Electronic Supplementary Material for:

Biogeography and conservation of the pinnipeds (Carnivora: Mammalia)

by

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Electronic Appendix A1. Supplementary material for Chapter 1

Table A1.1. List of world pinniped species, with IUCN status rank, best estimate of current population size and trend, and notes on distribution and population structure (summarized from IUCN 2010).

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Odobenidae	*Odobenus rosmarus*	Walrus	Data Deficient	> 200 K	Uncertain	Two subspecies, discontinuous circumpolar Arctic and sub-Arctic distribution. Population status not well understood, some populations may be declining.
Otariidae	*Arctocephalus australis*	South American fur seal	Least Concern	250-300 K	Increasing	Atlantic and Pacific sides of South America (concentrated in Atlantic side). Two subspecies described, but validity is disputed.
Otariidae	*Arctocephalus forsteri*	New Zealand fur seal	Least Concern	200 K	Increasing	Australia and New Zealand.
Otariidae	*Arctocephalus galapagoensis*	Galápagos fur seal	Endangered	10-15 K	Decreasing	Found throughout the Galápagos Archipelago. Sensitive to high mortality from El Niño events.
Otariidae	*Arctocephalus gazella*	Antarctic fur seal	Least Concern	> 4.5 million	Increasing	Widely-distributed in waters south of the Antarctic Convergence, with most breeding at South Georgia. Antarctic fur seals disperse widely at sea, but distribution and movements are not well known.
Otariidae	*Arctocephalus*	Juan Fernández fur	Near	12 K	Increasing	Regularly found only in the Juan Fernandez Archipelago, west of Chile. Increasing but small

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
	philippii	seal	Threatened			population, listed as NT due to limited range, and is close to qualifying for V. Hunted almost to extinction, but rediscovered in mid 20th century.
Otariidae	*Arctocephalus pusillus*	Afro-Australian fur seal	Least Concern	> 2 million	Increasing	Two subspecies: *A. p. pusillus* (Cape Fur seal) in southwestern and southern Africa, *A. p. doriferus* (Australian Fur seal) in Australia and Tasmania. Cape fur seal far more abundant.
Otariidae	*Arctocephalus townsendi*	Guadalupe fur seal	Near Threatened	15-17 K	Increasing	Found in Mexico and southern California, distribution expanding in recent years. Majority centred on Guadalupe Island, where nearly all pups are born. Extensive exploitation, slowly recovering.
Otariidae	*Arctocephalus tropicalis*	Subantarctic fur seal	Least Concern	> 310 K	Increasing	Widely distributed in the Southern Hemisphere.
Otariidae	*Callorhinus ursinus*	Northern fur seal	Vulnerable	ca. 1.1 million	Decreasing	Widely distributed in North Pacific Ocean and adjacent Bering Sea, Sea of Okhotsk and Sea of Japan, from northern Baja California north and offshore across North Pacific to Japan. Abundance is declining, for reasons that are poorly understood.
Otariidae	*Eumetopias jubatus*	Steller sea lion	Endangered	106-118 K	Decreasing	Found in the North Pacific, from California (USA) north to Aleutian Islands and west to Russia and Japan. Eastern and western stocks showing opposite trends: slight increases in the east and renewed declines in the west. Causes of severe decline of the western stock during 1970s-1980s remain unknown.

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
						Overall global decline of > 50% in last 3 generations.
Otariidae	*Neophoca cinerea*	Australian sea lion	Endangered	14 K	Decreasing	Southern and southwestern Australia, with breeding on island (mostly) and mainland sites. Reduced from past overexploitation, population is small and genetically fragmented.
Otariidae	*Otaria flavescens*	South American sea lion	Least Concern	> 250 K	Stable	Widely-distributed in South America, from Peru south to Cape Horn and north to Brazil in the east. Significant commercial harvests occurred and numbers drastically reduced in the last several centuries. Populations are sensitive to environmental perturbations from El Niño events. Numbers stable overall, but decreasing in some areas.
Otariidae	*Phocarctos hookeri*	New Zealand sea lion	Vulnerable	11.8 K	Decreasing	Primary habitat is several sub-Antarctic islands, south of New Zealand, with the principal breeding colony at the Auckland Islands. Historic range was more extensive and included most of New Zealand. There has been a 30% decline in pup production in the last decade at some major rookeries.

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Otariidae	*Zalophus californianus*	Californian sea lion	Least Concern	355 K	Increasing	Considered a subspecies of *Z. californianus* (*Z. c. californianus*) by some authors. Found in the eastern North Pacific from Mexico north to the Gulf of Alaska. Exploitation during the 19th and 20th centuries caused reductions, but numbers have increased. Reaching carrying capacity in USA.
Otariidae	*Zalophus japonicus*	Japanese sea lion	Extinct			Considered a subspecies of *Z. californianus* (*Z. c. japonicus*) by some authors, formerly known from the northwest Pacific - Japan, North/South Korea, and Russia. No documented reports since the late 1950s. Japanese sea lions were hunted for skins, oil, and internal organs for traditional medicine, although the main reason for extinction is thought be persecution by fishermen. Estimated 30-50 K animals in the mid-19th century and only ca. 300 in the late 1950s.
Otariidae	*Zalophus wollebaeki*	Galápagos sea lion	Endangered	20-40 K	Decreasing	Considered a subspecies of *Z. californianus* (*Z. c. wollebaeki*) by some authors, found throughout the Galápagos Archipelago. A 1978 census suggested a population size of ca. 40K, but a 50% decline by 2001. Numbers fluctuate widely due to die-offs and reproduction cessation during El Niño events, but the reasons for declines are not clearly understood.

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Phocidae	*Cystophora cristata*	Hooded seal	Vulnerable	> 600K	Decreasing	Single panmictic population, 3 breeding stocks, two in northwest Atlantic stable or increasing modestly, one in northeast Atlantic declined 85-90 % since mid-1900s (on-going despite recent protective measures). Global population decline ca. 35-40%.
Phocidae	*Erignathus barbatus*	Bearded seal	Least Concern	> 500-600 K	Stable	Widely distributed in circumpolar regions, large population. Two subspecies, but questionable validity.
Phocidae	*Halichoerus grypus*	Grey seal	Least Concern	>400 K	Increasing	Two subspecies recognized (western and eastern North Atlantic, Baltic Sea), western/eastern North Atlantic populations formerly recognized as distinct subspecies. Increasing at most locations, some localized declines. Half the global population found in Canada.
Phocidae	*Histriophoca fasciata*	Ribbon seal	Data Deficient	??	Unknown	Found in Bering, Chukchi, and Okhotsk seas and high latitudes of western and central North Pacific Ocean. Three separate populations proposed associated with aggregations of breeding animals , however distirbution is continuous and no morphological differences are known. Current abundance and trend unknown, previous estimates suggest 200-500 K.
Phocidae	*Hydrurga leptonyx*	Leopard seal	Least Concern	300 K	Unknown	Widely distributed in Antarctic and sub-Antarctic waters, large population size. Considerable uncertainty for population estimates.

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Phocidae	*Leptonychotes weddellii*	Weddell seal	Least Concern	1 million +	Unknown	Circumpolar and widespread in Southern Hemisphere, large population size on fast ice to shoreline of Antarctic continent, also offshore in pack ice zone, also present at many seasonally ice-free islands along Antarctic Peninsula.
Phocidae	*Lobodon carcinophagus*	Crabeater seal	Least Concern	> 7 million	Unknown	Widespread distribution in Southern Hemipshere, greatest numbers in the seasonally shifting pack ice surrounding Antarctic continent. Most recent estimate of 7 million is negatively biased, likely 11-12 million.
Phocidae	*Mirounga angustirostris*	Northern elephant seal	Least Concern	171 K	Increasing	Found in eastern and north central North Pacific, recovered from near extinction, population growth expected to continue, expanding range.
Phocidae	*Mirounga leonina*	Southern elephant seal	Least Concern	650 K	Unknown	Nearly circumpolar distribution in Southern Hemisphere, most common north of the seasonally shifting pack ice, especially in Subantarctic waters. Large global population size globally, but recent declines in some areas.
Phocidae	*Monachus monachus*	Mediterranean monk seal	Critically Endangered	350-450	Decreasing	Once widely distributed in Mediterranean, Black and adjacent seas, and in North Atlantic waters of northern Africa. Current distribution widespread but fragmented into very small breeding subpopulations, with declining numbers. Some genetic differentiation between subpopulations, but no formal taxonomic separation. Most endangered pinniped in the world.

