Resource Equivalency Analysis for Common Murre & Puffin
New Carissa Spill, February 1999

May 24, 2005

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Table of Contents

Injury Results 1
REA Inputs 6

Tables

Table 1. Total Lost Bird-Years (Debit) 1
Table 2. Direct Injury by Age Class 2
Table 3. Indirect Injury 4
Table 4. Injury, Life History & Demographic Parameters 6
Table 5. Murre & Puffin Population Information 7

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Resource Equivalency Analysis for Murre & Puffin
New Carissa Spill, February 1999

The New Carissa oil spill killed approximately 226 Common Murres and Puffins in February 1999. Resource equivalency analysis (REA) is used to evaluate the direct loss (birds killed) and indirect loss (two generations of lost reproduction) over time. Details on the method used are provided in the report for Marbled Murrelets in the Seabirds section. The scaling and results of restoration projects are provided in the Restoration Results section. Complete citations are provided in a separate References section. All figures are converted to 2004 values (present value, or PV) using a 3% discount rate. The injury results and REA inputs are provided in the tables below.

Injury Results

Table 1
Total Lost Bird-Years (Debit)

Interim Losses	Lost Bird-Years in PV
Direct Injury	**2,464.37**
1st Generation	2,981.01
+ 2nd Generation	2,392.98
= Total Indirect Injury	**5,373.99**
Total Direct & Indirect Injury:	**7,838.36**

Table 2
Direct Injury by Age Class*

Year	Discount Factor	Bird-Years by Age Class (0-1)	(1-2)	(2-3)	(3-4)	(4-5)	(5-6)	(6-7)	(7-8)	(8-9)	(9-10)	(10-11)	(11-12)	(12-13)	(13-14)
1999	1.16	32.996	21.244	21.244	21.244	21.244	56.391	26.955	12.884	6.159	2.944	1.407	0.673	0.322	0.154
2000	1.13	0.000	29.696	19.863	20.394	20.713	20.713	54.981	26.281	12.562	6.005	2.870	1.372	0.656	0.313
2001	1.09	0.000	0.000	25.836	18.274	19.375	19.677	20.195	52.232	24.967	11.934	5.705	2.727	1.303	0.623
2002	1.06	0.000	0.000	0.000	23.769	17.360	18.406	18.693	19.690	49.620	23.718	11.337	5.419	2.590	1.238
2003	1.03	0.000	0.000	0.000	0.000	22.581	16.492	17.486	17.759	19.198	47.139	22.533	10.771	5.148	2.461
2004	1.00	0.000	0.000	0.000	0.000	0.000	21.452	15.668	16.611	16.871	18.718	44.782	21.406	10.232	4.891
2005	0.97	0.000	0.000	0.000	0.000	0.000	0.000	20.379	14.884	15.781	16.027	18.250	42.543	20.336	9.720
2006	0.94	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19.360	14.140	14.992	15.226	17.794	40.416	19.319
2007	0.92	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18.392	13.433	14.242	14.465	17.349	38.395
2008	0.89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	17.472	12.761	13.530	13.741	16.915
2009	0.86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	16.599	12.123	12.853	13.054
2010	0.84	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.769	11.517	12.211
2011	0.81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14.980	10.941
2012	0.79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14.231
2013	0.77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2014	0.74	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2015	0.72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2016	0.70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2017	0.68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2018	0.66	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2019	0.64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2020	0.62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2021	0.61	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2022	0.59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total															

*Totals are rounded by the computer; hand calculations may not sum to those presented.

