## Introduction

Excavation of the Wai Kai Lagoon basin began late in 2003 and was completed in August 2008. Monitoring of the water quality in the lagoon began in January 2005, in accordance with the methodology approved by the State of Hawai`i Department of Health and pursuant to Haseko's Water Quality Certification[1] for the original marina project. Preliminary biological monitoring of the lagoon flora and fauna began in 2012. Results of this work are summarized in the environmental impact statement published for Haseko's zone change application.[2] In mid-2014 Haseko initiated monthly biological surveying in the lagoon to complement ongoing monthly water quality monitoring. This work continues to the present (July 2016). The available results for this comprehensive water quality and biological monitoring program are summarized here after a description of the methods used. Sample station locations used for routine monitoring are shown in the following figure. Each station location is marked with a small buoy to ensure consistent sampling coverage.

**Sample Stations Used for Monitoring in Wai Kai Lagoon**



[1] WQC 137, issued as required by the Clean Water Act of 1977 under Army File No. PODCO 2117

[2] http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Oahu/2010s/2014-11-23-OA-5E-FEIS-Hoakalei-Master-Plan-Update-Volume-I.pdf and http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Oahu/2010s/2014-11-23-OA-5E-FEIS-Hoakalei-Master-Plan-Update-Volume-II.pdf

## Monitoring Methods

*Water Quality Measurements*

Lagoon water samples are collected from surface water (within 6 inches of the surface) and near-bottom water (within 1 foot of the lagoon floor) under the supervision of Marine Research Consultants, Inc.[3] All samples are collected from a small, inflatable boat.

Surface samples are collected by filling bottles by hand over the side of the boat. Near-bottom samples are collected using a Van Dorn oceanographic sampling bottle, which is lowered to the desired sampling depth with spring-loaded end caps held open so water can pass freely through the bottle. A weight hung below the bottle signals the designated sampling depth above the bottom. At the desired sampling depth, a weighted messenger released from the surface triggers closure of the end caps, isolating a volume of water. Upon retrieval, water from the Van Dorn bottle is poured into 1-liter, triple-rinsed polyethylene bottles.

Water quality parameters evaluated for both the lagoon and nearshore ocean monitoring include all of the specific criteria designated for open coastal waters and embayments in Chapter 11-54 of the State of Hawai`i Department of Health (DOH) Water Quality Standards. These criteria include: total nitrogen (TN), nitrate + nitrite nitrogen ($NO_3^-$ + $NO_2^-$, hereafter referred to as $NO_3^-$), ammonium nitrogen ($NH_4^+$), total phosphorus (TP), chlorophyll-a (Chl-a), turbidity, pH, salinity and temperature. In addition, ortho-phosphate phosphorus ($PO_4^{3-}$) and silica (Si) are also measured, because these parameters are sensitive indicators of biological activity and the degree of groundwater mixing.

Following collection, subsamples for nutrient analysis are immediately placed in 125-milliliter (ml) acid washed, triple rinsed, polyethylene bottles and stored on ice. Analysis for $NH_4^+$, $PO_4^{3-}$, and $NO_3^-$ is performed with a Technicon autoanalyzer using standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983)[4]. TN and TP are analyzed in a similar fashion following oxidative digestion. Total organic nitrogen (TON) and total organic phosphorus (TOP) are calculated as the difference between TN and dissolved inorganic N and between TP and dissolved inorganic P, respectively.

Water for other testing is subsampled from the 1-liter polyethylene bottles and kept chilled until analysis. Chl-a is measured by filtering 300 ml of water through glass fiber filters; pigments on filters are extracted in 90% acetone in the dark at 20° C for 12-24 hours. Fluorescence before and after acidification of the extract is measured with a Turner Designs fluorimeter. Salinity is determined using an AGE Model 2100 laboratory salinometer with a readability of 0.0001‰ (ppt). Turbidity is determined on 60 ml subsamples using a Monitek Model 21 nephelometer, and reported in nephelometric turbidity units (NTU).

