

Supplementary material

Age validation of four rockfishes (genera *Sebastes* and *Sebastolobus*) with bomb-produced radiocarbon

Craig Kastle^{A,B}, *Thomas Helser*^A, *Todd TenBrink*^A, *Charles Hutchinson*^A, *Betty Goetz*^A,
Chris Gburski^A, and *Irina Benson*^A

^ANational Oceanic and Atmospheric Administration, National Marine Fisheries Service,
Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

^BCorresponding author. Email: craig.kastelle@noaa.gov

Table S1. Harlequin rockfish (*Sebastes variegatus*) data and results: collection type (Alaska Fisheries Science Center scientific bottom trawl ‘surveys’ or by National Marine Fisheries Service ‘fishery’ observers aboard commercial vessels), specimen ID, average and standard deviation of age estimated by six readers, estimated birth year (catch year – expert reader’s estimated age, or catch year – average estimated age, see column headings), fish weight, fish length, fish sex (1 = male, 2 = female), weight (wt) of whole otolith and core used for validation, $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ (‰) with one standard deviation

Average ages from up to six independent age readers. A blank value indicates that datum was not collected or measured

Collection type/year	Specimen ID	Average age (years)	1 s.d. age	Birth year (by expert age reader)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Survey/1996	42	16.5	1.8	1981	274	280	2	0.096	7.32	−5.78	61.27	2.09
Survey/1996	99	28.7	1.2	1968	430	310	2	0.135	3.85	−6.11	83.59	2.10
Survey/1996	120	27.8	1.2	1970	390	320	2	0.139	7.95	−5.58	106.52	2.79
Survey/1996	130 ^A	34.2	1.7	1963	380	290	1	0.133	7.58	−4.88	−2.41	2.10
Survey/1996	134	26.2	1.5	1969	352	290	1	0.129	6.76	−5.42	77.94	2.09
Survey/1996	143	35.2	2.6	1963	488	330	2	0.177	7.35	−4.74	−83.44	2.00
Survey/1996	150	40.3	5.0	1959	552	340	2	0.165	6.54	−4.85	−93.56	2.70
Survey/1996	153	27.2	1.2	1968	486	320	2	0.147	9.41	−4.77	97.97	2.59
Survey/1996	163	31.7	1.5	1966	386	320	2	0.142	10.84	−4.47	−9.87	1.90
Survey/1996	39	29.0	1.7	1967	390	300	1	0.107	5.32	−5.18	100.04	2.30
Survey/1996	90	27.2	1.3	1969	296	290	1	0.126	6.24	−5.74	75.13	2.09
Survey/1996	106	45.2	1.1	1952	256	280	1	0.140	7.70	−4.26	−100.54	1.90
Survey/1996	108	31.8	9.8	1949	296	280	1	0.143	6.58	−5.08	−87.74	2.00
Survey/1996	115	18.7	0.8	1976	226	260	1	0.097	7.46	−5.47	47.14	2.29
Survey/1996	121	33.4	6.4	1959	410	320	2	0.178	8.22	−4.87	−29.92	2.00
Survey/1996	130 ^A	23.0	1.3	1971	298	290	2	0.113	7.37	−5.32	83.36	2.09
Survey/1996	136	19.2	0.4	1977	184	250	2	0.089	6.41	−4.91	32.46	2.09
Survey/1996	138	27.2	4.4	1973	332	300	2	0.148	6.14	−4.69	−39.16	1.89
Survey/1996	155	18.5	0.5	1978	252	260	1	0.089	5.71	−4.96	38.86	1.99
Survey/1996	162	16.4	1.8	1982	250	260	2	Broken	6.57	−4.7	16.37	2.09
Survey/1996	6	29.2	1.0	1967	436	310	1	0.130	3.88	−5.69	79.21	2.10
Survey/1996	32	30.8	0.4	1965	658	350	1	0.166	6.56	−4.71	91.31	2.30
Survey/1996	70	31.5	0.8	1965	382	300	1	0.141	6.53	−5.39	19.66	2.00
Survey/1996	76	25.0	3.1	1971	494	330	2	0.152	7.96	−5.14	86.15	2.09
Survey/1996	77	34.8	2.3	1962	596	350	2	0.181	9.77	−4.07	−10.97	2.60
Survey/1996	78	24.0	1.1	1972	450	310	2	0.132	5.73	−5.11	63.00	2.09
Survey/1996	83	23.3	1.0	1974	378	300	2	0.139	5.49	−5.81	78.83	2.09
Survey/1996	87	25.2	2.1	1970	462	320	2	0.131	7.84	−5.62	79.55	2.19
Survey/1996	126	23.0	2.3	1975	250	280	2	0.140	7.58	−5.31	−23.93	2.39

