Supporting Information. Esquivel, K. E., Hesselbarth, M.H.K., Allgeier, J.E. 2022. Mechanistic support for increased primary production around artificial reefs. Ecological Applications

Appendix S1

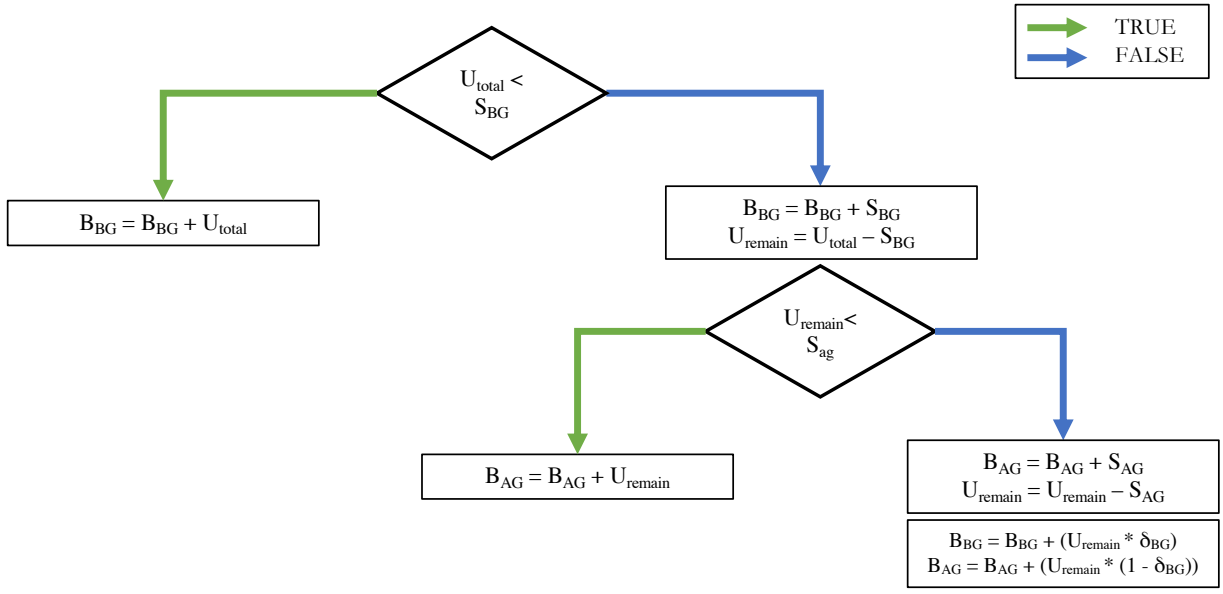

Figure S1: Visualization of where growth occurs specifically in the plant based on total nutrient uptake and current standing biomass during (1) Seagrass primary production subprocesses. Diamond-shaped boxes indicated if-else-statement in the model code and arrows of the corresponding cell fulfils the statement (green arrow) or not (blue arrow).

