The relationship between water depth and hypoxia in managed estuarine wetlands: analysis and management recommendations

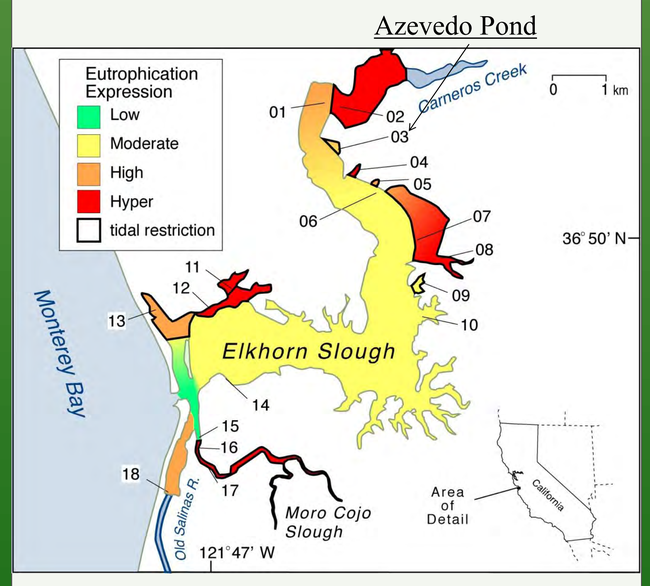
Miguel Rodriguez[1, 2], John Haskins[1], Brent Hughes[1], Rikke Preisler[1], Kerstin Wasson[1]
[1]Elkhorn Slough National Estuarine Research Reserve, [2]Hartnell College

1. Elkhorn slough: a unique estuary with impaired water quality

- Elkhorn slough is a rich and diverse estuarine system:
  - with migratory shorebird stopover, sea otter foraging and reproduction, and pickle weed marshes…
- Has the highest nutrient concentrations and lowest dissolved oxygen in the Sanctuary.
  - Received a low grade in recent state of sanctuary report (State of the Sanctuary Report 2006).
- Its high nutrient load leads to various eutrophic expressions such as:
  - high algal growth, increased water column productivity, elevated pH, and depressed night-time dissolved oxygen at many sites.
- Is highly anthropogenically altered:
  - 30% of the wetland is behind water control structures.

2. Sites with artificially restricted tidal exchange are more eutrophic

- About 1/3 of estuarine wetlands at Elkhorn Slough are behind water control structures.
- Recent analysis shows that these areas have greater algal cover, increased water column phytoplankton concentrations, and more extended night time hypoxia.
- Eutrophication can decrease abundance and diversity of estuarine inhabitants; in particular, hypoxia is a threat to estuarine animals.

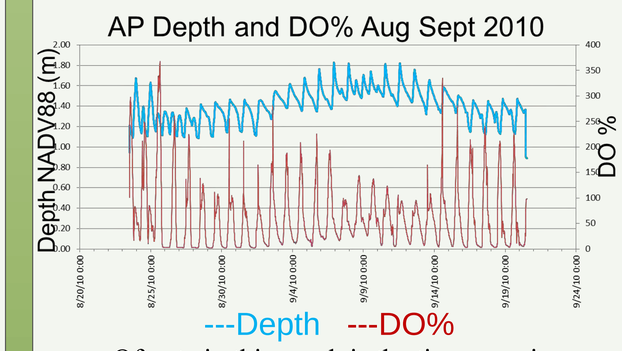


Source: Hughes et al 2011 MEPS

3. Azevedo pond: a "hyperventilating" wetland

- Azevedo Pond is a managed wetland in the northeastern portion of Elkhorn Slough,
- Tidal water must enter through water control structures under the rail road. Tidal range is about 1 meter in Azevedo Pond, compared to a tidal range of 2.5 meters in the adjacent main channel.
- Previous study (Beck & Bruland, 2000, Estuaries Vol. 23, No. 2, p. 177–187) highlighted extreme dissolved oxygen (dO) fluctuation on diurnal basis.
- We have observed fish kills and oyster die-offs at Azevedo Pond that may be due to low oxygen conditions.
- Long term ESNERR water quality monitoring shows a continuing pattern of low dissolved oxygen every night.

