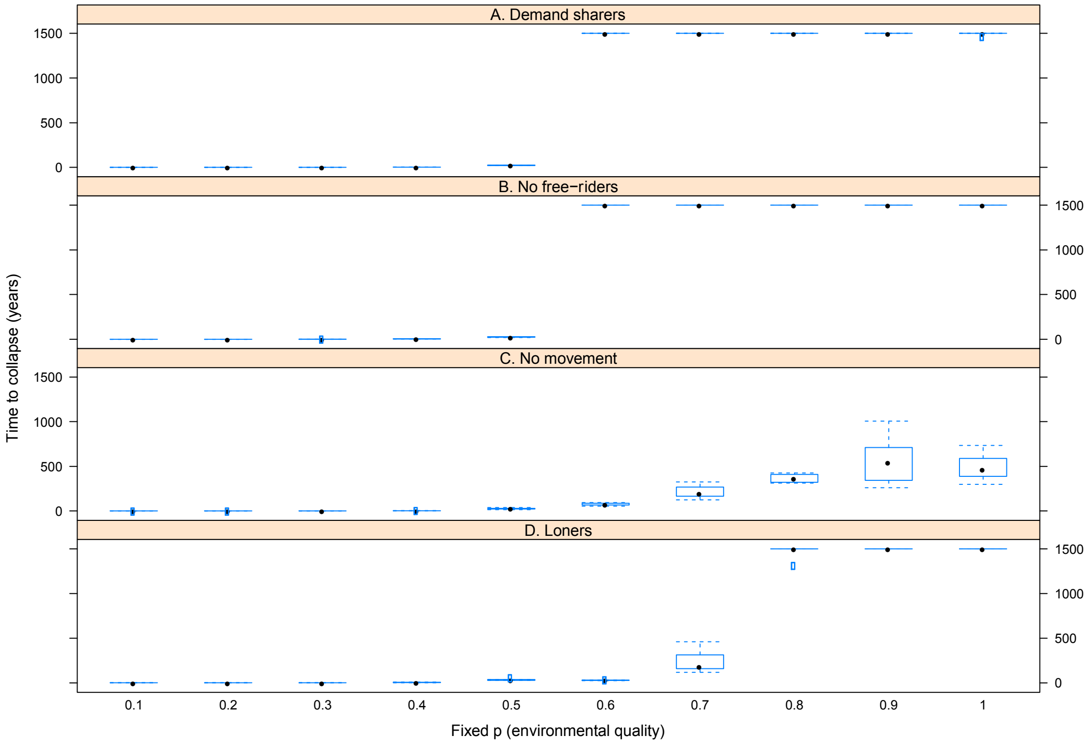
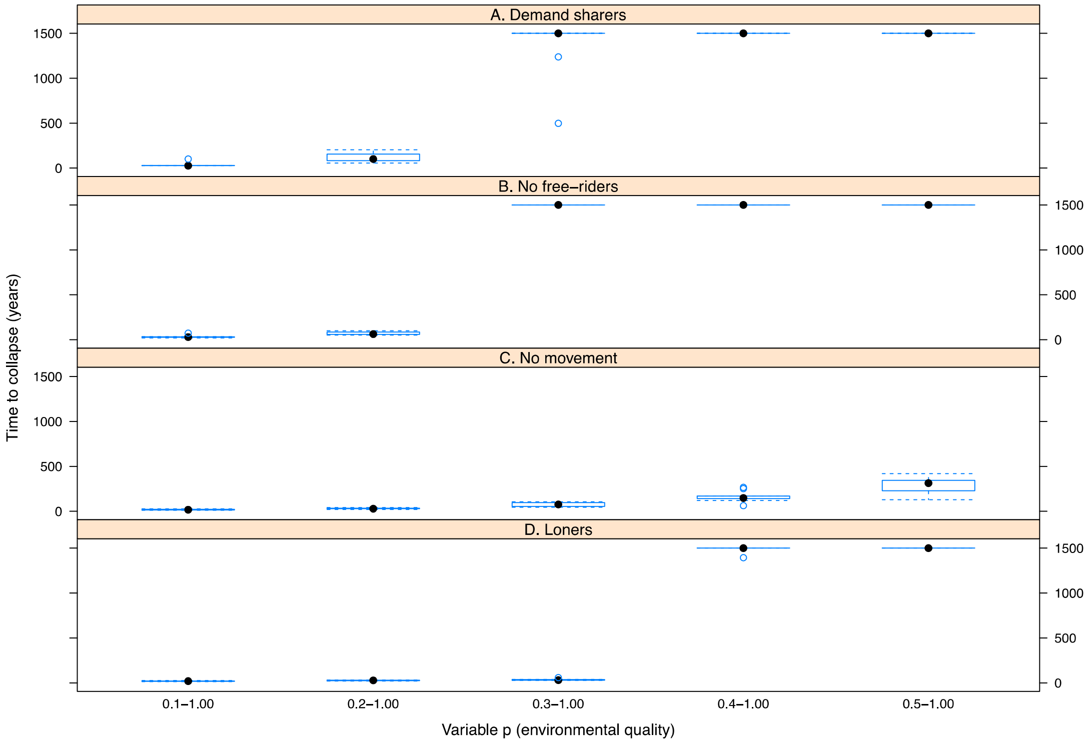
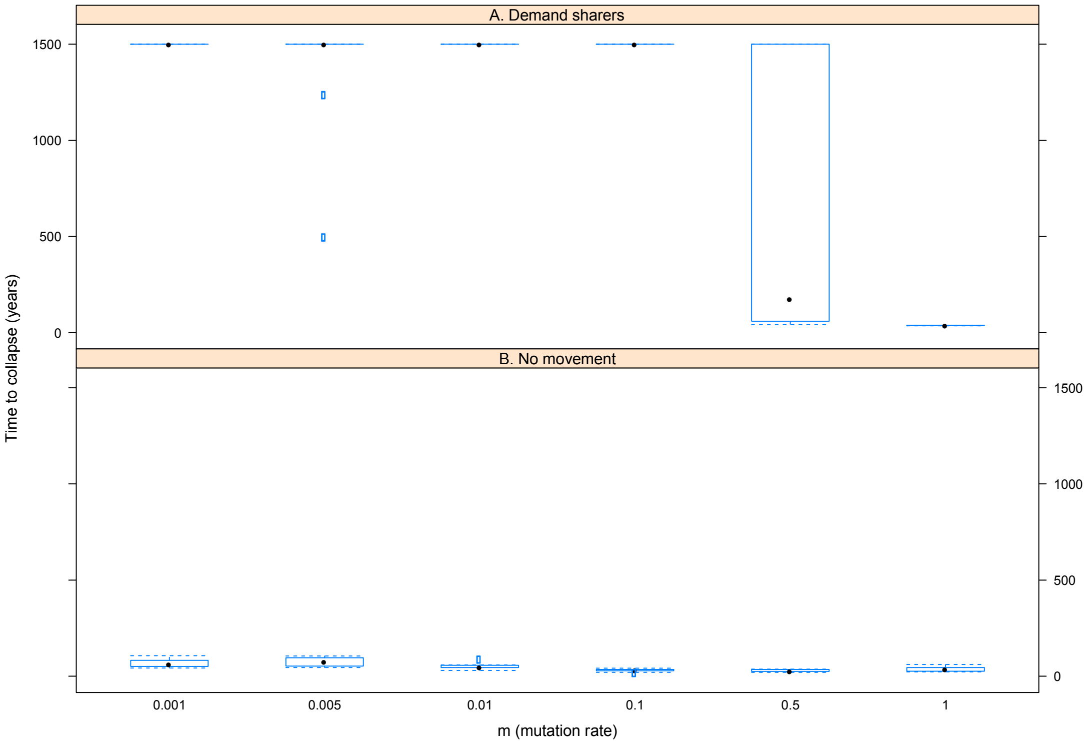


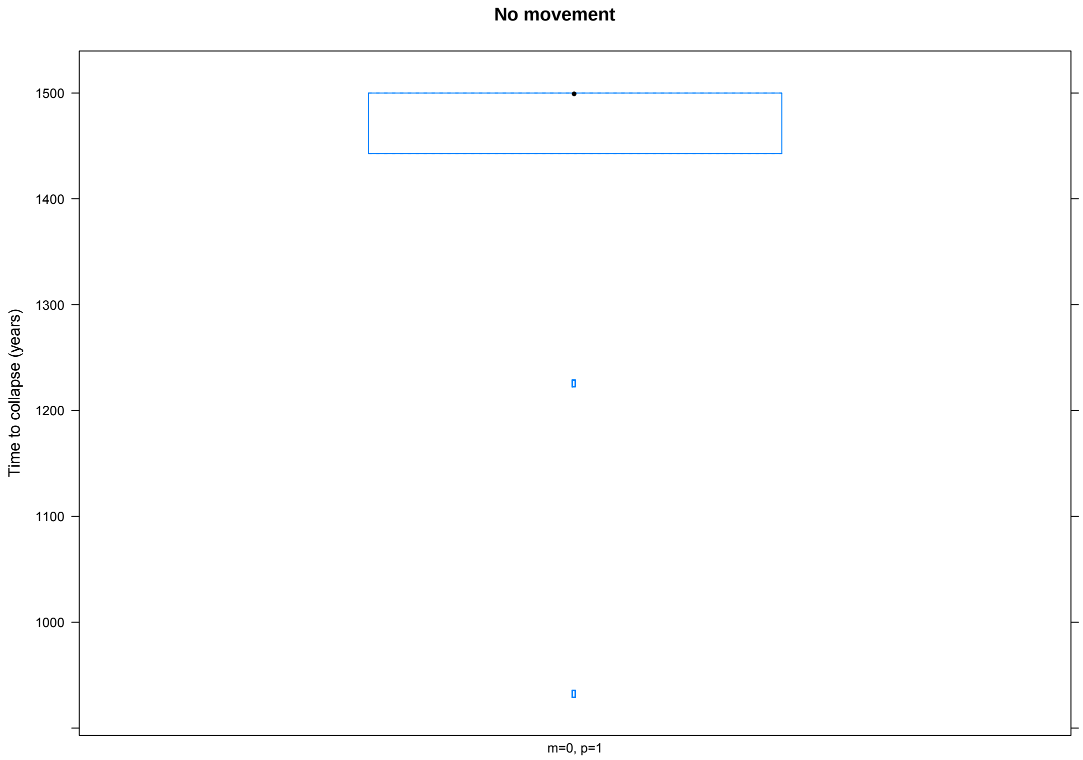
Supplementary Fig. 1. Time to collapse of simulated populations as a function of fixed environmental quality (*p*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