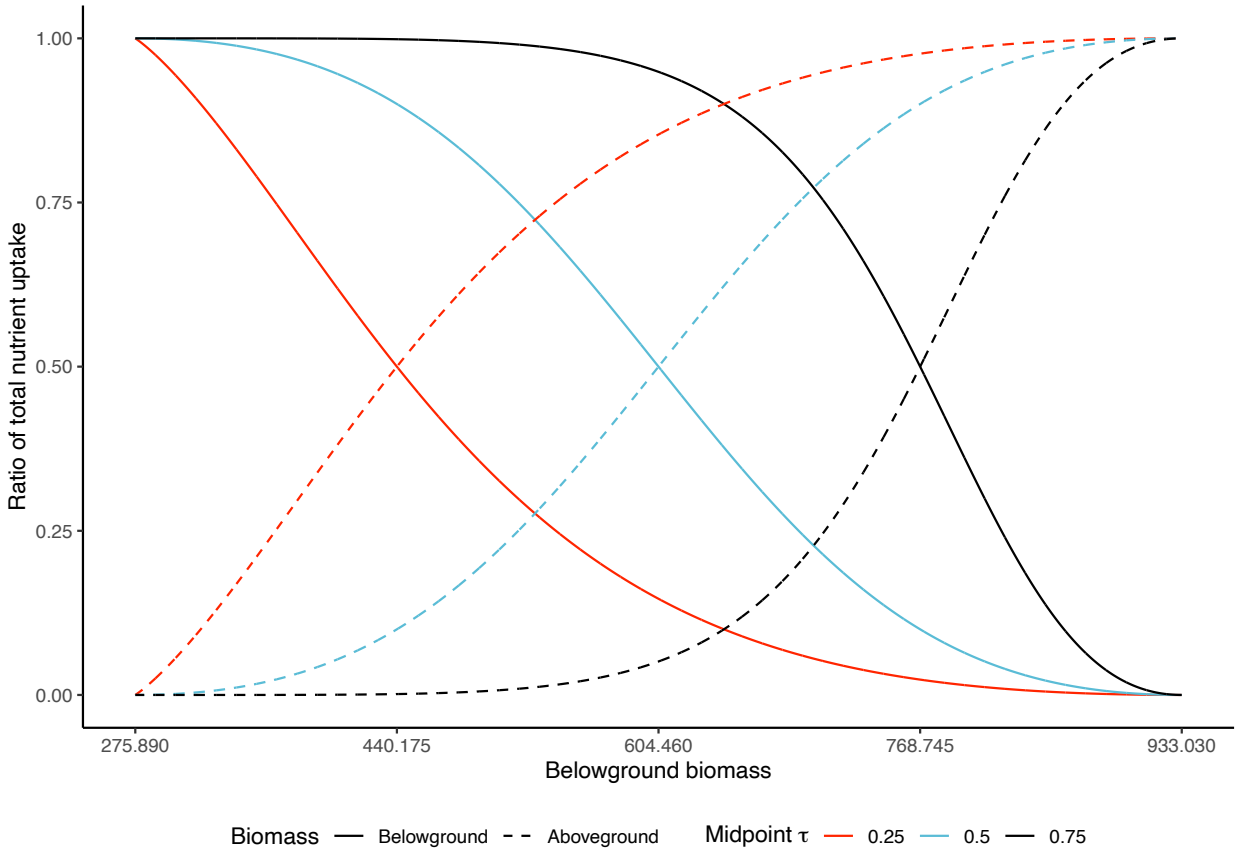

Figure S2: Sigmoid function that determines the ratios of how the remaining nutrient uptake are shared between belowground (solid lines) and aboveground biomass (dashed lines; after both belowground and aboveground biomasses were kept stable). Colors indicate different midpoint parameters $\tau = \frac{1}{4}, \frac{1}{2}, and \frac{3}{4}$, at which the allocation ratio between belowground and aboveground biomass is 50% - 50%.