Collection type/year	Specimen ID	Average age (years)	1 s.d. age	Birth year (by expert age reader)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Survey/1996	159	19.8	1.5	1974	324	290	1	0.104	6.20	-4.89	41.60	1.99
Survey/1996	175	24.5	2.0	1973	292	280	2	0.128	14.63	-4.34	27.93	2.09
Survey/1996	181	26.0	1.4	1972	370	300	2	0.132	8.61	-4.74	51.76	2.19
Survey/1996	202	20.5	6.3	1979	232	260	2	0.093	8.91	-4.32	21.99	1.99
Fishery/2014	3110	51.0	4.8	1964	676	380	2	0.237	7.33	-4.86	-105.95	1.80
Fishery/2014	3117	49.4	2.2	1966	584	350	2	0.234	7.63	-4.5	-38.90	1.90
Fishery/2015	16	59.6	4.4	1957	427	330	2	0.189	8.96	-3.13	-116.82	1.70
Fishery/2015	19	56.6	0.9	1958	480	330	2	0.212	7.20	-4.45	-103.51	1.80
Fishery/2015	4	53.2	1.9	1964	790	370	2	0.270	10.74	-3.54	-100.24	2.60
Fishery/2015	8	64.8	6.9	1953	700	370	2	0.289	5.12	-4.73	-119.77	1.80
Fishery/2015	9	71.8	12.6	1949	630	380	2	0.285	4.90	-4.55	-119.80	2.70

^ARepeat Specimen ID numbers are due to separate collections from two different vessels in the same year.

Table S2. Redstripe rockfish (*Sebastes proriger*) data and results: for column heading definitions see Table S1 caption