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Phocidae	*Monachus schauinslandi*	Hawaiian monk seal	Critically Endangered	ca. 1,012	Decreasing	Found throughout the Hawaiian Island chain, but small population size coupled with ongoing decline despite considerable conservation effort. Well studied, nearly all animals individually identifiable. Declined > 65% since late 1950s (continuing).
Phocidae	*Monachus tropicalis*	Caribbean monk seal	Extinct			Not seen since 1952, despite extensive search efforts, considered extinct. Formerly inhabited Caribbean Sea, Gulf of Mexico, Bahamas, Central American coast and northern Antilles.
Phocidae	*Ommatophoca rossii*	Ross seal	Least Concern	130 K	Unknown	Circumpolar distribution in the Southern Ocean surrounding Antarctica, typically in dense consolidated pack ice. Found in remote areas, making censusing difficut and uncertain.
Phocidae	*Pagophilus groenlandicus*	Harp seal	Least Concern	ca. 8 million	Increasing	Two subspecies sometimes recognized (but lack of genetic differentiation), three breeding localities. Western North Atlantic, Greenland Sea, White Sea. Most abundant pinniped in Northern Hemisphere.
Phocidae	*Phoca largha*	Spotted seal	Data Deficient	??	Unknown	North Pacific Ocean, including Bering and Chukchi Seas north into Arctic Ocean, Sea of Okhotsk and Sea of Japan, Yellow and Bohai Seas. No geographic substructure known (but limited samples). Moderately abundant, but faces numerous threats and recent declines in several subpopulations. No reliable estimates of current population size, poorly documented estimates of 400K (1970s).

Family	Species	Common name	IUCN status	Population size	Population trend	Distribution, population structure/status
Phocidae	*Phoca vitulina*	Harbour seal	Least Concern	350-500 K	Stable	One of the most widespread pinnipeds, found throughout coastal waters of Northern Hemisphere, from temperate to Polar Regions in Pacific and Atlantic. Some populations/subspecies occur in freshwater. Five subspecies recognized.
Phocidae	*Pusa caspica*	Caspian seal	Endangered	111 K	Decreasing	Confined to Caspian Sea. Population decline exceeding 50% over last three generations and range reduction within overall geographic range. Historic population size > 1 million.
Phocidae	*Pusa hispida*	Ringed seal	Least Concern	6-7 million	Unknown	Five recognized subspecies, circumpolar distribution throughout the Arctic Basin and subarctic waters. Significant declines for some subspecies.
Phocidae	*Pusa sibirica*	Baikal seal	Least Concern	80-100 K	Stable	Generally confined to Lake Baikal (Russia), will travel short distances into rivers that flow into and out of the lake. Considered at carrying capacity level of Baikal Lake ecosystem.

Electronic Appendix A2. Supplementary Material for Chapter 2

Table A2.1. GenBank accession numbers for all pinniped, canid and ursid sequences used in Chapter 2 (nomenclature follows Wilson and Reeder (1993), see Chapter 2 discussion).

Species	aldolase_a	aldolase_c	apob26	apob29	apob_editing	cyp1a1
Arctocephalus_australis						
Arctocephalus_forsteri	U03566	U03577				
Arctocephalus_galapagoensis						
Arctocephalus_gazella						
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus			AB193422			
Canis_latrans						
Canis_lupus	U03565	U03570			AJ399501	
Cystophora_cristata						
Erignathus_barbatus						
Eumetopias_jubatus			AB193423			AB014356
Halichoerus_grypus						AJ621378
Hydrurga_leptonyx	U03568	U03573				
Leptonychotes_weddellii	U03569	U03592				
Lobodon_carcinophagus						
Mirounga_angustirostris	U03572	U03574		DQ240354	AJ399499	
Mirounga_leonina	L17497	L17498				
Monachus_monachus						
Monachus_schauinslandi						
Neophoca_cinerea						
Odobenus_rosmarus				DQ240355		
Ommatophoca_rossii						
Otaria_byronia						
Phoca_caspica						
Phoca_fasciata						AB030451
Phoca_groenlandica						AJ621380
Phoca_hispida						
Phoca_largha			AB193424			AB014358
Phoca_sibirica						
Phoca_vitulina	U03567	U03571	AB193425		AJ399500	
Phocarctos_hookeri						
Ursus_americanus						
Ursus_arctos			AB193429		AJ399496	
Ursus_maritimus						
Zalophus_californianus			AF548424		AJ399498	

Table A2.1continued

Species	cyp1a2	histone_h2af	hla_doa	lyz	mhc_class_ii_dqa_1	mhc_class_ii_dqa_2
Arctocephalus_australis						
Arctocephalus_forsteri		U03597				U03580
Arctocephalus_galapagoensis						
Arctocephalus_gazella						
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus						
Canis_latrans						
Canis_lupus	NM_001008720	U03585			NM_001011726	NM_001011726
Cystophora_cristata						
Erignathus_barbatus						
Eumetopias_jubatus	AB014357					
Halichoerus_grypus	AJ621379			AJ831408		
Hydrurga_leptonyx		U03598	AY752950		AY283566	U03584
Leptonychotes_weddellii		U03587	AY752949	AJ831413	AY283565	U03594
Lobodon_carcinophagus					AY283568	
Mirounga_angustirostris		U03586	AY752947			U03582
Mirounga_leonina		L17501	AY752948		U91907	U91907
Monachus_monachus						
Monachus_schauinslandi					AF093799	
Neophoca_cinerea						
Odobenus_rosmarus						
Ommatophoca_rossii			AY131996		AY283567	
Otaria_byronia						
Phoca_caspica						
Phoca_fasciata	AB030452					
Phoca_groenlandica	AJ621381					
Phoca_hispida						
Phoca_largha						
Phoca_sibirica						
Phoca_vitulina		U03596		AJ831412		U03581
Phocarctos_hookeri						
Ursus_americanus						
Ursus_arctos						
Ursus_maritimus						
Zalophus_californianus						

Table A2.1continued

Species	mhc_dqb	mtatp6	mtatp8	mtco1	mtco2	mtco3
Arctocephalus_australis		AY377312	AY377196	AY377150	AY377173	AY377265
Arctocephalus_forsteri	AF111045	AF513820	AF513820	AF513820	AF513820	AF513820
Arctocephalus_galapagoensis						
Arctocephalus_gazella	AF111039					
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus						
Canis_latrans						
Canis_lupus	AF016909	AY729880	AY729880	AY729880	AF028213	AY729880
Cystophora_cristata		AY377306	AY377190	AY377144	AY377167	AY377259
Erignathus_barbatus		AY377305	AY377189	AY377143	AY377166	AY377258
Eumetopias_jubatus		AJ428578	AJ428578	AJ428578	AJ428578	AJ428578
Halichoerus_grypus		X72004	X72004	X72004	X72004	X72004
Hydrurga_leptonyx		AY377296	AY377181	AY377135	AY377157	AY377250
Leptonychotes_weddellii		AY377299	AY377183	AY377137	AY377159	AY377251
Lobodon_carcinophagus		AY377293	AY377177	AY377130	AY377154	AY377246
Mirounga_angustirostris	AF111031	AY377301	AY377184	AY377138	AY377161	AY377253
Mirounga_leonina	AF111036	AY377302	AY377186	AY377140	AY377163	AY377255
Monachus_monachus		AY377304	AY377188	AY377142	AY377165	AY377257
Monachus_schauinslandi		AY377303	AY377187	AY377141	AY377164	AY377256
Neophoca_cinerea						
Odobenus_rosmarus		AY377310	AY377194	AY377148	AY377171	AY377263
Ommatophoca_rossii		AY377295	AY377178	AY377132	AY377155	AY377247
Otaria_byronia		AY377311	AY377195	AY377149	AY377172	AY377264
Phoca_caspica				AY140964	AY140971	
Phoca_fasciata				AY140966	AY140973	
Phoca_groenlandica		AY377307	AY377191	AY377145	AY377168	AY377260
Phoca_hispida		AY377308	AY377192	AY377146	AY377169	AY377261
Phoca_largha		AY377309	AY377193	AY377147	AY377170	AY377262
Phoca_sibirica				AY140963	AY140970	
Phoca_vitulina		X63726	X63726	X63726	X63726	X63726
Phocarctos_hookeri						
Ursus_americanus						
Ursus_arctos		AF303110	AF303110	AF303110	AF303110	AF303110
Ursus_maritimus						
Zalophus_californianus						