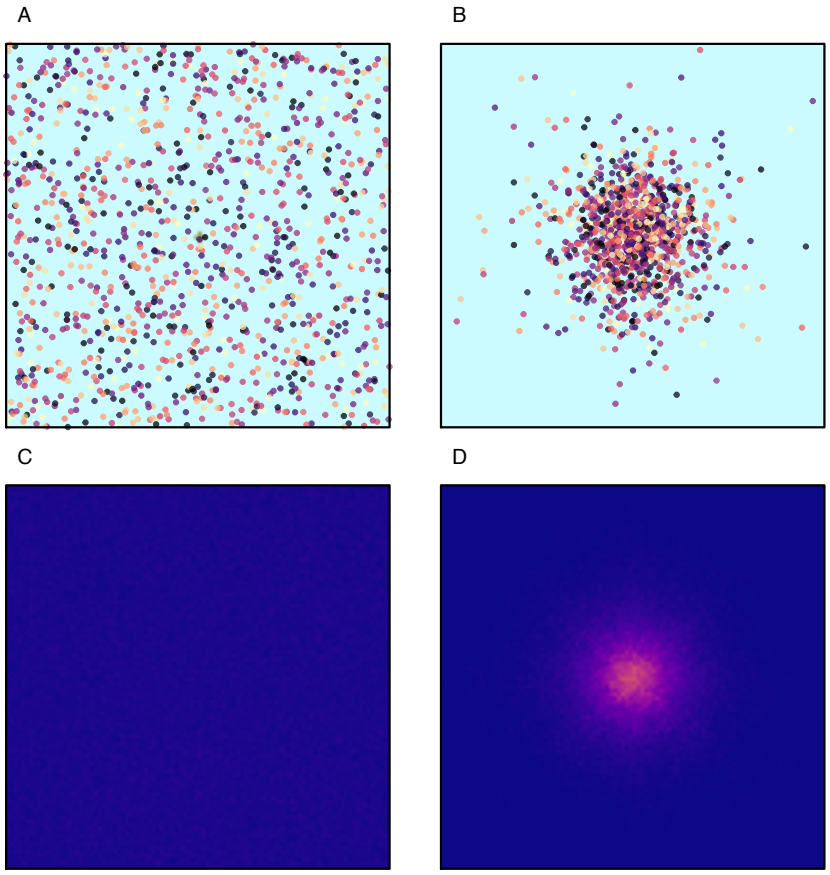

Figure S3: Locations of five fish individuals over one year (A, B). Fish locations within the model environment are indicated by points, and points of the same color refer to the same individual at different moments in time. The total excretion in each grid cell of the model environment (C, D) are depicted by the color, where purple colors correspond to lower total excretion and red colors to higher total excretion values in a given cell. For simulating no influence of the AR, fish locations are randomly distributed in the model environment (A, C), whereas fish locations are clustered around the AR for simulating attraction towards the reef (B, D). Thus, excretion values are uniformly distributed throughout the model environment when there is no aggregation (C) and excretion is higher around the AR when fish aggregate (D). The model environment is 100 x 100 grid cells, and each cell is 1 x 1 m. The artificial reef (AR) in the center of the model environment covers five cells in total.