Average age from up to six independent age readers

Collection type/year	Specimen ID	Age average (years)	1 s.d. age	Birth year (by expert age reader)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Fishery/1977	46	14.3	1.0	1963		360	2	0.132	10.40	-4.82	-40.58	2.10
Fishery/1977	50	11.5	0.6	1965		330	1	0.121	11.00	-4.83	72.30	2.89
Fishery/1977	57	31.3	1.0	1945		340	1	0.187	12.50	-4.08	-101.69	1.90
Fishery/1977	69	11.0	0.0	1966		320	1	0.117	9.30	-5.64	82.71	2.59
Fishery/1977	361	24.5	1.7	1953		430	2	0.247	11.80	-4.77	-84.38	2.20
Fishery/1977	377	23.3	0.5	1954		340	1	0.148	9.70	-4.52	-89.82	2.00
Fishery/1977	416	11.0	0.0	1966		370	2	0.146	10.60	-4.88	65.63	2.69
Fishery/1977	420	7.0	0.0	1970		290	1	0.083	10.30	-4.93	41.75	2.19
Fishery/1977	472	20.8	3.0	1955		390	2	0.215	11.70	-5.01	-96.03	2.30
Fishery/1977	476	15.3	1.3	1962		350	1	0.154	7.40	-5.63	-9.75	2.20
Fishery/1977	477	16.5	1.3	1960		400	2		9.52	-6.14	-10.27	2.20
Fishery/1977	484	13.8	0.5	1963		390	2	0.188	12.80	-4.67	-15.58	2.40
Fishery/1977	486	20.8	1.5	1957		400	2	0.190	7.00	-5.03	-84.00	2.00
Fishery/1977	488	24.5	1.0	1952		400	2	0.212	10.30	-4.91	-92.00	2.10
Fishery/1977	489	23.5	0.6	1953		410	2	0.196	9.50	-5.48	-90.05	2.00
Survey/1996	24 ^A	24.2	0.8	1971	616	370	2	0.171	8.00	-4.51	73.05	2.39
Survey/1996	34	32.3	2.7	1962	614	350	1	0.190	13.94	-4.16	-11.28	2.20
Survey/1996	41	26.5	3.5	1967	782	390	2	0.219	7.70		61.56	2.39
Survey/1996	65 ^A	24.5	3.9	1968	920	410	2	0.231	7.90		87.51	2.89
Survey/1996	90 ^A	33.0	3.8	1964	584	350	1	0.194	13.12	-4.03	-83.49	2.00
Survey/1996	100 ^A	35.7	1.9	1960	592	360	1	0.194	11.40	-4.15	-67.39	2.10
Survey/1996	119	29.2	2.1	1965	638	360	1	0.176	9.90	-4.58	67.07	2.20
Survey/1996	140	21.5	2.2	1977	842	410	2	0.223	9.80	-4.77	67.20	2.29
Survey/1996	10 ^A	26.2	2.2	1973	956	420	2	0.248	8.50	-5.18	68.62	2.59
Survey/1996	11	18.8	0.8	1978	776	420	2	0.217	9.65	-4.67	55.01	2.39
Survey/1996	63	32.2	1.5	1964	538	350	1	0.176	12.52	-4.66	-3.34	2.10
Survey/1996	65 ^A	27.8	0.8	1967	484	340	1	0.179	9.25	-4.97	56.16	2.29
Survey/1996	95	24.0	1.2	1973	866	410	2	0.197	8.93	-3.96	52.61	2.49
Survey/1996	4	19.7	1.5	1976	984	420	2	0.213	11.80	-4.61	77.43	2.39
Survey/1996	10 ^A	19.7	0.5	1976	564	340	1	0.152	9.40	-4.74	82.48	2.29
Survey/1996	18	21.5	1.0	1975	626	360	1	0.195	9.60	-4.92	73.28	2.39
Survey/1996	23	19.7	2.3	1977	954	430	2		14.30	-4.66	72.11	2.19
Survey/1996	24 ^A	19.0	2.3	1975	816	400	2	0.203	11.00	-4.65	75.30	2.39
Survey/1996	40	27.0	1.7	1969	482	330	1	0.166	9.00		85.09	2.49

Collection type/year	Specimen ID	Age average (years)	1 s.d. age	Birth year (by expert age reader)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Survey/1996	67	23.7	1.5	1972	976	420	2	0.235	8.90	−5.4	51.74	2.29
Survey/1996	81	26.0	1.7	1970	912	400	2	0.221	11.10		56.22	3.69
Survey/1996	90 ^A	25.2	0.8	1971	966	410	2	0.220	9.40		78.04	2.39
Survey/1996	98	17.2	1.0	1979	424	310	1		6.70	−4.98	51.98	2.39
Survey/1996	100 ^A	27.5	1.2	1969	624	350	1	0.178	12.00		67.84	2.19
Survey/1996	101	24.5	0.5	1972	554	340	1	0.167	11.30	−4.81	70.30	2.69
Survey/1996	105	28.5	1.0	1968	374	300	1	0.147	10.90		79.13	2.99

^ARepeat Specimen ID numbers are due to separate collections from two different vessels in the same year.

Table S3. Shortspine thornyhead (*Sebastolobus alascanus*) data and results: for definitions of data see Table S1 caption