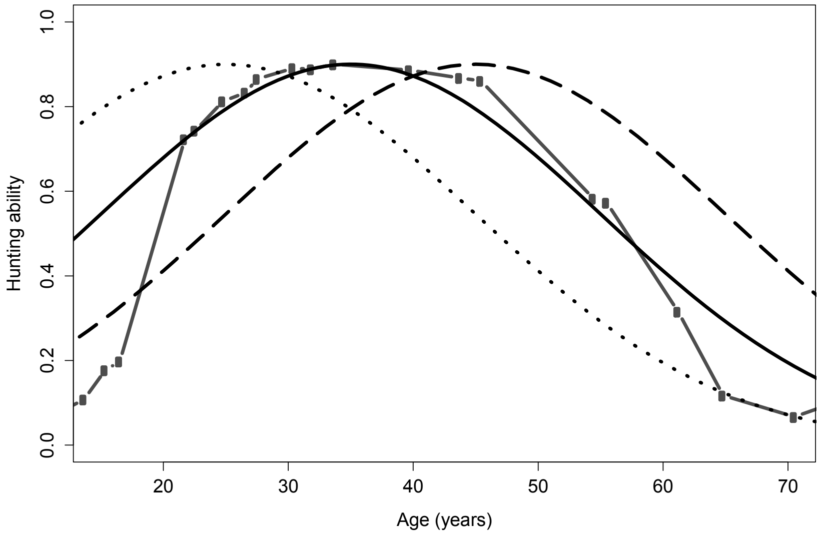
Supplementary Fig. 2. Time to collapse of simulated populations as a function of variable environmental quality (*p*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



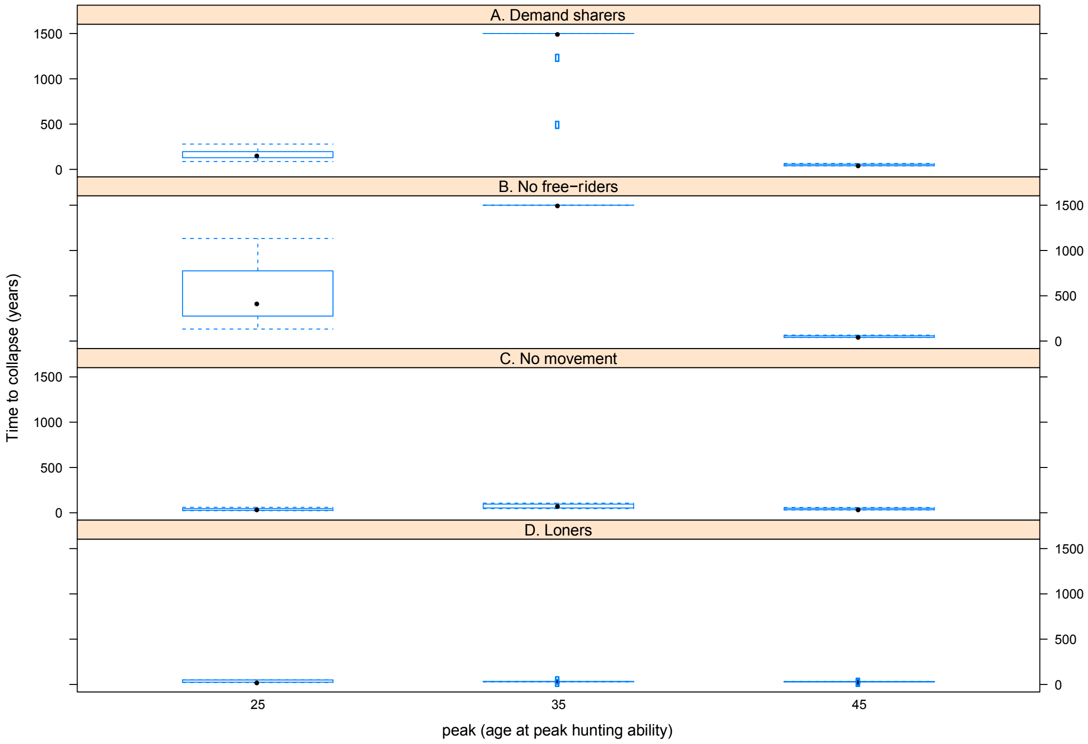
Supplementary Fig. 3. Time to collapse of simulated populations as a function of mutation rate (*m*). Mobile demand sharers with free riders (a) and sedentary demand sharers with free-riders (b). Box plots with central points as median (black dots) for 10 replicates each.



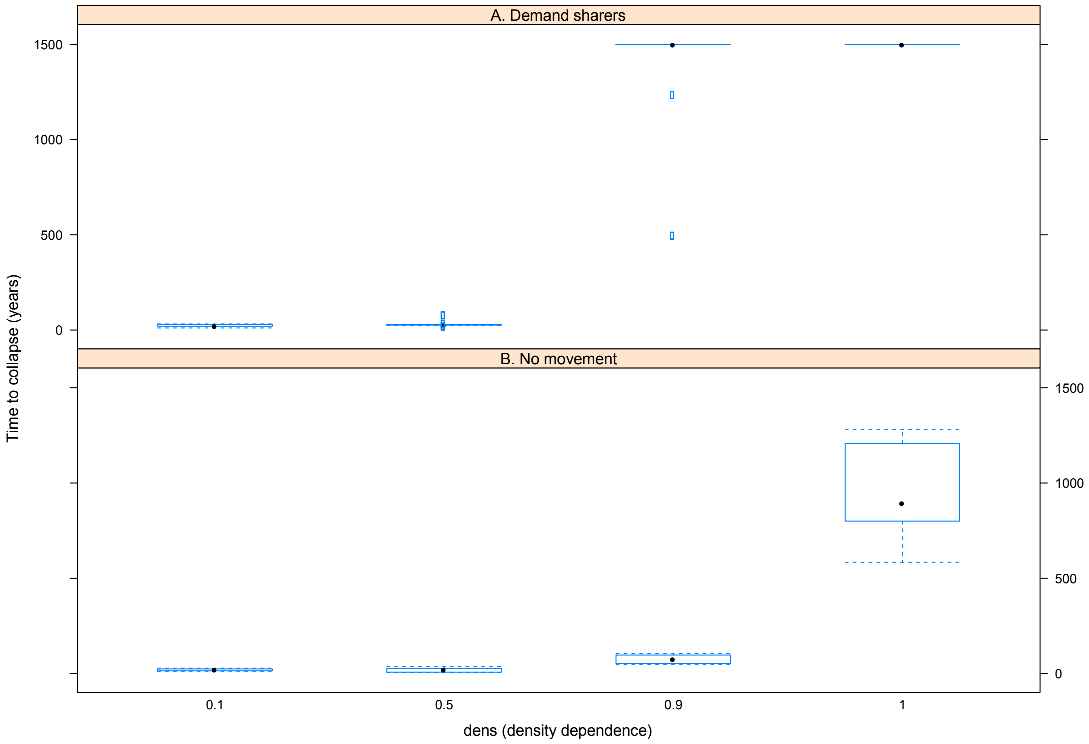
Supplementary Fig. 4. Time to collapse of simulated populations as a function of mutation rate (*m*=0) and environmental quality (*p*=1). Results shown for sedentary demand sharers with free-riders. Box plots with central points as median (black dots) for 10 replicates each.



