Supporting Information

Appendix S1. Additional information on data collection, preparation, and statistical analyses.

Study area

Nine regions spanning coastal British Columbia, Canada were sampled for fishes in seagrass meadows. The Skeena estuary (no. of sites = 15) and Central Coast (9) regions were in the Aleutian province, whereas all remaining regions were in the Oregonian province, including Comox Estuary (4), Bowser Lagoons (2), Clayoquot Sound (12), Barkley Sound (18), Fraser Estuary (8), Gulf Islands (12), and Southern Vancouver Island (9).

Lab measures

Seagrass quadrat samples were kept frozen until processing in the lab. To further characterize the meadow habitat, the number of shoots per quadrat was counted, and length and width measures were taken of the longest seagrass blade within each quadrat. Leaf area index provided a measure of surface area available for epiphytic growth, and was calculated for each quadrat as the average blade length * width * number of shoots. Seagrass epiphytes were scraped off the blades, and both seagrass shoots and epiphytes were dried in an oven for 48 hrs at 60º C and weighed for dry biomass. Averages of quadrat measures were used for one representative value per site (Fig. S1).

Physical and spatial measures

Additional physical measures were made from online geospatial data sources. Some oceanographic values did not extend to all nearshore sites, in which case values were averaged within a standard radius from each site. Mean July and annual (data from 2002-2010) sea surface temperatures (SST, °C) were calculated within 2 km of each site (data from MARSPEC; Sbrocco & Barber, 2013), and tidal current speed (root mean square, m/s) was averaged within 5 km of each site (data from The British Columbia Marine Conservation Analysis, www.bcmca.ca). Salinity was also obtained in this way to fill in data gaps, but was poorly correlated with our field measures, so we only used *in situ* salinity measures. Overall shoreline type was classified as beach, flat, estuary/lagoon, cliff, or human-made, and level of wave exposure was categorized as semi-protected or protected (data from the British Columbia Shorezone Mapping System, www.geobc.gov.bc.ca). The shortest path, overwater distance to a major freshwater input was associated rivers ("sp" in R; Bivand *et al.*, 2013). The area of the river within the watershed that contained the river mouth was obtained from a freshwater atlas (Freshwater Atlas, www.geobc.gov.bc.ca). Finally, freshwater influence was calculated as the river area divided by the distance to the river. Distances between sites within regions were calculated as the shortest path distance overwater.

