Environmental factors that influence benthic macroinvertebrate prey resources for waterbirds in managed ponds

Alison M. Flanagan[1], Susan E. W. De La Cruz[1], Laurie A. Hall[1]
[1]U.S. Geological Survey, Western Ecological Research Center,
San Francisco Bay Estuary Field Station, 505 Azuar Drive, Vallejo, California 94592

Project Summary

Which environmental factors govern macroinvertebrate prey composition in managed ponds?

To answer this question, we used multivariate analyses to evaluate the extent to which a suite of water quality, sediment chemistry, and sediment grain size variables influence macroinvertebrate community composition in managed ponds at Eden Landing Ecological Reserve in South San Francisco Bay, CA. An emphasis was placed on factors that can be managed through water manipulation (e.g., water depth and salinity). Several environmental factors influenced macroinvertebrate community composition in this study (e.g., pH, salinity, nitrate, sulfur, percent silt, etc.), with salinity and pH explaining the largest proportion of the community variation (~30%). With widespread, ongoing restoration efforts throughout the Bay, identifying the most important environmental drivers of macroinvertebrate composition in this region is timely.

Methods

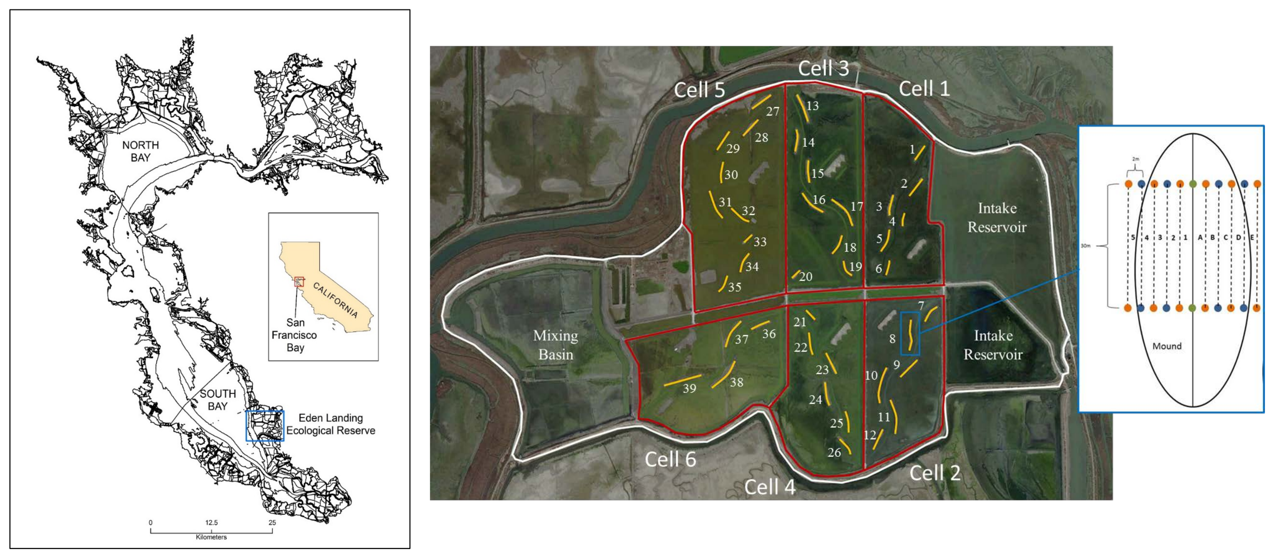

Figure 1. Eden Landing Ecological Reserve in South San Francisco Bay; cells with low, moderate, and high salinity treatments (red), foraging mounds (yellow; numbered 1 through 39), and zones (blue) of ponds E12 (top cells) and E13 (bottom cells). Locations of the intake reservoir and mixing basin are outlined in white. The schematic illustrates the 20 x 30 m mound survey plots and labeled 2 m zones.

MACROINVERTEBRATE DATA COLLECTION: Benthic samples (2.7 cm dia. x 10 cm deep cores) were collected and rinsed through a 0.5 mm sieve. Organisms were preserved in a 70% ethanol, Rose Bengal dye solution, identified to the lowest possible taxonomic level, and enumerated by IEL.