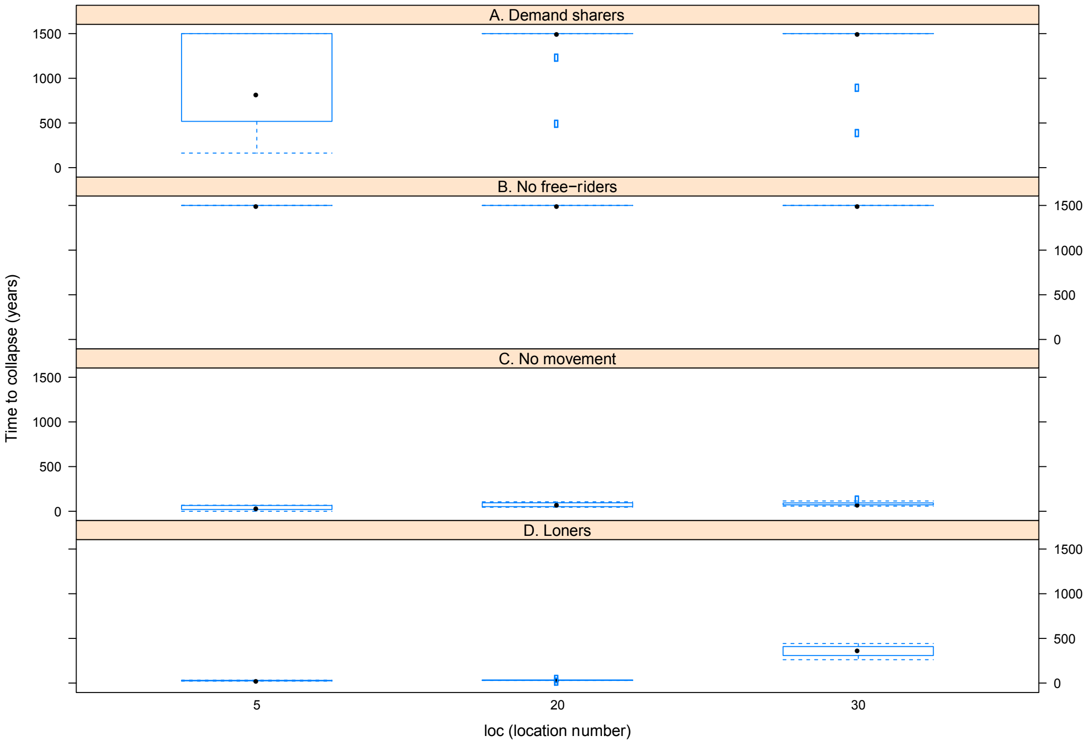
Supplementary Fig. 5. Age specific caloric production rates in real hunter-gatherers and for modelled populations. Daily averages for real hunter-gatherers age specific caloric production (solid line, open circles) from Kaplan *et al.*[1] plotted against modelled curves. Age at peak hunting ability curves shown for parameter *peak* set at 25 years (dotted line), 35 years (solid line) and 45 years (dashed line).



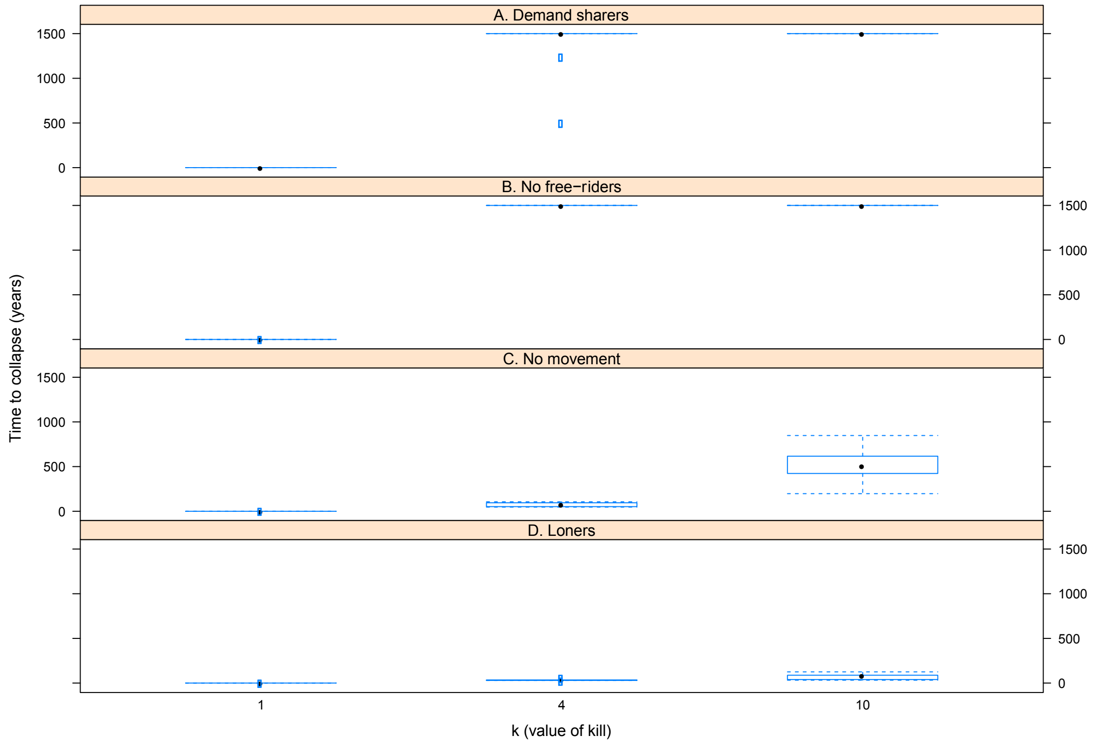
Supplementary Fig. 6. Time to collapse of simulated populations as a function of age at peak hunting ability (*peak*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



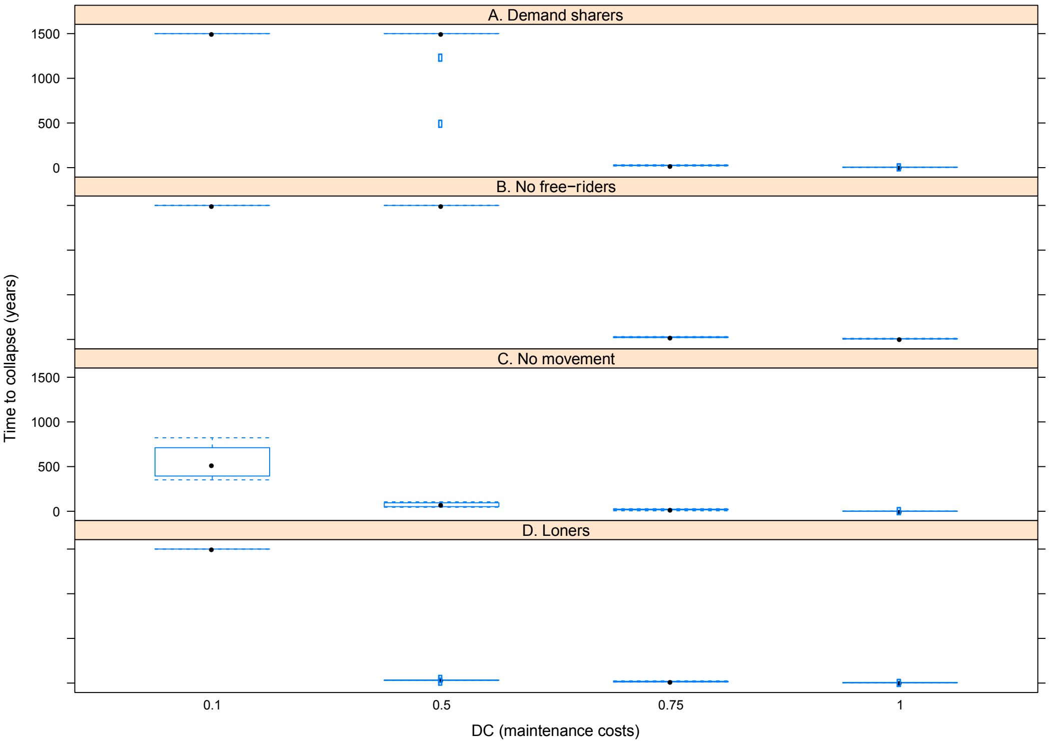
Supplementary Fig. 7. Time to collapse of simulated populations as a function of density dependence (*dens*). Mobile demand sharers with free riders (a) and sedentary demand sharers with free-riders (b). Box plots with central points as median (black dots) for 10 replicates each.



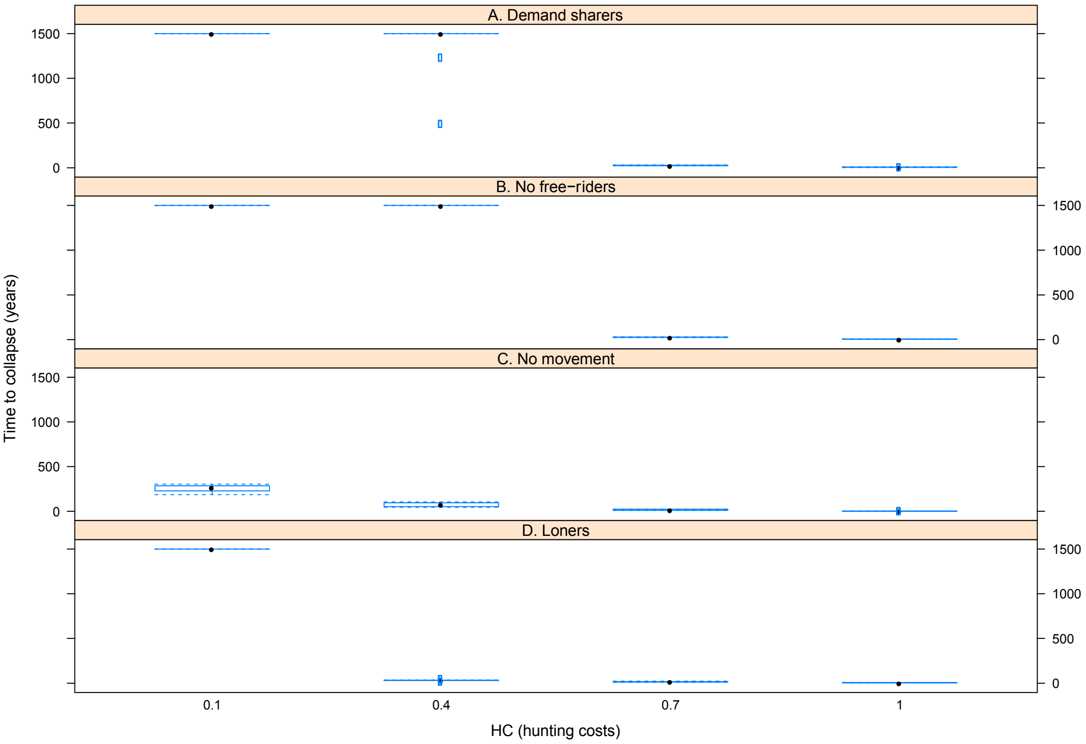
Supplementary Fig. 8. Time to collapse of simulated populations as a function of location number (*loc*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