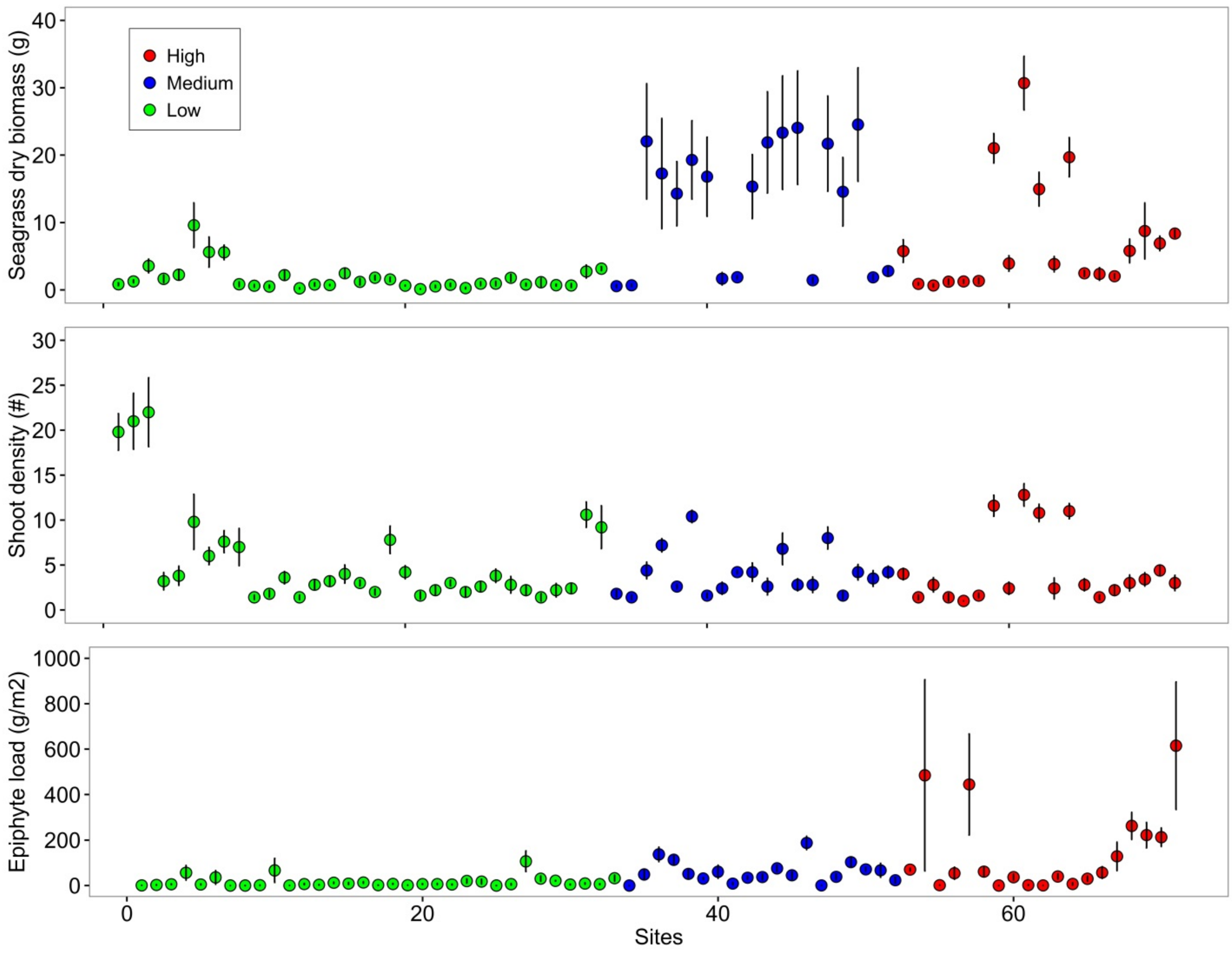

Figure S1. Site averages (± 1 SE) of quadrats (n=5) measuring seagrass (*Zostera marina*) dry biomass, shoot density, and epiphyte load. Sites are arranged in order along the anthropogenic disturbance gradient and identified by disturbance category as low (green), medium (blue), and high (red).

Anthropogenic disturbance measures

Population counts (Center for International Earth Science Information Network, 2005) were obtained for the entire area of watersheds (Freshwater Atlas Assessment Watersheds, www.geobc.gov.bc.ca) that had any overlap within a 5 km buffer of each site. The relevant scale for assessing impacts to seagrass meadows is suggested to be within 1-3 km of shoreline (Shelton *et al.*, 2017). We extended the radius to 5 km for the watershed population measure in order to capture some extent of land for all sites (i.e., the nearshore environment of the Fraser Estuary extends further from land than island sites, for instance). We included the full extent of watershed populations captured within this radius as watershed population size is an indicator of nutrient load (Tewfik *et al.*, 2007, Bricker *et al.* 2008), and nutrient inputs from watersheds are highly linked to coastal food webs (Martinetto *et al.* 2006). The area of overwater structures within a 2 km radius of each site was also measured in Google Earth. This radius was selected based on the area of the harbours surveyed (i.e., Southern Vancouver Island), as a site 1 km away from a marina may not be affected by the structure itself, but will likely receive increased boating activity; conversely, the effects of shoreline modification are expected to be more localized. Overwater structures included marinas, ferry terminals, coal ports, naval bases, and fish farms; private docks were not included as these measures were difficult to make at this scale and were captured in the shoreline modification measures. As the 2 km radius often contained land, the water surface area was measured, and the proportion of overwater structure area / water surface area was calculated. Shoreline modification was estimated as the percent of developed land within 100 m in either direction of the site, parallel to the shore, using Google Earth. Modification included presence of human-made structures and de-vegetation (e.g., lawns, concrete walls, boat ramps); land that was modified close to shore but was separated by a riparian buffer was not included as modified. These estimates were verified using site descriptions recorded in the field and by the field leads.

