Supplementary Figures

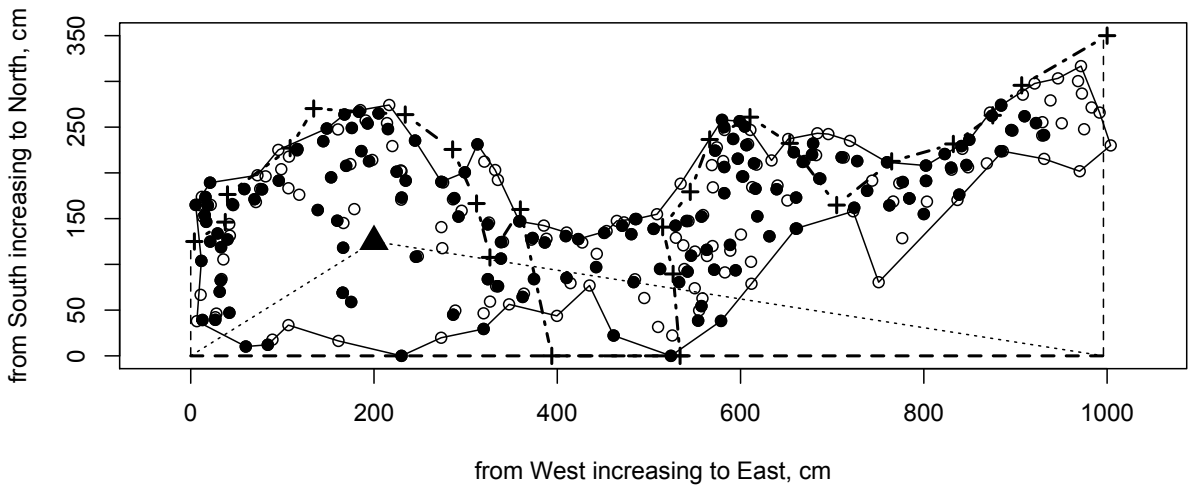

Fig. S1 Plot of positions of *Scutellastra laticostata* at Cape Vlamingh (CV2 North) and the boundary between terraced and pitted zones based on triangulation from 2 fixed benchmarks and used for calculations of zonal area and limpet density. Black triangle represents position of a limpet at our x, y coordinates of 200 cm, 125 cm. Dashed vertical line is the baseline with each end benchmarked by an eyebolt embedded in the rock. Dotted lines represent distance to the limpet from each benchmark. We used Heron's formula for a scalene triangle (https://en.wikipedia.org/wiki/Heron%27s_formula) to transform positions for individual limpets from these 2 distances and the length of the baseline (996 cm) into the x, y coordinates plotted here. Open symbols are for 150 limpets mapped in 2003, filled symbols are for 137 limpets in 1999. Solid black line joining positions of limpets at the outer extent of their distribution (pooled over both years) forms a complex polygon that bounds the population. Lines joining + symbols represent the boundary between terraced and pitted zones and divides the total population area into smaller polygons for each zone. We measured the area of the polygon bounding the population and that of polygons for each zone to estimate total population density, and density in each zone, based on counts of limpets in the respective polygons. Note: we have used data on limpet positions for 2 selected years for graphical clarity in this heuristic example. Our actual estimation of the population boundary was based on positional data for limpets concatenated for all sample years from 1993 to 2003, and therefore differs somewhat from that shown here.

