Appendixes

Appendix A. Ongoing and Recently Completed Fishery Studies Funded by Bureau of Ocean Energy Management in Arctic Outer Continental Shelf Lease Areas

Table A1 provides a comprehensive list with descriptions and access to reports of the following studies can be accessed at http://www.boem.gov/Environmental-Stewardship/Environmental- Studies/Alaska/Index.aspx.

Table A1. Ongoing studies in the Arctic Outer Continental Shelf lease areas.

[Blank cells indicate that the species occurrence has not been confirmed in that sea. Marine waters out to the U.S. Exclusive Economic Zone (200-mile limit) are included]

Bureau of Ocean Energy Management study	Research topic	Researcher organization
Genomics of Arctic Cod	Genetic structure and diversity	U.S. Geological Survey
U.S.-Canada Transboundary fish and lower trophic communities	Ecological baselines of marine fish and invertebrates in the Beaufort Sea	University of Alaska, Fairbanks, Department of Fisheries and Oceans Canada
Trophic links: Forage fish, their prey, and Ice Seals in the northeast Chukchi Sea	Food habits and trophic linkages of ice seals	University of Alaska, Fairbanks
Dispersal patterns and summer ocean distribution of adult Dolly Varden from the Wulik River, Alaska, using satellite tags	Coastal and ocean habitats of Dolly Varden	Alaska Department of Fish and Game
Population assessment of Snow Crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas (including oil and gas lease areas)	Population dynamics of snow crabs	University of Alaska, Fairbanks
Distribution and habitat use of fish in the nearshore ecosystem of the Beaufort and Chukchi Seas (Alaska Coastal Ecosystem Survey)	Coastal habitat use by marine fish	National Oceanic and Atmospheric Administration Alaska Fisheries Science Center
Distribution of fish, crab, and lower trophic communities in the Chukchi Sea lease area (Arctic Integrated Ecosystem Survey)	Ecological baselines of fish and invertebrates in the northeastern Chukchi Sea	University of Alaska, Fairbanks, National Oceanic and Atmospheric Administration Alaska Fisheries Science Center

Table A2. Recently completed Bureau of Ocean Energy Management studies by year of completion.

Year	Bureau of Ocean Energy Management selected reference citations
2014	Bluhm, B., Huettmann, Falk, and Norcross, Brenda, 2014, Ecological analysis of 2008 western Beaufort Sea data: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEM 2014-014.
	Hopcroft, R.R., and Clarke, Cheryl, 2013, Retrieval of historical arctic fisheries survey data: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEM 2014-084, 45 p.
	Morris, M.C., 2014, Alaska shorezone coastal habitat mapping protocol: Seldovia, Alaska, Contract Report by Nuka Research and Planning Group LCC for the Bureau of Ocean Energy and Energy Management (BOEM), Anchorage, Alaska, 164 p. [Also available at http://alaskafisheries.noaa.gov/shorezone/chmprotocolO114.pdf].
	Talbot, S.L., Sage, G.K., Sonsthagen, S.A., and Fowler, M.C., 2014, Arctic Cod pilot genomics study—Preliminary results from analyses of mitochondrial DNA: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEM 2014-050, 29 p.
	Zimmerman, C.E., and von Biela, C.E., 2014, Investigation of population of origin and migration of Arctic Cisco found in the Colville River, Alaska using molecular and otolith tools: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEM 2014-019, 107 p.
2013	Carothers, C., Cotton, S., and Moerlein, K., 2013, Subsistence use and knowledge of salmon in Barrow and Nuiqsut, Alaska: Fairbanks, Alaska, University of Alaska Coastal Marine Institute and U.S. Department of the Interior, BOEM, Alaska OCS Region, OCS Study BOEM 2012-0115. [Also available at http:// www.boem.gov/BOEM-Newsroom/Library/Publications/201 3/BOEM-2013-0015pdf.aspx]
2012	Dunton, K.H., 2012, Chukchi Sea offshore monitoring in drilling area (COMIDA)—Chemical and Benthos (CAB): Anchorage, Alaska, prepared by University of Texas for U.S. Department of the Interior, BOEM Alaska OCS Region, Final Report, OCS Study BOEM 2012-012. [Also available at http://www.data.boem.gov/P l /PDFimages/ES P1S/5/5182.pdf].
	Norcoss, B.L., Holladay, B.A., and Mecklenburg, C.W., 2012, Recent and historical distribution and ecology of demersal fishes in the Chukchi Sea planning area: Fairbanks, Alaska, University of Alaska Coastal Marine Institute and U.S. Department of the Interior, BOEM, Alaska OCS Region, OCS Study BOEM 2012-073. [Also available at: http://www.boem.gov/BOEM-Newsroom/Library/Publications/2012/CMI-2012-073_pdf.aspx].
2011	Hardy, S.M., lken, Katrin, Hundertmark, Kris, Albrecht, Greg, 2011, Defining genetic structure in Alaskan populations of the snow crab, *Chionoecetes opilio*: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEMRE 2011-060, 31 p.
	Konar, Brenda, 2012, Recovery in a high Arctic kelp community: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEM 2012-0II, 24 p.
	Loggerwell, Elizabeth, Rand, Kimberly, Parker-Stetter, Sandra, Horne, John, Weingartner, Tom, and Bluhm, Bodil, 2010, Beaufort Sea marine fish monitoring 2008—Pilot survey and test of hypotheses: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEMRE 201 0-048, 262 p.
	Pirtle, J.L., and Mueter, F.J., 2011, Beaufort Sea fish and their trophic linkages—Literature search and synthesis: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, BOEMRE 2011-021, 47 p.
2007	Murphy, S.M., Mueter, F.J., and Braund, S.R., 2007, Variation in the abundance of Arctic Cisco in the Colville River—Analysis of existing data and local knowledge, volumes I and II: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, MMS 2007-042, 240 p.
2004	MBC Applied Environmental Sciences, 2004, Proceedings of a workshop on the variability of Arctic Cisco (Qaaktaq) in the Colville River: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, MMS 2004-033, 90 p.
1998	Kline, T., Jr., and Goering, J., 1998, North Slope amphidromy assessment: Anchorage, Alaska, U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, MMS 1998-006, 90 p.

Appendix B. Age-At-Size and Length-Weight Relationships for Arctic Marine Fishes

The Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf (OCS) Region is in the process of publishing new age-at-size and length-weight relationships for marine fish species from new studies in the U.S. Chukchi and Beaufort Seas. As this report was nearing publication, a summary of the length-weight relationships from BOEM's U.S.–Canada Transboundary study in the Beaufort Sea was provided to the USGS (Brenda L. Norcross and others, University of Alaska, Fairbanks, written commun., 2016; and Kelly L. Walker, University of Alaska, Fairbanks, written commun., 2016). The transboundary study included field collections in offshore waters of the southeastern Beaufort and western Arctic Canada between 2012 and 2014.

There were 20 species for which sufficient numbers of fish were captured so that length-weight relationships could be established (table B1). The species are from nine families: Gadidae–*Boreogadus saida*, Cottidae–*Gymnocanthus tricuspis*, *Icelus bicornis*, *I. spatula*, *Triglops nybelini*, and *Triglops pingelii*, Psycholutidae–*Cottunculus microps*, Agonidae–*Aspidophoroides olrikii*, Cyclopteridae–*Eumicretremus derjugini*, Liparidae–*Careproctus sp*. and *Liparis fabricii*, Zoarcidae–*Lycodes adolfi*, *L. polaris*, *L. sagittarius* and *L. seminudus*, Stichaeidae–*Anisarchus medius*, *Lumpenus fabricii* and *Sticheaus punctatus*, and Pleuronectidae–*Reinhardtius hippoglossoides*. Fish sampling encompassed pelagic and benthic environments of the Beaufort Sea and the minimum and maximum lengths reported for each species varied greatly. The weight-at-length regressions fit the data closely, with r^2 values of 0.90–0.99 and all intercepts (*a*) were near zero (table B1). The range of slopes (*b*) was 2.49–3.59. A *b* value close to 3.0 indicates isometric growth, that is, growth of all body parts occurs at the same rate; values outside of that range indicate allometric growth, that is, the body changes shape with growth. The *b* value also indicates body shape; negative allometric growth ($b < 3$) and positive allometric growth ($b > 3$) indicate decreasing or increasing body thickness or plumpness with increasing fish length (Brenda L. Norcross and others, University of Alaska, Fairbanks, written commun., 2016; and Kelly L. Walker, University of Alaska, Fairbanks, written commun., 2016).

Table B1. Summary of length-weight relationships of marine fish collected in the U.S.–Canada transboundary study in the Beaufort Sea.

[**Source:** Brenda L. Norcross and others, University of Alaska, Fairbanks, written commun., 2016; and Kelly L. Walker, University of Alaska, Fairbanks, written commun., 2016. ***a***: intercepts. ***b***: range of slopes. $\mathbf{r}^2$: coefficient of determination. **Abbreviations:** g, gram; mm, millimeter]

Species	Number	Weight range (g)	Length range (mm)	a*10^5	b	r^2
Boreogadus saida	2,877	0.03–106.13	15–240	0.587	3.01	0.98
Artediellus scaber	137	0.03–13.63	14–95	1.690	2.98	0.99
Gymnocanthus tricuspia	683	0.08–20.89	19–119	0.315	3.33	0.99
Icelus bicornis	97	0.23–4.45	27–68	0.270	3.37	0.96
Icelus spatula	412	0.09–7.86	24–89	0.488	3.20	0.90
Triglops nybelini	15	4.29–14.67	81–118	0.425	3.14	0.93
Triglops pingelli	234	0.15–14.30	26–130	0.834	2.97	0.98
Cottonculus microps	14	1.27–208.33	45–223	2.770	2.93	0.99
Asidophoroides olrikii	335	0.04–3.69	23–80	0.351	3.17	0.93
Eumicretemus derjugini	8	0.23–14.48	15–64	4.170	3.07	0.99
Careproctus sp.	41	0.72–112.53	47–145	0.071	3.59	0.98
Liparis fabricii	120	0.07–112.53	19–212	0.050	3.58	0.93
Lycodes adolfi	232	0.19–26.62	38–205	0.201	3.09	0.97
Lycodes polaris	64	0.24–26.79	40–164	0.161	3.26	0.99
Lycodes saggittarius	191	0.33–347.60	44–427	0.812	2.88	0.92
Lycodes seminudus	154	0.30–535.99	41–465	1.540	2.82	0.98
Anisarchus medius	65	0.23–5.15	49–134	2.790	2.49	0.93
Lumpenus facricii	157	0.13–5.11	41–124	0.755	2.78	0.97
Sticheaus puncatatus	7	0.17–0.71	29–48	0.122	3.42	0.94
Reinhardtius hippoglossoides	9	400.20 –1,481.23	351–525	0.366	3.15	0.92

As part of this USGS study, the age and growth relationships for 19 marine fishes were reviewed and age-length and length-weight regressions are presented from collections in Arctic Alaska and adjacent seas. In certain instances, regressions are presented for data obtained from species collections in high-latitude areas far-removed from the Beaufort and Chukchi Seas, such as the Barents Sea. These examples highlight the limited availability of data for many species. In every case, the data are color-coded by investigator and area of fish collection. Because of the present-day ecological interest in *Boreogadus saidi*, the most current length-weight relationship described for this species from the Beaufort Sea, as indicated in table B1, is included for comparison with the historical data.

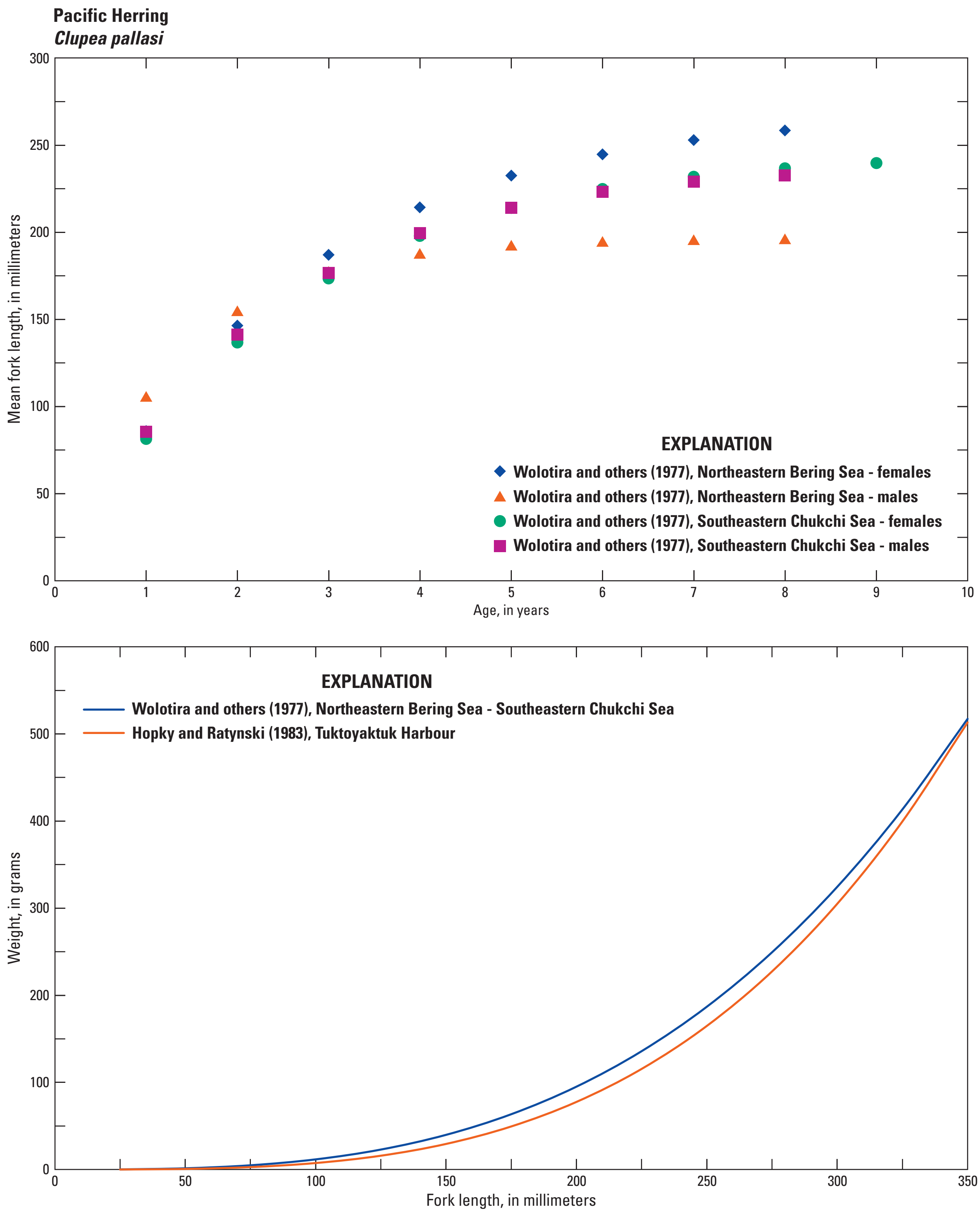


Figure B1. Age-at-length and length-weight relationships for Pacific Herring (*Clupea pallasii*). Data from Wolotira and others (1977).

