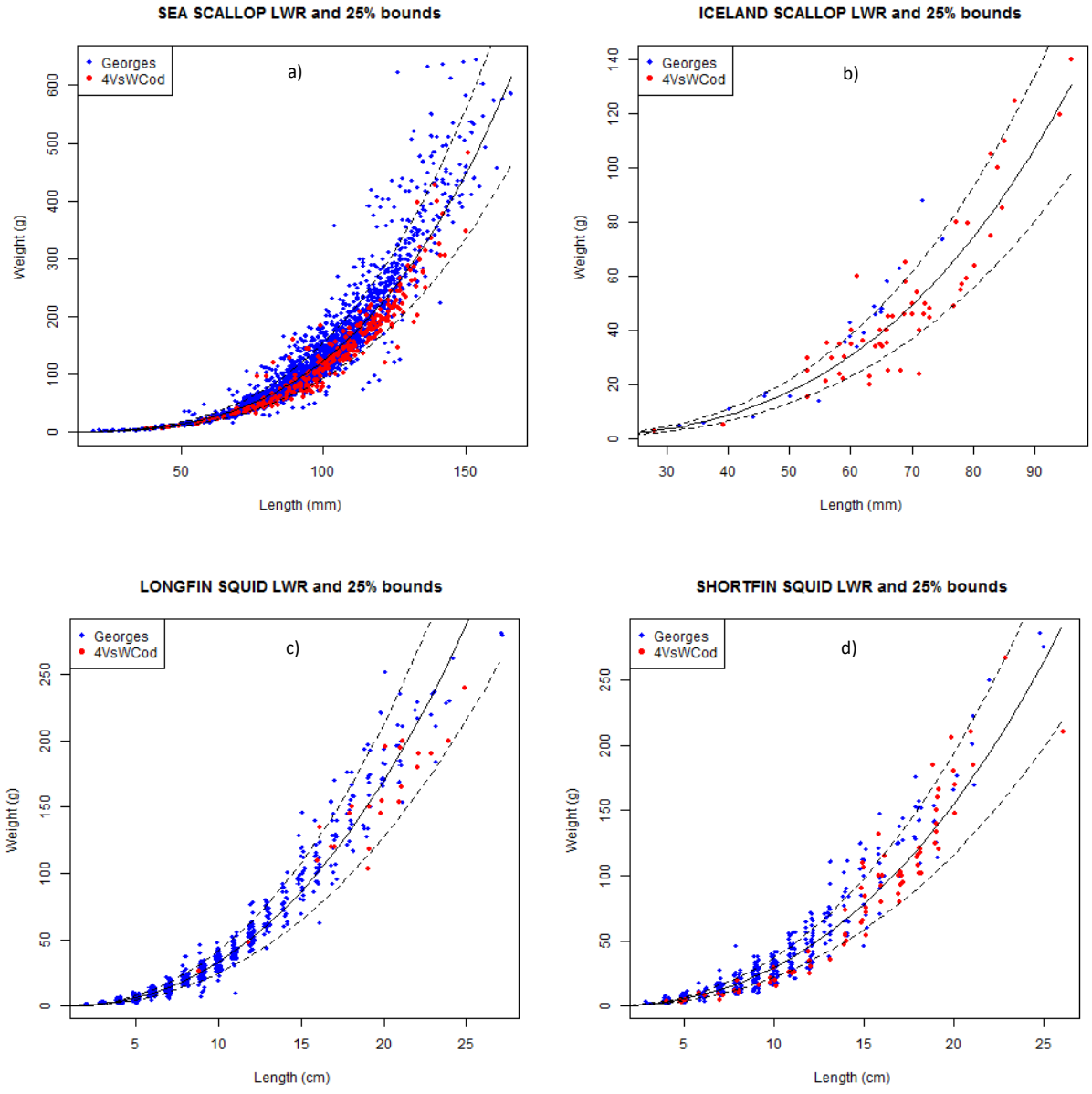

Figure 6. Solid line represents LWR of all Sea Scallop (a), Iceland Scallop (b), Longfin Squid (c) and Shortfin Squid (d) pooled from Georges Bank and March (winter) 4VsW surveys.

Sexually Dimorphic Invertebrate Species (2001-2017):

The following figures consist of a solid line that represents the LWR of each species caught in either summer surveys or winter surveys (Georges Bank and March 4VsW surveys combined) between 2001-2017.