Table 2 (continued)
Direct Injury by Age Class*

Year	Discount Factor	(14-15)	(15-16)	(16-17)	(17-18)	(18-19)	(19-20)	(20-21)	(21-22)	(22-23)	(23-24)	24.5	Total Lost Bird-Years	Total Lost Bird-Years in PV
1999	1.16	0.073	0.035	0.017	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	226.000	--
2000	1.13	0.150	0.072	0.034	0.016	0.008	0.004	0.002	0.001	0.000	0.000	0.000	216.707	243.905
2001	1.09	0.298	0.142	0.068	0.033	0.016	0.007	0.004	0.002	0.001	0.000	0.000	203.417	222.280
2002	1.06	0.592	0.283	0.135	0.065	0.031	0.015	0.007	0.003	0.002	0.001	0.000	192.976	204.728
2003	1.03	1.176	0.562	0.269	0.128	0.061	0.029	0.014	0.007	0.003	0.002	0.000	183.819	189.333
2004	1.00	2.338	1.117	0.534	0.255	0.122	0.058	0.028	0.013	0.006	0.003	0.000	175.106	175.106
2005	0.97	4.646	2.221	1.062	0.507	0.243	0.116	0.055	0.026	0.013	0.006	0.000	166.816	161.957
2006	0.94	9.234	4.414	2.110	1.009	0.482	0.230	0.110	0.053	0.025	0.012	0.000	158.926	149.803
2007	0.92	18.353	8.773	4.193	2.004	0.958	0.458	0.219	0.105	0.050	0.024	0.000	151.413	138.564
2008	0.89	36.475	17.435	8.334	3.984	1.904	0.910	0.435	0.208	0.099	0.048	0.000	144.253	128.167
2009	0.86	16.492	34.652	16.564	7.917	3.784	1.809	0.865	0.413	0.198	0.094	0.000	137.418	118.538
2010	0.84	12.402	16.080	32.919	15.735	7.521	3.595	1.719	0.821	0.393	0.188	0.000	130.870	109.602
2011	0.81	11.600	11.781	15.678	31.273	14.949	7.145	3.416	1.633	0.780	0.373	0.000	124.550	101.271
2012	0.79	10.394	11.020	11.192	15.286	29.709	14.201	6.788	3.245	1.551	0.741	0.000	118.360	93.435
2013	0.77	13.520	9.875	10.469	10.633	14.904	28.224	13.491	6.449	3.082	1.473	0.000	112.120	85.931
2014	0.74	0.000	12.844	9.381	9.946	10.101	14.531	26.813	12.817	6.126	2.928	0.000	105.487	78.492
2015	0.72	0.000	0.000	12.202	8.912	9.448	9.596	14.168	25.472	12.176	5.820	0.000	97.794	70.648
2016	0.70	0.000	0.000	0.000	11.592	8.466	8.976	9.116	13.814	24.199	11.567	0.000	87.729	61.532
2017	0.68	0.000	0.000	0.000	0.000	11.012	8.043	8.527	8.660	13.469	22.989	0.000	72.700	49.505
2018	0.66	0.000	0.000	0.000	0.000	0.000	10.461	7.641	8.101	8.227	13.132	0.000	47.562	31.444
2019	0.64	0.000	0.000	0.000	0.000	0.000	0.000	9.938	7.259	7.696	7.816	0.000	32.709	20.995
2020	0.62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.441	6.896	7.311	0.000	23.648	14.737
2021	0.61	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.969	6.551	0.000	15.520	9.390
2022	0.59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.521	0.000	8.521	5.005
Total													**2,708.423**	**2,464.369**

*Totals are rounded by the computer; hand calculations may not sum to those presented.

