INTEGRATED REGIONAL WETLANDS MONITORING (IRWM) PILOT PROJECT

Quantifying Landscape-level Drivers of Tidal Marsh Restoration in the Northern San Francisco Estuary and Western Delta

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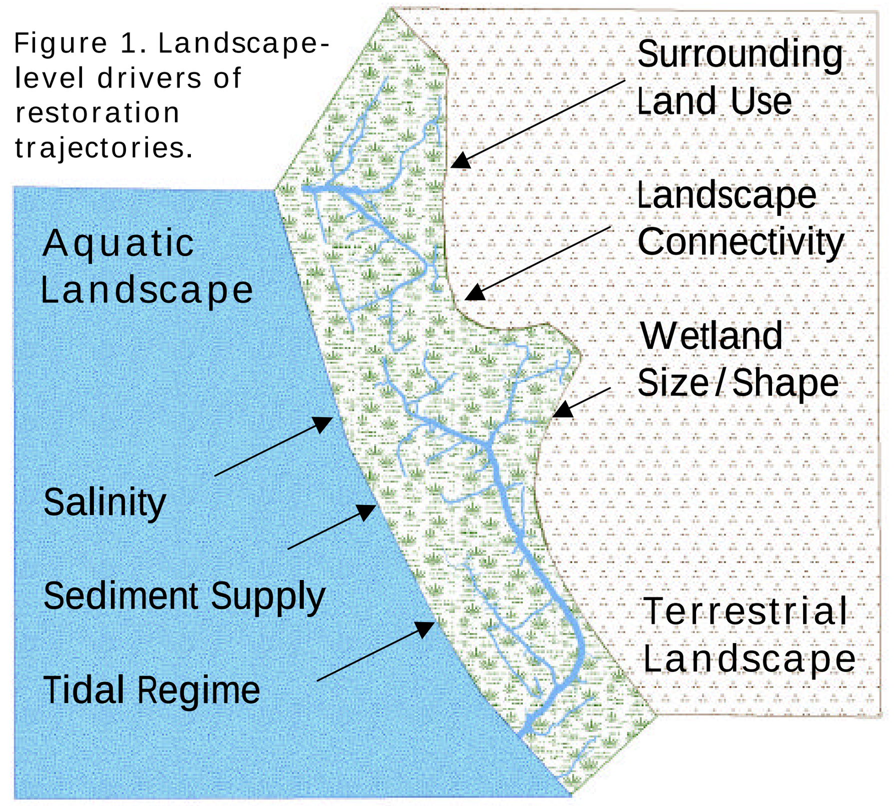
BACKGROUND

Indicators of tidal marsh restoration are generally measured at the scale of individual restoration sites. Marsh plain development and plant establishment, channel formation, and the presence or abundance of key wildlife species, are common ways of assessing restoration success. But factors controlling restoration trajectories, outcomes, and affected ecological processes may also operate at larger spatial scales, controlled by physical drivers, such as salinity, sediment supply, and tidal regime; as well as patterns of wetland configuration and surrounding upland land use characteristics (Figure 1). Thus it is important to examine the effects of restoring individual tidal marshes in a larger context, using a multi-scale synoptic approach that considers aquatic and terrestrial drivers of landscape change. Focusing first on the terrestrial landscape, we have developed a suite of site, patch, and landscape metrics that may be used to provide context and explanatory power for site-level restoration outcomes.

METHODS

1. Focusing on our six IRWM study sites (Figure 2), we generated and analyzed spatial metrics at three different scales: site, patch, and landscape (Figure 3, Table 1).
2. For each site, we generated spatial and non-spatial metrics based on field-collected data (salinity and elevation) and CIR aerial photography (geomorphology and vegetation).
3. For the entire North Bay from San Pablo Bay to the western Delta, three levels of wetland "patches" were defined using criteria modified from the San Francisco Bay EMAP project (Collins et al. 2004) (Figure 4). Corresponding GIS layers were generated from EcoAtlas modern bayland polygons (SFEI 1998).
4. For each patch at each level, a suite of patch metrics pertaining to patch size, shape, and edge characteristics was calculated using the Patch Analyst extension for ArcView 3.2 (Elkie et al. 1999).

