Appendix 1

Ecological Monographs

Roethler, M., Fales, R., Donoghue, C., and Padilla-Gamiño, J.

Global meta-analysis reveals the impacts of ocean warming and acidification on kelps

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Figure S1

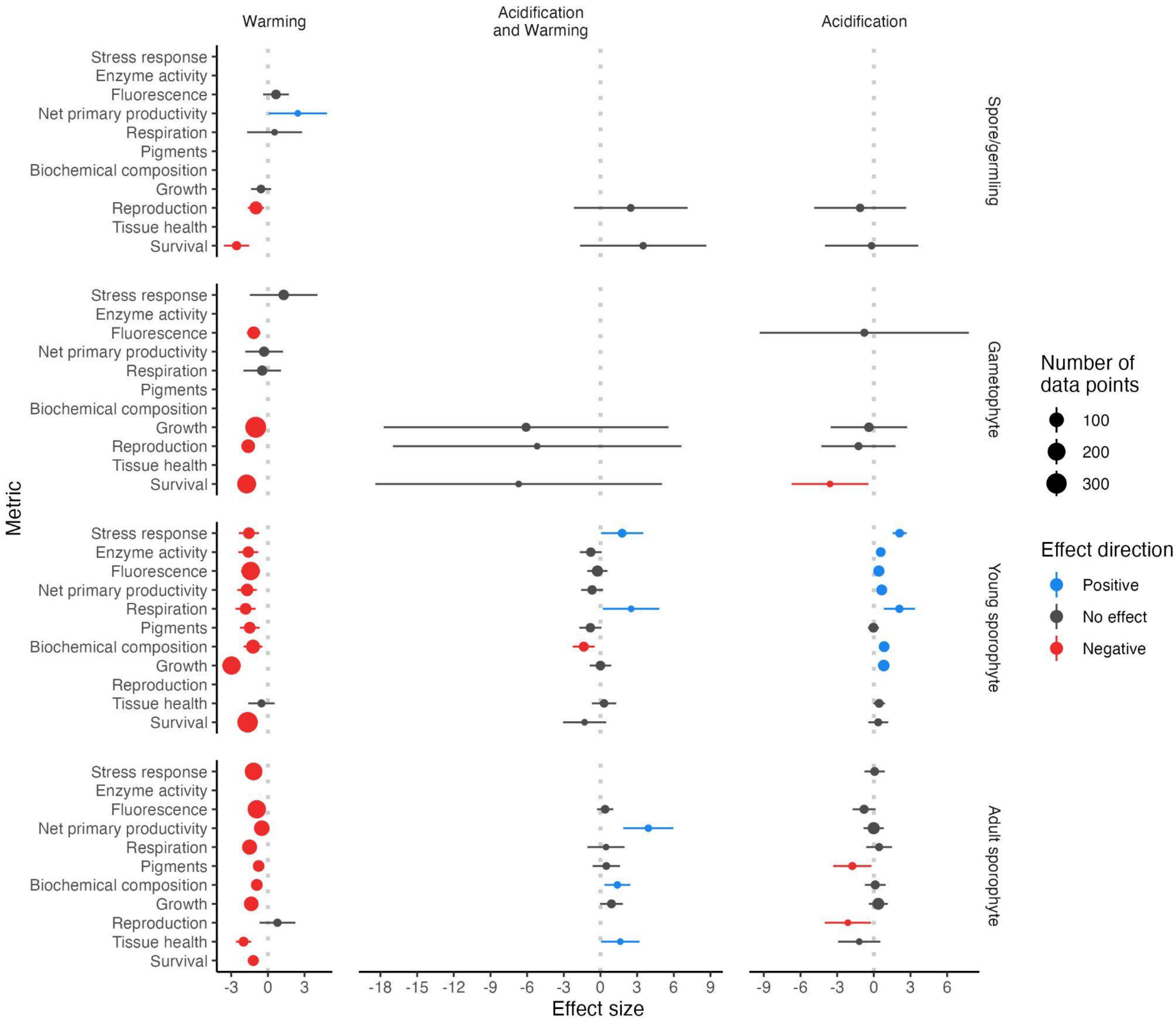

Figure S1. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different kelp life stages (rows). Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result.

Figure S2

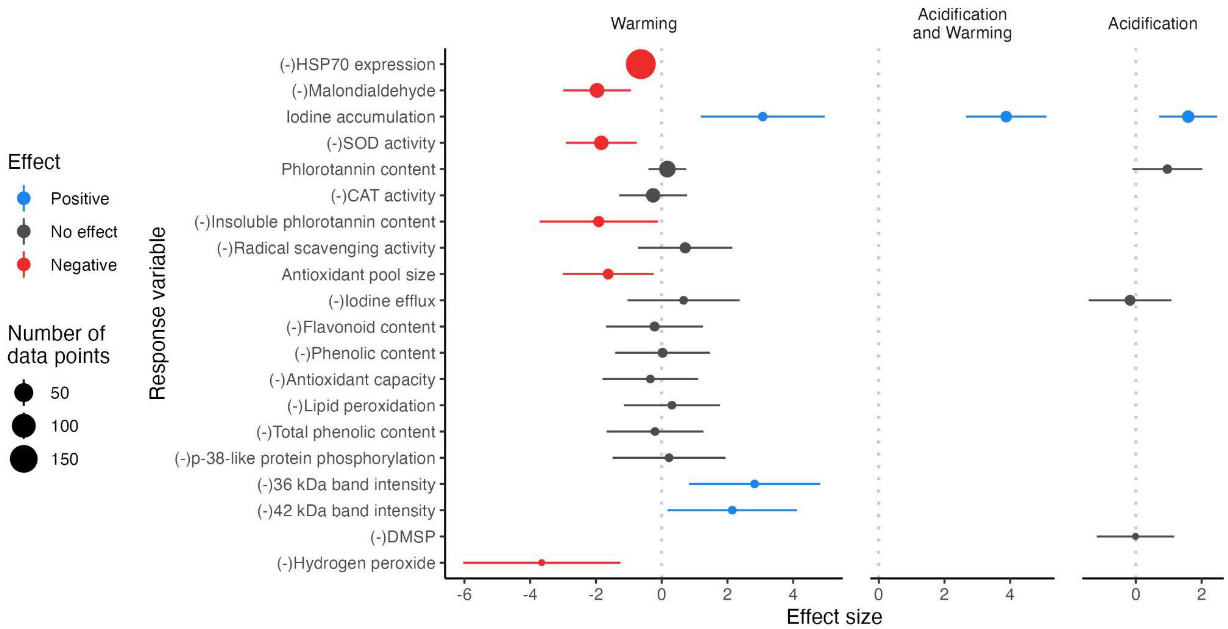

Figure S2. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Stress response" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S3

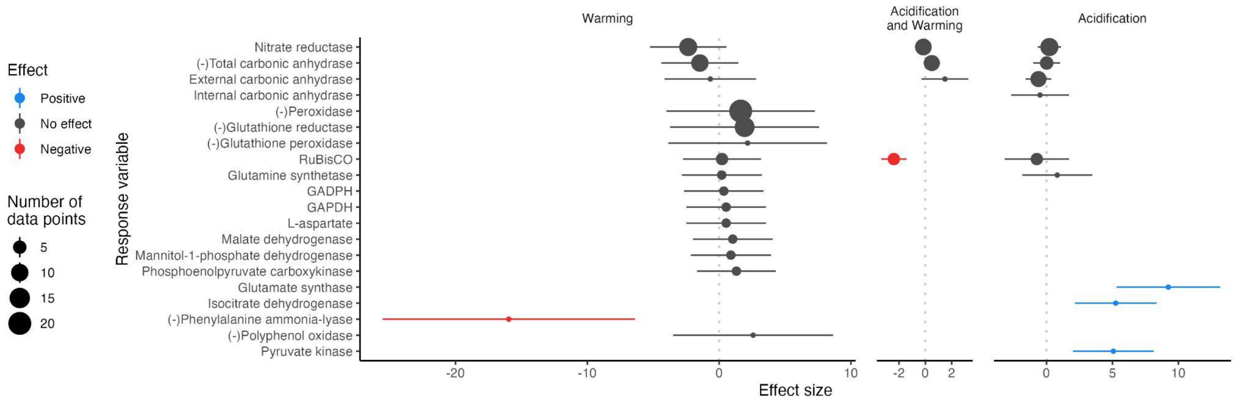

Figure S3. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the “Enzyme activity” category. Points indicate mean effect sizes (Hedges’ g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S4

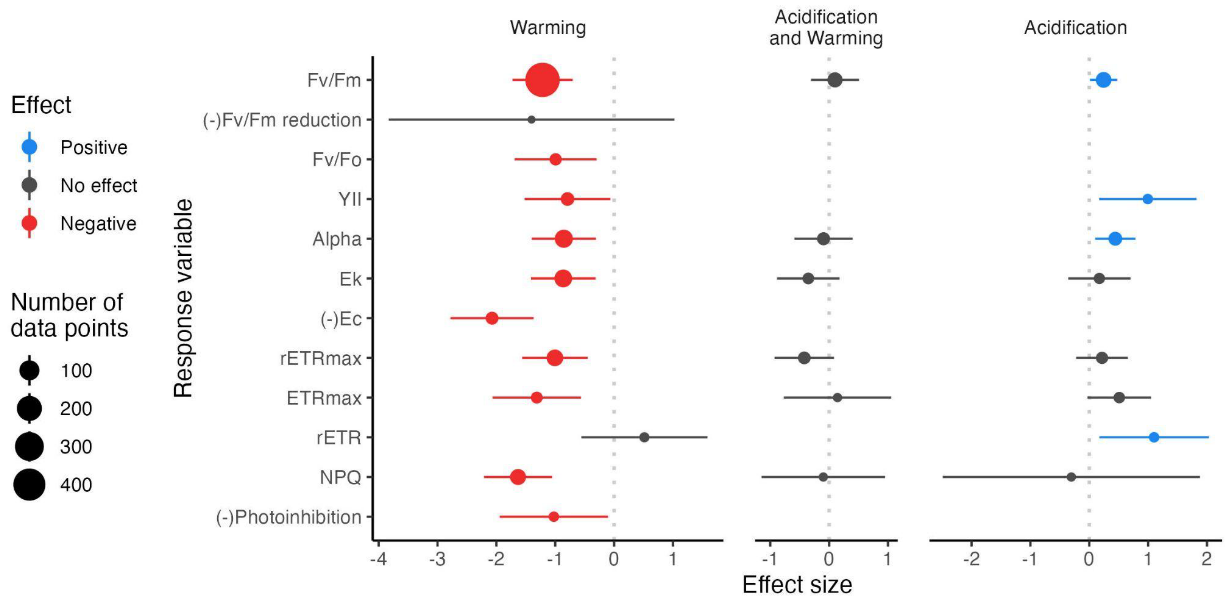

Figure S4. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the “Fluorescence” category. Points indicate mean effect sizes (Hedges’ g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S5

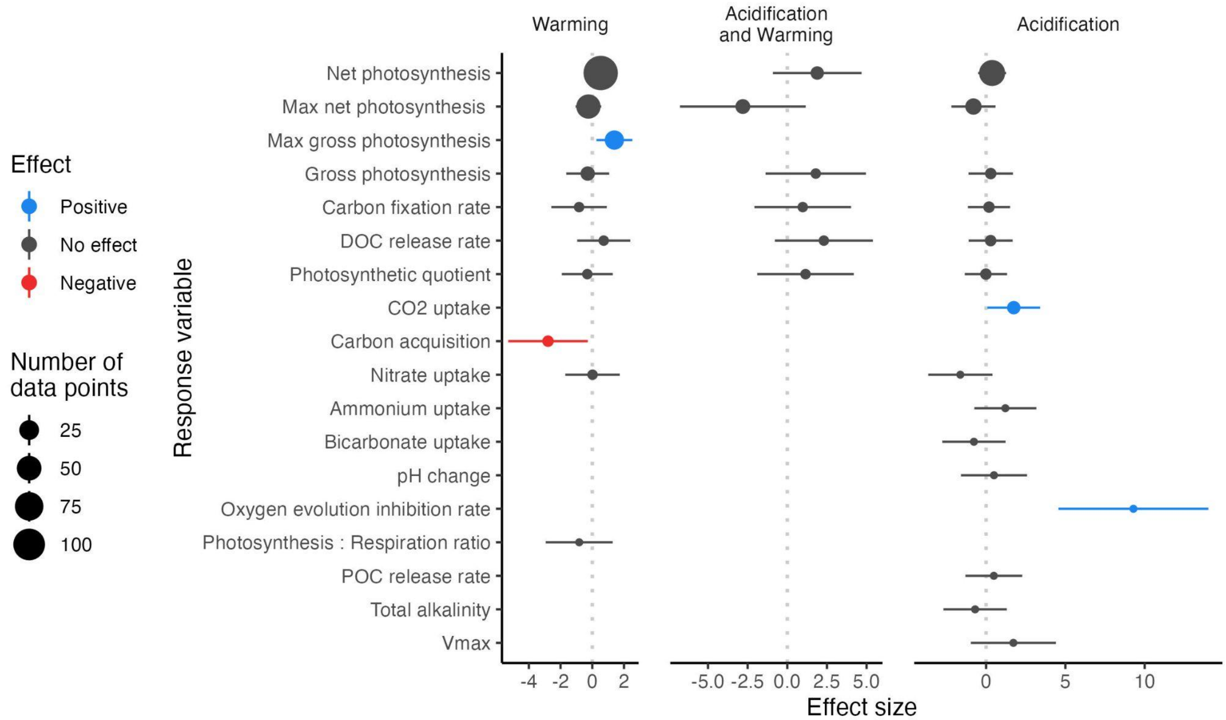

Figure S5. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Net primary productivity" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that blue indicates a positive physiological result and grey indicates a statistically non-significant result. Blank spaces indicate that no data was available.

Figure S6

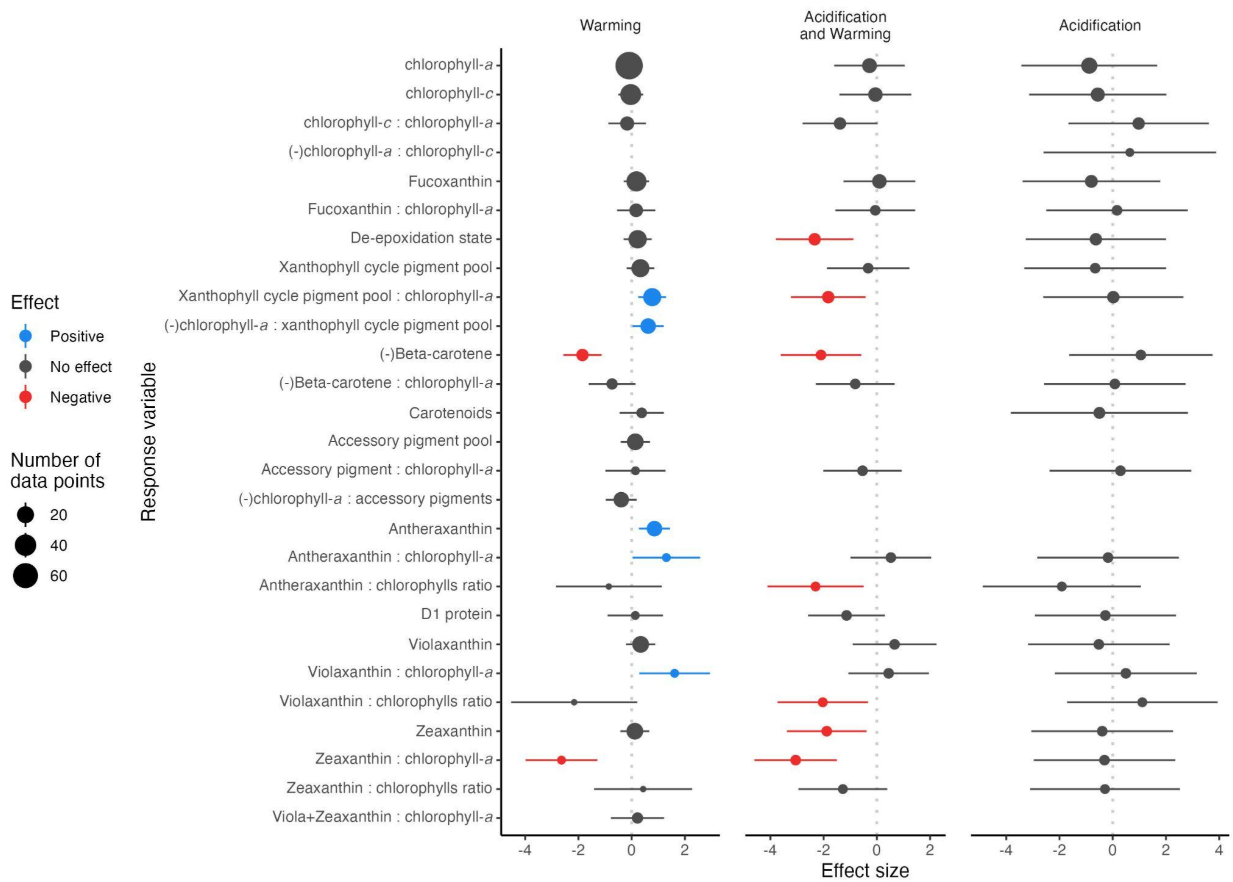

Figure S6. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Pigments" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S7

