Supplementary information

Extraordinarily low evolutionary rates of short wavelength-sensitive opsin pseudogenes

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Table S1.

The opsin genes considered.

Gene[a]	Organism	GenBank (accession no.)
SWS1 genes		
Caur$_{s1}$	goldfish (*Carassius auratus auratus*)	D85863
Drer$_{s1}$	zebrafish (*Danio rerio*)	AB087810
Ssal$_{s1}$	Atlantic salmon (*Salmo salar*)	AY214133
Bden$_{S1}\psi$	pearleye (*Benthalbella dentate*)	JX564538
Sleu$_{S1}$	lampfish (*Stenobrachius leucopsarus*)	FJ443127
Olat$_{S1}$	medaka (*Oryzias latipes*)	AB223058
Pret$_{S1}$	guppy (*Poecilia reticulate*)	DQ234861
Onil$_{S1}$	tilapia (*Oreochromis niloticus*)	AF191221
Nbris$_{S1}\psi$	cichlid (*Neolamprologus brichardi*)	AY775096
Nmon$_{S1}\psi$	cichlid (*Neolamprologus mondabu*)	HM135147
Lcha$_{S1}\psi$	coelacanth (*Latimeria chalumnae*)	(Yokoyama et al. 1999)
Lmen$_{S1}\psi$	coelacanth (*Latimeria menadoensis*)	(Yokoyama, Tada 2000)
Xlae$_{S1}$	frog (*Xenopus laevis*)	U23463
Cliv$_{S1}$	pigeon (*Columba livia*)	AF149234
Acar$_{S1}$	American chameleon (*Anolis carolinensis*)	AF134192
Taus$_{S1}$	bat (*Taphozous australis*)	EU912383
Mful$_{S1}$	bat (*Miniopterus fuliginosus*)	GQ863406
Raff$_{S1}\psi$	bat (*Rhinolophus affinis*)	EU912364
Rfer$_{S1}\psi$	bat (*Rhinolophus ferrumequinum*)	EU912380
Hsap$_{S1}$	human (*Homo sapiens*)	M13295
Cfam$_{S1}$	dog (*Canis lupus familiaris*)	XM_539386
Btau$_{S1}$	bovine (*Bos taurus*)	U92557
Scro$_{S1}$	pig (*Suss crofa*)	AY091587
Eful$_{S1}$	Brown lemur (*Eulemur fulvus*)	AB111464
Dmad$_{S1}$	Aye-Aye (*Daubentonia madagascariensis*)	EF667285
Gsen$_{S1}\psi$	galago (*Galago senegalensis*)	AB111465
Ncou$_{S1}\psi$	loris (*Nycticebus coucang*)	AB111466
Ttru$_{S1}\psi$	dolphin (*Tursiops truncatus*)	AF055458
Mden$_{S1}\psi$	beaked whale (*Mesoplodon densirostris*)	AY228441
Mnov$_{S1}\psi$	humpback whale (*Megaptera novaeangliae*)	AY228440
Bacu$_{s1}\psi$	minke whale (*Balaenoptera acutorostrata*)	AF545490
Bmus$_{s1}\psi$	blue whale (*Balaenoptera musculus*)	AF545484
Bmys$_{s1}\psi$	bowhead whale (*Balaena mysticetus*)	AF545491
Dcap$_{s1}\psi$	common dolphin (*Delphinus capensis*)	AB462251
Ddel$_{s1}\psi$	saddle dolphin (*Delphinus delphis*)	AB462250
Dleu$_{s1}\psi$	beluga whale (*Delphinapterus leucas*)	AF545485

Egla$_{s1}\psi$	right whale (*Eubalaena glacialis*)	AF545492
Erob$_{s1}\psi$	gray whale (*Eschrichtius robustus*)	AF545493
Gmac$_{s1}\psi$	short-finned dolphin (*Globicephala macrorhynchus*)	AB462241
Gmel$_{S1}\psi$	pilot whale (*Globicephala melas*)	AY228442
Kbre$_{s1}\psi$	pygmy sperm whale (*Kogia breviceps*)	AF545486
Igeo$_{s1}\psi$	Amazon river dolphin (*Inia geoffrensis*)	AF545495
Lbor$_{s1}\psi$	whale dolphin (*Lissodelphis borealis*)	AB462244
Lhos$_{s1}\psi$	Fraser's dolphin(*Lagenodelphis hosei*)	AB462254
Lobl$_{s1}\psi$	white-sided dolphin (*Lagenorhynchus obliquidens*)	AB462245
Mbid$_{s1}\psi$	beaked whale (*Mesoplodon bidens*)	AF545496
Pbla$_{s1}\psi$	La Plata dolphin (*Pontoporia blainvillei*)	AF545483
Pcat$_{s1}\psi$	sperm whale (*Physeter catodon*)	AF545482
Pcra$_{s1}\psi$	false killer whale (*Pseudorca crassidens*)	AB462242
Pgan$_{s1}\psi$	Ganges river dolphin (*Platanista gangetica*)	AF545487
Pgro$_{S1}\psi$	harp seal (*Phoca groenlandica*)	AY228445
Ppho$_{s1}\psi$	harbor porpoise (*Phocoena phocoena*)	AB462255
Psins$_{s1}\psi$	vaquita (*Phocoena sinus*)	AF545489
Pvit$_{S1}\psi$	harbor seal (*Phoca vitulina*)	AY228444
Sbre$_{s1}\psi$	rough-toothed dolphin (*Steno bredanensis*)	AB462246
Schi$_{s1}\psi$	humpback dolphin (*Sousa chinensis*)	AB462248
Scoe$_{s1}\psi$	striped dolphin (*Stenella coeruleoalba*)	AB462249
Sfro$_{s1}\psi$	spotted dolphin (*Stenella frontalis*)	AB462252
Slon$_{s1}\psi$	spinner dolphin (*Stenella longirostris*)	AB462243
RH1 genes		
Sana$_{RH1A}$	pearleye (*Scopelarchus analis*)	EF517404
Sana$_{RH1B}$	pearleye (*Scopelarchus analis*)	EF517405
RH2 gene		
Sana$_{RH2}$	pearleye (*Scopelarchus analis*)	EF517406