Figure 1. Landscape-level drivers of restoration trajectories.



5. Across the entire North Bay, we used Fragstats 3.3 (McGarigal et al. 2002) to calculate landscape spatial metrics at various scales, with moving circular windows of radius 500 m, 1 km, 2km, and 5 km (examples shown in Figures 5-7). 30-m land use grid layers were derived from multiple sources: NOAA, DWR, SFEI, and USGS.
6. IRWM study sites were characterized according to site-, patch-, and landscape-scale metrics and compared to other wetlands in the North Bay (Figure 8). Preliminary relationships between site and patch metrics were examined with correlation analysis (Figure 9).

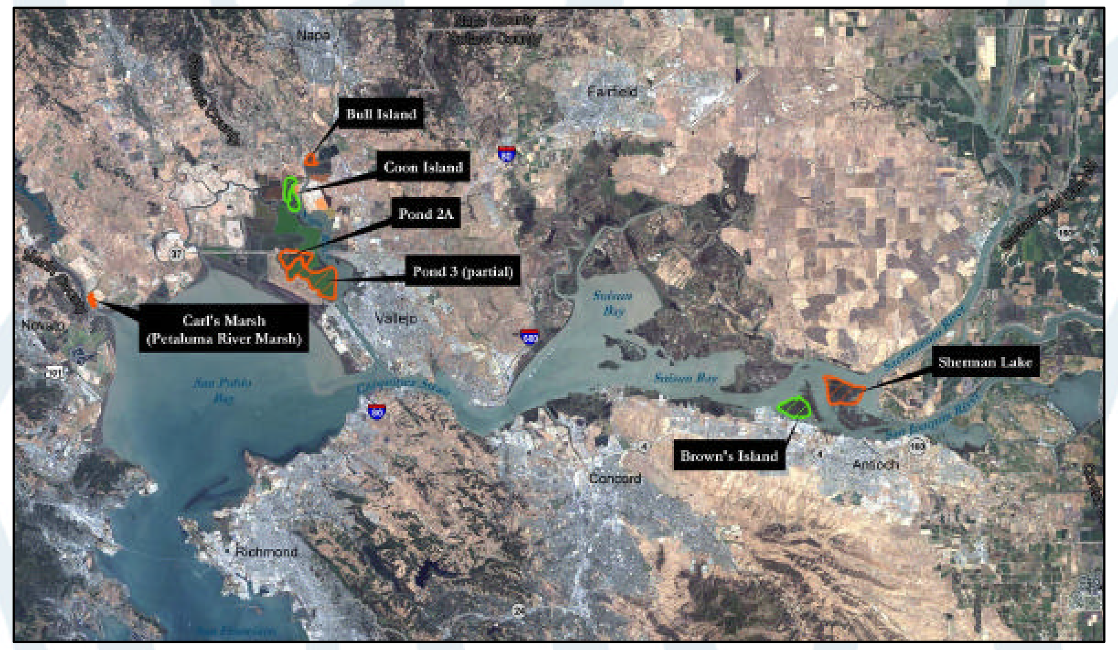


Figure 2. IRWM study sites

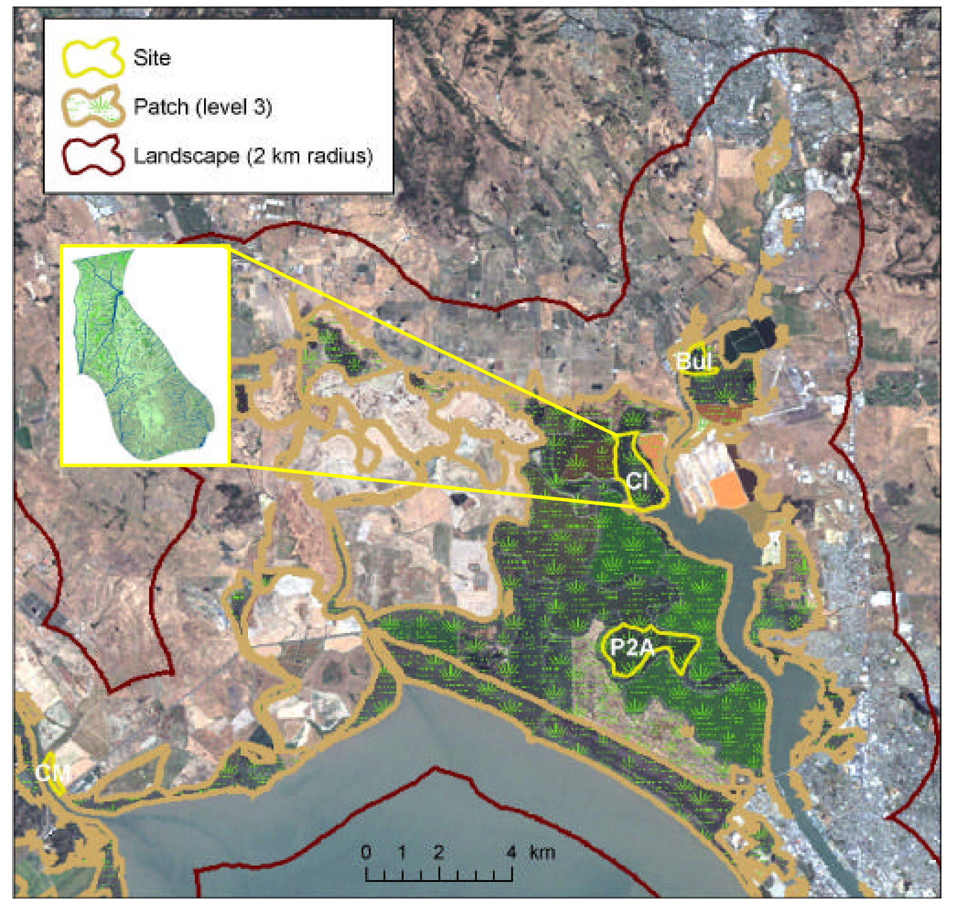


Figure 3. Site, patch, and landscape scales demonstrated for San Pablo Bay study sites.

Site-level Spatial Metrics (computed for IRWM study sites)	Potential Influence on Ecological Processes: Physical Processes, Primary Production, Plants	Invertebrates, Fish, Birds
Geomorphology Elevation range and topography Channel density (areal & linear) Channel sinuosity Pond/panne density	material exchange, salinity, tidal inundation, sedimentation	habitat quality, prey availability
Vegetation heterogeneity		
Percent cover of dominants Vegetation patch diversity and evenness Vegetation patch size diversity	sedimentation, salinity, transgression, plant establishment, succession	habitat quality, prey availability, predator avoidance