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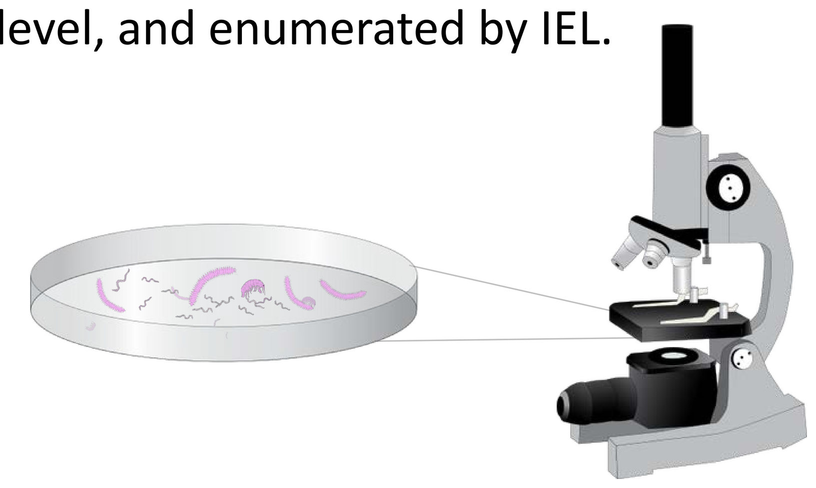

ENVIRONMENTAL DATA COLLECTION: Environmental factors used in our analyses included a suite of water quality, sediment chemistry, and sediment grain size variables measured at the study location using a combination of sensors (e.g., for water quality) and in situ sampling (e.g., for sediment characteristics; **Table 1**).

Multivariate Community Analyses

To examine which environmental factors had the greatest influence on community composition, we used a combination of multivariate regression tree (MRT) and redundancy analysis (RDA). Macroinvertebrate data were converted to presence-absence of broad taxonomic groups due to zero inflation (no fauna in cores). Models were run using data from October 2015 to May 2016 when the salinity gradient was well-established after draining the ponds for construction (**Fig 2**).

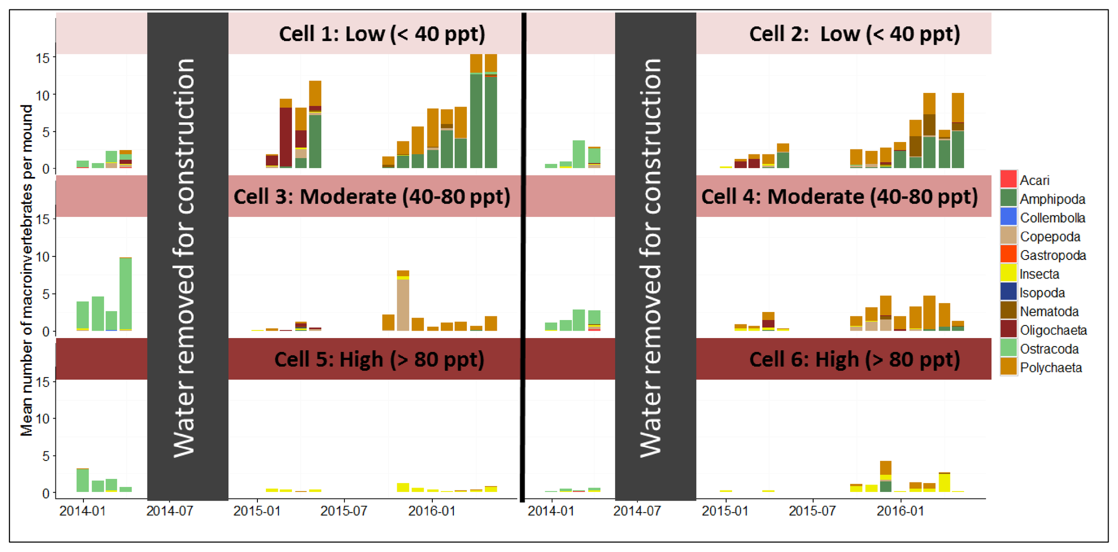

Figure 2. Mean number of macroinvertebrates per mound per month for the full study duration.

Results

The Water Quality RDA & MRT explained most of the community composition (**Table 1; Fig 3**). A larger number of broad taxa occurred at salinities ≤ 44.11 ppt. Most taxa found at high salinities (≥ 57.75 ppt) were insects (**Figs 2-5**).