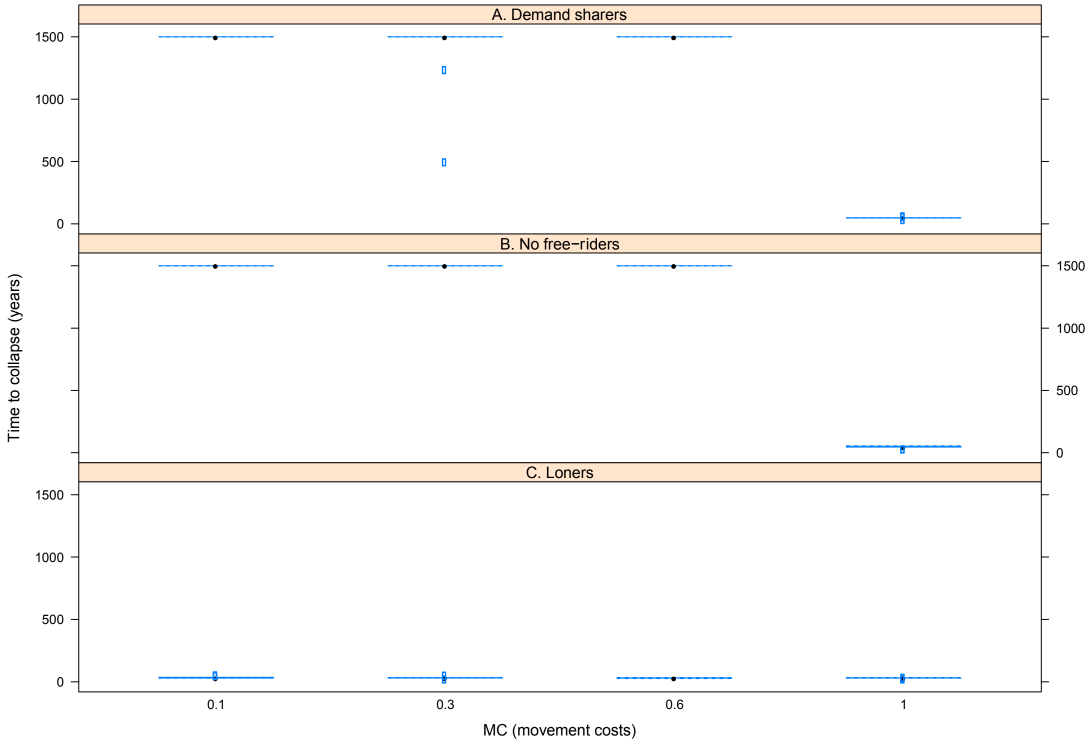
Supplementary Fig. 9. Time to collapse of simulated populations as a function of value of a kill (*k*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



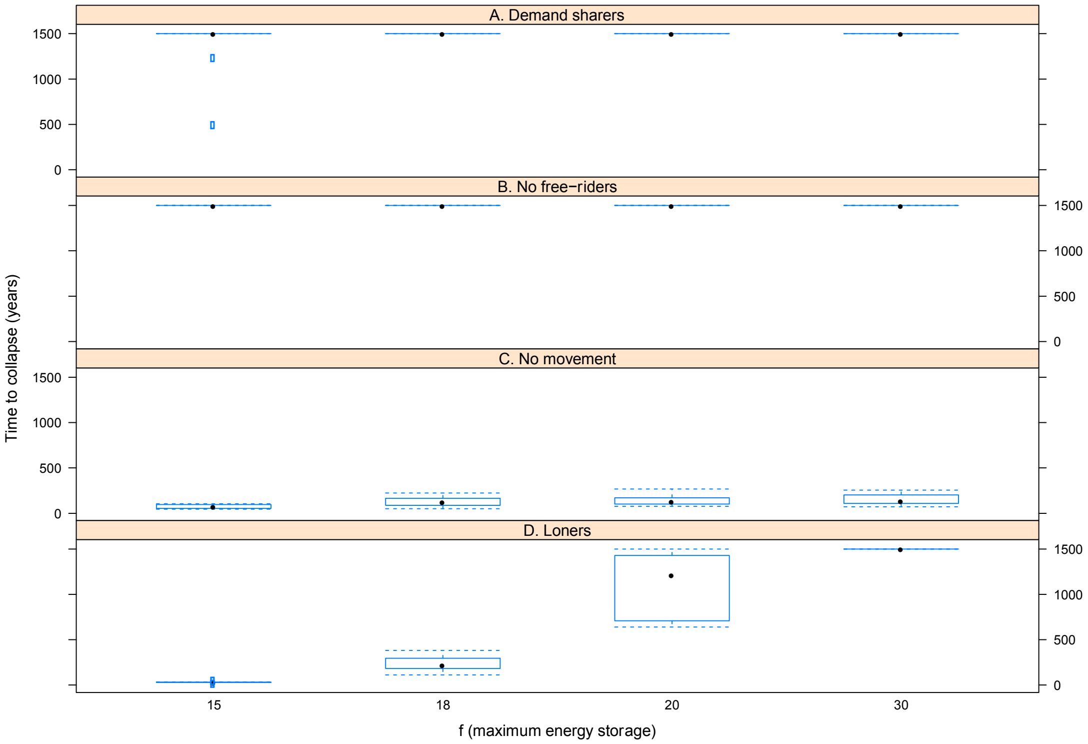
Supplementary Fig. 10. Time to collapse of simulated populations as a function of daily maintenance costs (*DC*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



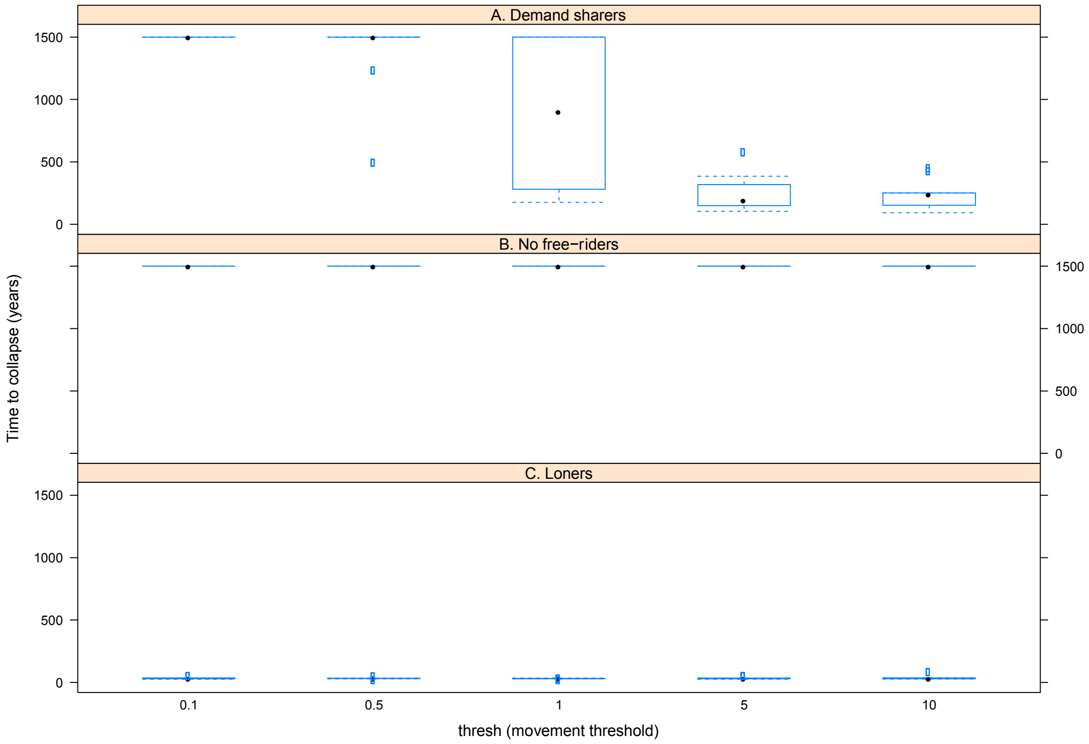
Supplementary Fig. 11. Time to collapse of simulated populations as a function of hunting costs (*HC*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



