



Progress Report

Biogeochemical Function of the San Lorenzo River Lagoon

and
Inter-Comparison of Central
California Coastal Lagoons

Fall 2001

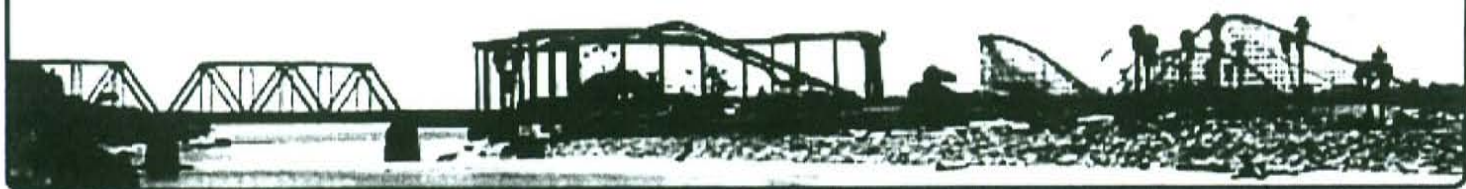
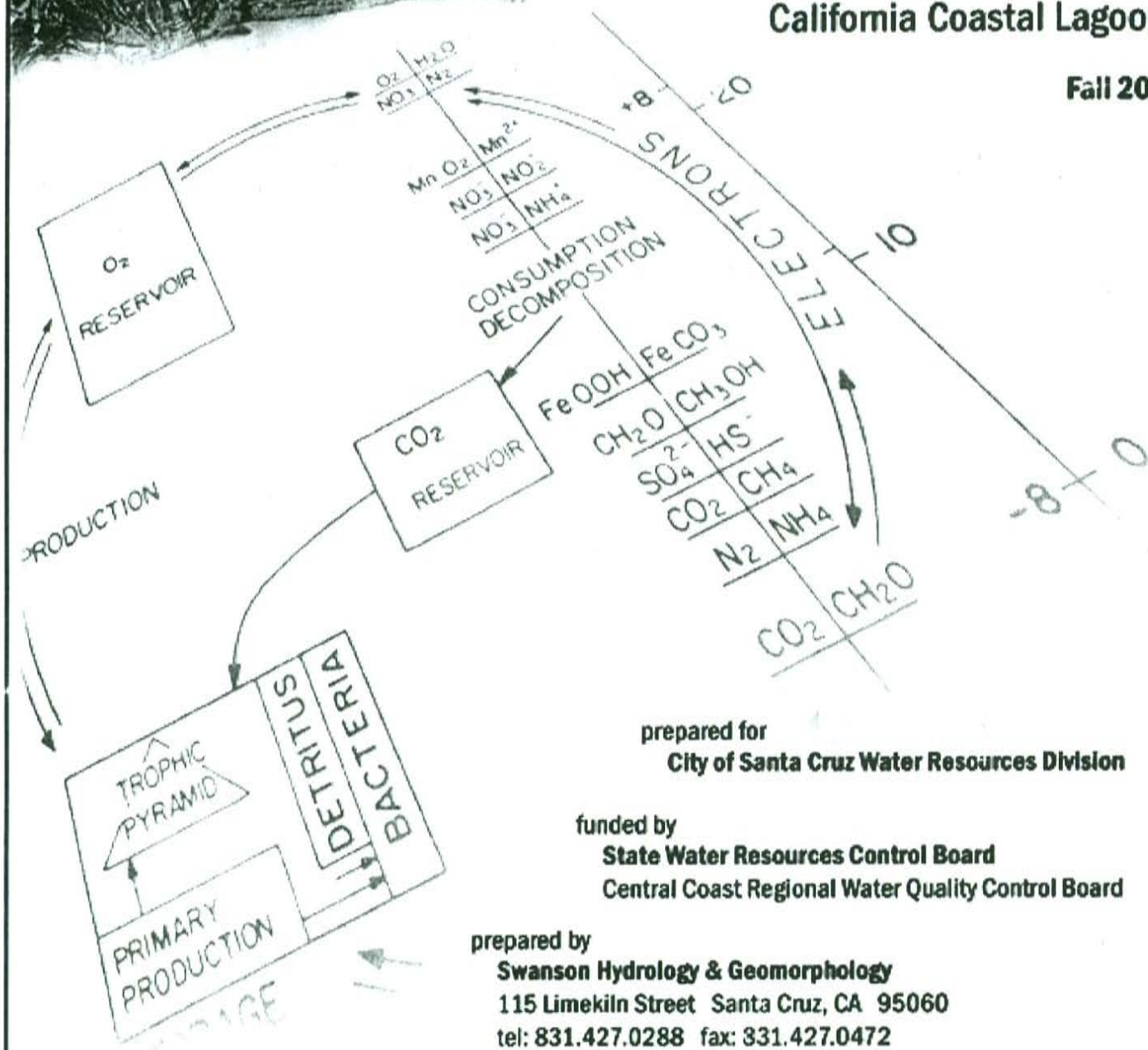


