

RMP Special Study Proposal: Synthesis of Benthic Community Data in the Whole of San Francisco Bay using the M-AMBI Index Phase II

Summary: Evaluation of macrobenthic community condition is an integral component of sediment quality assessment, and is a required element of the SQO assessment framework. We do not, at present, have robust and validated tools to interpret macrobenthic community health in the mesohaline, oligohaline, and tidal fresh water habitats of San Francisco Bay Estuary (i.e., 50% of the whole system). Consequently, SQO assessments showing 52% of San Francisco Bay with poor benthic condition may be inaccurate and misrepresenting the apparent extent of contaminant-impacted sediments. We propose to update the SQO assessments of San Francisco Bay by incorporating a newly revised version of the M-AMBI (Multivariate AZTI Marine Biotic Index) benthic index designed to work in multiple estuarine habitats across the United States, including the polyhaline, mesohaline, and oligohaline habitats in the San Francisco Bay Estuary. As part of the Phase I portion of this study (currently funded), we are calibrating the M-AMBI across the estuary's different habitats. Once this work is completed, we will be able to integrate the M-AMBI scores into the SQO assessment framework and recalculate SQO assessments (M-AMBI plus existing chemistry and toxicity tools) for the whole estuary. This will allow for the first time, a robust SQO assessment of the potential impacts of toxic, sediment-bound chemicals on the macrobenthic resources of the San Francisco Bay Estuary.

Estimated Cost: \$29,000

Proposed by: David Gillett, Ashley Parks, and Steve Bay – Southern California Coastal Water Research Project

Proposed Deliverables and Timeline

Deliverable	Due Date
Annotated copies of the R-scripts used to calculate the M-AMBI scores so that others can apply the tool	Month 12
Final report summarizing all of our findings, including Phase I M-AMBI calibration and full SQO assessments of 2008-2012 RMP samples	Month 12

Background

Benthic infauna are the most common faunal assemblage used to assess habitat quality across the globe due to their sessile lifestyle, taxonomic diversity, and that they integrate stressor exposure over time (e.g., Dauer 1993; Warwick 1988; Gray et al. 2002). These characteristics combine to make for relatively predictable community-scale changes in both structure and

function when exposed to disturbance (e.g., Rhoads et al. 1978; Pearson and Rosenberg 1978; Gillett 2010). Within the state of California, macrobenthic fauna are similarly used in a variety of monitoring programs that have been incorporated into a variety of regional and statewide environmental management policies. One such example is the State's Sediment Quality Objectives program.

California's sediment quality objectives (SQO) are used to assess the impacts of toxic, sediment-bound chemicals to the biological resources of the State's enclosed bays and estuaries (SWRCB 2009). The SQO framework uses a multiple lines of evidence approach built upon measures of sediment chemistry, sediment toxicity, and macrobenthic community composition (Bay et al. 2014). Evaluating impacts on macrobenthic community structure is a complex prospect, as perturbations are manifest through changes in abundance and, eventually, changes in the taxa that make up the community. For ease of communication and repeatability, the summarization and communication of those changes are typically done with a benthic assessment index that can distill complex ecological information into a single value easily understood by environmental managers, but grounded in sound ecological theory.

The San Francisco Bay Estuary is the largest embayment in California and it is an ecologically complex system that spans the full range of the estuarine salinity gradient from the tidal freshwater of the San Joaquin Delta to the polyhaline waters in the central bay. These natural gradients make consistent evaluation of macrobenthic fauna potentially problematic, as community composition naturally changes along the estuarine gradient of salinity too (e.g., Ranasinghe et al. 2012; Thompson et al. 2013). As a consequence, there is a lack of robustly calibrated and validated benthic indices for the mesohaline, oligohaline, and tidal freshwater parts of San Francisco Bay Estuary. The goal of this project is to improve our understanding of macrobenthic community condition in San Francisco Bay Estuary by applying a recently revised benthic index that is less sensitive to natural habitat gradients to existing RMP monitoring data.