[a]Greek letters ψ denote pseudogenes.

Table S2.

Log-likelihood values and parameter estimates for the 29 cetacean and two seal SWS1 pseudogenes

Model	Parameter	log-likelihood	Sites under positive selection	
			NEB	BEB
M1	$p_0 = 0.372$ ($p_1 = 0.628$), $\omega_0 = 0.396$ ($\omega_1 = 1$)	-1056.824	Not allowed	
M2	$p_0 = 0.9$, $p_1 = 0$ ($p_2 = 0.1$) $\omega_0 = 0.753$, $\omega_1 = 1$, ($\omega_2 = 5.855$)	-1047.477	69 ***107*** 118	***107*** 118
M7	$p = 0.893$, $q = 0.152$	-1057.327	Not allowed	
M8	$p_0 = 0.901$ ($p_1 = 0.099$), $p = 99$, $q = 32.137$, $\omega = 5.881$	-1045.669	69 ***107*** 118	***107*** 118

Sites with $P < 0.01$ levels are shown in bold.

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Goldfish          M-------DAWTYQFGNLSKISPFEGPQYHLAPKWAFYLQAAFMGFVFFVGT-PLNAIVLF 52
Zebrafish         M-------DAWAVQFGNASKVSPFEGEQYHIAPKWAFYLQAAFMGFVFIVGT-PMNGIVLF 52
Tilapia           M-------GKYFHLYENISKVSPFEGPQYYLAPTWAFYLQAAFMGFVLFAGT-PLNFVVLV 52
Medaka            M-------GKYFYLYENISKVGPYDGPQYYLAPTWAFYLQAAFMGFVFFVGT-PLNFVVLL 52
Pearleyeψ         R--------KNFHLYENISKVSPFEGPQYHLAPMWAFYPQTAFMGFVLFVGTXPLNLIVLL 52
Guppy             M-------GKHFHLYENISKVDPFEGSQHYLAPAWAFHLQALFMGFVFFAGT-PLNLLVLL 52
Salmon            M-------GKDFHLYENISKISPFEGPQYHLASMWAFYLQAAFMGFVFFAGT-PLNFIILV 52
Lampfish          M-------GKHFHLYENVSKVSPFEGPQYYLAPHWVFYLQTAFMGFVFFAGT-PLNFIVLF 52
Cichlid-Nbriψ     ---------KYFHLYENISKISPFEGPQYYLAPVWVFYLQAAFMGFVFLAGT-PLNFVVLL 50
Cichlid-Nmonψ     M-------GKYFHLYENISKISPFEGPQYYLAPVWVFYLQAAFMGFVFFAGA-PLNFVVLL 52
Coelacanth-Lmenψ  M-----LRGEDFYLFSKISSVGLWDGLQYHIAPIWAFYLQAVFMGFMFFVGT-LLNAIVLI 54
coelacanth-Lchaψ  M-------------FSKISSVGLWDGLQYHIAPIWAFYLQAVFMGFMFFVGT-LLNAIVLI 54
Frog              M-----LEEEDFYLFKNVSNVSPFDGPQYHIAPKWAFTLQAIFMGMVFLIGT-PLNFIVLL 54
Chameleon         M-----SGQEDFYLFENISSVGPWDGPQYHIAPMWAFYFQTAFMGFVFFAGT-PLNAIILI 54