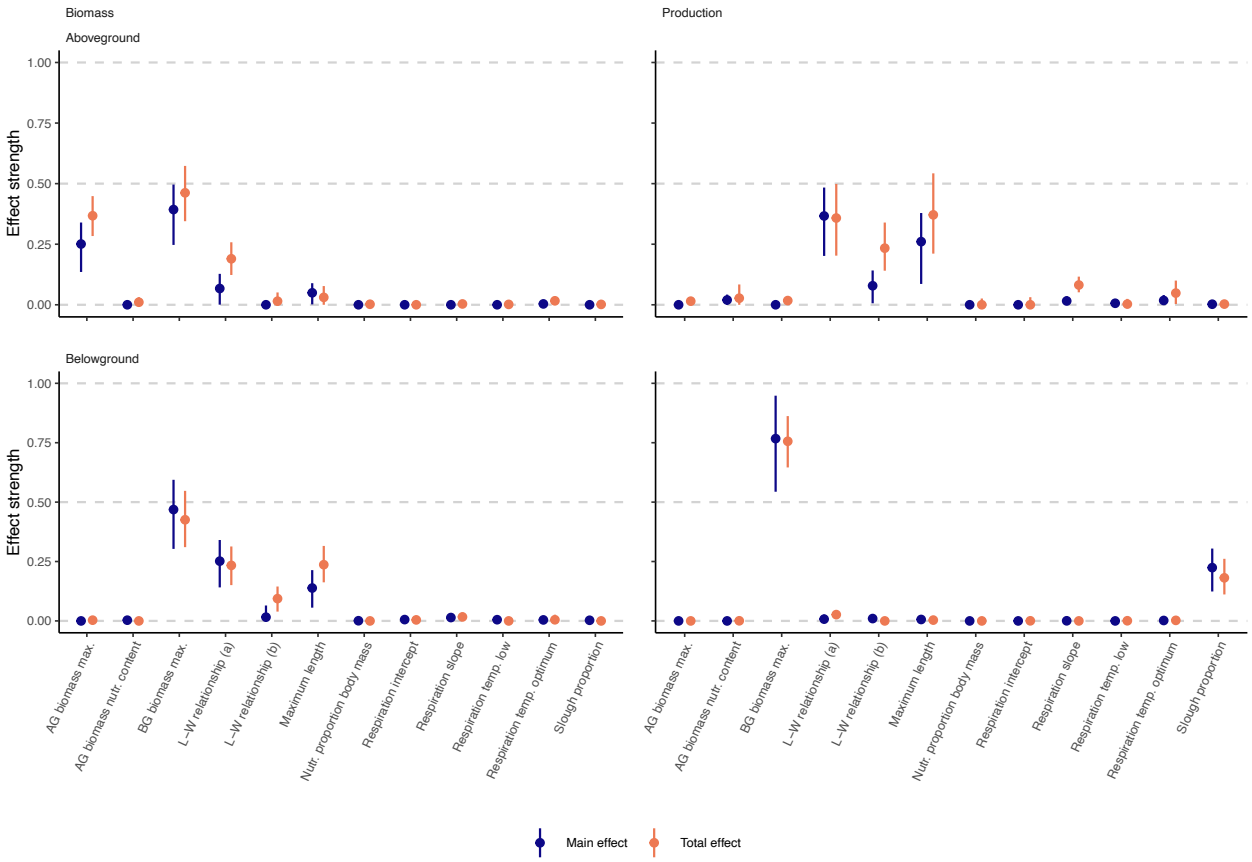

Figure S4: Main (blue) and total (orange) effect of the Sobol' sensitivity analysis. Only parameters that resulted in a relative change of the model output larger than 5% for a parameter change of 5% or 10% were included in the analysis (Appendix Table 1). The parameter space was sampled using Latin hypercube sampling (n=250).