Table A2.1continued

Species	mtcyb	mtnd1	mtnd2	mtnd3	mtnd4	mtnd4l
Arctocephalus_australis	AY377329	AY377363	AY377283	AY377219	AY377345	AY377242
Arctocephalus_forsteri	X82293	AF513820	AF513820	AF513820	AF513820	AF513820
Arctocephalus_galapagoensis	AF380900					
Arctocephalus_gazella	X82292					
Arctocephalus_philippii	AF380893					
Arctocephalus_pusillus	U18448					
Arctocephalus_townsendi	AF380896					
Arctocephalus_tropicalis	U18456					
Callorhinus_ursinus	AY424647		AY882068			
Canis_latrans						
Canis_lupus	AY170103	AB048590	AY170044	U96639	U96639	U96639
Cystophora_cristata	X82294	AY377357	AY377277	AY377213	AY377339	AY377236
Erignathus_barbatus	AY170104	AY377356	AY377276	AY377212	AY377338	AY377235
Eumetopias_jubatus	DQ145021	AJ428578	AJ428578	AJ428578	AJ428578	AJ428578
Halichoerus_grypus	NC_001602	X72004	X72004	X72004	X72004	X72004
Hydrurga_leptonyx	AY377323	AY377350	AY377270	AY377204	AY377332	AY377226
Leptonychotes_weddellii	AY377324	AY377351	AY377271	AY377205	AY377333	AY377229
Lobodon_carcinophagus	AY377321	AY377348	AY377268	AY377199	AY377330	AY377222
Mirounga_angustirostris	AY377325	AY377352	AY377272	AY377208	AY377334	AY377230
Mirounga_leonina	AY377326	AY377353	AY377273	AY377209	AY377335	AY377232
Monachus_monachus	AY377327	AY377355	AY377275	AY377211	AY377337	AY377234
Monachus_schauinslandi	X72209	AY377354	AY377274	AY377210	AY377336	AY377233
Neophoca_cinerea	AF380912					
Odobenus_rosmarus	X82299	AY377361	AY377281	AY377217	AY377343	AJ428576
Ommatophoca_rossii	AY377322	AY377349	AY377269	AY377201	AY377331	AY377224
Otaria_byronia	AY377328	AY377362	AY377282	AY377218	AY377344	AY377241
Phoca_caspica	AY140978					
Phoca_fasciata	X82302					
Phoca_groenlandica	X82303	AY377358	AY377278	AY377214	AY377340	AY377237
Phoca_hispida	X82304	AY377359	AY377279	AY377215	AY377341	AY377238
Phoca_largha	X82305	AY377360	AY377280	AY377216	AY377342	AB244723
Phoca_sibirica	AY140977					
Phoca_vitulina	X82306	X63726	X63726	X63726		X63726
Phocarctos_hookeri	U12851					
Ursus_americanus						
Ursus_arctos	U18877	AF303110	AF303110	AF303110	AF303110	AF303110
Ursus_maritimus						
Zalophus_californianus	X82310		AY750639			

Table A2.1continued

Species	mtnd5	mtnd6	mtrnr1	mtrnr2	mx	ob
Arctocephalus_australis	AY377381					
Arctocephalus_forsteri	AF513820	AF513820	Y08527	AF513820		
Arctocephalus_galapagoensis						
Arctocephalus_gazella			Y08526			
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus			U12830			
Canis_latrans				U78329		
Canis_lupus	U96639	U96639	AY729880		NM_001003134	AB020986
Cystophora_cristata	AY377375					
Erignathus_barbatus	AY377374					
Eumetopias_jubatus	AJ428578	AJ428578	NC_004030	AJ428578	AB222179	
Halichoerus_grypus	X72004	X72004	X72004	X72004		AJ618982
Hydrurga_leptonyx	AY377368	AY377317	AY377288	AY377386		
Leptonychotes_weddellii	AY377369	AY377318	AY377289	AY377387		AM157373
Lobodon_carcinophagus	AY377366	AY377315	AY377286	AY377384		
Mirounga_angustirostris	AY377370	AY377319	AY377290	AY377388		
Mirounga_leonina	AY377371	AY377320	Y08523	AY377389		
Monachus_monachus	AY377373					
Monachus_schauinslandi	AY377372		Y08524			
Neophoca_cinerea						
Odobenus_rosmarus	AY377379	AJ428576	AJ428576	AJ428576		
Ommatophoca_rossii	AY377367	AY377316	AY377287	AY377385		
Otaria_byronia	AY377380				AB222180	
Phoca_caspica						
Phoca_fasciata						
Phoca_groenlandica	AY377376					
Phoca_hispida	AY377377					
Phoca_largha	AY377378					
Phoca_sibirica						
Phoca_vitulina	X63726	X63726	X63726	X63726	AB222181	AJ618981
Phocarctos_hookeri			U12850			
Ursus_americanus						AY142109
Ursus_arctos	AF303110	AF303110	Y08519			
Ursus_maritimus				AJ428577		
Zalophus_californianus			Y08525	U78350		

Table A2.1continued

Species	rag1	rod_opsin	sry	tbg	trna_ala	trna_arg
Arctocephalus_australis			AY429653			
Arctocephalus_forsteri			AY429652		AF513820	AF513820
Arctocephalus_galapagoensis						
Arctocephalus_gazella			AY424651			
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus			AY424652	AY750663		
Canis_latrans						
Canis_lupus	XM_540538	NM_ 001008276	AF107021	AY750653	U96639	AY729880
Cystophora_cristata			AY424658			
Erignathus_barbatus			AY424665	AY750665		
Eumetopias_jubatus			AY424649		AJ428578	AJ428578
Halichoerus_grypus			AY424660		X72004	X72004
Hydrurga_leptonyx			AY424655			
Leptonychotes_weddellii						
Lobodon_carcinophagus						
Mirounga_angustirostris	DQ240719	AY228452	AY424656			
Mirounga_leonina			AY424657			
Monachus_monachus						
Monachus_schauinslandi			AY424654			
Neophoca_cinerea						
Odobenus_rosmarus	DQ240720		AY424653	AY750662	AJ428576	NC_004029
Ommatophoca_rossii						
Otaria_byronia						
Phoca_caspica			AY424661			
Phoca_fasciata						
Phoca_groenlandica		AF055318	AY424659			
Phoca_hispida			AY424663			
Phoca_largha			AY424664			AB244728
Phoca_sibirica						
Phoca_vitulina	AY239187	AF055317	AY424662	AY750666	X63726	X63726
Phocarctos_hookeri						
Ursus_americanus	DQ240717					
Ursus_arctos			AY424666	AY750671	AF303110	AF303110
Ursus_maritimus		AY883926				
Zalophus_californianus			AY424650	AY750664		

Table A2.1continued

Species	trna_asn	trna_asp	trna_cys	trna_gln	trna_glu	trna_gly
Arctocephalus_australis					AY712956	
Arctocephalus_forsteri	NC_ 004023	NC_ 004023	AF513820	AF513820	AF513820	AF513820
Arctocephalus_galapagoensis						
Arctocephalus_gazella						
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus						
Canis_latrans						
Canis_lupus	U96639	U96639	U96639	U96639	AB048590	U96639
Cystophora_cristata						
Erignathus_barbatus						
Eumetopias_jubatus	AJ428578	AJ428578	AJ428578	AJ428578	AJ428578	AJ428578
Halichoerus_grypus	X72004	X72004	X72004	X72004	X72004	X72004
Hydrurga_leptonyx						
Leptonychotes_weddellii						
Lobodon_carcinophagus						
Mirounga_angustirostris						
Mirounga_leonina						
Monachus_monachus						
Monachus_schauinslandi						
Neophoca_cinerea						
Odobenus_rosmarus	AJ428576	AJ428576	AJ428576	NC_ 004029	AJ428576	AJ428576
Ommatophoca_rossii						
Otaria_byronia					AY713005	
Phoca_caspica						
Phoca_fasciata						
Phoca_groenlandica						
Phoca_hispida						
Phoca_largha						
Phoca_sibirica						
Phoca_vitulina	X63726	X63726	X63726	X63726	X63726	X63726
Phocarctos_hookeri						
Ursus_americanus						
Ursus_arctos	AF303110	AF303110	AF303110	AF303110	AF303110	AF303110
Ursus_maritimus						
Zalophus_californianus						

