Supplementary Material

Measuring post-reproductive lifespan

An extensive literature search was conducted to identify all wild mammalian species for which reliable PRLS data is available using the following search term in Google Scholar (where … is substituted for each mammalian taxonomic order): "Post reproductive lifespan" OR PRLS OR Menopause OR "Reproductive cessation" AND "…" . When a hit was found for a given order, the search term was repeated for each genus within that order, and resulting hits were examined individually to assess the information contained in each.

We made an effort to standardise definitions of PRLS since most of our source publications used different methods and criteria. PRLS was quantified in two ways: 1. The average interval between last birth and death (only for females whose span between last live birth and death exceeded that of their own average inter-birth interval, plus two standard deviations). 2. The maximum lifespan minus the average age at reproductive cessation (where reproductive cessation was confirmed through the cessation of menstrual cycle, changes in ovarian anatomy, low/erratic progesterone levels or the absence of pregnancies in a population). Table S1 details the ways in which PRLS was determined for each study population. We note that definition 2, which considers the maximum lifespan and average age at reproductive cessation, could feasibly lead to a bias in which better sampled populations are more likely to find a particularly long-lived individual which leads to inference of PRLS being present. However, our data suggest that this is not a problem here as the median sample size for species found to have PRLS was actually slightly lower than that for species lacking PRLS (medians of 184 and 257 respectively). Also, the overall distributions of sample size in these two groups were greatly overlapping, again suggesting that we are not seeing such a bias. Nevertheless we stress that this measure more accurately reflects the presence of PRLS in some individuals within the population, rather than implying that it is commonly experienced by individuals (the prevalence within the population was also recorded – see below).

In order to measure the duration of PRLS, we calculated the proportion of maximum lifespan spent post-reproductive. This allowed us to include all species that show PRLS. In contrast, using the mean period post-reproductive would under-estimate the occurrence of PRLS in species with high early-life mortality, even when a substantial number of females showed PRLS (Cohen 2004). We therefore chose to measure intrinsic PRLS, even if it is realised in a relatively small (but non-zero) proportion of individuals. Data were also collected from the literature on the proportion of females experiencing PRLS.

While we considered using a combined index for PRLS, such as Levitis and Lackey's (2011) measure: PrR, this measure was not used for two reasons. First, the calculation of PrR requires life-history tables, which are not available for the vast majority of wild species. Second, by independently analysing three separate aspects of PRLS (presence, relative duration, and frequency) we are able to reveal factors that influence these components separately. In contrast, combining these different (and independent) aspects into one index, such as PrR, could easily obscure variation in one element of PRLS and also fails to acknowledge that different reasons could be behind these different aspects of the trait.

References

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Levitis, D.A. and Lackey, L.B. (2011). A measure for describing and comparing postreproductive life span as a population trait. *Methods in Ecology and Evolution*, 2(5), 446-453.

Table S1. Life-history data obtained from the literature. Numbers after values indicate the literature source of the data. Mating system data are abbreviated to pg: polygynous, pga: polygynandrous, mg: monogamous. PRLS definitions are coded as follows: (1) average interval between last birth and death, only for females whose span between last live birth and death exceeded that of their own average inter birth interval plus 2 SD; (2) maximum lifespan minus age at reproductive cessation. For definition 2, reproductive cessation was defined through (a) cessation of menstrual/oestrous cycle (b) changes in ovarian/uterine anatomy (c) last birth/ no more pregnant females / no more females with offspring recorded (d) low/erratic progesterone levels (e) no decrease in pregnancy rate with age (f) no changes in ovarian anatomy/ oestrous cycle recorded (g) substantial decrease in pregnancy rate with age (but no data available on individual females - there may be PRLS, or alternatively, just reduced success shortly before death)