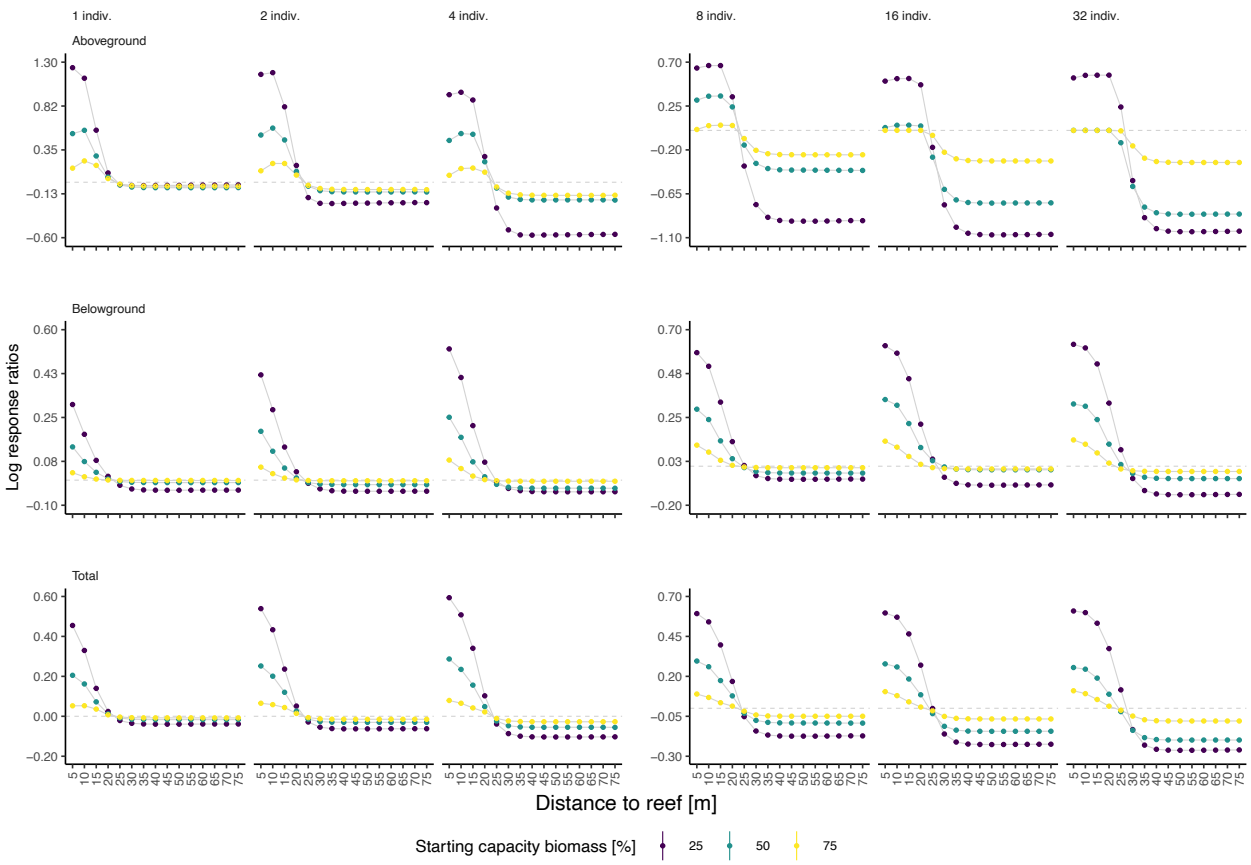

Figure S5: Log response ratios of the *random movement* and *attracted movement scenario* for aboveground, belowground, and total standing biomass in distance to the artificial reef. Distances were classified into 5 m classes. Initial biomass capacities are indicated by colors and fish densities increase across the panels from left to right

