

Trends in the effects of kelp removal on kelp populations, herbivores, and understory algae

Supplementary material

Table S1. Studies included in the meta-analyses. *The former species *Lessonia nigrescens* was split in *Lessonia berteriana* in northern Chile and *Lessonia spicata* south of the biogeographic break at 30°S along the Chilean coast (Tellier et al. 2009; González et al. 2012). The broad geographic extent of the surveys in one study did not allow to distinguish if the targeted species was the northern or the southern *Lessonia*.

Study #	Authors and year	Title	Country	Targeted kelp species*
1	Bularz et al., 2022	Effects of harvesting on subtidal kelp forests (<i>Lessonia trabeculata</i>) in central Chile	Chile	<i>Lessonia trabeculata</i>
2	González-Roca et al., 2021	Exploring the role of access regimes over an economically important intertidal kelp species	Chile	<i>Lessonia berteriana</i> , <i>Lessonia spicata</i>
3	Gouraguine et al., 2021	The intensity of kelp harvesting shapes the population structure of the foundation species <i>Lessonia trabeculata</i> along the Chilean coastline	Chile	<i>Lessonia trabeculata</i>
4	Wernberg et al., 2020	Disturbance intensity, disturbance extent and ocean climate modulate kelp forest understory communities	Australia	<i>Ecklonia radiata</i>
5	Norderhaug et al., 2020	Ecosystem-level effects of large-scale disturbance in kelp forests.	Norway	<i>Laminaria hyperborea</i>
6	Ulaski et al., 2020	Seaweed Reproduction and Harvest Rebound in Southcentral Alaska: Implications for Wild Stock Management	USA	<i>Nereocystis luetkeana</i> , <i>Saccharina latissima</i>
7	Vega et al., 2019	Abundance and population structure of two benthic fishing resources outside and inside a port maritime concession area in Caldera, Region of Atacama,	Chile	<i>Lessonia berteriana</i>

		Chile		
8	Schiel, 2019	Experimental analyses of diversity partitioning in southern hemisphere algal communities	New Zealand	<i>Durvillaea poha</i>
9	Vega and Toledo, 2018	The chemical composition of <i>Lessonia berteroa</i> (ex <i>L. nigrescens</i>) in kelp harvest management and open access areas near Coquimbo, Chile	Chile	<i>Lessonia berteroa</i>
10	Schiel et al., 2018	Ecological tipping points for an invasive kelp in rocky reef algal communities	New Zealand	<i>Durvillaea antarctica</i>
11	De Leij et al., 2017	The influence of native macroalgal canopies on the distribution and abundance of the non-native kelp <i>Undaria pinnatifida</i> in natural reef habitats	UK	<i>Laminaria digitata</i> , <i>Saccharina latissima</i> , <i>Saccorhiza polyschides</i>
12	Pérez-Matus et al., 2017	Exploring the effects of fishing pressure and upwelling intensity over subtidal kelp forest communities in Central Chile	Chile	<i>Lessonia trabeculata</i>
13	Leclerc et al., 2015	Community, trophic structure and functioning in two contrasting <i>Laminaria hyperborea</i> forests	France	<i>Laminaria hyperborea</i>
14	Vega et al., 2013	Monitoring the sustainability of <i>Lessonia nigrescens</i> (Laminariales, Phaeophyceae) in northern Chile under strong harvest pressure	Chile	Former <i>Lessonia nigrescens</i>
15	Borras-Chavez et al., 2012	Testing sustainable management in Northern Chile: harvesting <i>Macrocystis pyrifera</i> (Phaeophyceae, Laminariales). A case study	Chile	<i>Macrocystis pyrifera</i>
16	Engelen et al., 2011	Spatial and temporal patterns of recovery of low intertidal <i>Laminaria digitata</i> after experimental spring and autumn removal	France	<i>Laminaria digitata</i>