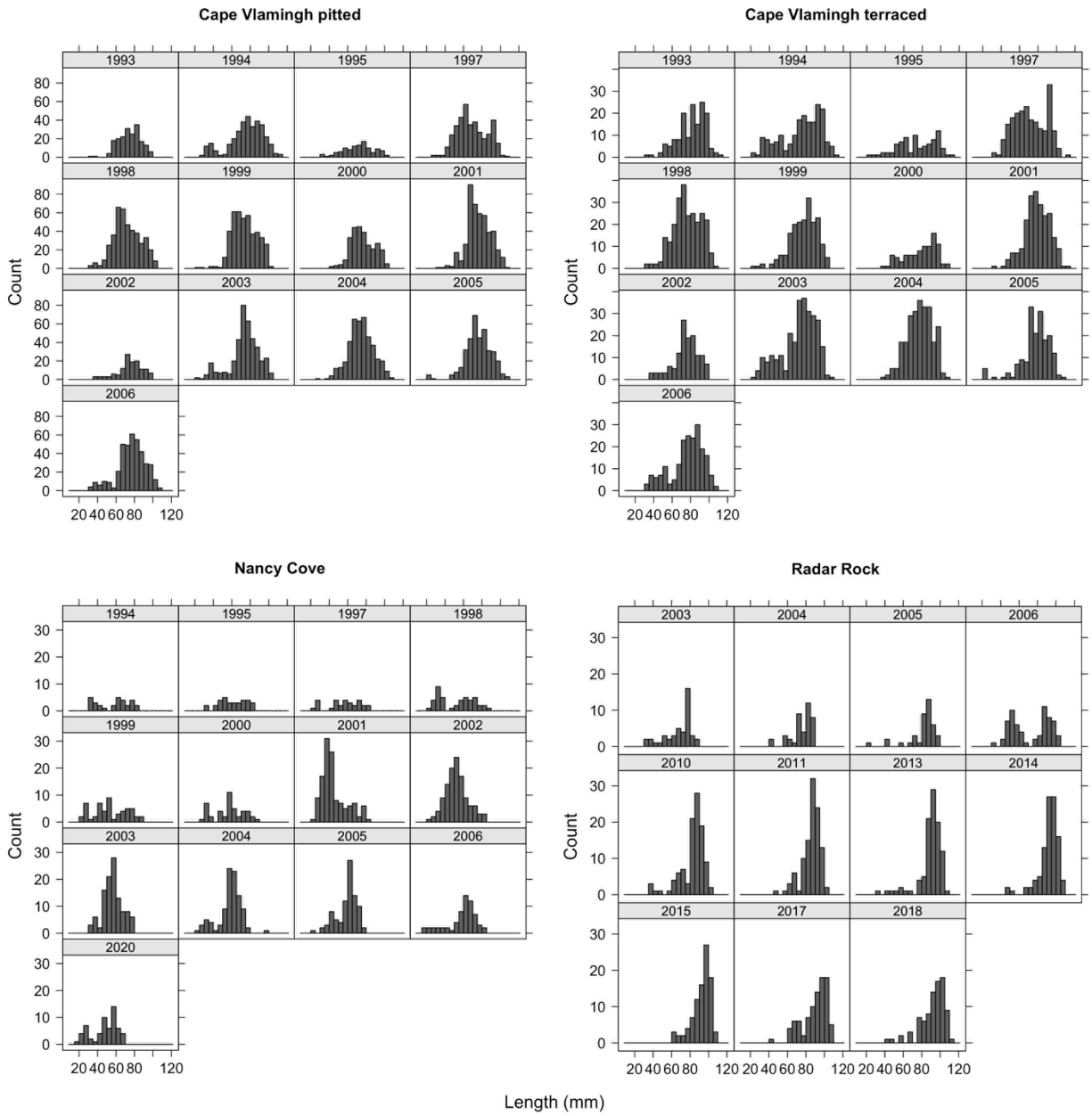

Fig. S2. Length-frequency distributions of *Scutellastra laticostata* in the pitted zone and terraced zone at Cape Vlamingh (pooled across all sites) from 1993 to 2006, and on the notch at Nancy Cove from 1994 to 2006 and 2020, and on Radar Rock from 2003 to 2018.

Supplementary Tables

Table S1. Description of sampling grids at study sites on Rottnest Island: Cape Vlamingh (CV1, CV2), Nancy Cove (NC), and Radar Rock (RR).