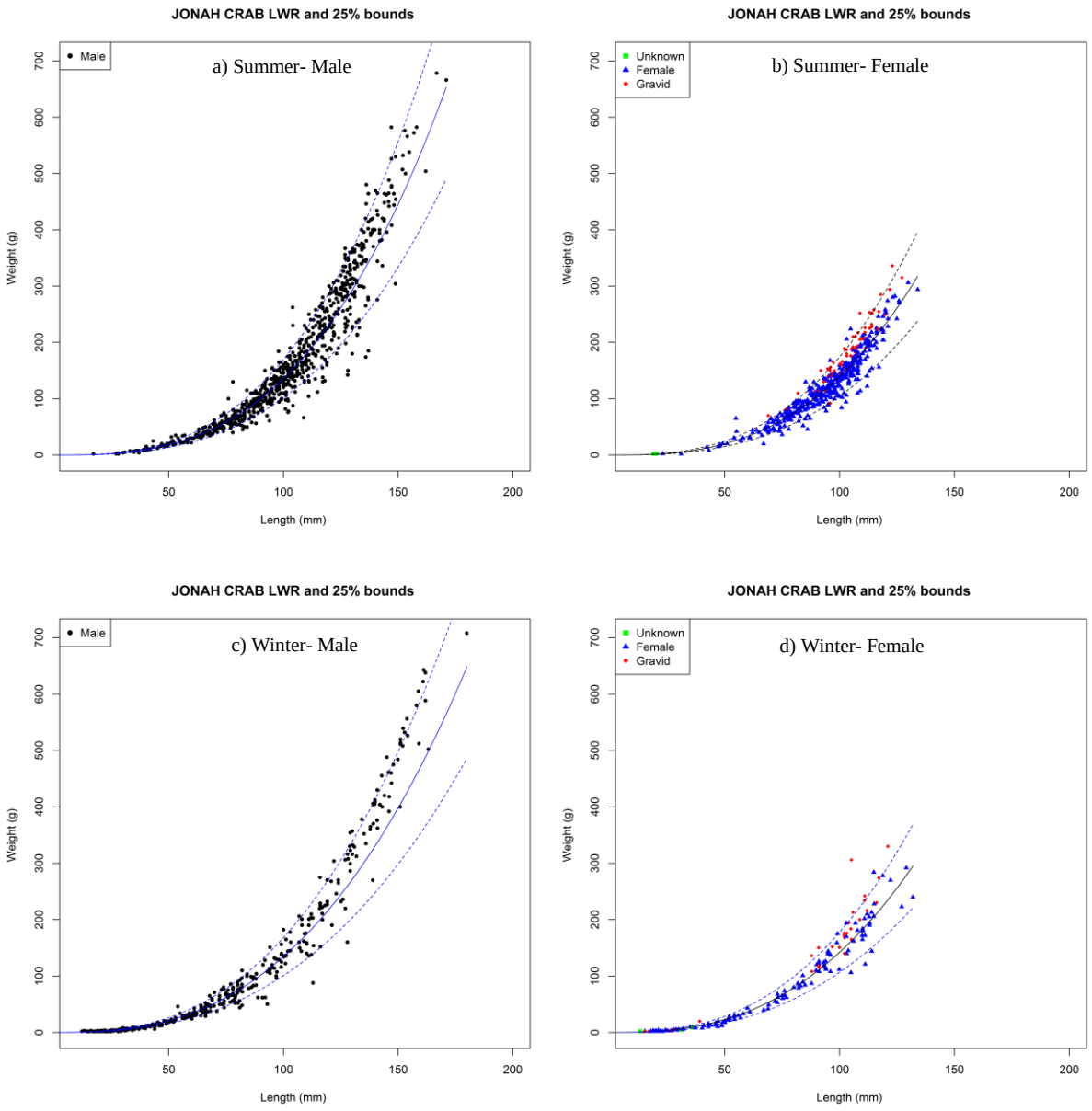

Figure 7 a) Solid line represents LWR of male Jonah Crab in summer surveys. b) Solid line represents LWR of female crabs pooled in the summer surveys. c) Solid line represents LWR of male crabs pooled in the Georges Bank and 4VsW surveys. d) Solid line represents LWR of female crabs pooled in the Georges Bank and 4VsW surveys.