Species	**PRLS present**	**Relative duration PRLS (% max. lifespan)**	**Maximum lifespan**	**Mean group size**	**Frequency of PRLS (%)**	**Philopatry**	**Type of study population**	**Sample size**	**Definition of PRLS**	**Comments**
Primates										
Common marmoset *Callithrix jacchus*	yes[1]	21.15[1]	10[1]	9[2]	36.4% (of females reaching middle age)[1]	none[3, 4]	captive	14[1]	1	Not included in analyses as data is from a captive population.
Vervet monkey *Chlorocebus*	no[1]	NA	17[1]	40.5[2]	NA[1]	female[2]	captive	12[1]	1	Not included in analyses as data is from a captive

aethiops										population.
Western lowland gorilla *Gorilla gorilla*	yes[5]	20[5]	50[5]	12[2]	NA	none[2]	captive	NA	2d	Not included in analyses as data is from a captive population.
	yes[1]	15.11[1]	30[1]	12[2]	40% (of females reaching middle age)[1]	none[2]	captive	12[1]	1	Not included in analyses as data is from a captive population.
	yes[63]	16.15[63]	52[63]	12[2]	23% (of geriatric females)[63]	none[2]	captive	22[63]	2a	Mean age of acyclic females (43.6) used as onset PRLS. Not included in analyses as data is from a captive population.
Golden lion tamarin *Leontopithecus rosalia*	yes[1]	32.22[1]	12[1]	9[2]	47.4% (of females reaching middle age)[1]	none[2]	captive	21[1]	1	Not included in analyses as data is from a captive population.

Japanese macaque *Macaca fuscata*	yes[6]	13.64 (mean PRLS 4.5 years)[6]	33[6]	47.25[66]	50% (of old females)[6]	female[2]	wild (provisioned)	33 (total females), 14 old aged females (20+ years)	1*	* PRLS is defined as interval between last birth and death minus average period of offspring dependency (1.5 years). Not included in analyses as data is from a provisioned population and we have data on a non-provisioned wild population (see next row).
	yes[6]	18 (mean PRLS 3.6 years)[6]	20[6]	47.25[66]	28.6% (20 of 70 females experienced post reproductive lifespan)[6]	female[2]	wild (non-provisioned)	9 old aged females (15+ years)	1*	* PRLS is defined as interval between last birth and death minus average period of offspring dependency (1.5 years).
Rhesus macaque *Macaca mulatta*	yes[1]	12.90[1]	20[1]	30[2]	13.2% (of females that reached middle age)[1]	female[2]	captive	38[1]	1	Not included in analyses as data is from a captive population.

Pigtail macaque *Macaca nemestrina*	yes[1]	20.11[1]	20[1]	27.5[2]	25.6% (of females that reached middle age)[1]	female[2]	captive	209[1]	1	Not included in analyses as data is from a captive population.
Bonnet macaque *Macaca radiata*	yes[1]	35.28[1]	19[1]	27.5[2]	3.8% (of females that reached middle age)[1]	none[2]	captive	26[1]	1	Not included in analyses as data is from a captive population.
Barbary macaque *Macaca sylvanus*	yes[7]	21.43[7]	28[7]	35.5[2]	NA	female[2]	captive	NA	2a	Not included in analyses as data is from a captive population.
Ring-tailed lemur *Lemur catta*	no[67]	NA	17[65]	11.5[64]	NA	female[70]	wild	77[65]	2e	No significant decline in birth rate between middle aged females (4-11 years): 80.2% and old aged females (12-17 years): 72%
Mouse lemur *Microcebus*	no[8]	NA	14[8]	1[2]	NA	none[10]	captive	NA	NA	Not included in analyses as data is from a captive

murinus										population.
Chimpanzee *Pan troglodytes*	yes[11]	16.75 (based on average PRLS of 8.38)[11]	50[11]	74[11]	23.5% (of old females)[11]	male[2]	wild	34 old females[11]	1*	*Interval between last birth and death minus period of offspring dependency (5 years) Not included in analyses of frequency of PRLS as we couldn't determine the proportion of the population, only "of old females".
	yes[1]	19.28[1]	48[1]	74[11]	60% (of females that reached middle age)[1]	male[2]	captive	15[1]	1	Not included in analyses as data is from a captive population.
	no[62]	NA	NA (last birth with 55)[62]	74[11]	NA	male[2]	wild	165[62]	NA	47% of females that lived beyond 40 years reproduced successfully. Chimpanzee fertility declines are consistent with

										declines in survivorship, and healthy females maintain high birth rates late into life. Not used for analysis due to the definition used being a measure of the population, not individuals, but PRLS is an individual trait. In essence, the individual-level data should better reflect the occurrence of PRLS than population-level measures.
Olive baboon *Papio anubis*	yes[12]	11.11 (fertility ceases at 24 years)[12]	27[12]	50[2]	NA	female[2]	wild	NA	2a	
Orangutan *Pongo*	yes[1]	18.64[1]	38[1]	2[2]	31.9% (of females that reached	none[2]	captive	53[1]	1	Not included in analyses as data is from a captive