*In situ* field measurements of water temperature, dissolved oxygen and salinity are acquired using an RBR Model XR-620 CTD (Conductivity, Temperature, Depth) profiling instrument, calibrated to factory specifications. The CTD has a readability of 0.001°C, 0.001 pH units, 0.001% oxygen saturation, and 0.001 parts per thousand (salinity). It is lowered slowly through the water column and automatically records data six times per second. The laboratory testing for water quality variables is conducted by Marine

[3] Marine Research Consultants, Inc., 1039 Wa`akaua Place, Honolulu, HI 96822

[4] Grasshoff, K. 1983. Methods of seawater analysis. *Verlag Chemie, Weinheim*, 419 pp.; Strickland J. D. H. and T. R. Parsons. 1968. *A practical handbook of sea water analysis*. Fisheries Research Bd. of Canada, Bull. 167. 311 pp.

Analytical Specialists in Honolulu, Hawai`i. Marine Analytical Specialists possesses an acceptable rating for EPA-compliant proficiency and quality control testing.

Screening for *Enterococci* bacterial contamination is conducted by Analytical Services Inc.[5] Water samples are collected from a depth of 2 feet using a Niskin sampler and transferred to sterile containers. Collected samples are placed in a cooler containing an ice pack and then transported to the lab for immediate processing. Standard Method 9230C, membrane filter procedure (mE1 Agar, 24h incubation at 41°C) is used for the detection and enumeration of *Enterococci* bacteria in water as described in *Standard Methods for the Examination of Water and Wastewater*[6].

*Chara Percent Coverage and Canopy Height*

Preliminary surveys within the lagoon found that the canopy-forming macro alga *Chara zeylanica (Chara)* covers most of the lagoon bottom. Estimates of percent *Chara* coverage on the lagoon bottom and average canopy height above the bottom are made monthly by Aquatic Research Consultants LLC[7] at designated stations using SCUBA diving transects 50 m (~165 feet) in length, each starting from the station marker buoys and each carried out along predetermined headings. At each site, the beginning and end of each transect are marked with buoys, and the GPS location for each is noted. The percent cover of *Chara* is determined using the point contact method. The presence/absence of *Chara* is measured at every 1 m increment, for a total of 50 points sampled. The % cover of *Chara* is calculated as the percentage of the points sampled where *Chara* is present. For example, if a diver noted that *Chara* is present at 14 of 50 points sampled along the transect, then the coverage equals 28%. The *Chara* canopy height is measured every 5 m, if present, along the transect.

*Tilapia Nest Occurrence*

In addition, during the *Chara* coverage and height surveys, when water clarity allows for accurate enumeration, the number of Tilapia (*Oreochromis mossambicus*) nests are counted to a distance of 1 m from the transect along one side of the transect. Visibility at depth is also noted along the transect line over un-vegetated (bare sediment) and vegetated (*Chara*) areas.

*Chara Nitrogen Stable Isotope Ratios*

The ratio found in *Chara* plant tissue between the stable heavy isotope of nitrogen ($^{15}N$) and the more commonly occurring isotope ($^{14}N$) is related to the potential sources of the nitrogen nutrients[8] assimilated into the alga from the ambient water. The indicator variable used, $\delta^{15}N$, is normalized to the ratio of these two isotopes found in the atmosphere.[9] The $\delta^{15}N$ values for this monitoring effort are determined at the Biogeochemical Stable Isotope Facility for Stable Isotopes at the University of Hawai`i.[10]

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[5] P. O. Box 62311, Honolulu, HI 96839 808-358-0414, pfang@hawaii.rr.com

[6] Clesceri, L. S., A. E. Greenberg, and D.A. Eaton. 1998. *Standard Methods for the Examination of Water and Wastewater.* American Public Health Association. Washington, DC)

[7] Aquatic Research Consultants LLC, PO Box 61471, Honolulu, HI 96839

[8] Fertilizers, sanitary waste water, manure, and other potential sources of nitrogen nutrients all have distinctive ratios.

[9] $\delta^{15}N = 1000((R_x - R_s)/R_s)$, where $R_x$ is the $^{15}N$:$^{14}N$ ratio in the sample and $R_s$ is the corresponding ratio in air.