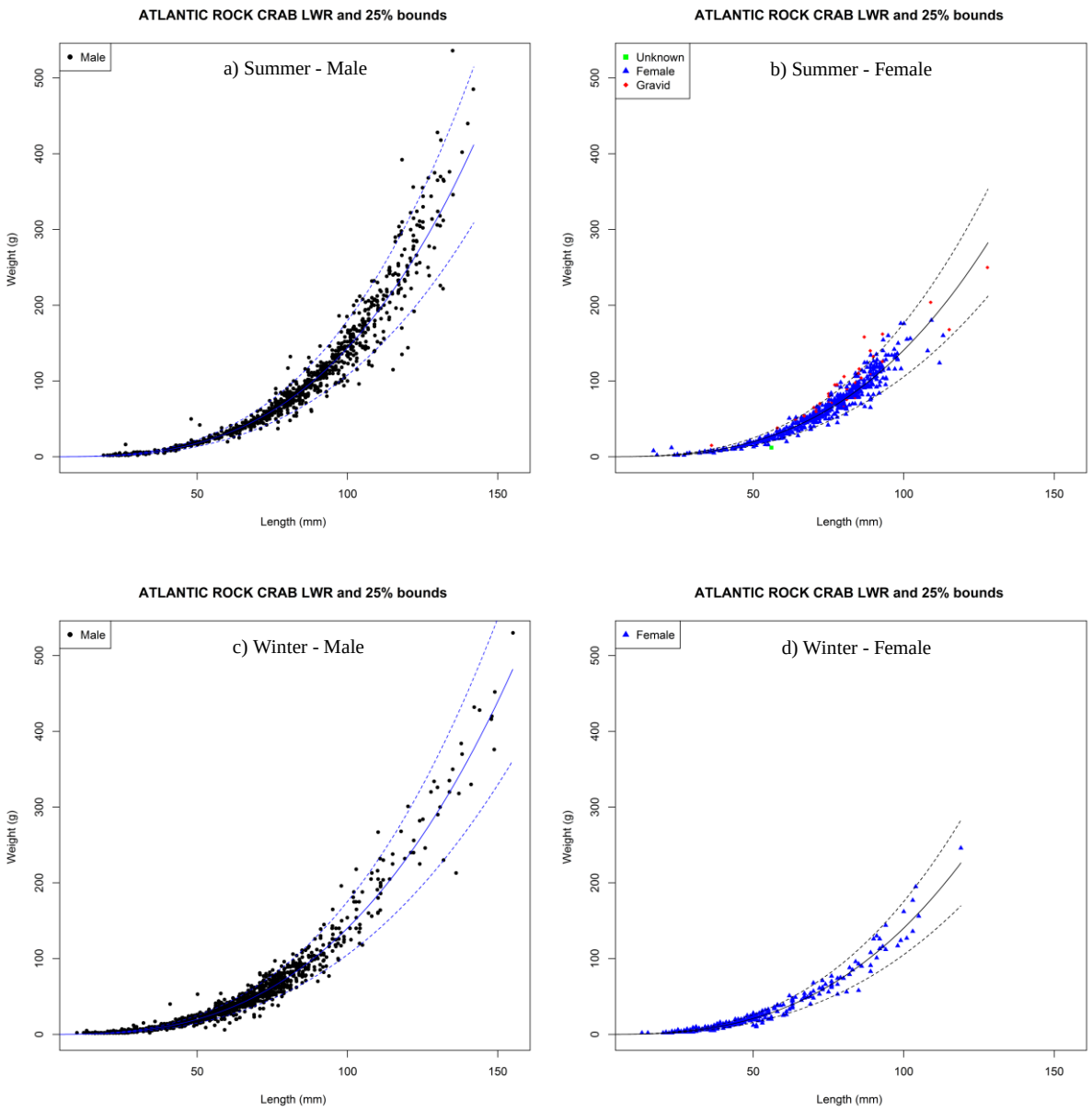

Figure 8 a) Solid line represents LWR of male Atlantic Rock Crab in summer surveys. b) Solid line represents LWR of female Atlantic Rock Crab in summer surveys. c) Solid line represents LWR of male Atlantic Rock Crab in Georges Bank and 4VsW surveys. d) Solid line represents LWR of female Atlantic Rock Crab in Georges Bank and 4VsW surveys.

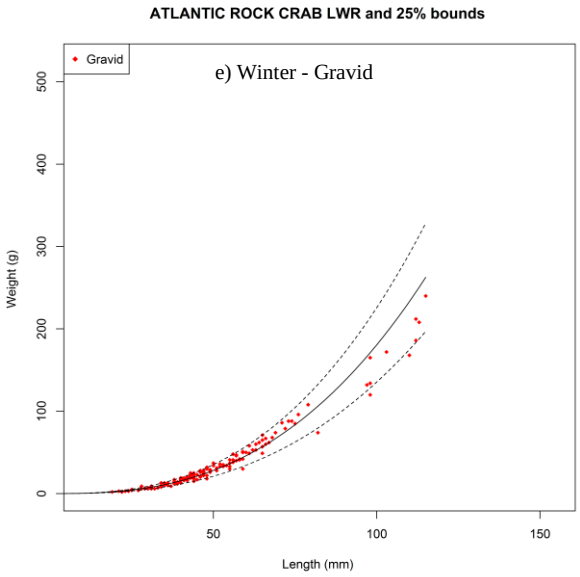

Figure 8 e) Solid line represents LWR of all ovigerous Atlantic Rock Crab in Georges Bank and 4VsW surveys.