Sensitivity analyses

Influence of alpha-diversity

Sample-based rarefaction curves were generated (999 bootstrapped replications) to compare species richness across anthropogenic disturbance categories using incidence-based data ("iNEXT" in R; Chao *et al.*, 2014). Sample-based rarefaction curves are appropriate to estimate species richness from collection methods including beach seines as the spatial structure of the data (i.e., aggregation of individuals) is preserved (Gotelli & Colwell, 2010; Colwell *et al.*, 2012). Non-overlapping 95% confidence intervals around the rarefaction curves indicate significant differences between categories. The contribution of turnover versus nestedness to differences in beta-diversity between anthropogenic disturbance categories was also determined using Sorensen dissimilarities (i.e., incidence-based version of Bray-Curtis) within all regions ("betapart" in R; Baselga & Orme, 2012).

Influence of spatial autocorrelation

Two within-region sensitivity analyses were conducted to verify beta-diversity comparisons after controlling for spatial autocorrelation, one removed average geographic distance differences between anthropogenic disturbance levels and another fixed the relationship between geographic distance and beta-diversity values to be the same across disturbance categories (Karp *et al.*, 2012). Within-region geographic distances were greater between low disturbance sites (22.35 km ± 1.47) than medium (16.43 km ± 1.00) and high disturbance sites (16.56 km ± 3.03; linear regression: $F_{2,367} = 3.755$, p=0.024); for this analysis, we excluded all low disturbance site comparisons with a distance > 40 km (34 comparisons) to remove the difference between disturbance categories (new low disturbance geographic distance mean: 13.94 km ± 8.26; $F_{2,333} = 1.842$, p=0.160) and re-ran bootstrapped comparisons with the reduced dataset. In the second analysis, the slope between all within-region BC beta-deviation values versus pairwise geographic distances was calculated and then fixed to generate bootstrapped (n=2000) intercept values for each anthropogenic disturbance category. The mean dissimilarity and 95% CIs were compared across disturbance levels for both of these sensitivity analyses.

dbRDA model preparation

Pearson correlation coefficients were checked for all continuous variables prior to running the distance-based redundancy analysis. Field measured temperature was highly correlated with mean July SST (r = 0.7), but was missing measures for two sites, so mean July SST was used instead. Freshwater influence was also highly correlated with each of the anthropogenic disturbance measures (r = 0.6 – 0.8) and with salinity (r = 0.7), and had a high variance inflation factor (VIF; > 4) in combination with other physical variables; therefore, freshwater influence was not included in the full physical models. However, salinity was included in the models as another metric of freshwater input, measured directly in the field, that was less strongly correlated with the anthropogenic measures (r = 0.4 – 0.6) and did not lead to high VIF. Full models were assembled separately for each variable component using additive terms for anthropogenic disturbance (watershed population, overwater structures, shoreline modification; only used for site comparisons across all disturbance categories), physical (mean July SST, mean annual SST, salinity, tidal current speed, habitat shoreline type, wave exposure), and biotic components (seagrass dry biomass, seagrass shoot density, epiphyte load, meadow form, meadow distribution, tidal range).

Figure S2. Diagram of workflow for statistical analyses, highlighting the conceptual process (boxes) and statistical test details (green text). Overall division and use of data is noted in headings (blue text), with sorting of data for some analyses by zoogeographic province (Oregonian, Aleutian) and region (9 regions sampled across British Columbia, with 7 in the Oregonian province). Most analyses compare sites across anthropogenic disturbance categories (low, medium, high), including non-metric multidimensional scaling (NMDS) and permutational analysis of variance (PERMANOVA), though distance-based redundancy analysis (dbRDA) across all sites and fourth-corner trait analysis used the gradient of disturbance scores. Analyses that required linked steps are connected by blue arrows.