[10] http://www.soest.hawaii.edu/GG/isotope_biogeochem/index.htm

*C:N:P Ratios*

Carbon:Nitrogen:Phosphorus ratios (C:N:P) are analyzed for *Chara* tissue samples by the Agricultural Diagnostic Service Center at the University of Hawai`i at Mānoa.[11] These ratios provide some indication of which of these nutrients might be limiting for the growth of aquatic plants such as *Chara.*

*Irradiance Profiles*

Measuring irradiance, or light, in the Lagoon water column allows comparison of changes in the attenuation of light in the water over time due to increases or decreases in phytoplankton and other materials in the water. Irradiance profiles are measured mid-day at 1 m depth increments from just below the water surface to the Lagoon bottom (or top of the *Chara* canopy, as determined when the profiling line becomes slack). Measurements are only taken when weather conditions are clear and sunny. Profiles are conducted on the sunny side of the boat to minimize the effect of boat shadow. A LI-COR LI-1400 data logger coupled with a LI-COR underwater spherical quantum sensor mounted on a profiling frame with a 10 m LI-COR underwater cable is used to measure irradiance. Depth is measured with a line marked at 0.5 m increments. A spherical sensor is used instead of a cosine sensor, because the spherical sensor more accurately measures light in a manner consistent with how *Chara* absorbs light at depth. The Secchi depth is also recorded at each site to compare with the diffuse attenuation coefficient.

*Plankton Assemblages*

Samples for analysis of the plankton assemblage are collected to evaluate temporal and spatial variability, the stability of the microbial system, and to complement water chemistry measurements. Whole water samples[12] for phytoplankton and zooplankton determinations are collected in 1L dark bottles and 5 x 1-gallon plastic jugs respectively, from the surface waters of each station. Zooplankton samples are preserved on site; phytoplankton samples are immediately taken to the laboratory on ice and preserved within 2 hours for subsequent analysis. Because the size range of the plankton assemblage spans four orders of magnitude (<1 µm to >1 mm), a suite of different preservatives and methods is necessary to address each segment of the population. Detailed descriptions of these methods are available from Dr. Susan Brown of the University of Hawai`i at Mānoa[13]

**Data Time Series**

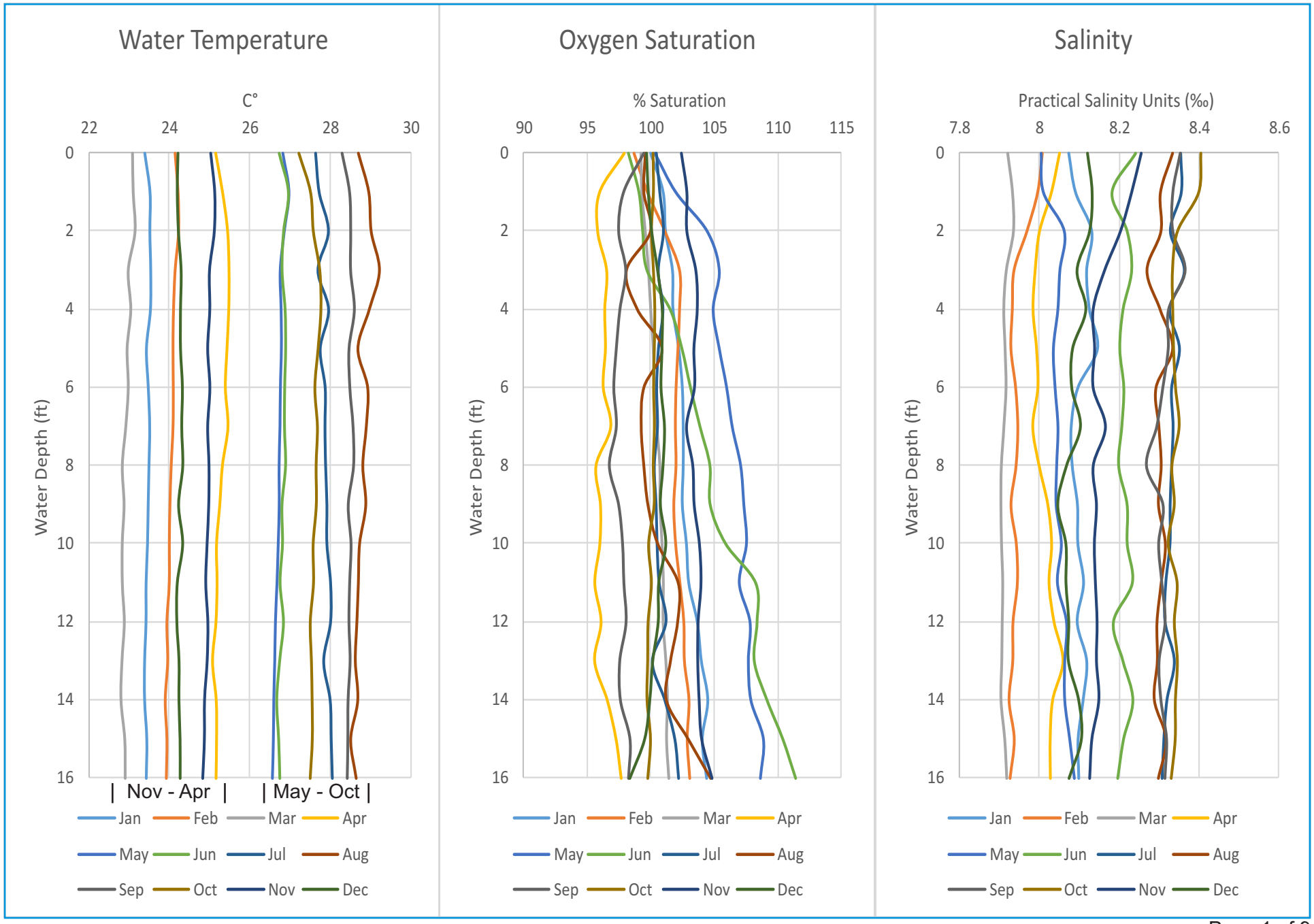
The following graphs present time series of the values for the variables described above, averaged for each collection date.