17	O'Connor and Anderson, 2010	Consequences of habitat disturbance and recovery to recruitment and the abundance of kelp forest fishes	USA	<i>Macrocystis pyrifera</i>
18	Wernberg and Connell, 2008	Physical disturbance and subtidal habitat structure on open rocky coasts: Effects of wave exposure, extent and intensity	Australia	<i>Ecklonia radiata</i>
19	Siddon et al., 2008	Community level effects of <i>Nereocystis luetkeana</i> in southeastern Alaska.	USA	<i>Nereocystis luetkeana</i>
20	Toohey et al., 2007	Disturbance and reef topography maintain high local diversity in <i>Ecklonia radiata</i> kelp forests	Australia	<i>Ecklonia radiata</i>
21	Schmidt and Scheibling, 2007	Effects of native and invasive macroalgal canopies on composition and abundance of mobile benthic macrofauna and turf-forming algae	Canada	<i>Laminaria digitata</i> , <i>Saccharina longicuris</i>
22	Kennelly and Underwood, 1993	Geographic consistencies of effects of experimental physical disturbance on understory species in sublittoral kelp forests in central New South Wales	Australia	<i>Ecklonia radiata</i>
23	Reed, 1990	An experimental evaluation of density dependence in a subtidal algal population.	USA	<i>Pterygophora californica</i>
24	Kennelly, 1987	Physical disturbances in an Australian kelp community. 2. Effects on understory species due to differences in kelp cover.	Australia	<i>Ecklonia radiata</i>
25	Kennelly, 1987	Physical disturbances in an Australian kelp community. 1. Temporal effects	Australia	<i>Ecklonia radiata</i>
26	Reed and Foster, 1984	The effects of canopy shadings on algal recruitment and growth in a giant kelp forest.	USA	<i>Pterygophora californica</i>
27	Dayton, 1975	Experimental evaluation of ecological dominance in a rocky intertidal algal community.	USA	<i>Hedophyllum sessile</i> , <i>Lessoniopsis littoralis</i>

Table S2. Target kelp species and locations (number of articles in each country in parentheses) that were targeted in kelp removal experiments. Note that several articles included over one species. ¹The former species *Lessonia nigrescens* was split in *Lessonia berteroa* in northern Chile and *Lessonia spicata* south of the biogeographic break at 30°S along the Chilean coast (Tellier et al. 2009; González et al. 2012). *They can also be observed in shallow subtidal zones but mainly in intertidal zones and therefore they were considered as such in the analyses.

Kelp species	Number of articles	Location	Subtidal or intertidal distribution
<i>Ecklonia radiata</i>	6	Australia (6)	Subtidal
<i>Lessonia berteroa</i> and <i>Lessonia spicata</i> ¹	4	Chile (4)	Intertidal
<i>Laminaria digitata</i>	3	Canada (1), France (1), UK (1)	Intertidal*
<i>Lessonia trabeculata</i>	3	Chile (3)	Subtidal
<i>Macrocystis pyrifera</i>	3	Chile (1), USA (2)	Subtidal
<i>Durvillaea antarctica</i> and <i>Durvillaea poha</i>	2	New Zealand (2)	Intertidal
<i>Laminaria hyperborea</i>	2	France (1), Norway (1)	Subtidal
<i>Nereocystis luetkeana</i>	2	USA (2)	Subtidal
<i>Pterygophora californica</i>	2	USA (2)	Subtidal
<i>Saccharina latissima</i>	2	USA (1), UK (1)	Intertidal*
<i>Hedophyllum sessile</i>	1	USA (1)	Intertidal
<i>Laminaria setchellii</i>	1	USA (1)	Intertidal*
<i>Lessoniopsis littoralis</i>	1	USA (1)	Intertidal
<i>Saccharina longicuris</i>	1	Canada (1)	Subtidal
<i>Saccorhiza polyschides</i>	1	UK (1)	Intertidal*