Pigeon            M-----SGDEEFYLFKNGSSVGPWDGPQYHIAPPWAFYLQTAFMGFVFLVGT-PFNAIVLV 54
Human             M--RKMS-EEEFYLFKNISSVGPWDGPQYHIAPVWAFYLQAAFMGTVFLIGF-PLNAMVLV 56
bat-Taus          ----------------NISSVGPWDGPQYHIAPVWAFHLQAAFMGFVFFVGT-PLNATVLV 43
bat-Mful          ----------------------------------------FMGFVFFVGT-PLNATVLV 17
bat-Raffψ         ----------------NIS-VGPW---------XWVFRLQAAFVGFVFIAGM-PLNA---- 30
bat-Rferψ         ----------------NIS-VGPW---------XWAFRLQAAFVGFVFIAGM-PLNA---- 30
Brown lemur       M--CKMSGEEEFYLFKNLSPVGPWDGPQYHIAPVWAFYLQAAFMGLVFFAGA-PLNVMVLV 57
aye-aye           M--RKMSGEE-FYLFKNLSSVGPWDGPQYHIAPVWAFYLQAAFMGFVFFAGT-PLNVMVLV 56
Dog               M--SKMSGEEEFYLFKNISLVGPWDGPQYHIAPVWAFHLQAVFMGFVFFAGT-PLNGTVLV 57
Bovine            M--SKMSEEEEFLLFKNISLVGPWDGPQYHLAPVWAFHLQAVFMGFVFFVGT-PLNATVLV 57
Pig               MSKMPEEEEEEFLLFKNISLVGPWDGPQYHLAPVWVFHLQAAFMGFVFLVGT-PLNATVLV 59
Galagoψ           V--GKMSGEGVFYX---------------HLAPVWAFCLQEAFMGFVFFAGT-PFNVIVLV 42
lorisψ            V--SNMSGKEELYX---------------HLAPVWAFYLQAAFMGFVFFAGT-PLNVMVLV 42
Dolphinψ          M--RKMSEEEEFXLFKNIXXVGPWDGPQYRLAPVWGFHLHAAFTGFVFLVWR-ALDATVLV 57
beaked whaleψ     M--SKMSEEEEFFLF--ISLVGPWDGPQHHLAPVWAFHLQAAFTGFVFFVET-PLNATVLV 55
humpback whaleψ   M--SKMSEEEEFFLFKNISLVGPWDGPQYHLTPVWAFHLQAAFTGFVFFVGM-PLNATVLV 57
pilot whaleψ      M--SXMSEEEEFFLFKNIXXVGPWDGPQYRLAPVWAFHLQAAFTGFVFVVGT-PLDATVLV 57
harbor sealψ      M--SKMSEEEEFYLFKNISLVGPWDGPQYHIAPVWAFRLQAVFIGFVFFAGT-PLNASVLV 57
harp sealψ        M--RKMSEEEEFYLFKNISLVGPWDGPQYHIAPVWAFRLQAVFMGFVFFAGT-PLNASVLV 57
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Fig. S1. Aligned amino acid sequences of SWS1 opsins. Amino acid site numbers are shown in right. Dashes (-), Xs, and * (stars) indicate the sites of indels, incomplete codons, and stop codons, respectively.