Patch-level Spatial Metrics (computed for 3 levels of wetland patches)	**Physical Processes, Primary Production, Plants**	**Invertebrates, Fish, Birds**
Wetland patch size	topographic and vegetation heterogeneity, channelization patterns	population persistence
Wetland patch shape		
Core area Perimeter/area ratio Shape index, fractal dimension	succession, material exchange (nutrients, sediments, contaminants), invasive species	predator/prey dynamics, habitat quality (human disturbance, invasive species)
Wetland patch edge characteristics Upland edge Mudflat/water edge	"	"
Landscape-Scale Spatial Metrics (computed for north bay region with moving windows of radius 500 m, 1 km, 2 km, 5km)	**Physical Processes, Primary Production, Plants**	**Invertebrates, Fish, Birds**
Landscape context (inverse-distance weighted)		
Marsh proportion Mudflat proportion Urban proportion Agriculture proportion	material exchange, nutrient supply (urban/agricultural run-off), invasive species	predator/prey dynamics, dispersal, habitat quality (human disturbance, invasive species)
Upland edge characteristics Total wetland/upland edge Wetland/upland edge density	"	"
Landscape connectivity and wetland patch configuration		
Number of patches Patch size mean, coeff. of variation Connectivity, contagion, proximity Patch interspersion, aggregation	plant species diversity, plant establishment, channelization patterns	metapopulation dynamics (dispersal, colonization, genetic exchange), predator/prey dynamics
Landscape heterogeneity Wetland patch diversity and evenness Wetland patch size diversity	"	Metapopulation dynamics, species accumulation