Table A2.1continued

Species	trna_his	trna_ile	trna_lys	trna_met	trna_phe	trna_pro
Arctocephalus_australis						
Arctocephalus_forsteri	AF513820	AF513820	AF513820	AF513820	AF513820	
Arctocephalus_galapagoensis						
Arctocephalus_gazella						
Arctocephalus_philippii						
Arctocephalus_pusillus						
Arctocephalus_townsendi						
Arctocephalus_tropicalis						
Callorhinus_ursinus						
Canis_latrans						
Canis_lupus	U96639	AB048590	U96639	U96639	AB048590	U96639
Cystophora_cristata						
Erignathus_barbatus						
Eumetopias_jubatus	AJ428578	AJ428578	AJ428578	AJ428578	AJ428578	AJ428578
Halichoerus_grypus	X72004	X72004	X72004	X72004	X72004	X72004
Hydrurga_leptonyx						
Leptonychotes_weddellii						
Lobodon_carcinophagus						
Mirounga_angustirostris						
Mirounga_leonina						
Monachus_monachus						
Monachus_schauinslandi						U59753
Neophoca_cinerea						
Odobenus_rosmarus	NC_004029	AJ428576	AJ428576	AJ428576	AJ428576	AJ428576
Ommatophoca_rossii						
Otaria_byronia						
Phoca_caspica						
Phoca_fasciata						
Phoca_groenlandica						
Phoca_hispida						
Phoca_largha						DQ153240
Phoca_sibirica						
Phoca_vitulina	X63726	X63726	X63726	X63726	X63726	AF522763
Phocarctos_hookeri						
Ursus_americanus						
Ursus_arctos	AF303110	AF303110	AF303110	AF303110	AF303110	AY331262
Ursus_maritimus						
Zalophus_californianus						

Table A2.1continued

Species	trna_thr	trna_trp	trna_tyr	trna_val
Arctocephalus_australis				
Arctocephalus_forsteri	AF513820	AF513820	AF513820	AF513820
Arctocephalus_galapagoensis				
Arctocephalus_gazella				
Arctocephalus_philippii				
Arctocephalus_pusillus				
Arctocephalus_townsendi				
Arctocephalus_tropicalis				
Callorhinus_ursinus				
Canis_latrans				
Canis_lupus	AB048590	U96639	U96639	AB048590
Cystophora_cristata				
Erignathus_barbatus				
Eumetopias_jubatus	AJ428578	AJ428578	AJ428578	AJ428578
Halichoerus_grypus	X72004	X72004	X72004	X72004
Hydrurga_leptonyx				
Leptonychotes_weddellii				
Lobodon_carcinophagus				
Mirounga_angustirostris				
Mirounga_leonina				
Monachus_monachus				
Monachus_schauinslandi	U59753			
Neophoca_cinerea				
Odobenus_rosmarus	AJ428576	AJ428576	AJ428576	U78343
Ommatophoca_rossii				
Otaria_byronia				
Phoca_caspica				
Phoca_fasciata				
Phoca_groenlandica				
Phoca_hispida				
Phoca_largha	DQ153240			
Phoca_sibirica				
Phoca_vitulina	X63726	X63726	X63726	X63726
Phocarctos_hookeri				
Ursus_americanus				
Ursus_arctos	AY331262	AF303110	AF303110	AF303110
Ursus_maritimus				
Zalophus_californianus				U78350

Electronic Appendix A3: Supplementary material for Chapter 4, Rapoport effect in world pinnipeds

The Stevens' and midpoint methods

I consider the "species as data" approach as the primary test of the Rapoport effect, but also used the Stevens and modified midpoint (Stevens 1989; Rohde et al. 1993) methods, as outlined here (these analyses control for neither body size nor phylogeny). For the Stevens method, I calculated the mean and median geographic range size ($\log_{10}$ km^2) for all species whose ranges fell within each 5^o equal-area latitude band (n = 36), and regressed latitude (midpoint of 5^o band, cube-root transformed) against geographic range size. One problem with the Stevens method is statistical non-independence of latitudinal means because each species often contributes to more than one latitude band (Pagel et al. 1991; Rhode et al. 1993), although this method in unique in that it incorporates information on all species occurring in each latitude band (Blackburn and Gaston 1996; Macpherson 2003). Rohde et al. (1993) developed the midpoint method to circumvent the problem of non-independence, which calculates the range size only for species whose latitudinal midpoints fall in a given band. The midpoint method also introduces statistical artifacts (Taylor and Gaines 1999) but I include it to compare with previous studies. Stevens (1989, 1992, 1996) used the mean per latitude band to depict range size (also see Macpherson 2003). Roy et al. (1994) argued that median range size was a better measure of central tendency given the highly skewed distribution of range sizes typically observed in single latitude bands.

For world pinniped ranges the Rapoport effect is strongly supported using both the Stevens and midpoint methods, using both mean and median latitude in each band (Table A3.1, Figure A3.1). The observed relationship is strongest using the Stevens method, although the Rapoport effect is still strongly supported ($P \leq 0.05$) using the midpoint method.

A stronger positive association between latitude and range size is usually revealed using band methods versus those that use species as data (Ruggiero and Werenkraut 2007). Among different band methods, the magnitude of the observed Rapoport effect is affected by the way range size is measured over latitudinal bands. Studies that use Stevens' (1989) method of including all species that occur within a band show a significant and strong positive latitudinal pattern in mean range size, while those that use the Rohde et al. (1993) midpoint method often do not reveal latitudinal trends (Ruggiero and Werenkraut 2007). In this study both methods supported the Rapoport effect, although the trend was much stronger for the Stevens method. Results were also similar whether mean or median range size values were used.

Phylogenetic signal and branch length fit for independent contrasts

Three different sets of branch lengths were applied to the molecular supertree topology used (Higdon et al. 2007, Chapter 2). I examined two sets of divergence dates (in millions of years) as estimated using 1) a Bayesian relaxed molecular clock method implemented in *multidivtime* (Kishino et al 2001; Thorne et al 1998) and 2) the local-clock *relDate* script (Bininda-Emonds 2007) (see Higdon et al. 2007 for details). These estimated branch lengths can be considered gradual models of range size evolution (Martins and Garland 1991). Constant (or equal) branch lengths (all = 1) were also included as a speciational model (Martins and Garland 1991). The relative suitability of the different sets of branch lengths was assessed using the diagnostic correlation of Garland et al. (1992) and the MSE and K calculations of Blomberg et al. (2003).

For the diagnostic correlation (Garland et al. 1992), a statistically significant (2-tailed test) Pearson product-moment correlation (not through the origin) indicates significant lack of fit of the tree to the tip data. The two-tailed critical value for the correlation coefficient with 31 degrees of freedom (34 tips, 33 contrasts) is 0.344. I also calculated mean squared error (MSE), equivalent to the variance of the standardized independent contrasts once the trees have been scaled such that the determinant of the variance-covariance matrix is a constant (Blomberg et al. 2003). A lower MSE indicates a better fit, and the MSE of each branch length option was also compared to the MSE of a star phylogeny (i.e., no phylogenetic signal).

In addition to these two diagnostic tests, the amount of phylogenetic signal (the tendency for closely related species to resemble one another, Blomberg and Garland 2002) present for each trait/branch length combination was examined using the randomization test and MatLab program (PHYSIG_LL.M) of Blomberg et al. (2003) with 1000 permutations. The K statistic was used as a measure of the amount of phylogenetic signal. A value of 1.00 indicates that the trait has exactly the amount of signal expected under Brownian motion, values less than 1.00 indicate less signal than expected, and values greater than 1.00 indicate more signal than expected. The three measures together (diagnostic correlation, MSE and K) provide a reasonable indication of which branch lengths best fit the tip data and also indicate when conventional (non-phylogenetically informed) statistics are adequate (i.e., in cases where a star phylogeny provides a better fit and no phylogenetic signal is indicated).