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Goldfish              VTMKYKKLRQPLNYILVNISLGG---FIFD-TFS-VSQVFFSALRGYYFFGYTLCAMEAAM 109
Zebrafish             VTMKYKKLRQPLNYILVNISLAG---FIFD-TFS-VSQVFVCAARGYYFLGYTLCAMEAAM 109
Tilapia               ATMKYKKLRVPLNFILVNISFSG---FIFV-TFS-VSQVFLASMRGYYFLGHTLCALEAAV 109
Medaka                ATAKYKKLRVPLNYILVNITFAG---FIFV-TFS-VSQVFLASVRGYYFFGQTLCALEAAV 109
Pearleyeψ             VMIIYKRLRVPLNYVLINVSLAG---FIFV-TFS-VSQVFISSTS*YYFLGHTLRALESCM 109
Guppy                 ATAKYKKLRAPLNYILVNISFAG---FIFV-TFS-VSQVFVASLRGYYFLGYTLCALEAAM 109
Salmon                VTVKYKKLRQPLNFILVNISLAG---FIFV-TFS-VSQVFVSSARGYYFLGYTLCAMEACM 109
Lampfish              VTMKYKKLRVPLNYILVNISLAG---FIFV-TFS-VSQVFVSTTKGYFFLGHTMCALESCM 109
Cichlid-Nbriψ         ATMKYKKLRVPLNFILVNISFCG---FIFV-TFSXVSQVFVSSMRGYYFLGHTLCALESAV 109
Cichlid-Nmonψ         ATMKYKKLRVPLNFILVNISFCG---FIFVXTFS-VSQVFVSSXRGYYFLGHTLCALESAV 110
coelacanth-Lmenψ      VTLKYNKL*QPLNYILLNISLAG---FIVC-LFX-IFTVFISSSRGYFIFGRAVCAIESFL 111
coelacanth-Lchaψ      VTLKYNKL*QPLNYILLNISLAG---FIVC-LFX-IFTVFISSSRGYFIFGRX--------  95
Frog                  VTIKYKKLRQPLNYILVNITVGG---FLMC-IFS-IFPVFVSSSQGYFFFGRIACSIDAFV 111
Chameleon             VTVKYKKLRQPLNYILVNISFAG---FLFC-TFS-VFTVFMASSQGYFFFGRHVCAMEAFL 111
Pigeon                VTIKYKKLRQPLNYILVNISFSG---FISC-IFS-VFTVFVSSSQGYFIFGKDMCALEAFV 111
Human                 ATLRYKKLRQPLNYILVNVSFGG---FLLC-IFS-VFPVFVASCNGYFVFGRHVCALEGFL 113
bat-Taus              ATLRYKTLRQPLNYILVNVSLGG---FLFC-IFS-VSTVFVASCQGYFIFGRHVCALEAFL 100
bat-Mful              ATLRYKKLRQPLNYILVNVSLGG---FLFC-IFS-VFTVFVASXQGYFIFGRRVCALEAFX  74
bat-Raffψ             -TLRYRKLWQPLNYILVNVSRGGXVGFLFC-VFX-GFTVFMASCQGC-IFGRRVYALGDFL  87
bat-Rferψ             -TLCYRKLRQPLNYILVNVLGRGXGGFLFC-VFX-GFTVFMASCQGC-IFGCRVCALGDFL  87
Brown lemur           ATLRYKKLRQPLNYILVNLSFGG---FLCC-IFS-VLPVFIASCRGYFLFGRHVCALEGFL 114
aye-aye               ATLRYKKLRQPLNYVLVNVSFGG---FLFC-IFS-VFPVFIASCRGYFVFGRHVCALEGFL 113
Dog                   ATLRYKKLRQPLNYILVNVSLGG---FLYC-I-S-VSTVFIASCQGYFVFGRHVCALEAFL 113
Bovine                ATLRYRKLRQPLNYILVNVSLGG---FIYC-IFS-VFIVFITSCYGYFVFGRHVCALEAFL 114
Pig                   ATLRYRKLRQPLNYILVNVSLGG---FIYC-IFS-VFSVFIASCHGYFVFGRRVCAMEAFL 116
Galagoψ               ATLCYKKLWQPLSYILVNLSLGG---ILYC-ILS-VLPIFVASCRGYFLFGCHACALEGFL  99
lorisψ                ATLCYKKLWQPLSYILVNLSSGG---FLYC-IFS-VLPIFVASC*GYFPFGCHACALEGFL  99
Dolphinψ              ATLRYRKLRQPLNYILVNVSLGG---FIYC-IFS-VFVVFITSCHGYFVFGRHVCALGAFL 114
beaked whaleψ         ATLRYRKLRQPLNYILVNVSLGG---FIYC-IFS-LX-VFITSCHGYFVFGHHVCALGAFL 111
humpback whaleψ       ATLRYRKLRQPLNYILVNVSLGG---FIYC-TFS-LXXVFITSCHEYFVFGSHVCALEAFL 114
pilot whaleψ          ATLRYRKLRQPLNYILVNVSLGG---FIYX-XF----------------GRHVCALGAFL  98
harbor sealψ          ATLRYKKLRQPLNYILVNVSLGG---FLYC-IPV-SSXXFIASCQGYFIFGRHVCALEAFL 114
harp sealψ            ATLRYKKLQQPLNYILVNVSLGG---FLYC-ISV-SSXVFMASCQGYFIFGRHVCALETFL 114
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Fig. S1. (continued).