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EXECUTIVE SUMMARY

- This study was designed to provide a comprehensive overview of the hydrologic behavior and biogeochemical cycling of the San Lorenzo River Estuary in response to tidal and non-tidal conditions. The purpose of this study is to provide recommendations concerning the future management strategies of the San Lorenzo Lagoon available to the City of Santa Cruz to best manage the Lagoon for salmonid habitat. This report summarizes the findings of the first year of data collection of a two-year project.
- The sandbar at the mouth of the San Lorenzo River opened and closed over 5 times during the 2001 season. When the sandbar is open, the Lagoon behaves like a deltaic system, with a well-mixed water column and relatively uniform vertical profile structure of temperature, dissolved oxygen, pH and salinity. Within days of the sandspit closure, a halocline develops and extreme biological productivity in the surface waters leads to low dissolved oxygen (DO) values in the bottom waters. The Lagoon formation did not exceed 3 weeks in duration for any given closure due to either natural or unauthorized breaching of the sandbar.
- It is difficult to predict the response of the San Lorenzo Lagoon to sustained summer closures when it did not remain closed for a substantial period of time. Therefore, Swanson Hydrology collected data in three nearby coastal lagoons and presents a comparison to expand our knowledge of the processes controlling these dynamic systems.
- Suggestions have been made that a closed summer lagoon system at a defined water elevation will provide an ideal habitat for young anadromous fish. While this strategy appears to be working for Soquel Lagoon, the sustained closure of Pescadero Marsh appears to have resulted in significant fish kills by the buildup and subsequent release of hydrogen sulfide into the water column, the most recent of which was observed by Swanson Hydrology in November 2001.
- Would the conversion of each of these coastal lagoon systems to a seasonal fresh water column allow a poorly mixed, nutrient-enriched water body to maintain an aerobic water column and prevent anoxic conditions and the subsequent production of hydrogen sulfide? This question needs to be addressed.
- Swanson Hydrology recommends that the San Lorenzo River Lagoon be artificially closed for up to 5 to 6 weeks in the Fall of 2002 in order to conduct a more comprehensive biogeochemical study of the subject site.
- A more detailed study of the seasonal biogeochemical cycling within other regional coastal lagoon systems needs to be conducted to understand the site-specific processes controlling the aquatic chemistry and ecological dynamics. Only once we understand the primary processes controlling each of these systems can we adapt future management strategies that will create healthy sustainable summer lagoon environments.

deposition and decreased inflows. The San Lorenzo and Aptos lagoons opened and closed numerous times over the 5-month period. Figure 11 is a compilation of photographs of each of the four lagoons during closure to illustrate the physical habitat created in each lagoon system. Below is brief summary of each lagoon system and relevant observations made in 2001.

Historic Nitrate Loading

As part of the Lagoon comparison, we compiled available nutrient data and average water flows from contributing waters to each of these lagoons during the critical months of the year (June to October). The Santa Cruz County Environmental Health Department has been conducting long term monitoring of the local waterways since the late 1970's. We utilized the nitrate concentration data from the Santa Cruz County database to provide the following nitrate loading comparisons for Aptos, Soquel and San Lorenzo Lagoon. No long-term nutrient data has been collected for Pescadero Watershed. Figure 12 provides an estimate of the average instantaneous nitrate loading per month delivered to each Lagoon, based on average nitrate concentrations and average daily flow data per month for the contributing waterway inflowing to each lagoon. The relatively high levels of nitrate loading to the San Lorenzo River must be taken into account when considering future management to the Lagoon.

