Exposure to Polluted Sediment Elutriate in the Tijuana River Estuary Increased Deformity Rates in Medaka Embryos

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Abstract

The Tijuana River Estuary is the largest, but also one of the most polluted, wetlands in Southern California. To measure the potential effects of polluted sediments on estuary wildlife development, medaka embryos were exposed for seven days to varying concentrations of sediment elutriate. Deformities in the heart, eyes, and tails were observed by light microscopy by the end of exposure. Deformity and mortality rates correlated positively with increasing sediment elutriate concentrations.

Introduction

Urban, industrial, and sewage pollution contaminate the Tijuana River Estuary (TRE), the largest intact coastal wetland in southern California. Organic pollutants can be bound within sediment and potentially released into the water when disturbed (Chiaia-Hernández et al., 2022). Targeted chemical analysis of TRE sediments have detected polycyclic aromatic hydrocarbons (PAHs), pesticides (many banned by the US government), polychlorinated biphenyls (PCBs), and phthalates (McLamb et. al 2024). These pollutants have been shown to alter fish development and increase mortality rates under acute exposure (Rohr et al., 2009). Sublethal developmental abnormalities can still occur at lower concentrations. Zebrafish exposed to low concentrations of hydroxychloroquine had higher rates of developmental deformities (Hedgpeth et al., 2019). Monitoring development and tracking abnormalities provides an exposure risk assessment to lower but chronic concentrations of a mix of organic pollutants . We propose to use the medaka as a vertebrate model to test embryotoxicity of TRE sediments because they have well-characterized developmental stages and morphology, and are easy to observe translucent embryos (Iwamatsu, 2004).

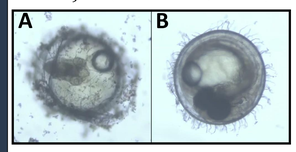

Figure 1. Medaka embryo showing abnormal ocular development (A) next to a normal embryo (B) at 7 days post-fertilization

Hypothesis

Medaka embryos exposed to TRE sediment elutriate will have higher rates of deformities than control embryos without inducing high mortality rates.

Methodology

Sample Collection

- Sediment was collected from 4 sites
  - Each site had 4 sampling areas, each around 20m apart
  - A Van Veen grab sampler obtained sediment ~3 inches deep from surface
- Targeted chemical analysis of Site 1 sediments (32.547251, -117.064224) showed PAHs, PCBs, and legacy pesticides among highest concentrations
- Using modified sediment elutriate EPA protocol (EPA, 1991) to prepare sediment elutriate for exposures

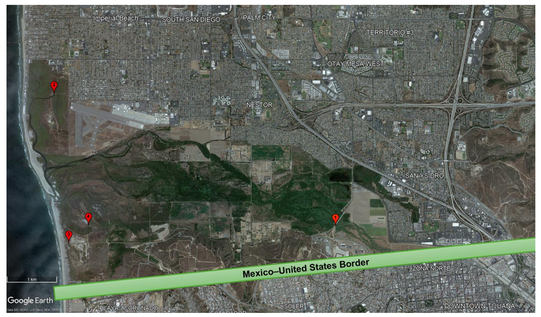

Figure 2. The map shows 4 sites at which sediments were sampled. Sediment sampled at site 1 during the dry season was used for subsequent embryo toxicity tests.

Medaka Exposure and Observation

- Medaka embryos were exposed to sediment elutriate diluted with 15 ppt saltwater at 0%, 10%, 50%, 75%, and 100% concentrations.
- Fish embryos were observed for deformities in the heart, eyes, and tail, scored from 0-1, seven days post fertilization (dpf)
  - 0 = Normal
  - 0.5 = Minor deformities
  - 1 = Major deformities

Figure 3. The embryo exhibits lack of melanization and tail curvature malformation, scoring a 1 for deformities in eyes and tail.

Data Analysis

- Weighted linear regression (WLS) was used to estimate the correlation between elutriate concentration and deformity rates and between concentration and mortality
- Total deformity rate was calculated averaging the individual deformity rates of the heart, eye, and tail

Results

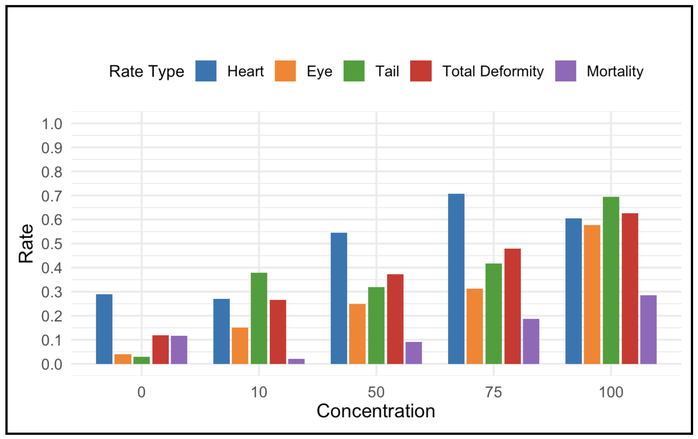

Figure 4. Deformity rates in medaka embryos increase as exposure concentration increases from TRE sediment elutriate

Correlation between Concentration and...	R-value	R^2-value
Heart Deformity Rate	0.56	0.31
Eye Deformity Rate	0.52	0.27
Tail Deformity Rate	0.53	0.28
Total Deformity Rate	0.62	0.38, 0.36*
Mortality Rate	0.39	0.15

Fig. 5: Correlation values between elutriate concentration and deformities rates: * value is the adjusted R^2-value for all three predictors.

Discussion and Conclusion

- Deformity rates increased with increasing concentration exposures (Fig. 4)
- While no single deformity score had a strong correlation with elutriate concentration, the combined total deformity score did have a slightly stronger correlation. The mortality rate however was less correlated to elutriate concentration compared to deformity rate (Fig. 5)
  - Our hypothesis is supported, R^2 value of total deformity rate is two times that of the mortality rate, suggesting a stronger relationship with sediment elutriate concentration (Fig. 5)
- PAHs and endocrine disruptors in sediment samples are associated with fish developmental toxicity (Rohr et al., 2009)
- Deformity rates and types at chronic levels may provide more information on pollutant composition in the TRE and potentially predict effects of sediments on native fish in estuary.

Limitations

- Only one species was observed (medaka)
- Only one life stage was analyzed (embryo, 7dpf)
- Specific pollutants causing the malformations were not identified

Future Direction

In future experiments, specific compounds (PAHs, pesticides, PCBs, or phthalates) can be isolated to analyze their individual effects on mortality rates and deformities in medaka embryos. Identifying the body burden in exposed medaka embryo tissue can further correlate observed deformities with specific chemicals

Bibliography

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