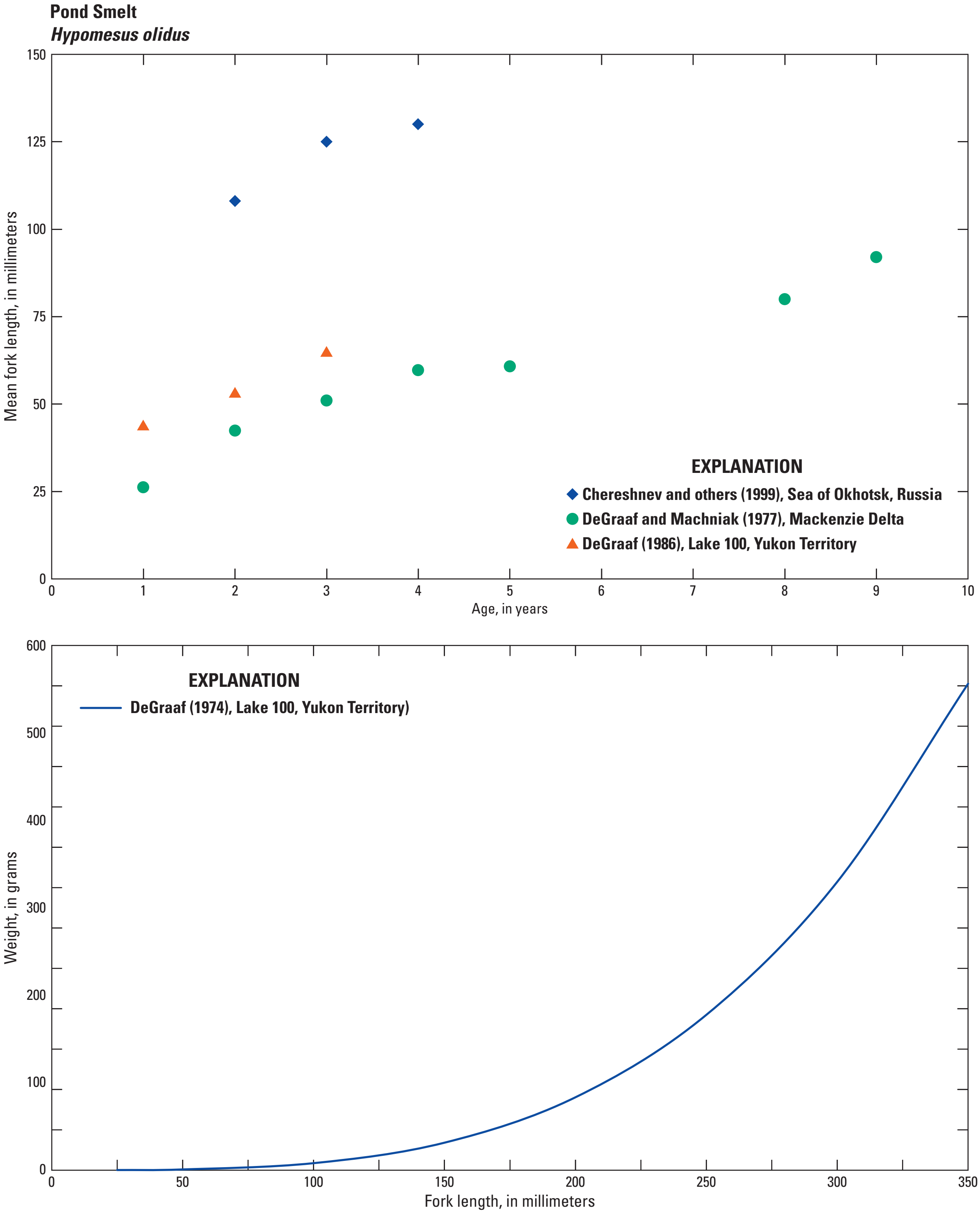


Figure B2. Age-at-length and length-weight relationships for Pond Smelt (*Hypomesus olidus*).

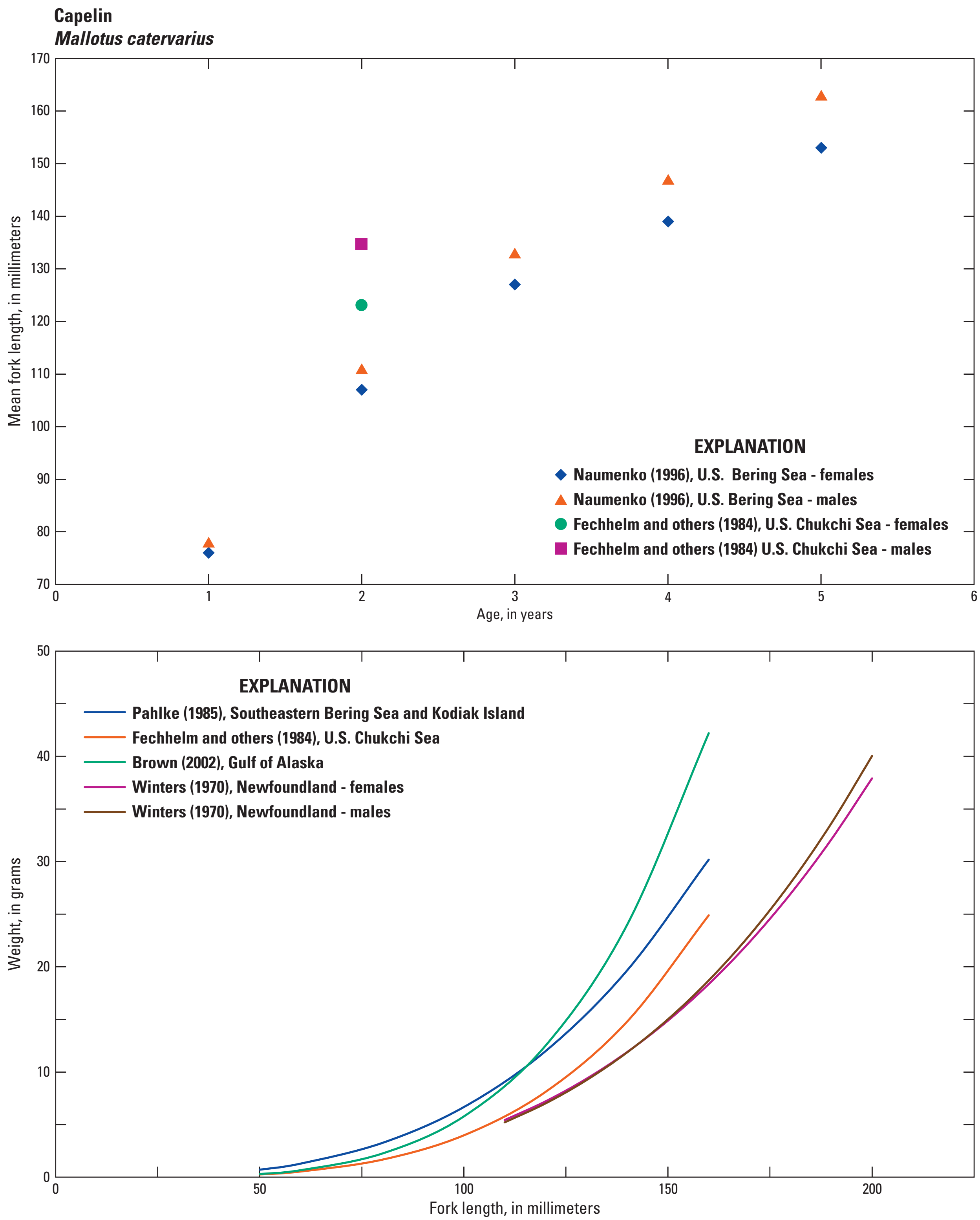


Figure B3. Age-at-length and length-weight relationships for Capelin (*Mallotus catervarius*).

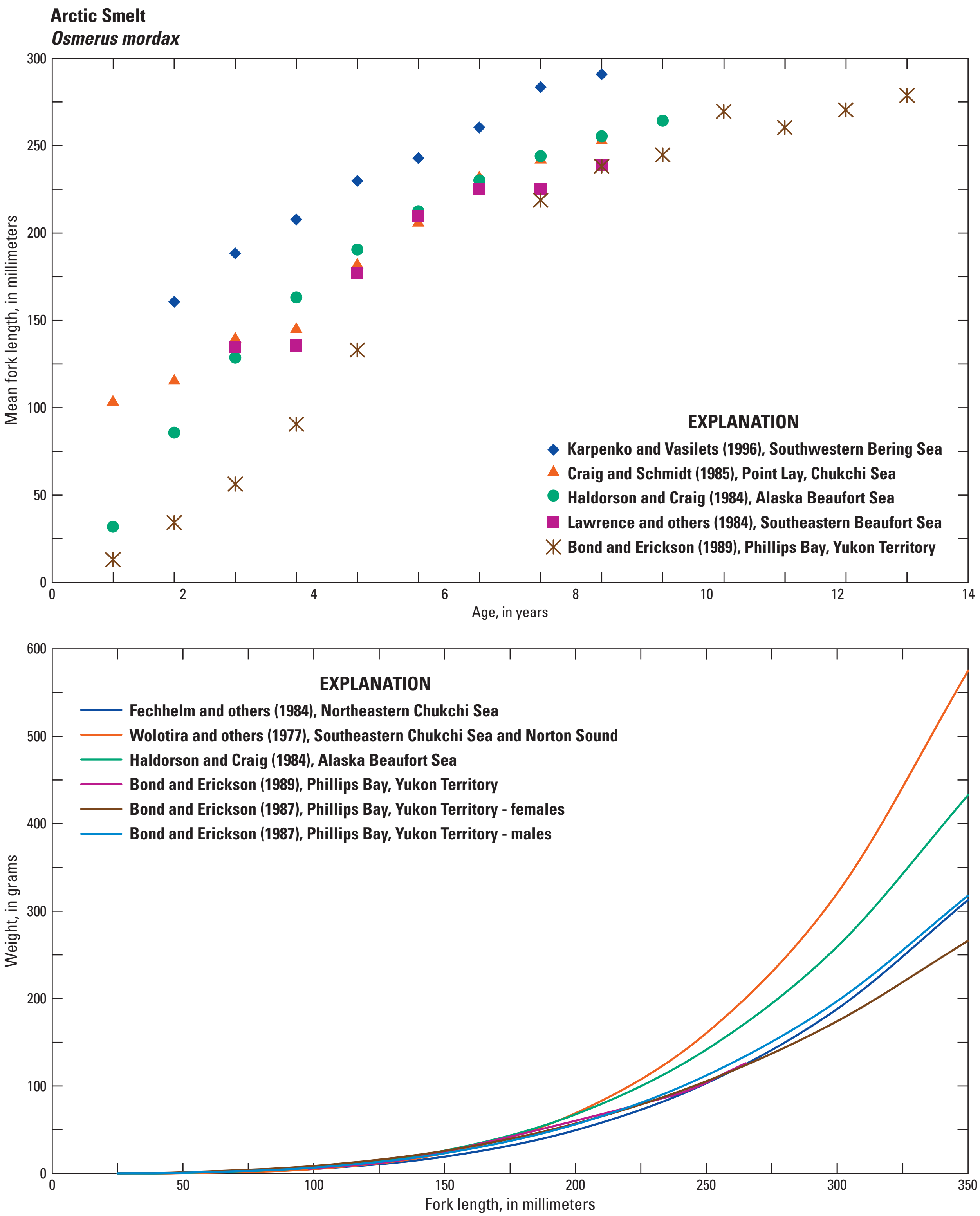
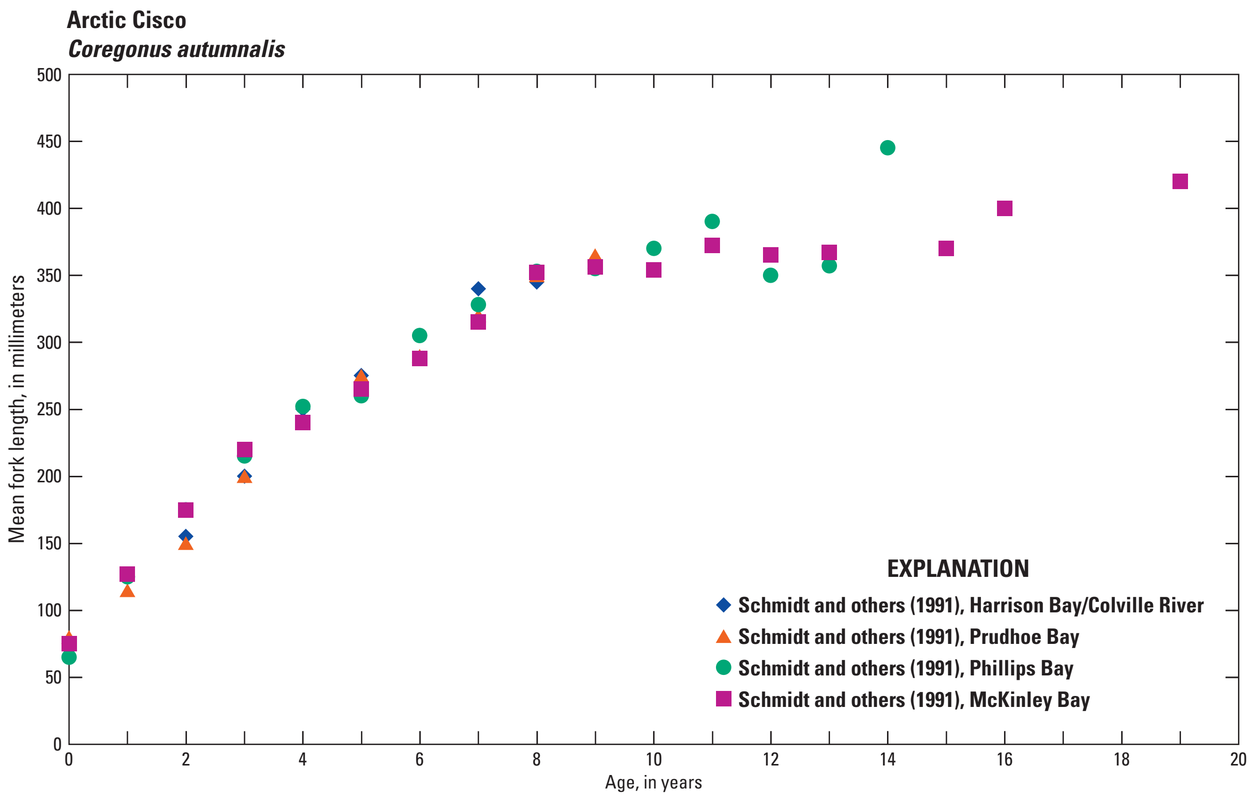