On October 2, 2001 Swanson Hydrology collected water samples for nutrient analyses from Aptos, Soquel and San Lorenzo Lagoons. Figure 13A displays the maximum biologically available nitrate and phosphate values determined at each of the sample sites and Figure 13B indicates the dissolved nitrate and phosphate detected at each site sampled. The relatively low nitrate loading in Soquel suggests that the nutrient concentrations available for phytoplankton growth are much less than those found in the three other watersheds. The data provided from Pescadero Marsh was collected and analyzed in November 1997 (Beck, N.) while the mouth of the Marsh was closed, and is the only reliable nutrient data that Swanson Hydrology could locate.

Soquel Lagoon

Perennial inflows from Soquel Creek and Noble Gulch transport water and nutrients to the lagoon. A flume was installed in Soquel Lagoon in the early 1990's as part of the Soquel Creek Lagoon Management Plan. Capitola City Public Works Department manufactures a sandbar at the mouth of the lagoon the week before Memorial Day and later breaches the sandbar following the first significant storm of the rainy season. The flume drains surface water from the lagoon to the ocean, maintaining a maximum water depth in the Lagoon of approximately 7 ft.

near the mouth (measured 10-2-01). The lagoon is confined to the north by a bluff and to the south by urban development, with an average width of approximately 150 ft. Upstream of the Stockton Avenue Bridge, the banks are well vegetated with large trees and plants, providing a significant amount of cover for the water body below. On October 2, 2001 Swanson Hydrology field personnel conducted vertical profiles at three locations within the Soquel Lagoon at sites ranging from the Shadowbrook Restaurant to the Mouth (Figure 14). The water column in Soquel Creek was entirely fresh water with a uniform DO profile slightly below 100% saturation. The vertical profiles were conducted in the early morning, following the nighttime hours of sustained respiratory oxygen removal. Chlorophyll *a* levels ranged from 0.0079 to 0.220 mg/L, indicating relatively little algal loading. We would expect a slightly supersaturated water column with respect to oxygen in the late afternoon following many hours of photosynthetic activity. The water was relatively clear and the bottom was visible at depth up to 3 ft.

Chlorophyll *a* and nutrient data illustrated minimal photosynthetic biomass indicative of relatively low supply of nutrients. This system appears to be much less enriched with nutrients and biologically productive than the San Lorenzo River, for instance. The management strategy for enhancing salmonid rearing habitat employed in Soquel Creek appears to be a good fit and should be continued.

Aptos Lagoon

The physical dynamics of Aptos Lagoon are very similar to those controlling the San Lorenzo Lagoon. Perennial inflows from Aptos Creek and Valencia Creek transport water and nutrients to the Lagoon. While the watershed of Aptos Creek is fairly undeveloped, Valencia Creek is a highly urbanized watershed with a high density of operating septic systems. The incoming reach to the lagoon is confined to a width of approximately 100 foot-wide concrete levee structures. Oceanward of the foot bridge the channel meanders along the Rio Del Mar Beach. Swanson Hydrology installed a YSI 100 ft upstream of the pedestrian bridge on August 21, 2001. From late August to November 2001 the mouth at Aptos Lagoon open and closed six times, with the longest duration of closure being 5 weeks. There are suspicions that some of the sandbar breaches may have been artificially created. When closed, the Aptos Lagoon continued to expand both north and southward along the Rio Del Mar Beach, devoid of vegetation or habitat for salmonids (see Figure 11). The intense exposure to sunlight causes dangerously high water temperatures for aquatic species. Vertical profiles conducted on October 2, 2001 indicated a distinct halocline at a depth of 3 ft and anoxic conditions in the bottom waters due to extreme

water temperatures exceeding 25°C and excessive biomass loading from the surface waters (Figure 15). Another vertical profile at the location of the YSI on October 10th illustrated the sustained anoxic bottom waters. These trends indicate that when closed Aptos Lagoon is a hypereutrophic system.

Pescadero Marsh

Pescadero Marsh is the largest of the four lagoon systems investigated, occupying over 300 acres when the sandbar is closed. Fresh water inputs are dominated by the perennial flows of Butano and Pescadero Creeks. Land uses within the watershed contributing to excess nutrient inputs to the Marsh include septic systems, urban activities and agricultural practices (greenhouses). An extensive earthen levee system was installed in the Marsh in the early 1900's during land reclamation efforts and the conversion of lands to agricultural crops. The goal of the 1990 Pescadero Marsh Enhancement Plan was to restore the apparent hydrologic conditions reflected on early maps (1853) and aerial photographs (1920s). The primary method was to strategically remove reclamation levees and restore tidal prism and circulation to marsh areas. The plan was partially implemented in early 1993 and additional work was done in 1997. 'Mysterious' fish kills have been reported in the fall of 1996 and 1997 within Pescadero Marsh.