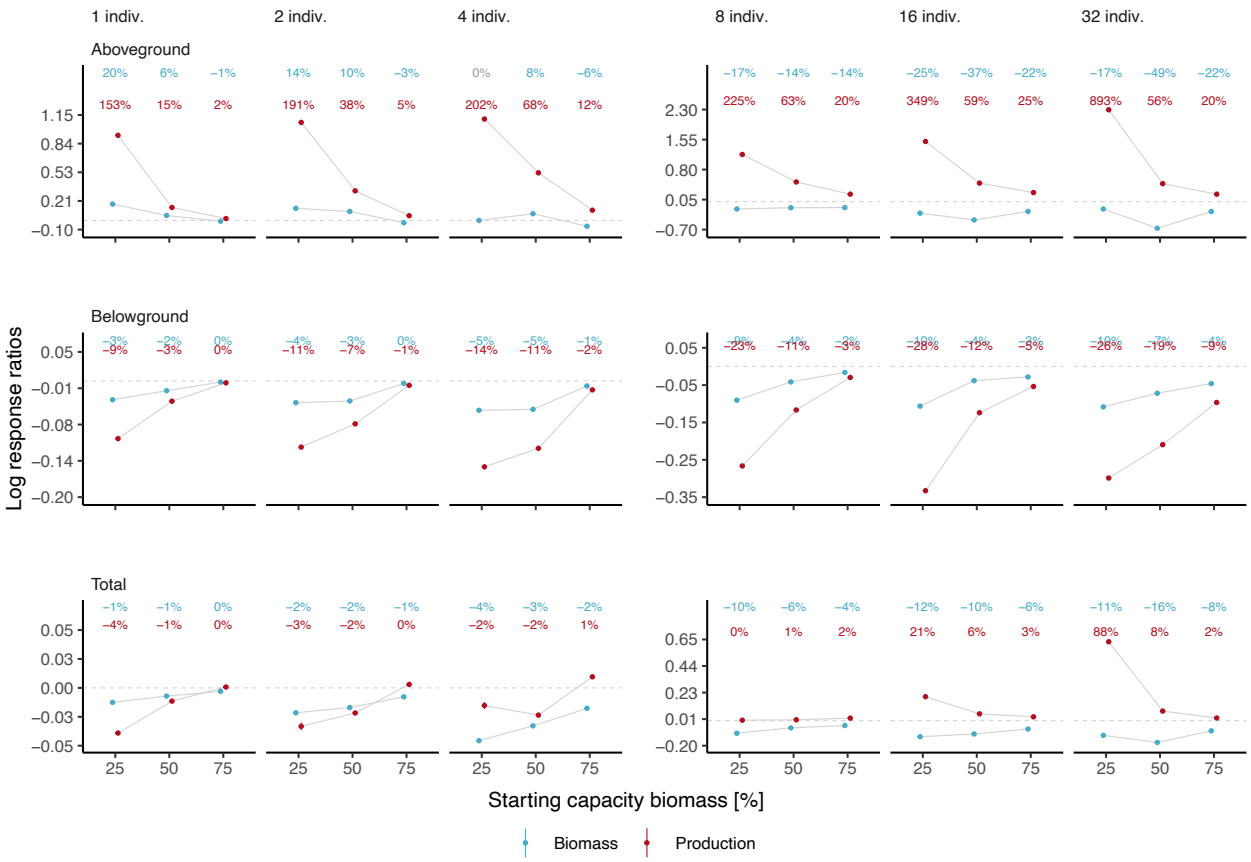

Figure S6: Log response ratios of *random movement* and *attracted movement scenario* for aboveground, belowground and total standing biomass (blue) and production (red) for an allocation midpoint parameter $\tau = \frac{1}{2}$. Initial biomass capacities increase along the x-axis and fish densities increase across the panels from left to right. The percentage value describes the relative difference between the *random movement* and the *attracted movement scenario* of biomass (blue) and production (red). If percentage values are written in grey, the log response ratios overlapped zero, i.e., no significant difference was present.