Table 1. Site, patch, and landscape metrics considered.

For more information visit: www.irwm.org

Site Metrics

	Carl's Marsh CM	Pond 2A P2A	Coon Island CI	Bull Island Bul	Brown's Island BrI	Sherman Lake SL
Type	Restoration	Restoration	Reference	Restoration	Reference	Restoration
Areal Channel Density	0.078	0.147	0.048	0.083	0.061	0.085
Linear Channel Density (km / km2)	25.9	18.2	19.7	20.6	9.8	13.2
Ratio of Linear to Areal Channel Density (km / km2)	330	124	408	247	161	156
Channel Sinuosity	0.07	0.20	0.17	0.14	0.10	0.11
Pond/Panne Density	N/A	0.0013	N/A	N/A	0.0280	0.0056
Salinity Range (PSU)	1.9 - 28.6	1.7 - 21.3	2.7 - 22.5	0.2 - 19.6	0 - 7.3	0 - 0.2
Mean Salinity (PSU)	17.1	14.1	14.5	11.8	1.4	0.1
Mean Marsh Plain Elevation (m NAVD)	1.53	1.75	1.89	1.98	1.74	1.49
Mean Marsh Plain Elevation (m MHHW)	-0.43	-0.09	0.05	0.14	-0.09	-0.34
Dominant Vegetation	*Salicornia europea/ Scirpus maritimus*	*Scirpus maritimus*	*Salicornia virginica/ Scirpus maritimus*	*Scirpus maritimus*	*Scirpus americanus*	*Scirpus acutus*
Shannon's Diversity Index	1.70	1.70	1.35	1.86		
Shannon's Evenness Index	0.87	0.68	0.61	0.78		

Table 2. Preliminary site metrics for IRWM study sites. IRWM study sites varied considerably in their elevation, salinity, geomorphology, and vegetation characteristics. For all metrics examined, variation among sites was greater than variation between restoration and reference sites.