Average age from two independent age readers

Collection type/year	Specimen ID	Age average (years)	1 s.d. age	Birth year (average)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Survey/1996	372	29.0	1.4	1967.0	782	400	1		6.47	-3.46	-108.13	1.90
Survey/1996	376	25.0	0.0	1971.0	1240	440	1	0.195	2.54	-4.48	-19.59	2.39
Survey/1999	950	33.0	5.7	1966.0	2598	580	2		4.69	-3.52	-106.75	1.80
Survey/1996	377	29.5	10.6	1966.5	498	330	2	0.117	5.22	-4.17	-118.51	2.30
Survey/2007	693	46.0	4.2	1961.0	614	370	1	0.222	5.02	-3.03	-136.93	2.20
Survey/2007	699	33.5	2.1	1973.5	1152	430	2		3.12	-4.16	-45.52	2.59
Survey/2005	658	35.5	9.2	1969.5	788	400	2		3.88	-3.56	-128.68	1.90
Survey/2005	29	27.0	5.7	1978.0	552	360		0.146	3.40	-4.17	-72.58	1.89
Survey/2005	70	41.0	5.7	1964.0	1240	450	1		2.71	-3.84	-119.21	2.00
Survey/1987	6	29.0	1.4	1958.0		360	2		6.85	-1.91	-134.60	2.40
Survey/1987	15	33.0	4.2	1954.0		380	2	0.139	3.63	-2.78	-129.58	2.00
Survey/1987	25	27.0	1.4	1960.0		330	1	0.114	9.42	-2.9	-133.48	2.10
Survey/1987	35	29.0	0.0	1958.0		320	1		5.08	-3.32	-122.55	1.80
Survey/1987	77	22.0	0.0	1965.0		340	2	0.146	5.90	-2.25	-108.11	2.00
Survey/1987	83	36.5	4.9	1950.5		400	1	0.185	6.11	-2.66	-131.36	2.30
Survey/1987	91	31.5	17.7	1955.5		310	1	0.114	4.93	-2.64	-157.90	2.00
Survey/1987	110	28.0	1.4	1959.0		430	2		6.69	-3.26	-148.81	3.40
Survey/1987	123	13.0	1.4	1974.0	379	310	2		8.74	-3.08	0.05	2.19
Survey/1987	125	19.5	0.7	1967.5	300	300	2		6.64	-2.5	-97.06	1.90
Survey/1987	141	28.5	3.5	1958.5		340	1		5.51	-3.44	-120.50	2.20
Survey/1987	161	20.5	0.7	1966.5		360	1	0.130	6.55	-3.37	-4.32	2.20
Survey/1987	169	23.5	2.1	1963.5		410	2	0.148	5.25	-4.14	-66.66	2.50
Survey/1987	171	35.5	2.1	1951.5		450	2	0.176	4.56	-5.42	-99.00	2.90
Survey/1987	216	19.0	0.0	1968.0		310	1	0.087	3.46	-5.3	-25.37	2.00
Survey/1987	237	18.0	0.0	1969.0		270	1	0.079	6.09	-2.36	-88.43	2.39
Survey/1987	247	27.5	0.7	1959.5		340	1	0.120	4.40	-3.12	-132.91	1.90
Survey/1987	288	21.5	0.7	1965.5		310	2		7.35	-2.9	-119.58	2.00
Survey/1987	302	23.0	0.0	1964.0	890	390	2	0.159	5.89	-3.39	-36.50	2.30
Survey/1987	313	22.0	2.8	1965.0	613	350	2		5.13	-2.93	-141.75	1.90

Table S4. Shortraker rockfish (*Sebastes borealis*) data and results: for definitions of data see Table S1 caption