In 2001, the sandbar formed at the mouth in mid-June and remained closed until November 14th. Concerned about the ramifications of a sustained closure, Swanson Hydrology installed a YSI 1.5 ft. from the bottom at the Highway 1 Bridge on October 10, 2001 (Figure 16). At this location, the bottom waters had nearly converted to fresh water, with average salinity readings of 3.4 ppt. The DO values appear to follow climatic warming and cooling trends, where warm periods oxygenate the system due to increase photosynthetic inputs, followed by cooling trends that allow bacteria to respire the entire reservoir of oxygen. It must be emphasized that the location of this YSI was not in a representative location to interpret the maximum amount of biological activity within the Marsh during this time period. Regardless, a relatively fresh water column displayed very low DO values. It appears that locations further from the Mouth have much greater rates of photosynthetic production. On November 16th, 30 hrs following the breach of the sandbar, Swanson Hydrology personnel conducted a site visit. November 16th was also the opening day for fisherman in Pescadero. Over 30 dead fish were identified along the Marsh banks from Highway 1 to the confluence of Butano and Pescadero Creeks, including both young and adult steelhead (Figure 17). Many conversations with the anglers revealed that nothing in the Marsh appeared to be alive. Reports of dead crustaceans and fish were prevalent and, needless to

say, there were no reports of a catch. Observations of the tidal gates and North Marsh indicated an extremely pungent 'rotten egg' odor, indicative of the degassing of hydrogen sulfide. We have little doubt that hydrogen sulfide poisoning was responsible for this massive kill in Pescadero Marsh.

CONCLUSIONS

There are two main components that appear to control the response of these coastal lagoon systems to sustained summer closure. The first is the physical size of the lagoon. In relatively small systems, such as the Soquel Lagoon, the conversion to a completely fresh-water marsh may occur within weeks of closure. However, in a lagoon system with a significant volume of water and complex hydraulics, the complete conversion to fresh-water of the entire marsh area may never occur.

The second factor is the amount of chronic nutrient loading to the system and/or the amount internally cycled following decreases in circulation. It appears that the relatively low nutrient inputs to Soquel contribute to the success of the manual seasonal Lagoon closure. Assuming that the San Lorenzo Lagoon would convert to a fresh water column, would the same response be observed if the system was allowed to remain closed for significant number of weeks, even though nitrate loads are more than an order of magnitude higher than those observed in Soquel?

Therefore the two unanswered questions regarding the San Lorenzo Lagoon are 1) would a sustained closure result in the complete conversion to fresh water, and if so 2) would a fresh water column provide a large enough oxygen reservoir to prevent summer anoxic conditions given the relatively high nutrient loading rates?

The comparative information of the geochemical behavior of other Central California lagoons is invaluable to our understanding of the San Lorenzo Lagoon system. We have shown that Pescadero Marsh does not respond in a similar manner as Soquel Lagoon to summer closure. The excessive build-up of hydrogen sulfide in Pescadero Marsh in the summer and Fall 2001 suggests that either 1) portions of Pescadero Marsh did not convert to a fresh water column, or 2) even the conversion to fresh water did not prevent anoxic conditions and subsequent hydrogen sulfide buildup. At this point, we do not know if all of Pescadero Marsh converted to a complete fresh water column. Assuming yes, then the simple conversion to fresh water is not the solution to eliminate anoxic events in these coastal systems. If the Marsh did not completely convert to fresh water during the 5-month isolation, then how can future management and restoration