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Goldfish          GSIA-GLVTGWSLAVLAFERYVVICKPFGSFKFGQSQALGAVALTWIIGIGCA-TPPFWGW 168
Zebrafish         GSIA-GLVTGWSLAVLAFERYVVICKPFGSFKFGQGQAVGAVVFTWIIGTACA-TPPFFGW 168
Tilapia           GAIA-GLVTAWSLAVLSFERYLVICKPFGAFKFGSNHALAAVAFTWFMGVGCA-CPPFFGW 168
Medaka            GAVA-GLVTSWSLAVLSFERYLVICKPFGAFKFGSNHALAAVIFTWFMGVGCA-CPPFFGW 168
Pearleyeψ         GSIT-GLVTAWSLAVLSLVRYLVICKPFGAFKFTGNHALAAVGFTWLMGIGCA-TPPFFGW 168
Guppy             GAVA-GLVTSWSLAVLSFERFLVICKPFGAFKFGSTHAAAAVVFTWFMGVGCA-SPPFFGW 168
Salmon            GSIA-GLVSAWSLAVLAFERYVVICKPFGTFKFDNNQALAAVAFTWVMGIGCA-TPPFFGW 168
Lampfish          GSIA-GLVTAWSLAVLSLERYLVICKTFGAFKFGSNHALAAVAFTWIMGIGCA-TPPFFGW 168
Cichlid-Nbriψ     GSVA-GLVTAWSLAVXSFERYLVICKPFGAFKFGSNHALAAVAFTWFMGVGCA-CPPFFGW 168
Cichlid-Nmonψ     GSXA-GLVTAWSLAXLSFERYLVICKPFGAFKFGSNHALAAVAFTWFMGVGCA-CPPFFGW 169
coelacanth-Lmenψ GSMT-GLITGXT---LAFERDIVICKPFSNFCFGSKQSLLAVGATWVIXTXVQXLPPVFGW 168
coelacanth-Lchaψ -----------------FERDIVICKPFSNFCFGSKQSLLAVGATWVIXTXVQXLP----- 134
Frog              GTLT-GLVTGWSLAFLAFERYIVICKPMGNFNFSSSHALAVVICTWIIGIVVS-VPPFLGW 170
Chameleon         GSVA-GLVTGWSLAFLAFERYIVICKPFGNFRFNSKHALLVVAATWFIGIGVS-IPPFFGW 170
Pigeon            GATG-GLVTGWSLAFLAFERYIVICKPFGNFRFNSKHALMAVVATWVIGLGVA-LPPWFGW 170
Human             GTVA-GLVTGWSLAFLAFERYIVICKPFGNFRFSSKHALTVVLATWTIGIGVS-IPPFFGW 172
bat-Taus          GSTA-GLVTGWSLAFLAFERYIVICKPFGSFRFSSKHALMVVLATWTIGIGVS-IPPFFGW 159
bat-Mful          GSTA-GLXTGWSLAFLAFERYIVICKPFGSFHFSSKHALLVVLATWAIGIGVS-IPPFFGW 133
bat-Raffψ         GSMA-GLVTGWSXAFLALEHYTVICKPFGSFGFSSKRARMVVLAAWTIGIGVS-IPPFSG* 146
bat-Rferψ         GSMA-GLVTGWSXAFLASEHYTVICKPFGSFRFSSKHARMAVLAAWTIGIGVS-IPPFSV* 146
Brown lemur       GSAA-GLVIGWSLAFLAFERYVIICKPFGNFRFSSKHALMVVLATWTIGVGVS-IPPFFGW 173
aye-aye           GSVA-GLVIGWSLAFLAFERYIVICKPFGNFHFSSKHALMVVLATWTIGIGVS-IPPFFGW 172
Dog               GSTA-GLVTGWSLAFLAFERYIVICKPFGNFRFSSKHALMVVLATWTIGIGVS-IPPFFGW 172
Bovine            GCTA-GLVTGWSLAFLAFERYIIICKPFGNFRFSSKHALMVVVATWTIGIGVS-IPPFFGW 173
Pig               GSAA-GLVTGWSLAFLAFERYIIICKPFGNFRFSSKHALIAVLATWAIGIGVS-IPPFFGW 175
Galagoψ           SSVA-GLVIGWSLAFLAFECYIVICKPFGNFCFSFKPALMVVLAIWTIGIGIS-ISTXFGW 158
loris             SSAA-GLVIGWSLAFLAFELYIAICKPFSNFCFGSKHVLMVVPAA*--------------- 144
Dolphinψ          GRTA-GLLTGWSLAFLVFERYIIICKPFGNFRFSSKHALMVVLATWTIGIGVS-IPPFFGW 173
beaked whaleψ     GYTA-G----WSLAFLVFEHYISICKPFGNFRFSSKHALMVVLATWTIGIGAS-IPPFFGW 166
humpback whaleψ   GCTA-G----WSLAFLAFERYIIICKPCGNFHFSSKHALTVVLATWTIGIGVS-IPPFFGW 169
pilot whaleψ      GRTA-G----WSLAFLVFERYIIICKPFGNFRFSSKHALMVVLATWTIGIGVS-IPPFFGW 153
harbor sealψ      APTA-G----WSLAFLAFERYMVICKPFGNFRFSSKHALMVVLATWTIGVGVS-IPPFFGW 169
harp sealψ        APTAXG----WSLAFLAFERYMVICKPFSNFRFSSKNALMVVLATWTIGVGVS-IPPFFGW 170
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Fig. S1. (continued).