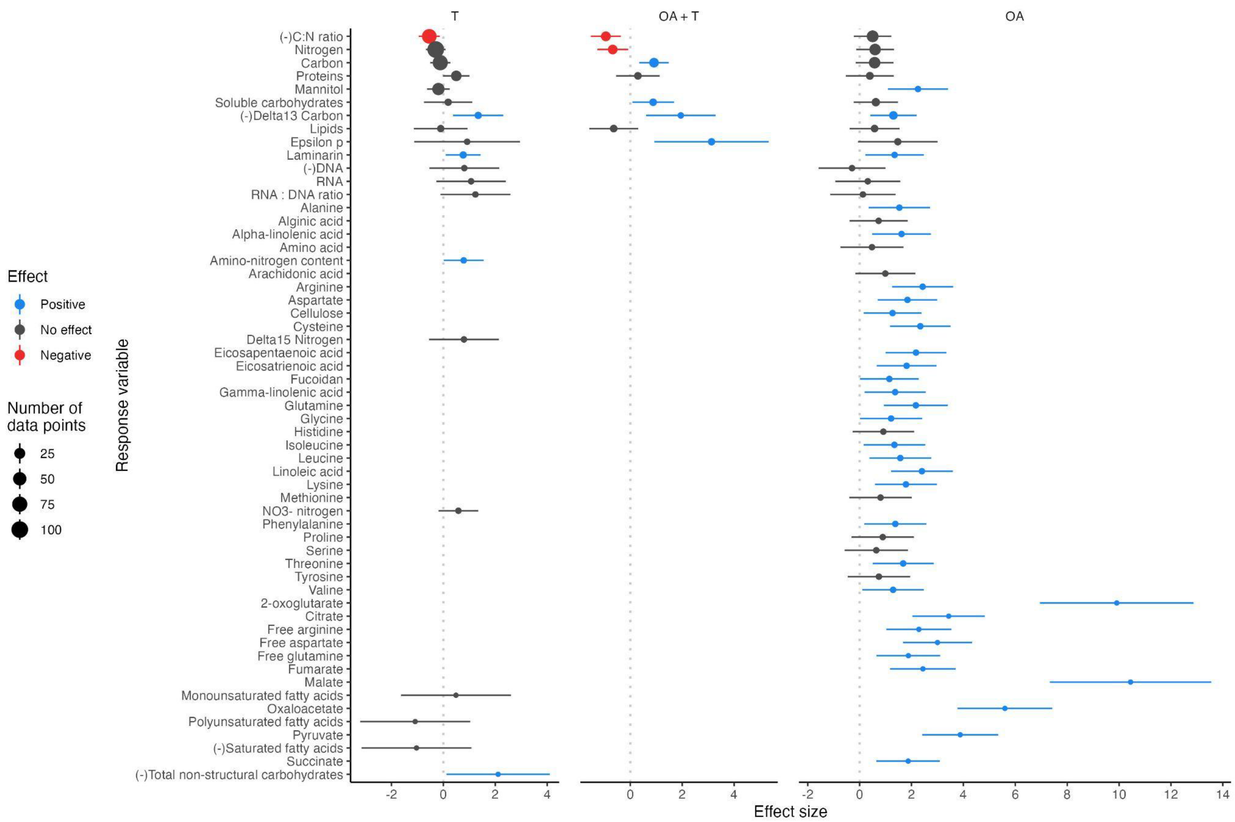

Figure S7. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Biochemical composition" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S8

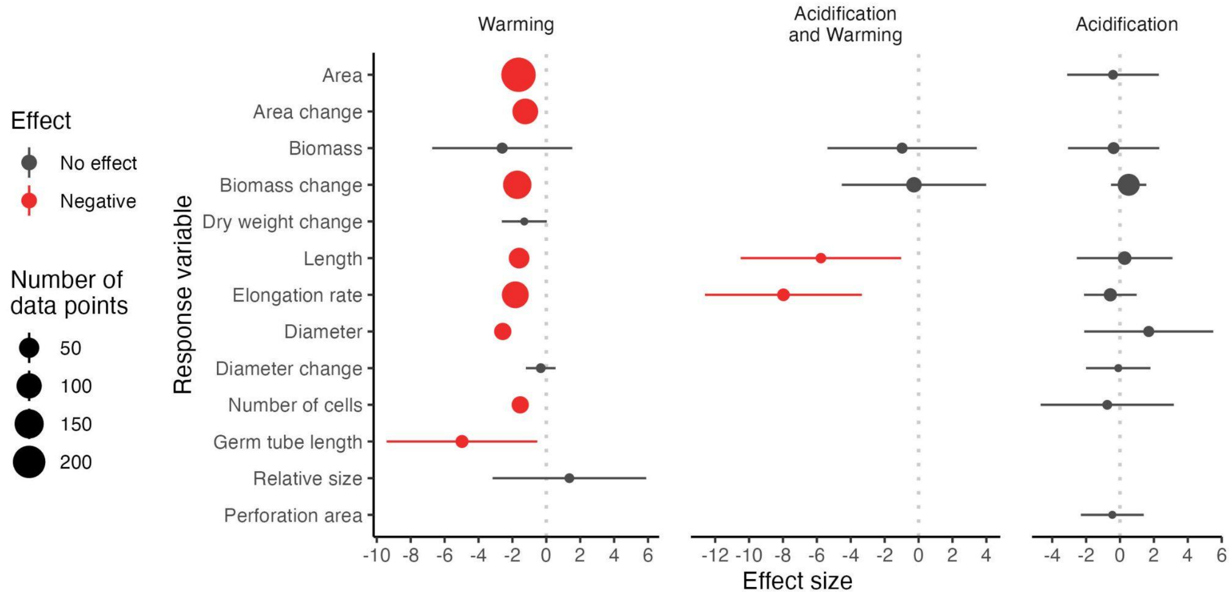

Figure S8. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Growth" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and grey indicates a statistically non-significant result. Blank spaces indicate that no data was available.

Figure S9

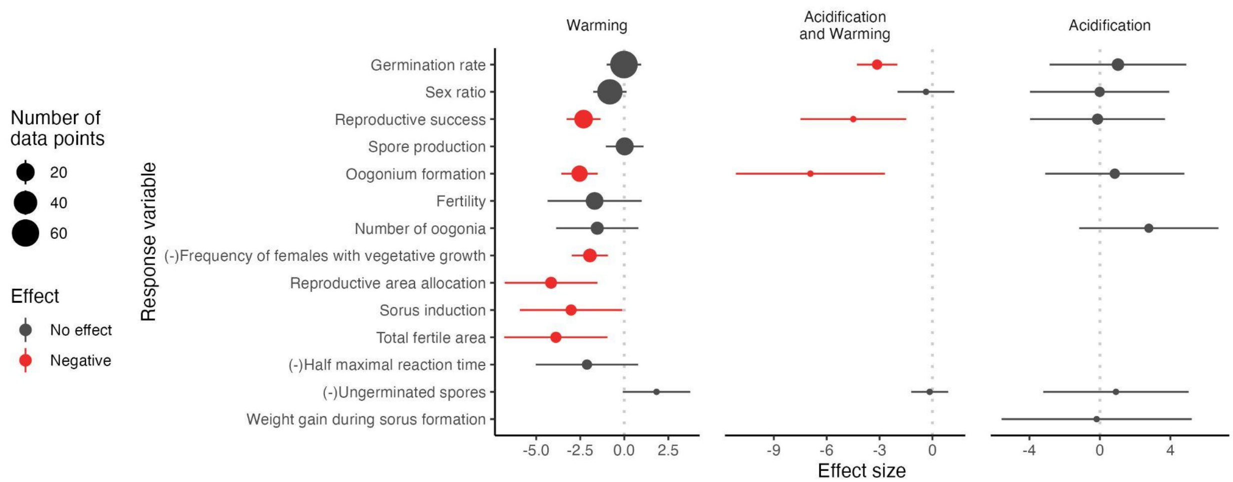

Figure S9. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Reproduction" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S10

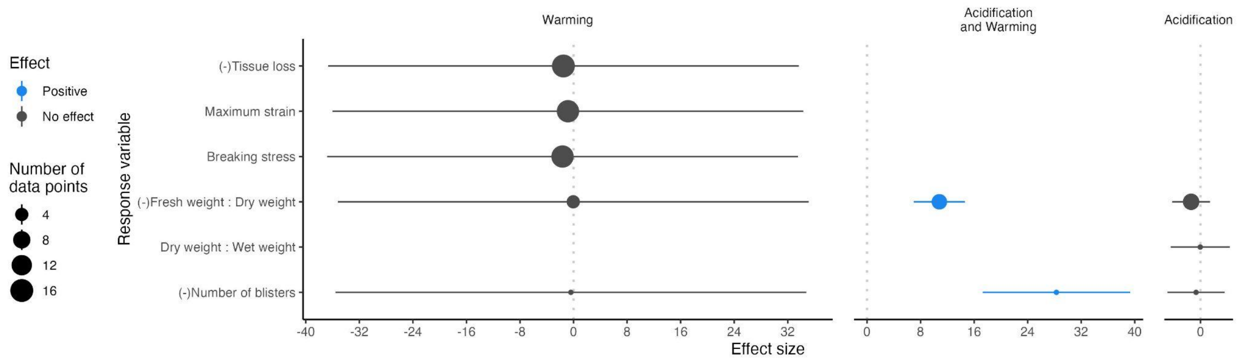

Figure S10. Forest plot showing the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel) on different specific response variables grouped within the "Tissue Health" category. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available. A negative sign in front of the variable name indicates that the sign of this variable was switched because an increase in this variable results in a negative consequence for the organism.

Figure S11

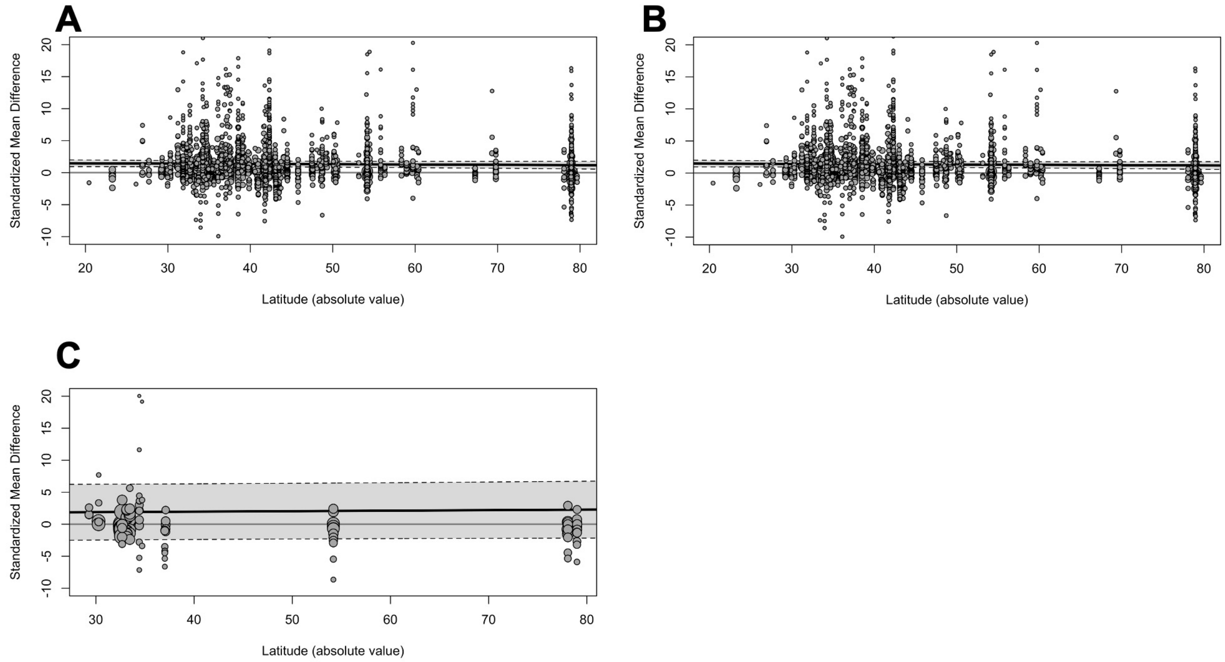

Figure S11: Bubble plot of latitude (absolute value) versus the observed effect sizes calculated in the meta-regression model under (A) warming, (B) acidification, and (C) both warming and acidification. The black line is a regression line with shaded 95% confidence intervals; the grey line indicates a SMD of zero. Point size indicates the weight of the data point in model calculations. Graphs are cropped to omit outliers.

Figure S12

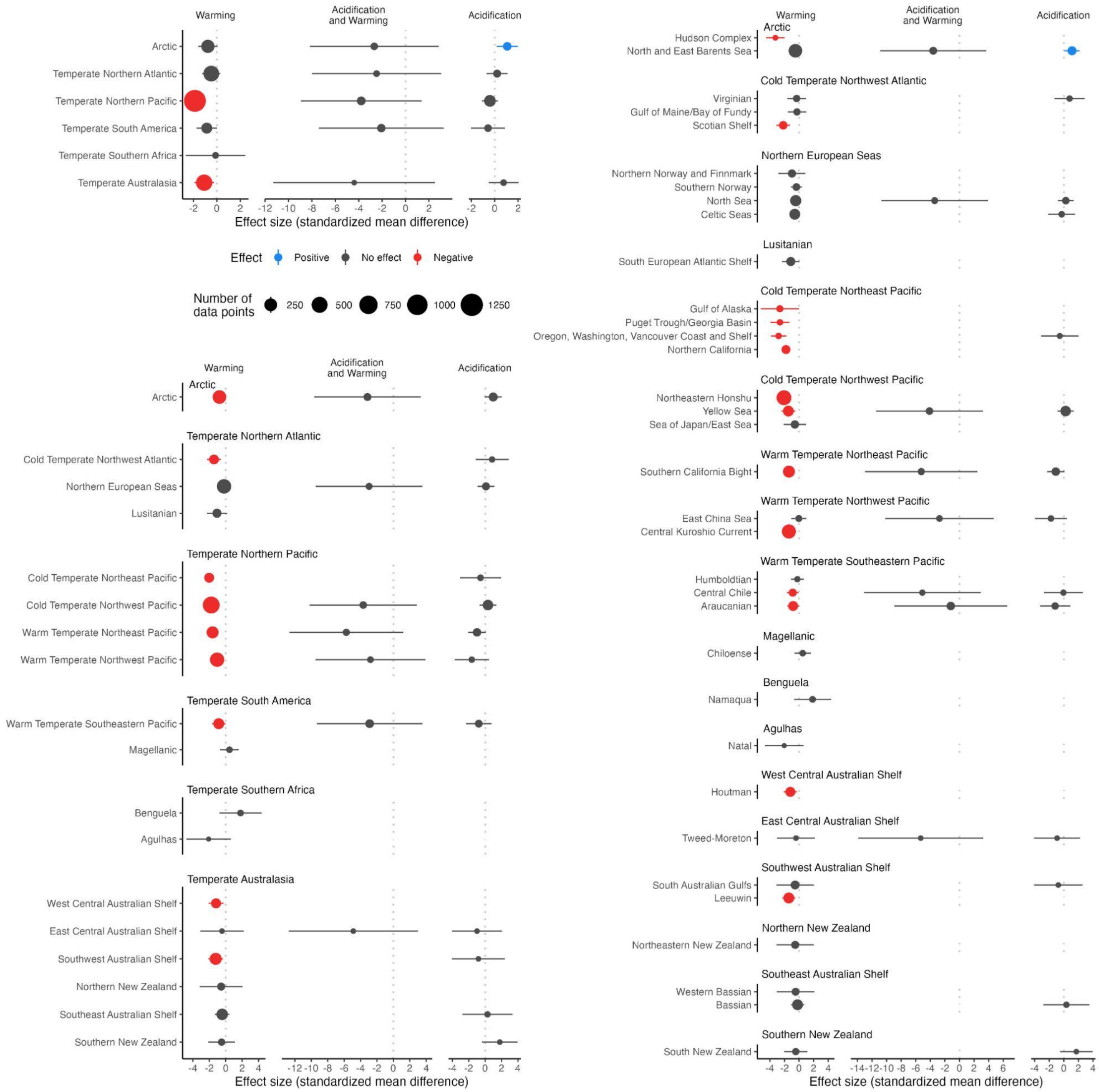

Figure S12. Forest plot showing global realms (top left), provinces (center and bottom left), and ecoregions (right). For each plot, warming effects are shown in the left panel, acidification in the right panel, and both warming and acidification in the center panel. Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by metrics with the most to least data. Results are color-coded so that red indicates a negative physiological result and blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available.

Figure S13

Figure S13. Forest plot showing kelp families (top left), genera (center and bottom left), and species (right) the effects of warming (left panel), acidification (right panel), and both warming and acidification (center panel). Points indicate mean effect sizes (Hedges' g) +/- 95% confidence interval. Point size indicates the number of data points available for each category, and the y-axis is arranged by taxa with the most to least data. Results are color-coded so that red indicates a negative physiological result blue indicates a positive physiological result; grey indicates a statistically non-significant result. Blank spaces indicate that no data was available.