Table S3. Model outputs of kelp removal effects on kelp abundance and understory algae abundance excluding outliers. Significance is shown by p-values in bold

Effect type	Average effect size g (\pmSE)	p-value	Confidence interval (CI)	Confidence interval (CI)

			Lower limit	Upper limit
Kelp abundance without	-1.3288 (0.2875)	<0.0001	-1.8923	-0.7652
outlier $g < -10$				
Understory algae	0.7144 (0.205)	0.0019	0.2626	1.1662
abundance without				
outlier $g < -10$				
Understory algae	0.7137 (0.2307)	0.0020	0.2615	1.1660
abundance without				
outliers $g < -10$ & $g > 10$				

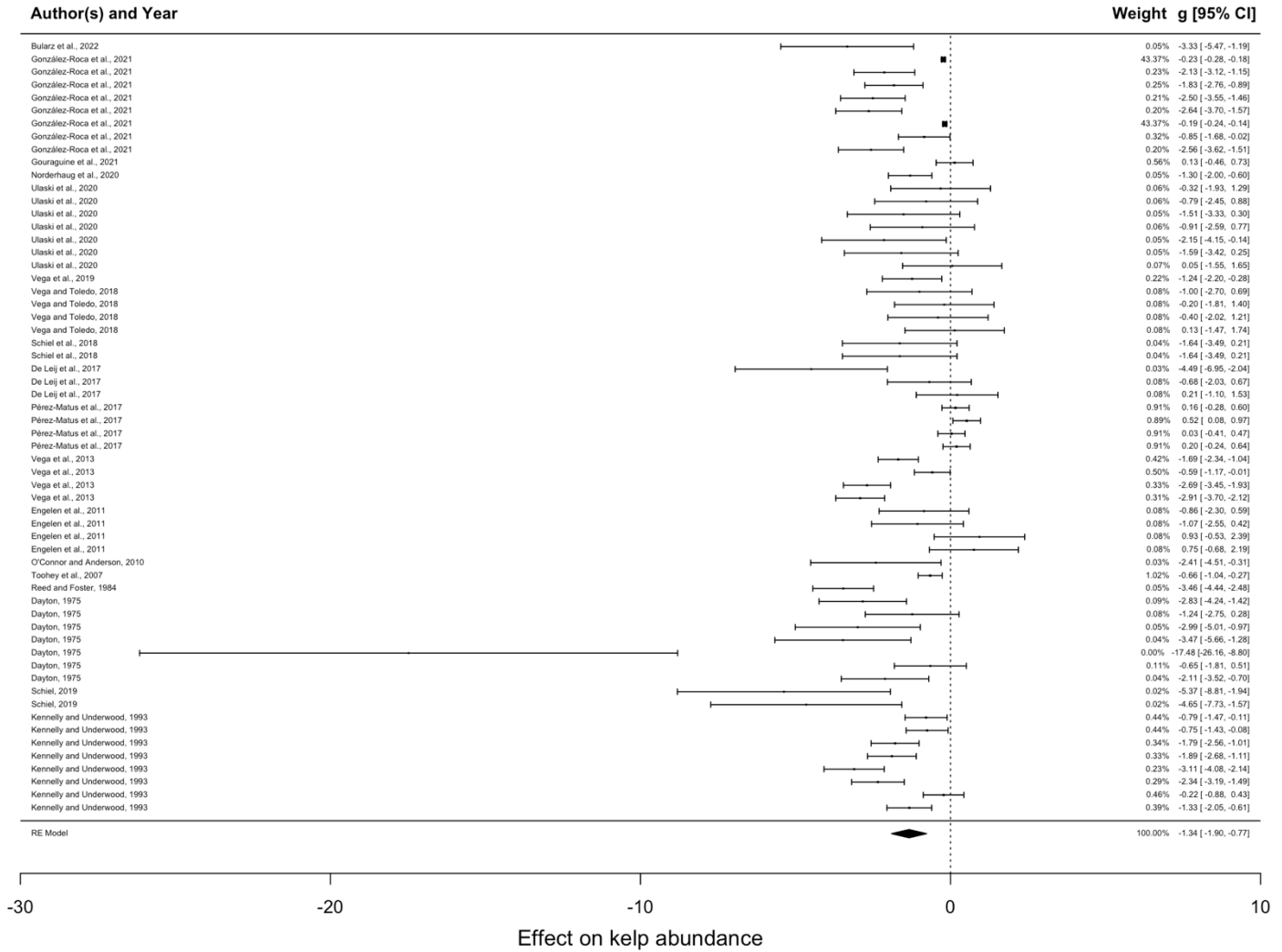


Figure S1. Forest plot of kelp abundance (Hedges' g)

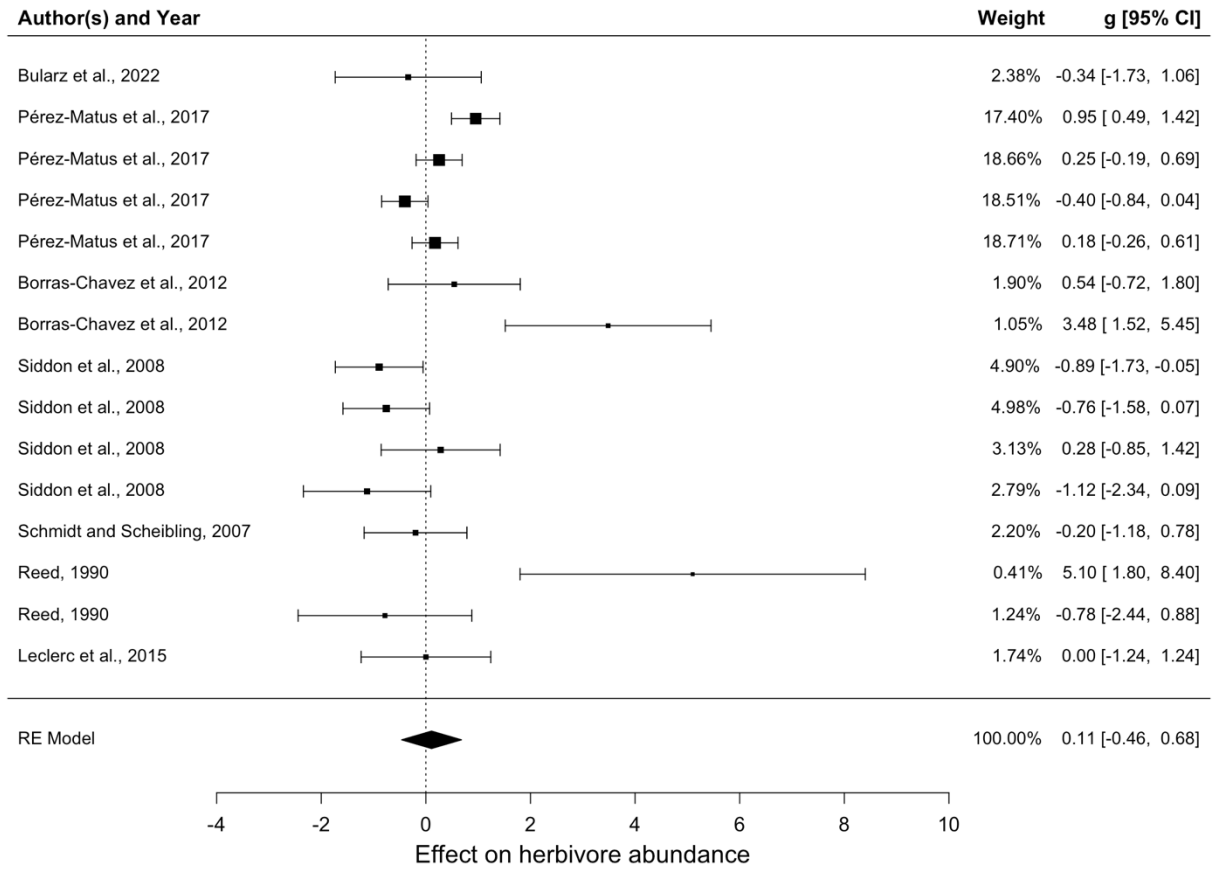


Figure S2. Forest plot of herbivore abundance (Hedges' g)