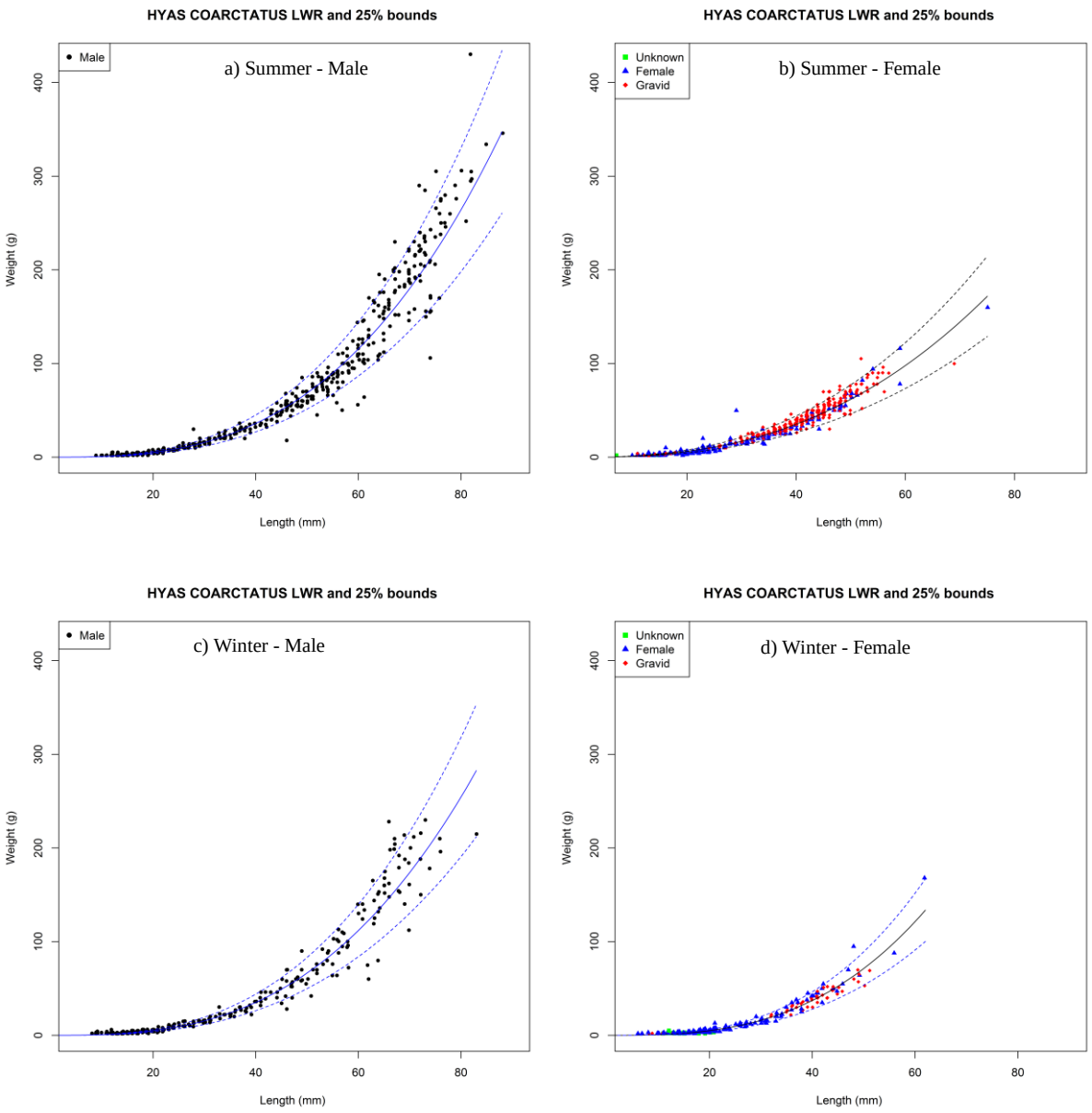

Figure 9 a) Solid line represents LWR of male Hyas Coarctatus crab in summer surveys. b) Solid line represents LWR of all female and unknown Hyas Coarctatus crab in summer surveys. c) Solid line represents LWR of male Hyas Coarctatus crab in Georges Bank and 4VsW surveys. d) Solid line represents LWR of all female and unknown sexes of Hyas Coarctatus crab in Georges Bank and 4VsW surveys.

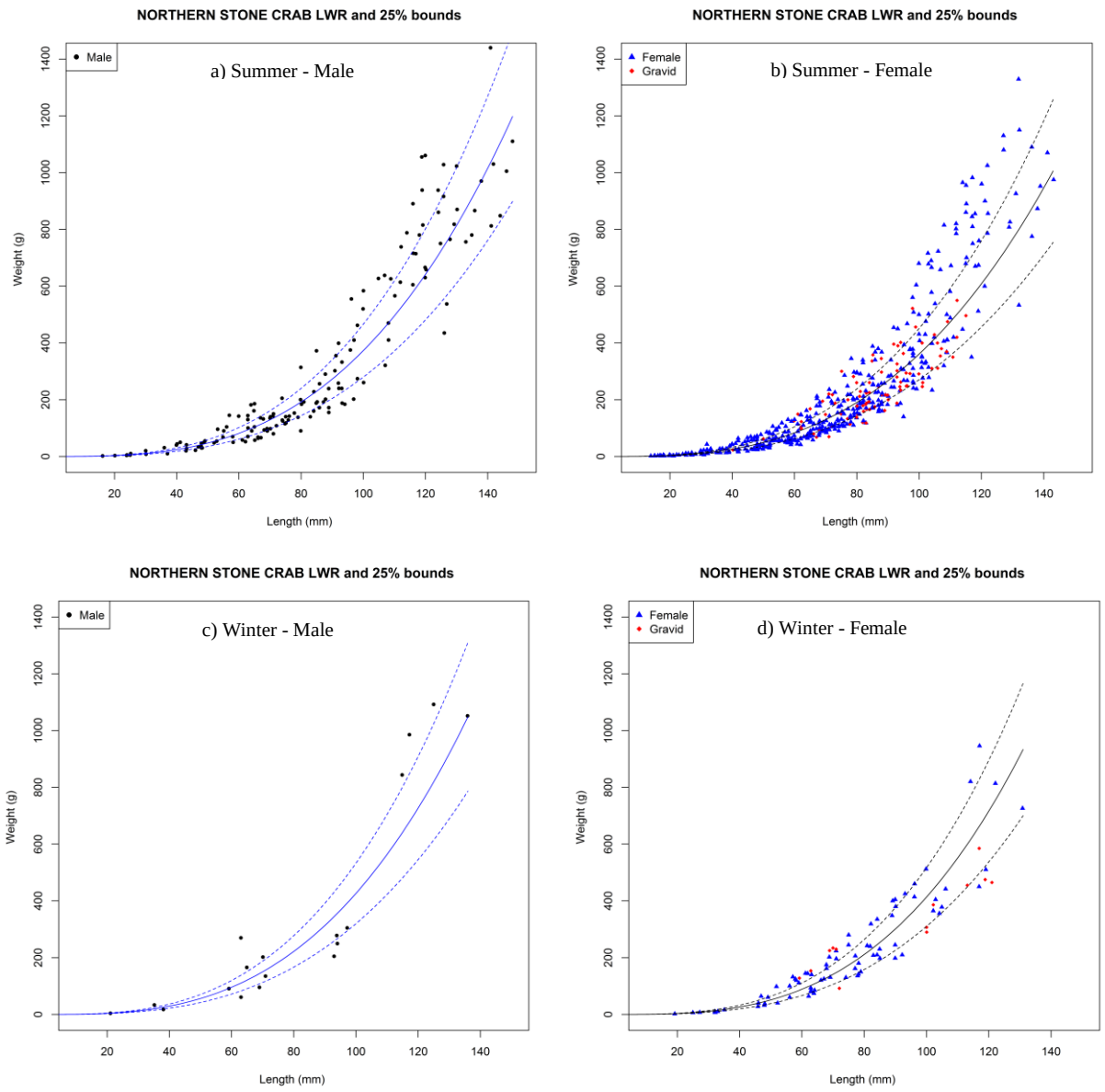

Figure 10 a) Solid line represents LWR of all male Northern Stone Crab in summer surveys. b) Solid line represents LWR of all female Northern Stone Crab in summer surveys. c) Solid line represents LWR of all male Northern Stone Crab in Georges Bank and 4VsW surveys. d) Solid line represents LWR of all female Northern Stone Crab in Georges Bank and 4VsW surveys.