Figure S14

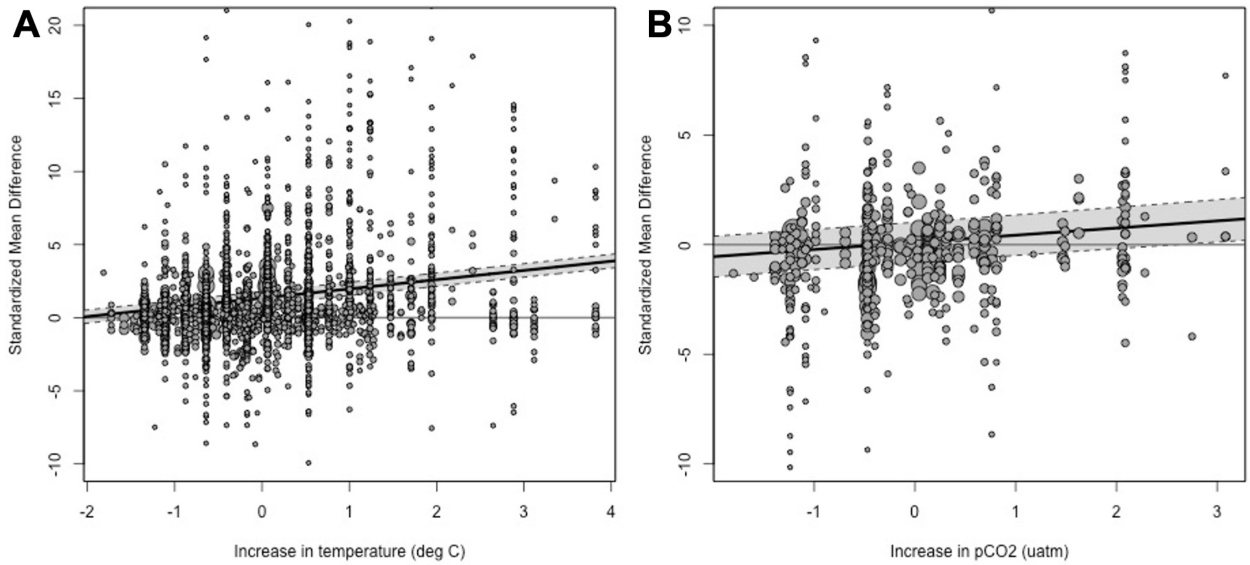

Figure S14: Bubble plot of treatment intensity (change in temperature or pCO_2 from the control to the treatment groups) versus the observed effect sizes calculated in the meta-regression model under (A) warming and (B) acidification. The black line is a regression line with shaded 95% confidence intervals; the grey line indicates a SMD of zero. Point size indicates the weight of the data point in model calculations. Graphs are cropped to omit outliers.

Figure S15

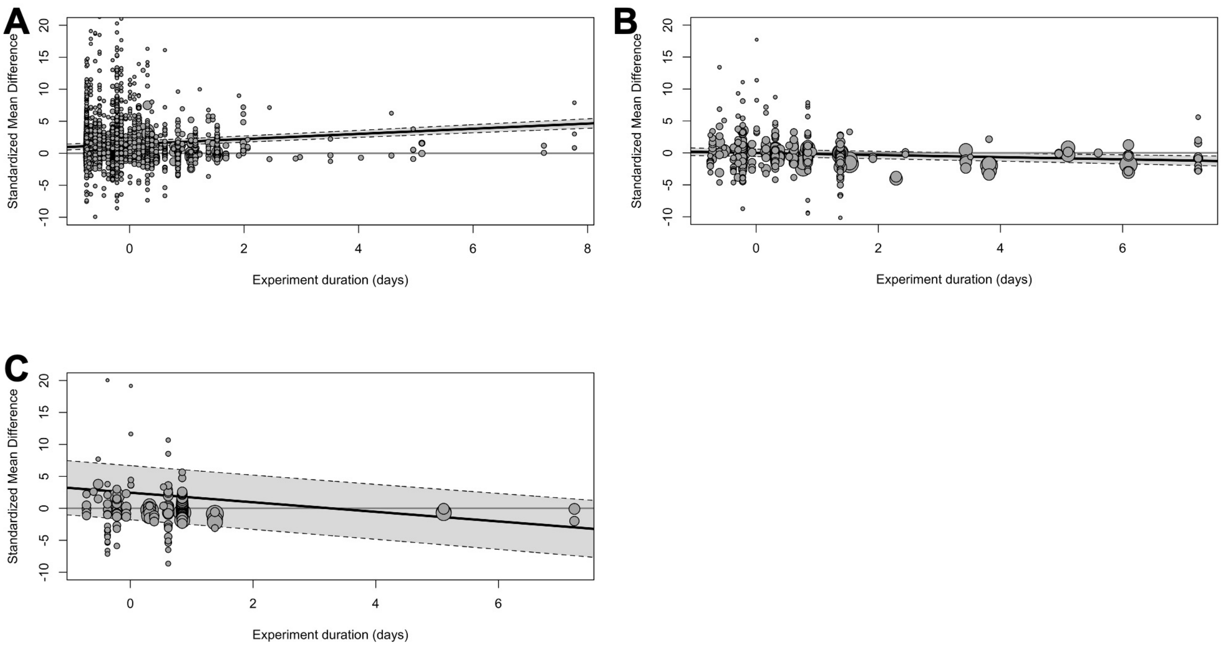

Figure S15: Bubble plot of experiment duration versus the observed effect sizes calculated in the meta-regression model under (A) warming, (B) acidification, and (C) both warming and acidification. The black line is a regression line with shaded 95% confidence intervals; the grey line indicates a SMD of zero. Point size indicates the weight of the data point in model calculations. Graphs are cropped to omit outliers.

Table S1

Table S1. Summary of data pulled from each study.

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Andersen et al. 2013	Warming	*Saccharina latissima*	Norway (Bergen / Grimstad / Drøbak)	Southern Norway / North Sea	Northern European Seas	Temperate Northern Atlantic	Young sporophyte	Net primary productivity	NP_{max}
								Fluorescence	α, E_k, F_v/F_m, NPQ, E_c
								Pigments	Chlorophyll-*a*, Chlorophyll-*c* : Chlorophyll-*a* ratio, Fx : Chlorophyll-*a* ratio, V+Z : Chlorophyll-*a* ratio
								Respiration	R_D
Augyte et al. 2019	Warming	*Saccharina agustisima*	USA (Maine, Casco Bay, Harpswell, Bailey Island)	Gulf of Maine/ Bay of Fundy	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Gametophyte	Growth	Number of cells
							Young sporophyte		Length
Bartsch et al. 2013	Warming	*Laminaria digitata*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Reproduction	Sorus induction, Total fertile area, Reproductive area allocation, Half maximal reaction time
							Spore/germling		Germination rate, Spore production
Bi et al. 2021	Acidification	*Saccharina japonica*	China (Shanghai)	East China Sea	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Enzyme activity	Total CA, CA_{ext}, CA_{int}
Biskup et al. 2014	Warming	*Laminaria ochroleuca*	Portugal	South European Atlantic Shelf	Lusitanian	Temperate Northern Atlantic	Young sporophyte	Net primary productivity	GP_{max}
								Respiration	R_D
Bollen et al. 2016	Warming	*Undaria pinnatifida, Ecklonia radiata, Lessonia variegata*	New Zealand (Tauranga Harbour)	Northeastern New Zealand	Northern New Zealand	Temperate Australasia	Adult sporophyte	Stress response	Antioxidant pool size
								Fluorescence	ETR_{max}, F_v/F_m
								Pigments	Chlorophyll-*a*, VAZ : Chlorophyll-*a* ratio
Bolton & Anderson 1987	Warming	*Ecklonia biruncinata*	South Africa (Glengariff)	Natal	Agulhas	Temperate Southern Africa	Gametophyte	Growth	Length
		Ecklonia maxima	South Africa (Kommetjie)	Namaqua	Benguela			Reproduction	Number of oogonia
Bolton & Levitt 1985	Warming	*Ecklonia maxima*	South Africa (Cape Peninsula)	Namaqua	Benguela	Temperate Southern Africa	Gametophyte	Growth	Length

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Bolton & Lüning 1982	Warming	*Saccharina latissima*	Norway (Espegrend)	Southern Norway	Northern European Seas	Temperate Northern Atlantic	Young sporophyte	Growth	Elongation rate
			United Kingdom (Isle of Man, Port Erin)	Celtic Seas					
			France (Brittany, Brest)						
			Germany (Helgoland)	North Sea					
		Laminaria hyperborea							
		Laminaria digitata	Canada (Nova Scotia, St. Margerets Bay	Scotian Shelf	Cold Temperate Northwest Atlantic				
		Saccharina latissima							
			Canada (North West Territories, Igloolik)	Hudson Complex	Arctic	Arctic			
Borlongan et al. 2018	Warming	*Costaria costata*	Japan (Hokkaido Island, Muroran City)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte, gametophyte	Net primary productivity	NP
								Fluorescence	F_v/F_m
								Respiration	R_D
Borlongan et al. 2019a	Warming	*Alaria crassifolia*	Japan (Hokkaido Island, Muroran City)	Northeastern Honshu	Cold Temperate NorthwestPacific	Temperate Northern Pacific	Adult sporophyte, gametophyte	Net primary productivity	NP
								Fluorescence	F_v/F_m
								Respiration	R_D
Borlongan et al. 2019b	Warming	*Saccharina Angustata*	Japan (Hokkaido Island, Muroran City)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP
								Fluorescence	F_v/F_m
								Respiration	R_D
Borlongan et al. 2020	Warming	*Saccharina japonica*	Japan (Hokkaido Island, Muroran City)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte, gametophyte	Net primary productivity	NP
								Fluorescence	F_v/F_m
								Respiration	R_D
Britton et al. 2016	Acidification	*Ecklonia radiata*	Australia (Tasmania, Fortescue Bay)	Bassian	Southeast Australian Shelf	Temperate Australasia	Young sporophyte	Biochemical composition	RNA : DNA ratio, RNA, DNA, δ_{13} C, C:N ratio
								Fluorescence	F_v/F_m, $rETR_{max}$
								Growth	Weight change
								Net primary productivity	NP
Brown et al. 2014	Warming, acidification, multiple stressors	*Macrocystis pyrifera*	USA (California, San Diego, Point Loma)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Biochemical composition	C:N ratio
								Fluorescence	α
								Growth	Weight
								Net primary productivity	NP_{max}

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Burdett et al. 2019	Warming	*Laminaria hyperborea*	United Kingdom (Plymouth Sound)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Net primary productivity	NP
		Laminaria digitata						Fluorescence	F_v/F_m, E_k, α, $rETR_{max}$
Buschmann et al. 2004	Warming	*Macrocystis pyrifera*	Chile	Central Chile, Araucanian	Warm Temperate Southeastern Pacific	Temperate South America	Spore/germling	Reproduction	Spore production, germination rate
							Young sporophyte	Growth	Elongation rate
Choi et al. 2019	Warming	*Eisenia bicyclis*	Korea (Gyubuk, Ulleungdo, Dokdo)	Sea of Japan/ East Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Growth	Elongation rate
		Ecklonia cava	Korea (Cheonan, Shinan, Jangsan)	East China Sea	Warm Temperate Northwest Pacific				
Chu et al. 2019	Acidification	*Saccharina japonica*	China (Shandong, Rongcheng)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Biochemical composition	Soluble carbohydrates, proteins
								Growth	Weight change
								Net primary productivity	NP
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*
Chu et al. 2020	Acidification	*Saccharina japonica*	China (Shandong, Rongcheng)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Biochemical composition	C:N ratio, Carbon, Nitrogen
								Growth	Weight change
								Net primary productivity	NP
								Respiration	R_D
Cornwall et al. 2012	Acidification	*Undaria pinnatifida*	New Zealand (South Island, Otago Harbour)	South New Zealand	Southern New Zealand	Temperate Australasia	Young sporophyte	Net primary productivity	NP
Cruces et al. 2013	Warming	*Lessonia nigrescens*	Chile (Valdivia, Playa Rosada)	Araucanian	Warm Temperate Southeastern Pacific	Temperate South America	Young sporophyte	Fluorescence	F_v/F_m, ETR_{max}
								Stress response	Phlorotannin content, Malondialdehyde, Radical scavenging activity, Insoluble phlorotannin content
Davison 1987	Warming	*Saccharina latissima*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Young sporophyte	Net primary productivity	NP_{max}
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Fx, Beta-carotene

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Davison & Davison 1987	Warming	*Saccharina latissima*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Young sporophyte	Biochemical composition	Proteins, Amino-nitrogen content, NO_3- nitrogen, Nitrogen, Laminarin, Mannitol
								Enzyme activity	RuBisCO, GADPH, GAPDH, NR, Glutamine synthetase, Phosphoenolpyruvate carboxykinase, MDH, l-aspartate, M-1-PDH
								Growth	Weight change
								Net primary productivity	NP_{max}
Delebe-cq et al. 2016	Warming	*Laminaria digitata*	France (Roscoff)	South European Atlantic Shelf	Lusitanian	Temperate Northern Atlantic	Gametophyte	Fluorescence	α, $rETR_{max}$, E_k, NPQ
			France (Wissant)	North Sea	Northern European Seas				
Diehl et al. 2020	Warming	*Laminaria solidungula*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Biochemical composition	Carbon, Nitrogen, Mannitol, C:N ratio
								Fluorescence	F_v/F_m
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Fx, VAZ, DPS, Beta-carotene
								Stress response	Phlorotannin content
Diehl et al. 2021	Warming	*Saccharina latissima*	France (Brittany, Locmariaquer) / Germany (Helgoland) / Norway (Bergen / Bodø / Svalbard, Spitsbergen, Kongsfjorden)	South European Atlantic Shelf / North Sea / Southern Norway / Northern Norway and Finnmark / North and East Barents Sea	Lusitanian / Northern European Seas / Arctic	Temperate Northern Atlantic / Arctic	Adult sporophyte	Biochemical composition	C:N ratio, Carbon, Nitrogen, Mannitol
								Fluorescence	F_v/F_m
								Growth	Surface area
								Pigments	Acc, Antheraxanthin, Chlorophyll-*a*, Chlorophyll-*a* : Acc ratio, Chlorophyll-*a* : VAZ, Chlorophyll-*c*, Fucoxanthin, V, VAZ, Z
								Stress response	Phlorotannin content
								Survival	Survival
Donham et al. 2021	Acidification	*Macrocystis pyrifera*	USA (California, San Diego, Mia's Reef)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Survival	Density

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Endo et al. 2017	Warming	*Eisenia bicyclis*	Japan (Oshika Peninsula)	Sea of Japan/ East Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Carbon, Nitrogen
								Growth	Weight change, Elongation rate, Area change
								Stress response	Phlorotannin content
Endo et al. 2020	Warming	*Eisenia bicyclis*	Japan (Miyagi Prefecture, Oshika Peninsula, Kitsune-zaki)	Sea of Japan/East Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Carbon, Nitrogen
								Fluorescence	F_v/F_m
								Growth	Area change, diameter change, dry weight change, elongation rate, weight change
								Stress response	Phlorotannin content
Endo et al. 2021	Warming	*Undaria pinnatifida*	Japan (Shizugawa Bay)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Growth	Weight change
Fain & Murray 1982	Warming	*Macrocystis pyrifera*	USA (California, Laguna Beach)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Gametophyte, Young sporophyte	Net primary productivity	NP_{max}
								Respiration	R_D
Falkenberg et al. 2013	Acidification	*Ecklonia radiata*	Australia (Adelaide, Outer Harbor)	Southern Australian Gulfs	Southwest Australian Shelf	Temperate Australasia	Adult sporophyte	Biochemical composition	C:N ratio, Carbon, Nitrogen
								Growth	Weight change
Fernández et al. 2017	Acidification	*Macrocystis pyrifera*	New Zealand (Otago Harbour, Aramoana Beach)	South New Zealand	Southern New Zealand	Temperate Australasia	Adult sporophyte	Net primary productivity	pH change, NO_3- uptake, HCO_3- uptake, CO_2 uptake, Total alkalinity
Fernández et al. 2021	Warming, acidification, multiple stressors	*Macrocystis pyrifera*	Chile (El Tabo / Las Docas)	Araucanian	Warm Temperate Southeastern Pacific	Temperate South America	Young sporophyte	Biochemical composition	C:N ratio, Nitrogen, Carbon
								Enzyme activity	NR, Total CA
								Fluorescence	α, $rETR_{max}$, E_k, F_v/F_m
								Growth	Weight change
								Net primary productivity	NP_{max}
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Fx
Fonck et al. 1998	Warming	*Lessonia nigrescens*	Chile (Coquimbo)	Central Chile	Warm Temperate Southeastern Pacific	Temperate South America	Spore/germling	Reproduction	Spore production
		Lessonia trabeculata							

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Fortes & Lüning 1980	Warming	*Saccharina latissima*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Growth	Elongation rate
Franco et al. 2017	Warming	*Laminaria ochrole-uca*	Portugal (São Bartolomeu, Amorosa and Viana do Castelo)	South European Atlantic Shelf	Lusitanian	Temperate Northern Atlantic	Young sporophyte	Biochemical composition	Nitrogen
								Growth	Weight change
								Survival	Survival
Franke et al. 2021	Warming	*Laminaria digitata, Hedophyllum nigripes*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Gametophyte	Reproduction	Sex ratio
								Survival	Density
							Young sporophyte	Biochemical composition	C:N ratio, Carbon, Nitrogen
								Fluorescence	F_v/F_m
								Growth	Area change
Fredersdorf et al. 2009	Warming	*Alaria esculenta*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Spore/germling	Reproduction	Germination rate
							Adult sporophyte	Fluorescence	F_v/F_m
Fu et al. 2010	Warming	*Costaria costata*	China (Dalian)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Growth	Length
Fukuhara et al. 2002	Warming	*Saccharina japonica*	Japan (Hokkaido, Minamikayabe)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Spore/germling	Fluorescence	α, E_c, E_k
								Net primary productivity	GP
								Respiration	R_D
Gaitán-Espitia et al. 2014	Warming, acidification, multiple stressors	*Macrocystis pyrifera*	USA (California, Santa Barbara)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Spore/germling	Reproduction	Germination rate, Ungerminated spores
								Survival	Survival
Gao et al. 2013a	Warming	*Undaria pinnatifida*	Japan (Matsushima / Naruto)	Northeastern Honshu / Central Kuroshio Current	Cold Temperate Northwest Pacific / Warm Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Carbon, Nitrogen
								Growth	Weight change
								Survival	Survival
Gao et al. 2013b	Warming	*Undaria pinnatifida*	Japan (Okirai Bay / Matsushima / Naruto)	Northeastern Honshu / Central Kuroshio Current	Cold Temperate Northwest Pacific / Warm Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Nitrogen
								Growth	Weight change
								Net primary productivity	GP_{max}
								Respiration	R_D
								Survival	Survival