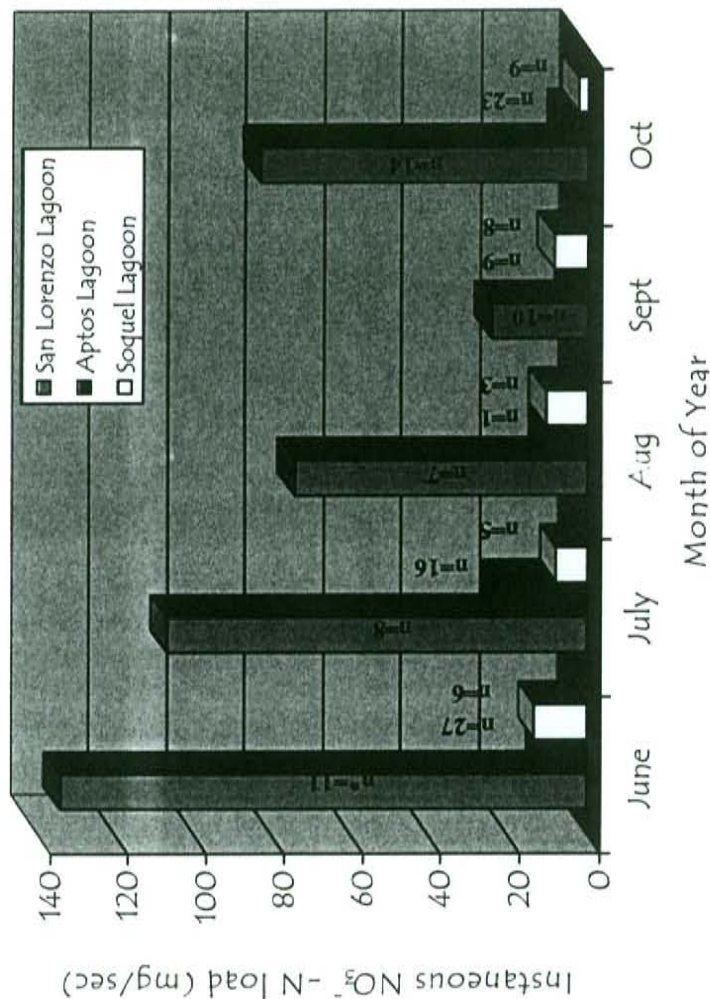
objectives accomplish a complete conversion, assuming that a fresh water column will prevent anoxic conditions? The dynamics observed in Pescadero Marsh bring up relevant questions on the possible geochemical behavior of the San Lorenzo River Lagoon given sustained sandbar closure.

RECOMMENDATIONS FOR 2002

- A controlled sustained closure of the San Lorenzo Lagoon should be conducted by heavy equipment to build up the mouth. If possible, a PVC 2-foot culvert should be buried beneath the sandbar to allow some water removal from the lagoon, to avoid extreme water levels and to simulate conditions created in Soquel Lagoon. During the closure, Swanson Hydrology will maintain the two YSI's and conduct a series of vertical profile sampling events, including nutrient and chlorophyll sample collections. Should deleterious conditions develop, the sandbar will be breached and allowed to function naturally for the remainder of the season.
- The San Lorenzo River Lagoon Water Quality Assessment would benefit from an expanded scope to include regional comparative sampling of Central California Lagoon systems, such as Aptos, Pescadero, Pajaro, Carmel and San Lorenzo. It is understood that such an expanded scope may not be accommodated under the existing scope of work, however additional sources should be sought to accommodate such a comparative analysis. Ideally, water samples for nutrient analysis and hydrologic flow data should be collected from the inflowing waters to better constrain the nutrient loading to each lagoon. In addition, high resolution ancillary data and vertical profile studies should be conducted within each lagoon over a three-year period. Special attention should be made to document the timing and duration of lagoon closure to put the interpreted biogeochemical data into perspective.