Site	Coordinates	Seaward direction	Baseline (m)	Habitat/ Zone	Area (m^2)
CV1	-32° 1' 21.67"S, 115° 26" 54.89"E	South	8.1	Pitted	3.2
				Terraced	8.1
		North	12.2	Pitted	20.0
				Terraced	7.4
CV2	-32° 1' 15.03"S, 115° 26" 57.31"E	South	7.2	Pitted	17.4
		North	10.0	Pitted	5.1
				Terraced	13.2
NC	-32° 0' 56.88"S, 115° 30" 7.94"E	South	25.0	Notch	15.0
RR	-32° 1' 35.07"S, 115° 27" 25.68"E	South	6.7	Terraced	16.8

Table S2: Factorial ANOVA comparing total population density of *Scutellastra laticostata*, and density of recruits only, between zones and over time at 3 sites at Cape Vlamingh.

A. Model: Sites (S) were CV1N, CV1S, CV2N each with pitted and terraced zones (Z); year (Y) had values as shown in Fig. S1. Terms 1, 3 and 6 are random, terms 2, 4 and 5 are fixed. The df are for a balanced data set, but our observations had 5 missing values. We used JMP 7.0 to perform the analysis using the restricted maximum likelihood (REML) method recommended for data with missing values.

Term	Source	df	Term as denominator in F test for expected mean squares method
1	S	2	
2	Z	1	3
3	S x Z	2	
4	Y	12	7
5	Y x Z	12	7
6	Y x S	24	7
7	Y x S x Z (Residual)	24	
	Total	77	

B. REML fixed effect tests (with df for denominator term): Total population.

Source	df	F	P
Z	2.0	0.562	0.531
Y	20.8	2.531	0.031
Y x Z	21	1.626	0.159

C. REML fixed effect tests (with df for denominator term): Recruits only.

Source	df	F	P
Z	2.0	4.009	0.181
Y	21.8	5.147	0.001
Y x Z	21.9	1.810	0.110

Table S3 Descriptive statistics of size structure (shell length, mm) of *Scutellastra laticostata* at Cape Vlamingh (CV, pooled across zones at CV1, CV2), Nancy Cove (NC), and Radar Rock (RR) throughout the respective census periods.

	Sample size			Mean			SD			Minimum			Maximum		
Year	CV	NC	RR	CV	NC	RR	CV	NC	RR	CV	NC	RR	CV	NC	RR
1993	344			77.6			13.5			31			112		
1994	524	30		75.5	57.8		19.8	17.3		23	31		113	82	
1995	194	33		73.5	61.3		18.2	14.2		23	32		112	85	
1997	594	29		70.4	56.9		16.5	17.4		26	25		111	85	
1998	676	45		74.0	52.7		14.7	19.0		35	21		110	88	
1999	622	54		75.3	54.6		13.9	18.2		21	23		103	89	
2000	370	45		77.1	57.5		13.9	15.9		39	28		109	88	
2001	667	126		77.6	45.4		12.8	13.6		32	25		112	81	
2002	260	118		75.3	52.9		13.7	11.8		37	24		100	82	
2003	664	111	44	73.4	57.2	68.1	17.0	10.4	14.8	25	32	32	108	79	88
2004	676	99	41	76.0	58.6	76.4	13.2	12.7	11.7	29	25	42	106	98	90
2005	539	88	40	76.9	59.4	81.9	14.4	11.3	16.1	21	23	22	109	79	100
2006	591	63	65	77.2	58.5	73.3	15.9	15.6	20.3	32	18	35	109	81	102
2010			105			82.9			13.2			37			103
2011			108			86.6			10.0			47			105
2013			100			89.9			13.0			32			108
2014			103			92.4			10.9			46			108
2015			94			92.7			10.2			63			109
2017			91			90.4			13.2			44			108
2018			87			92.8			13.5			44			112
2020		59			47.9			14.2			18			70	

Table S4. Change in number of individuals and annual survival rate (p_x) of cohorts of tagged *Scutellastra laticostata* with lower (L) and upper (U) 95% confidence intervals based on profile likelihood estimates (for details, see 2.5 Statistical Analyses) over census periods at Cape Vlamingh (CV), Nancy Cove (NC) and Radar Rock (RR). P is the probability of slope homogeneity in Fig. 7.