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Goldfish          SRY-IPEGIGTA--CG-PDWYTKNEEYNTESYTYFLLVSCFMMP--IMIITFSYSQLLGAL 223
Zebrafish         SRY-IPEGLGTA--CG-PDWYTKSEEYNSESYTYFLLITCFMMP--MTIIIFSYSQLLGAL 223
Tilapia           SRY-IPEGLGCS--CG-PDWYTHNEEYNTTSYIYFLLITCFIFP--LTIIIFCYSQLLGAL 223
Medaka            SRY-IPEGLGCS--CG-PDWYTNCEEFSCASYSKFLLVTCFICP--ITIIIFSYSQLLGAL 223
Pearleyeψ         SRY-IPEGLGCS--CG-LDWYTHNEEFNCTSYVYFLMV---------------------- 202
Guppy             SRY-IPEGLGCS--CG-PDWYTHNEEYGCTSYMYFLLITCFCMP--LSIIIFSYSQLLGAL 223
Salmon            SRY-IPEGLGCS--CG-PDWYTNNEEYHCASYTKFLIVTCFLMP--MSIIFFSYSQLLGAL 223
Lampfish          SRY-IPEGLGCS--CG-PDWYTHNEEFHCTSYMYFLMVTCFVAP--LTIIIFSYSQLLGAL 223
Cichlid-Nbriψ     SRY-IPEGLGCS--CG-PDWYTHNVEYNTNXYTHFLMLTCFIIP--LTIIMFCYSQLLGAL 223
Cichlid-Nmonψ     SRY-IPEGLGCS--CG-PDWYTHNVEYNTNSYTHFLMLTCFIIP--LTIIMFCYSQLLGAL 224
coelacanth-Lmenψ  SQY-IPEGLQCS--CG-PEWYTVNNKWNNESYVIFLFSFCFGLP--LSIIIFSYTKLLMTL 223
coelacanth-Lchaψ  ----------CS--CG-PEWYTVNNKWNNESYVIFLFSFCFGLP--LSIIIFSYTKLL--- 177
Frog              SRY-MPEGLQCS--CG-PDWYTVGTKYRSEYYTWFIFIFCFVIP--LSLICFSYGRLLGAL 225
Chameleon         SRY-IPEGLQCS--CG-PDWYTVGTKYKSEYYTWFLFIFCFIVP--LTLIIFSYSQLLGAL 225
Pigeon            SRY-VPEGLQCS--CG-PDWYTVGTKYKSEYYTWFLFIFCFIVP--LSLIIFSYSQLLSAL 225
Human             SRF-IPEGLQCS--CG-PDWYTVGTKYRSESYTWFLFIFCFIVP--LSLICFSYTQLLRAL 227
bat-Taus          SRF-IPEGLQCS--CG-PDWYTVGTRYRSEYYTWFLFVFCFIVP--LSLICFSYSQLLRAL 214
bat-Mful          SRF-IPEGLQCS--CG-PDWYTVGTKYRSEYYTWFLFIFCFIVP--LSLVCFSYSQLLGAL 188
bat-Raffψ         SRF-APEGLQCS--CG-PDWY--GTKYGSEDCT*FLFIFCVTVP--LPRXCCSYSQLLGAL 199
bat-Rferψ         SQF-APEGLQCS--CS-PDWYTLGTKYGSEDCTWFL-----------PXICCSYSQLLGXL 192
Brown lemur       SRF-IPEGLQCS--CG-PDWYTVGTKYRSEYYTWFLFIFCFIVP--LSLICFSYSQLLRAL 228
aye-aye           SRF-IPEGLQCS--CG-PDWYTVGTKYHSEYYTWFLFIFCFIVP--LSLICFSYSQLLGAL 227
Dog               SRF-IPEGLQCS--CG-PDWYTVGTKYRSEYYTWFLFIFCFIVP--LSLICFSYLQLLRAL 227
Bovine            SRF-VPEGLQCS--CG-PDWYTVGTKYYSEYYTWFLFIFCYIVP--LSLICFSYSQLLGAL 228
Pig               SRF-LPEGLQCS--CG-PDWYTVGTKYYSEYYTWFLFIFCYIVP--LALICFSYSQLLRAL 230
Galagoψ           S*F-IPEGLQCSFXWG-PSYYHXGTKYYHEYYTWFLFIFCFIVL--LSLICFSYSQLLGXL 215
lorisψ            --F-IPKGLQCS--CG-PNWYTVGTKYYSEYCAWFLFIFCFILP--LSLICFSYSQLLGAL 197
Dolphinψ          SRF-APEGLQCS--X-----XTVGTKYYSEYYTWFLFIFCYTVP--LSLICFSYSQLLGVF 224
beaked whaleψ     SRF-VPEGLQCP--CG-PNWYTVGTKYYSEYYTWFLFIFCYIVX--LSLICFSYSQLLGVF 221
humpback whaleψ   SRF-VPKGLQCS--CG-PDWYTVGTKYYSEYYTWSLFIFCYIVP--LSLICFSYSQLLGVF 224
pilot whaleψ      SRF-VPEGLQXS--C------TVGTKYYSEYYTWFLFIFCYTVPLXLSLICFSYSQLLGVF 205
harbor sealψ      SRF-IPEGLQCS--CG-PDWYPVGTKHRSEYYTWFLFIFCFXVP--LSLICFSYSQLLGAL 224
harp sealψ        SRFXIPEGLQCS--CGXPTRYPVGTKHXNEYYTWSL-IXCXRVP--LSLICFSYSQLLXAL 226
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Fig. S1. (continued).