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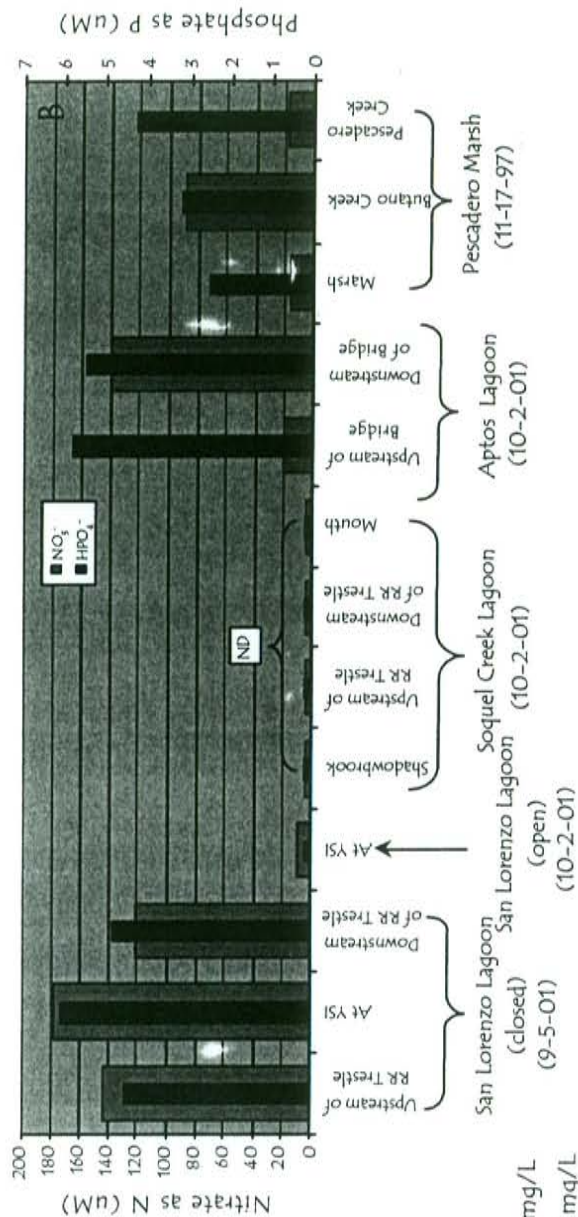
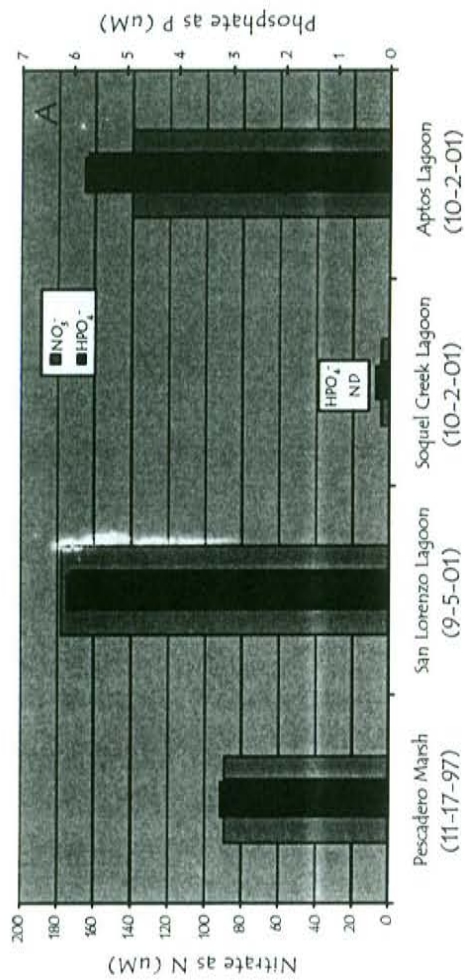


*n equals the number of samples used to calculate average.

Average Monthly Nitrate Loading to San Lorenzo, Aptos and Soquel Lagoons:

Comparison of three local lagoons during months when mouth closure occurs. Observe the significantly greater amount of NO_3^- loading into the San Lorenzo Lagoon, relative to Soquel. Estimates were determined from the average monthly nitrate concentrations measured by Santa Cruz County at the station in the watershed nearest to the lagoon. Average daily stream flows per month were generated from the USGS gage station closest to the lagoon in each watershed.

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1 uM $\text{NO}_3^- \text{N} = 0.014 \text{ mg/L}$
 1 uM $\text{HPO}_4^- \text{P} = 0.031 \text{ mg/L}$

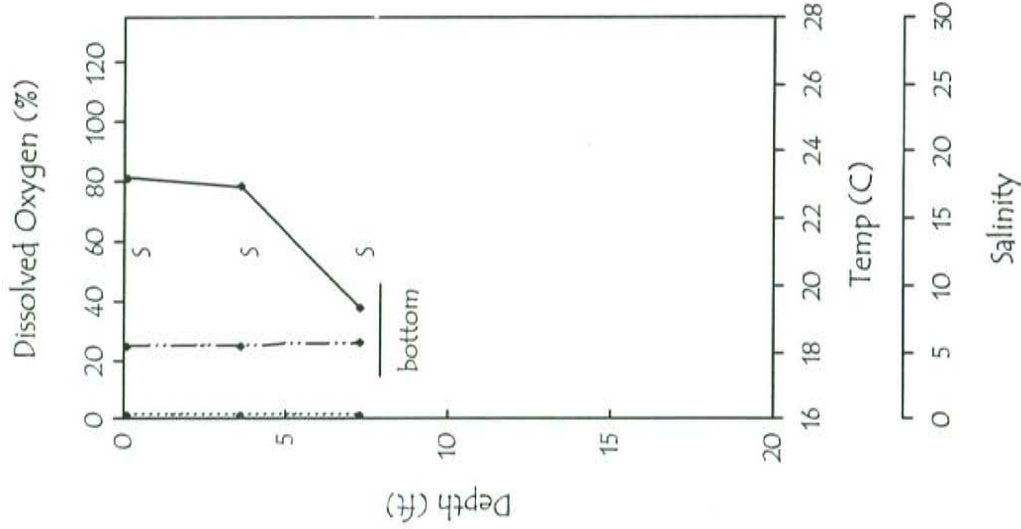
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Figure A: Maximum values of nitrogen and phosphorus measured in four closed Central California Coastal Lagoons by Swanson Hydrology.