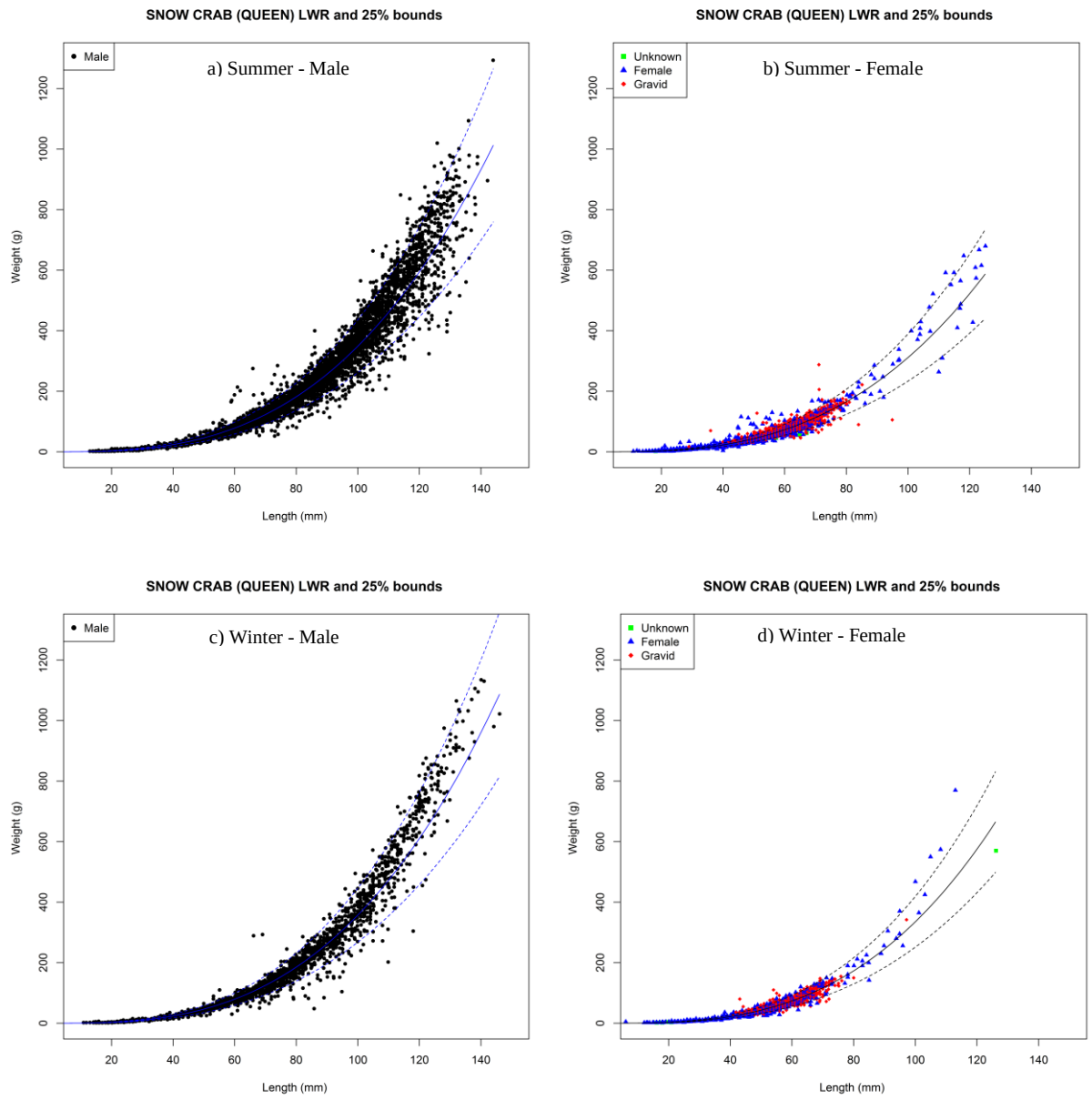

Figure 11 a) Solid line represents LWR of all male Snow Crab in summer surveys. b) Solid line represents LWR of all female Snow Crab in summer surveys. c) Solid line represents LWR of male Snow Crab in Georges Bank and 4VsW survey. d) Solid line represents LWR of all female Snow Crabs in the Georges Bank and 4VsW surveys.