Figure B4. Age-at-length and length-weight relationships for Arctic Smelt (*Osmerus dentex*)



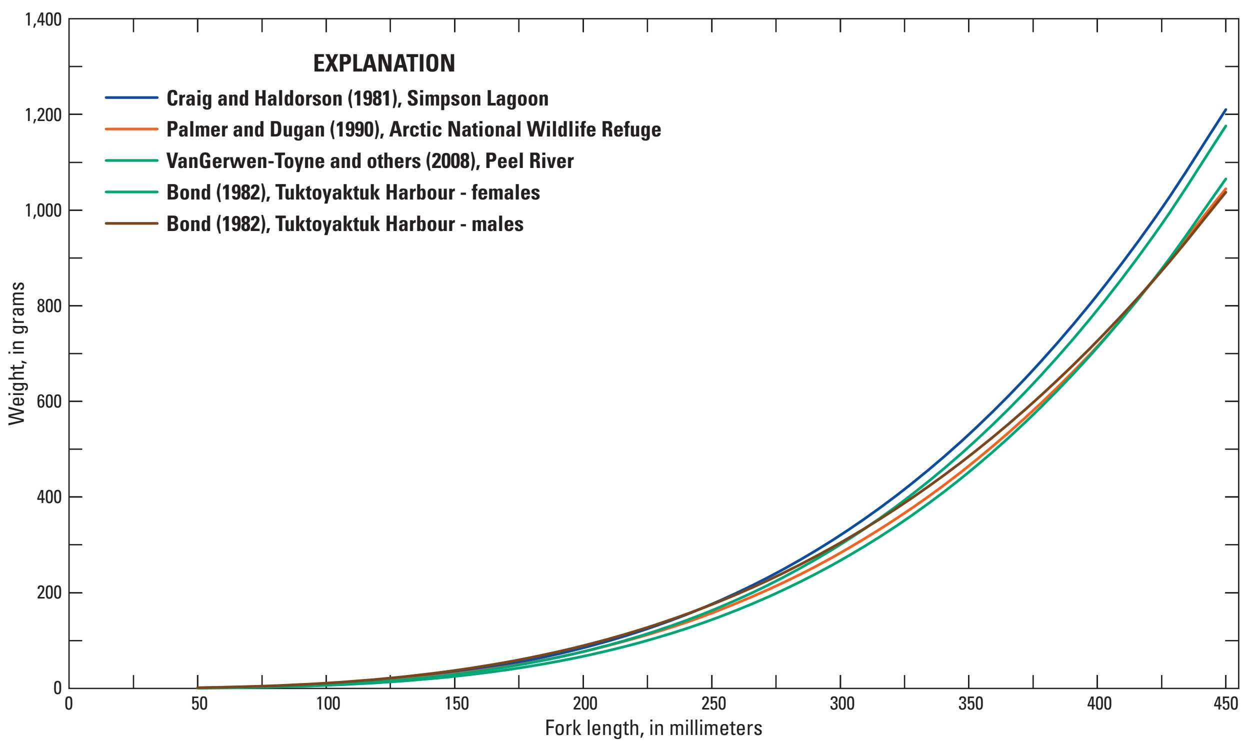


Figure B5. Age-at-length and length-weight relationships for Arctic Cisco (*Coregonus autumnalis*). Data from Schmidt and others (1991).

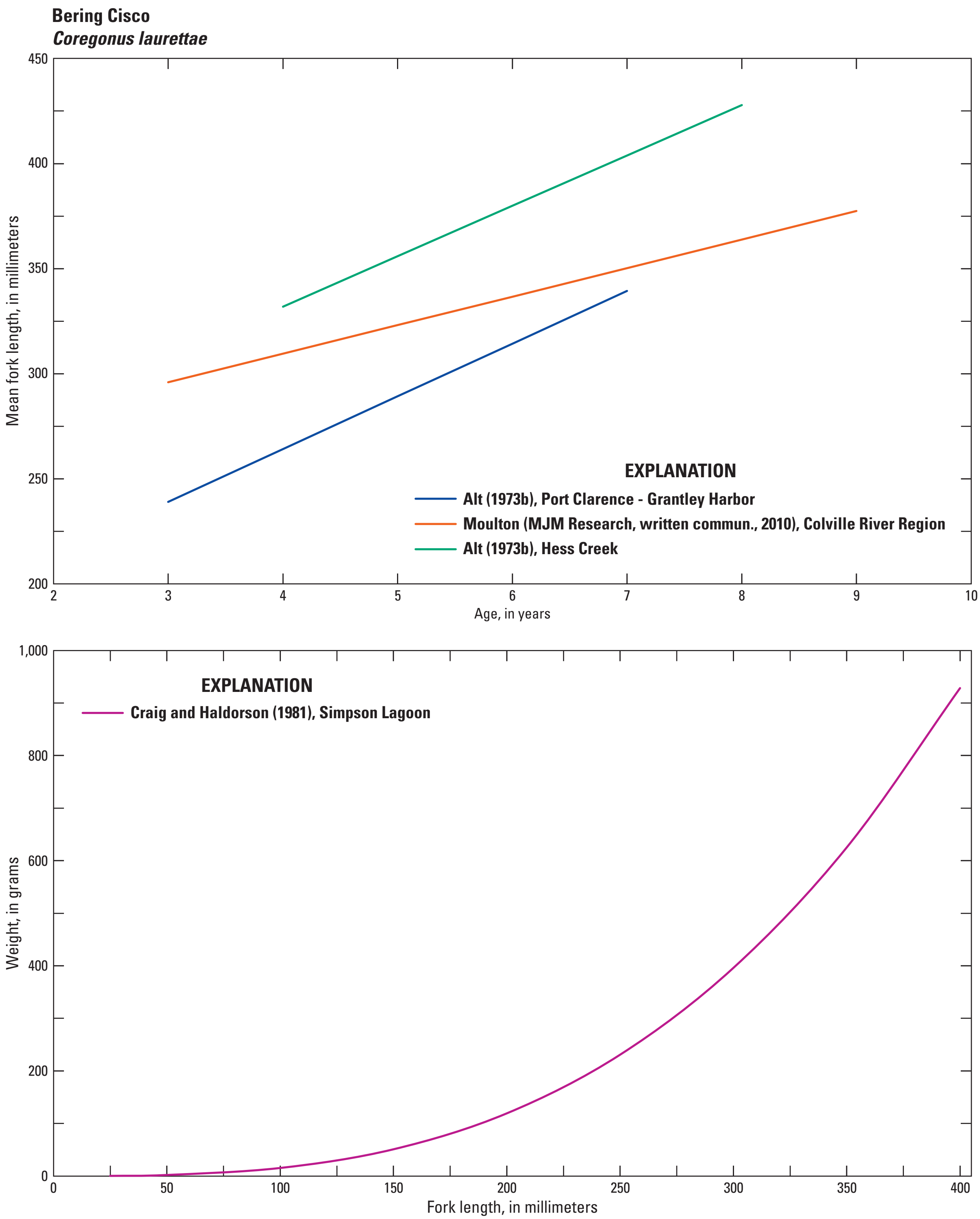


Figure B6. Age-at-length and length-weight relationships for Bering Cisco (*Coregonus laurettae*).

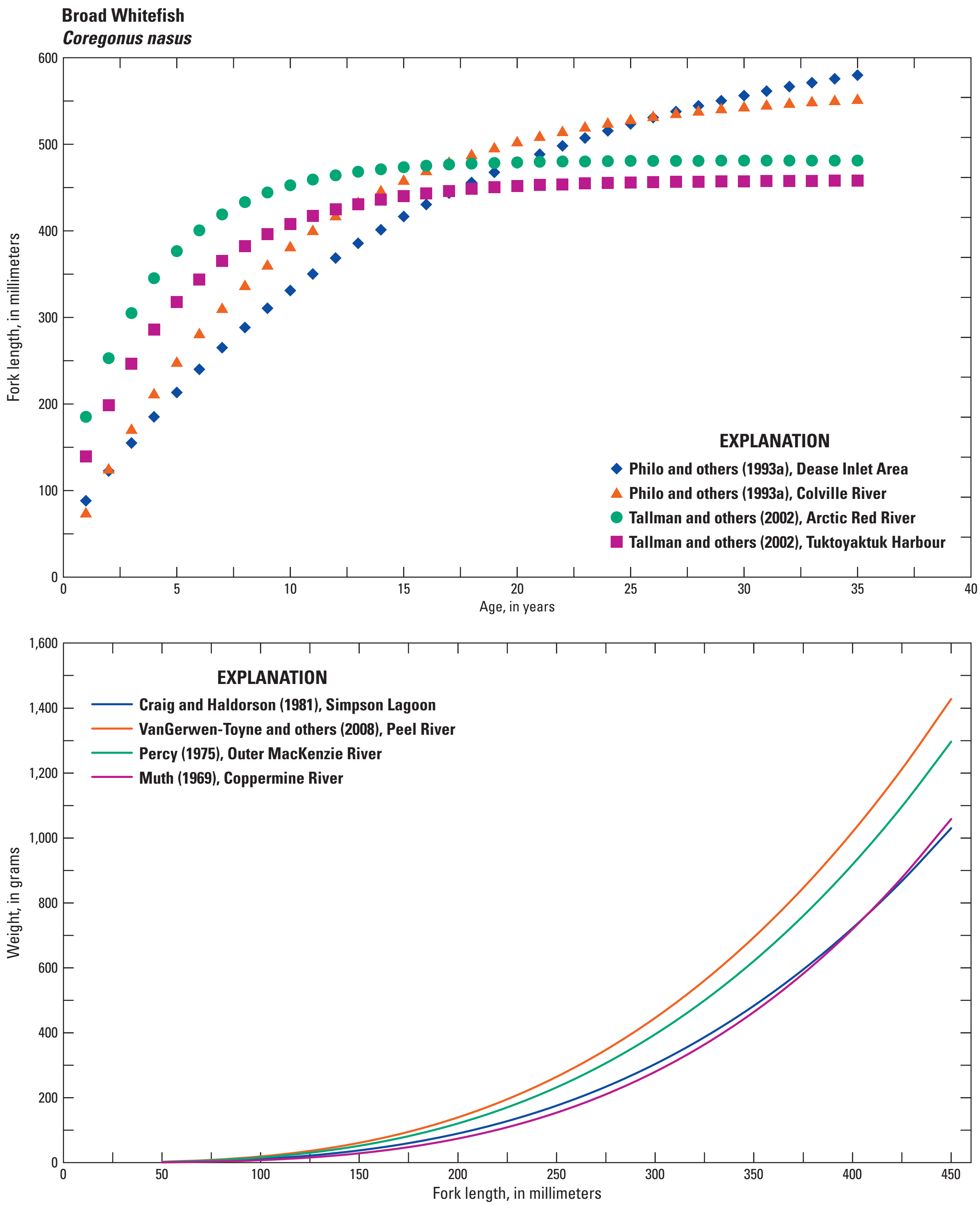


Figure B7. Age-at-length and length-weight relationships for Broad Whitefish (*Coregonus nasus*).

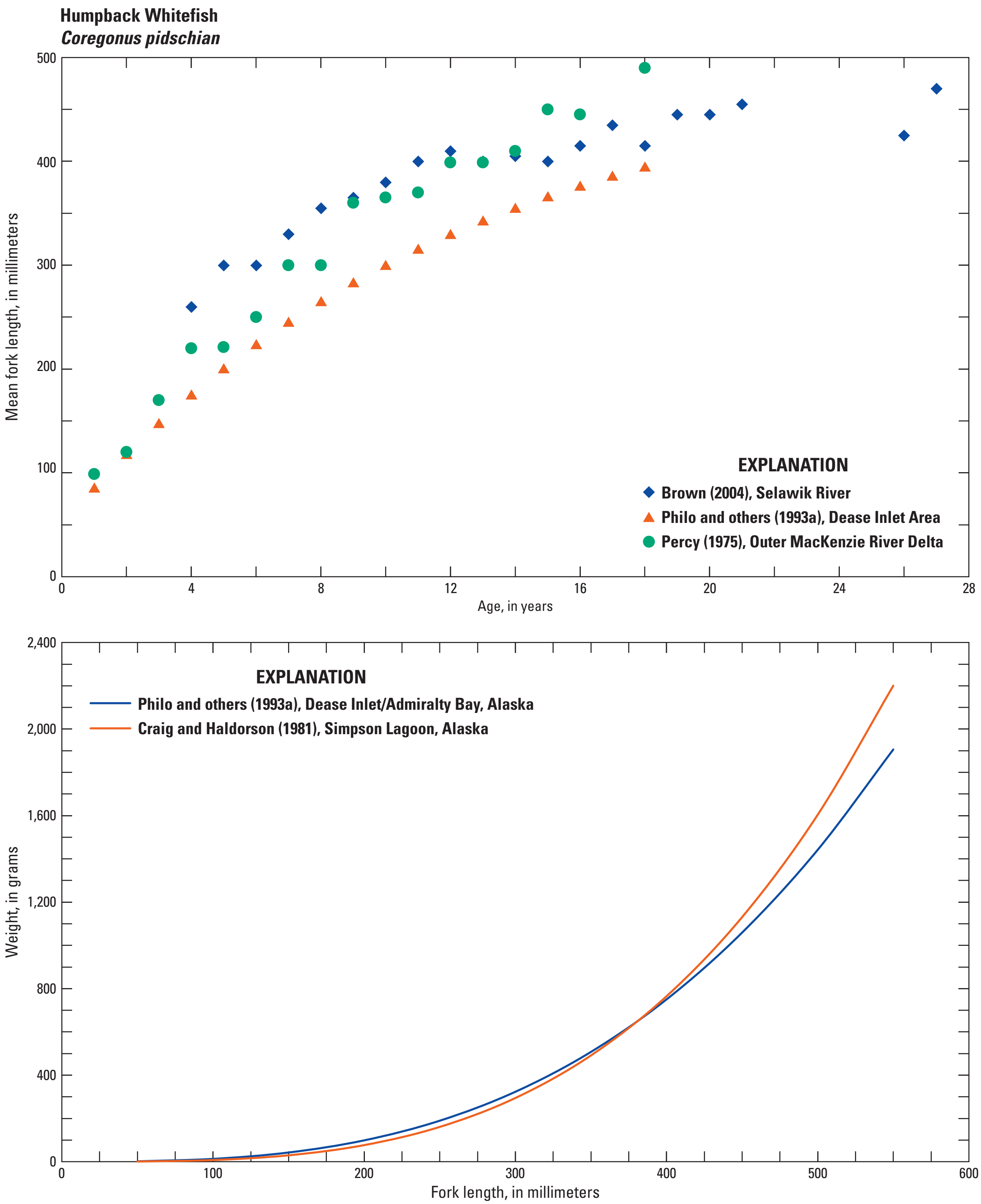


Figure B8. Age-at-length and length-weight relationships for Humpback Whitefish (*Coregonus pidschian*)