Average age from up to six independent age readers

Collection type/year	Specimen ID	Age average (years)	1 s.d. age	Birth year (average)	Weight (g)	Length (mm)	Sex	Whole otolith weight (g)	Core weight (mg)	$\delta^{13}\text{C}$ (‰)	$\Delta^{14}\text{C}$ (‰)	1 s.d. $\Delta^{14}\text{C}$
Survey/1996	27 ^A	22	5.7	1974	1540	470	1		9.8	-2.95	62.10	4.09
Survey/1996	36 ^A	40	9.9	1956	3742	610	2		4.2	-1.86	-175.70	2.10
Survey/1996	37	31	0.0	1965	3486	600	2		14	-2.15	-163.10	2.89
Survey/1996	49	37.5	0.7	1958.5	2314	520	1		5.7	-2.08	-138.50	4.80
Survey/1996	66	28.5	2.1	1967.5	2272	520	2		5.6	-1.75	-119.00	3.69
Survey/1996	70	32.5	2.1	1963.5	4478	620	1		9.1	-2.42	-102.70	3.89
Survey/1996	93 ^A	28.5	4.9	1967.5	2934	540	2		15.8	-2.98	58.90	5.79
Survey/1996	99	33.5	2.1	1962.5	2900	570	1		3.9	-3.6	-58.80	3.00
Survey/1996	21	11	0.0	1985	1128	430	1		6.1	-4.54	50.34	3.39
Survey/1996	30	35	0.0	1961	580	3408	2		11.5	-1.61	-140.60	2.70
Survey/1996	40	30.5	3.5	1965.5	530	2748	2		7.4	-2.36	-100.00	3.09
Survey/1996	51	31.5	0.7	1964.5	1904	480	2		4.5	-2.47	-75.60	4.19
Survey/1996	81 ^A	33.5	12.0	1962.5	1754	470	2		9.7	-2.88	-167.10	3.19
Survey/1996	101 ^A	40.5	14.8	1955.5	2716	570	2		7.3	-2.03	-147.60	2.80
Survey/1996	124	34.5	0.7	1961.5	3320	560	2		5.8	-4.37	-45.90	3.50
Survey/1996	125 ^A	33	14.1	1963	3270	520	2		4.2	-2.76	-142.80	3.30
Survey/1996	126 ^{A,B}	35.5	10.6	1960.5	3393	570	2		5.3	-2.46	-137.10	2.89
Survey/1996	296	34	1.4	1962	2342	520	2		6.8	-2.02	-140.70	3.79
Survey/2003	31	32.5	0.7	1970.5	410	NA	1		5	-1.86	-80.10	3.69
Survey/2003	41	32	0.0	1971	440	1386	1		2.6	-2.45	-108.40	4.09
Survey/2005	117 ^A	46.5	10.6	1958.5	5490	700	1		5	-2.84	-138.60	3.99
Survey/2005	186 ^A	53	8.5	1952	2920	560	2		7.6	-2.35	-153.00	4.09
Survey/2005	18	33.5	0.7	1971.5	3258	580	1		7	-3.01	-66.10	4.39
Survey/2005	86	41.5	3.5	1963.5	4680	630	1		9.7	-1.72	-136.30	2.99
Survey/2005	98	40	2.8	1965	5878	680	2		6.9	-2.71	-150.00	3.00
Survey/2005	126 ^B	36	1.4	1969	2092	500	2		3.9	-2.41	-70.00	3.49
Survey/2006	94	26.5	2.1	1979.5	2126	490	1		5.7	-3.5	-47.93	3.49

^ASpecimens that were 'difficult to read' and where two independent age readings differed by more than 5 years.

^BRepeat Specimen ID numbers are due to separate collections from two different vessels and in different years.

Table S5. Between reader precision statistics for harlequin rockfish (*Sebastes variegatus*), redstripe rockfish (*Sebastes proriger*), shortspine thornyhead (*Sebastolobus alascanus*) and shortraker rockfish (*Sebastes borealis*)

Note: the precision statistics are based on calculation procedures in Beamish and Fournier (1981) and Chang (1982). Sample type precision statistics are usually based on specimens chosen in a routine randomised fashion while at sea, either on Alaska Fisheries Science Center scientific bottom trawl surveys or by National Marine Fisheries Service fishery observers aboard commercial vessels

Species	Sample size	Average age (year)	Age range (year)	Percentage agreement	Coefficient of variation	Average percent error	Sample type
Redstripe rockfish	446	12.58	5–37	51.35	3.77	2.67	Routine shipboard randomised
Harlequin rockfish	563	14.18	2–75	47.60	4.62	3.27	Routine shipboard randomised
Shortspine thornyhead	66	27.12	11–52	21.21	8.72	6.17	Preselected for ≥ 24 cm
Shortraker rockfish	699	32.93	2–139	5.58	14.45	10.22	Routine shipboard randomised

(A)