Diagnostic correlations (Garland et al. 1992) indicate that constant branch lengths have the best fit to the tip data (Table A3.2). With the exception of female body mass, the two estimated sets of gradual dates (from Higdon et al. 2007) have a significant lack of fit to the data. Results of the Blomberg et al. (2003) provide similar results (Table A3.3), with MSE and log maximum likelihood scores indicating that only constant branch lengths provide a better fit to the data relative to a star phylogeny (i.e., conventional statistics) for all the variables. With both sets of estimated branch lengths the randomization test of the MSE indicated significant phylogenetic signal for female mass only. In contrast, significant phylogenetic signal was indicated for all four variables under a speciational model of evolution (constant branch lengths). All PIC analyses were therefore conducted using constant branch lengths.

The species-as-data method using maximum latitude

The primary analyses presented in the manuscript included midpoint latitude (i.e., midpoint of latitudinal range) as the main predictor variable for testing the Rapoport effect. The same series of analyses were also conducted using maximum (northern or southern) latitude. As discussed in Chapter 4 for midpoint latitude, I used a square root transformation of the maximum latitude to create a linear trend as required for Felsenstein's independent contrasts (Felsenstein 1985; Garland et al. 1992; Quader et al. 2004).

A conventional single quadratic regression on maximum latitude also provides support for the Rapoport effect, and the pattern is more pronounced than with midpoint latitude ($n = 34$, $R^2 = 0.61$, $F(2, 30) = 23.88$, $p < 0.0001$). A conventional single linear regression (using the absolute value of latitude square-root transformed, for reasons noted above), is also significant ($n = 34$, $R^2 = 0.54$, $F(1, 31) = 39.8$, $p < 0.0001$), as is the interaction between latitude and mass ($n = 34$, $R^2 = 0.58$, $F(1, 31) = 45.6$, $p < 0.0001$). Phylogenetically-informed regressions, using Felsenstein's independent contrasts, were similar to those using midpoint latitude (latitude: $n = 33$, $R^2 = 0.52$, $F(1, 31) = 34.7$, $p < 0.0001$; latitude*mass: $n = 33$, $R^2 = 0.20$, $F(1, 31) = 7.99$, $p = 0.008$). Conventional and phylogenetically-informed GLM analyses on maximum latitude are summarized in Table A3.4. Results are similar to those for midpoint latitude, and the Rapoport effect is strongly supported for world pinnipeds after controlling for body size (and latitudinal variation in size) and phylogeny.

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Table A3.1. One-dimensional analyses of the Rapoport effect using the Stevens’ and modified midpoint methods, using 5^{o} latitude bands (n = 36, n = 15 for midpoint method because some bands contain no range midpoints). Analyses were conducted using both mean and median range size in each latitudinal band. Results are quadratic regressions of mean or median range size ($\log_{10}$ km^{2}) versus latitude band midpoint (cube-root transformed).

Stevens’ method			
Range size measure	R^2	F (2, 33)	P
Mean	0.847	113.755	< 0.001
Median	0.822	104.463	< 0.001
Midpoint method			
Range size measure	R^2	F (2, 12)	P
Mean	0.512	13.433	0.013
Median	0.561	15.942	0.007

Table A3.2. Diagnostic correlations (Garland et al. 1992) to assess suitability of three different sets of branch lengths to data on pinniped range size, body size, and geographic distribution. Values are the Pearson product-moment correlation (not through the origin). An asterisk indicates a statistically significant (2-tailed test) lack of fit of the tree to the tip data (two-tailed critical value for the correlation coefficient with 31 degrees of freedom (34 tips, 33 contrasts) is 0.344).

Variable[1]	Branch lengths		
	Constant (all = 1)	MultiDivTime	relDate
Range size	-0.2227	-0.6054*	-0.6574*
Female mass	-0.1974	0.0335	-0.1017
Midpoint latitude	-0.1998	-0.5336*	-0.5054*
Maximum latitude	-0.1778	-0.4721*	-0.4644*

[1] Range size – $\log_{10}$ km^2; Female mass – $\log_{10}$ grams; Midpoint and maximum-latitude – absolute value, square-root transformed

Table A3.3. Statistics for randomization tests for significance of phylogenetic signal for geographic range size, female body mass, and midpoint and maximum latitude for the 34 species in this study as calculated with the Matlab program PHYSIG_LL.m (Blomberg et al. 2003). The phylogenetic tree is from Higdon et al. (2007) and three different sets of branch lengths were examined. Significant results for the randomization test of the mean squared error (MSE; lower values indicate better fit of tree to data) on the phylogenetic tree indicate the presence of phylogenetic signal for a trait. K-statistics indicate the amount of phylogenetic signal relative to a Brownian motion expectation (Blomberg et al. 2003).

Branch lengths	Trait[1]	Expected MSE_0/MSE	Observed MSE_0/MSE	K	MSE	MSE_{star}	P	log maximum likelihood	log maximum $likelihood_{star}$
Constant (all 1)	Range size	2.5085	1.3477	0.5373	3.2421	3.4938	0.007	-39.3752	-40.6461
	Female mass	2.5085	2.7211	1.0848	0.1054	0.8374	< 0.001	-9.4800	-16.3634
	Midpoint latitude	2.5085	1.2442	0.4960	2.2460	2.4082	0.004	-61.4917	-62.6774
	Maximum latitude	2.5085	1.1924	0.4753	2.4169	2.4327	0.006	-62.7386	-62.8495
MultiDivTime	Range size	2.1283	0.6501	0.3055	5.8920	3.4938	0.248	-49.5307	-40.6461
	Female mass	2.1283	2.7967	1.3141	0.3961	0.8374	< 0.001	-3.6336	-16.3634
	Midpoint latitude	2.1283	0.3674	0.1726	6.9273	2.4082	0.775	-80.6394	-62.6774
	Maximum latitude	2.1283	0.3438	0.1615	7.5346	2.4327	0.803	-82.0681	-62.8495
relDate	Range size	3.0322	0.5489	0.1810	6.9979	3.4938	0.219	-52.4805	-40.6461
	Female mass	3.0322	2.7000	0.8904	0.4191	0.8374	< 0.001	-4.5956	-16.3634
	Midpoint latitude	3.0322	0.3864	0.1274	6.5889	2.4082	0.501	-79.7879	-62.6774
	Maximum latitude	3.0322	0.3870	0.1276	6.7055	2.4327	0.493	-80.0861	-62.8495

[1] Range size – $\log_{10}$ km^2; Female mass – $\log_{10}$ grams; Midpoint and maximum-latitude – absolute value, square-root transformed

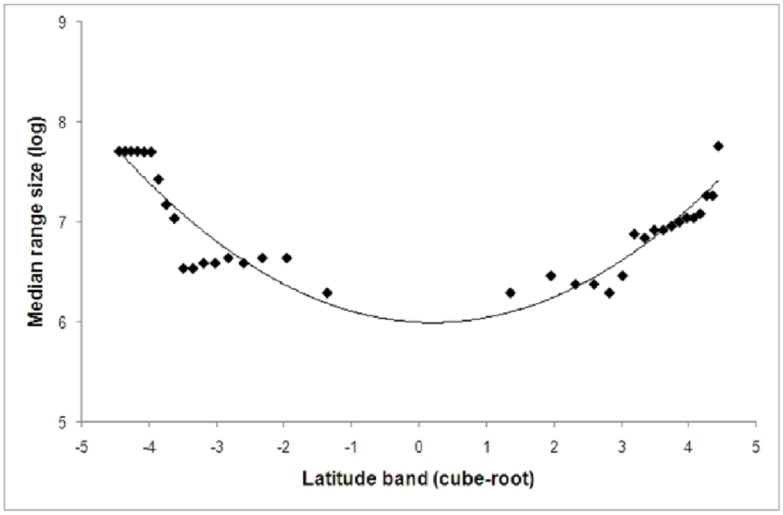
Table A3.4. Comparison of general linear models for a Rapoport effect on pinniped range size (34 world species). Only models with moderate or substantial support are presented (Δ_i AICc < 3). Models used maximum latitude (versus latitudinal midpoint in the manuscript) and were analyzed using both raw data (conventional statistics) and standardized phylogenetically-independent contrasts to control for phylogeny. Blanks in the “variables” fields indicate variables not included in the model, “*” indicates the variable was included and significant at $p < 0.05$, “< 0.10” indicates included variables that were significant at a reduced $p < 0.10$, and “NS” indicates included variables that were not significant ($p > 0.10$).