Estuarine habitat gradients are not unique to the San Francisco Bay Estuary. In Europe, the European Water Framework Directive (EU WFD) has adopted a benthic assessment approach using the Multivariate AZTI Marine Biotic Index (M-AMBI) (Muxika et al. 2007) an index designed for consistent evaluation of benthic communities as they change across natural gradients. The M-AMBI is a weighted tolerance type of index that uses habitat-specific expectations of community metrics (diversity, richness, etc) and the relative abundance of pollution tolerant and sensitive taxa in a sample to evaluate the condition of the location from where it was collected. Because of the way it was constructed, the M-AMBI does not require a large calibration/validation data set and can therefore be applied in novel systems with relative ease.

However, when the M-AMBI has been applied in systems outside of the European continent where it was originally developed, its performance has produced mixed results at best (e.g., Borja et al. 2008; Borja and Tunberg 2011; Tiexiera et al. 2012). To solve some of these problems both the AMBI (a univariate version of the M-AMBI) and the M-AMBI have been recalibrated for application in coastal and estuarine waters of the continental United States using data from the US EPA National Coastal Assessment (NCA) surveys (including data and taxonomic experts from the San Francisco Bay area) (Gillett et al. 2015; Pelletier et al., 2018).

This new, revised version of the M-AMBI is going to be the single, generalized benthic index for application across all coastal and estuarine waters of the United States. Existing locale-specific benthic indices will continue to be used – and new ones likely developed – but we now have a tool that can confidently be applied in all estuaries across the country. The M-AMBI will be used in the benthic assessment component of the 2015 US EPA NCA survey and as the standard benthic index for NCA surveys in the future. Using this tool to assess benthic community samples collected by RMP surveys will allow for easier integration into the national program and for direct, meaningful comparisons of ecosystem health in the San Francisco Bay Estuary to other

regions of the country.

Previous calibration of the M-AMBI for West Coast applications was conducted on a broad regional scale for use as a stand-alone assessment tool. As part of ongoing work funded by the RMP, we are presently working to further calibrate the M-AMBI to San Francisco Bay and confirm its applicability in the different salinity zones of the estuary. An important piece of this work is to adjust M-AMBI condition thresholds (i.e., reference, low disturbance, etc.) to conform with those used in the benthic SQO framework.

For this second phase of this process, we propose to apply the newly revised M-AMBI (Pelletier et al. 2018) to assess macrobenthic samples in the polyhaline, mesohaline, and oligohaline regions of San Francisco Bay Estuary to evaluate macrobenthic response to pollution. These results will then be incorporated into the SQO assessment framework, allowing a more complete assessment of California’s largest estuary, and setting a template for assessments going forward. The products from this study will provide the RMP and associated stakeholders with a better understanding of the health of the San Francisco Bay Estuary’s macrobenthic communities, and also an evaluation of the suitability of the M-AMBI for use in the SQO assessment framework. These results can be used to infer the impacts of pollution on the estuary, how it has changed since 2008, and how it may change in the future. Furthermore, we will be able to provide interested parties a tool to do their own assessments of data collected in future benthic surveys.

Study Objectives and Applicable RMP Management Questions

The study will provide information essential to understanding the impact of pollution on the macrobenthic fauna of San Francisco Bay Estuary. The specific objectives of this study will be to:

1. Integrate M-AMBI scores with the SQO chemistry and toxicity lines of evidence
2. Calculate M-AMBI scores for RMP data from 2008-2012 and describe spatial and temporal trends in the assessment results
3. Compare M-AMBI performance in San Francisco Bay to that of existing SQO benthic indices and provide recommendations for future application in RMP

Table 1 illustrates how the objectives of this project relate to the RMP’s high-level management questions.

Table 1. Study objectives and questions relevant to RMP management questions.

RMP Management Question	Proposal Study Objective	Example Information Application
1) Are chemical concentrations in the Estuary at levels of potential concern and are associated impacts likely?	1. Integrate M-AMBI scores with the SQO chemistry and toxicity lines of evidence 2. Calculate M-AMBI scores and SQO assessment categories for RMP benthic samples 3. Evaluate M-AMBI performance and develop recommendations for future application.	Assess benthic community condition and association with chemistry and toxicity in San Francisco Bay Estuary
4) Have the concentrations, masses, and associated impacts of contaminants in the	2. Calculate M-AMBI scores and SQO assessment categories for RMP benthic	Compare time series of macrobenthic community status to sediment

Estuary increased or decreased? 4.1. What are the effects of management actions on concentrations and mass?	samples	contamination in different regions of San Francisco Bay Estuary
--	---------	---

Approach

In brief, our approach will be to leverage our ongoing work by applying the M-AMBI in SQO assessments of the multiple habitats of the San Francisco Bay Estuary. We will integrate the M-AMBI benthic assessment scores with thresholds designed to complement existing SQO framework – potentially in combination with other existing benthic indices (see Ranasinghe et al. 2009) – with the sediment toxicity and sediment chemistry SQO lines of evidence to produce updated SQO assessment scores for 2008-12 RMP samples.