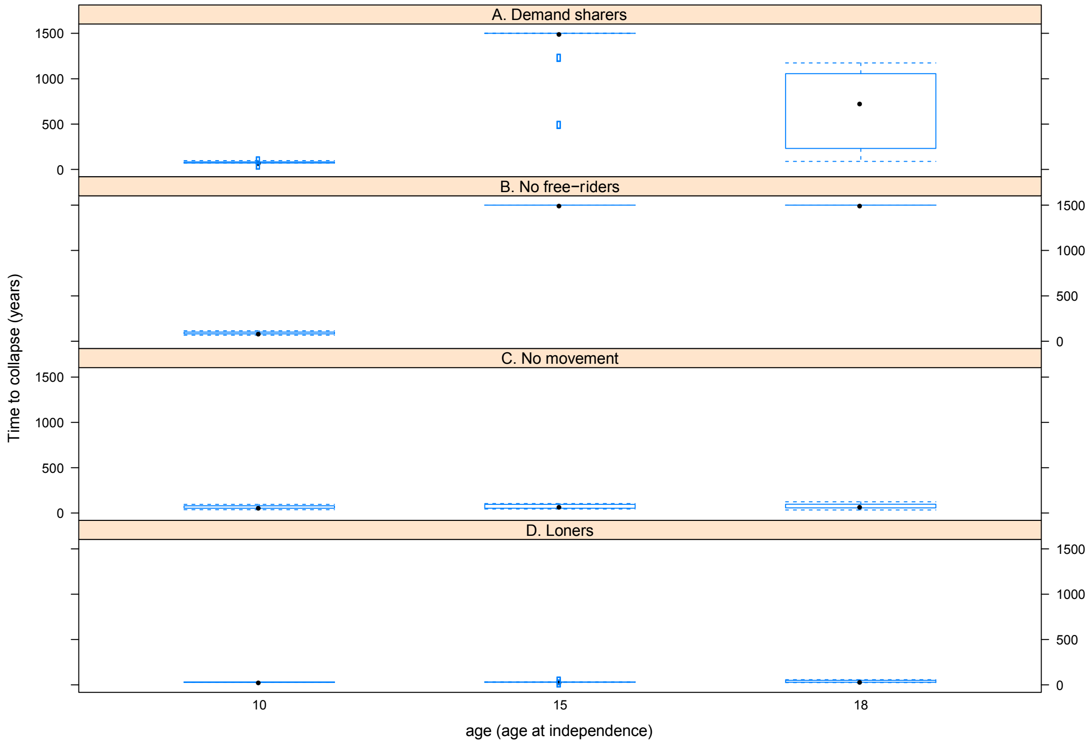
Supplementary Fig. 12. Time to collapse of simulated populations as a function of movement costs (*MC*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), and mobile loner populations (c). Box plots with central points as median (black dots) for 10 replicates each.



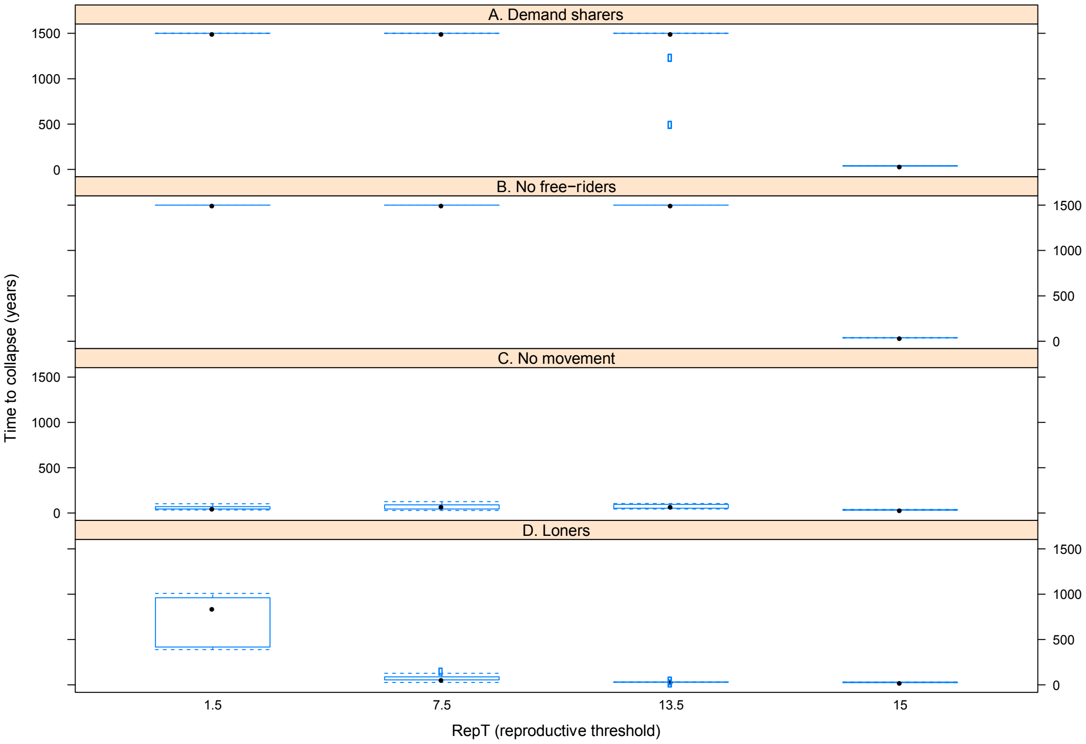
Supplementary Fig. 13. Time to collapse of simulated populations as a function of maximum energy storage (*f*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



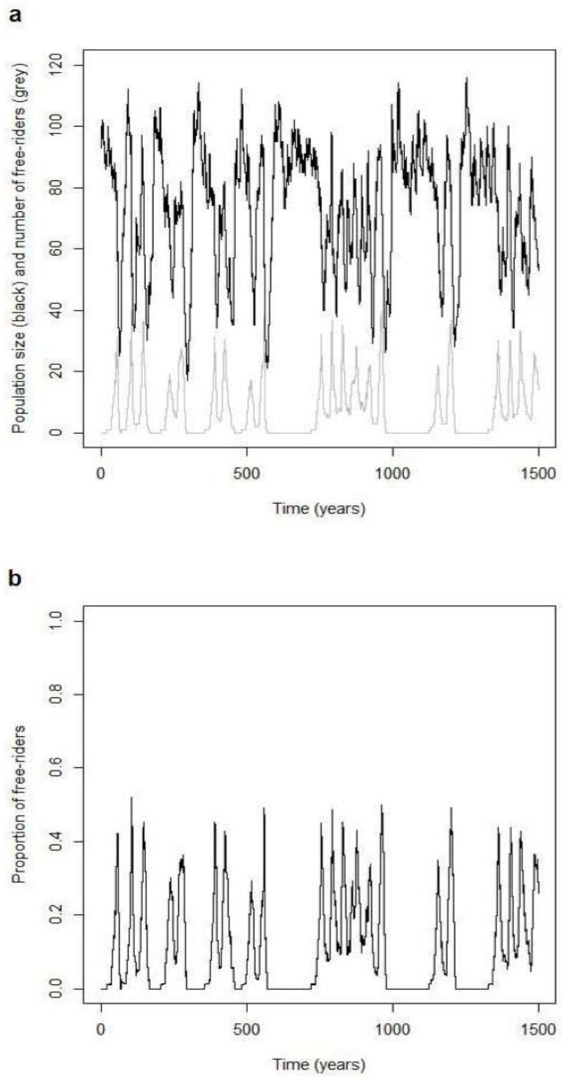
Supplementary Fig. 14. Time to collapse of simulated populations as a function of movement threshold (*thresh*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b) and mobile loner populations (c). Box plots with central points as median (black dots) for 10 replicates each.



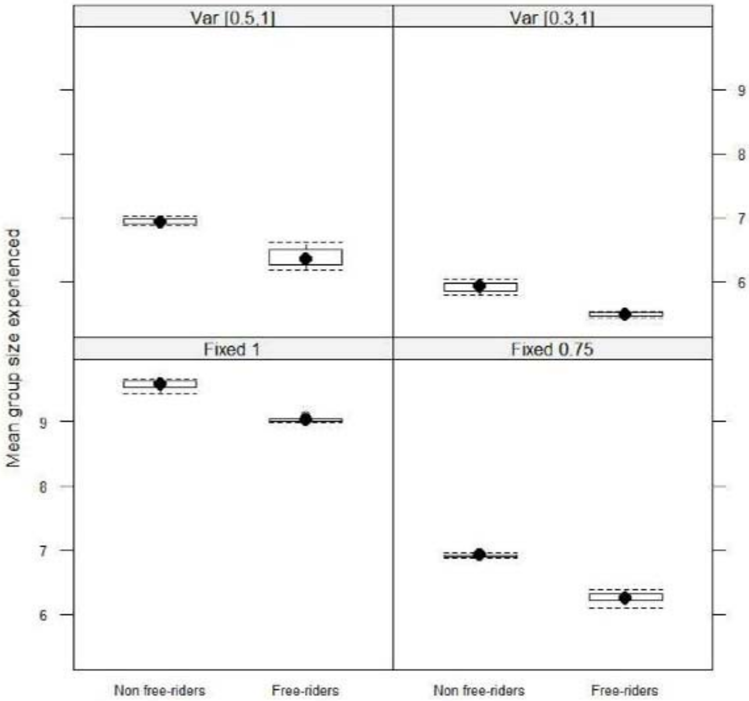
Supplementary Fig. 15. Time to collapse of simulated populations as a function of age at independence (*age*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