A. Comparison of survival rates between pitted and terraced zone of 1991 and 1997 cohorts at Cape Vlamingh.

Cohort	Zone	Years		Numbers		Profile likelihoods			P
		Start	End	Start	End	L 95%	p_x	U 95%	
1991	Pitted	1993	2001	25	1	0.469	0.669	0.798	0.061
	Terraced	1993	2003	61	4	0.679	0.762	0.825	
1997	Pitted	1998	2003	17	1	0.322	0.567	0.748	0.036
	Terraced	1998	2003	11	2	0.505	0.711	0.857	

B. Comparison of survival rate of 1991 cohort with 1997 or 2003 cohorts at Cape Vlamingh (CV) and Nancy Cove (NC) respectively.

Site	Cohort	Years		Numbers		Profile likelihoods			P
		Start	End	Start	End	L 95%	p_x	U 95%	
CV	1991	1993	2003	86	4	0.537	0.736	0.787	0.004
	1997	1998	2003	28	3	0.488	0.640	0.761	
NC	1991	1991	1999	19	1	0.526	0.721	0.842	0.012
	2003	2003	2006	27	2	0.233	0.420	0.596	

C. Comparisons of annual survival rate of the 2003 cohort at Cape Vlamingh (CV), Nancy Cove (NC), and Radar Rock (RR).

Site	Years		Numbers		Profile likelihoods			P
	Start	End	Start	End	L 95%	p_x	U 95%	
RR	2003	2018	44	5	0.810	0.865	0.906	0.067
NC	2003	2006	27	2	0.233	0.420	0.596	
CV	2003	2008	33	10	0.697	0.788	0.860	

Table S5. Rate of growth of the 2003 cohort of tagged *Scutellastra laticostata* at Cape Vlamingh (CV, pitted and terraced zones pooled across sites), Nancy Cove and Radar Rock.

A. Regressions of increase in length (mm) per yr on initial length (mm). LSM is least squares mean (mm) for initial length of 78 mm. Group is from Tukey's HSD test.

Site/Zone	n	Intercept (SE)	Slope (SE)	R^2	LSM	Group
CV pitted	28	34.4 (4.09)	-0.39 (0.07)	0.566	4.37	B
CV terraced	47	39.2 (1.70)	-0.40 (0.02)	0.884	7.86	A
Nancy Cove	12	12.3 (8.11)	-0.12 (0.16)	0.056	2.86	AB
Radar Rock	157	33.0 (1.92)	-0.34 (0.02)	0.595	6.42	AB

B. Analysis of covariance of increase in length of tagged *Scutellastra laticostata* among sites.

Source	df	MS	F	P
Site	3	50.19	3.024	0.030
Initial length	1	383.21	23.769	<0.000
Site x initial length	3	21.91	1.320	0.268
Residual	236	16.60		

C. von Bertalanffy growth equations fitted to the growth data for *Scutellastra laticostata* (no useful fit for Nancy Cove sample). K is the growth rate constant (yr^{-1}) and L_∞ is asymptotic size (mm).

Site	sample size	K ± SE	L_∞ ± SE
CV pitted	28	0.488 ± 0.108	89.25 ± 6.04
CV terraced	47	0.515 ± 0.036	97.48 ± 1.67
Radar Rock	157	0.418 ± 0.034	96.74 ± 1.24

Table S6. Summary of size, life history traits and dynamics of *Scutellastra laticostata* and other species of giant limpets: min and max are size (shell length) in mm, K is the growth rate coefficient yr^{-1} and L_∞ is the asymptotic size in mm from the von Bertalanffy growth model, and p_x is the annual finite rate of survival (values in italics are calculated from information given in the reference if they were not explicitly presented). 3/K and $Y_{10\%}$ are our estimates from these data of how many years it would take to reach 95% of L_∞ or 10% of population size. Species names of the Patellidae follow (Ridgway et al. 1998). *Cymbula granatina* and *Scutellastra argenvillei* are included (although max size records given here are < 100) because they are listed as giant limpets (≥ 100 cm) in Espinosa and Rivera-Ingraham (2017).