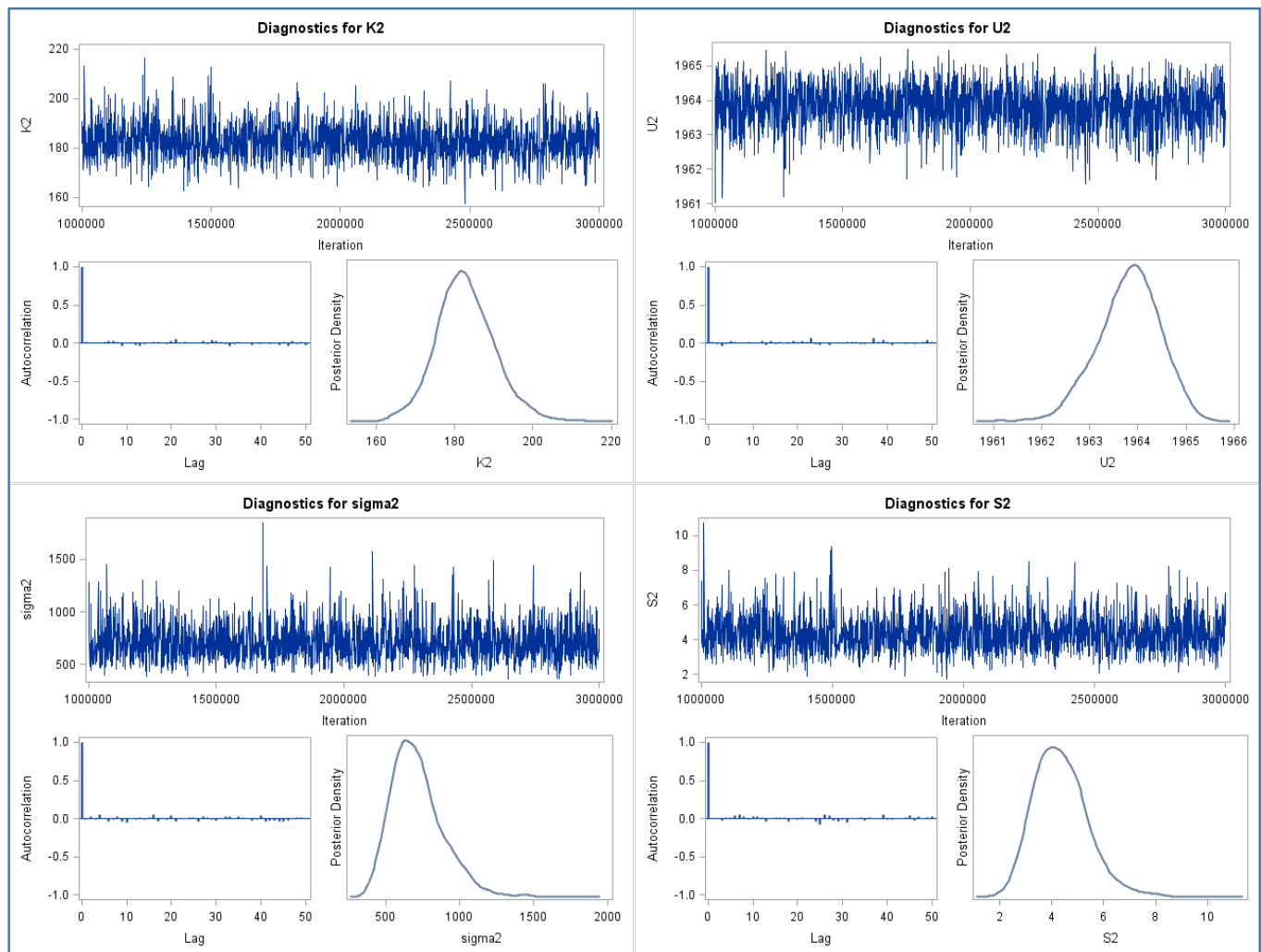


Fig. S1. Markov chain Monte Carlo (MCMC) diagnostic plots for Bayesian modelling of $\Delta^{14}\text{C}$: shown are MCMC trace, autocorrelation function, and posterior density plots for each parameter (K2 = Absolute $\Delta^{14}\text{C}$ (%), U2 = year of 50% rise, S2 = pulse curve s.d., sigma2 = Error variance) estimated in (A) redstripe rockfish (*Sebastes proriger*) specimens and (B) harlequin rockfish (*Sebastes variegatus*) specimens.