pygmaeus					middle age)[1]					population.
Milne-Edward's sifaka *Propithecus diadema edwardsi*	no[13]	NA	32[13]	6[2]	NA	female[2]	wild	NA	2f	
Saddleback tamarin *Saguinus fuscicollis*	yes[1]	33.54[1]	12[1]	6.5[2]	47.4% (of females that reached middle age)[1]	none[14]	captive	6[1]	1	Not included in analyses as data is from a captive population.
	yes[15]	16.67[15]	20.4[15]	6.5[2]	100% (of old females *)	none[14]	captive	6[15]	2a,2b,2d	*Both of 2 old females had PRLS. Not included in analyses as data is from a captive population.
Cotton-top tamarin *Saguinus oedipus*	yes[15]	6.59[15]	18.2[15]	8[2]	100% (of old females *)	none[16]	captive	6[15]	2a,2b,2d	*All 4 old females had PRLS. Not included in analyses as data is from a

										captive population.
Hanuman Langur *Semnopithecus entellus*	Yes[17]	14.57 (5.1 average PRLS)[17]	35[17]	38.5[17]	16.13 % (includes all observed females, not only aged females)	female[17]	Wild (1/3 of foraged food provisioned)	31	1	Relative duration PRLS calculated using average PRLS (5.1 years)
Squirrel monkey *Saimiri sciureus*	yes[1]	17.29[1]	19[1]	32[2]	32.1% (of females that reached middle age)	female[2]	captive	28[1]	1	Not included in analyses as data is from a captive population.
Humans *Homo sapiens* Ache people, Paraguay	yes[58]	45.45[58]	77[58]	168[58]	-	male[102]	wild	292[58]	2a	
!Kung Bushmen, Botswana	yes[59]	60.23[59]	88[59]	35[61]	80%[59]	male[102]	wild	500[59]	2a	

(Krummhorn, Germany, 18th & 19th Century)	yes[1]	30.18[1]	97[1]	NA	97% (of females that reached middle age)[1]	male[102]	wild	106[1]	1	
Cetaceans										
Antarctic minke whale *Balaenoptera acutorostrata*	no[18]	NA	50[20]	2[19]	NA	none[19]	wild	>12000[18]	2e	
Antarctic fin whale *Balaenoptera physalus*	no[96]	NA	85[96]	1.56[97]	NA	NA	wild	1422[96]	2e	
Sei whale *Balaenoptera borealis*	no[18]	NA	60[21]	3[19]	NA	NA	wild	1521[18]	2e	

Short-finned pilot whale *Globicephala macrorhynchus*	yes[22]	45.24[22]	63[22]	27.5[19]	25%[24]	both[23]	wild	245[22]	2b, 2c	Relative duration of PRLS calculated based on mean age at onset of PRLS (34.5 years)
Long-finned pilot whale *Globicephala melas*	yes[24]	0.32[24]	59[24]	30[19]	4.4% (of mature females)[24]	both[25, 26]	wild	1070[24]	2a, 2b	
Killer whale *Orcinus orca Northern*	yes[28]	54.44 (50% post reproductive at 41 years)[28]	90[28]	9.7[28]/ 26[8]*	10% of population[28]	both[23]	Wild	63[28]/ 41[28]*	2c	*Northern/ Southern population
Franciscana *Pontoporia blainvillei*	no[30]	NA	19[30]	NA	NA	female[32]	Wild	97[30]	2f	
False killer whale	yes[18]	NA	NA	30[19]	17.91% (of all mature	female[68]	wild	67 (mature females)[1]	2c	

Pseudorca crassidens					females)[18]			[8]		
Estuarine dolphin *Sotalia guianensis*	yes[33]	16.67[33]	30[34]	12.4[35]	NA	NA	wild	23[33]	2b	
Spinner dolphin *Stenella longirostris*	yes[98]	NA	536[98]	211[69]	0.74% (of adult females)[101]	Variable[70]	wild	536[98]	2b	Not used as data are extremely uncertain as to whether PRLS exists in this species. Although reported to have PRLS this is based on data from non-aged individuals that could have been pathological aberrations of ovaries.
Spotted dolphin *Stenella attenuata*	yes[36]	55.43[36]	46 (mean LS)[37]	252.5[19]	NA	Uncertain[71]	wild	257[36]	2c	