Family and Species	min	max	K	L_∞	p_x	3/K	$Y_{10\%}$	Reference*
Patellidae								
Scutellastra laticostata	44	125						Scheibling et al. 1990
	28	86	0.258	82.6	0.789	11.6	9.7	(N) Scheibling & Black 1993
	24	84	0.091	79.6	0.403	33.0	2.5	(P) Scheibling & Black 1993
	38	106	0.421	99.6	0.803	7.1	10.5	(T) Scheibling & Black 1993
	18	98			0.420		2.7	(N) This study
	32	113	0.487	89.3	0.618	6.2	4.8	(P) This study
	38	113	0.515	97.5	0.736	5.8	7.5	(T) This study
	22	102	0.418	96.7	0.865	7.2	15.9	(R) This study
Cymbula granatina			*0.195*	85	0.500	15.4	3.3	Arendse et al. 2007
		91			0.884		18.7	Bustamante et al. 1995
	2	95	0.483	96.3	0.403	6.2	2.5	Branch 1974
Cymbula oculus	2	76	0.483	91.9	0.171	6.2	1.3	Branch 1974
	20	100						Lasiak 1991
	5	105						Whittington-Jones 1997
			1.022	65.5		2.9		(L) Branch & Odendaal 2003
	35	105	0.881	92.7	0.887	3.4	19.2	(1) Branch & Odendaal 2003
	37	66	2.346	58.7	0.802	1.3	10.4	(2) Branch & Odendaal 2003
	41	93	0.663	84.9	0.722	4.5	7.1	(3) Branch & Odendaal 2003
	29	65	1.288	52.5	0.659	2.3	5.5	(4) Branch & Odendaal 2003
Patella ferruginea	18	100	0.061	113.6		49.2		Espinosa et al. 2008
			0.144	119.6		20.8		Espinosa et al. 2009
	9	99						Coppa et al. 2012
	10	110						Rivera-Ingraham et al. 2011a
	10	105						Espinosa et al. 2009
	5	100	*0.195*	*93.5*	0.659	15.4	5.5	Rivera-Ingraham et al. 2011b
					0.916		26.2	(C) Zarrouk et al. 2018
					0.817		11.4	(NC) Zarrouk et al. 2018
Scutellastra argenvillei	5	70						Sebastian et al. 2002
	12	75						Steffani & Branch 2005

		91			0.881		18.2	Bustamante et al. 1995
Scutellastra kermadecensis	20	160						Creese et al. 1990
Scutellastra mexicana	15	265						Carballo et al. 2020
Lottiidae								
Lottia gigantea	29	73	*0.155*	*57.6*	0.87	19.4	16.5	Denny & Blanchette 2000
	8	104						Sagarin et al. 2007
	15	79	*0.18*	*66*		16.7		Kido & Murray 2003
	25	75						Wright 1989
	14	72	*0.274*	*61.3*	0.826	10.9	12.0	Stimson 1973
	12	91	*0.116*	*89.5*	0.72	25.9	7.0	Fenberg & Roy 2012
	10	85	*0.159*	*67.3*	0.677	18.9	5.9	Fenberg & Roy 2012
	13	70	*0.156*	*61.2*	0.687	19.2	6.1	Fenberg & Roy 2012
Fissurellidae								
Fissurella crassa	25	79	*0.322*	*89.3*		9.3		Bretos 1978
	26	78	*0.159*	*94.5*		18.9		Bretos 1980
	5	100						Navarrete & Castilla 1993
	25	85						Oliva & Castilla 1986
	70	130						Serra et al. 2000
	20	90						Loot et al. 2005
Fisurella cumingi	80	100						McLean 1984
	60	100						Durán & Oliva 1987
Fissurella maxima	22	99	0.413	102.8		7.3		Bretos et al. 1983
	35	130						Oliva & Castilla 1986
	80	135						McLean 1984
	30	130						Durán & Oliva 1987
Fissurella nigra	70	110						McLean 1984
Fissurella picta	10	100						Moreno et al. 1984
	10	95						Duarte et al. 1996
Megathura crenulata	40	220						Reed 2020
	10	187						Kushner et al. 2013