Model		Variables used in the analysis	Number of variables (RDA) or number of splits (MRT)	Variables Selected (in order)	r^2
Water Quality	RDA	Temperature, Salinity, Dissolved oxygen (DO), water column pH, & proportion of foraging mound exposed (a proxy for prey accessibility)	4	pH, Salinity, Temp, DO	27.40
	MRT		3	{8.915 > pH ≥ 8.915} {44.11 > Salinity ≥ 44.11} {10.77 > DO ≥ 10.77}	30.00
Sediment Chemistry	RDA	Estimated nitrogen release (ENR), Organic matter (OM), Phosphorous (P1), Bicarbonate phosphorous (HCO3P), Potassium (K), Magnesium (MG), Calcium (CA), Sodium (NA), Nitrate (NO3N), Sulfur (S), Sedimentary pH (PH), Ammonium (NH4), Cation exchange capacity (CEC)	4	NO3N, S, K, HCO3P	13.90
	MRT		5	{2.25 > NO3N ≥ 2.25} {101.5 > CEC ≥ 101.5} {2434 > MG ≥ 2434} {11.25 > HCO3P ≥ 11.25} {4.05 > NO3N ≥ 4.05}	29.79
Sediment Grain Size	RDA	Grain size (% Sand, % Silt, % Clay)	2	% Clay, % Sand	3.90
	MRT		5	{17.6 > % Silt ≥ 17.6} {34.55 > % Clay ≥ 34.55} {44.2 > % Sand ≥ 44.2} {60.2 > % Silt ≥ 60.2} {36.2 > % Silt ≥ 36.2}	18.61

Table 1. Summary of explanatory variables used in the analyses and of MRT & RDA model results.

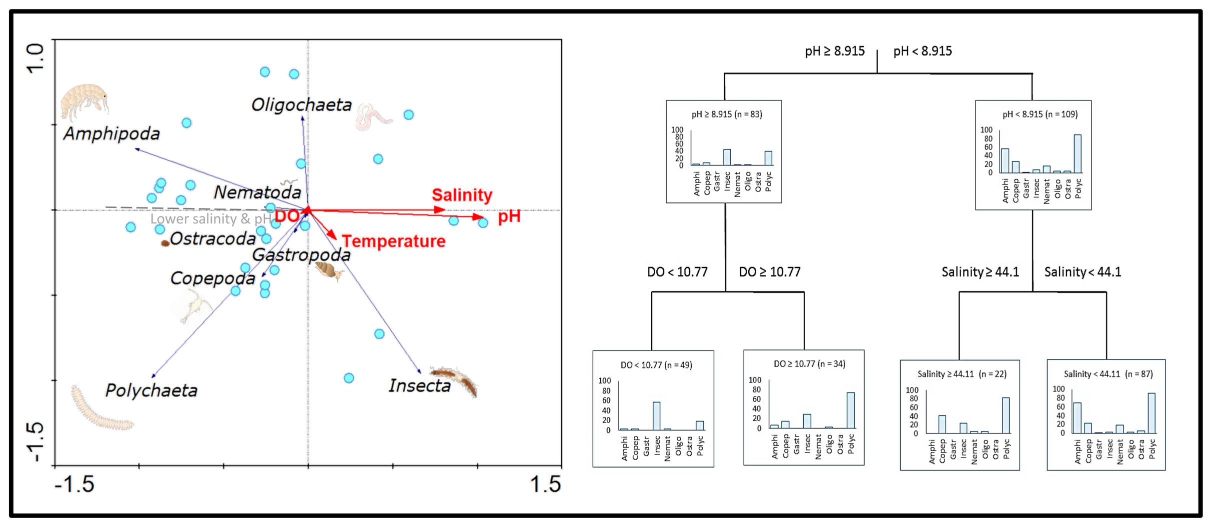

Figure 3. Water quality RDA triplot (left) and corresponding MRT (right). Biotic-environmental relationships are indicated by acute angles in the RDA triplot; insects are associated with high pH and high salinities whereas a larger number of taxa are associated with lower pH and lower salinities. This pattern is also detected by MRT.

Discussion

Overall, salinity was the most important "manageable" environmental variable for explaining differences in macroinvertebrate community composition; a larger number of taxa occurred at salinities ≤ 57.75 ppt (**Figs 2-5**).