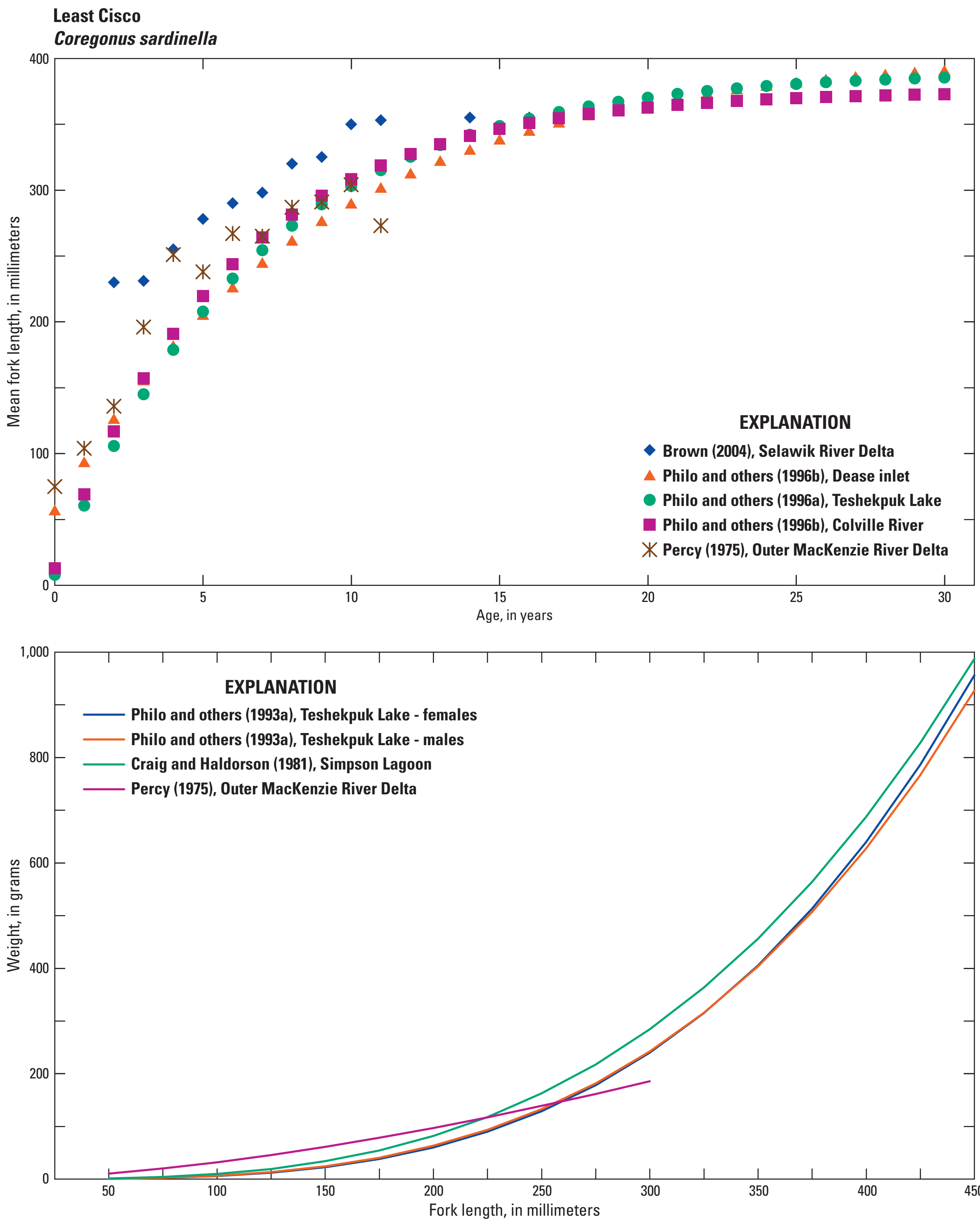
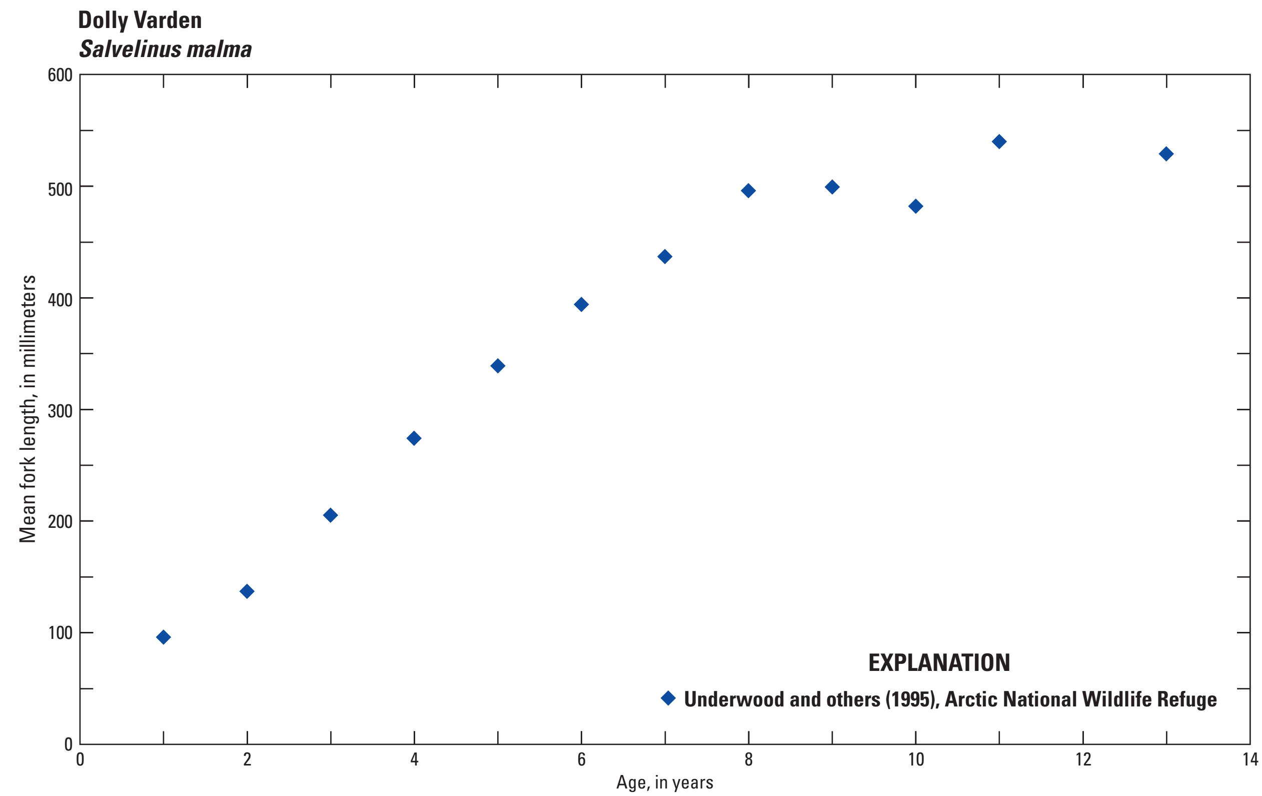


Figure B9. Age-at-length and length-weight relationships for Least Cisco (Coregonus sardinella).



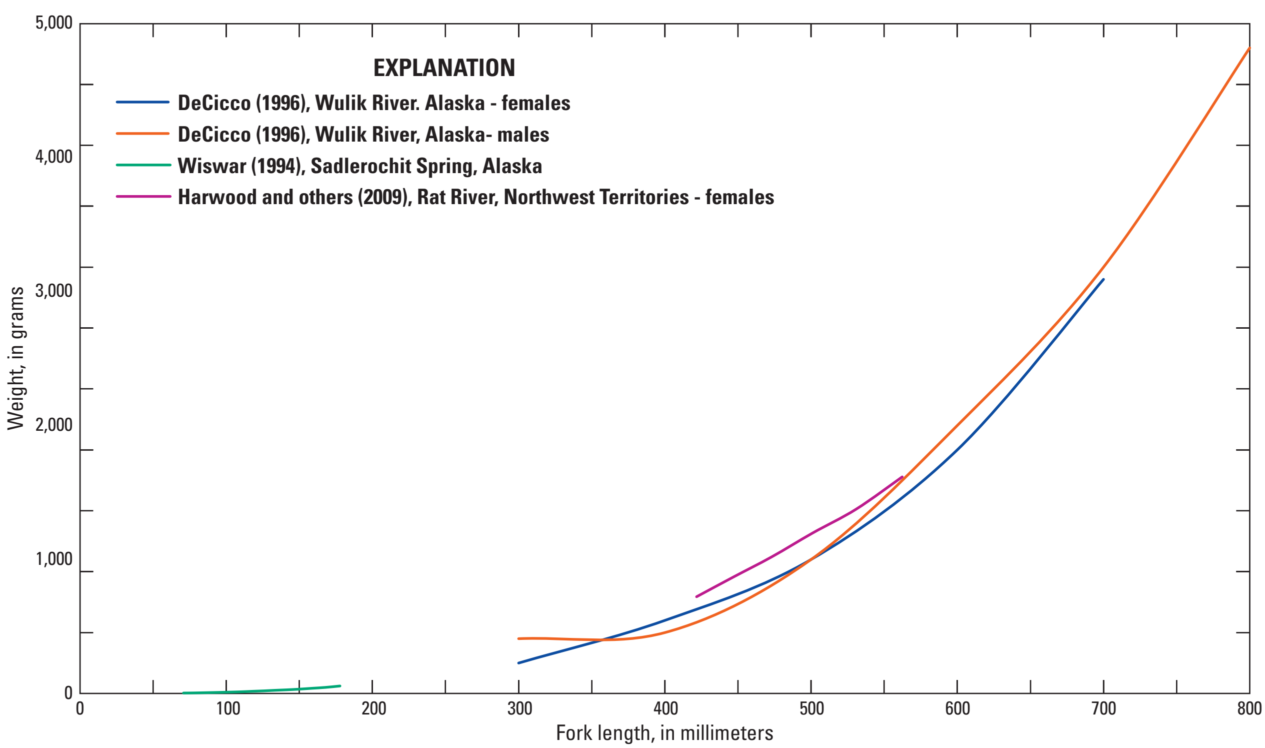
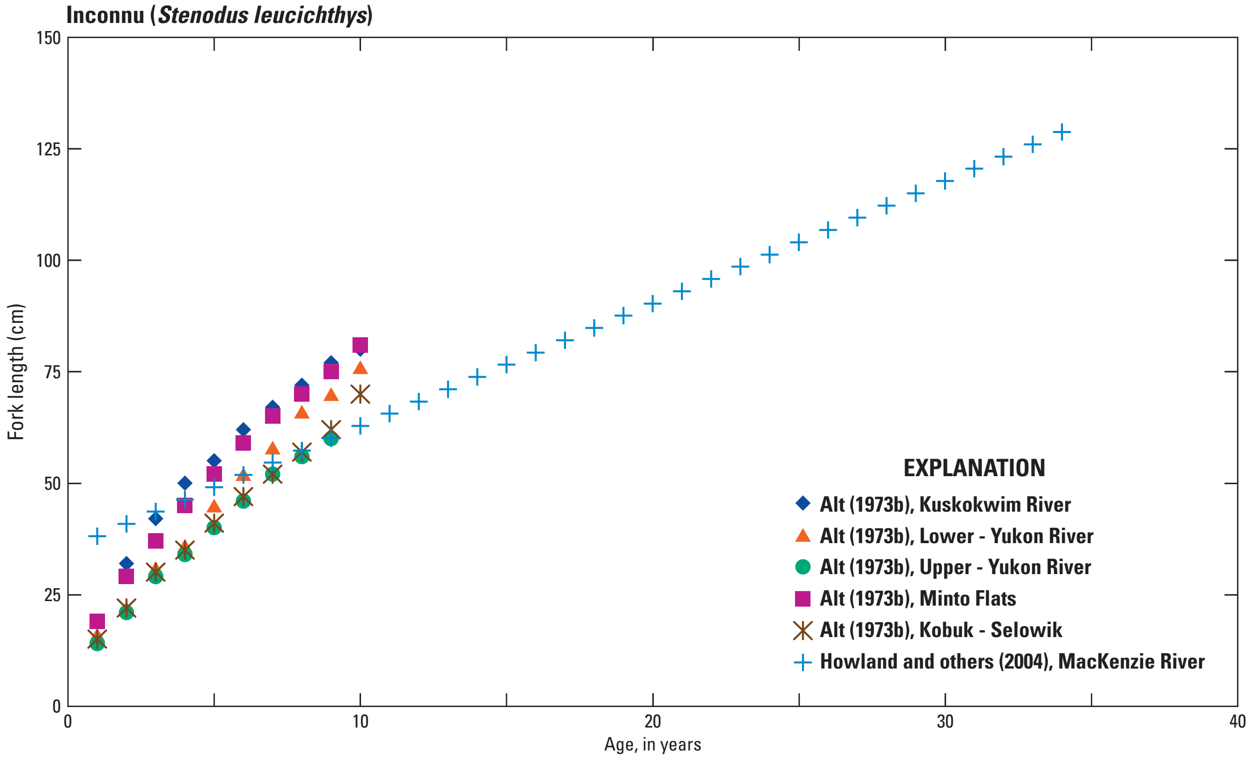


Figure B10. Age-at-length and length-weight relationships for Dolly Varden (Salvelinus malma). Age-length relationship not described from U.S. Beaufort and Chukchi Seas.