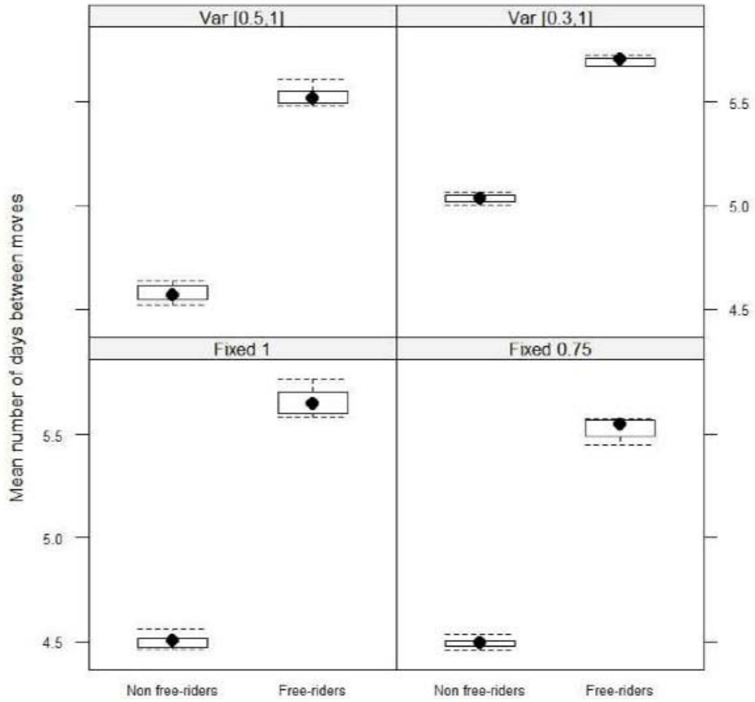
Supplementary Fig. 16. Time to collapse of simulated populations as a function of reproductive threshold (*RepT*). Mobile demand sharers with free riders (a), mobile demand sharers without free riders (b), sedentary demand sharers with free-riders (c) and mobile loner populations (d). Box plots with central points as median (black dots) for 10 replicates each.



Supplementary Fig. 17. Example replicate of moving demand sharing population with free riders in a variable environment *p* in [0.3-1]. (a) Total population size (black) and the number of free-riders (grey); (b) The corresponding proportion of the population that are free-riders. Time averaged proportion of free-riders is 0.1 in this replicate. Although the number of free-riders falls to 0 in some instances, they are not permanently eliminated as they are re-introduced by mutation. Data show one example out of the 10 simulations. Over 10 simulations the mean time-averaged proportion of free-riders is 0.108 (standard deviation 0.015), with a mean standard deviation within replicates of 0.125.



Supplementary Fig. 18. Mean group size experienced by free-riders and active hunters. Populations are mobile demand sharing populations under different environmental qualities (*p*). There were no free-riders present in the poorest environments as the populations died out before they could be introduced through mutation and so data were removed. Measures shown taken across 10 replicates: median (solid circle), inter-quartile range (box) and range (whiskers), with extreme values (open circles).



Supplementary Fig. 19. Mean lifetime number of days between moves by free-riders and non-free-riders. Populations are demand sharing under different environmental qualities (*p*). There were no free-riders present in the poorest environments as the populations died out before they could be introduced through mutation and so data were removed. Measures shown taken across 10 replicates: median (solid circle), inter- quartile range (box) and range (whiskers), with extreme values (open circles).

Supplementary Table 1 Definition, tested range and selected values of model parameters

Parameter	**Definition**	**Tested values**	**Results**	**Parameter values used in main simulation**
Environmental quality (p)	*p* is a measure of the daily probability of presence of game at a given location	fixed: *p*=0.1, *p*=0.2, *p*=0.3, *p*=0.4, *p*=0.5, *p*=0.6, *p*=0.7, *p*=0.8, *p*=0.9, *p*=1.00 variable: *p*=[0.1, 1.00] *p*=[0.3, 1.00] *p*=[0.5, 1.00]	Supplementary Fig. 1 (fixed *p*), Supplementary Fig. 2 (variable *p*)	Variable p=[0.3, 1.00]
Daily propensity to hunt (w)	*w* is the fixed daily probability that an agent goes on a hunt	Rather than testing for values of *w* ranging between 0 and 1.00, simulations established a contrast between active hunters (high propensity to hunt) and free-riders (low propensity to hunt), to make sure that a mutation in offspring of active hunters always introduced free-riders		Active hunter: *w*=[0.75-1.00] Free-rider: *w*=[0-0.1]

Mutation rate (m)	m is the rate of mutation of active hunters offspring into free-riders	m=0.001, m=0.005, m=0.01, m=0.1, m=0.5, m=1.00	Supplementary Fig. 3	m=0.005 (except in demand sharing populations without free-riders where m=0)
Age at peak hunting ability (peak)	*peak* is the age that maximises the value of age-specific hunting ability, defined by the function $huntab=0.9 \times \exp(-(age-peak) \times 365))2/(2 \times 7300^2))$	*peak*=25, *peak*=35, *peak*=45	Supplementary Fig. 5 and 6	*peak*=35
Density dependence effect on hunting success (dens)	*dens* is a parameter that quantifies the negative effect on the hunting success of a hunter caused by other hunters resent at the same location. Such density-dependent effect was defined as $(dens)^{N-1}$	*dens*=0.1, *dens*=0.5, *dens*=0.9, *dens*=1	Supplementary Fig. 7	*dens*=0.9
Age-specific mortality parameters (a and b)	a and b are the two parameters of the background daily mortality rate given by the equation $1 - \exp(-(a/b)\times(\exp(b\times(age+1))-\exp(b\times(age-1))))$, where age is in days	a and b were determined by fitting the mortality curve to real hunter-gatherer mortality curves, resulting in the values a=2.7×10-7 and b=2.4×10-4.		$a=2.7\times10^{-7}$ and $b=2.4\times10^{-4}$
Location number (loc)	*loc* is number of camps that agents can move to	*loc*=5, *loc*=20, *loc*=30	Supplementary Fig. 8	*loc*=20

Value of a kill (k)	*k* is the energetic value (in energy units) of a kill (or the daily sum of kills) by a hunter	*k=1, k=4, k=10*	Supplementary Fig. 9	*k*=4
Daily maintenance costs (DC)	*DC* are the daily energetic costs required for survival of each agent (i.e. the whole family unit consisting of adults and offspring)	*mc*=0.1, *mc*=0.5, *mc*=0.75, *mc*=1	Supplementary Fig. 10	*DC*=0.5
Hunting costs (HC)	*HC* are all the daily energetic costs derived from hunting, including chasing, killing, transporting, and processing game	*hc*=0.1, *hc*=0.4, *hc*=0.7, *hc*=1	Supplementary Fig. 11	*HC*=0.4
Movement costs (MC)	*MC are is the energetic costs of moving between camps for each agent (i.e. the whole family unit)*	*mc*=0.1, *mc*=0.3, *mc*=0.6, *mc*=1	Supplementary Fig. 12	*MC*=0.3
Maximum energy storage (f)	*f* is the maximum amount of energy (fat deposits) that each agent (family unit) is able to accumulate	*f*=15, *f*=18, *f*=20, *f*=30	Supplementary Fig. 13	*f*=15
Movement threshold (thresh)	*thresh* is the minimum value of a three-day average net energy balance that triggers obligatory movement of agents to a new location	*thresh*=0.5, *thresh*=1, *thresh*=5, *thresh*=10	Supplementary Fig. 14	*thresh*=0.5
Age at independence	*age* is the age (in years) when agents became energetically independent	*age*=10, *age*=15, *age*=18	Supplementary Fig. 15	*age*=15 years

(age)	from their parental family units and start their own families			
Reproductive threshold (RepT)	*RepT* is the minimum energy balance (both the current level and the average of the previous 15 years) required for successful reproduction	*RepT*=1.5, *RepT*=7.5, *RepT*=13.5, *RepT*=15	Supplementary Fig. 16	*RepT*=13.5

Supplementary Table 2. Age-specific life expectancy for simulated populations of mobile demand sharers and loners, real hunter-gatherers and chimpanzees.