AP Depth and DO% Aug Sept 2010

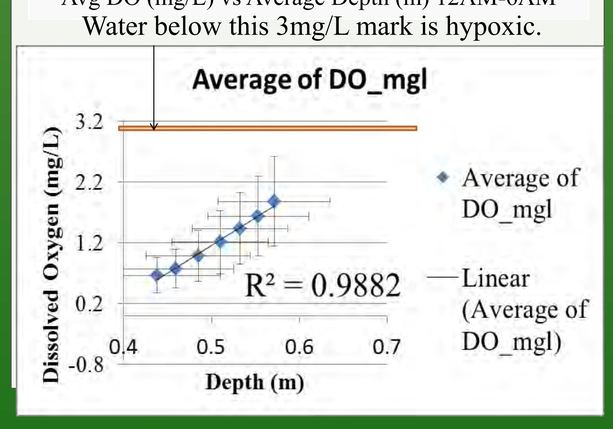


- Of note in this graph is the time span in the middle, where the average depth is higher. During this time period the % dO is neither hyperoxic nor hypoxic.

4. Increased night time hypoxia at shallow depths

- To separate the effects of depth and diurnal variation on hypoxia, we looked at dissolved oxygen (dO) only during nighttime hours, from 12-6 AM. This is when a water body is most vulnerable to hypoxia (low oxygen).
- Seasonal hypoxia is maximized during August. August thousands of dO and depth points were averaged by hour and binned into these few points.
- We found a strong relationship: at night time, depth explains 98% of the variation of dO concentration. Note the low average depth values at nigh and how all corresponding average dO values are hypoxic..

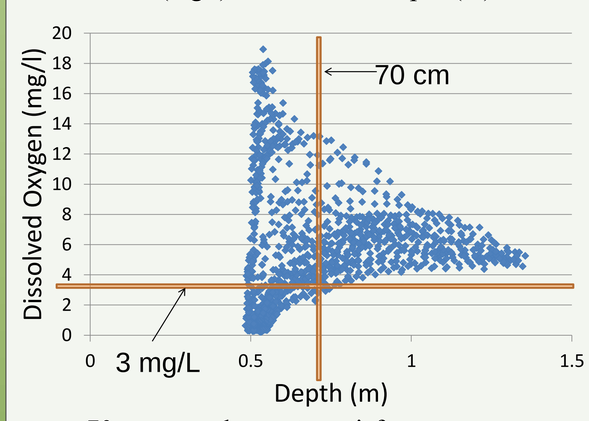
Avg DO (mg/L) vs Average Depth (m) 12AM-6AM
Water below this 3mg/L mark is hypoxic.



5. Oxygen is highly variable when water is shallow at Azevedo Pond

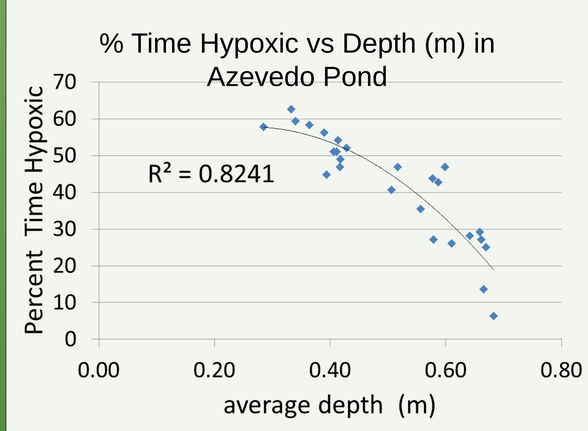
- We examined the role of depth at Azevedo Pond, as a part of an adaptive management and monitoring program.
- Goal is to inform managers of optimum depth for wetland health. Too high may drown vegetation, but too low may lead to excessive hypoxia (low oxygen).
- We examined time series data from water monitoring data to look for relationship between depth and dissolved oxygen (dO).
- dO variation is much greater at depths less than 70 cm
- dO variation decreases with increasing depth