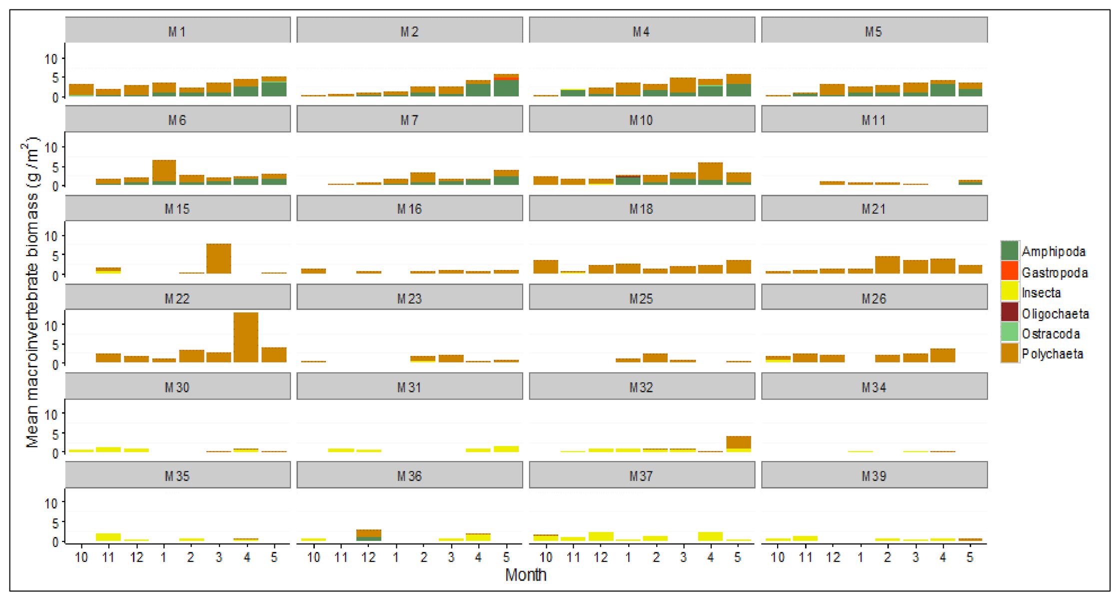

Figure 4. Mean abundance of macroinvertebrates per mound per month from October 2015 to May 2016 (n = 574 cores). Foraging mounds M1 to M11 were located in low salinity cells, mounds M15 to M26 were located in moderate salinity cells, and mounds M30 to M39 were located in high salinity cells.

The importance of nitrate (NO3N) in the Sediment Chemistry models probably reflects the fact that nitrogen is an essential limiting factor for primary production, which is oftentimes used as a proxy for food supply to benthic fauna.

Although sediment characteristics are generally known to influence macroinvertebrate distributions, no clear relationship was detected between percent sand, silt, and clay and community composition in this study; this is consistent with other animal-sediment relationship studies in soft sediment environments (Flanagan and Cerrato 2015).

Management Implications

Since salinity is one "manageable" environmental factor, efforts to influence community composition may benefit from modifying pond salinity.

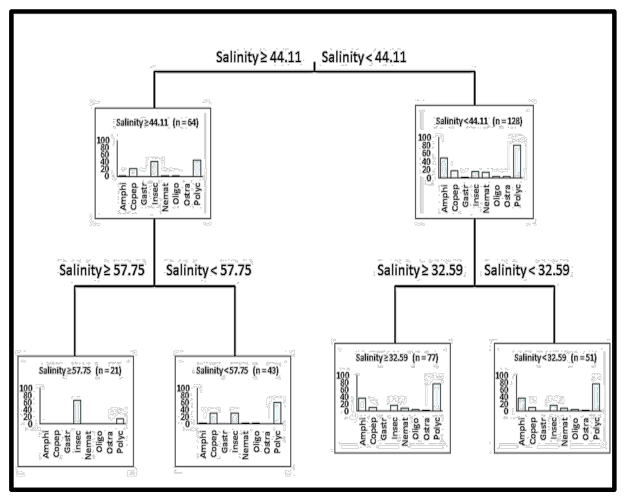

Figure 5. Salinity only MRT.

Salinity could be maintained at or below 44.11 ppt, which is near the maximum allowable discharge value to maximize taxonomic richness (**Fig 5**), but, for some waterbird species, such as small shorebirds and eared grebes, taxa found in high salinity ponds (i.e., predominantly insects) may provide important foraging resources not found elsewhere.

Contact

Alison Flanagan, Ph.D.
Invertebrate Ecology Laboratory (IEL)
USGS Western Ecological Research Center
Email: aflanagan@usgs.gov
Phone: 631-790-8393

Acknowledgments & References

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