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Goldfish            RAVA-AQQAE-SASTQKAEKEVSRMVVVMVGSFVVCYGP-YAITALYFSYAEDSNKDYRLV 281
Zebrafish           RAVA-AQQAE-SESTQKAEREVSRMVVVMVGSFVLCYAP-YAVTAMYFANSDEPNKDYRLV 281
Tilapia             RAVA-AQQAE-SASTQKAEKEVSRMIIVMVGSFVTCYGP-YALAALYFAYSTDENKDYRLV 281
Medaka              RAVA-AQQAE-SASTQKAEKEVSRMIIVMVASFVTCYGP-YALTAQYYAYSQDENKDYRLV 281
Pearleyeψ           ---A-AQQAE-SASTQKAEREVSRMIVMTVGSYVTCSGP-YAIAALYFATSTDENKDYRLV 257
Guppy               RAVA-AQQAE-SASTQKAEKEVSRMIIVMVGSFVTCYGP-YALTGLWYANSEEVNKDYRLV 281
Salmon              RAVA-AAQAE-SASTQKAEKEVSRMVIVMVCSFILCYGP-YALAGLYFAYTTSENKDYRLV 281
Lampfish            RAVA-AQQAE-SASTQKAEKEVSRMIIVMVGSFITCYGP-YAIAALYFANSTDENKDYRLV 281
Cichlid-Nbriψ       RAVA-AQQAE-SASTQKAEKEVSRMIIVMVGSFVTCYGP-YALAALYFAYSTEENKDYRLV 281
Cichlid-Nmonψ       RAVA-AQHAE-SASTQKAEKEVSRMIIVMVGSFVTCYGP-YALAALYFAYSTEENKDYRLV 282
coelacanth-Lmenψ    HTX*VAKQQEQSASAQKAEREVXKMVIVMVLGFLMCWLP-YASFALWVITHRGEPFDLRMA 283
coelacanth-Lchaψ    -----------SASTQKAEREVTKMVIVMVLGFLMCWLP-YASFALWVITHRGEPFDLRMA 226
Frog                RAVA-AQQQE-SASTQKAEREVSRMVIFMVGSFCLCYVP-YAAMAMYMVTNRNHGLDLRLV 283
Chameleon           RAVA-AQQQE-SATTQKAEREVSRMVVVMVGSFCLCYVP-YASLAMYMVNNRDHGLDLRLV 283
Pigeon              RAVA-AQQQE-SATTQKAEREVSRMVVVMVGSFCLCYVP-YAALAMYMVNNRNHGLDLRLV 283
Human               KAVA-AQQQE-SATTQKAEREVSRMVVVMVGSFCVCYVP-YAAFAMYMVNNRNHGLDLRLV 285
bat-Taus            RAVA-AQQQE-SASTQKAEREVSRMVVVMVGSFCLCYVP-YAALAMYMVNNRNHGLDLRLV 272
bat-Mful            RAVA-AQQQE-SASTQKAEREVSRMVVVMVGSFCLCYVP-YAALAMYMVNNRNHGLDLRLV 246
bat-Raffψ           RAVA-AEQQQ-XTLTQKAEQ-VSHMVVGTVGSFCLRYVP-YAALTMSMVNSHPHGLDLQLV 256
bat-Rferψ           RAVA-AEQQ*-XTWTQMAEQ-VRHMVVGTVGSFCLWYVP-YAALTMSMVNSHPHGLDLRLV 249
Brown lemur         RAVA-AQQQE-SATTQKAEREVSRMVVVMVGSFCLCYVP-YAALAMYIVNNRNHGLDLRLV 286
aye-aye             RAVA-AQQQE-SATTQKAEREVSRMVVVMVGSFCLCYVP-YATLAMYMVNNRNHGLDLRLV 285
Dog                 RAVA-AQQQE-SASTQKAEREVSRMVVVMVGSFCLCYTP-YAAMAMYMVNNRNHGLDLRLV 285
Bovine              RAVA-AQQQE-SASTQKAEREVSHMVVVMVGSFCLCYTP-YAALAMYIVNNRNHGVDLRLV 286
Pig                 RAVA-AQQQE-SASTQKAEREVSHMVVVMVGSFCVCYTP-YAALAMYIVNNRNHGVTLRLV 288
Galagoψ             RDVA-AQQQE-SAMTHKAEREVSHMVVLMVGSFCXCYVPXYAALAMYVVNNSNHGRDLLLV 274
lorisψ              RAVA-VQQQ-----AHKAEQ-MSHMVVVMVGSFCXCYML-YAALAMYMVNNCNHGLDLLFV 250
Dolphinψ            RAVA-AQQQE-AATTQKAGREVSHKVVMMVGSFCLCYTP-YAALAMYIVNNHNHGVDLRFV 282
beaked whaleψ       RAV--TQQQE-SGTTQKAEREMSHMVVMMVGSFCLCYTP-CAALPMYIVNNRNHGVDLRFV 278
humpback whaleψ     RAV--TQQQE-SATTQKAEREVSHTVVMMVGSFCLCCTP-YAALAMYIVNNHNHGVDLRFV 281
pilot whaleψ        RAV--TQQQE-AATTQKAGREVSHKVVMMVGSFCLCYTP-YAALAMYIVNNHKQGVDLRFV 262
harbor sealψ        RAV--TQQQE-SASTQKAEREVSRTVVVMVGSLCLCYTP-YAAMAMDMVNNRNHGLDLRLV 281
harp sealψ          RAV--TQQQE-SASTQKAEREVSRTVVVMVGSLCXXYTP-YAAMAMDMVNNRNHGLHLRLV 283
```

Fig. S1. **(**continued).