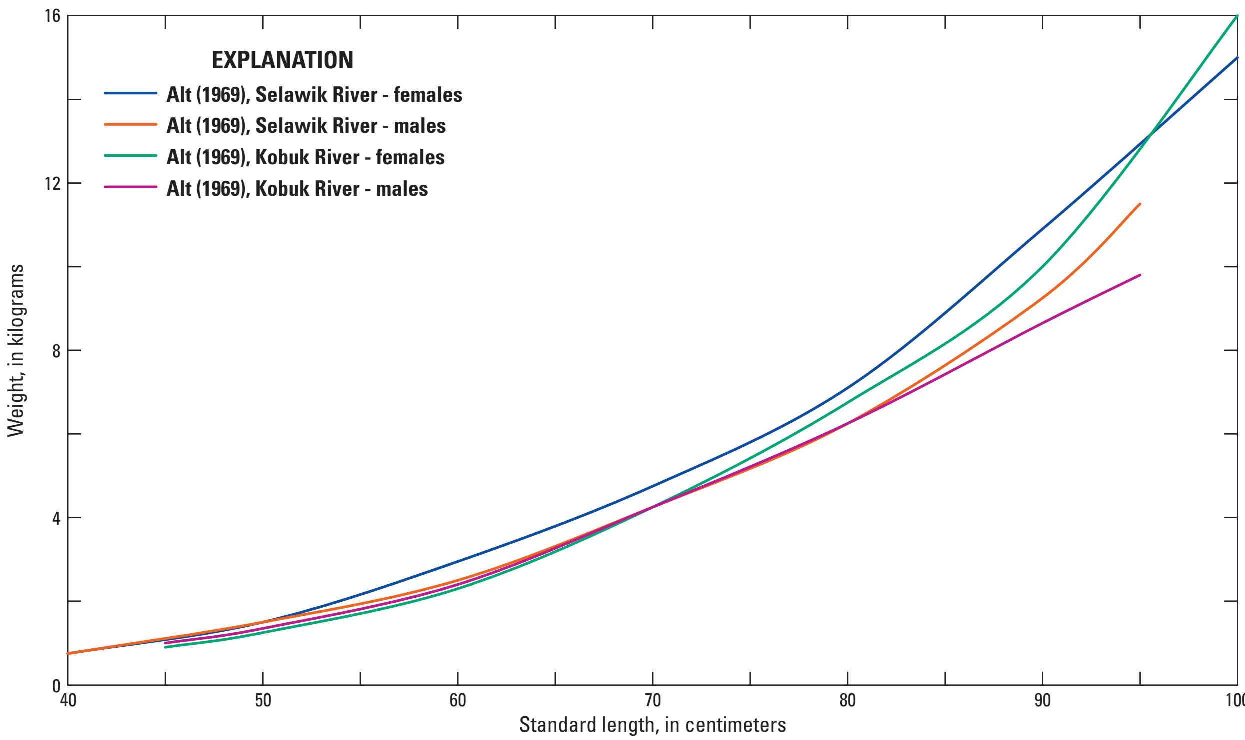
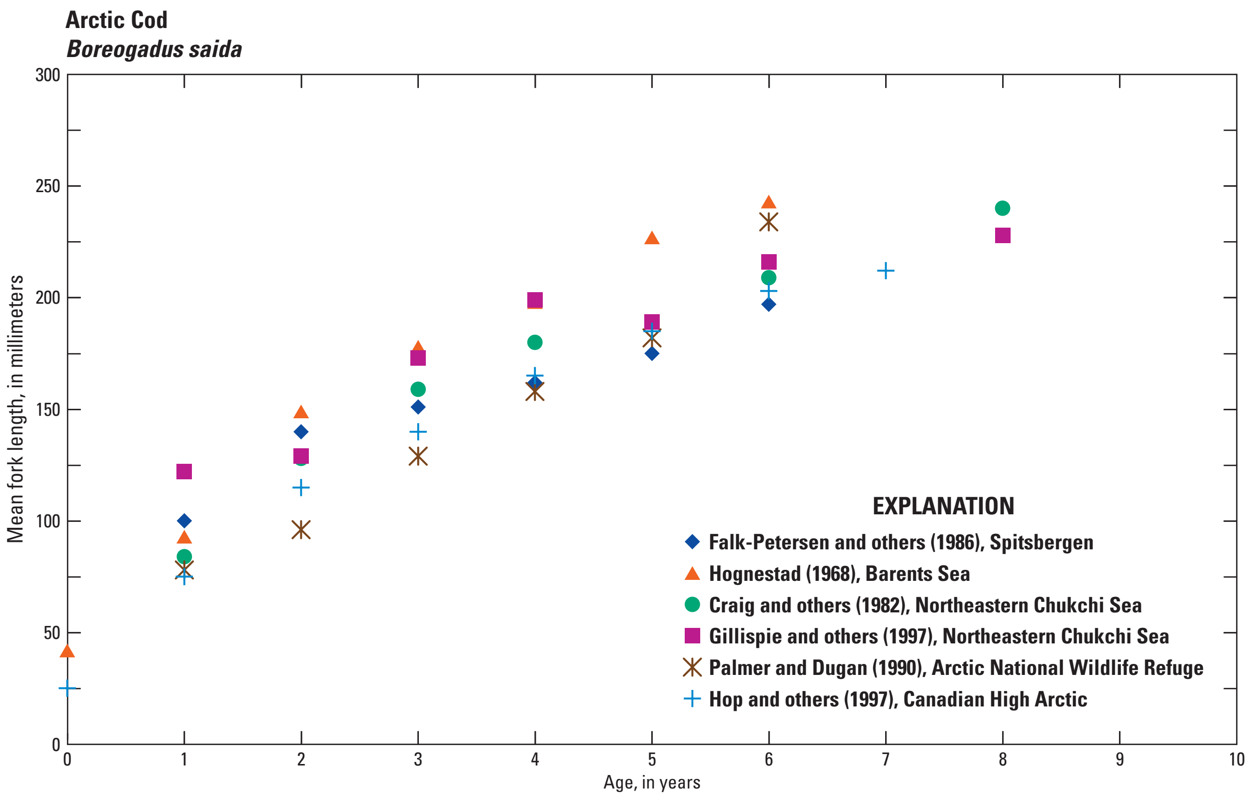


Figure B11. Age-at-length and length-weight relationships for Inconnu (*Stenodus leucichthys*).



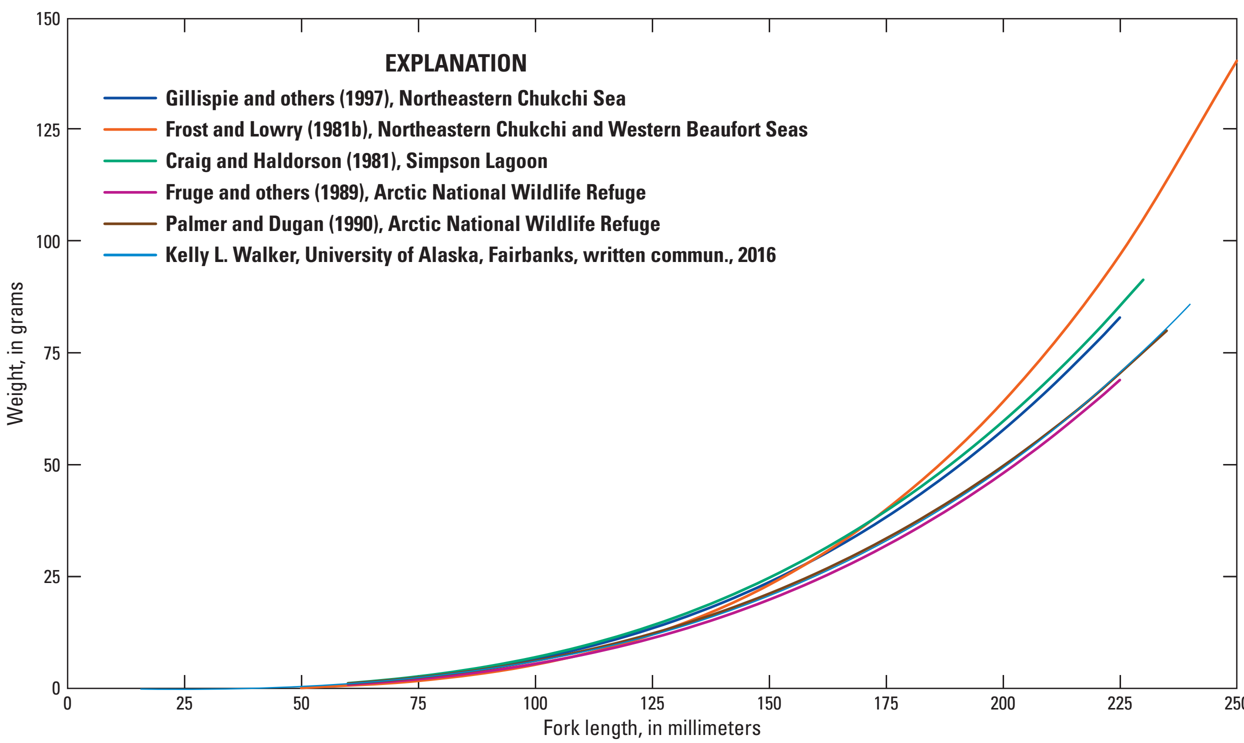
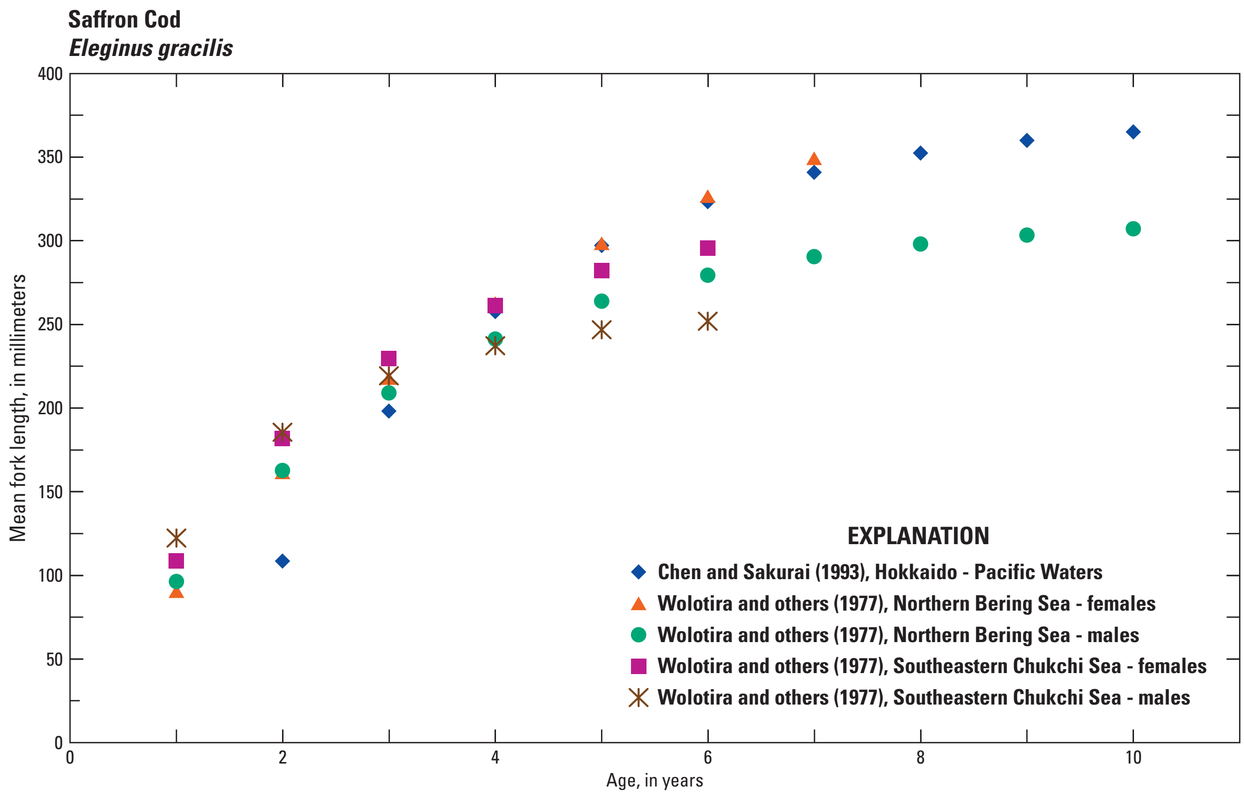


Figure B12. Age-at-length and length-weight relationships for Arctic Cod (*Boreogadus saida*).



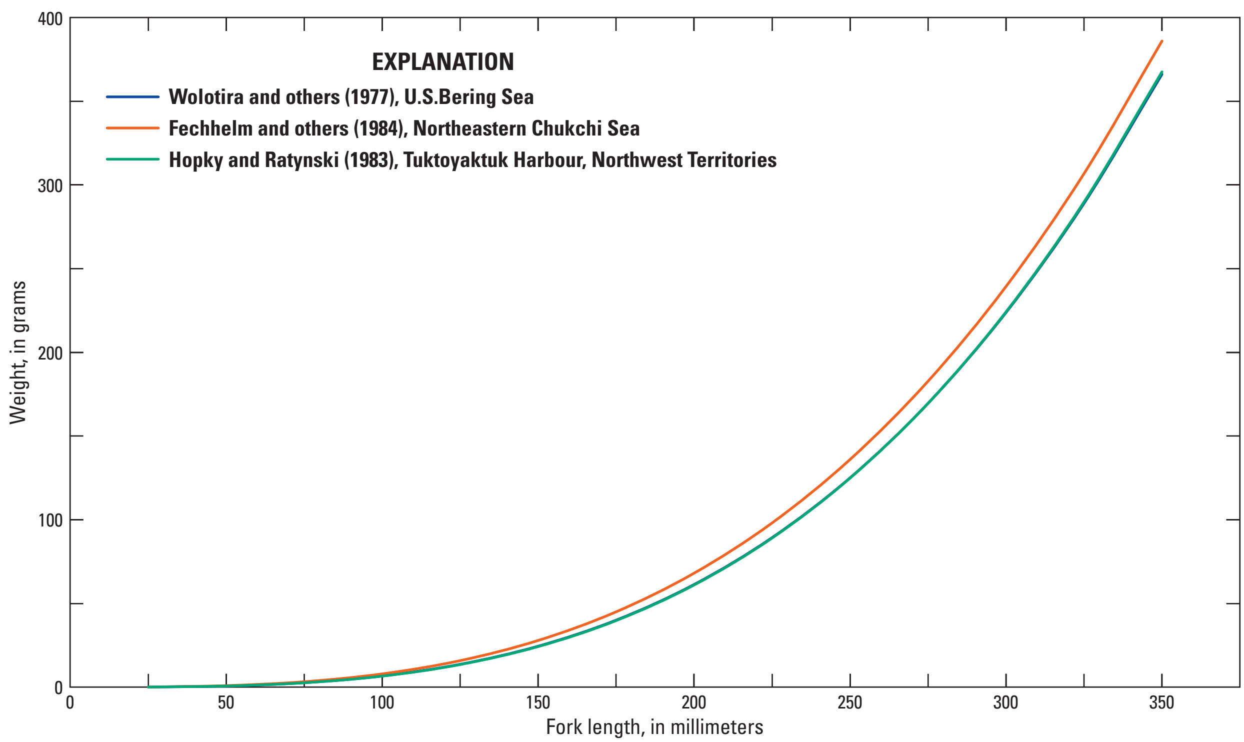


Figure B13. Age-at-length and length-weight relationships for Saffron Cod (*Eleginus gracilis*).