(B)

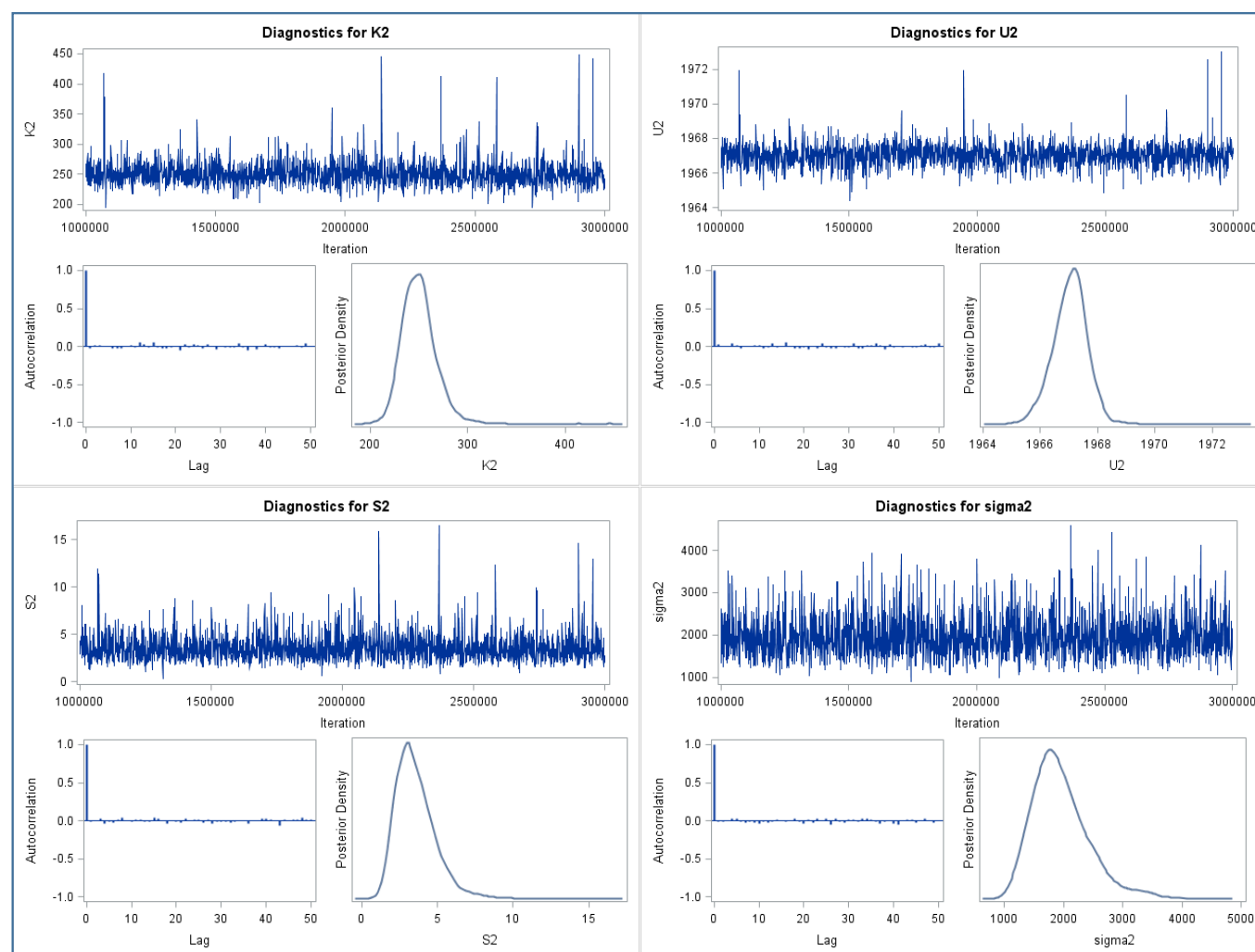


Fig. S1. (Cont.)

References

- Chang, W. Y. B. (1982). A statistical method for evaluating the reproducibility of age determination. *Canadian Journal of Fisheries and Aquatic Sciences* **39**(8), 1208–1210. [doi:10.1139/f82-158](https://doi.org/10.1139/f82-158)
- Beamish, R. J., and Fournier, D. A. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences* **38**(8), 982–983. [doi:10.1139/f81-132](https://doi.org/10.1139/f81-132)