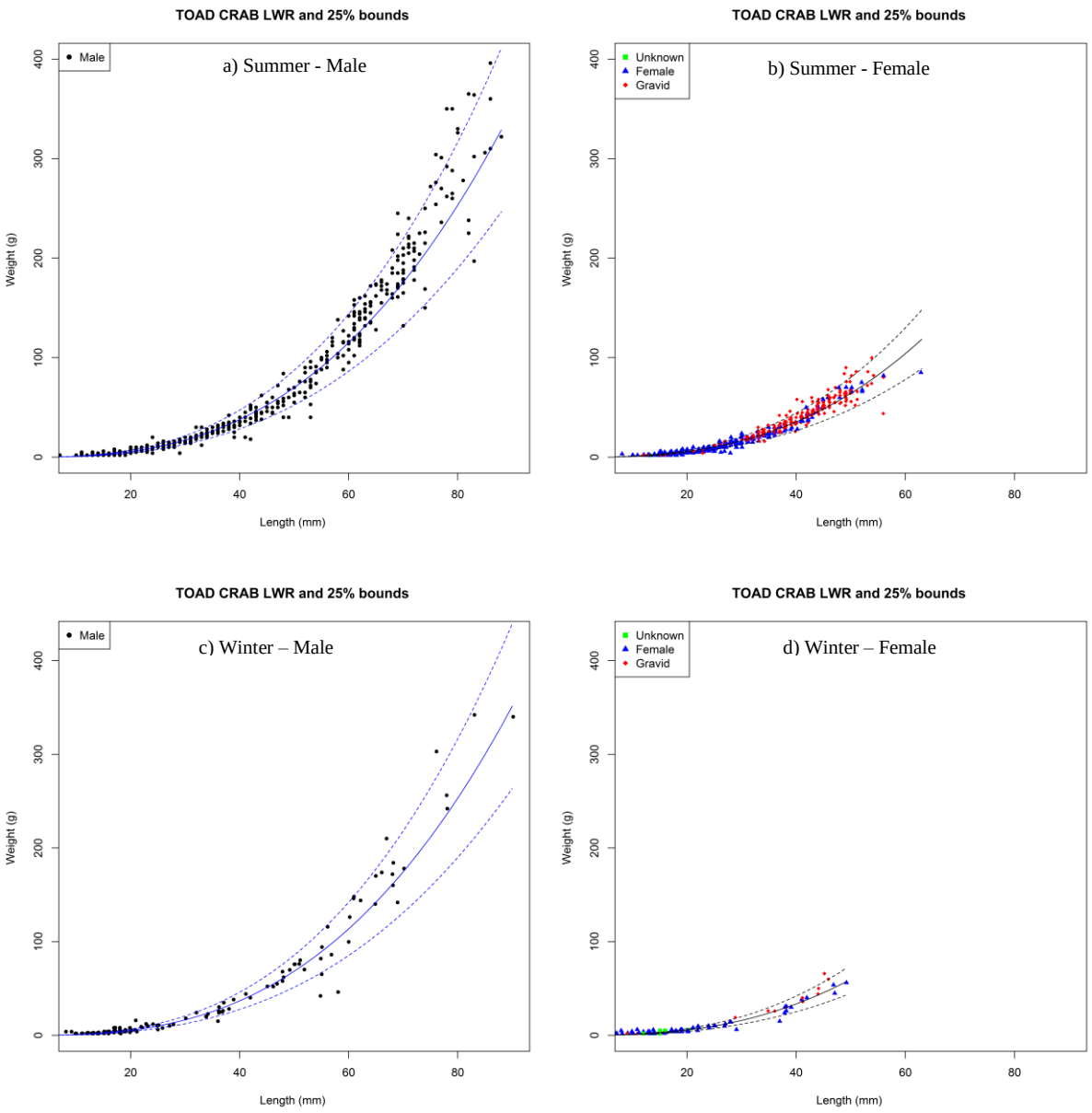

Figure 12 a) Solid line represents LWR of male Toad Crab in summer surveys. b) Solid line represents LWR of all female crabs in the summer. c) Solid line represents LWR of male of Toad Crab in Georges Bank and 4VsW surveys. d) Solid line represents LWR of female and unknown Toad Crab in Georges Bank and 4VsW surveys.

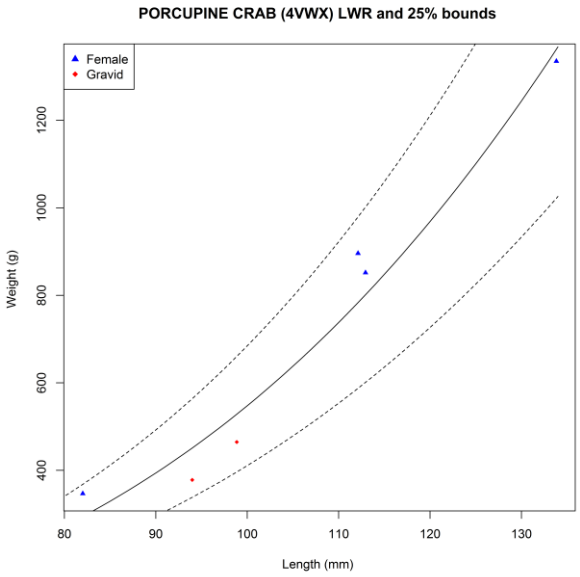

Figure 13. Solid line represents the LWR of all Porcupine Crab caught in the summer survey and the coefficients of the LWR will be used to predict LWR of all sexes of Porcupine Crab in all surveys.