In detail, the two tasks in the proposed work will be:

Task 1 – Synthesis of benthic community data and revision of SQO assessment trends (\$15,000)

The calibrated M-AMBI will be used to evaluate benthic samples from RMP surveys conducted from 2008 – 2012. All of these samples have been utilized for SQO assessment previously (e.g., Bay et al. 2013), and the previous chemistry and toxicity lines of evidence results will be combined with the M-AMBI results to conduct a revised and more complete assessment.

The assessment results will be analyzed to describe changes in the magnitude and extent of sediment quality impacts over time for different habitats of the estuary. Changes in assessment results related to the use of the M-AMBI will also be described.

Deliverable 1 – Annotated R scripts used to calculate the M-AMBI scores so that others can apply the tool.

Task 2 – Final Report and Presentation of Results (\$14,000)

A final report will be created to synthesize the findings from Phase I and provide our recommendations on the incorporation of the revised M-AMBI for benthic community assessments associated with the SQO program and other assessment studies in the San Francisco Bay Estuary. We will also prepare an oral presentation to SFEI staff, Regional Water Quality Control Board staff, and RMP technical advisory board members as desired. Additionally, we will provide copies of R-scripts to calculate the M-AMBI so that the index can be applied by others in the region.

Deliverable 2 - A final report summarizing our findings from Phase I and task 1 of the presently proposed work.

Budget

Table 2. Proposed Budget.

Expense	Estimated Hours	Estimated Cost
Labor		
Project Staff	200	\$25,900
Senior Management Review	8	\$1,700
Direct Costs		
Equipment		
Travel		\$1,400
Printing		
Shipping		
Other		
Grand Total		\$29,000

Budget Justification

Project Staff Labor – will cover the cost of D. Gillett (Senior Scientist) and A. Parks (Scientist) time to aggregate data, conduct the various analyses, write the final report, and compose R-scripts.

Senior Management Review Labor – will cover the cost S. Bay (Principal Investigator) to review the analyses, as well as technical memos and final report produced by Gillett and Parks

Travel Direct Costs – Estimated costs for travel of Gillett, Bay, and Parks between Costa Mesa and San Francisco on at least one occasion to present interim and final results to the RMP advisory boards, SFEI staff, Regional Board staff, and other appropriate/interested parties.

References

- Alden, R.W., Dauer, D.M., Ranasinghe, J.A., Scott, L.C., Llansó, R.J., 2002. Statistical verification of the Chesapeake Bay benthic index of biotic integrity. *Environmetrics* 13, 473–498. doi:10.1002/env.548
- Bay, S.M., D.J. Greenstein, S.L. Moore, K. J. Ritter, and J.A. Ranasinghe. 2013. Evaluation of sediment condition using California’s sediment quality objectives assessment framework. Technical Report 764. Southern California Coastal Water Research Project. Costa Mesa, CA.
- Bay, S.M., Greenstein, D.J., Ranasinghe, J.A., Diehl, D.W., Fetscher, A.E., 2014. Sediment Quality Assessment Technical Support Manual. South. Calif. Coast. Water Res. Proj. 142.
- Borja, A., Dauer, D.M., Díaz, R., Llansó, R.J., Muxika, I., Rodríguez, J.G., Schaffner, L., 2008. Assessing estuarine benthic quality conditions in Chesapeake Bay: A comparison of three