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Gao et al. 2016	Warming	*Ecklonia cava*	Japan (Izu Peninsula)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Nitrogen
								Growth	Weight change
								Pigments	Chlorophyll-*a*
								Respiration	Oxygen evolution
								Survival	Survival
Gao et al. 2017	Warming	*Saccharina japonica*	Japan (Hokkaido, Osatsube)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte, Adult sporophyte	Biochemical composition	Nitrogen
								Growth	Weight change
								Net primary productivity	GP
								Pigments	Chlorophyll-*a*
								Survival	Survival
Gao et al. 2019a	Warming, acidification, Multiple stressors	*Ecklonia stolonifera*	Korea (Jeonam, Jindo)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Fluorescence	F_v/F_m, $rETR_{max}$
							Gametophyte	Growth	Elongation rate
Gao et al. 2019b	Warming, acidification, multiple stressors	*Saccharina japonica, Undaria pinnatifida*	Korea (Jeonam, Jindo)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Fluorescence	F_v/F_m, $rETR_{max}$, α
							Gametophyte	Growth	Elongation rate
Gerard 1997a	Warming	*Saccharina latissima*	USA (New Hampshire, Portsmouth)	Gulf of Maine/ Bay of Fundy	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Young sporophyte	Growth	Weight change
								Survival	Density change
Gerard 1997b	Warming	*Saccharina latissima*	USA (Maine, South Bristol / New York, Long Island Sound)	Gulf of Maine/ Bay of Funday / Virginian	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Young sporophyte	Biochemical composition	Nitrogen, Proteins, Carbon
								Fluorescence	F_v/F_m reduction
								Net primary productivity	GP_{max}
								Respiration	R_D
Gerard & DuBois 1988	Warming	*Saccharina latissima*	USA (New York, Maine)	Virginian, Gulf of Maine/ Bay of Fundy	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Young sporophyte	Fluorescence	α
								Growth	Weight change
								Net primary productivity	GP_{max}
								Pigments	Chlorophyll-*a*
								Respiration	R_D
González et al. 2018	Warming, acidification, multiple stressors	*Lessonia trabeculata*	Chile (Coquimbo, Puerto Aldea)	Central Chile	Warm Temperate Southeastern Pacific	Temperate South America	Gametophyte	Growth	Elongation rate
								Reproduction	Sex ratio, Oogonium formation, Reproductive success
							Spore/germling		Germination rate
González et al. 2021	Warming, acidification, multiple stressors	*Lessonia trabeculata*	Chile (Coquimbo, El Frances)	Central Chile	Warm Temperate Southeastern Pacific	Temperate South America	Adult sporophyte	Fluorescence	F_v/F_m
							Spore/germling	Reproduction	Germination rate

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Gordillo et al. 2015	Acidification	*Alaria esculenta, Saccharina latissima*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Biochemical composition	Carbon, Nitrogen, C:N ratio
								Enzyme activity	CA_{ext}, NR activity
								Fluorescence	F_v/F_m, α, ETR_{max}
								Growth	Weight change
								Pigments	Chlorophyll-*a*, Carotenoids
Gordillo et al. 2016	Warming, acidification, multiple stressors	*Alaria esculenta*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Biochemical composition	Carbon, Nitrogen, Proteins, Soluble carbohydrates, Lipids, C:N ratio
								Enzyme activity	CA_{ext}, NR
								Fluorescence	F_v/F_m, E_k, α, ETR_{max}
								Growth	Weight change
								Pigments	Chlorophyll-*a*
Hargrave et al. 2017	Warming	*Laminaria digitata, Laminaria ochroleuca*	United Kingdom (Plymouth Sound)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Fluorescence	F_v/F_m
								Growth	Elongation rate, Weight change
								Stress response	Phenolic content, Flavonoid content
Henkel & Hofmann 2008a	Warming	*Egregia menziesii*	USA (California, Carmel and Monterey Bay)	Northern California	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Stress response	hsp70 expression
			USA (California, Santa Barbara) to Mexico (Todos Santos)	Southern California Bight	Warm Temperate Northeast Pacific				
Henkel & Hofmann 2008b	Warming	*Undaria pinnatifida*	USA (California, Monterey Bay)	Northern California	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Gametophyte	Stress response	hsp70 expression
			USA (California, Santa Barbara to San Diego)	Southern California Bight	Warm Temperate Northeast Pacific				
Henkel et al. 2009	Warming	*Egregia menziesii*	California (multiple locations in Los Angeles, San Diego, and Santa Barbara)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Stress response	hsp70 expression
		Pterygophora californica							
		Undaria pinnatifida							
Hoffman et al. 2003	Warming	*Alaria marginata*	USA (Washington, Friday Harbor)	Puget Trough / Georgia Basin	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Spore/germling	Growth	Number of cells
								Reproduction	Germination rate

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Hwang et al. 2018	Warming	*Saccharina japonica*	Korea (Haenam)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Fluorescence	F_v/F_m
								Growth	Elongation rate
Iñiguez et al. 2016a	Acidification	*Alaria esculenta*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Biochemical composition	Carbon, Nitrogen, C:N ratio, δ_{13} C
								Fluorescence	ETR_{max}, α, E_k, F_v/F_m
								Growth	Weight change
								Net primary productivity	NP, GP, Carbon fixation rate, DOC release rate, POC release rate, Photosynthetic quotient
								Respiration	R_D
								Tissue health	FW:DW ratio
Iñiguez et al. 2016b	Warming, acidification, multiple stressors	*Laminaria solidungula* / *Saccharina latissima*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Adult sporophyte / Young sporophyte	Biochemical composition	Carbon, Nitrogen, C:N ratio, δ_{13} C
								Fluorescence	ETR_{max}, α, E_k, F_v/F_m
								Growth	Weight change
								Net primary productivity	NP, GP, Carbon fixation rate, DOC release rate, Photosynthetic quotient
								Respiration	R_D
								Tissue health	FW:DW ratio
Kang & Chung 2018	Acidification	*Saccharina japonica*	South Korea (Jindo)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Biochemical composition	Carbon, Nitrogen, C:N ratio
								Fluorescence	F_v/F_m
								Growth	Weight change
								Net primary productivity	NP, O_2 evolution inhibition rate, NH_4+ uptake
King et al. 2018	Warming	*Laminaria digitata, Laminaria ochrouleuca*	United Kingdom (Cornwall)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Fluorescence	F_v/F_m
								Stress response	hsp70 expression
King et al. 2019	Warming	*Laminaria digitata*	Scotland (Warbeth)	North Sea	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Stress response	hsp70 expression
			Scotland (Easdale), United Kingdom (Cornwall)	Celtic Seas					
Komazawa et al. 2015	Warming	*Ecklonia radicosa*	Japan (Izu-Oshima Island)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Growth	Area change
							Young sporophyte		
Leal et al. 2017b	Warming (acidification and multiple stressor data excluded)	*Macrocystis pyrifera, Undaria pinnatifida*	New Zealand (Otago Harbour)	South New Zealand	Southern New Zealand	Temperate Australasia	Spore/germling	Growth	Area change
								Reproduction	Germination rate
							Gametophyte	Growth	Area
								Reproduction	Sex ratio

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Leal et al. 2018	Warming (acidification and multiple stressor data excluded)	*Macrocystis pyrifera, Undaria pinnatifida*	New Zealand (Otago Harbour)	South New Zealand	Southern New Zealand	Temperate Australasia	Spore/germling	Growth	Area change
								Reproduction	Germination rate
							Gametophyte	Growth	Area
								Reproduction	Sex ratio
Lee & Brinkhuis 1988	Warming	*Saccharina latissima*	USA (New York, Long Island Sound)	Virginian	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Gametophyte	Reproduction	Sex ratio
Li et al. 2020	Warming	*Saccharina latissima*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Fluorescence	F_v/F_m
								Growth	Weight change
								Pigments	Chlorophyll-*a*, Acc, VAZ, DPS
Liesner et al. 2020	Warming	*Laminaria digitata*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Adult sporophyte	Fluorescence	F_v/F_m, rETR$_{max}$, α, E_k, NPQ
								Growth	Weight change
			France (Quiberon)	South European Atlantic Shelf	Lusitanian	Temperate Northern Atlantic		Biochemical composition	Carbon, Nitrogen, C:N ratio, Mannitol
								Fluorescence	F_v/F_m, rETR$_{max}$, α, E_k, NPQ
								Growth	Weight change
								Pigments	Chlorophyll-*a*, VAZ : Chlorophyll-*a* ratio, DPS
			France (Roscoff) / Germany (Helgoland) / Norway (Tromsø)	Celtic Seas / North Sea / Northern Norway and Finnmark)	Northern European Seas	Temperate Northern Atlantic		Biochemical composition	Carbon, Nitrogen, C:N ratio, Mannitol
								Fluorescence	F_v/F_m, rETR$_{max}$, α, E_k, NPQ
								Growth	Weight change
								Pigments	Chlorophyll-*a*, VAZ : Chlorophyll-*a* ratio, DPS
Lind & Konar 2017	Warming	*Eularia fistulosa, Nereocystis luetkeana, Saccharina latissima*	Alaska (Kachemak Bay)	Gulf of Alaska	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Spore/germling	Survival	Density
							Gametophyte	Growth	Germ tube length
Liu & Pang 2010	Warming	*Saccharina japonica*	China (Daban / Benniu / Zhen / Yanza / Fujian / Gaolv / Qingdao)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Proteins
								Enzyme activity	Peroxidase, Glutathione reductase
								Fluorescence	F_v/F_m, F_v/F_0
								Growth	Elongation rate
								Stress response	Malond-ialdehyde, SOD activity, CAT activity
Liu et al. 2019	Warming	*Saccharina japonica*	China (Shandong Province, Rongcheng)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Enzyme activity	Peroxidase
								Stress response	SOD activity, CAT activity

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Longphuirt et al. 2013	Acidification	*Saccharina latissima*	Ireland (County Galway, Letterard)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Fluorescence	E_k
								Net primary productivity	CO_2 uptake, V_{max}
Lüning 1980	Warming	*Laminaria digitata*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Gametophyte	Growth	Diameter
		Laminaria hyperborea							
		Saccharina latissima							
Lüning & Neuschul 1978	Warming	*Alaria marginata, Hedophyllum dentigerum, Hedophyllum sessile, Laminaria sinclairii, Macrocystis pyrifera* / *Egregia menziesii, Laminaria forlowii, Macrocystis pyrifera, Pterygophora californica*	USA (central California) / USA (California, Santa Barbara)	Northern California / Southern California Bight	Cold Temperate Northeast Pacific / Warm Temperate Northeast Pacific	Temperate Northern Pacific	Gametophyte	Growth	Length
								Reproduction	Fertility
Mabin et al. 2013	Warming	*Ecklonia radiata*	Australia (Tasmania, Bicheno)	Bassian	Southeast Australian Shelf	Temperate Australasia	Gametophyte	Growth	Area, Number of cells
							Young sporophyte		Area
Mabin et al. 2019	Warming	*Macrocystis pyrifera*	Australia (Tasmania, Fortescue Bay)	Bassian	Southeast Australian Shelf	Temperate Australasia	Young sporophyte	Biochemical composition	Nitrogen, Carbon, δ_{15} N, RNA, RNA : DNA ratio, C:N ratio, δ_{13} C, DNA
								Fluorescence	$rETR_{max}$, Ek, F_v/F_m
								Growth	Weight change
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Fx
Martins et al. 2017	Warming	*Laminaria digitata*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Gametophyte	Growth	Area
Matson & Edwards 2007	Warming	*Eisenia arborea*	USA (California, San Diego)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Survival	Density
		Pterygophora californica							

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Minich et al. 2018	Warming, Acidification, multiple stressors	*Macrocystis pyrifera*	USA (California, San Diego)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Growth	Weight change
Mohring et al. 2013	Warming	*Ecklonia radiata*	Australia (Western Australia, Shoalwater Islands)	Leeuwin	Southwest Australian Shelf	Temperate Australasia	Gametophyte	Growth	Area
								Survival	Density
Mohring et al. 2014	Warming	*Ecklonia radiata*	Australia (Bicheno)	Bassian	Southeast Australian Shelf	Temperate Australasia	Gametophyte	Growth	Area
			Australia (Fortesque)						
			Australia (Southport)						
			Australia (Encounter)	Western Bassian					
			Australia (Albany)	Leeuwin					
			Australia (Hamelin Bay)						
			Australia (Adelaide)	South Australian Gulfs					
			Australia (Yorke)						
			Australia (Marmion)	Houtman	West Central Australian Shelf			Survival	Density
Monteiro et al. 2019	Warming	*Saccharina latissima*	France (Brittany, Roscoff) / Norway (Svalbard, Spitsbergen)	Celtic Seas / North and East Barents Sea	Northern European Seas / Arctic	Temperate Northern Atlantic / Arctic	Young Sporophyte	Pigments	V, Z
Monteiro et al. 2021	Warming	*Saccharina latissima*	France (Brittany, Roscoff)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Young sporophyte	Biochemical composition	Carbon, Nitrogen, Mannitol, C:N ratio
								Fluorescence	F_v/F_m
								Growth	Weight change
								Pigments	Chlorophyll-*a*, Acc, VAZ, DPS
Morita et al. 2003a	Warming	*Undaria pinnatifida*	Japan (Mugisaki)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Growth	Area change
			Japan (Gokasyo Bay)						
Morita et al. 2003b	Warming	*Undaria pinnatifida*	Japan (Mugisaki)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Growth	Area change
			Japan (Gokasyo Bay)						
Muñoz et al. 2004	Warming	*Macrocystis pyrifera*	Chile (Bahía Mansa / Metri)	Araucanian / Chiloense	Warm Temperate Southeastern Pacific / Magellanic	Temperate South America	Gametophyte	Growth	Diameter
								Reproduction	Number of oogonia
								Survival	Density

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Murúa et al. 2021	Warming	*Macrocystis pyrifera*	Chile (Puerto Montt)	Chiloense	Magellanic	Temperate South America	Gametophyte	Reproduction	Reproductive success, Sex ratio
			Chile (Bahía Inglesa)	Central Chile	Warm Temperate Southeastern Pacific				
Muth et al. 2019	Warming	*Alaria marginata, Costaria costata, Dictyoneurum reticulatum, Eisenia arborea, Egregia menziesii, Laminaria ephemera, Laminaria setchellii, Lessoniopsis littoralis, Macrocystis pyrifera, Nereocystis luetkeana, Postelsia palmiformis, Pterygophora californica*	USA (California, Big Creek Cove / Carmel Bay / Soberanes Point / Stillwater Cove)	Northern California	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Survival	Density
			Canada (Vancouver Island)	Oregon, Washington, Vancouver Coast and Shelf					
			USA (Washington, Tatoosh Island)						
			USA (Washington, San Juan Island)	Puget Trough / Georgia Basin					
			USA (California, Catalina / Los Angeles / San Diego)	Southern California Bight	Warm Temperate Northeast Pacific				
Nepper-Davidsen et al. 2019	Warming	*Saccharina latissima*	Denmark (Southern Kattegat)	North Sea	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Biochemical composition	Carbon, Nitrogen, Mannitol
								Fluorescence	α, F_v/F_m, rETR, NPQ, E_c
								Growth	Elongation rate, Weight change
								Net primary productivity	GP, Carbon acquisition
								Pigments	Chlorophyll-*a*, Chlorophyll-*c* : Chlorophyll-*a* ratio, Fx : Chlorophyll-*a* ratio, VAZ : Chlorophyll-*a* ratio, DPS, Beta-carotene : Chlorophyll-*a* ratio
								Respiration	R_D
								Survival	Mortality

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Nitschke et al. 2013	Warming	*Laminaria digitata*	Ireland (Co. Clare, Finavarra)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Fluorescence	F_v/F_m, rETR, YII
								Stress response	Iodine efflux
Nunes et al. 2016	Acidification	*Saccharina latissima*	United Kingdom (Plymouth Sound)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Growth	Elongation rate, Perforation area
								Net primary productivity	NP
								Respiration	R_D
								Stress response	DMSP
Olischläger et al. 2012	Acidification	*Laminaria hyperborea*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Spore/germling	Reproduction	Germination rate
							Gametophyte		Reproductive success
							Young sporophyte	Fluorescence	F_v/F_m, $rETR_{max}$
								Growth	Weight change
								Net primary productivity	NP
								Pigments	Chlorophyll-*a*
								Stress response	Phlorotannin content
								Tissue health	DW:WW ratio
							Adult sporophyte	Fluorescence	F_v/F_m, $rETR_{max}$
								Reproduction	Weight gain during sorus formation
Olischläger et al. 2014	Warming, acidification, multiple stressors	*Saccharina latissima*	Germany (Helgoland) / Norway (Svalbard, Spitsbergen)	North Sea / North and East Barents Sea	Northern European Seas / Arctic	Temperate Northern Atlantic / Arctic	Young sporophyte	Biochemical composition	Carbon, Soluble carbohydrates, Nitrogen, Proteins, Lipids, C:N ratio
								Tissue health	FW:DW ratio