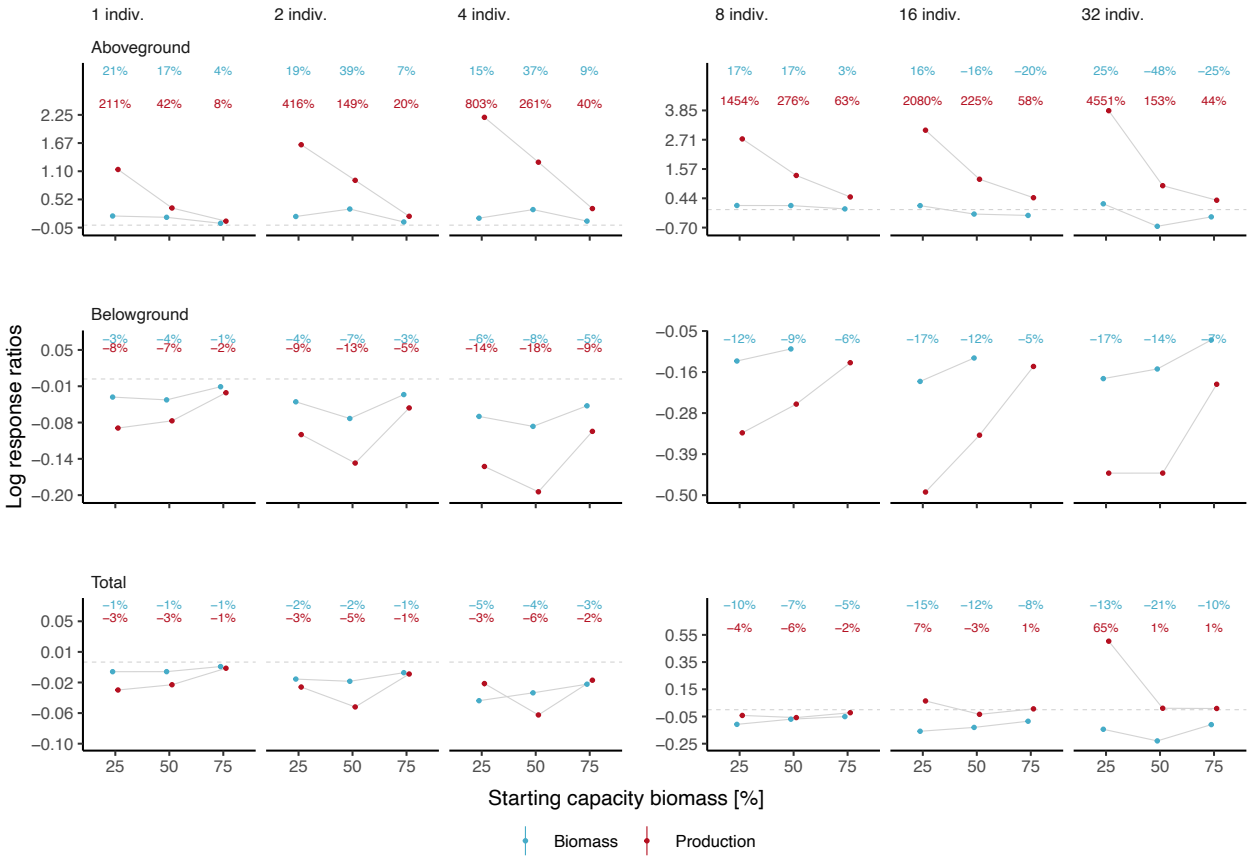

Figure S7: Log response ratios of *random movement* and *attracted movement scenario* for aboveground, belowground and total standing biomass (blue) and production (red) for an allocation midpoint parameter $\tau = \frac{3}{4}$. Initial biomass capacities increase along the x-axis and fish densities increase across the panels from left to right. The percentage value describes the relative difference between the *random movement* and the *attracted movement scenario* of biomass (blue) and production (red). If percentage values are written in grey, the log response ratios overlapped zero, i.e., no significant difference was present.

Table S1: Model parameters for which the relative model output changed more than 5% in comparison to the default parameters. Parameters were one-at-a-time increased and decreased by 5% and 10%, respectively. If the relative model output changes were below 5% for a given parameter change, no results are reported.

Model output	**Parameter**	**Increased 5%**	**Increased 10%**	**Decreased -5%**	**Decreased -10%**
Aboveground biomass	Maximum aboveground standing biomass	-	9.68	-	-9.65
Aboveground production	Nutrient content percent of standing biomass	-	-5.38	-	6.44
	Length-weight relationship (a)	-	5.05	-	-5.14
	Length-weight relationship (b)	30.70	78.30	-19.70	-32.30
	Maximum length of fish individuals	9.06	18.50	-8.57	-16.00
	Nutrient proportion of individuals' body mass	-	6.33	-	-5.95
	Intercept of respiration function	-	6.24	-	-6.00
	Slop of respiration function	-	-7.08	-	7.76
	Rate at which respiration increases over low water temp	-	-5.23	-	5.46
	Optimum water temperature for respiration	-	16.40	7.13	16.00
Belowground biomass	Maximum belowground standing biomass	-	7.67	-	-7.69

Belowground production	Maximum belowground standing biomass	-	7.37	-	-7.45
	Proportion of biomass that is sloughed to detrital biomass	-	9.71	-	-9.72

Table S2: Total standing biomass and biomass production after 50 simulation years for all different *fish density treatments* and *biomass capacities treatments*. Values are presented for aboveground and belowground separately for the *random movement* (Rand) and *attracted movement scenario* (Attr). The relative difference (Diff) describes the relative increase (positive value) or decrease (negative value) for the *attracted movement scenario*. A relative difference of 0% means that the relative change was -1% < Diff < 1%. The response ratio column (RR) indicates if the confidence interval of the bootstrapped response values included zero (n.s.), were above zero (Attr) or below zero (Rand).

Fish density	Biomass capacity [%]	Aboveground value								Belowground value							
		Biomass				Production				Biomass				Production			
		Rand	Attr	Diff [%]	RR	Rand	Attr	Diff [%]	RR	Rand	Attr	Diff [%]	RR	Rand	Attr	Diff [%]	RR
	25	511592	550990	8	Attr	209149	310819	49	Attr	4579926	4484269	-2	Rand	2352378	2194266	-7	Rand
1	50	1036766	1029181	-1	Rand	1006566	1049339	4	Attr	6100693	6078780	0	Rand	5648611	5605011	-1	Rand
	75	1516902	1492236	-2	Rand	2166819	2202598	2	Attr	7692993	7691117	0	Rand	10542482	10538034	0	Rand
	25	576862	553442	-4	Rand	303957	439672	45	Attr	4599660	4528609	-2	Rand	2443148	2306915	-6	Rand
2	50	1066155	1037114	-3	Rand	1096350	1218144	11	Attr	6150776	6103272	-1	Rand	5765819	5671204	-2	Rand
	75	1565505	1499617	-4	Rand	2330127	2419902	4	Attr	7701951	7697718	0	Rand	10567105	10557345	0	Rand
	25	728250	555466	-24	Rand	553704	769947	39	Attr	4608874	4589762	0	Rand	2525402	2473688	-2	Rand
4	50	1134384	1044157	-8	Rand	1299275	1602326	23	Attr	6238707	6140445	-2	Rand	5977800	5777649	-3	Rand
	75	1656141	1507430	-9	Rand	2648633	2872383	8	Attr	7717190	7708961	0	Rand	10609839	10591405	0	Rand