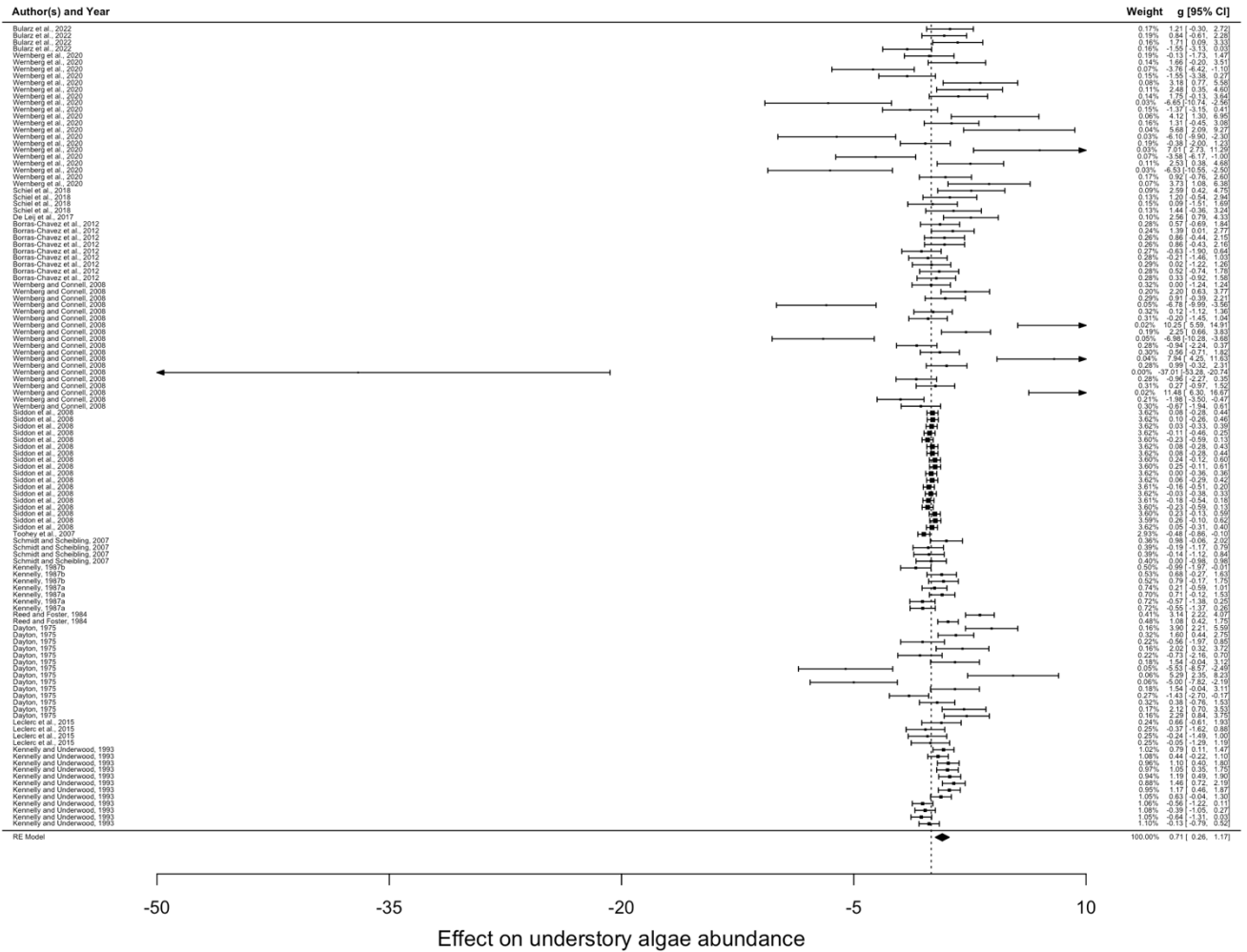


Figure S3. Forest plot of understory algae abundance (Hedges' g)