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Olischläger et al. 2017	Warming, acidification, multiple stressors	*Saccharina latissima*	Germany (Helgoland) / Norway (Svalbard, Spitsbergen)	North Sea / North and East Barents Sea	Northern European Seas / Arctic	Temperate Northern Atlantic / Arctic	Young sporophyte	Biochemical composition	ε_p
								Enzyme activity	RuBisCO
								Fluorescence	F_v/F_m
								Growth	Weight change
								Net primary productivity	NP
								Pigments	Accessory pigment : Chlorophyll-*a* ratio, Beta-carotene, Beta-carotene : Chlorophyll-*a* ratio, Chlorophyll-*a*, Chlorophyll-*c*, Chlorophyll-*c* : Chlorophyll-*a* ratio, D1 protein, DPS, Fx, Fx : Chlorophyll-*a* ratio, V, V : Chlorophyll-*a* ratio, VAZ, VAZ : Chlorophyll-*a* ratio, Z, Z : Chlorophyll-*a* ratio
Olischläger & Wiencke 2013	Warming	*Alaria esculenta*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Spore/germling	Reproduction	Germination rate
		Laminaria digitata							
Oppliger et al. 2011	Warming	*Lessonia nigrescens*	Chile (El Quisco / Las Cruces / Valdivia)	Araucanian	Warm Temperate Southeastern Pacific	Temperate South America	Gametophyte	Reproduction	Sex ratio
			Chile (Pan de Azucar)	Central Chile					
			Chile (Los Verdes)	Humboldtian					
Oppliger et al. 2012	Warming	*Lessonia nigrescens*	Chile (Las Cruces / Chañaral de Aceituno, Choros Ventana / Iquique and Carrizal Bajo)	Araucanian / Central Chile / Humboldtian	Warm Temperate Southeastern Pacific	Temperate South America	Spore/germling	Reproduction	Germination rate
							Gametophyte		Frequency of females with vegetative growth, Oogonium formation, Reproductive success, Sex ratio
								Survival	Survival
Paine et al. 2021	Warming	*Lessonia corrugata*	Australia (Tasmania, Crayfish Point)	Bassian	Southeast Australian Shelf	Temperate Australasia	Gametophyte	Growth	Area
								Reproduction	Oogonium formation
Pang et al. 2007	Warming	*Saccharina japonica*	China (Fujian / Qingdao)	East China Sea / Yellow Sea	Warm Temperate Northwest Pacific / Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Fluorescence	F_v/F_m
								Growth	Elongation rate

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Parages et al. 2013	Warming	*Laminaria solidungula, Saccharina latissima*	Norway (Svalbard, Blomstrand-halvøya)	North and East Barents Sea	Arctic	Arctic	Young sporophyte	Fluorescence	F_v/F_m
								Stress response	36 kDa band intensity, 42 kDa band intensity, p-38-like protein phosphorylation
Park et al. 2017	Warming	*Alaria esculenta, Saccharina latissima*	Norway (Svalbard, Blomstrand-halvøya)	North and East Barents Sea	Arctic	Arctic	Gametophyte	Fluorescence	α, E_k, F_v/F_m, NPQ, $rETR_{max}$
								Growth	Area, Diameter, Length, Number of cells
								Reproduction	Reproductive success, Sex ratio
Pereira et al. 2011	Warming	*Laminaria ochroleuca*	France (Brittany, Morlaix Bay)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Gametophyte	Reproduction	Sex ratio
								Survival	Survival
Pereira et al. 2015	Warming	*Laminaria ochroleuca*	France (Brittany)	Celtic Seas	Northern European Seas	Temperate Northern Atlantic	Adult sporophyte	Fluorescence	F_v/F_m
			Portugal	South European Atlantic Shelf	Lusitanian				
Qiu et al. 2019	Warming, acidification, multiple stressors	*Ecklonia radiata*	Australia (Charlesworth Bay)	Tweed-Moreton	East Central Australian Shelf	Temperate Australasia	Young sporophyte	Fluorescence	F_v/F_m
								Tissue health	Number of blisters
Roelda 2009	Warming	*Alaria esculenta*	Norway (Svalbard, Blomstrand-halvøya)	North and East Barents Sea	Arctic	Arctic	Spore/ germling	Fluorescence	F_v/F_m, NPQ, Photoinhibition
		Laminaria digitata							
		Saccharina latissima							
Roleda 2016	Warming	*Laminaria solidungula*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Spore/ germling	Fluorescence	F_v/F_m
								Growth	Relative size
Rothäusler et al. 2009	Warming	*Macrocystis pyrifera*	Chile (Coquimbo)	Central Chile	Warm Temperate Southeastern Pacific	Temperate South America	Young sporophyte	Growth	Weight change, Elongation rate
			Chile (Calfuco)	Araucanian					
Rothäusler et al. 2011a	Warming	*Macrocystis pyrifera*	Chile (Coquimbo / Calfuco)	Central Chile / Araucanian	Warm Temperate Southeastern Pacific	Temperate South America	Young sporophyte	Biochemical composition	Carbon, Nitrogen
								Enzyme activity	Total CA
								Fluorescence	α, E_k, ETR_{max}, F_v/F_m
								Pigments	Carotenoids, Chlorophyll-*a*, Chlorophyll-*c*
Rothäusler et al. 2011b	Warming	*Macrocystis pyrifera*	Chile (Los Vilos, Caleta San Pedro)	Central Chile	Warm Temperate Southeastern Pacific	Temperate South America	Adult sporophyte	Fluorescence	F_v/F_m
								Growth	Elongation rate, weight change
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*
								Reproduction	Reproductive area allocation

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Sakanishi et al. 1989	Warming	*Ecklonia cava*	Japan (Shimoda, Nabeta Bay)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP
								Respiration	R_D
Sánchez-Barredo et al. 2020	Warming	*Macrocystis pyrifera*	Mexico (Baja California, Bahía Todos Santos)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Nitrogen, Total non-structural carbohydrates
								Fluorescence	α, ETR_{max}, F_v/F_m, NPQ, YII
								Net primary productivity	Nitrate uptake
								Pigments	Carotenoids, Chlorophyll-*a*, Chlorophyll-*c*
								Stress response	Antioxidant activity, Lipid peroxidation, Total phenolic content
Sato et al. 2020	Warming	*Saccharina sculpera*	Japan (Hokkaido Island, Hakodate)	Sea of Japan/ East Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Fluorescence	F_v/F_m
								Net primary productivity	NP_{max}
								Respiration	R_D
Sato et al. 2021	Warming	*Undaria pinnatifida*	Japan (Miyagi, Matsushima Bay)	Northeastern Honshu	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Fluorescence	F_v/F_m, YII
								Net primary productivity	NP_{max}
								Respiration	R_D
Scheschonk et al. 2019	Warming	*Laminaria solidungula*	Norway (Svalbard, Spitsbergen)	North and East Barents Sea	Arctic	Arctic	Adult sporophyte	Biochemical composition	Laminarin
		Saccharina latissima							
Schmid et al. 2020	Warming	*Macrocystis pyrifera*	Australia (Tasmania, Bruny Island)	South New Zealand	Southern New Zealand	Temperate Australasia	Adult sporophyte	Biochemical composition	Lipids, MUFA, PUFA, SFA
Serisawa et al. 2001	Warming	*Ecklonia cava*	Japan (Shimoda / Tosa Bay)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP
								Respiration	R_D
Shukla & Edwards 2017	Warming, acidification, multiple stressors	*Macrocystis pyrifera*	USA (California, San Diego)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Spore/germling	Survival	Density
							Gametophyte	Growth	Length
								Survival	Survival
							Young sporophyte	Growth	Length
								Survival	Density
Simonson et al. 2015a	Warming	*Agarum clathratum, Laminaria digitata, Saccharina latissima*	Canada (Nova Scotia, Halifax)	Scotian Shelf	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Adult sporophyte	Growth	Elongation rate
								Tissue health	Breaking stress, Maximum strain, Tissue loss

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Simonson et al. 2015b	Warming	*Agarum clathratum, Laminaria digitata, Saccharina latissima*	Canada (Nova Scotia, Halifax)	Scotian Shelf	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Adult sporophyte	Biochemical composition	C:N ratio
								Tissue health	Tissue loss
								Stress response	Phlorotannin content
Staehr & Wernberg 2009	Warming	*Ecklonia radiata*	Australia (Hamelin Bay / Marmion Lagoon / Jurien Bay)	Leeuwin / Houtman	Southwest Australian Shelf / West Central Australian Shelf	Temperate Australasia	Adult sporophyte	Fluorescence	E_c, E_k
								Net primary productivity	NP_{max}
								Respiration	R_D
Steinhoff et al. 2008	Warming	*Laminaria hyperborea*	Germany (Helgoland)	North Sea	Northern European Seas	Temperate Northern Atlantic	Spore/germling	Reproduction	Germination rate
Supratya et al. 2020	Warming	*Nereocystis luetkeana*	Canada (British Columbia, Vancouver)	Puget Trough / Georgia Basin	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Growth	Elongation rate, Diameter change
Swanson & Fox 2007	Acidification	*Nereocystis luetkeana, Saccharina latissima*	Canada (British Columbia, Barkley Sound)	Oregon, Washington, Vancouver Coast and Shelf	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Growth	Area, weight
								Stress response	Phlorotannin content
Terada et al. 2016	Warming	*Ecklonia radicosa*	Japan (Kagoshima Prefecture, Nagashima)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP
								Respiration	R_D
Thom 1996	Acidification	*Nereocystis luetkeana*	USA (Washington, Sequim)	Puget Trough/ Georgia Basin	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP_{max}
Thornber et al. 2004	Warming	*Undaria pinnatifida*	USA (California, Monterey)	Northern California	Cold Temperate Northeast Pacific	Temperate Northern Pacific	Gametophyte	Survival	Density
			USA (California, Santa Barbara)	Southern California Bight	Warm Temperate Northeast Pacific		Young sporophyte		
Umanzor et al. 2021	Warming	*Macrocystis pyrifera*	Mexico (Baja California, Bahía Todos Santos)	Southern California Bight	Warm Temperate Northeast Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Nitrogen, Soluble carbohydrates
								Fluorescence	α, E_c, ETR_{max}, F_v/F_m, NPQ, YII
								Growth	Elongation rate
								Net primary productivity	GP_{max}, Nitrate uptake, NP_{max}, Photosynthesis : Respiration ratio
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Fx
								Respiration	R_D
								Stress response	Antioxidant activity, lipid peroxidation, total phenolic content

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Watanabe et al. 2014	Warming	*Undaria pinnatifida*	Japan (Kagoshima, Ibusuki, Yamagawa)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Gametophyte	Growth	Number of cells, weight change
							Adult sporophyte	Fluorescence	YII
								Net primary productivity	NP_{max}
								Respiration	R_D
Wernberg et al. 2016	Warming	*Ecklonia radiata*	Australia (Jurien Bay / Marmion Lagoon / Hamelin Bay)	Houtman / Leeuwin	West Central Australian Shelf / Southwest Australian Shelf	Temperate Australasia	Adult sporophyte	Net primary productivity	NP
								Respiration	R_D
Wilson et al. 2015	Warming	*Laminaria digitata*	Canada (Nova Scotia)	Scotian Shelf	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Young sporophyte	Biochemical composition	Carbon, Nitrogen
								Growth	Weight change
Xiao et al. 2015	Warming	*Ecklonia radiata*	Australia (Marmion)	Houtman	West Central Australian Shelf	Temperate Australasia	Young sporophyte	Growth	Elongation rate, weight change
								Fluorescence	F_v/F_m
Xu et al. 2015	Acidification	*Saccharina japonica*	China (Yellow Sea, Sungo Bay)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Spore/germling	Reproduction	Germination rate
							Gametophyte		Number of oogonia, Oogonium formation, Reproductive success, Sex ratio
								Fluorescence	α, F_v/F_m, rETR, YII
								Growth	Diameter, number of cells
							Young sporophyte	Biochemical composition	C:N ratio, Carbon, Nitrogen
								Fluorescence	α, F_v/F_m, rETR, YII
								Growth	Length
								Pigments	Chlorophyll-*a*, Chlorophyll-*c*, Chlorophyll-*a* : Chlorophyll-*c* ratio
								Survival	Density
Xu et al. 2017	Acidification	*Saccharina japonica, Undaria pinnatifida*	China (Sungo Bay)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Growth	Weight change
								Net primary productivity	NP
								Respiration	R_D
		Macrocystis pyrifera	Mexico (Santo Tomás)	Southern California Bight	Warm Temperate Northeast Pacific		Young sporophyte	Growth	Weight change
								Net primary productivity	NP
								Respiration	R_D

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Xu et al. 2019	Warming, Acidification, multiple stressors	*Macrocystis pyrifera, Undaria pinnatifida*	China (Yellow Sea, Sungo Bay	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Growth	Weight change
								Stress response	Iodine accumulation
		Saccharina japonica					Young sporophyte	Fluorescence	F_v/F_m
								Stress response	Iodine accumulation, Iodine efflux
Yokohama 1973	Warming	*Undaria pinnatifida*	Japan (Shimoda, Izu Peninsula)	Central Kuroshio Current	Warm Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Net primary productivity	NP
								Respiration	R_D
Young et al. 2021	Acidification	*Saccharina latissima*	USA (New York, Moriches Bay)	Virginian	Cold Temperate Northwest Atlantic	Temperate Northern Atlantic	Adult sporophyte	Biochemical composition	Carbon, Nitrogen, C:N ratio, δ_{13} C
								Growth	Weight change
Zhang et al. 2013	Warming	*Saccharina japonica*	China (Yellow Sea)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Spore/germling	Reproduction	Germination rate
							Gametophyte	Growth	Length, Area
								Survival	Survival
Zhang et al. 2020	Warming, acidification, multiple stressors	*Saccharina japonica*	China (Sungo Bay)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Adult sporophyte	Fluorescence	NPQ
								Pigments	Antheraxanthin : Chlorophylls ratio, Chlorophyll-*c* : Chlorophyll-*a* ratio, de-epoxidation state, V : Chlorophylls ratio, VAZ : Chlorophyll-*a* ratio, Z : Chlorophylls ratio

Study	Stressor	Species	Location	Ecoregion	Province	Realm	Life stage	Response category	Response variable
Zhang et al. 2021	Acidification	*Saccharina japonica*	China (Sungo Bay)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	2-oxoglutarate, Alanine, Alginic acid, Alpha-linolenic acid, Amino acid, Arachidonic acid, Arginine, Aspartate, C:N ratio, Carbon, Cellulose, Citrate, Cysteine, EPA, Eicosatrienoic acid, Free arginine, Free aspartate, Free glutamine, Fucoidan, Fumarate, Gamma-linolenic acid, Glutamine, Glycine, Histidine, Isoleucine, Laminarin, Leucine, Linoleic acid, Lysine, Malate, Mannitol, Methionine, Nitrogen, Oxaloacetate, Phenylalanine, Proline, Pyruvate, Serine, Soluble carbohydrates, Succinate, Threonine, Tyrosine, Valine
								Enzyme activity	Glutamate synthase, Glutamine synthetase, Isocitrate dehydrogenase, Pyruvate kinase
								Growth	Elongation rate, Weight change, Diameter change
Zhou et al. 2010	Warming	*Saccharina japonica*	China (Shandong Province, Yantai Sea Farm)	Yellow Sea	Cold Temperate Northwest Pacific	Temperate Northern Pacific	Young sporophyte	Biochemical composition	Proteins
								Enzyme activity	Glutathione peroxidase, Peroxidase, Phenylalanine ammonia-lyase, Polyphenol oxidase
								Pigments	Chlorophyll-*a*
								Stress response	CAT activity, Hydrogen peroxide, Malondialdehyde, SOD activity

Abbreviations: α, light affinity/photon yield; Acc, Accessory pigment pool; CA, Carbonic anhydrase; CA_{ext}, external carbonic anhydrase; CA_{int}, internal carbonic anhydrase; DPS, De-epoxidation state; DW, Dry weight; E_C, Compensation irradiance; E_K, Saturation irradiance; $\varepsilon_{P,}$ Isotopic fractionation of organic carbon production; EPA, eicosapentaenoic acid; F_v/F_m, maximum quantum yield of photosynthesis; FW, Fresh weight; Fx, Fucoxanthin; GP, Gross photosynthesis; MDH, Malate dehydrogenase; M-1-PDH, mannitol-1-phosphate dehydrogenase; MUFA, Monounsaturated fatty acids; NPQ, non-photosynthetic quenching; NP, Net photosynthesis; NP_{max}, Maximum net photosynthetic rate; NR, Nitrate reductase; PUFA, polyunsaturated fatty acids; R_D, dark respiration rate; SFA, saturated fatty acids; SOD, Superoxide dismutase; V, Violaxanthin; VAZ, Xanthophyll cycle pigment pool; WW, Wet weight; Z, Zeaxanthin.

Table S2

Table S2. Response variables in each response category and the corresponding number of data points and number of studies with data for each response variable.