[11] http://www.ctahr.hawaii.edu/site/adsc.aspx

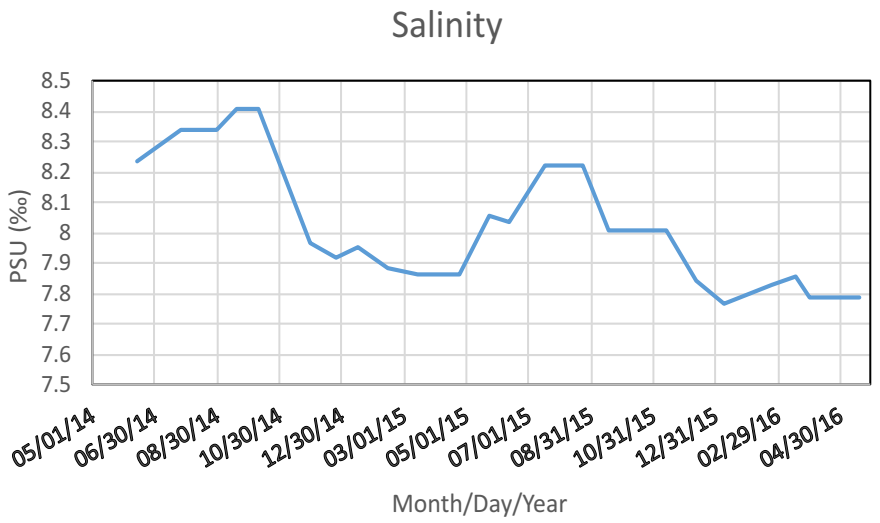
[12] Whole water samples are aqueous, non-filtered samples that contain natural colloidal and suspended particulate matter.

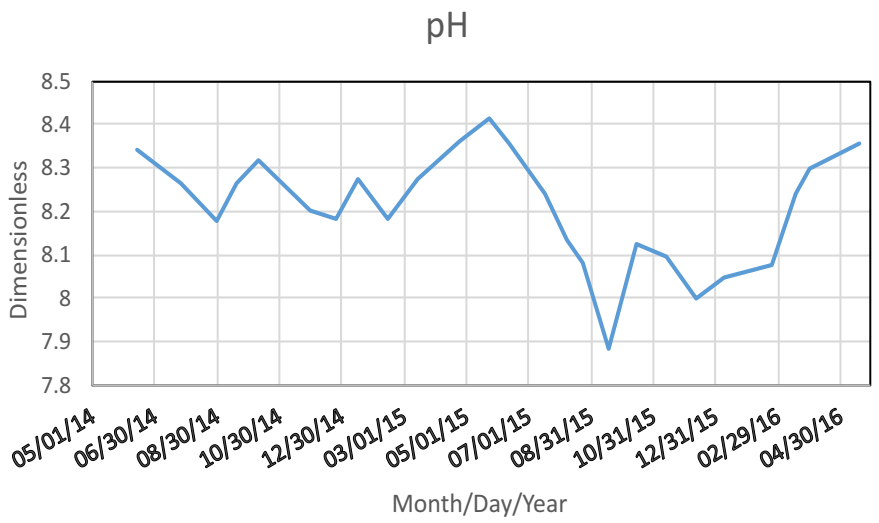
[13] Department of Oceanography Center for Marine Microbial Ecology, POST 105, Honolulu HI 96822, sbrown@apps.soest.hawaii.edu