			Life expectancy (remaining) at each age												
Age	Simulated		Hadza			Agta			Ache			Chimpanzee			
	sharing	loner	(F)	(M)	Combined	(F)	(M)	Combined	(F)	(M)	Combined	(F)	(M)	Combined	
0	–	–	35.6	30.8	32.7	26.5	25.3	24.3	37.1	37.8	37.3	14.6	11.2	12.9	
1	–	–	44.3	37.6	40.7	36.0	34.6	35.1	40.9	41.6	41.1	16.6	13.1	15.0	
2	–	–	46.2	39.8	43.0	37.8	36.5	37.0	42.9	41.7	42.1	17.8	14.7	16.5	
3	–	–	46.6	41.1	43.9	38.2	36.9	37.4	43.2	41.4	42.1	18.6	15.1	17.1	
4	–	–	47.5	42.4	45.1	38.3	36.7	37.4	43.7	41.8	42.5	18.7	15.0	17.0	
5	–	–	48.1	42.1	45.2	38.7	36.3	37.4	44.9	41.5	42.8	18.3	15.1	17.0	
6	–	–	48.0	42.3	45.3	38.2	36.4	37.2	45.4	40.8	42.6	19.3	15.0	17.4	
7	–	–	47.4	41.3	44.4	37.3	35.7	36.5	46.1	40.4	42.6	19.1	15.6	17.6	
8	–	–	47.0	41.6	44.4	36.9	35.1	36.0	47.2	40.1	42.8	18.8	14.9	17.1	
9	–	–	47.7	40.9	44.4	36.2	34.6	35.4	46.2	39.9	42.3	18.5	14.2	16.7	
10	–	–	47.0	41.2	44.2	35.7	34.0	34.8	45.8	39.8	42.1	18.7	14.5	17.0	
11	–	–	47.1	40.5	43.9	34.7	33.3	34.0	45.3	39.5	41.7	18.4	14.3	16.7	
12	–	–	46.4	40.9	43.7	33.9	32.6	33.2	44.5	38.8	41.0	17.4	13.3	15.7	
13	–	–	46.1	39.9	43.1	33.0	31.7	32.3	43.7	38.2	40.3	16.7	12.9	15.2	
14	–	–	45.4	38.9	42.2	32.1	31.1	31.6	43.4	37.5	39.8	16.2	13.6	15.1	
15	20.8	3.6	44.8	38.2	41.6	31.7	30.4	31.0	43.3	36.8	39.3	15.4	14.2	14.8	
16	25.0	7.9	44.1	37.5	40.9	30.8	29.5	30.2	42.6	35.9	38.5	14.9	13.2	14.1	
17	26.9	12.7	43.5	37.2	40.5	30.0	28.8	29.4	42.0	35.3	37.9	13.9	12.5	13.3	
18	28.2	17.1	42.9	37.2	40.2	29.2	28.3	28.8	41.5	34.5	37.2	13.4	11.9	12.7	
19	28.9	20.2	41.9	36.6	39.4	28.5	27.6	28.1	40.8	33.9	36.6	13.6	11.5	12.7	
20	29.4	22.6	41.8	36.3	39.2	27.7	26.9	27.3	39.8	34.2	36.3	13.4	11.2	12.4	
21	29.5	23.7	41.2	35.3	38.4	26.8	26.3	26.5	39.1	34.3	36.1	13.0	10.5	11.9	
22	29.3	24.3	40.9	34.6	38.0	26.1	25.6	25.9	38.8	33.8	35.8	12.2	10.2	11.3	
23	29.0	24.7	39.9	34.0	37.1	25.2	24.9	25.0	37.8	33.2	35.0	12.1	9.5	10.9	
24	28.6	24.6	38.9	33.4	36.3	24.2	24.2	24.2	38.0	32.7	34.8	11.1	8.5	9.9	
25	28.1	24.0	37.9	33.2	35.7	23.9	23.4	23.7	37.0	31.7	33.8	11.2	8.0	9.7	
26	27.5	23.5	36.9	33.0	35.1	23.2	22.9	23.1	36.3	31.3	33.2	10.2	8.1	9.3	
27	26.8	22.7	35.9	32.3	34.3	22.5	22.2	22.3	35.3	30.9	32.6	9.7	8.2	9.1	
28	26.0	21.9	35.8	31.3	33.7	22.0	21.9	21.9	34.3	30.5	32.0	10.0	7.6	8.9	
29	25.2	21.1	34.8	30.3	32.7	21.4	21.2	21.3	33.3	29.5	31.0	9.7	6.9	8.5	
30	24.4	20.3	34.2	29.7	32.1	20.9	21.0	21.0	32.7	28.5	30.1	9.1	7.5	8.5	
31	23.7	19.3	33.6	28.7	31.3	20.6	20.9	20.7	31.7	28.3	29.6	9.7	7.4	8.8	
32	22.9	18.5	32.6	28.1	30.5	19.9	20.3	20.1	31.4	27.5	29.0	8.7	6.4	7.8	
33	22.0	17.6	31.6	27.1	29.5	19.4	19.8	19.6	31.2	26.8	28.5	8.2	6.2	7.5	
34	21.2	16.8	30.9	26.8	29.0	18.7	19.1	18.9	31.1	26.0	27.9	8.5	6.0	7.6	
35	20.4	15.9	29.9	26.2	28.2	18.7	18.7	18.7	30.1	25.2	27.1	8.4	5.9	7.6	
36	19.6	15.0	28.9	25.2	27.2	18.0	18.4	18.2	29.1	24.9	26.6	7.4	4.9	6.6	
37	18.8	14.1	28.8	24.2	26.6	17.4	17.6	17.5	28.1	23.9	25.6	7.3	5.6	6.8	
38	18.0	13.3	27.8	23.2	25.6	16.6	17.0	16.8	37.1	23.7	25.0	6.3	5.3	6.1	
39	17.2	12.4	27.2	22.9	25.2	16.0	16.8	16.4	26.5	22.9	24.3	5.7	5.0	5.6	
40	16.4	11.5	27.2	23.1	25.3	15.8	16.5	16.2	25.5	21.9	23.3	6.4	4.9	6.1	
41	15.6	10.6	26.8	22.1	24.6	14.9	15.9	15.4	24.5	21.5	22.7	5.4	3.9	5.1	
42	14.8	9.7	26.3	21.5	24.1	14.1	15.1	14.6	23.9	20.5	21.8	4.4	2.9	4.1	
43	14.1	8.8	25.3	20.9	23.3	13.8	14.8	14.3	23.3	19.5	21.0	4.0	3.5	4.2	
44	13.3	7.9	24.3	19.9	22.3	13.2	14.0	13.6	23.1	18.5	20.3	4.0	2.5	3.9	
45	12.6	7.1	23.3	18.9	21.3	12.8	13.6	13.2	22.1	18.0	19.6	3.0	1.5	2.9	
46	11.8	6.2	22.9	17.9	20.6	12.5	13.0	12.7	21.1	17.8	19.1	4.5	0.5	3.7	
47	11.1	5.4	23.0	17.9	20.7	11.7	12.2	11.9	20.6	17.0	18.5	7.5		7.5	
48	10.4	4.7	22.0	17.3	19.9	11.4	11.5	11.4	20.6	16.6	18.2	6.5		6.5	
49	9.8	3.9	21.0	16.7	19.1	11.2	10.7	10.9	20.2	15.8	17.6	5.5		5.5	
50	9.1	3.3	20.5	15.7	18.3	11.1	10.5	10.8	19.2	14.8	16.6	4.5		4.5	
51	8.5	2.7	19.5	14.7	17.3	10.9	9.8	10.3	18.6	14.8	16.4	3.5		3.5	
52	8.0	2.2	19.3	14.0	16.9	10.6	9.6	10.0	18.1	14.9	16.3	2.5		2.5	
53	7.3	1.7	18.8	14.0	16.7	9.9	9.6	9.7	17.1	14.2	15.4	1.5		1.5	
54	6.8	1.4	18.2	13.0	15.9	9.6	9.1	9.3	16.1	13.5	14.6	1.5		1.5	
55	6.3	1.1	17.6	12.3	15.2	9.3	9.4	9.4	15.1	12.8	13.8				
56	5.8	0.9	17.0	11.6	14.6	9.4	8.8	9.1	15.1	12.7	13.7				
57	5.5	0.7	16.0	11.8	14.2	9.3	8.2	8.7	16.4	12.1	13.1				
58	5.1	0.8	15.2	12.1	14.0	9.1	7.8	8.4	14.2	11.4	12.6				
59	4.8	0.5	14.2	11.4	13.1	8.5	7.5	8.0	13.2	11.1	12.0				
60	4.4		13.5	11.4	12.7	9.1	6.9	7.9	12.2	10.4	11.2				
61	4.1		12.8	11.5	12.3	9.0	6.3	7.5	11.7	11.0	11.4				
62	3.8		12.1	10.9	11.7	8.8	6.1	7.2	10.7	10.5	10.6				
63	3.5		11.1	10.2	10.8	8.8	6.1	7.3	10.3	10.6	10.5				
64	3.3		10.6	10.3	10.5	8.0	5.3	6.5	10.5	9.6	10.0				
65	3.0		9.6	9.3	9.5	7.9	5.4	6.6	9.5	9.1	9.3				
66	2.8		8.6	8.3	8.5	7.6	5.4	6.5	8.5	9.3	9.0				
67	2.6		8.5	7.9	8.4	7.6	4.7	6.1	7.5	8.3	8.0				
68	2.3		7.8	7.2	7.6	7.2	4.8	6.0	6.5	7.3	7.0				
69	2.1		6.8	7.5	7.2	6.2	4.6	5.5	6.2	6.3	6.3				
70	1.7		6.5	6.9	6.7	6.2	3.8	5.1	5.2	5.3	5.3				
71	1.7		5.7	6.2	6.1	5.5	4.0	4.9	5.2	4.8	5.0				
72	1.6		5.0	5.5	5.4	5.6	4.0	5.0	4.2	3.8	4.0				
73	1.3		4.3	4.8	4.7	5.3	3.3	4.5	3.2	2.8	3.0				
74	1.3		4.1	4.4	4.4	5.0	3.5	4.5	3.5	3.5	3.7				
75	0.7		3.8	4.4	4.3	4.9	3.0	4.2	2.5	2.5	2.7				
76	0.5		4.3	3.4	3.9	4.3	3.3	4.0	1.5	3.5	2.8				
77			3.7	4.1	3.9	3.7	5.0	4.0	0.5	2.5	1.8				
78			4.0	4.1	4.1	3.6	4.0	3.7		1.5	1.5				
79			3.7	3.1	3.4	3.2	3.0	3.1		0.5					
80			3.5	2.5	3.0	2.2	2.0	2.1							
81			2.5	2.0	2.3	1.5	1.0	1.4							
82			3.5	1.0	2.3	1.2	0.5	1.0							
83			2.5	0.5	1.8	1.5		1.5							
84			1.5		1.5	0.5		0.5							
85			1.5		1.5										
86			0.5		0.5										

For simulated data, one representative replicate is shown. Real data from Hadza[2], Agta[3], and Ache[4], and chimpanzees[5].