Bottlenose dolphin *Tursiops truncatus*	no[18]	NA	40[18]	13[19]	NA	female[38]	wild	151[18]	2e	
Perissodactyla										
Domestic horse *Equus caballus*	Yes[73]	6.67[73]	45[73]	4.52[72]	NA	none[74]	captive (domestic)	NA	2c	Not included in analyses as data is from a captive population.
Artiodactyla										
Domestic cattle *Bos primigenius Taurus*	yes[40]	25	20[40]	10.5[41]	>50% (infertile at 15 years)	female[42]	captive	152[40]	2c	Not included in analyses as data is from a captive population.
White-tailed deer	no[44]	NA	17.50[44]	3[47]	NA	female[45]	wild	284[44]	2e	

Odocoileus virginianus										
Bighorn sheep *Ovis canadensis*	Yes[75]	5.26[75]	19[75]	10[75]	0.75%[75]	female[78]	wild	265[75]	2c	Evidence of reproductive senescence, evidence of PRLS was indirect but retained as many individuals appeared to stop reproducing. At age 12, ~30% of females produced offspring.
Soay sheep *Ovis aries*	Maybe[91]	NA	12[91]	NA	NA	NA	wild	894[91]	2f	Not used in analysis as data were insufficient to determine whether PRLS occurs in this species. The published data only suggest than decline in reproduction is related to within-individual changes but not whether the change is a cessation of reproduction or

										merely a reduction.
Red deer *Cervus elaphus*	yes[92, 93]	> 9.52[93]	> 21 (females were culled at 21 years)[93]	30[95]	47.5% (of population)[93]	female[98]	captive	40[93]	2c	Approx 5% of females bred at age 20+. The rest had ceased reproducing due to ovarian failure (confirmed by dissection). Not included in analyses as data is from a captive population.
	maybe[94]	NA	18 (very few females live beyond this age)	30[95]	NA	female[98]	wild	551[95]	2f	The species shows a rapid decline in fertility past age 14, but it is not clear whether there is substantial PRLS. By age 17+, 20% of females were still reproducing. Not included in analyses as data are insufficient to differentiate PRLS in individuals from reduction in

										reproductive output with age across the population as a whole.
Carnivora										
Cat *Felis catus*	Yes[82]	30[82]	20[85]	Variable[83] (solitary and group-living)	NA	none[83]	captive (domestic)	NA	NA	Relative duration PRLS is calculated using mean age at reproductive cessation (14 years). Not included in analyses as data is from a captive population.
Polar bear *Ursus maritimus*	yes[48]	33.33[48]	30[48]	1[49]	2.2%*	none[49]	wild	402[48]	2c	*9 non-reproductive females over age 18 in a population of 402[48]
African lion *Panthera*	yes[12]	14.27[12]	19.83[12]	4.64[77]	1.7% (pers. com. Prof C Packer)	female/none[76]	wild	123[12]	2c	

leo										
Banded Mongoose *Mungos mungo*	no[61]	NA	10.50[61]	14[61]	NA	none[61]	wild	NA	1	
Meerkat *Suricata suricatta*	maybe[80]	NA	12[80]	16.7[81]	NA	none[81]	Wild	42 (dominant females)[80]	2f	Substantial reproductive senescence occurs. However, females were still producing on average ~0.5 litters per year at age 12 (maximum age). Not included in analyses as data are insufficient to differentiate PRLS in individuals from reduction in reproductive output with age across the population as a whole

Dog *Canis familiaris*	yes[73]	43.75[73]	16	4[78]	<50%[79]	none[78]	captive (domestic)[73]	NA	2c	Not included in analyses as data is from a captive population
Proboscidae										
African elephant *Loxodonta africana*	no[50]	NA	65[50]	9[51]	NA	female[52]	wild	546 (38 survived reached >50)[50]	2e	
Asian elephant Elephas maximus	Yes[85]	12.5[85]	79.64[85]	8[84]	32.95% (457/1040) live past 40 years: age when 75% of females ceased to reproduce)[85]	female[84]	Mixed[84]	1040[85]	Mean lifespan – mean age at last reproduction	Authors state PRLS present in species. Calculated as interval between average age at last birth and mean lifespan. This data was subdivided into wild and captive individuals, which we describe separately in the following two rows.