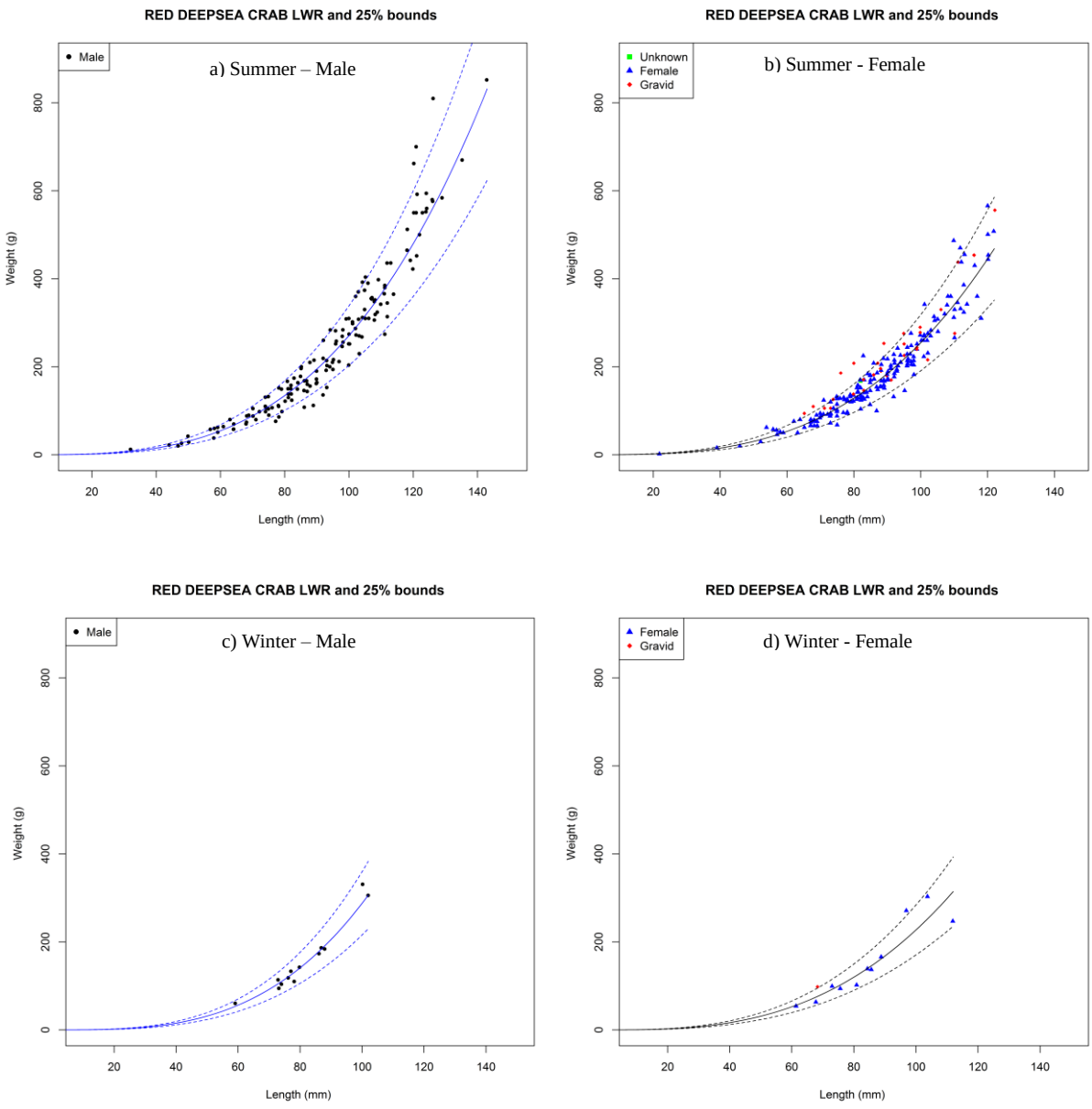

Figure 14 a) Solid line represents LWR of male Deep Sea Red Crabs in the Winter surveys. b) Solid line represents LWR of female Deep Sea Red Crabs (excluding ovigerous females) in the summer survey. c) Solid line represents LWR of male crabs in the Georges Bank and 4VsW surveys. d) Solid line represents LWR of all female crabs in the Georges Bank and 4VsW surveys.