* Prefixes with Branch & Odendaal (2003) refer to data from a study by Lasiak (L), from site Tsitsikamma (1 for sheltered, 2 for exposed conditions), and from site Dwesa (3 sheltered, 4 exposed conditions). Prefixes with Scheibling & Black (1993) and this study refer to habitats they call notch, pitted, terraced, and Radar rock (N, P, T, R). Prefixes for Zarrouk et al. 2018 refer to experimental treatments: C = control, days 2-697; NC = no cage days 48-697)

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Table S7. Dynamics of populations of *Patella ferrunginea*, at sites in the western Mediterranean (Ceuta, the Zembra Archipelago, Sardinia), and *Megathura crenulata* at sites in southern California, USA (Channel Islands, Santa Barbara, San Nicolas Island), during the monitoring period at each site. Data are starting and ending counts of limpets per linear m[a], all sampled limpets[b], or per unit area (m^{-2})[c] or (20 m^{-2})[d] over this period, and observed mean finite rate of change, λ (yr^{-1}). Also given are results of 1000 simulations using annual estimates of observed λ projected for 10 yr (for populations that were not extinct at the end of monitoring period): the median relative size of the population after 10 yr and the number of simulations with relative population size <0.5 or <0.1. For details, see 2.4 Simulation model.

Sites	Years	Initial count	Final count	Observed mean λ (yr^{-1})	Median relative size, population after 10 yr	No. / 1000 simulations, relative size: < 0.5, <0.1	Reference
Patella ferrunginea							
Ceuta [a]							
a	2007–2016	9.8	12.5	1.03	1.37	171, 3	Espinosa et al. 2018
b		4.6	3.2	1.08	0.71	402, 74	
c		3.9	4.8	1.03	1.39	290, 77	
d		2.1	4.1	1.08	1.93	44, 0	
e		5.5	18.1	1.14	3.68	1, 0	
f		10.5	46.0	1.18	5.24	0, 0	
g		2.9	18.4	1.23	8.02	2, 0	
Zembra [b]							
A	2012–2015	217	141	0.87	0.25	822, 87	Zarrouk et al. 2016
B		130	17	0.51	0	1000, 1000	
C		53	0				
D		260	384	1.14	4.85	86, 20	
E		99	53	0.81	0.11	998, 326	
F		269	277	1.01	0.86	297, 23	
Sardinia [b]							
H sites	2009–2016	0.13	0.11	0.98	0.84	225, 5	Coppa et al. 2016
Megathura crenulata							
Channel Is [c]							

6	1983–2011	0.23	0.01	0.90	0.34	564, 317	Kushner et al. 2013
7	1983–2011	0.16	0.07	0.97	0.69	427, 127	
9	1983–2011	0.10	0.31	1.04	1.8	231, 50	
11	1983–2011	0.29	0.44	1.02	1.57	390, 255	
26	2005–2011	0.17	0.59	1.23	7.61	0, 0	
28	2005–2011	0.09	0.06	0.95	0.68	443, 183	
29	2005–2011	0.22	0.43	1.12	2.83	51, 0	
32	2005–2011	0.07	0.35	1.31	13.39	6, 0	
33	2005–2011	0.19	0.01	0.62	0.01	996, 932	
35	2005–2011	0.04	0.15	1.25	9.16	0, 0	
S Barbara [d]							
CARP	2000–2019	2.34	1.94	0.99	0.73	386, 90	Reed 2020
NAPL	2000–2019	3.94	3.38	0.99	0.89	320, 31	
MOHK	2001–2019	4.38	2.63	0.97	0.67	432, 111	
GOLB	2001–2019	0.13	0.13	1.00	0	970, 962	
SCTW	2004–2019	1.38	0.25	0.89	0	837, 724	
SCDI	2004–2019	0.87	0				
S Nicolas I [c]							
1	1981–2011	0.01	0				Kenner et al. 2013
2	1980–2011	0.07	0				
3	1980–2011	0.04	0				
4	1980–2011	0.01	0.10	1.160	0	710, 614	
5	1981–2011	0.02	0.02	1.000	0.13	613, 482	
6	1985–2011	0.01	0.01	1.000	0	753, 670	
7	1986–2011	0.05	0				

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