Method	Variable(s)[1]						F	d.f.	R^2	*P*	AIC_c	Δ_i AIC_c	w
	LAT		MASS		LAT*MASS								
	P	b	*P*	b	*P*	b							
Conventional (n = 34)					*	0.066	45.629	1, 32	0.575	0.0001	-40.940	0.000	0.419
			NS	-0.241	*	0.073	22.753	2, 31	0.569	0.0001	-39.112	1.828	0.168
	NS	0.083			NS	0.053	22.322	2, 31	0.564	0.0001	-38.725	2.215	0.139
	*	0.388					39.811	1, 32	0.540	0.0001	-38.292	2.648	0.112
PIC (n = 33)	*	0.399					37.694	1, 32	0.541	0.0001	-69.805	0.000	0.564
	*	0.41			NS	-0.169	18.415	2, 31	0.528	0.0001	-67.685	2.120	0.195
	*	0.401	NS	-0.029			18.267	2, 31	0.526	0.0001	-67.543	2.262	0.182

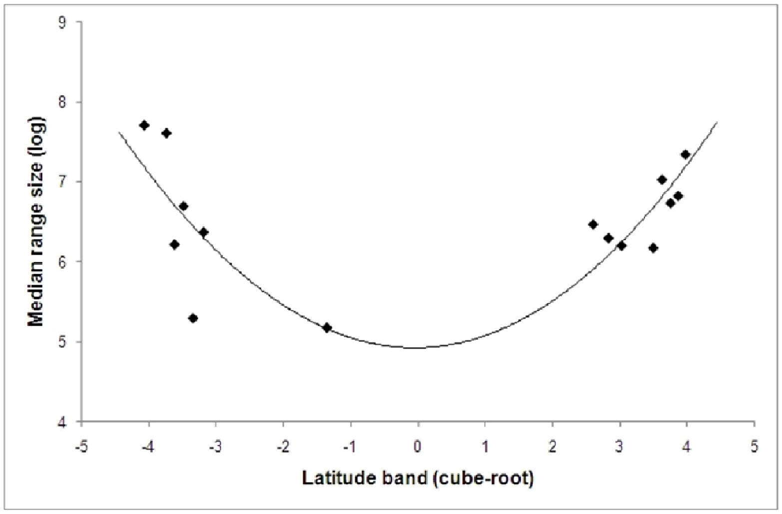
[1] LAT = absolute value of maximum latitude, square-root transformed; MASS = female mass in log10 grams; LAT*MASS = interaction between latitude and mass (i.e., Bergmann’s Rule)

Figure A3.1. Latitudinal variation in pinniped range size measured using the (a) Stevens and (b) modified midpoint methods. Data are median range size (km^2, log$_{10}$) per 5^o latitude band (cube-root transformed), for all species in each band (Stevens method, n = 36) or only the species whose midpoint latitude occur within the band (modified midpoint method, n = 15). Plots for mean range size are similar (see Table A3.1).

a)



b)



Electronic Appendix 4. Supplementary analyses and data for Chapter 5

Branch lengths and branch length fit for phylogenetic comparative analysis

The supertree of topology of Higdon *et al.* (2007) was used as the phylogenetic hypothesis for phylogenetically-informed analyses. The supertree was based on data available from GenBank in early 2006 and only included sequence data from one of three *Zalophus* sea lion taxa (*Z. californianus*). The supertree therefore included 34 pinniped species, treating *Zalophus* as a single species (with three subspecies). Additional genetic data from both other taxa have since become available. Sequences for the mitochondrial control region have been isolated from ancient DNA of the Japanese sea lion (*Z. japonicus*, or *Z.c. zaponicus*) (Sakahira & Niimi 2007). Wolf *et al.* (2007) used their sequence data in conjunction with those from the other two taxa, and suggested that the three should be separate species. In their reconstructions, the Japanese sea lion was the first to diverge; followed by the Galapagos sea lion (they are in agreement with Higdon *et al.*, 2007 that *Eumetopias* is the *Zalophus* sister-species). Sakahira and Niimi (2007) estimated that the Japanese and California sea lions diverged 2.2 million years ago. Wolf *et al.* (2007) calculated a similar time to common ancestry for the California and Galápagos sea lion (2.3 ± 0.5 mya), with minimum radiation times for the two species estimated as 1.31 ± 0.43 mya and 0.58 ± 0.29 mya, respectively.

The phylogeny (Higdon *et al.*, 2007) was therefore modified to include these two additional taxa (species) (n = 36, but with *P. sibirica* then removed due to missing climate data), with *Z. japonicus* the first species to diverge. Three different sets of branch lengths were originally examined. Constant (equal) branch lengths (all = 1) were examined in addition to two sets of estimated dates (Higdon *et al.*, 2007). For both sets of estimated dates (in millions of years), we set the original Zalophus divergence (*Z. japonicus*) as 2.5 mya and next split as 2 mya. Diagnostic correlations (Garland *et al.*, 1992) indicated that only constant branch lengths suitably fit the tip data for all variables (Table A4.1). The two sets of gradual dates adequately fit one variable only, female mass. All phylogenetically-informed analyses were therefore conducted with constant branch lengths.

Testing the climatic variability hypothesis using latitude bins

I consider the species-as-data approach as the primary analyses of the CVH. However the CVH was also tested using latitude-band methods to allow comparisons with past studies. The planet was divided into 36 5^{o} latitude bins and summary statistics were calculated for each climate variable. Median geographic range size was calculated for each bin and regressed against median climate values. Both methods were used: the Stevens (1989) method, in which all species in each bin are included, and the modified midpoint method (Rhode *et al.*, 1993) where only species with their midpoint range within the bin are included.

Bin-methods provided similar results for the climatic variability hypothesis (Table A4.2, Figure A4.1). Only mean annual temperature was significant using the Stevens

(1989) method of measuring range size. When the modified midpoint method was used instead the overall regression model was significant at a reduced p-value (≤ 0.10) only, although mean annual temperature was still a significant predictor of range size (Table A4.2). Latitude-band methods therefore provide similar results as species-as-data approaches with respect to climatic variability and pinniped geographic range size, similar to the Rapoport effect analyses (Chapter 4).

Pinniped climatic data summary

The CVH was tested using two different methods, using species as data points and summarizing species data across latitude bands. Table A4.3 summarizes the data used for the species as data analyses, including range size, and adult female mass data (used to control for body size allometry), and median values plus range and interquartile range (IQR) for climate variables. Median values were used as species data points, and one important assumption of this approach is that these median values are representative of the climatic conditions experienced, at least accurately enough to make species comparisons meaningful. For the two measures of climate variability the measure represents a midpoint value for temporal variability (intra- and inter-annual). However, all three climate variables are also spatially variable, and pinniped species ranges each encompass a number of different individual measures of climate and temporal climate variability. The total range and IQR presented in Table A4.3 provide some indication of the degree of spatial variability (which, for sdSST and seSST, represents spatial variation in temporal variation).

To assess the impact of spatial variability for the species as data method, I calculated correlation coefficients and P-values for range size and IQR for each climate variable, to determine if larger ranges exhibit more spatial variation in climate (which would bias the analysis). Species geographic range size was not significantly correlated with IQR for any of the climate variables (r = -0.205 to 0.239, P = 0.167-0.689, n = 35, worst correlation for meanSST). Larger ranges do not exhibit more spatial variability in climate than small ranges. This suggests that median climate variables are not biased and represent a suitable measure of temporal climate variability, regardless of the range size in question. The latitude-bin data used to test the CVH with the Stevens (1989) and Rhode *et al.* (1993) method are presented in Table S4.

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Figure A4.1. Test of the climatic variability hypothesis using pinniped range sizes and the Stevens (1989) method of using latitude bins (similar trend using the modified midpoint method, Rhode *et al.*, 1993, not shown, see Table S2).