	No/maybe[85]	17.01(54 oldest reproducing female) 54.11 (Mean age at last reproduction 29.88) [85]	65.11[85]	8[84]	NA	female[84]	captive	471[85]	1*	When PRLS was calculated using oldest age at last reproduction, interval does not exceed mean IBI + 2SD. * (Mean IBI 5.99 ± 2.99 years). Not included in analyses as data is from a captive population
	Yes [85]	56.49 (mean age at last reproduction 34.65)[85]	79.64[85]	8[84]	32.95% [85]	female[84]	wild	569[85]	1*	Interval between oldest age at last reproduction and death exceeds mean IBI+2SD for wild population. *Mean IBI 5.99 ± 2.99 years
Lagomorpha										
Domestic rabbit *Oryctolagus*	yes[86]	66.67[86]	15[86]	7[90]	NA	female[87]	captive (domestic)	NA	2 (method NR)	Not included in analyses as data is from a captive population

cuniculus										
Rodontidae										
Lab mouse *Mus musculus*	yes[73]	60.00[73]	4.17[73]	1[88]	NA	none[88]	captive (domestic)	NA	2c	Not included in analyses as data is from a captive population
Lab rat *Rattus norvegicus*	yes[76]	52.00[73]	4.17[73]	Variable (solitary when food dispersed, in urban environments mean groups of 22.5) [89]	NA	none[90]	captive (domestic)	NA	2c	Not included in analyses as data is from a captive population
Chinese hamster *Cricetulus*	no[53]	NA	1.75[53]	NA	NA	NA	captive	25 (aged females) [53]	2c, g	Signs of reproductive senscence (reduced litter size, 23% of aged females failed

griseus										to ovulate). However, 60% of aged females still reproduced no oocyte depletion in aged females. Not included in analyses as data is from a captive population
Columbian ground squirrel *Spermophilus columbianus*	no[54]	NA	9[54]	29[57]	NA	female[55]	wild	229[54]	2g	60% of older females (6-9 years) weaned litters successfully

References for Table S1

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Table S2. Results from MCMC GLMMs testing for effects of four natural history variables on the presence/absence of PRLS. We coded the absence or presence of PRLS as having states 0 and 1 respectively and used this as our response variable. Estimated coefficients and 95% confidence intervals are given, and significant predictors are highlighted in bold. N is the number of species included in the model. Species that had missing data for a particular variable were excluded from the relevant models (i.e. those models that included that variable). We considered a variable to be a significant predictor of the presence of PRLS when P≤0.05.

natural history variable	β	lower 95% CI	upper 95% CI	P	N
Maximum lifespan	3.186	-1.872	9.211	0.190	27
Group size	1.740	-0.062	3.504	0.073	26
Male philopatry	**340.523**	**39.603**	**632.792**	**0.018**	**25**
Female philopatry	-59.950	-375.380	292.930	0.692	25

Table S3. Results from GEEs testing for effects of four natural history variables on the relative duration of PRLS and on the frequency with which PRLS is experience in the population. Estimated coefficients (± SE) are given, and significant predictors are highlighted in bold. Species that had missing data for a particular variable were excluded from the relevant models (i.e. those models that included that variable). N is the number of species included in the model.

Response term	Natural history variable	β±SE	t	P	N
Relative duration of PRLS	**Maximum lifespan**	**0.038±0.011**	**3.482**	**0.007**	**25**
	Group size	0.009±0.005	1.841	0.100	24
	Male philopatry	1.394±0.676	2.063	0.071	22
	Female philopatry	**-1.573±0.681**	**-2.308**	**0.048**	**22**
Frequency with which PRLS is experienced in population (proportion of females that experience PRLS)	Maximum lifespan	0.0376±0.0159	2.364	0.052	16
	Group size	**0.0515±0.0137**	**3.762**	**0.007**	**17**
	Male philopatry	**1.900±0.786**	**2.418**	**0.047**	**17**
	Female philopatry	-0.914±0.828	-1.104	0.307	17