```
Goldfish            AIPSLFSKSSCVYNPLIYAFMNKQFNACIMETVFGKKIDESSEVSS---KTETSSVSA       336
Zebrafish           AIPAFFSKSSCVYNPLIYAFMNKQFNACIMETVFGKKIDESSEVSS---KTETSSVSA       336
Tilapia             TIPAFFSKSSCVYNPLIYVFMNKQFNGCIMEMVFGKKMDESSEVST---KTEVSTAS        335
Medaka              TIPAFFSKSSCVYNPLIYAFMNKQFNGCIMEMVFGKKMEEASEVSS---KTEVSTAS        335
Pearleyeψ           TIPAFFSKSACVYNPLIYAFMNKQFNACIMETVLGRKIEEASEMSS---KTDGSSVSSTDS    315
Guppy               TIPAFFSKSSCVYNPLIYAFMNKQFNACIMEMVFGKKMEEASEVSS---KTEVSTAS        335
Salmon              TIPAFFSKSSCVYNPLIYAFMNKQFNACIMETVFGKQIEETS-VSAS--KTEVSTA         334
Lampfish            TIPAFFSKSSCVYNPLIYAFLNKQFNACIMETVFGKKMEDASEVSS---KTGVSSVSTAS     338
Cichlid-Nbriψ       TIPAFFSKSACVYNPLIYVFMNKQFNGCIMEMVFGKTMDESSEVST---KTEVSTAS        335
Cichlid-Nmonψ       XIPAFFSKSACVYNPLIYVFMNKQFNGCIMEMVFGKTMDESSEVST---KTEVSTAS        336
coelacanth-Lmenψ    SIPSVFSKASTVYNPIIYIFMNKQ                                        307
coelacanth-Lchaψ    SIPSVFPK                                                        234
Frog                TIPAFFSKSSCVYNPIIYSFMNKQFRGCIMETVCGRPMSDDSSVSSTSQRTEVSTVSSSQVSPA 347
Chameleon           TIPAFFSKSSCVYNPIIYCFMNKQFRACILETVCGKPMSDESDVSSSAQKTEVSSVSSSQVSPS 347
Pigeon              TIPAFFSKSSCVYNPIIYCFMNKQFRACILELVCGRPMTDDSDVSSSAQRTEVSSVSSSQVSPS 347
Human               TIPSFFSKSACIYNPIIYCFMNKQFQACIMKMVCGKAMTDESD-TCSSQKTEVSTVSSTQVGPN 348
bat-Taus            TIPAFFSKSSCVYN                                                  286
bat-Mful            TIPAFFSKSACV                                                    258
bat-Raffψ           TIPAFFSKSAGVSN                                                  270
bat-Rferψ           TIPAFFSKSACVYN                                                  263
Brown lemur         TIPAFFSKSACVYNPIIYCFMNKQFQACIMEMVCGKAMTDESNTSSS-QKTEVSTFSSSQVGPN 349
aye-aye             TIPAFFSKSACVYNPIIYCFMNKQFQACILGMVCGKAVTDESDTSSS-WKMQVSTVSSSQVGPN 348
Dog                 TIPAFFSKSACVYNPIIYCFMNKQFRACIMEMVCGKSMTEDSEMSSS-QKTEVSTVSPSQVGPN 348
Bovine              TIPAFFSKSACVYNPIIYCFMNKQFRACIMEMVCGKPMTDESELSSS-QKTEVSTVSSSQVGPN 349
Pig                 TIPAFFSKSACIYNPIIYCFMNKQFRACIMEMVCGKPMTDESDMSSS-QKTEVSTVSSTQVGPN 351
Galagoψ             TIPAFFSKSACVYNPPIYCFMSKQFQACIMEMVCRKALTDESNIFSP-QKTEVSILSSSHVGPI 337
lorisψ              TIPAFFSKSACVYNPII-CFMNKQFQACIMEMVCRKDVTDESDIFSP-QKMEVSILF         305
Dolphinψ            TIPSFFSKSACIYNPIIYCFMNKQFQACIMKMVCGKAMTDESDTCSS-QKTEVSTVSSTQVGPN 345
beaked whaleψ       TIPAFFSKSX                                                      289
humpback whaleψ     TIPAFFSKSACVYNPIIYCFMNKQFRACIMEMVCGKPMTDESDMSSS-QKMEVPTVSSSQVGPN 344
pilot whaleψ        TIPAFFPKSACVYNPIIYCFMNKQFQACIMEMVCGRPMTDESDMSSS-QKMEVSTVXSSQVGPN 325
harbor sealψ        TIPAFFSKSACVYNPIIYCFMNKQFRACIMEMVCGKSMTDDSEMSSS-QKTEVSTV          336
harp sealψ          TIPAFFFKSACVYNPIIYCFMNKQFRACITEMVCGKSMTDDSEMSSS-QKTEVSTVKP        340
```

Fig. S1. (continued).

A

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31  264

HrbrPorpoi
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gccttcctgggctgtacagcaggt
vaquita-S1
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gccttcctgggccgtacagcaggt
WhaleDolph
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```

Fig. S2. Data set used for detecting positively selected amino acid sites. (A) nucleotide sequence file. (B) tree file.

SpotdDolph
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DolphinSW1
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Fig. S2. **(**continued).

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Fig. S2. **(**continued).

riverdolph
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SpmWhaleS1
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BwhedWhale
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Fig. S2. **(**continued).

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Grey-Whale
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B

```
   31  1


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(DolphinSW1,stripedDol,SpotdDolph,(saddleDolp,CommonDolp)),(F
killWhale,SFpiltWhal),FrasersDol,humpbckDol,spinnerDol,rfTthd
Dolp)),beluga--S1),(AmazonDolp,LaPlataDol)),(SbeakdWhal,
BeakdWhale)),riverdolph),(PgSprmWhal,SpmWhaleS1)),((BwhedWhal
e,rightWhale),(minkeWhale,((bluewhalS1,humpbackS1),Grey-
Whale))),(HrbrSealS1,HarpSealS1));
```

Fig. S2. (continued).