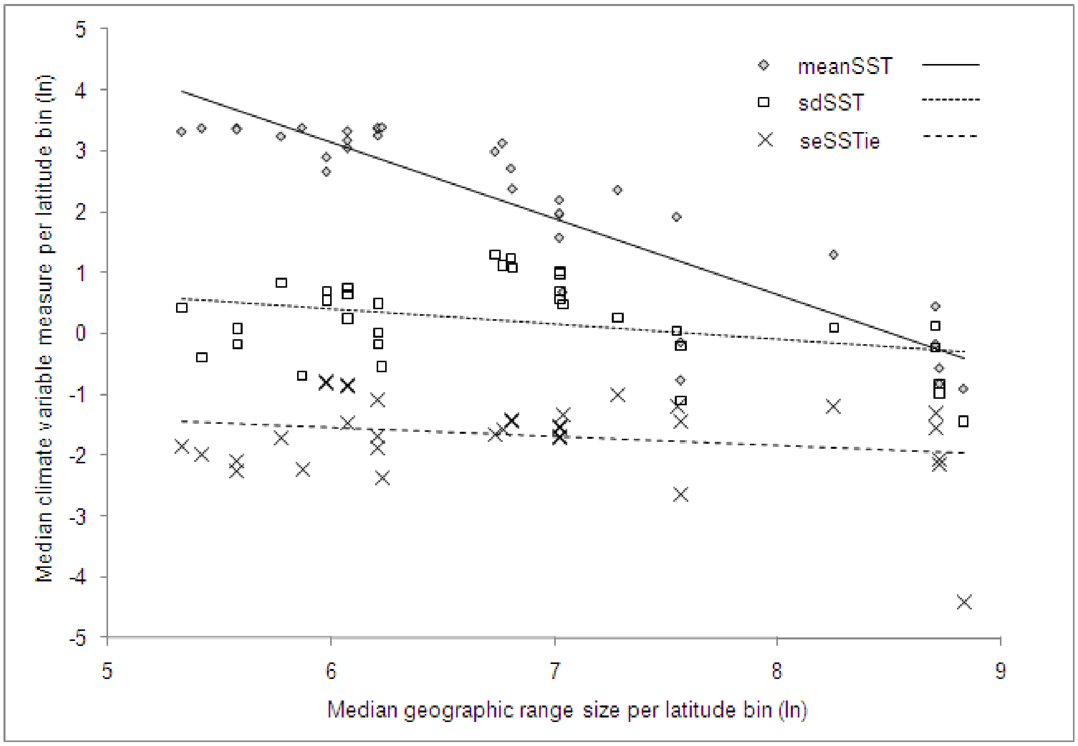

Table A4.1. Diagnostic correlations (Garland *et al.*, 1992) to assess suitability of three different sets of branch lengths to data on pinniped range size, body size, and climatic variability. Values are the Pearson product-moment correlation (not through the origin). An asterisk indicates a statistically significant (2-tailed test) lack of fit of the tree to the tip data (* < 0.05, ** < 0.01, *** < 0.001, ^{NS} = not significant, i.e., no lack of fit).

	Branch lengths		
Variable	Constant	relDate	multidivtime
Ann. mean SST	0.200^{NS}	-0.442**	-0.400*
SD ann. mean	-0.077^{NS}	-0.404**	-0.350*
Inter-annual SE	-0.362^{NS}	-0.537**	-0.517**
Geog. range size	-0.275^{NS}	-0.626***	-0.608***
Female mass	-0.107^{NS}	-0.085^{NS}	0.082^{NS}
Residual range size	-0.130^{NS}	-0.610***	-0.609***

Table A4.2. Relationship between climate variables and pinniped range size using latitude bin-based methods. Dependent variable is median range size per 5^{o} latitude bin, using all species (Stevens method) or only those species whose range midpoint falls in that bin (midpoint method, note reduced sample size as some bins contain no range midpoints). Climate variables are median value of all ocean data points within each bin (all variables ln-transformed prior to analyses, constant (2) added to meanSST due to negative values in high latitude bins).

Stevens method								
n	R^2	F (4, 29)	P	Variable	β	SE	t	P
34	0.787	42.035	< 0.001	meanSST	-0.681	0.067	-10.206	< 0.001
				sdSST	0.150	0.177	0.847	0.404
				seSSTie	0.053	0.169	0.311	0.758
Midpoint method								
n	R^2	F (3, 11)	P	Variable	β	SE	t	P
15	0.437	4.618	0.025	meanSST	-1.516	0.408	-3.710	0.003
				sdSST	0.525	0.727	0.723	0.485
				seSSTie	-0.317	0.883	-0.359	0.727

Table A4.3. Species data used to test the climatic variability hypothesis (CVH) for world pinniped range sizes. Range size measured as the total number of 1^{o} grid cells occurring in the species geographic range, using pre-human exploitation range if applicable. Female mass data (in grams) from Ferguson and Higdon (2006) updated with Zalophus data from IUCN (2010). Three climate variables extracted from World Ocean Atlas 2005 (WOA05) (Locarnini *et al.*, 2006): 1) meanSST, mean annual SST, measured as the mean of the monthly objectively analyzed mean values, 2) sdSST, standard deviation of the mean monthly SST, a measure of intra-annual temperature seasonality, 3) seSSE, standard error of the statistical mean temperature measured across multiple years of data, a measure of inter-annual (between year) variation. Median climate values (median value for all cells included within a species range) were the primary measure used for analyses, with total range and interquartile range (IQR) provided as a measure of variation within geographic ranges.

Family	Species	Code	Range size (1^{o} cells)	Female mass (grams)	meanSST			sdSST			seSST		
					Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
Odobenidae	*Odobenus rosmarus*	Od	1883	811,500	0.846	4.184	13.951	1.807	1.364	6.158	0.244	0.25	2.059
Otariidae	*Arctocephalus australis*	Aa	562	48,500	13.297	10.835	21.042	2.168	1.154	4.723	0.277	0.165	1.009
	Arctocephalus forsteri	Af	357	38,100	11.053	7.509	15.694	1.561	0.804	2.826	0.245	0.182	1.14
	Arctocephalus galapagoensis	Aga	18	27,400	23.705	1.567	3.299	1.703	0.596	1.208	0.22	0.119	0.221
	Arctocephalus gazella	Agz	1899	45,000	1.22	2.132	10.87	1.109	0.24	1.214	0.297	0.253	1.683
	Arctocephalus philippii	Aph	26	48,100	14.146	1.646	3.807	2.093	0.221	0.403	0.348	0.285	0.725
	Arctocephalus	Apu	158	64,100	17.055	3.255	9.891	1.664	0.328	1.413	0.202	0.142	0.557

Family	Species	Code	Range size (1° cells)	Female mass (grams)	meanSST			sdSST			seSST		
					Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
	pusillus												
	Arctocephalus townsendi	Ato	177	49,550	22.641	7.967	15.895	1.668	0.642	4.667	0.143	0.133	0.307
	Arctocephalus tropicalis	Atr	1019	35,000	9.342	6.772	17.249	1.154	0.674	1.613	0.403	0.279	2.625
	Callorhinus ursinus	Cu	1631	33,300	8.672	5.6	16.441	2.999	0.775	6.039	0.271	0.16	1.355
	Eumetopias jubatus	Ej	910	287,550	5.144	2.85	21.222	3.227	1.662	6.101	0.271	0.314	2.003
	Neophoca cinerea	Nc	109	78,550	17.334	1.959	8.77	1.612	0.348	0.924	0.227	0.129	0.833
	Otaria flavescens	Of	435	144,000	12.374	9.309	18.669	2.131	1.151	3.479	0.264	0.166	1.009
	Phocarctos hookeri	Pho	208	114,700	8.201	2.722	10.689	0.917	0.23	1.619	0.234	0.172	0.801
	Zalophus californianus	Zc	207	81,000	19.896	12.432	18.416	1.69	1.166	4.799	0.1	0.09	0.307
	Zalophus japonicus	Zj	145	77,000	15.301	10.176	19.331	5.574	2.63	4.122	0.112	0.151	0.673
	Zalophus wollebaeki	Zw	11	75,000	23.503	1.622	2.375	1.843	0.521	0.913	0.222	0.144	0.211
Phocidae	*Erignathus barbatus*	Eb	2630	326,000	0.414	3.672	12.67	1.712	1.15	6.055	0.269	0.255	2.059
	Cystophora cristata	Cc	1106	222,500	2.515	4.869	11.123	1.648	0.625	5.957	0.208	0.14	1.492
	Halichoerus grypus	Hg	311	205,800	7.965	3.737	15.099	2.65	3.21	5.524	0.105	0.061	0.358
	Histriophoca fasciata	Hf	759	80,360	4.533	1.794	9.393	3.242	1.187	4.254	0.318	0.351	1.954
	Pagophilus groenlandicus	Pg	1984	139,000	0.576	3.994	11.028	1.647	0.79	6.135	0.236	0.193	1.715
	Pusa caspica	Pc	37	55,000	14.55	4.668	11.058	7.09	3.884	6.178	1.264	0.58	3.747
	Pusa hispida	Phi	6855	81,200	-1.298	1.955	20.624	0.55	1.433	7.026	0.228	0.254	2.059
	Phoca largha	Pl	899	71,300	3.981	4.032	24.738	3.302	2.336	6.928	0.298	0.338	2.009
	Phoca vitulina	Pv	1140	85,200	5.784	6.884	27.446	2.427	1.46	6.396	0.154	0.17	2.059