Table 3
Indirect Injury*

Year	Discount Factor	Total # Birds-- Reproduction Age	# Reproducing Females	# 1st Gen Fledglings	Bird-Years/ Fledge in PV	1st Gen Lost Bird-Years Total in PV
1999	1.16	108.028	48.613	41.321	3.870	159.911
2000	1.13	126.040	56.718	48.210	3.754	180.977
2001	1.09	139.933	62.970	53.524	3.641	194.897
2002	1.06	151.847	68.331	58.081	3.532	205.146
2003	1.03	161.238	72.557	61.674	3.426	211.299
2004	1.00	175.106	78.798	66.978	3.323	222.589
2005	0.97	166.816	75.067	63.807	3.224	205.689
2006	0.94	158.926	71.517	60.789	3.127	190.081
2007	0.92	151.413	68.136	57.915	3.033	175.663
2008	0.89	144.253	64.914	55.177	2.942	162.336
2009	0.86	137.418	61.838	52.563	2.854	150.005
2010	0.84	130.870	58.892	50.058	2.768	138.571
2011	0.81	124.550	56.048	47.640	2.685	127.923
2012	0.79	118.360	53.262	45.273	2.605	117.918
2013	0.77	112.120	50.454	42.886	2.526	108.350
2014	0.74	105.487	47.469	40.349	2.451	98.882
2015	0.72	97.794	44.007	37.406	2.377	88.921
2016	0.70	87.729	39.478	33.557	2.306	77.376
2017	0.68	72.700	32.715	27.808	2.237	62.197
2018	0.66	47.562	21.403	18.193	2.170	39.470
2019	0.64	32.709	14.719	12.511	2.104	26.330
2020	0.62	23.648	10.642	9.045	2.041	18.465
2021	0.61	15.520	6.984	5.937	1.980	11.755
2022	0.59	8.521	3.834	3.259	1.921	6.260
2023	0.57	0.000	0.000	0.000	0.000	0.000
2024	0.55	0.000	0.000	0.000	0.000	0.000
2025	0.54	0.000	0.000	0.000	0.000	0.000
2026	0.52	0.000	0.000	0.000	0.000	0.000
2027	0.51	0.000	0.000	0.000	0.000	0.000
2028	0.49	0.000	0.000	0.000	0.000	0.000
2029	0.48	0.000	0.000	0.000	0.000	0.000
2030	0.46	0.000	0.000	0.000	0.000	0.000
2031	0.45	0.000	0.000	0.000	0.000	0.000
2032	0.44	0.000	0.000	0.000	0.000	0.000
2033	0.42	0.000	0.000	0.000	0.000	0.000
2034	0.41	0.000	0.000	0.000	0.000	0.000
2035	0.40	0.000	0.000	0.000	0.000	0.000
2036	0.39	0.000	0.000	0.000	0.000	0.000
2037	0.38	0.000	0.000	0.000	0.000	0.000
2038	0.37	0.000	0.000	0.000	0.000	0.000
2039	0.36	0.000	0.000	0.000	0.000	0.000
2040	0.35	0.000	0.000	0.000	0.000	0.000
2041	0.33	0.000	0.000	0.000	0.000	0.000
2042	0.33	0.000	0.000	0.000	0.000	0.000
2043	0.32	0.000	0.000	0.000	0.000	0.000
2044	0.31	0.000	0.000	0.000	0.000	0.000
2045	0.30	0.000	0.000	0.000	0.000	0.000
Total		**2,598.590**	1,169.365	993.961		**2,981.009**

*Totals are rounded by the computer; hand calculations may not sum to those presented.

Table 3 (continued)
Indirect Injury*

Year	Discount Factor	Total # Birds-- 1st Gen-- Reproduction Age	# Reproducing Females	# 2nd Gen Fledglings	Bird-Years/ Fledge in PV	2nd Gen Lost Bird-Years Total in PV
1999	1.16	0.000	0.000	0.000	0.000	0.000
2000	1.13	0.000	0.000	0.000	0.000	0.000
2001	1.09	0.000	0.000	0.000	0.000	0.000
2002	1.06	0.000	0.000	0.000	0.000	0.000
2003	1.03	0.000	0.000	0.000	0.000	0.000
2004	1.00	10.054	4.524	3.846	3.323	12.781
2005	0.97	21.282	9.577	8.140	3.224	26.241
2006	0.94	33.242	14.959	12.715	3.127	39.758
2007	0.92	45.712	20.570	17.485	3.033	53.033
2008	0.89	58.433	26.295	22.351	2.942	65.758
2009	0.86	71.809	32.314	27.467	2.854	78.386
2010	0.84	83.744	37.685	32.032	2.768	88.672
2011	0.81	94.348	42.457	36.088	2.685	96.903
2012	0.79	103.723	46.675	39.674	2.605	103.335
2013	0.77	111.962	50.383	42.826	2.526	108.198
2014	0.74	119.154	53.619	45.576	2.451	111.693
2015	0.72	125.376	56.419	47.956	2.377	114.000
2016	0.70	130.699	58.815	49.992	2.306	115.275
2017	0.68	135.180	60.831	51.706	2.237	115.650
2018	0.66	138.856	62.485	53.112	2.170	115.231
2019	0.64	141.731	63.779	54.212	2.104	114.089
2020	0.62	143.746	64.686	54.983	2.041	112.239
2021	0.61	144.724	65.126	55.357	1.980	109.613
2022	0.59	144.254	64.914	55.177	1.921	105.979
2023	0.57	137.674	61.953	52.660	1.863	98.111
2024	0.55	129.408	58.234	49.499	1.807	89.453
2025	0.54	120.224	54.101	45.986	1.753	80.612
2026	0.52	110.324	49.646	42.199	1.700	71.755
2027	0.51	99.938	44.972	38.226	1.649	63.050
2028	0.49	88.792	39.956	33.963	1.600	54.337
2029	0.48	78.493	35.322	30.024	1.552	46.594
2030	0.46	68.987	31.044	26.388	1.505	39.722
2031	0.45	60.220	27.099	23.034	1.460	33.634
2032	0.44	52.143	23.464	19.945	1.416	28.249
2033	0.42	44.710	20.119	17.101	1.374	23.495
2034	0.41	37.878	17.045	14.488	1.333	19.308
2035	0.40	31.610	14.224	12.091	1.293	15.629
2036	0.39	25.872	11.643	9.896	1.254	12.409
2037	0.38	20.641	9.288	7.895	1.216	9.603
2038	0.37	15.904	7.157	6.083	1.180	7.177
2039	0.36	11.674	5.253	4.465	1.144	5.110
2040	0.35	8.010	3.604	3.064	1.110	3.401
2041	0.33	5.056	2.275	1.934	1.077	2.082
2042	0.33	3.133	1.410	1.198	1.044	1.252
2043	0.32	1.827	0.822	0.699	1.013	0.708
2044	0.31	0.905	0.407	0.346	0.983	0.340
2045	0.30	0.315	0.142	0.120	0.953	0.115
Total		3,011.767	1,355.295			**2,392.979**