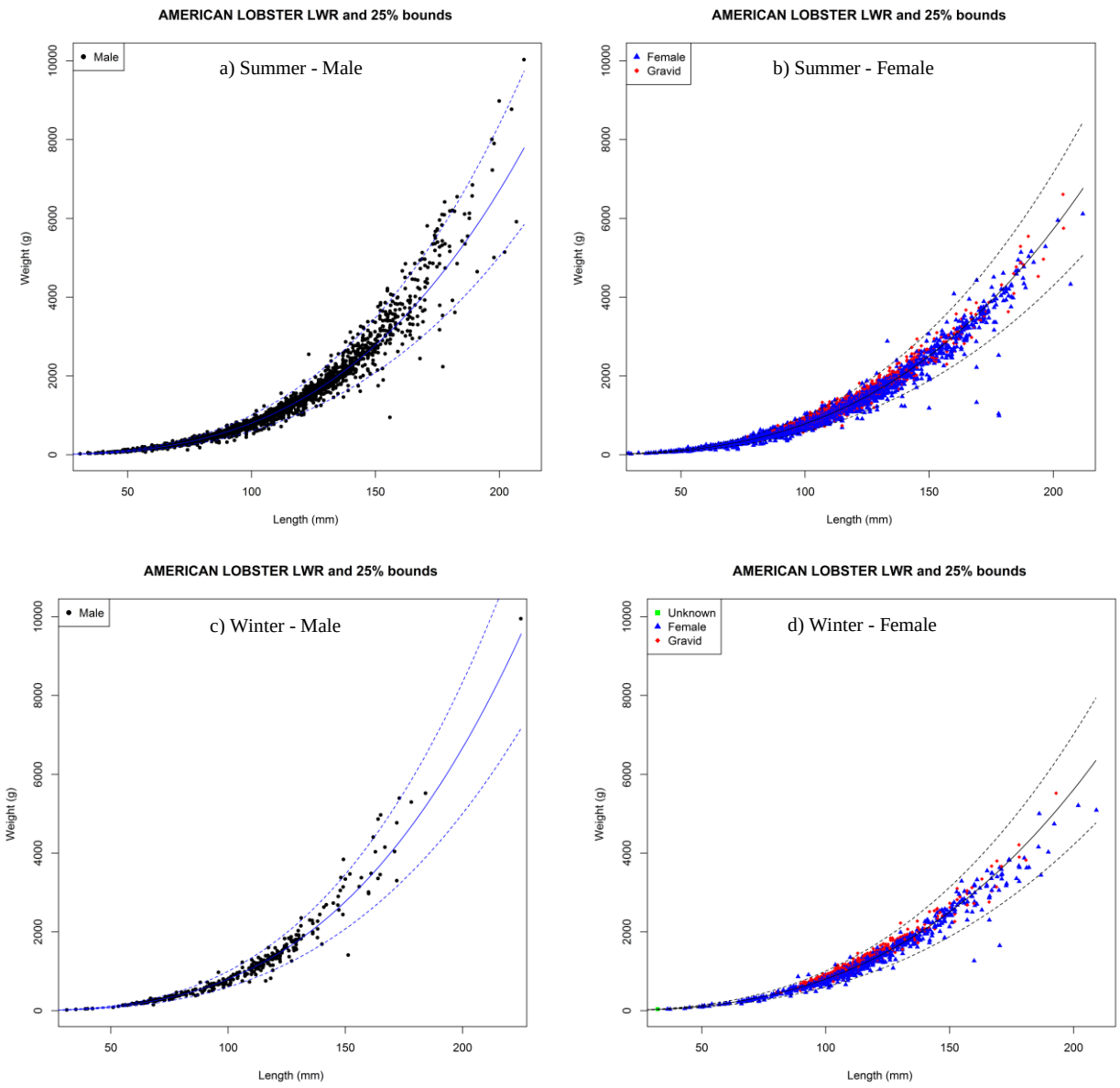

Figure 15 a) Solid line represents LWR of male lobsters in summer surveys. b) Solid line represents LWR of female lobsters in summer surveys. c) Solid line represents LWR of male lobsters in the Georges Bank and 4VsW surveys. d) Solid line represents LWR of pooled female lobsters in the Georges Bank and 4VsW surveys.

APPENDIX

Appendix Table 1. Accepted scientific names and the names (common and scientific) and codes of the invertebrates species caught and measured in the Maritimes Region.

Accepted Scientific Name	Accepted TSN	Accepted Rank	Given Common Name	Given Scientific Name	Given Species Code	Accepted Author
Brachyura	98276	Infraorder	BRACHYURAN CRABS	BRACHYURA S.	2510	(Latreille, 1802)
Cancer borealis	98678	Species	JONAH CRAB	CANCER BOREALIS	2511	(Stimpson, 1859)
Cancer irroratus	98679	Species	ATLANTIC ROCK CRAB	CANCER IRRORATUS	2513	(Say, 1817)
Hyas	98421	Genus	TOAD CRAB,UNIDENT.	HYAS SP.	2520	(Leach, 1814)
Hyas coarctatus	98423	Species	HYAS COARCTATUS	HYAS COARCTATUS	2521	(Leach, 1815)
Lithodes maja	97943	Species	NORTHERN STONE CRAB	LITHODES MAJA	2523	(Linnaeus, 1758)
Chionoecetes opilio	98428	Species	SNOW CRAB (QUEEN)	CHIONOECETES OPILIO	2526	(J. C. Fabricius, 1788)
Hyas araneus	98426	Species	TOAD CRAB	HYAS ARANEUS	2527	(Linnaeus, 1758)
Neolithodes grimaldii	97960	Species	PORCUPINE CRAB	NEOLITHODES GRIMALDII	2528	(A. Milne-Edwards and Bouvier, 1894)
Chaceon quinquedens	620992	Species	RED DEEPSEA CRAB	CHACEON QUINQUEDENS	2532	(S. I. Smith, 1879)
Axius serratus	97710	Species	AXIUS SERRATUS	AXIUS SERRATUS	2541	(Stimpson, 1852)
Homarus americanus	97314	Species	AMERICAN LOBSTER	HOMARUS AMERICANUS	2550	(H. Milne Edwards, 1837)
Munida iris	97967	Species	MUNIDA IRIS	MUNIDA IRIS	2555	(A. Milne-Edwards, 1880)
Munida valida	97986	Species	MUNIDA VALIDA	MUNIDA VALIDA	2556	(S. I. Smith, 1883)
Placopecten magellanicus	79718	Species	SEA SCALLOP	PLACOPECTEN MAGELLANICUS	4321	(Gmelin, 1791)
Chlamys islandica	79619	Species	ICELAND SCALLOP	CHLAMYS ISLANDICA	4322	(Müller, 1776)
Cephalopoda	82326	Class	CEPHALOPODA C.	CEPHALOPODA C.	4500	(Cuvier, 1797)
Illex illecebrosus	82521	Species	SHORT-FIN SQUID	ILLEX ILLECEBROSUS	4511	(Lesueur, 1821)
Loligo pealeii	82372	Species	LONGFIN SQUID, LONGFIN INSHORE SQUID	LOLIGO PEALEII	4512	(Lesueur, 1821)
Loligo	82370	Genus	LOLIGO SP.	LOLIGO SP.	4541	(Lamarck, 1798)
Mastigoteuthis	82558	Genus	MASTIGOTEUTHIS SP.	MASTIGOTEUTHIS SP.	7584	(Verrill, 1881)