indices. *Ecol. Indic.* 8, 395–403. doi:10.1016/j.ecolind.2007.05.003

- Borja, A., Franco, J., Pérez, V., 2000. A marine Biotic Index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Mar. Pollut. Bull.* 40, 1100–1114. doi:10.1016/S0025-326X(00)00061-8
- Borja, A., Tunberg, B.G., 2011. Assessing benthic health in stressed subtropical estuaries, eastern Florida, USA using AMBI and M-AMBI. *Ecol. Indic.* 11, 295–303. doi:10.1016/j.ecolind.2010.05.007
- Dauer, D. M. 1993. Biological criteria, environmental health, and estuarine macrobenthic community structure. *Marine Pollution Bulletin*, **26**:249-257.
- Gillett, D.J. 2010. Effects of Habitat Quality on Secondary Production in Shallow Estuarine Waters and the Consequences for the Benthic-Pelagic Food Web. Ph.D. Dissertation, The College of William and Mary.
- Gillett, D.J., Weisberg, S.B., Grayson, T., Hamilton, A., Hansen, V., Leppo, E.W., Pelletier, M.C., Borja, A., Cadien, D., Dauer, D., Diaz, R., Dutch, M., Hyland, J.L., Kellogg, M., Larsen, P.F., Levinton, J.S., Llansó, R., Lovell, L.L., Montagna, P.A., Pasko, D., Phillips, C.A., Rakocinski, C., Ranasinghe, J.A., Sanger, D.M., Teixeira, H., Van Dolah, R.F., Velarde, R.G., Welch, K.I., 2015. Effect of ecological group classification schemes on performance of the AMBI benthic index in US coastal waters. *Ecol. Indic.* 50, 99–107. doi:10.1016/j.ecolind.2014.11.005
- Gray, J. S., R. S. Wu, and Y. Y. Or. 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. *Marine Ecology Progress Series*, **238**:249-279.
- Muxika, I., Borja, A., Bald, J., 2007. Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. *Mar. Pollut. Bull.* 55, 16–29. doi:10.1016/j.marpolbul.2006.05.025
- Pelletier, M.C., D.J. Gillett, A. Hamilton, T. Grayson, V. Hansen, E.W. Leppo, S. B. Wesiberg, and A. Borja. 2018. Adaptation and application of multivariate AMBI (M-AMBI) in US coastal waters. *Ecol Indic* 89: 818-827.
- Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the environment. *Oceanography and Marine Biology an Annual Review*, 16:229-311.
- Pinto, R., Patrício, J., Baeta, A., Fath, B.D., Neto, J.M., Marques, J.C., 2009. Review and evaluation of estuarine biotic indices to assess benthic condition. *Ecol. Indic.* 9, 1–25. doi:10.1016/j.ecolind.2008.01.005
- Ranasinghe, J.A., Weisberg, S.B., Smith, R.W., Montagne, D.E., Thompson, B., Oakden, J.M., Huff, D.D., Cadien, D.B., Velarde, R.G., Ritter, K.J., 2009. Calibration and evaluation of five indicators of benthic community condition in two California bay and estuary habitats. *Mar. Pollut. Bull.* 59, 5–13. doi:10.1016/j.marpolbul.2008.11.007
- Ranasinghe, J.A., Welch, K.I., Slattery, P.N., Montagne, D.E., Huff, D.D., Lee, H., Hyland, J.L., Thompson, B., Weisberg, S.B., Oakden, J.M., Cadien, D.B., Velarde, R.G., 2012. Habitat-related benthic macrofaunal assemblages of bays and estuaries of the western united states. *Integr. Environ. Assess. Manag.* 8, 638–648. doi:10.1002/ieam.62
- Rhoads, D.C., P.L. McCall, and J.Y. Yingst. 1978. Disturbance and production on the estuarine seafloor. *American Science*, **66**:577-586.

- State Water Resources Control Board (SWRCB). 2009. Water Quality Control Plan for Enclosed Bays and Estuaries - Part 1: Sediment Quality. SWRCB. Sacramento, CA.
- Teixeira, H., Weisberg, S.B., Borja, A., Ranasinghe, J.A., Cadien, D.B., Velarde, R.G., Lovell, L.L., Pasko, D., Phillips, C.A., Montagne, D.E., Ritter, K.J., Salas, F., Marques, J.C., 2012. Calibration and validation of the AZTI's Marine Biotic Index (AMBI) for Southern California marine bays. *Ecol. Indic.* 12, 84–95. doi:10.1016/j.ecolind.2011.05.025
- Warwick, R. M. 1988. Effects on community structure of a pollutant gradient - summery. *Marine Ecology Progress Series*, **46**:207-211.