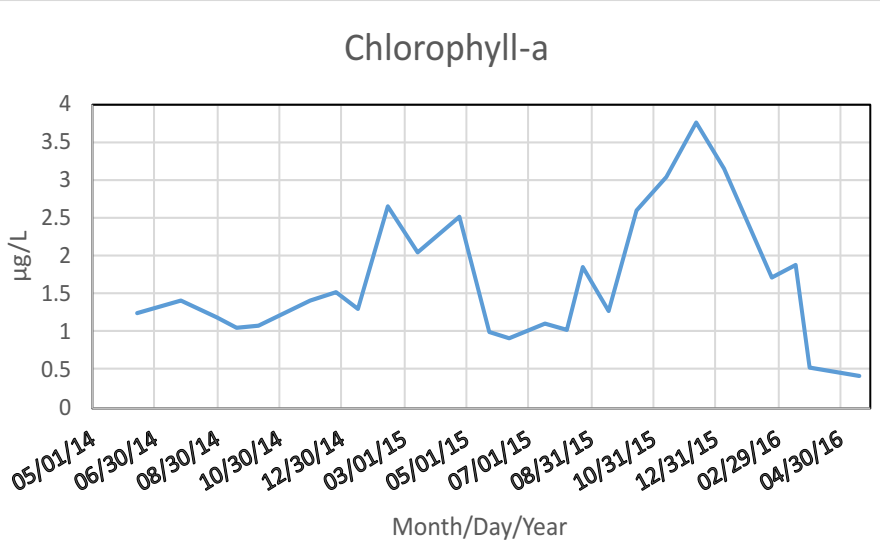
# Wai Kai Lagoon Depth Profiles
# (Average Monthly Values from June 2014 - May 2016)