Supplementary Methods

Parameter Explorations

Environmental quality (*p*). Supplementary Fig. 1 and 2 show that when fixed $p \leq 0.5$, or variable $p \leq [0.2\text{-}1.00]$, all populations quickly go extinct including demand sharing populations, suggesting very harsh environmental conditions. When *p* values are intermediate (fixed p=0.6 or p=0.7, variable p=[0.3-1]), mobile demand sharing populations (with or without free-riders) survived to the end of the 1500 simulated years, while loners and sedentary demand sharers quickly went extinct. For high values of *p* (fixed $p \geq 0.8$, variable $p \geq [0.4\text{-}1.00]$, loners also survive to the end of the simulation, while sedentary populations still showed low survival (i.e. even in favourable environments with abundance of food). Sedentary demand sharing populations never survive to the end of the simulations even under 'ideal' environmental conditions (p=1), demonstrating that demand sharing populations require movement in order to avoid the spread of free-riders. We therefore selected p=[0.3-1.00] in our main simulations, which resulted in a daily probability of hunting success that closely matched data from real hunter-gathering populations (Table 1).

Mutation rates (*m*). Supplementary Fig. 3 shows that our main result holds irrespective of mutation rate: when mutation rate is m=0.1 or lower, mobile demand sharing populations (active hunters with free-riders) survive to the end of the simulation. Even when mutation rates are as high as m=0.5 (i.e. 50% of free riders are introduced in each generation), the mobile population manage to survive for an average of 658 years. In contrast, sedentary populations do not survive whenever there is introduction of free riders through mutation. The only condition in which sedentary populations show high survival to the end of the 1500 years of simulation is when the environment is ideal (p=1) and there is no introduction of free-riders (m=0) (Supplementary Fig. 4). Sedentary populations seem to be are unable to avoid the spread of free-riders (even when they are introduced in very low proportions), and therefore constant movement is fundamental for demand sharing populations.

Peak Hunting Ability (*peak*). Supplementary Fig. 5 shows plots for peak ability at ages 25, 35, 45, and the empirical production curve from Kaplan at al. [1]. Varying age at peak hunting ability affects survival of demand sharing populations. Supplementary Fig. 6 shows that time to population extinction is reduced when hunting ability peaks earlier (25 years), due to earlier onset of decline in hunting ability, and later (45 years), due to lower initial value of hunting ability at independence and to the lower number of hunters alive at old age to reap the benefits of late-peaking hunting ability.

Density Dependence (*dens*). Supplementary Fig. 7 also presents the same comparisons between mobile and sedentary demand sharing populations when density-dependence is set as $(0.1)^{N-1}$ (very high), $(0.5)^{N-1}$ (high), or 1 (no density-dependence). We observe that when the effect of population density is modelled as very strong (*dens*=0.1, or *dens*=0.5), both mobile and sedentary mixed demand-sharing populations quickly collapse. When density-dependence is removed (i.e. when *dens*=1), sedentary demand sharing populations increase survival, but are still more likely to go extinct before the end of the 1500 years of simulation.

Location number (loc). We also ran simulations assuming *loc*=5 (closer to what is found in groups such as the Hadza) and *loc*=30. The main results did not change (Supplementary Fig. 8). Time to extinction tends to increase with increasing location number. For all location numbers, demand sharing populations without free-riders show higher time to extinction than loners, and mobile demand sharing populations with free-riders have longer times to extinction than sedentary demand sharing populations. In addition, when location number is small (*loc=5*), mobile demand sharing populations with free-riders show lower survival compared to mobile demand sharers without free-riders. This is expected since fewer locations represent in practice a reduction in mobility (at the limit, setting *loc*=1 would turn a mobile into a sedentary population). With reduced mobility, demand sharing populations undergo extinction more quickly. Mobile demand sharers without free-riders are not affected by location number and their time to extinction remains high. Loners show a slightly higher survival with increasing location number, due to reduction in density and thus in the effect of density dependence on hunting success, but not enough for populations of loners to avoid extinction before the end of the simulation. Finally, sedentary hunter-gatherers show short times to extinction irrespective of location number, as they are never able to move between existing camps to avoid free-riders.

Value of a kill (k). Supplementary Fig. 9 shows results of simulations when we vary the value of *k*. For all populations, a low value of kill (*k*=1) implies very low survival. For loners and sedentary populations, survival does not increase significantly even when the value of the kill is as high as *k*=10. In the case of the loners, this happens because since there is no sharing or storage the outcome of hunting remains unpredictable, still creating enough days of starvation for families to collapse. Sedentary populations also go extinct in a few generations even if *k*=10, since active hunters cannot move to other camps and avoid free-riders.

Daily Maintenance costs (DC). We have tested a range of parameter values (Supplementary Fig. 10). When daily maintenance costs are low (*DC*=0.1), loner populations survive to the end of the simulations, while sedentary populations survive to an average of 600 years. This is because decreasing the costs of maintenance will reduce the chances of starvation when resources are scarce (which increases survival of loners) and will decrease the costs of having free-riders around (which increases survival of sedentary populations). When *DC* is increased to 0.75, maintenance costs are too high, and therefore even demand sharing populations collapse.

Hunting Costs (HC). When hunting costs are lower (*HC*=0.1) demand sharing populations and loners survive, but sedentary populations still undergo quick extinction. The reason is that sedentary but active hunters incur low hunting costs, but not as low as free-riders (who rarely hunt), and the former are still unable to move away and avoid the latter. When hunting costs are high (HC=0.75), all populations die including demand sharing without free riders (Supplementary Fig. 11).

Movement costs (MC). We have tested a range of parameter values and the mail results remain the same either when movements costs are reduced to *MC*=0.1 our doubled to *MC*=0.6 (Supplementary Fig. 12). In either case, demand sharers and demand sharers without free-riders survive, while loners quickly disappear. Only when movement costs are set to *MC*=1, corresponding to twice the value of daily maintenance costs, do all populations undergo quick extinction. Loners do not survive even when costs of movement are low (*MC*=0.1), suggesting that the limiting factor to their survival is not the cost of moving but the uncertainty of production. Sedentary populations are not included, as they do no incur movement costs.

Maximum energy storage (f). We have run simulations with storage levels up to *f*=30, equivalent to 2 months without food (Supplementary Fig. 13). Sedentary demand sharers populations fail to survive to the end of 1500 years even when *f*=30, suggesting that free-riding remains a challenge to survival of those populations. Loners on the other hand show a gradual increase in survival with increasing storage, with populations showing similar survival to demand sharers when *f*=30. This indicates that external storage can be an alternative to demand sharing under conditions of food uncertainty.

Movement threshold (thresh). Supplementary Fig. 14 shows simulations with different *thresh* values. High *thresh* values mean that an agent remains in a location only if the three-day net income balance is very high (i.e. if a given camp is highly productive); a low value means that agents are very tolerant to low-quality camps and remain in a camp even when net income is low. We use a flat value of *thresh*=0.5 energy unit in our main simulations, because daily maintenance costs of an agent are set at *DC*= 0.5 too. This means that agents move to a new camp if they did not obtain enough energy for daily maintenance, on average, in the previous three days. Results show that the low survival of loners is not modified by variation in *thresh*. Demand sharers without free-riders always survive to the end of simulations even when movement threshold is increased by 10 or 20 times (*thresh*=5 or *thresh*=10), suggesting that they are able to maintain high energy incomes above movement threshold levels, possibly due to the absence of free-riders. Demand sharers with free riders are resilient to decreasing movement threshold to 0.1, but not to increasing it by 10 times. This is possibly because when *thresh* is increased to 5 or 10, frequency of movement increases and so do movement costs, making it difficult for active hunters (who will achieve their *thresh* limits earlier than free riders) to survive.

Age at independence (age). We ran simulations with age=10 and age=18 (Supplementary Fig. 15). Age at independency does not cause any difference in survival rates for sedentary or loner populations, as they quickly collapse. Demand sharing populations (with or without free-riders) collapse if age at independence is reduced to 10 years of age. This is because production levels of independent children at age 10 are lower than at age 15 years. When age of independence is set at 18, demand sharing populations without free riders survive to the end of the simulation (1500 years), while demand sharing populations with free riders have slightly reduced survival (1000 years on average). This is because although individuals are more productive and therefore more able to survive when they become independent at age 18, they take longer to reach peak productivity.

Reproductive threshold (RepT). We have run simulations varying and the amount of energy required for reproduction (Supplementary Fig. 16). When *RepT*=15 (or 100% of the total storage) all populations collapse, since populations cannot possibly maintain an average energy balance at its maximum level *f*=15. When *RepT* is reduced to values between 1.5 and 10.5, all demand sharing populations (with or without free-riders) survive to the end of the simulation. Sedentary populations always collapse even when costs of reproduction are only 1.5 (or 10% of maximum fatness storage *f*), which indicates that costs of reproduction are not the main factor limiting the survival of sedentary demand-sharing populations. Loners respond better to variation in *RepT*, but only survive to an average of 730 years when *RepT* is reduced to 1.5 (10% of *f*). Therefore, even with very low costs of reproduction loners are failing to overcome the effects of variable and poor environments, since they don't have food sharing.

Supplementary References

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