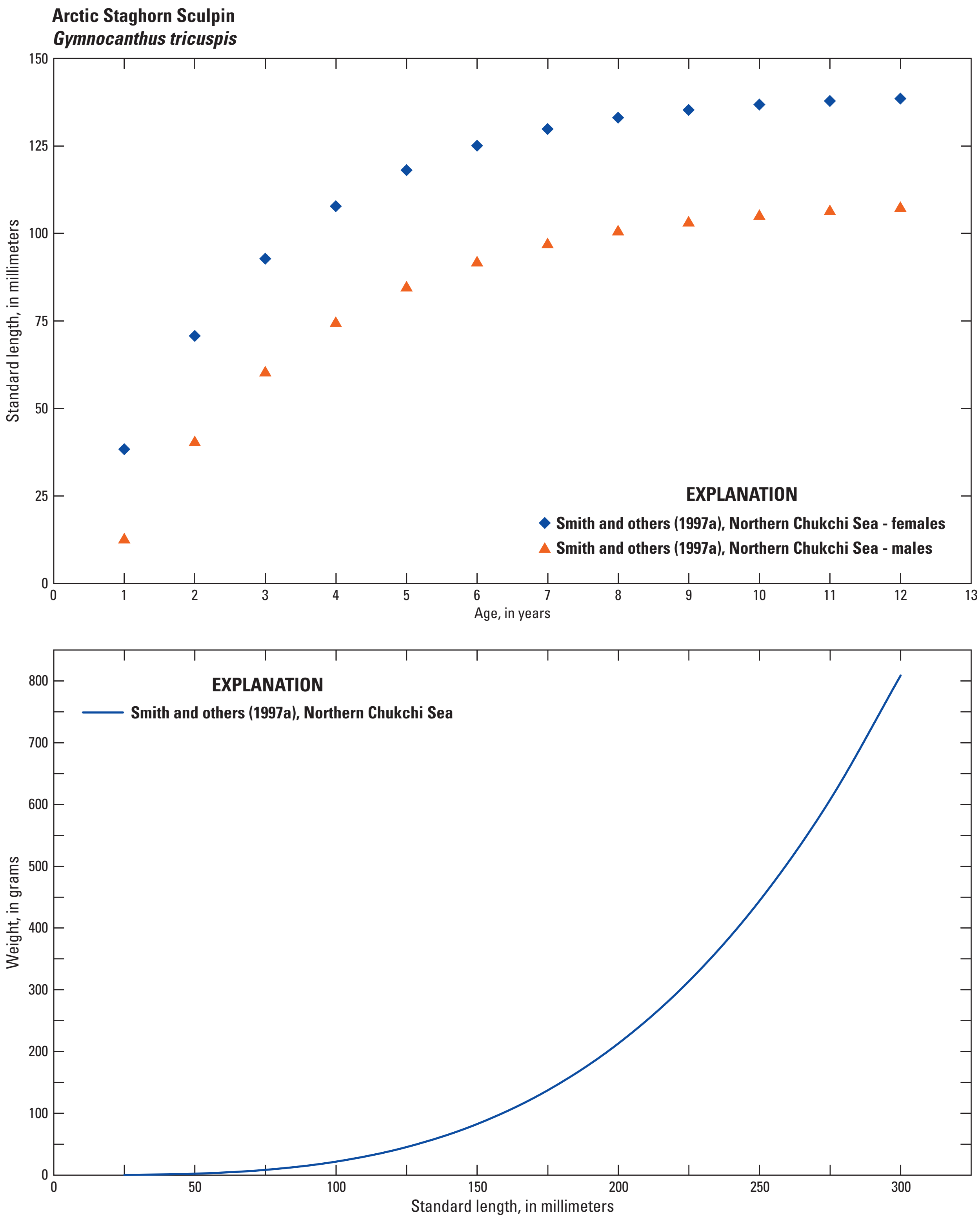


Figure B14. Age-at-length and length-weight relationships for Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*).

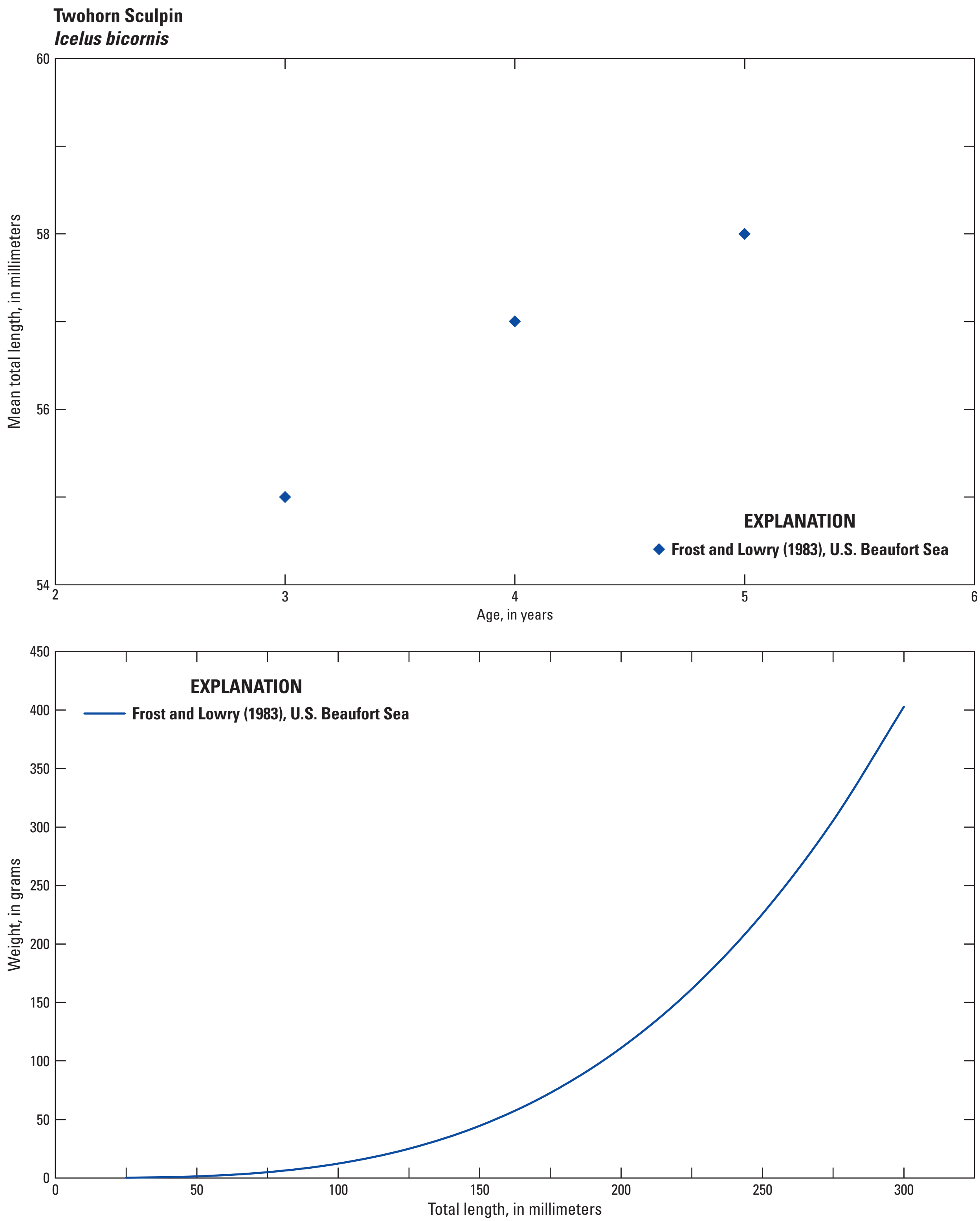


Figure B15. Age-at-length and length-weight relationships for Twohorn Sculpin (*Icelus bicornis*).

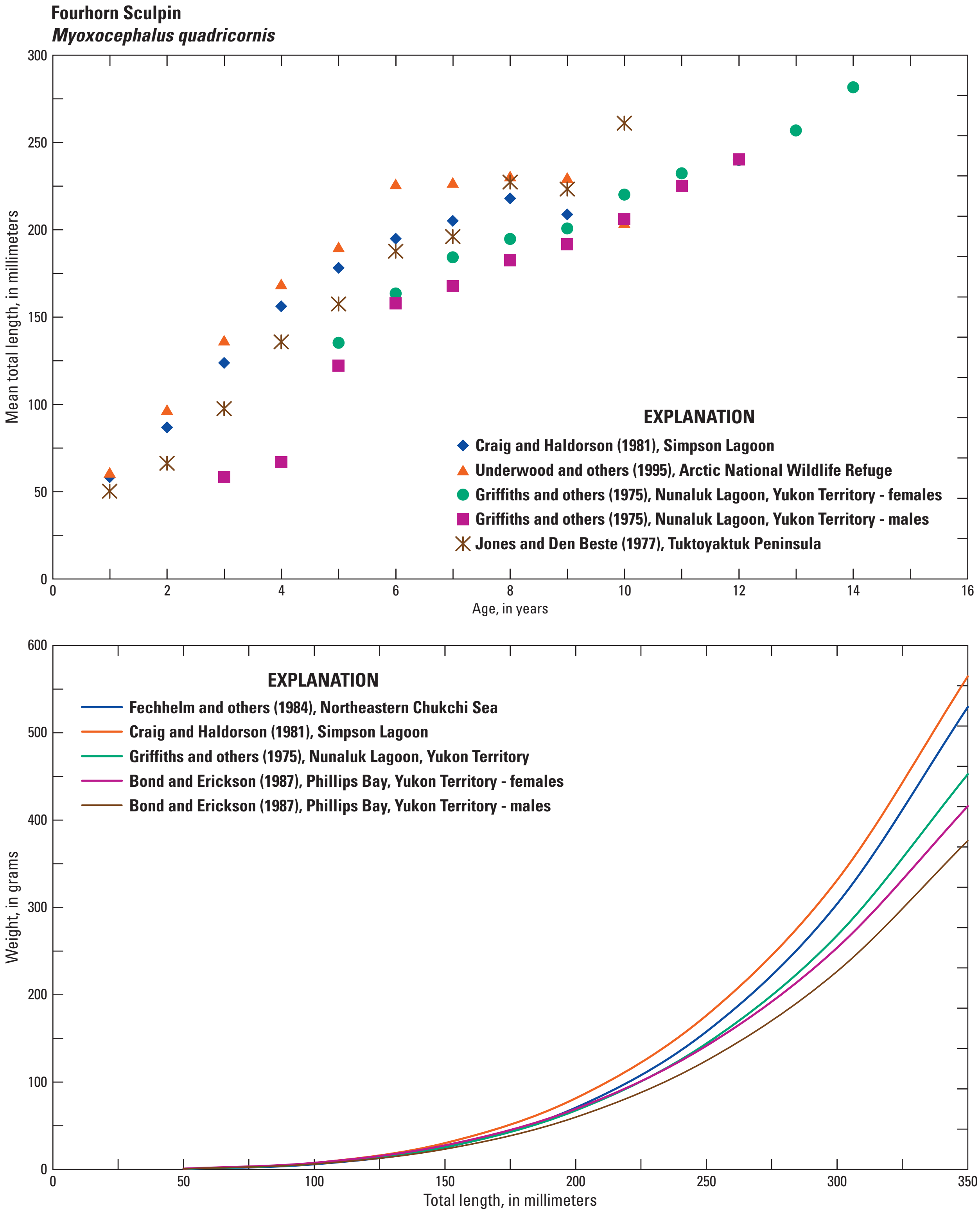
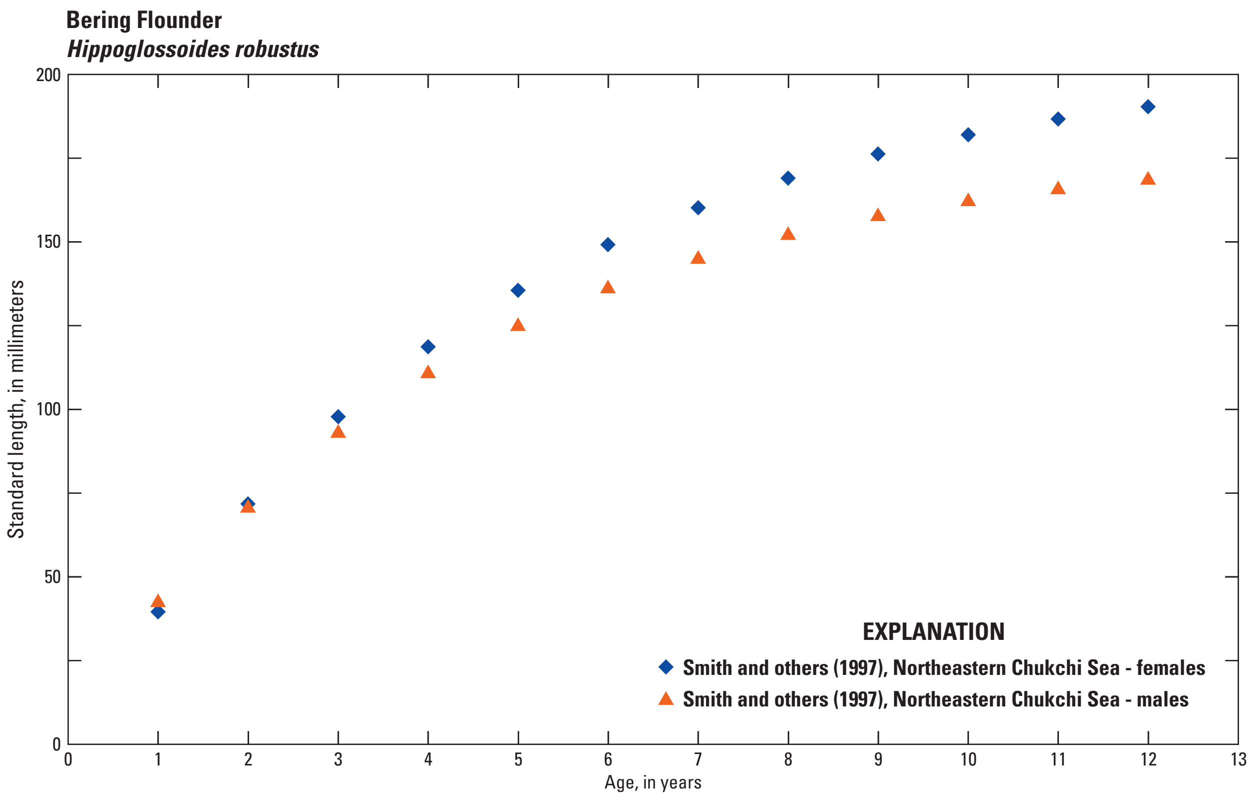


Figure B16. Age-at-length and length-weight relationships for Fourhorn Sculpin (*Myoxocephalus quadricornis*).