Response variable	Data points	Studies
Biochemical composition		
C:N ratio	116	21
Nitrogen	145	32
Carbon	120	25
Mannitol	40	7
Proteins	33	7
Soluble carbohydrates	17	5
δ_{13} C	15	5
Lipids	14	5
$\boldsymbol{\varepsilon_p}$	10	1
Laminarin	6	3
DNA	4	2
RNA	4	2
RNA : DNA ratio	4	2
Alanine	2	1
Alginic acid	2	1
Alpha-linolenic acid	2	1
Amino acid	2	1
Amino-nitrogen content	2	1
Arachidonic acid	2	1
Arginine	2	1
Aspartate	2	1
Cellulose	2	1
Cysteine	2	1
δ_{15} N	2	1
Eicosapentaenoic acid	2	1
Eicosatrienoic acid	2	1
Fucoidan	2	1
Gamma-linolenic acid	2	1
Glutamine	2	1
Glycine	2	1
Histidine	2	1
Isoleucine	2	1
Leucine	2	1
Linoleic acid	2	1
Lysine	2	1
Methionine	2	1
NO_3^- nitrogen	2	1
Phenylalanine	2	1
Proline	2	1
Serine	2	1
Threonine	2	1
Tyrosine	2	1
Valine	2	1
2-oxoglutarate	1	1
Citrate	1	1
Free arginine	1	1
Free aspartate	1	1
Free glutamine	1	1
Fumarate	1	1

Response variable	Data points	Studies
Malate	1	1
Monounsaturated fatty acids	1	1
Oxaloacetate	1	1
Polyunsaturated fatty acids	1	1
Pyruvate	1	1
Saturated fatty acids	1	1
Succinate	1	1
Total non-structural carbohydrates	1	1
Enzyme activity		
Nitrate reductase	31	4
Total carbonic anhydrase	23	3
Peroxidase	20	3
Glutathione reductase	14	1
RuBisCO	12	2
External carbonic anhydrase	10	3
Glutamine synthetase	3	2
GADPH	2	1
GAPDH	2	1
L-aspartate	2	1
Malate dehydrogenase	2	1
Mannitol-1-phosphate dehydrogenase	2	1
Phosphoenolpyruvate carboxykinase	2	1
Glutamate synthase	1	1
Glutathione peroxidase	1	1
Internal carbonic anhydrase	1	1
Isocitrate dehydrogenase	1	1
Phenylalanine ammonia-lyase	1	1
Polyphenol oxidase	1	1
Pyruvate kinase	1	1
Fluorescence		
F_v/F_m	554	52
α	115	19
E_k	86	14
$rETR_{max}$	83	10
NPQ	50	9
YII	28	6
ETR_{max}	25	9
E_c	17	5
F_v/F_o	14	1
rETR	8	3
Photoinhibition	6	1
F_v/F_m reduction	2	1
Growth		
Surface area	234	10
Biomass change	224	39
Elongation rate	137	22
Change in surface area	106	8
Length	68	9
Diameter	33	4
Number of cells	31	6
Weight	14	2
Germ tube length	9	1
Change in width	3	3
Relative size	2	1
Dry weight change	1	1
Perforation area	1	1

Response variable	Data points	Studies
Net primary productivity		
Net photosynthesis	188	21
NP_{max}	69	12
GP_{max}	23	5
Gross photosynthesis	13	5
Carbon fixation rate	7	2
DOC release rate	7	2
Photosynthetic quotient	7	2
CO_2 uptake	6	2
Carbon acquisition	3	1
Nitrate uptake	3	3
Ammonium uptake	1	1
Bicarbonate uptake	1	1
Change in pH	1	1
Oxygen evolution inhibition rate	1	1
Photosynthesis : Respiration ratio	1	1
POC release rate	1	1
Total alkalinity	1	1
V_{max}	1	1
Pigments		
chlorophyll-*a*	107	25
chlorophyll-*c*	60	12
Fucoxanthin	53	7
De-epoxidation state	39	7
Xanthophyll cycle pigment pool : chlorophyll-*a* ratio	38	5
Xanthophyll cycle pigment pool	32	5
Violaxanthin	27	3
Zeaxanthin	27	3
chlorophyll-*c* : chlorophyll-*a* ratio	25	4
Accessory pigment pool	19	3
Fucoxanthin : chlorophyll-*a* ratio	18	3
Antheraxanthin	15	1
Beta-carotene	15	3
chlorophyll-*a* : Accessory pigments ratio	15	1
chlorophyll-*a* : Xanthophyll cycle pigment pool ratio	15	1
Beta-carotene : chlorophyll-*a* ratio	13	2
Carotenoids	10	4
Accessory pigment : chlorophyll-*a* ratio	10	1
Antheraxanthin : chlorophyll-*a* ratio	10	1
D1 protein	10	1
Violaxanthin : chlorophyll-*a* ratio	10	1
Zeaxanthin : chlorophyll-*a* ratio	10	1
Antheraxanthin : chlorophylls ratio	7	1
Violaxanthin : chlorophylls ratio	7	1
Zeaxanthin : chlorophylls ratio	7	1
Viola+Zeaxanthin : chlorophyll-*a* ratio	5	1
chlorophyll-*a* : chlorophyll-*c* ratio	2	1
Reproduction		
Germination rate	70	15
Sex ratio	53	11
Reproductive success	26	6
Spore production	19	4
Fertility	18	1
Oogonium formation	18	4
Number of oogonia	9	3
Frequency of females with vegetative growth	8	1
Reproductive area allocation	5	2

Response variable	Data points	Studies
Sorus induction	4	1
Total fertile area	4	1
Half maximal reaction time	3	1
Ungerminated spores	3	1
Weight gain during sorus formation	1	1
Respiration		
Dark respiration	182	27
Oxygen evolution	3	1
Stress response		
hsp70 expression	183	5
Phlorotannin content	36	8
Malondialdehyde	22	3
Iodine accumulation	22	1
SOD activity	20	3
CAT activity	20	3
Iodine efflux	8	2
Insoluble phlorotannin content	7	1
Radical scavenging activity	7	1
Antioxidant pool size	6	1
Flavonoid content	4	1
Phenolic content	4	1
Antioxidant capacity	2	2
Lipid peroxidation	2	2
Total phenolic content	2	2
p-38-like protein phosphorylation	2	1
36 kDa band intensity	2	1
42 kDa band intensity	2	1
DMSP	1	1
Hydrogen peroxide	1	1
Survival		
Survival	305	11
Density	283	11
Mortality	6	2
Change in density	1	1
Tissue Health		
Fresh weight : Dry weight ratio	17	3
Tissue loss	16	2
Maximum strain	15	1
Breaking stress	15	1
Number of blisters	3	1
Dry weight : Wet weight	1	1

Within each category, variables are listed in prioritization order (most to least data points, except for biochemical composition, where C:N ratio is prioritized despite having less data). Bolded variables indicate that this variable made it into the final analysis because higher-ranked variables were unavailable for that study.

Table S3

Table S3. The effect of stressor (warming, acidification, or acidification and warming) on standardized effects as Hedges' g.

Stressor	Effect size	*Z*	*P*
Warming	-1.3966	-5.9511	<.0001*
Acidification and warming	-2.8494	-1.3169	0.1879
Acidification	0.0014	0.0049	0.9961

Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks.

Table S4

Table S4. The effect of life stage on standardized effects as Hedges' g.

	Warming			Acidification and Warming			Acidification		
Metric	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Spore/ germling	-1.2943	-4.8021	<.0001*	-3.7192	-1.4489	0.1474	-0.8504	-1.7977	0.0722
Gametophyte	-1.3073	-5.3491	<.0001*	-2.6004	-1.0630	0.2878	-0.8305	-1.8564	0.0634
Young sporophyte	-1.3959	-5.7536	<.0001*	-3.2155	-1.3180	0.1875	-0.1076	-0.3280	0.7429
Adult sporophyte	-1.4354	-5.9084	<.0001*	-2.9179	-1.1496	0.2503	0.4536	1.4077	0.1592

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks.

Table S5

Table S5. The effect of response category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Biochemical composition	-0.7592	-3.0987	0.0019*	-3.4030	-1.7520	0.0798	0.3621	0.9981	0.3182
Enzyme activity	-0.9077	-3.2553	0.0011*	-3.2130	-1.6529	0.0984	-0.1268	-0.3247	0.7454
Fluorescence	-0.9050	-3.7495	0.0002*	-2.6370	-1.3606	0.1736	-0.2159	-0.6025	0.5468
Growth	-1.7701	-7.4155	<.0001*	-2.8753	-1.4844	0.1377	0.3168	0.9027	0.3667
Net primary productivity	-0.7927	-3.1410	0.0017*	-2.9631	-1.5242	0.1275	-0.0064	-0.0175	0.9861
Pigments	-0.8749	-3.4759	0.0005*	-3.1977	-1.6445	0.1001	-0.6663	-1.6942	0.0902
Reproduction	-2.0151	-8.3024	<.0001*	-3.6535	-1.8058	0.0709	-1.3210	-2.9971	0.0027*
Respiration	-1.3954	-5.4308	<.0001*	-2.3471	-1.1519	0.2494	0.3063	0.6752	0.4996
Stress response	-1.1261	-4.4572	<.0001*	0.0617	0.0227	0.9819	0.3416	0.8979	0.4040
Survival	-1.6157	-6.7160	<.0001*	-3.8336	-1.9345	0.0531	0.1910	0.4112	0.6809
Tissue health	-1.5405	-4.8062	<.0001*	-1.9155	-0.9769	0.3286	-0.1479	-0.3449	0.7301

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks.

Table S6

Table S6. The effect of response category, separated by life stage, on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Spore/germling									
Fluorescence	0.6600	-1.2300	0.2187	–	–	–	–	–	–
Growth	-0.5648	-1.3465	0.1781	–	–	–	–	–	–
Net primary productivity	2.4499	2.0076	0.0447*	–	–	–	–	–	–
Reproduction	-0.9789	-2.8766	0.0040*	2.4786	1.0426	0.2971	-1.1193	-0.5833	0.5597
Respiration	0.5462	0.4757	0.6343	–	–	–	–	–	–
Survival	-2.5628	-4.8658	<.0001*	3.4943	1.3263	0.1847	-0.1818	-0.0933	0.9257
Gametophyte									
Enzyme activity	–	–	–	–	–	–	-0.7779	-0.1783	0.8585
Fluorescence	-1.1627	-4.1003	<.0001*	–	–	–	-0.4026	-0.2521	0.8010
Growth	-0.9974	-5.3009	<.0001*	-6.0879	-1.0240	0.3058	-1.2551	-0.8103	0.4177
Net primary productivity	-0.3140	-0.3987	0.6901	–	–	–	–	–	–
Reproduction	-1.6115	-8.3847	<.0001*	-5.1829	-0.8608	0.3893	-3.5864	-2.2396	0.0251*
Respiration	-0.4674	-0.5950	0.5519	–	–	–	–	–	–
Stress response	1.2887	0.9137	0.3609	–	–	–	–	–	–
Survival	-1.7403	-8.6240	<.0001*	-6.6911	-1.1186	0.2633	-1.1651	-0.6907	0.4897
Young sporophyte									
Biochemical composition	-1.2187	-3.0784	0.0021*	-1.3646	-2.9775	0.0029*	0.8421	5.2563	<.0001*
Enzyme activity	-1.6041	-3.8405	0.0001*	-0.7913	-1.7356	0.0826	0.5666	2.8492	0.0044*
Fluorescence	-1.4158	-3.5664	0.0004*	-0.2490	-0.5941	0.5524	0.4112	2.8000	0.0051*
Growth	-2.9784	-7.5886	<.0001*	-0.0022	-0.0048	0.9961	0.8112	5.5305	<.0001*
Net primary productivity	-1.7035	-4.1798	<.0001*	-0.6866	-1.4979	0.1342	0.6475	3.3751	0.0007*
Pigments	-1.4863	-3.6290	0.0003*	-0.8263	-1.7863	0.0740	-0.0334	-0.1468	0.8833
Respiration	-1.8258	-4.3767	<.0001*	2.5084	2.1236	0.0337*	2.0917	3.2097	0.0013*
Stress response	-1.5552	-3.6775	0.0002*	1.7690	2.0028	0.0452*	2.1088	7.1821	<.0001*
Survival	-1.6596	-4.2502	<.0001*	1.2987	1.4447	0.1485	0.3577	0.8626	0.3883
Tissue health	-0.5284	-0.9588	0.3377	0.2951	0.5787	0.5628	0.4352	1.7607	0.0783
Adult sporophyte									
Biochemical composition	-0.9071	-4.3211	<.0001*	1.3789	2.5370	0.0112*	0.1146	0.2641	0.7917
Fluorescence	-0.9115	-5.0257	<.0001*	0.3792	1.1124	0.2660	-0.7982	-1.6600	0.0969
Growth	-1.3652	-6.9581	<.0001*	0.8989	1.8891	0.0589	0.3665	0.9317	0.3515
Net primary productivity	-0.5035	-2.3642	0.0181*	3.9175	3.7428	0.0002*	-0.0119	-0.0283	0.9774
Pigments	-0.7582	-3.6753	0.0002*	0.4786	0.8384	0.4018	-1.7582	-2.2040	0.0275*
Reproduction	0.7787	1.0407	0.2980	–	–	–	-2.1226	-2.2014	0.0277*
Respiration	-1.5001	-6.8440	<.0001*	0.4529	0.5843	0.5590	0.4316	0.7989	0.4244
Stress response	-1.1723	-5.9654	<.0001*	–	–	–	0.0654	0.1535	0.8780
Survival	-1.1956	-4.9819	<.0001*	–	–	–	–	–	–
Tissue health	-1.9946	-6.3260	<.0001*	1.6209	2.0123	0.0442*	-1.1954	-1.3555	0.1753

Note that separate models were run for the three stressor scenarios and all four life stages. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Change in pCO_2 and duration were removed as moderators from the acidification-gametophyte and acidification-spore/germling models as they were nonsignificant. Change in pCO_2, change in temperature, and duration were all removed as moderators from the multiple stressor-gametophyte model as they were nonsignificant. Duration was removed as a moderator from the acidification-young sporophyte, warming-gametophyte, multiple stressor-spore and multiple stressor-young sporophyte models as it was nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S7

Table S7. The effect of response variables within the “Stress Response” category on standardized effects as Hedges’ g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
36 kDA band intensity	2.8276	2.7749	0.0055*	–	–	–	–	–	–
42 kDa band intensity	2.1494	2.1418	0.0322*	–	–	–	–	–	–
Antioxidant capacity	-0.3433	-0.4625	0.6438	–	–	–	–	–	–
Antioxidant pool size	-1.6286	-2.3055	0.0211*	–	–	–	–	–	–
CAT activity	-0.2596	-0.4927	0.6222	–	–	–	–	–	–
DMSP	–	–	–				-0.0117	-0.0195	0.9845
Flavonoid content	-0.2147	-0.2855	0.7752	–	–	–	–	–	–
hsp70 expression	-0.6347	-2.9972	0.0027*	–	–	–	–	–	–
Hydrogen peroxide	-3.6490	-2.9906	0.0028*	–	–	–	–	–	–
Insoluble phlorotannin content	-1.9135	-2.0809	0.0374*	–	–	–	–	–	–
Iodine accumulation	3.0761	3.1971	0.0014*	3.8771	6.2213	<.0001*	1.5925	3.5219	0.0004*
Iodine efflux	0.6676	0.7662	0.4436	–	–	–	-0.1770	-0.2758	0.7827
Lipid peroxidation	0.3122	0.4184	0.6756	–	–	–	–	–	–
Malondialdehyde	-1.9660	-3.7501	0.0002*	–	–	–	–	–	–
p-38-like protein phosphorylation	0.2247	0.2562	0.7978	–	–	–	–	–	–
Phenolic content	0.0272	0.0370	0.9705	–	–	–	–	–	–
Phlorotannin content	0.1729	0.5888	0.5560	–	–	–	0.9584	1.7670	0.0772
Radical scavenging activity	0.7160	0.9787	0.3277	–	–	–	–	–	–
SOD activity	-1.8370	-3.3411	0.0008*	–	–	–	–	–	–
Total phenolic content	-0.2027	-0.2694	0.7877	–	–	–	–	–	–

Note that separate models were run for the three stressor scenarios. Change in temperature and/or $p\mathrm{CO_2}$ and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Change in $p\mathrm{CO_2}$ was excluded as a moderator from the OA model and duration was excluded from the OW model because they were nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S8

Table S8. The effect of response variables within the “Enzyme Activity” category on standardized effects as Hedges’ g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Total carbonic anhydrase	-1.4596	-1.4182	0.1561	0.4899	1.5278	0.1266	–	–	–
External carbonic anhydrase	-0.6623	-0.3737	0.7086	1.4874	1.6419	0.1006	-0.6152	-1.2273	0.2197
Internal carbonic anhydrase	–	–	–	–	–	–	-0.4952	-0.4435	0.6574
GADPH	0.3535	0.2299	0.8182	–	–	–	–	–	–
GAPDH	0.5350	0.3481	0.7278	–	–	–	–	–	–
Glutamate synthase	–	–	–	–	–	–	9.2429	4.6094	<.0001*
Glutamine synthetase	0.2000	0.1293	0.8971	–	–	–	0.8126	0.5993	0.5490
Glutathione peroxidase	2.1643	0.7046	0.4810	–	–	–	–	–	–
Glutathione reductase	1.9357	0.6715	0.5019	–	–	–	–	–	–
Isocitrate dehydrogenase	–	–	–	–	–	–	5.2497	3.3235	0.0009*
L-aspartate	0.5354	0.3474	0.7283	–	–	–	–	–	–
Malate dehydrogenase	1.0362	0.6725	0.5013	–	–	–	–	–	–
Mannitol-1-phosphate dehydrogenase	0.8935	0.5749	0.5653	–	–	–	–	–	–
Nitrate reductase	-2.3429	-1.5859	0.1128	-0.1519	-0.4912	0.6233	0.2176	0.4831	0.6290
Peroxidase	1.6364	0.5692	0.5692	–	–	–	–	–	–
Phenylalanine ammonia-lyase activity	-15.9564	-3.2655	0.0011*	–	–	–	–	–	–
Phosphoenol-pyruvate carboxykinase	1.3136	0.8623	0.3885	–	–	–	–	–	–
Polyphenol oxiadase	2.5814	0.8338	0.4044	–	–	–	–	–	–
Pyruvate kinase	–	–	–	–	–	–	5.0674	3.2397	0.0012*
RuBisCO	0.2205	0.1458	0.8840	-2.3897	-4.8504	<.0001*	-0.7374	-0.5922	0.5922