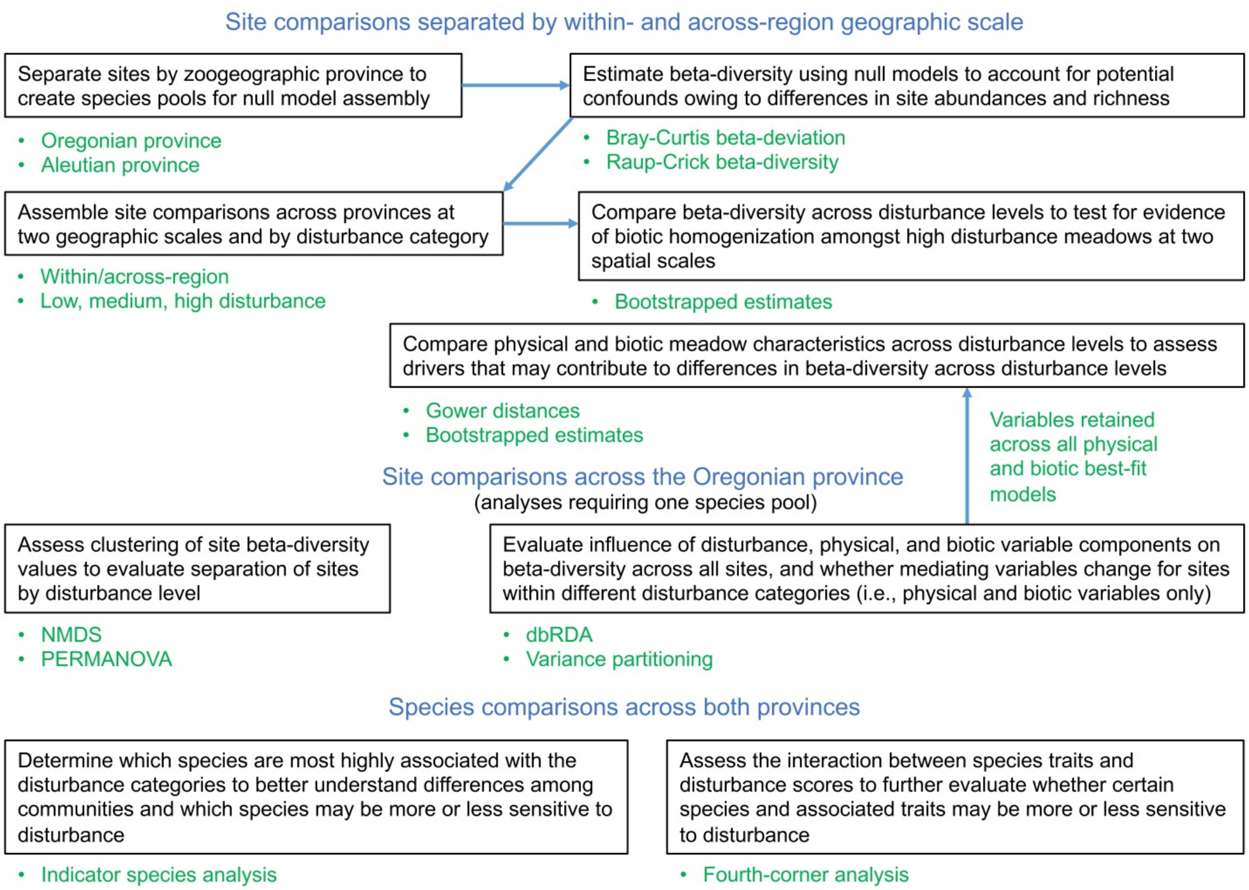

Table S1. Physical and biotic measures used to characterize field sites.

Category	Variable	Units	Source
Physical	Mean July sea surface temperature (SST)	°C	MARSPEC; Sbrocco & Barber, 2013
	Mean annual SST	°C	MARSPEC; Sbrocco & Barber, 2013
	In situ temperature	°C	Field
	In situ salinity	‰	Field
	Tidal current speed	Root mean square (m/s)	The British Columbia Marine Conservation Analysis, www.bcmca.ca
	Habitat shoreline type	Categories: beach, flat, estuary/lagoon, cliff, human-made	British Columbia Shorezone Mapping System, www.geobc.gov.bc.ca
	Wave exposure	Categories: semi-protected, protected	British Columbia Shorezone Mapping System, www.geobc.gov.bc.ca
	Freshwater influence	Area of nearest major freshwater input / shortest path overwater distance	Freshwater Atlas, www.geobc.gov.bc.ca
	Shortest overwater path distance	km	Analysis in R
Biotic	Seagrass dry biomass (ave.)	g/quadrat	Lab
	Seagrass shoot density (ave.)	#/quadrat	Lab
	Epiphyte load (ave.)	Epiphyte dry biomass / leaf area index (g/m^2)	Lab
	Meadow form	Categories: fringing, flat	Field
	Meadow distribution	Categories: continuous, continuous with bare patches, patchy cover	Field
	Tidal range	Categories: subtidal, both subtidal & intertidal	Field

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