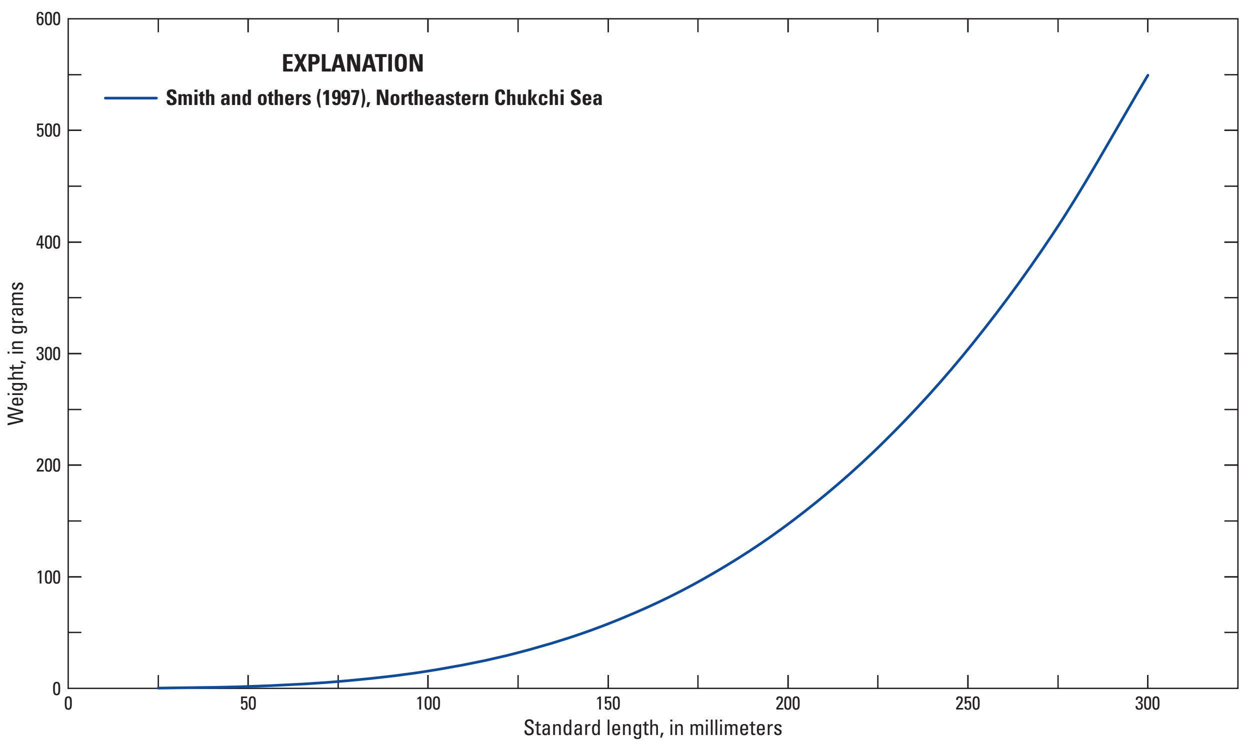


Figure B17. Age-at-length and length-weight relationships for Bering Flounder (*Hippoglossoides robustus*).

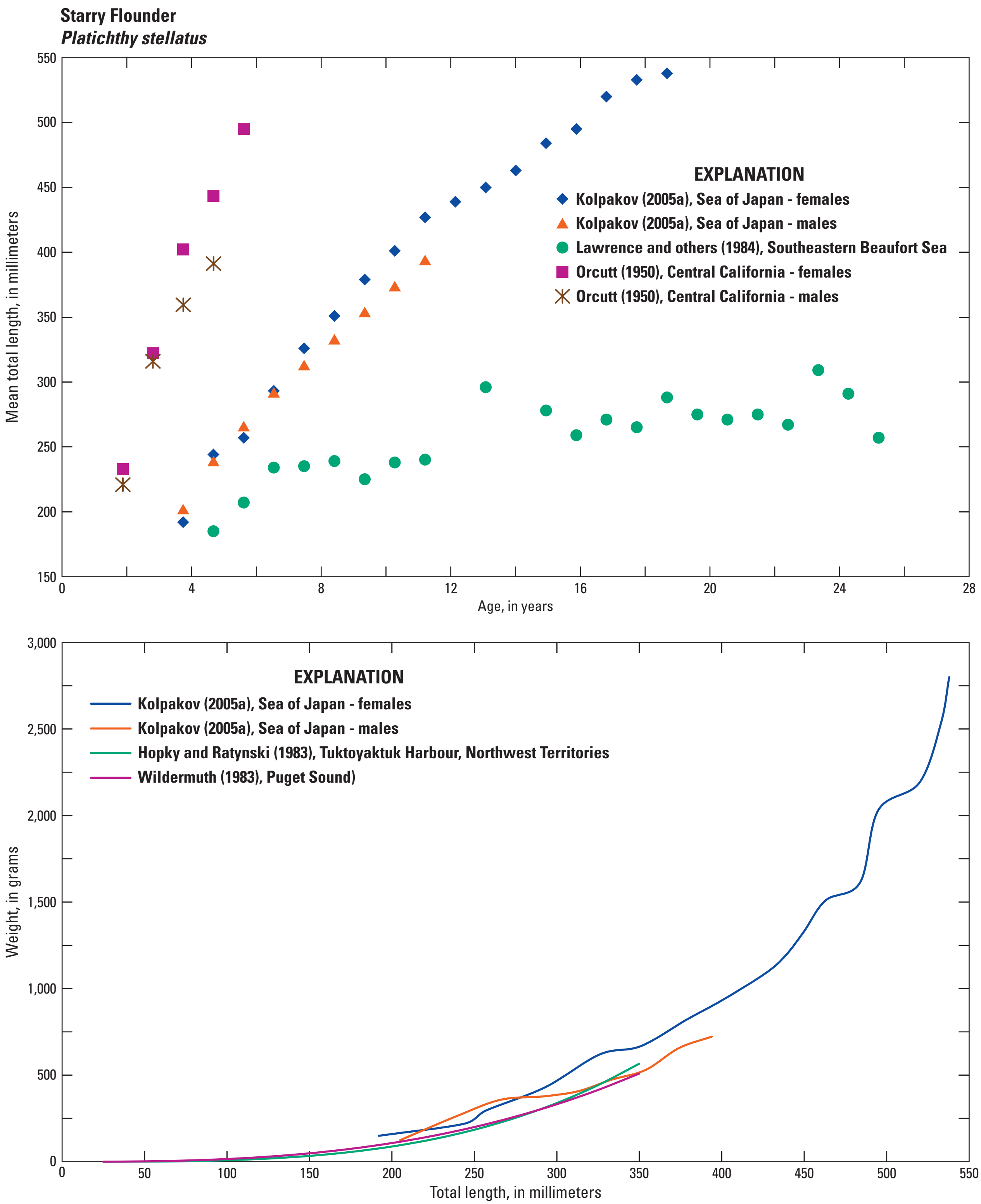
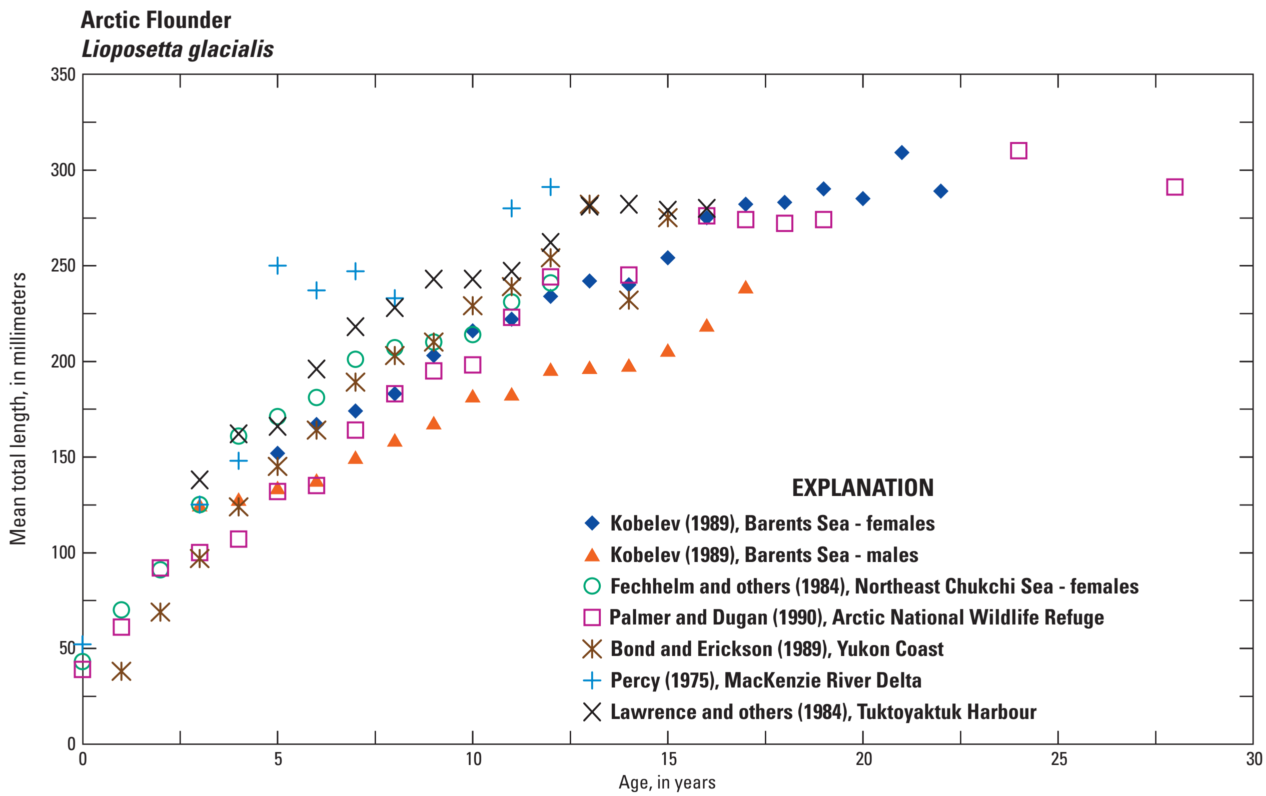


Figure B18. Age-at-length and length-weight relationships for Starry Flounder (*Platichthy stellatus*).



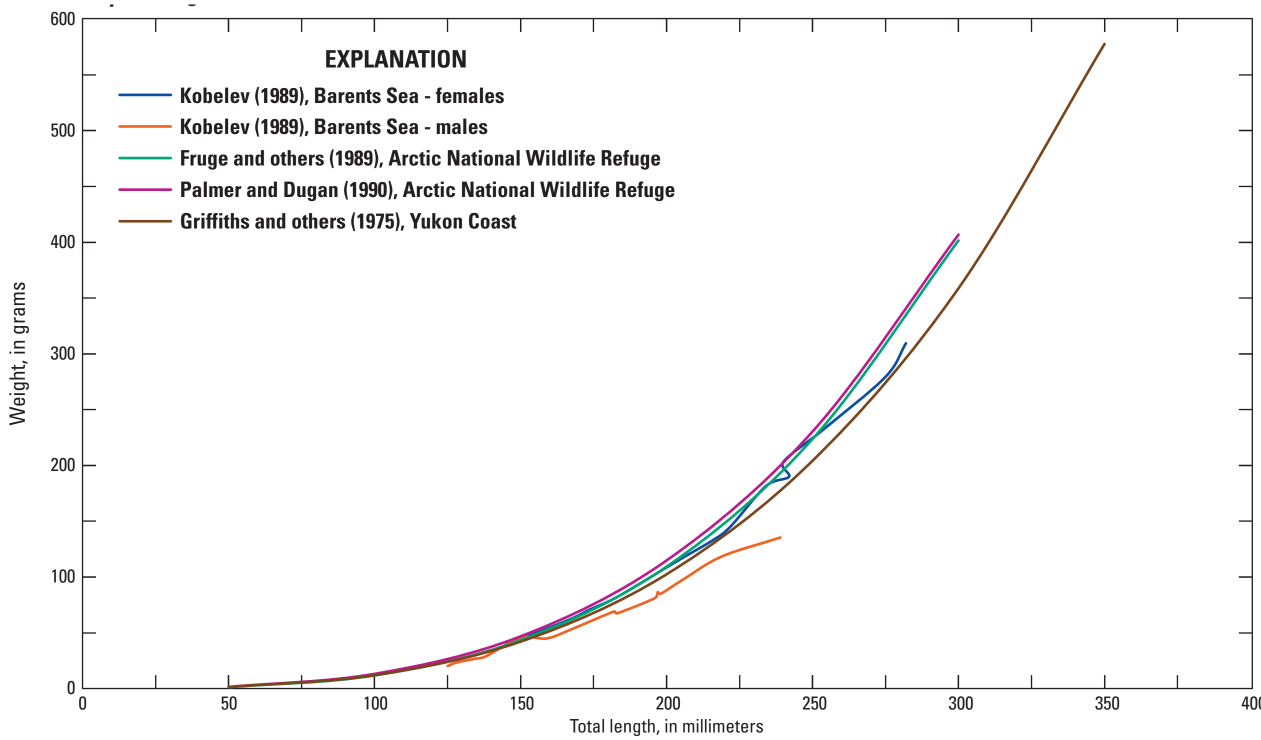


Figure B19. Age-at-length and length-weight relationships for Arctic Flounder (*Lioposetta glacialis*) from the Chukchi, Beaufort, and Barents Seas.