*Totals are rounded by the computer; hand calculations may not sum to those presented.

REA Inputs

Table 4
Injury, Life History & Demographic Parameters

Parameter	REA Value	Reference
Species	Common Murres Puffins	Morgue database
# shorebirds killed (carcasses in hand)	106	Morgue database
# injured (rehabbed birds)	26	Rehabilitation records
Estimated direct mortality (includes injured birds)	226	Morgue database; Ford *et al.* 2001
Confidence in mortality estimate	High	Ford *et al.* 2001
Age Distribution of Birds Killed (estimate)	14.6% 0-1 year old 37.6% 1-5 years old 47.8% 5-20 years old	Nevins & Carter 2003
Average life span	24.5 years	Mean life span calculated using adult survivorship of 0.95
Age of first breeding	5 years	Hudson 1985; Nur *et al.* 1994; DeSanto & Nelson 1995
Expected years of breeding	19.5 years	Average lifespan – Age of first breeding
% of adult females that breed	90%	Manuwal & Carter 2001; Hudson 1985
# eggs/nest	1	Hudson 1985; Nur *et al.* 1994; DeSanto & Nelson 1995
Nesting success (% of nests that successfully fledge a chick)	85% 0.85 fledglings/pair	Manuwal & Carter 2001
Fecundity	0.38	Nur *et al.* 1994
year 0-1 survival	0.40	Nur *et al.* 1994; Russell 1999
year 1-2 survival	0.80	Nur *et al.* 1994
year 2-3 survival	0.87	Nur *et al.* 1994
year 3-4 survival	0.92	Nur *et al.* 1994
year 4+ survival	0.95	Nur *et al.* 1994; Ainley *et al.* 2002
Threatened or Endangered?	No	–
Locally overpopulated?	No	–
Additional factors affecting recovery	None	–

Source: Research and data were provided by Mike Szumski, Natural Resource Damage Assessment/Spill Response, US Fish & Wildlife Service, US Department of the Interior, 2600 SE 98th Ave., Suite 100, Portland, OR, 97266-1398, August 24, 2004, and finalized on May 5, 2005.

Table 5
Murre and Puffin Population Information

% of Total Population	Age	Age Distribution of 226 Birds*	Annual Survival Rate
14.6%	0–1	32.9960	0.40
37.6%	1–2	21.2440	0.80
	2–3	21.2440	0.87
	3–4	21.2440	0.92
	4–5	21.2440	0.95
47.8%	5–6	56.3907	
	6–7	26.9547	
	7-8	12.8844	
	8-9	6.1587	
	9-10	2.9439	
	10-11	1.4072	
	11-12	0.6726	
	12-13	0.3215	
	13-14	0.1537	
	14-15	0.0735	
	15-16	0.0351	
	16-17	0.0168	
	17-18	0.0080	
	18-19	0.0038	
	19-20	0.0018	
	20-21	0.0009	
	21-22	0.0004	
	22-23	0.0002	
	23-24	0.0001	
	24.5	0.0000	
	Total:	226	

*Totals are rounded by the computer; hand calculations may not sum to those presented.