	25	992460	585456	-41	Rand	1061724	1571485	48	Attr	4645002	4622265	0	Rand	2694118	2619059	-3	Rand
	50	1359583	1048665	-23	Rand	1881771	2445148	30	Attr	6256335	6191415	-1	Rand	6123669	5935689	-3	Rand
8																	
	75	1829927	1514155	-17	Rand	3308942	3788236	14	Attr	7742689	7725968	0	Rand	10683494	10646455	0	Rand
	25	1133943	632391	-44	Rand	1500256	3333430	122	Attr	4674668	4644834	-1	Rand	2881613	2778152	-4	Rand
16	50	1825780	1051347	-42	Rand	3315347	4226041	27	Attr	6154730	6255234	2	Attr	5993901	6144537	3	Attr
	75	1927775	1520365	-21	Rand	4936843	5663263	15	Attr	7791260	7749820	-1	Rand	10820574	10727826	-1	Rand
	25	1094010	683494	-38	Rand	1482755	6986391	371	Attr	4762558	4671524	-2	Rand	3103064	2981637	-4	Rand
32	50	1928556	1050716	-46	Rand	6260223	7883142	26	Attr	6439041	6330252	-2	Rand	6706337	6405896	-4	Rand
	75	1928979	1524758	-21	Rand	8594895	9489150	10	Attr	7893140	7780662	-1	Rand	11116409	10839847	-2	Rand

Table S3: Relative change *%diff* between the *random movement* and the *attracted movement scenario* of mean aboveground and belowground biomass and production per m^2 after 50 simulation years for all different *fish density treatments* and *biomass capacity treatments* at different distances to the artificial reef (AR). The 5 m columns include all cells within the distance 0 < dist <= 3 m to the AR, the 30 m columns include all cells within the distance 27.5 m < dist <= 32.5 m to the AR. A positive value indicates an increased value, while a negative value indicates a reduced value for the *attracted movement scenario*. A relative difference of *%diff* < 1% means that the relative change was 0 < *%diff* < 1, a relative difference of *%diff* >-1% means that the relative change was -1 < *%diff* < 0.

		Relative change aboveground value [%]				**Relative change belowground value [%]**			
Fish density	**Biomass capacity [%]**	**Biomass**		**Production**		**Biomass**		**Production**	
		3 m	**30 m**	**3 m**	**30 m**	**3 m**	**30 m**	**3 m**	**30 m**
1	25	234	-4	2338	-18	40	-4	195	-14
	50	63	-5	612	-14	16	-1	47	-2
	75	11	-4	325	-9	4	0	8	0
2	25	215	-21	4201	-61	56	-4	280	-16
	50	60	-9	1179	-24	24	-2	74	-4
	75	8	-7	618	-15	6	0	14	0
4	25	153	-43	5463	-89	72	-4	369	-18
	50	51	-16	2134	-38	31	-3	102	-7

	75	4	-12	1126	-26	9	0	22	-1
	25	86	-57	6179	-94	80	-6	422	-26
8	50	33	-31	3357	-59	35	-3	124	-9
	75	0	-20	1871	-40	12	-1	31	-1
	25	63	-60	9245	-93	86	-7	450	-35
16	50	2	-49	4150	-77	41	-1	149	-6
	75	0	-24	2635	-59	14	-1	40	-3
	25	69	-53	18996	-87	86	-10	456	-41
32	50	0	-51	4504	-87	37	-5	140	-15
	75	0	-21	3158	-75	15	-2	44	-5