Family	Species	Code	Range size (1° cells)	Female mass (grams)	meanSST			sdSST			seSST		
					Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
	Hydrurga leptonyx	Hl	7162	367,000	-0.381	3.045	10.954	0.993	0.428	1.883	0.256	0.233	1.878
	Leptonychotes weddellii	Lw	5777	447,000	-0.8	1.701	7.977	0.978	0.527	1.584	0.244	0.222	1.878
	Lobodon carcinophaga	Lc	6154	224,000	-0.702	2.06	9.342	0.985	0.498	1.584	0.249	0.232	1.878
	Ommatophoca rossii	Or	5949	164,000	-0.759	1.868	7.692	0.976	0.514	1.584	0.245	0.229	1.878
	Mirounga angustirostris	Ma	842	488,000	9.736	4.74	14.185	2.901	0.261	2.714	0.26	0.161	1.355
	Mirounga leonina	Ml	13363	565,700	4.268	11.84	25.947	1.154	0.674	4.279	0.327	0.287	2.747
	Monachus monachus	Mm	692	275,000	20.962	3.605	14.504	2.223	2.249	6.018	0.155	0.088	1.012
	Monachus schauinslandi	Ms	63	272,200	24.215	1.176	3.219	1.939	1.03	1.959	0.172	0.111	0.3
	Monachus tropicalis	Mt	323	160,000	27.441	0.839	2.746	0.98	0.785	2.434	0.084	0.043	0.669

Table A4.4. Latitudinal bin data used to test the CVH for world pinniped range sizes. Sample size is number of cells with data in each 5^{o} latitudinal band, with reduced sample size for seSST in parentheses. Range size measured as the median value for all species occurring in that bin or the species with their midpoint in that bin. Climate data summarized from World Ocean Atlas 2005 (WOA05) (Locarnini *et al.*, 2006): median climate values (median value for all cells included within a latitude band) were the primary measure used for analyses, with total range and interquartile range (IQR) provided as a measure of variation within geographic ranges.

Latitude band	No. 1^{o} cells	Species richness	Median pinniped range/bin		meanSST			sdSST			seSST		
			Stevens	Midpoint	Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
-87.5	0 (0)	5	6154										
-82.5	163 (0)	5	6154		-1.331	0.356	0.959	0.487	0.104	0.462			
-77.5	345 (182)	5	6154		-1.434	0.314	1.137	0.375	0.287	0.782	0.125	0.082	0.565
-72.5	708 (307)	5	6154		-1.562	0.22	2.433	0.435	0.226	0.929	0.115	0.146	0.812
-67.5	1373 (1130)	6	6052	6051.5	-1.16	0.44	2.161	0.795	0.312	1.13	0.214	0.186	1.091
-62.5	1785 (1569)	6	6052		-0.431	1.471	5.589	1.14	0.263	1.253	0.268	0.231	1.876
-57.5	1797 (1601)	10	3838		1.676	3.744	8.815	1.102	0.25	0.968	0.298	0.245	1.682
-52.5	1759 (1560)	11	1899	7631	4.853	4.807	10.596	1.035	0.265	1.246	0.302	0.239	1.487
-47.5	1742 (1566)	12	1459	208	8.671	3.835	10.919	1.301	0.605	2.403	0.366	0.269	1.709
-42.5	1716 (1639)	10	396	688	12.407	2.357	10.327	1.724	0.624	2.669	0.437	0.27	2.618
-37.5	1660 (1629)	8	396	26	16.306	2.17	9.376	2.008	0.536	3.275	0.459	0.306	2.723
-32.5	1491 (1485)	7	435	296.5	19.334	2.038	9.662	2.115	0.326	3.409	0.433	0.282	2.147
-27.5	1394 (1375)	7	435		22.181	1.875	10.018	1.912	0.271	1.748	0.417	0.298	1.838
-22.5	1329 (1300)	4	499		24.232	2.161	11.67	1.629	0.379	1.946	0.337	0.224	1.725
-17.5	1343 (1340)	3	435		26.084	2.57	10.74	1.278	0.618	2.449	0.227	0.179	1.302
-12.5	1407 (1406)	2	499		27.262	2.61	10.822	1.015	0.69	2.685	0.183	0.148	1.549
-7.5	1345 (1333)	2	499		27.814	2.501	9.718	0.832	0.86	2.854	0.154	0.145	1.605
-2.5	1305 (1300)	3	227	14.5	27.526	2.849	8.757	0.673	0.944	2.452	0.138	0.146	1.003

Latitude band	No. 1° cells	Species richness	Median pinniped range/bin		meanSST			sdSST			seSST		
			Stevens	Midpoint	Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
2.5	1377 (1377)	3	355		27.728	1.817	5.117	0.5	0.527	1.747	0.106	0.1	0.832
7.5	1314 (1314)	2	508		27.926	1.14	3.321	0.579	0.282	1.686	0.093	0.055	0.482
12.5	1322 (1322)	4	265		27.565	1.625	4.863	0.834	0.301	3.169	0.105	0.074	0.587
17.5	1223 (1223)	4	265	323	26.967	2.266	9.51	1.084	0.376	3.483	0.123	0.082	0.923
22.5	1129 (1128)	5	207		25.925	2.582	9.903	1.512	0.575	3.636	0.155	0.088	0.67
27.5	1034 (1034)	7	323	177	23.797	2.485	11.001	2.281	1.064	4.955	0.179	0.108	0.538
32.5	998 (998)	9	871	207	21.07	2.541	10.776	3.069	1.137	6.123	0.204	0.16	1.099
37.5	977 (976)	12	842		18.059	3.456	10.647	3.618	1.111	6.56	0.192	0.197	2.584
42.5	876 (872)	15	905	145	13.206	4.856	14.54	3.452	1.622	8.75	0.241	0.171	4.33
47.5	768 (753)	16	910	1270.5	8.879	6.151	13.279	2.926	0.979	9.135	0.235	0.19	1.777
52.5	684 (682)	12	1123	899	7.033	4.603	12.585	2.67	0.841	7.01	0.213	0.132	1.621
57.5	726 (721)	12	1123	759	5.127	4.942	11.871	2.799	1.414	4.989	0.218	0.286	2.039
62.5	445 (443)	12	1123	2256.5	5.259	5.78	10.719	1.738	0.925	4.704	0.178	0.205	1.492
67.5	362 (360)	10	1123		2.857	4.888	10.008	2.016	0.71	4.387	0.185	0.123	1.099
72.5	1022 (912)	9	1140		-0.022	2.207	8.906	1.619	1.13	2.673	0.266	0.232	1.714
77.5	1234 (741)	6	1934		-1.133	0.88	5.38	0.814	0.954	1.965	0.238	0.249	1.7
82.5	1503 (309)	6	1934		-1.536	0.256	3.176	0.331	0.32	2.596	0.072	0.194	1.106
87.5	1800 (83)	1	6855		-1.598	0.114	0.682	0.237	0.059	0.379	0.012	0.023	0.579