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Change in pCO_2 and duration were removed as moderators from the OA model as they were nonsignificant. Change in temperature was removed as a moderator from the OW model as it was nonsignificant. Duration was removed as a moderator from the multiple stressor model as it was nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S9

Table S9. The effect of response variables within the "Fluorescence" category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
α	-0.8543	-3.0692	0.0021*	-0.0954	-0.3784	0.7052	0.4425	2.5374	0.0112*
E_c	-2.0730	-5.7512	<.0001*	–	–	–	–	–	–
E_k	-0.8637	-3.0862	0.0020*	-0.3535	-1.3034	0.1924	0.1717	0.6350	0.5254
ETR_{max}	-1.3135	-3.4262	0.0006*	0.1425	0.3059	0.7596	0.5100	1.8515	0.0641
F_v/F_m	-1.2160	-4.6574	<.0001*	0.0995	0.4778	0.6328	0.2436	-2.0484	0.0405*
F_v/F_m reduction	-1.4025	-1.1324	0.2575	–	–	–	–	–	–
F_v/F_0	-0.9928	-2.7931	0.0052*	–	–	–	–	–	–
NPQ	-1.6316	-5.5292	<.0001*	-0.0987	-0.1845	0.8536	-0.3042	-0.2728	0.7850
Photoinhibition	-1.0236	-2.1804	0.0292*	–	–	–	–	–	–
rETR	0.5146	0.9416	0.3464	–	–	–	-1.1015	-2.3200	0.0203*
$rETR_{max}$	-1.0057	-3.5449	0.0004*	-0.4222	-1.6379	0.1015	0.2167	0.9669	0.3336
YII	-0.7916	-2.1269	0.0334*	–	–	–	0.9944	2.3556	0.0185*

Note that separate models were run for the three stressor scenarios. Change in temperature and/or $p\mathrm{CO_2}$ and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Duration was removed from the multiple stressor model because it was nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S10

Table S10. The effect of response variables within the "Net Primary Productivity" category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Ammonium uptake	–	–	–	–	–	–	1.2154	1.2171	0.2236
Bicarbonate uptake	–	–	–	–	–	–	-0.7670	-0.7529	0.4515
Carbon acquisition	-2.7910	-2.1773	0.0295*	–	–	–	–	–	–
Carbon fixation rate	-0.8324	-0.9321	0.3513	0.9737	0.6262	0.5312	0.1839	0.2708	0.7866
CO_2 uptake	–	–	–	–	–	–	1.7444	2.0555	0.0398*
DOC release rate	0.7206	0.8435	0.3989	2.3047	1.4614	0.1439	0.2879	0.4071	0.6839
Maximum gross photosynthesis	1.3927	2.4043	0.0162*	–	–	–	–	–	–
Gross photosynthesis	-0.2869	-0.4155	0.6777	1.7955	1.1117	0.2663	0.2929	0.4097	0.6820
Net photosynthesis	0.5317	1.1796	0.2382	1.8881	1.3240	0.1855	0.3798	0.8420	0.3998
Nitrate uptake	0.0168	0.0192	0.9847	–	–	–	-1.6245	-1.5733	0.1157
Maximum net photosynthesis	-0.2424	-0.5867	0.5574	-2.8048	-1.3864	0.1656	-0.7976	-1.1225	0.2616
Oxygen evolution inhibition rate	–	–	–	–	–	–	9.2924	3.8525	0.0001*
pH change	–	–	–	–	–	–	0.4994	0.4696	0.6386
Photosynthesis : respiration ratio	-0.8234	-0.7643	0.4447	–	–	–	–	–	–
Photosynthetic quotient	-0.3136	-0.3826	0.7020	1.1505	0.7410	0.4587	-0.0125	-0.0184	0.9853
POC release rate	–	–	–	–	–	–	0.4890	0.5346	0.5929
Total alkalinity	–	–	–	–	–	–	-0.6915	-0.6784	0.4975
V_{max}	–	–	–	–	–	–	1.7208	1.2570	0.2088

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S11

Table S11. The effect of response variables within the "Pigments" category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Accessory pigment : Chlorophyll-*a* ratio	0.1437	0.2494	0.8031	-0.5378	-0.7157	0.4742	0.2906	0.2142	0.8304
Accessory pigment pool	0.1365	0.4859	0.6270	–	–	–	–	–	–
Antherax-anthin	-0.8553	-2.8714	0.0041*	–	–	–	–	–	–
Antherax-anthin : chlorophyll-*a* ratio	1.3036	2.0117	0.0442*	0.5251	0.6793	0.4970	-0.1750	-0.1291	0.8973
Antherax-anthin : chlorophylls ratio	-0.8572	-0.8446	0.3983	-2.3034	-2.5003	0.0124*	-1.9120	-1.2620	0.2069
Beta-carotene	-1.8486	-5.0772	<.0001*	-2.0988	-2.7155	0.0066*	1.0569	0.7690	0.4419
Beta-carotene : chlorophyll-*a* ratio	-0.7356	-1.6410	0.1008	-0.8130	-1.0772	0.2814	0.0800	0.0590	0.9529
Carotenoids	0.3771	0.8895	0.3737	–	–	–	-0.5005	-0.2950	0.7680
Chlorophyll-*a*	-0.0954	-0.4518	0.6514	-0.2767	-0.4092	0.6824	-0.8806	-0.6763	0.4988
Chlorophyll-a : accessory pigments ratio	-0.3916	-1.3171	0.1878	–	–	–	–	–	–
Chlorophyll-*a* : chlorophyll-*c* ratio	–	–	–	–	–	–	0.6429	0.3887	0.6975
Chlorophyll-a : Xanthophyll cycle pigment pool ratio	0.6192	2.0831	0.0372*	–	–	–	–	–	–
Chlorophyll-*c*	-0.0354	-0.1484	0.8820	-0.0545	-0.0790	0.9370	-0.5613	-0.4269	0.6694
Chlorophyll-*c* : chlorophyll-*a* ratio	-0.1686	-0.4683	0.6396	-1.3847	-1.9297	0.0536	0.9741	0.7240	0.4691
D1 protein	0.1372	0.2581	0.7963	-1.1383	-1.5478	0.1217	-0.2750	-0.2032	0.8390
De-epoxidation state	0.2239	0.8303	0.4063	-2.3369	-3.1422	0.0017*	-0.6334	-0.4713	0.6374
Fucoxanthin	0.1804	0.7374	0.4609	0.0950	0.1380	0.8903	-0.8027	-0.6079	0.5432
Fucoxanthin : chlorophyll-*a* ratio	-0.1689	-0.4603	0.6453	-0.0592	-0.0774	0.9383	0.1605	0.118	0.9058

Table continues

Table S11, Continued

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Violaxanthin + Zeaxanthin : chlorophyll-*a* ratio	0.2197	0.4308	0.6666	–	–	–	–	–	–
Violaxanthin	0.3373	1.2060	0.2278	0.6655	0.8274	0.4080	-0.5220	-0.3846	0.7005
Violaxanthin : chlorophyll-*a* ratio	1.6138	2.3835	0.0171*	0.2898	0.4424	0.5740	0.5660	0.3625	0.7170
Violaxanthin : Chlorophylls ratio	-2.1595	-1.7870	0.0739	-2.0319	-2.3420	0.0192*	1.1124	0.7713	0.4405
Xanthophyll cycle pigment pool	0.3296	1.2382	0.2157	-0.3269	-0.4137	0.6791	-0.6592	-0.4851	0.6276
Xanthophyll cycle pigment pool : chlorophyll-*a* ratio	0.7718	2.9061	0.0037*	-1.8257	-2.5459	0.0109*	0.0213	0.0159	0.9873
Zeaxanthin	0.1194	0.4292	0.6678	-1.8835	-2.4706	0.0135*	-0.3946	-0.2908	0.7712
Zeaxanthin : chlorophyll-*a* ratio	-2.6359	-3.8321	<00001*	-3.0499	-3.8531	0.0001*	-0.3097	-0.2282	0.8195
Zeaxanthin : chlorophylls ratio	0.4314	0.4592	0.6461	-1.2765	-1.5012	0.1333	-0.2912	-0.2030	0.8391

Note that separate models were run for the three stressor scenarios. Change in temperature and/or $p\mathrm{CO_2}$ were z-transformed and included as continuous moderators; study and species were included as random effects. All moderators were excluded from the multiple stressor model as they were nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S12

Table S12. The effect of response variables within the “Biochemical composition” category on standardized effects as Hedges’ g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
2-oxoglutarate	–	–	–	–	–	–	9.9112	6.5607	<.0001*
Alanine	–	–	–	–	–	–	1.5316	2.5357	0.0112*
Alginic acid	–	–	–	–	–	–	0.7334	1.2828	0.1996
Alpha-linolenic acid	–	–	–	–	–	–	1.6174	2.8025	0.0051*
Amino acid	–	–	–	–	–	–	0.4766	0.7691	0.4418
Amino-nitrogen content	0.7831	1.9921	0.0464*	–	–	–	–	–	–
Arachidonic acid	–	–	–	–	–	–	0.9909	1.6805	0.0929
Arginine	–	–	–	–	–	–	2.4296	4.0407	<.0001*
Aspartate	–	–	–	–	–	–	1.8443	3.1508	0.0016*
C : N ratio	-0.5429	-2.6075	0.0091*	-0.9427	-3.1923	0.0014*	0.5013	1.3634	0.1728
Carbon	-0.1193	-0.5988	0.5493	0.9133	3.1369	0.0017*	0.5783	1.5580	0.1192
Cellulose	–	–	–	–	–	–	1.2707	2.2285	0.0258*
Citrate	–	–	–	–	–	–	3.4328	4.8304	<.0001*
Cysteine	–	–	–	–	–	–	2.3394	3.9301	<.0001*
$\delta^{13}C$	1.3426	2.7171	0.0066*	1.9474	2.8483	0.0044*	1.3019	2.8482	0.0044*
$\delta^{15}N$	0.7936	1.1564	0.2475	–	–	–	–	–	–
DNA	0.8069	1.1741	0.2404	–	–	–	-0.2934	-0.4461	0.6555
Eicosapent-aenoic acid	–	–	–	–	–	–	2.1741	3.6382	0.0003*
Eicosatri-enoic acid	–	–	–	–	–	–	1.8118	3.0803	0.0021*
ε_p	0.9170	0.8810	0.3783	3.1323	2.7831	0.0054*	1.4716	1.8790	0.0602
Free arginine	–	–	–	–	–	–	2.2848	3.5727	0.0004*
Free aspartate	–	–	–	–	–	–	3.0018	4.4200	<.0001*
Free glutamine	–	–	–	–	–	–	1.8797	3.0068	0.0026*
Fucoidan	–	–	–	–	–	–	1.1467	1.9860	0.0470*
Fumarate	–	–	–	–	–	–	2.4401	3.7735	0.0002*
Gamma-linolenic acid	–	–	–	–	–	–	1.3692	2.2763	0.0228*
Glutamine	–	–	–	–	–	–	2.1678	3.4480	0.0006*
Glycine	–	–	–	–	–	–	1.2135	1.9887	0.0467*
Histidine	–	–	–	–	–	–	0.9152	1.5099	0.1311
Isoleucine	–	–	–	–	–	–	1.3409	2.2092	0.0272*
Laminarin	0.7652	2.2302	0.0257*	–	–	–	1.3478	2.3459	0.0190*
Leucine	–	–	–	–	–	–	1.5679	2.5828	0.0098*
Linoleic acid	–	–	–	–	–	–	2.4015	3.9483	<.0001*
Lipids	-0.1028	-0.1943	0.8459	-0.6401	-1.3356	0.1817	0.5766	1.1791	0.2383
Lysine	–	–	–	–	–	–	1.7855	2.9295	0.0034*
Malate	–	–	–	–	–	–	10.4432	6.5768	<.0001*
Mannitol	-0.1919	-0.8559	0.3920	–	–	–	2.2500	3.8060	0.0001*
Methionine	–	–	–	–	–	–	0.8056	1.3118	0.1896

Table continues

Table S12, Continued

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Monounsatu-rated fatty acids	0.4855	0.4484	0.6539	–	–	–	–	–	–
Nitrogen	-0.2948	-1.5252	0.1272	-0.6782	-2.2308	0.0257*	0.5964	1.6023	0.1091
NO_3^- nitrogen	0.5797	1.4819	0.1384	–	–	–	–	–	–
Oxaloacetate	–	–	–	–	–	–	5.6009	6.0181	<.0001*
Phenylalanine	–	–	–	–	–	–	1.3774	2.2507	0.0244*
Polyunsatura-ted fatty acids	-1.0874	-1.0040	0.3154	–	–	–	–	–	–
Proline	–	–	–	–	–	–	0.8920	1.4543	0.1459
Proteins	0.4975	1.9183	0.0551	0.2921	0.6808	0.4960	0.3936	0.8340	0.4043
Pyruvate	–	–	–	–	–	–	3.8777	5.1819	<.0001*
RNA	1.0691	1.5649	0.1176	–	–	–	0.3148	0.4922	0.6226
RNA : DNA ratio	1.2359	1.7959	0.0725	–	–	–	-0.1271	-0.1974	0.8435
Saturated fatty acids	-1.0353	-0.9586	0.3378	–	–	–	–	–	–
Serine	–	–	–	–	–	–	0.6417	1.0320	0.3021
Soluble carbohydrates	0.1847	0.3884	0.6977	0.8807	2.1538	0.0313*	0.6248	1.4321	0.1521
Succinate	–	–	–	–	–	–	1.8712	2.9943	0.0028*
Threonine	–	–	–	–	–	–	1.6791	2.7929	0.0052*
Total non-structural carbohydrates	2.1102	2.0791	0.0376*	–	–	–	–	–	–
Tyrosine	–	–	–	–	–	–	0.7435	1.2081	0.2270
Valine	–	–	–	–	–	–	1.2912	2.1345	0.0328*

Note that separate models were run for the three stressor scenarios. Change in temperature and/or *p*CO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Change in *p*CO_2 was removed as a moderator from the OA model as it was nonsignificant. Change in temperature and duration were removed as moderators from the OW model as they were nonsignificant. Duration was removed from the multiple stressor model because it was nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S13

Table S13. The effect of response variables within the "Growth" category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Area	-1.6404	-8.2041	<.0001*	–	–	–	-0.4133	-0.2997	0.7644
Area change	-1.2142	-3.9198	<.0001*	–	–	–	–	–	–
Diameter	-2.5692	-12.1901	<.0001*	–	–	–	1.6957	0.8727	0.3828
Diameter change	-0.3277	-0.7344	0.4627	–	–	–	-0.1021	-0.1054	0.9161
Dry weight change	-1.2987	-1.9187	0.0550	–	–	–	–	–	–
Elongation rate	-1.8291	-8.8031	<.0001*	-7.9731	-3.3756	0.0007*	-0.5699	-0.7188	0.4723
Germ tube length	-4.9742	-2.1923	0.0284*	–	–	–	–	–	–
Length	-1.6032	-7.8959	<.0001*	-5.7606	-2.3855	0.0171*	0.2745	0.1905	0.8489
Number of cells	-1.5379	-8.1644	<.0001*	–	–	–	-0.7519	-0.3748	0.7078
Perforation area	–	–	–	–	–	–	-0.4537	-0.4791	0.6318
Relative size	1.3607	0.5884	0.5562	–	–	–	–	–	–
Weight	-2.6030	-1.2342	0.2171	-0.9716	-0.4323	0.6655	-0.3778	-0.2751	0.7832
Weight change	-1.7146	-10.9984	<.0001*	-0.2721	-0.1252	0.9004	0.5131	0.9641	0.3350

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S14

Table S14. The effect of response variables within the "Reproduction" category on standardized effects as Hedges' g.

	Warming			Acidification and Warming			Acidification		
Metric	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Fertility	-1.6844	-1.2356	0.2166	–	–	–	–	–	–
Frequency of females with vegetative growth	-1.9495	-3.7273	0.0002*	–	–	–	–	–	–
Germination rate	-0.0186	-0.0372	0.9703	-3.1397	-5.3546	<.0001*	5.3995	1.0353	0.3005
Half maximal reaction time	-2.1186	-1.4279	0.1533	–	–	–			
Number of oogonia	-1.5333	-1.2868	0.1982	–	–	–	2.3660	0.5032	0.6148
Oogonium formation	-2.5405	-4.8154	<.0001*	-6.9236	-3.2068	0.0013*	-0.0587	-0.0124	0.9901
Reproductive area allocation	-4.1551	-3.0937	0.0020*	–	–	–	–	–	–
Reproductive success	-2.3092	-4.6894	<.0001*	-4.4900	-2.9310	0.0034*	-2.5652	-0.5287	0.5970
Sex ratio	-0.8199	-1.6982	0.0895	-0.3636	-0.4416	0.6587	2.3229	0.4793	0.6317
Sorus induction	-3.0204	-2.0353	0.0418*	–	–	–	–	–	–
Spore production	0.0231	0.0423	0.9663	–	–	–	–	–	–
Total fertile area	-3.8822	-2.5963	0.0094*	–	–	–	–	–	–
Ungerminated spores	1.8317	1.8746	0.0608	-0.1550	-0.2895	0.7722	5.2033	0.9928	0.3208
Weight gain during sorus formation	–	–	–	–	–	–	-17.0986	-1.4984	0.1340

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Duration was excluded as a moderator in the OA model because it was nonsignificant. All continuous moderators were excluded from the multiple stressor model as they were nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S15

Table S15. The effect of response variables within the "Tissue Health" category on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Breaking stress	-1.6508	-0.0920	0.9267*	–	–	–	–	–	–
Dry weight : wet weight ratio	–	–	–	–	–	–	-0.0339	-0.0150	0.9880
Fresh weight : Dry weight ratio	-0.0426	-0.0024	0.9981	10.8039	5.5338	<.0001*	-1.3997	-0.9677	0.3332
Maximum strain	-0.8346	-0.0465	0.9629	–	–	–	–	–	–
Number of blisters	-0.4010	-0.0223	0.9822	28.2915	5.0387	<.0001*	-0.6591	-0.3023	0.7624
Tissue loss	-1.5141	-0.0844	0.9327	–	–	–	–	–	–

Note that separate models were run for the three stressor scenarios. Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Change in pCO_2 and duration were excluded from the OA model because they were nonsignificant. Duration was excluded from the OW model because it was nonsignificant. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S16

Table S16. The effect of latitude (absolute value) on standardized effects as Hedges' g.