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Appendix C. Models Evaluated for Simulating Effects of Climate Change on the Distributions and Abundances of Arctic Cod and Saffron Cod in the Eastern Bering Sea

Table C1. Candidate models evaluated in search of a model to simulate the distribution (presence/absence) of Arctic Cod in the eastern Bering Sea using a smooth (s) GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Arctic Cod (*Boreogadus saida*) distribution models								
gam(*Boreogadus saida*) family=binomial,method="REML" smooth (s) models								
Model	**Akaike Information Criterion**	**Deviance (percent)**	**REML score**	**r^2**	**n**		**FALSE**	**TRUE**
s(GEAR_TEMPERATURE,BOTTOM_DEPTH,SURFACE_TEMPERATURE)	2,781.838	54.70	1,425.3	0.524	9,423	FALSE	8,349	339
						TRUE	173	562
s(GEAR_TEMPERATURE,BOTTOM_DEPTH)	2,941.793	51.30	1,504.3	0.484	9,423	FALSE	8,343	377
						TRUE	179	524
s(GEAR_TEMPERATURE,SURFACE_TEMPERATURE)	2,976.595	50.80	1,515.9	0.493	9,423	FALSE	8,356	388
						TRUE	166	513
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	2,797.761	53.50	1,419.1	0.511	9,423	FALSE	8,357	365
						TRUE	165	536
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH)	2,946.398	50.90	1,488.9	0.482	9,423	FALSE	8,355	388
						TRUE	167	513
s(GEAR_TEMPERATURE) + s(SURFACE_TEMPERATURE)	3,129.55	47.90	1,584.6	0.466	9,432	FALSE	8,366	419
						TRUE	156	482
s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	5,484.76	8.15	2,759.9	0.052	9,432	FALSE	8,521	899
						TRUE	1	2

Table C2. Candidate models evaluated in search of a model to predict the distribution of Arctic Cod in the eastern Bering Sea using a tensor smooth and (or) interaction smooth GAM models.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Arctic Cod (*Boreogadus saida*) distribution models								
Tensor product smooths (te) and Tensor product Interaction (ti) models gam(*Boreogadus saida*) family=binomial,method="REML"								
Model	**Akaike Information Criterion**	**Deviance (percent)**	**REML score**	**r^2**	**n**		**FALSE**	**TRUE**
te(GEAR_TEMPERATURE, BOTTOM_ DEPTH, SURFACE_TEMPERATURE)[1]	2,663.922	56.5	1,338	0.545	9,423	FALSE	8,367	314
						TRUE	155	587
te(GEAR_TEMPERATURE, BOTTOM_ DEPTH) + s(SURFACE_TEMPERATURE)	2,782.59	53.8	1,402.3	0.515	9,423	FALSE	8,349	351
						TRUE	173	550
te(GEAR_TEMPERATURE, BOTTOM_ DEPTH)	2,915.461	51.4	1,463.2	0.487	9,423	FALSE	8,344	370
						TRUE	178	531
te(GEAR_TEMPERATURE, SURFACE_ TEMPERATURE) + s(BOTTOM_DEPTH)	2,740.1	54.6	1,386.5	0.528	9,423	FALSE	8,342	326
						TRUE	180	575
te(GEAR_TEMPERATURE, SURFACE_ TEMPERATURE) + te(GEAR_ TEMPERATURE, BOTTOM_DEPTH)	2,708	55.3	1,377	0.534	9,423	FALSE	8,355	328
						TRUE	167	573
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)	4,473.568	26.2	2,340.7	0.307	9,423	FALSE	8,428	625
						TRUE	94	276
ti(GEAR_TEMPERATURE, BOTTOM_ DEPTH) +te(SURFACE_TEMPERATURE)	3,452	42.50	1,766.4	0.447	9,423	FALSE	8,376	426
						TRUE	146	475

[1]Selected as the best model based on model fit, low Akaike Information Criterion (AIC) score and the percent of deviance explained by the model.

Table C3. Candidate models evaluated in search of a model to predict abundance of Arctic Cod in the eastern Bering Sea using a smooth (s) GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Arctic Cod (*Boreogadus saida*) abundance models					
gam(ln(abundance +1)) method="REML" smooth (s) models					
Model	**Akaike Information Criterion**	**Deviance (percent)**	**REML score**	**r^2**	**n**
s(GEAR_TEMPERATURE,BOTTOM_DEPTH, SURFACE_TEMPERATURE)	20,072.9	51	10,190	0.505	9,423
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	19,500.69	53.25	9,794.7	0.531	9,423
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH)	19,618	52.50	9,846.2	0.524	9,423
s(GEAR_TEMPERATURE,BOTTOM_DEPTH)	23,235.07	30.50	11,671	0.303	9,423
s(GEAR_TEMPERATURE) + s(SURFACE_TEMPERATURE)	19,741.89	51.90	9,904.7	0.518	9,423
s(GEAR_TEMPERATURE,SURFACE_TEMPERATURE)	19,530.79	53.10	9,828.3	0.529	9,423
s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	26,186.95	4.64	13,120	0.0448	9,423

Table C4. Candidate models evaluated in search of a model to predict abundance of Arctic Cod in the eastern Bering Sea using a tensor smooth and (or) interaction smooth GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Arctic Cod (*Boreogadus saida*) abundance models					
Tensor product smooths (te) and Tensor product Interaction (ti) models gam(ln(*abundance* +1)) method="REML"					
Model	**Akaike Information Criterion**	**Deviance (percent)**	**REML score**	**r^2**	**n**
te(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)[1]	18,772.98	57.10	9,501.1	0.568	9,423
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)	24,648.37	19.50	12,413	0.191	9,423
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH)+ te(SURFACE_TEMPERATURE)	21,108.77	44.40	10,600	0.443	9,423
ti(GEAR_TEMPERATURE, SURFACE_TEMPERATURE)+ te(BOTTOM_DEPTH)	25,968.32	6.91	13,047	0.0672	9,432
te(GEAR_TEMPERATURE, SURFACE_TEMPERATURE)+ te(BOTTOM_DEPTH)	20,081.09	50.20	10,096	0.501	9,432
te(GEAR_TEMPERATURE)	20,833.78	45.80	10,428	0.458	9,432
te(SURFACE_TEMPERATURE)	26,546.83	0.68	13,281	0.00643	9,432
te(BOTTOM_DEPTH)	26,450.3	1.69	13,229	0.0165	9,423

[1]Selected as the best model based on model fit, low Akaike Information Criterion (AIC) score and the percent of deviance explained by the model.

Table C5. Candidate models evaluated in search of a model to predict distribution of Saffron Cod in the eastern Bering Sea using a smooth (s) GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Saffron Cod (*Eleginus gracilis*) distribution models								
Models gam(*Eleginus gracilis*) family=binomial,method="REML" smooth(s) models								
Model	Akaike Information Criterion	Deviance (percent)	REML score	r^2	n		FALSE	TRUE
s(GEAR_TEMPERATURE,BOTTOM_DEPTH, SURFACE_TEMPERATURE)[1]	2,026.113	51.60	1,022.6	0.422	9,423	FALSE	8,794	298
						TRUE	98	233
s(GEAR_TEMPERATURE,BOTTOM_DEPTH)	2,103.427	49.20	1,063.4	0.388	9,423	FALSE	8,798	316
						TRUE	94	215
s(GEAR_TEMPERATURE,SURFACE_ TEMPERATURE)	2,628.688	36.70	1,329.5	0.325	9,423	FALSE	8,823	351
						TRUE	69	180
s(GEAR_TEMPERATURE) + s(BOTTOM_ DEPTH) + s(SURFACE_TEMPERATURE)[2]	2,048.516	50.60	1,035.1	0.417	9,423	FALSE	8,796	286
						TRUE	96	245
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH)	2,134.97	48.10	1,072.6	0.38	9,423	FALSE	8,804	322
						TRUE	88	209
s(GEAR_TEMPERATURE) + s(SURFACE_TEMPERATURE)	2,662.401	35.50	1,346.5	0.312	9,423	FALSE	8,829	362
						TRUE	63	169
s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	2,061.879	50.00	1,039.2	0.408	9,423	FALSE	8,780	285
						TRUE	112	246
s(BOTTOM_DEPTH, SURFACE_ TEMPERATURE)	2,069.542	50.00	1,044.4	0.398	9,423	FALSE	8,795	309
						TRUE	97	222

[1]Identified as a potential best model.

[2]Selected as the best model after reviewing the environmental response curves for the other models even though the Akaike Information Criterion (AIC) is higher and the deviance explained was lower.

Table C6. Candidate models evaluated in search of a model to predict distribution of Saffron Cod in the eastern Bering Sea using a tensor smooth and (or) interaction smooth GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Saffron Cod (*Eleginus gracilis*) distribution models								
gam(*Eleginus gracilis*) family=binomial,method="REML" tensor product smooths (te) and Tensor product Interaction (ti) models								
Model	Akaike Information Criterion	Deviance (percent)	REML score	r^2	n		FALSE	TRUE
te(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)[1]	1,953.825	53.80	967.42	0.45	9,423	FALSE	8,814	286
						TRUE	78	245
te(BOTTOM_DEPTH, SURFACE_TEMPERATURE)	2,041.313	50.60	1,022.7	0.414	9,423	FALSE	8,780	287
						TRUE	112	244
te(BOTTOM_DEPTH) + te(SURFACE_TEMPERATURE)	2,074.152	49.60	1,040.5	0.402	9,423	FALSE	8,784	305
						TRUE	108	226
te(GEAR_TEMPERATURE, BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	2,030.963	51.10	1,017.7	0.422	9,423	FALSE	8,805	295
						TRUE	87	236
te(GEAR_TEMPERATURE, BOTTOM_DEPTH)	2,109.372	48.90	1,051.7	0.387	9,423	FALSE	8,809	329
						TRUE	83	202
te(GEAR_TEMPERATURE, SURFACE_TEMPERATURE) + s(BOTTOM_DEPTH)	1,990.718	52.20	1,003.1	0.44	9,423	FALSE	8,806	281
						TRUE	86	250
te(GEAR_TEMPERATURE, SURFACE_TEMPERATURE) + te(GEAR_TEMPERATURE, BOTTOM_DEPTH)	1,964.257	53.10	998.51	0.446	9,423	FALSE	8,813	288
						TRUE	79	243
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)	2,564.903	38.70	1,316.4	0.381	9,423	FALSE	8,827	320
						TRUE	65	211
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH) + te(SURFACE_TEMPERATURE)	2,365.397	42.90	1,203.3	0.375	9,423	FALSE	8,810	326
						TRUE	82	205
ti(BOTTOM_DEPTH, SURFACE_TEMPERATURE) + s(BOTTOM_DEPTH)	2,028.882	50.90	1,021.3	0.416	9,423	FALSE	8,772	281
						TRUE	120	250

[1]Identified as a potential best model.

Table C7. Candidate models evaluated in search of a model to predict abundance of Saffron Cod in the eastern Bering Sea using a smooth (s) GAM model.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Saffron Cod (*Eleginus gracilis*) abundance models					
gam(ln(*abundance* +1)) method="REML" smooth (s) models					
Model	Akaike Information Criterion	Deviance (percent)	REML score	r^2	n
s(GEAR_TEMPERATURE,BOTTOM_DEPTH, SURFACE_TEMPERATURE)	18,888.36	56	9,597.5	0.55	9,423
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	19,871.85	49.90	9,997.6	0.497	9,423
s(GEAR_TEMPERATURE) + s(BOTTOM_DEPTH)	20,658.18	45.40	10,370	0.453	9,423
s(GEAR_TEMPERATURE,BOTTOM_DEPTH)	20,606.26	45.80	10,367	0.457	9,423
s(GEAR_TEMPERATURE) + s(SURFACE_TEMPERATURE)	21,309.22	41.50	10,699	0.414	9,423
s(GEAR_TEMPERATURE,SURFACE_TEMPERATURE)	20,304.42	47.50	10,219	0.474	9,423
s(BOTTOM_DEPTH) + s(SURFACE_TEMPERATURE)	20,783.68	44.70	10,434	0.446	9,423

Table C8. Candidate models evaluated in search of a model to predict abundance of Saffron Cod in the eastern Bering Sea using a tensor smooth and (or) interaction smooth GAM models.

[**Abbreviations:** REML, restricted maximum likelihood; r^2, coefficient of determination; n, number]

Saffron Cod (*Eleginus gracilis*) abundance models					
gam(ln(abundance + 1)) method="REML" tensor product smooths (te) and Tensor product Interaction (ti) models					
Model	Akaike Information Criterion	Deviance (percent)	REML score	r^2	n
te(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)[1]	17,389.91	61.80	8,795.9	0.615	9,423
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH, SURFACE_TEMPERATURE)	18,566.81	56.50	9,408.1	0.563	9,423
ti(GEAR_TEMPERATURE, BOTTOM_DEPTH)+ te(SURFACE_TEMPERATURE)	20,012.76	49.00	10,046	0.489	9,423
ti(GEAR_TEMPERATURE, SURFACE_TEMPERATURE)+ te(BOTTOM_DEPTH)	20,115.11	48.50	10,135	0.484	9,423
te(GEAR_TEMPERATURE, SURFACE_TEMPERATURE)+ te(BOTTOM_DEPTH)	19,389.26	52.40	9,755	0.522	9,423
te(GEAR_TEMPERATURE)	22,310.26	34.70	11,165	0.347	9,423
te(SURFACE_TEMPERATURE)	25,199.78	11.30	12,612	0.113	9,423
te(BOTTOM_DEPTH)	22,614.04	32.60	11,319	0.326	9,423

[1]Selected as the best model based on model fit, low Akaike Information Criterion (AIC) score and the percent of deviance explained by the model.