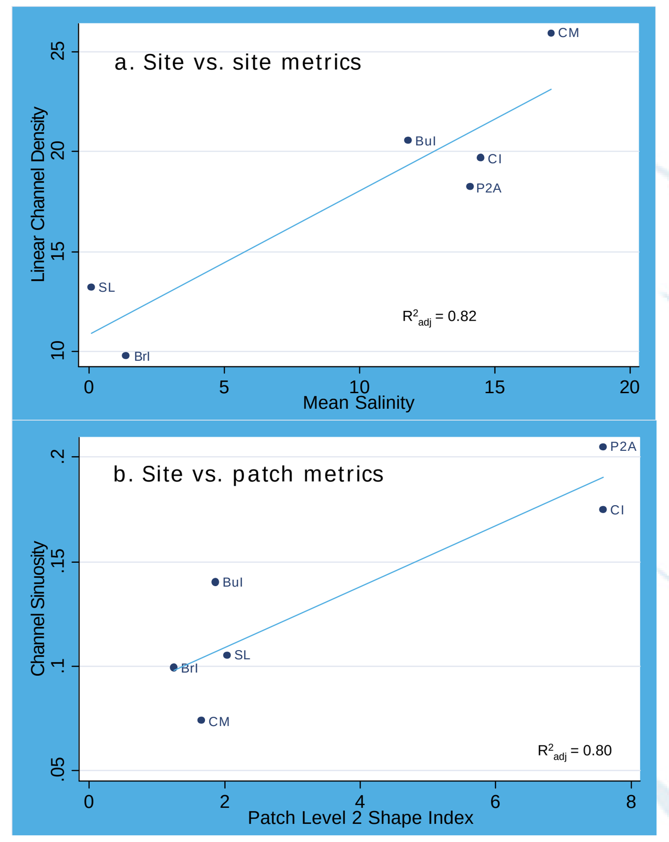


Figure 9. Correlations among site and patch metrics. Correlation analysis revealed some associations between site and patch metrics. Linear channel density increased with mean site salinity (a). Channel sinuosity increased with patch shape index (an index of shape complexity) (b). Due to our small sample size, results should be interpreted with caution.