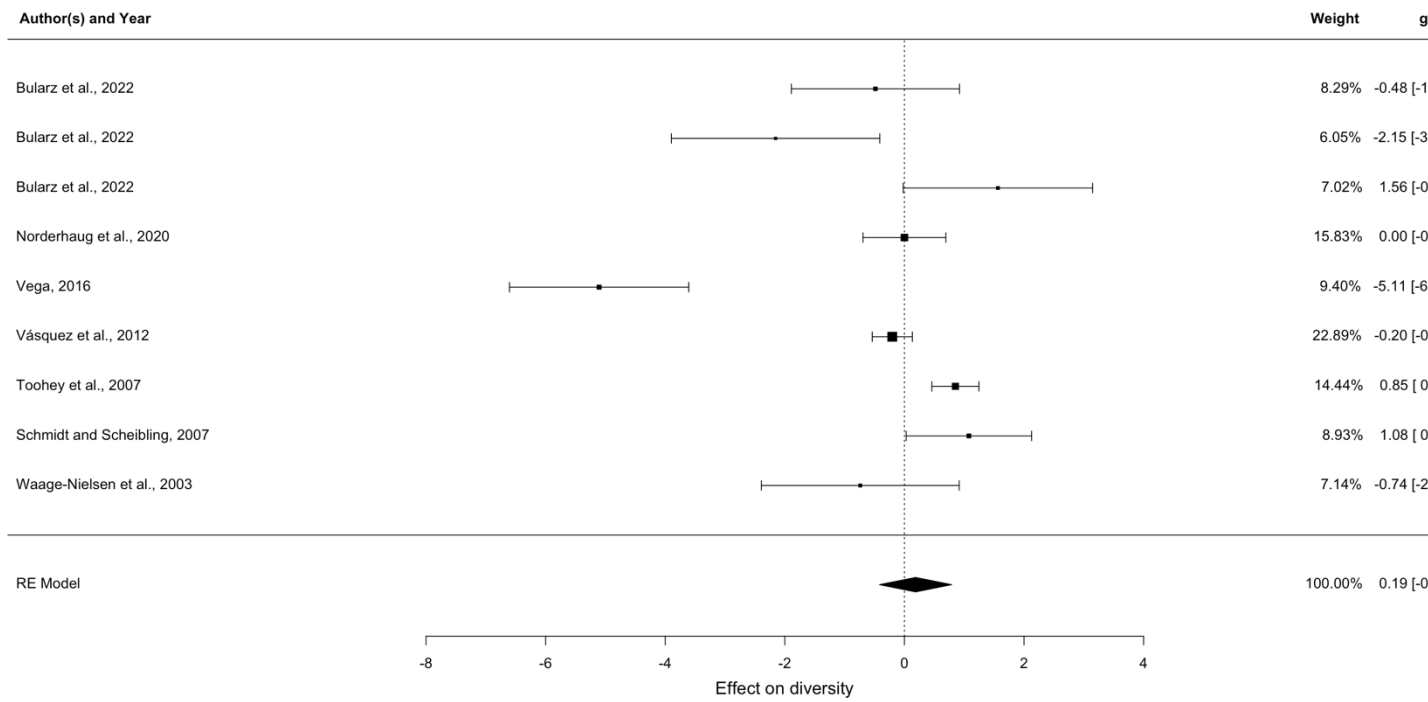


Figure S4. Forest of plot diversity (Hedges' g)