AP 08/01-14/2009
DO (mg/l) vs corrected Depth (m)



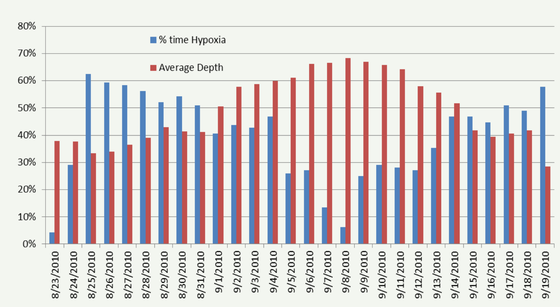
- 70 cm was chosen to satisfy management goals: to decrease hypoxia without drowning valuable marsh habitat.

6. Percent time hypoxic and water depth



Azevedo Pond 8/23/2010-9/18/2010

-----Daily %Time Hypoxic
-----Average Daily Depth (m)

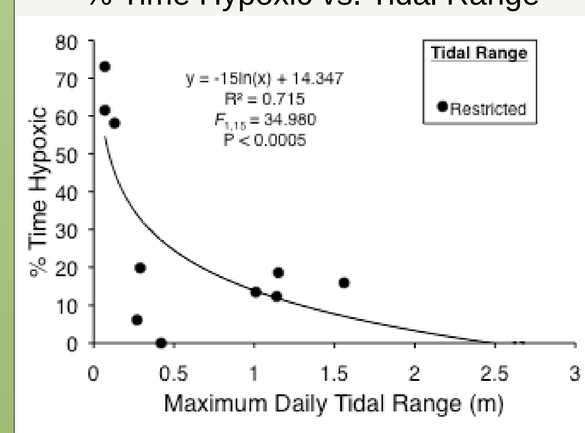


Azevedo Pond 8/23/2010-9/18/2010

7. Tidal range also affects dissolved oxygen at sites with water control structures

- We examined the duration of hypoxia at 10 wetlands behind water control structures at Elkhorn Slough
- We found a very strong relationship across these sites: the higher the water column tidal range, the less hypoxia the site experienced.
- Note how tidal range, which may be used as a proxy for depth, is used here in place of depth when comparing sites.

% Time Hypoxic vs. Tidal Range

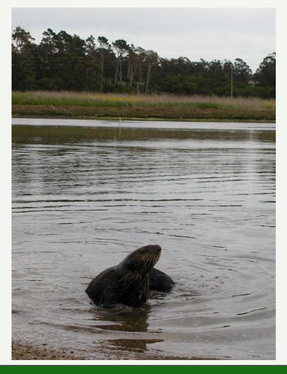


- Linear regression in the figure shows the relationship of % Time hypoxic vs. tidal range. Tidal range was measured during 2-4 week deployments and does not necessarily reflect the maximum tidal range for the entire year, which is similar for all fully tidal sites. Sites in the full tidal range category (no water control structure) are not shown.

8. Management recommendation: avoid shallow depths in eutrophic wetlands

- Analysis of 10 managed wetlands behind water control structures clearly showed that shallower wetlands have more hypoxia than deeper ones.
- Case study at Azevedo Pond showed that hypoxia could be avoided by keeping depth of channel at a minimum of 70 cm.
- Overall, if it is consistent with other management goals and feasible with regard to capacity of water control structures, it is probably best to vary shallow depths in highly nutrient-loaded lagoonal estuarine wetlands.
- Deeper managed wetlands in this region, such as Whistlestop Lagoon and Bennett Slough, host richer animal communities, perhaps due to their lack of hypoxia.

Sea otter in an Elkhorn slough wetland with restricted tidal exchange where depth is sufficient to provide good water quality and food resources,



California State University Monterey Bay

UROC