Patch Metrics

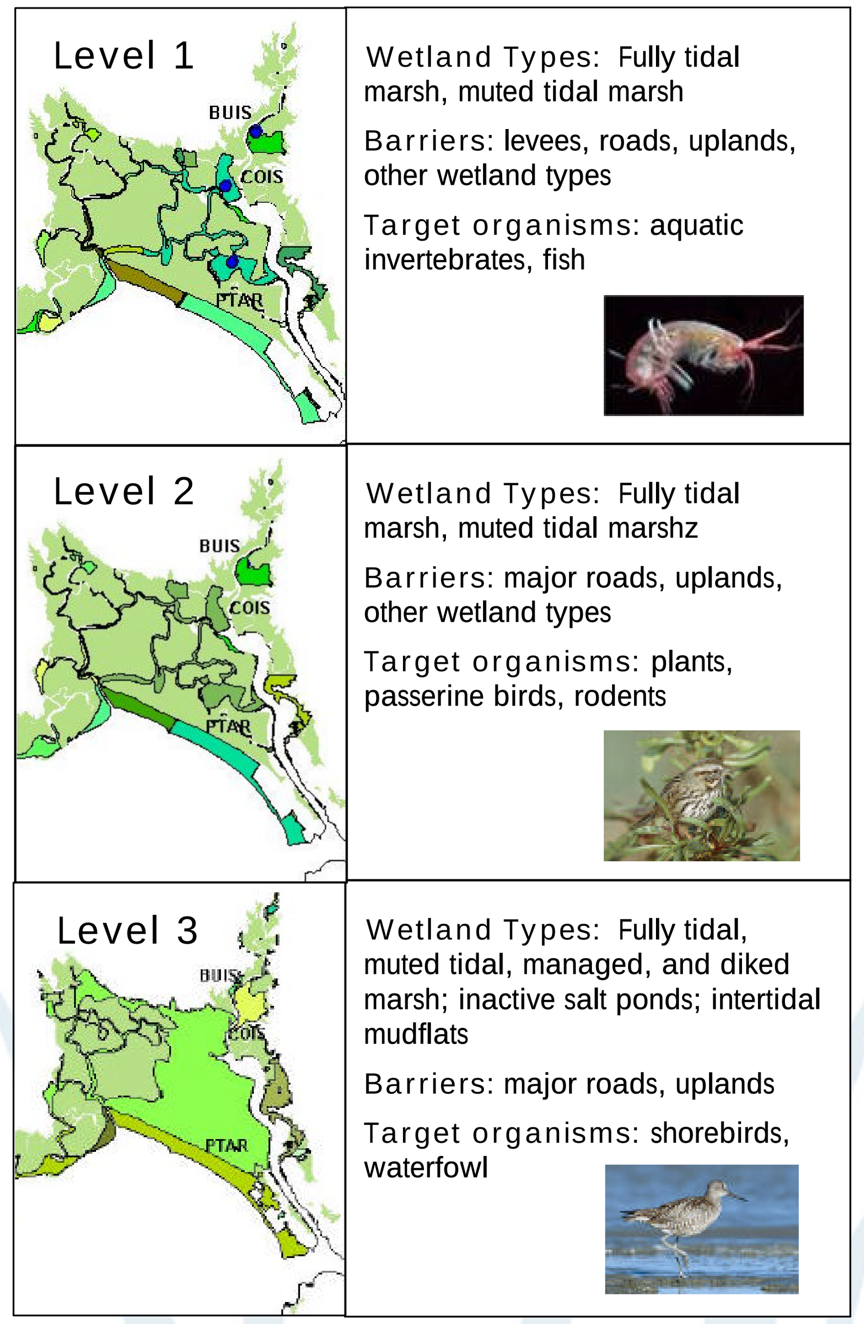


Figure 4. Patch level definitions and target organisms.

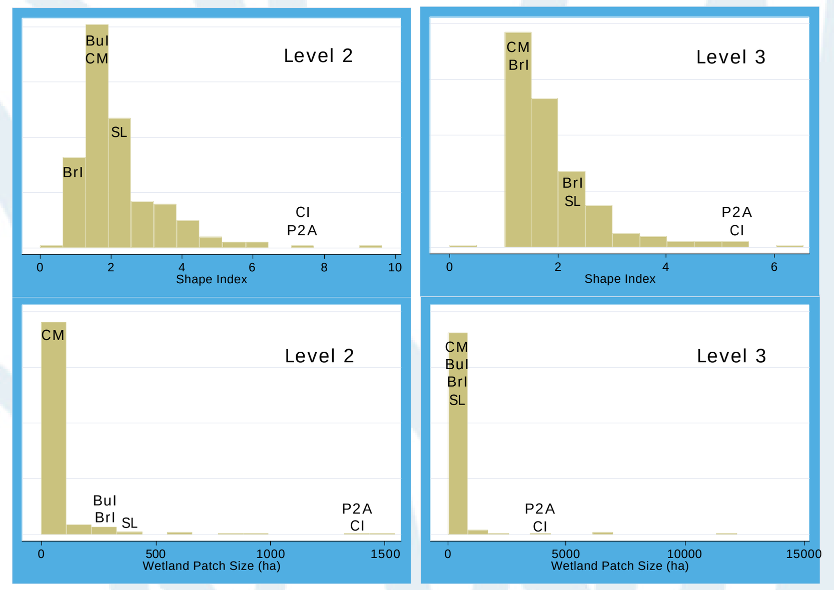


Figure 8. IRWM patch characteristics in a regional context. Frequency distributions of level 2 and level 3 patches for shape index and size metrics (IRWM sites indicated).

Landscape Metrics

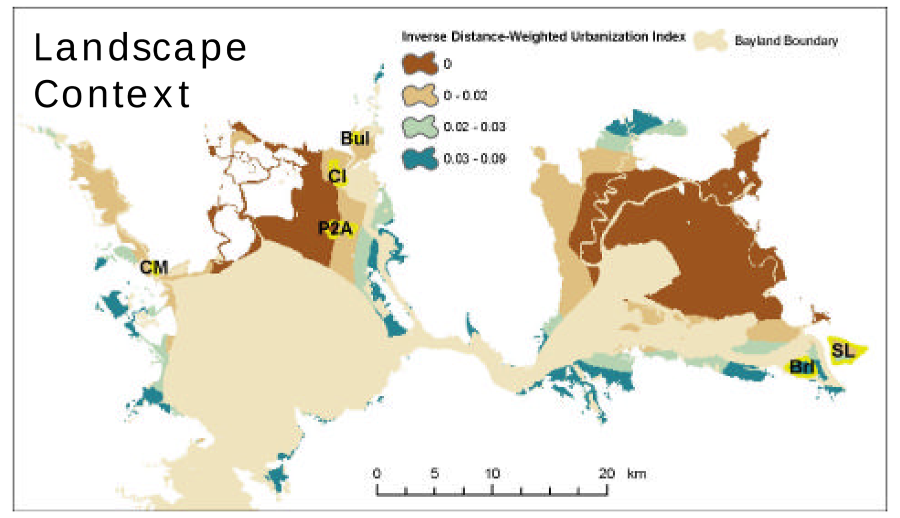


Figure 5. Inverse distance weighted urbanization index. The sum of all urban pixels within a 5-km radius, each pixel negatively weighted by its distance. May affect material exchange, nutrient inputs, invasive species spread, and abundance of human-enhanced predators.

