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NOTE

Delta Smelt Habitat in the San Francisco Estuary: A Reply to Manly, Fullerton, Hendrix, and Burnham's "Comments on Feyrer et al. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish"

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Manly et al. (2015) commented on the approach we (Feyrer et al. 2011) used to calculate an index of the abiotic habitat of delta smelt *Hypomesus transpacificus*. The delta smelt is an annual fish species endemic to the San Francisco Estuary (SFE) in California, USA. Conserving the delta smelt population while providing reliability to California's water supply with water diverted from the SFE ecosystem is a major management and policy issue. Feyrer et al. (2011) evaluated historic and projected future abiotic habitat conditions for delta smelt. Manly et al. (2015) specifically commented regarding the following: (1) use of an independent abundance estimate, (2) spatial bias in the habitat index, and (3) application of the habitat index to future climate change projections. Here, we provide our reply to these three topics. While we agree that some of the concepts raised by Manly et al. (2015) have the potential to improve habitat assessments and their application to climate change scenarios as knowledge is gained, we note that the Feyrer et al. (2011) delta smelt habitat index is essentially identical to one reconstructed using Manly et al.'s (2015) preferred approach (their model 8), as shown here in Fig. 1.

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Concern (1): Use of an Independent Abundance Index Manly et al. (2015) state: "Feyrer et al. (2011) used an abundance index in their work, but it was constructed from the Fall Midwater Trawl (FMWT) catch data. These catch data were the same source as the presence/absence data used by Feyrer et al. (2011) and thus were not an independent data source." We clarify that while the FMWT index was considered as a covariate in one form of the generalized additive model (GAM), it was not included in the final model. We agree with Manly et al. (2015) that including an appropriate independent measure of abundance could potentially improve a GAM for the probability of occurrence of delta smelt. Intuitively, the higher the abundance of delta smelt, the higher the probability of occurrence in a fish survey. While the abundance variable used by Manly et al. (2015), the Summer Townet Abundance Index, is independent of the FMWT and collects data on an earlier life stage, it does not appear to be a particularly good predictor of fall abundance as the addition of this index explained just 3 % more of the variation than Manly et al.'s (2015) next largest model. This could be due to the way the index is constructed, sampling noise in the Summer Townet Survey, or interannual variability in summer to fall mortality (Bennett 2005; Nobriga et al. 2013). Constructing more reliable measures of delta smelt abundances at different life stages using fish survey data is an area of current research by the authors.

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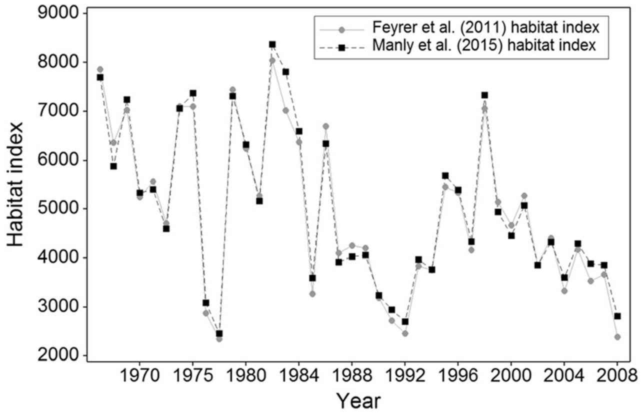

Fig. 1 Time series of the Feyrer et al. (2011) delta smelt habitat index and the habitat index reconstructed using model no. 8 from Manly et al. (2015)

Concern (2): Detection of Spatial Bias in the Habitat Index Manly et al. (2015) found that adding a categorical region variable to a model containing smooth functions of conductivity and Secchi (model 8) explained an additional 4.7 % of the variation compared to a model without the region variable (model 4). Based upon this result, longitudinally indexed plots of observed proportions of samples with delta smelt present, and model-based predicted proportions for models 4 and 8, Manly et al. (2015) concluded that failing to account for regional effects led to a spatial bias in Feyrer et al.'s (2011) habitat index. We agree that smooth functions of conductivity and Secchi alone could not match observed proportions in the Honker Bay and Lower Sacramento River regions (often underestimating) or the San Joaquin River regions (overestimating) as well as smooth functions of conductivity and Secchi *and* 13 regional indicator variables could. This latter comparison suggests that there are factors other than conductivity and Secchi alone affecting delta smelt occurrence at the locations sampled by the FMWT survey and that these other factors have a distinct spatial distribution. Unfortunately, carving up the geographic range of delta smelt into 13 longitudinally organized geographic sub regions of arbitrary boundary and dimension does not provide any insight into what these other factors might be. Imposing such an organizational scheme unsupported by a particular hypothesis leads to mechanistically uninterpretable results and provides no insight for determining how climate change or changes in particular ecological processes might affect delta smelt abundance and distribution.

Concern (3): Application of the Habitat Index to Future Climate Change Projections Manly et al. (2015) criticized the application of Feyrer et al.'s (2011) habitat index to future climate change projections for two reasons. First, they argued that using X2 (the position of the 2 PSU isohaline) alone to assess the impact of various climate change scenarios largely reflects changes in the salinity (conductivity) field but does not necessarily reflect changes in the turbidity (Secchi) field. We acknowledge that including predicted changes in salinity and turbidity in forecasts of the probability of delta smelt occurrence would be better than just including changes in salinity. That said, we note that the turbidity field may be relatively constant for a variety of reasonable climate change scenarios. Delivery of suspended sediment to SFE from the Sacramento River watershed has decreased by about 50 % over the last half century (Wright and Schoellhamer 2004) and turbidity in the Sacramento-San Joaquin Delta has correspondingly decreased by about 50 % (Jassby et al. 2002; Jassby 2008). Projected future deliveries of suspended sediment concentrations have only recently become available and are shown to either remain constant or decline over the next century (Cloern et al. 2011; Brown et al. 2013). Second, Manly et al. (2015) commented that the two-step approach used by Feyrer et al. (2011) to link the habitat index to future climate change scenarios may shift the emphasis away from the initial dependent variable of interest, namely, the occurrence of delta smelt, and mask its predictive ability. We agree that the development of a more direct single-step approach could potentially improve the application of habitat assessments to future climate change scenarios, particularly if climate change forecasts include fine scale spatial-temporal predictions of salinity and turbidity.

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