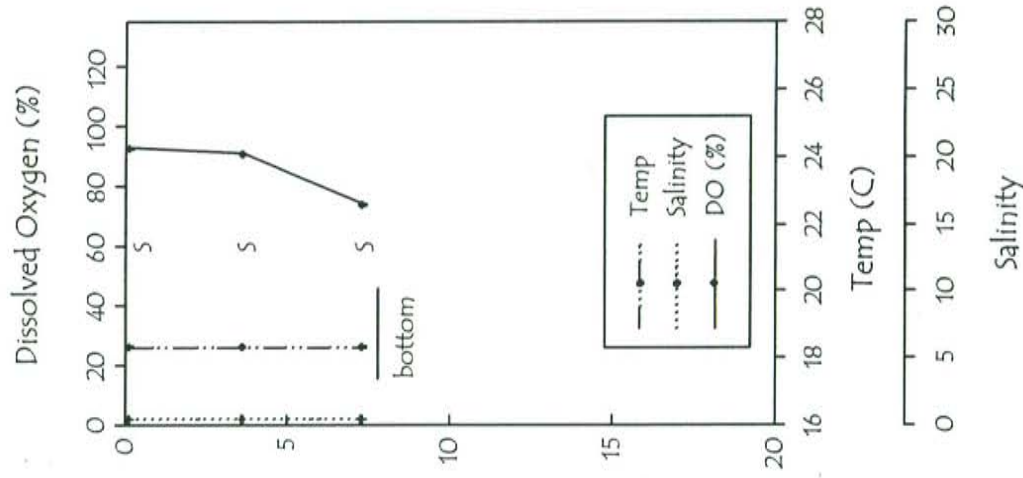
Figure B: Nitrate and phosphate concentrations at various sampling locations in Central California Coastal Lagoons measured by Swanson Hydrology.

Figure 13

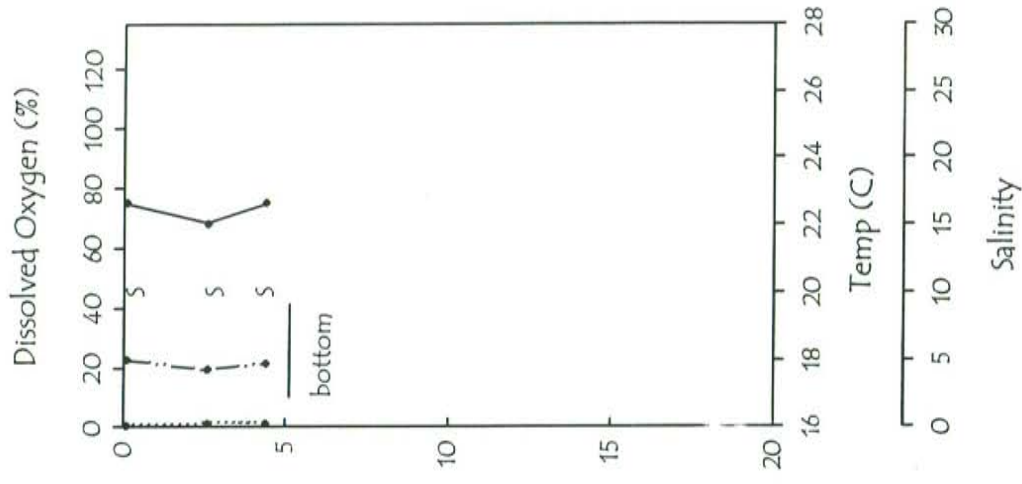
At Mouth



50ft Downstream of RR Trestle



100ft Upstream of Shadowbrook



At Mouth

50ft Downstream of RR Trestle

100ft Upstream of Shadowbrook