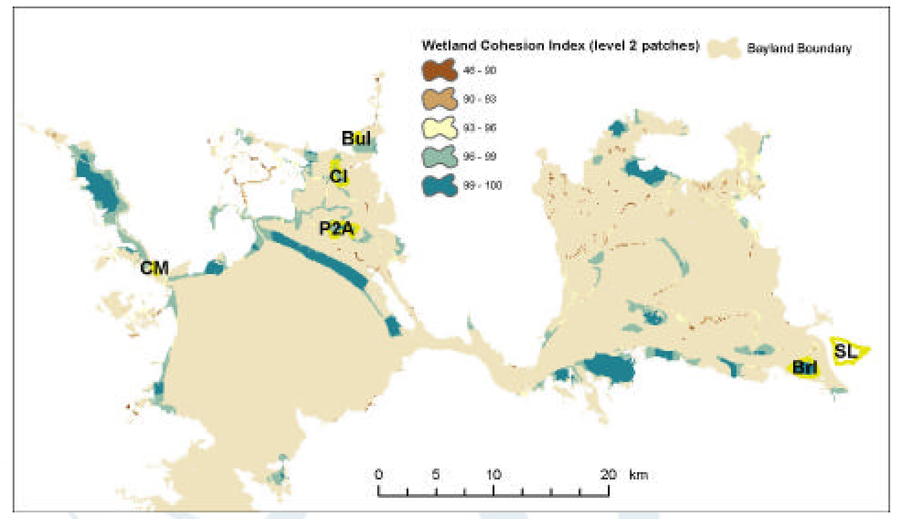


Figure 6. Wetland cohesion index. Increases as wetlands become more aggregated in their distribution, or more physically connected (McGarigal et al. 2002). May affect plant species diversity, channelization patterns, and animal metapopulation dynamics.

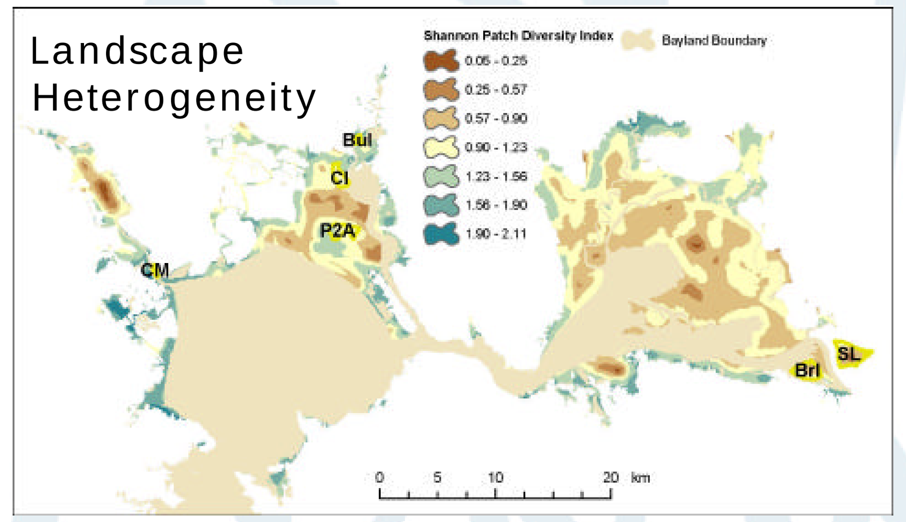


Figure 7. Shannon-Wiener patch diversity index. The negative of the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion. May affect animal metapopulation dynamics and species accumulation.