Stressor	Effect size	*Z*	*P*
Warming	0.0048	0.9182	0.3585
Acidification and warming	-0.0077	-0.6183	0.5364
Acidification	0.0348	3.6520	0.0003*

Note that separate models were run for the three stressors scenarios (warming, acidification, or acidification and warming). Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks.

Table S17

Table S17. The effect of geographic location (Realm, Province, and Ecoregion), on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Arctic (Realm)	-0.7669	-1.8145	0.0696	-2.6727	-0.9519	0.3412	1.0734	2.3378	0.0194*
Arctic (Province)	-0.7615	-2.1323	0.0330*	-3.1612	-0.9552	0.3395	0.9672	1.8257	0.0679
Hudson Complex	-3.2515	-5.0434	<.0001*	–	–	–	–	–	–
North and East Barents Sea	-0.5005	-1.4101	0.1585	-3.5994	-0.9687	0.3327	1.1231	2.0829	0.0373*
Temperate Australasia	-1.0835	-2.5019	0.0124*	-4.3878	-1.2453	0.2130	0.7617	1.1714	0.2414
East Central Australian Shelf	-0.4537	-0.3356	0.7372	-4.8815	-1.2165	0.2238	-0.9952	-0.6426	0.5205
Tweed-Moreton	-0.4217	-0.3185	0.7501	-5.3165	-1.2173	0.2235	-0.9279	-0.5767	0.5642
Northern New Zealand	-0.5569	-0.4176	0.6763	–	–	–	–	–	–
Northeastern New Zealand	-0.5283	-0.4048	0.6857	–	–	–	–	–	–
Southeast Australian Shelf	-0.4299	-0.9420	0.3462	–	–	–	0.2783	0.1791	0.8579
Bassian	-0.2065	-0.4493	0.6532	–	–	–	0.3472	0.2151	0.8297
Western Bassian	-0.4714	-0.3579	0.7204	–	–	–	–	–	–
South New Zealand	-0.4990	-0.6000	0.5485	–	–	–	1.7816	1.6105	0.1073
South New Zealand	-0.4528	-0.5573	0.5773	–	–	–	1.7186	1.5080	0.1316
Southwest Australian Shelf	-1.2223	-2.6906	0.0071*	–	–	–	-0.8222	-0.5000	0.6170
Leeuwin	-1.4054	-3.0795	0.0021*	–	–	–	–	–	–
South Australian Gulfs	-0.5421	-0.4124	0.6800	–	–	–	-0.7589	-0.4462	0.6555
West Central Australian Shelf	-1.1806	-2.5535	0.0107*	–	–	–	–	–	–
Houtman	-1.1943	-2.5802	0.0099*	–	–	–	–	–	–
Temperate Northern Atlantic	-0.4766	-1.1988	0.2306	-2.4774	-0.8796	0.3791	0.2067	0.4483	0.6540
Cold Temperate Northwest Atlantic	-1.4266	-3.3586	0.0008*	–	–	–	0.8322	0.8145	0.4154
Gulf of Maine/ Bay of Fundy	-0.2822	-0.4354	0.6633	–	–	–	–	–	–
Scotian Shelf	-2.1718	-4.5454	<.0001*	–	–	–	–	–	–
Virginian	-0.3343	-0.5119	0.6088	–	–	–	0.7897	0.7428	0.4576
Lusitanian	-1.0628	-1.6953	0.0900	–	–	–	–	–	–
South European Atlantic Shelf	-1.1341	-1.8453	0.0650	–	–	–	–	–	–
Northern European Seas	-0.2066	-0.6080	0.5432	2.9639	-0.8935	0.3716	0.0847	0.5322	0.8735
Celtic Seas	-0.5838	-1.6260	0.1039	–	–	–	-0.3001	-0.3192	0.7496
North Sea	-0.4573	-1.3187	0.1873	-3.4020	-0.9139	0.3608	0.2651	0.4752	0.6346
Northern Norway and Finnmark	-0.9744	-1.0249	0.3054	–	–	–	–	–	–

Table continues

Table S20, Continued

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	Z	P	Effect size	Z	P	Effect size	Z	P
South Norway	-0.3656	-0.9490	0.3426	–	–	–	–	–	–
Temperate Northern Pacific	-1.8749	-7.1195	<.0001*	-3.7885	-1.4398	0.1499	-0.4060	-1.1666	0.2434
Cold Temperate Northeast Pacific	-2.0133	-7.3874	<.0001*	–	–	–	0.5771	0.4538	0.6500
Gulf of Alaska	-2.6307	-1.9701	0.0488*	–	–	–	–	–	–
Northern California	-1.7925	-6.2253	<.0001*	–	–	–	–	–	–
Oregon, Washington, Vancouver Coast and Shelf	-2.8078	-5.1695	<.0001*	–	–	–	-0.5597	-0.4268	0.6695
Puget Tough/ Georgia Basin	-2.6204	-3.9824	<.0001*	–	–	–	–	–	–
Cold Temperate Northwest Pacific	-1.7669	-6.1044	<.0001*	-3.6771	-1.1019	0.2705	0.3272	0.6244	0.5324
Northeastern Honshu	-2.0682	-6.5727	<.0001*	–	–	–	–	–	–
Sea of Japan/East Sea	-0.5694	-0.7280	0.4666	–	–	–	–	–	–
Yellow Sea	-1.4665	-3.0191	0.0025*	-4.1136	-1.1011	0.2708	0.2435	0.4274	0.6691
Warm Temperate Northeast Pacific	-1.6009	-5.8203	<.0001*	-5.7376	-1.6214	0.1049	-1.0037	-1.8146	0.0696
Southern California Bight	-1.3912	-4.8242	<.0001*	-5.2381	-1.3321	0.1828	-1.1074	-1.8330	0.0668
Warm Temperate Northwest Pacific	-1.0496	-3.5812	0.0003*	-2.7961	-0.8190	0.4128	-1.6415	-1.5447	0.1224
Central Kuroshio Current	-1.3942	-4.4028	<.0001*	–	–	–	–	–	–
East China Sea	-0.0287	-0.0546	0.9564	-2.7471	-0.7227	0.4698	-1.7720	-1.5840	0.1132
Temperate South America	-0.8619	-1.9248	0.0543	-2.0721	-0.7610	0.4467	-0.5693	-0.7703	0.4411
Warm Temperate Southeastern Pacific	-0.8504	-2.0460	0.0408*	-2.8969	-0.8817	0.3780	-0.7857	-0.9947	0.3199
Araucanian	-0.8117	-1.9934	0.0462*	-1.1922	-0.3014	0.7631	-1.1960	-1.1225	0.2616
Central Chile	-0.8699	-2.1116	0.0347*	-5.0914	-1.2450	0.2131	-0.0590	-0.0434	0.9654
Humboldtian	-0.2374	-0.5322	0.5946	–	–	–	–	–	–
Magellanic	0.4574	0.7903	0.4294	–	–	–	–	–	–
Chiloense	0.5012	0.8777	0.3801	–	–	–	–	–	–
Temperate South Africa	-0.1135	-0.0870	0.9306	–	–	–	–	–	–
Agulhas	-2.0838	-1.5108	0.1308	–	–	–	–	–	–
Natal	-2.0344	-1.5023	0.1330	–	–	–	–	–	–
Benguela	1.8045	1.3722	0.1700	–	–	–	–	–	–
Namaqua	1.8545	1.4389	0.1502	–	–	–	–	–	–

Note that separate models were run for the three stressor scenarios and were run separately at the Realm, Province, and Ecoregion level (9 models total). Geographic delineations are based on The World Wildlife Fund and The Nature Conservancy's Marine Ecoregions of the World. Included moderators for the warming model were study, species, duration, and change in temperature (exception: at the province level, species was removed as a moderator). Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study and species were included as random effects. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S18

Table S18. The effect of taxonomy (at the Family, Genus, and Species level), on standardized effects as Hedges' g.

Metric	Warming			Acidification and Warming			Acidification		
	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
Family Agaraceae	-0.9976	-3.8972	<.0001*	–	–	–	–	–	–
Genus Agarum	-1.0610	-3.5019	0.0005*	–	–	–	–	–	–
A. clathartum	-0.5790	-1.7951	0.0726	–	–	–	–	–	–
Genus Costaria	-1.3900	-3.0609	0.0022*	–	–	–	–	–	–
C. costata	-1.4785	-3.3342	0.0009*	–	–	–	–	–	–
Genus Dictyoneurum	-0.0963	-0.1133	0.9098	–	–	–	–	–	–
D. reticulatum	-0.3523	-0.4150	0.6781	–	–	–	–	–	–
Family Alariaceae	-0.6497	-3.8124	0.0001*	-5.1295	-2.0250	0.0429*	-0.3012	-2.1976	0.0280
Genus Alaria	-0.6095	-3.3342	0.0009*	-2.2348	-0.6862	0.4926	-1.7313	-4.6696	<.0001*
A. crassifolia	-1.6681	-1.8023	0.0715	–	–	–	–	–	–
A. esculenta	-0.3057	-1.2928	0.1961	-2.4979	-0.6890	0.4908	-1.2010	-2.7687	0.0056*
A. marginata	-0.8933	-4.1944	<.0001*	–	–	–	–	–	–
Genus Eualaria	-10.7016	-8.9864	<.0001*	–	–	–	–	–	–
E. fistulosa	-10.5019	-8.8045	<.0001*	–	–	–	–	–	–
Genus Lessoniopsis	-1.4380	- 1.9165	0.0553	–	–	–	–	–	–
L. littoralis	-1.5026	-2.0319	0.0422*	–	–	–	–	–	–
Genus Pterygophora	-0.7379	-3.9371	<.0001*	–	–	–	–	–	–
P. californica	-1.0421	-4.9331	<.0001*	–	–	–	–	–	–
Genus Undaria	-0.6725	-3.2242	0.0013*	-4.2996	-1.7497	0.0802	0.2514	0.8481	0.3964
U. pinnatifida	-0.9294	-4.3139	<.0001*	-3.5892	-1.2711	0.2037	0.0602	1.1982	0.8429
Family Arthroth-amnaceae	-0.9156	-5.4080	<.0001*	-2.3836	-0.9716	0.3312	-0.0659	-0.8030	0.4220
Genus Ecklonia	-0.8737	-3.7515	0.0002*	-5.4270	-1.9852	0.0471*	-1.0857	-1.5602	0.1187
E. biruncinata	-2.3133	-2.0983	0.0359*	–	–	–	–	–	–
E. cava	-0.0557	-0.1043	0.9169	–	–	–	–	–	–
E. maxima	1.5627	1.5306	0.1259	–	–	–	–	–	–
E. radiata	-1.1785	-4.5838	<.0001*	-4.3737	-1.2051	0.2282	-0.6175	-0.7810	0.4348
E. radicosa	-1.3392	-1.7530	0.0796	–	–	–	–	–	–
E. stolonifera	-3.0948	-2.6459	0.0081*	-7.1224	-2.0983	0.0359*	-2.0709	-1.5971	0.1102
Genus Egregia	-0.7549	-4.0474	<.0001*	–	–	–	–	–	–
E. menziesii	-1.0467	-5.0688	<.0001*	–	–	–	–	–	–
Genus Nereocystis	-1.3586	-3.3211	0.0009*	–	–	–	1.5216	4.3344	<.0001*
N. luetkeana	-1.2516	-3.0105	0.0026*	–	–	–	2.1017	4.7735	<.0001*
Genus Saccharina	-1.1325	-6.0654	<.0001*	-1.1552	-0.4860	0.6269	-0.0347	-0.1329	0.8943
S. angustata	-1.7654	-1.8943	0.0582	–	–	–	–	–	–
S. angustissima	-0.4277	-0.3185	0.7501	–	–	–	–	–	–
S. japonica	-1.3183	-3.8743	0.0001*	-0.3248	-0.1170	0.9068	-0.2479	-0.8833	0.3771

Table continues

Table S18, continued

	Warming			Acidification and Warming			Acidification		
Metric	Effect size	*Z*	*P*	Effect size	*Z*	*P*	Effect size	*Z*	*P*
S. latissima	-0.7810	-3.5276	0.0004*	-2.6345	-0.8902	0.3733	0.5522	1.4653	0.1428
S. sculpera	-0.5427	-0.7060	0.4802	–	–	–	–	–	–
Family Laminariaceae	-1.4066	-8.2586	<.0001*	-2.6271	-1.0684	0.2853	0.1724	1.4632	0.1434
Genus Hedophyllum	-2.1833	-11.7930	<.0001*	–	–	–	–	–	–
H. dentigerum	-2.1384	-9.8179	<.0001*	–	–	–	–	–	–
H. nigripes	-2.1125	-7.9183	<.0001*	–	–	–	–	–	–
H. sessile	-2.7106	-12.2753	<.0001*	–	–	–	–	–	–
Genus Laminaria	-1.3801	-7.6594	<.0001*	-1.3098	-0.5423	0.5876	0.0636	0.1530	0.8784
L. digitata	-0.7181	-3.1445	0.0017*	–	–	–	–	–	–
L. ephemera	-2.9480	-1.9823	0.0474*	–	–	–	–	–	–
L. farlowii	-1.1546	-5.3641	<.0001*	–	–	–	–	–	–
L. hyperborea	-1.1504	-3.9873	<.0001*	–	–	–	-0.2229	-0.3058	0.7598
L. ochroleuca	-1.2353	-3.8765	0.0001*	–	–	–	–	–	–
L. setchellii	-1.5914	-2.6247	0.0087*	–	–	–	–	–	–
L. sincharii	-2.9077	-13.0883	<.0001*	–	–	–	–	–	–
L. solidungula	-1.0196	-2.7306	0.0063*	-2.7671	-0.9277	0.3536	0.7283	1.3097	0.1903
Genus Macrocystis	-0.9186	-5.0387	<.0001*	-3.0646	-1.2816	0.2000	0.4000	1.4218	0.1551
M. pyrifera	-1.2145	-5.9295	<.0001*	-3.2535	-1.2090	0.2267	0.2271	0.8141	0.4156
Genus Postelsia	-1.8496	-2.3639	0.0181*	–	–	–	–	–	–
P. palmiformis	-1.8710	-2.3691	0.0178*	–	–	–	–	–	–
Family Lessoniaceae	-1.4387	-6.2920	<.0001*	-4.0421	-1.3506	0.1768	-0.2729	-0.3318	0.7400
Genus Eisenia	-1.0240	-2.3226	0.0202*	–	–	–	–	–	–
E. arborea	-1.0453	-2.0514	0.0402*	–	–	–	–	–	–
E. bicyclis	-0.8937	-1.1564	0.2475	–	–	–	–	–	–
Genus Lessonia	-1.5455	-5.8719	<.0001*	-3.8839	-1.3760	0.1688	-0.3925	-0.3881	0.6980
L. corrugata	-1.4257	-1.0890	0.2761	–	–	–	–	–	–
L. nigrescens	-0.2053	-0.3434	0.7313	–	–	–	–	–	–
L. trabeculata	-2.4386	-2.4685	0.0136*	-4.1474	-1.3148	0.1886	-0.2999	-0.3017	0.7629
L. variegata	-1.9252	-6.5525	<.0001*	–	–	–	–	–	–

Note that separate models were run for the three stressor scenarios and were run separately at the Family, Genus, and Species level (9 models total). Change in temperature and/or pCO_2 and duration were z-transformed and included as continuous moderators; study was included as a random effect. Statistically significant p-values are marked with asterisks. Dashes indicate categories where no data was available.

Table S19

Table S19. The effect of stressor intensity (defined for warming as the difference in °C between the control and the treatment temperatures, and for acidification as the difference in μatm between the control and treatment pCO_2 levels) on standardized effects as Hedges' g. Changes in pCO_2 and temperature have been transformed to z-scores.

Stressor	Effect size	*Z*	*P*
Warming (increase in temperature, °C)	-0.6307	-35.1817	<.0001*
Acidification (increase in pCO_2, μatm)	-0.3261	-6.6541	<.0001*

Note that separate models were run for the two different stressors (warming and acidification). Duration (z-transformed) was included as a fixed effect and study and species were included as random effects in both studies. Statistically significant p-values are marked with asterisks.

Table S20

Table S20. The effect of experiment duration on standardized effects as Hedges' g. Duration was z-transformed before analysis.

Stressor	Effect size	*Z*	*P*
Warming	-0.4035	-11.1413	<.0001*
Acidification and warming	0.7494	7.7899	<.0001*
Acidification	0.1685	4.3523	<.0001*

Note that separate models were run for the three stressors scenarios (warming, acidification, or acidification and warming). Change in pCO_2 and/or change in temperature were z-transformed and included as fixed effects and study and species were included as random effects. Statistically significant p-values are marked with asterisks.