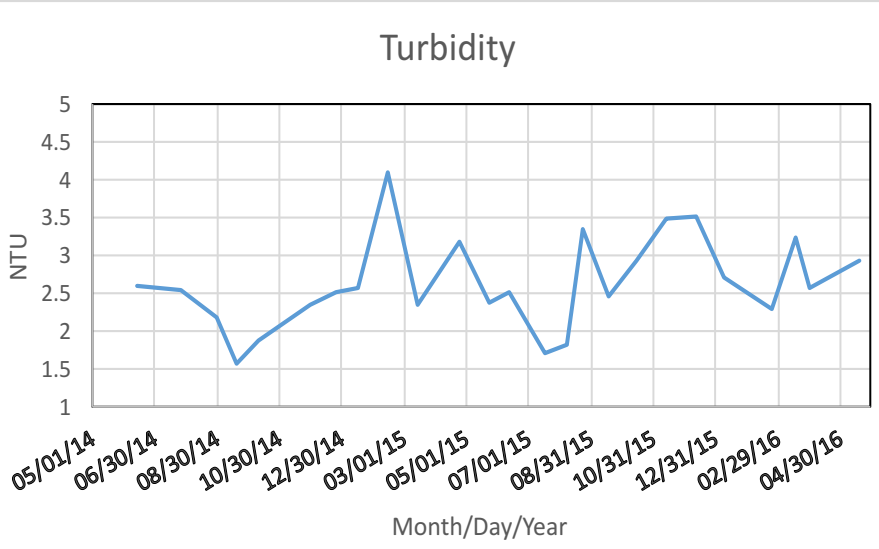


# Wai Kai Lagoon Water Quality Time Series, Indicator Variables (June 2014 - May 2016)

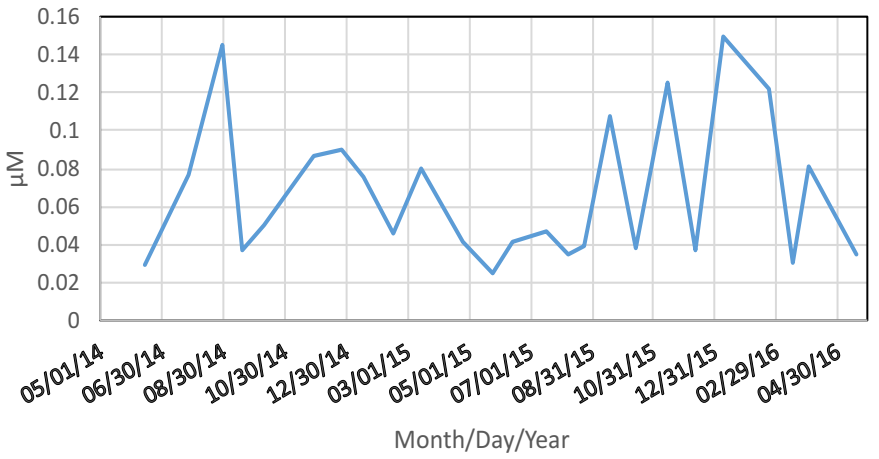


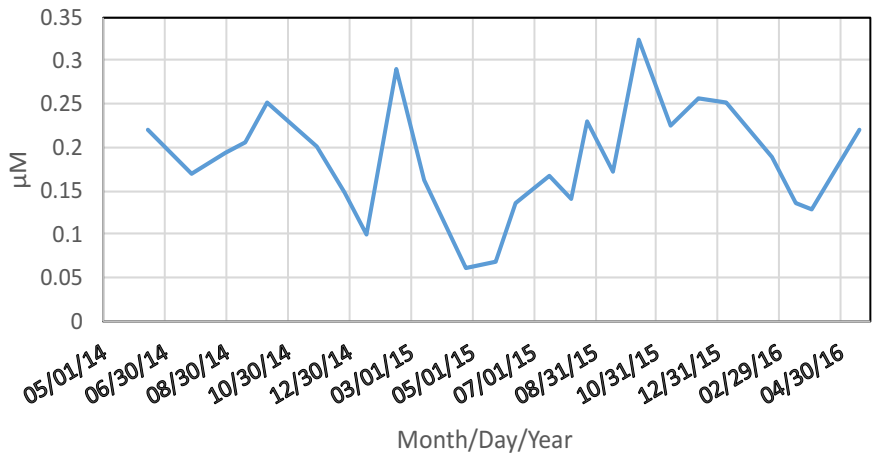



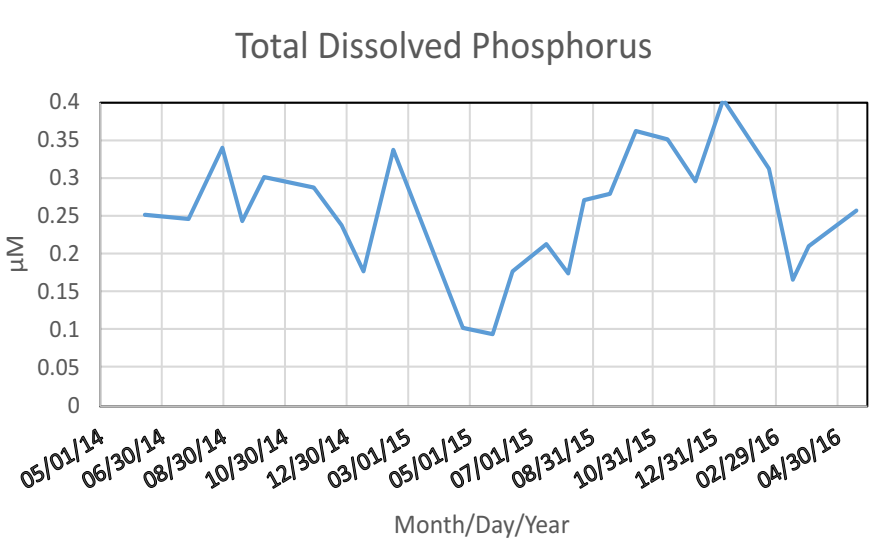



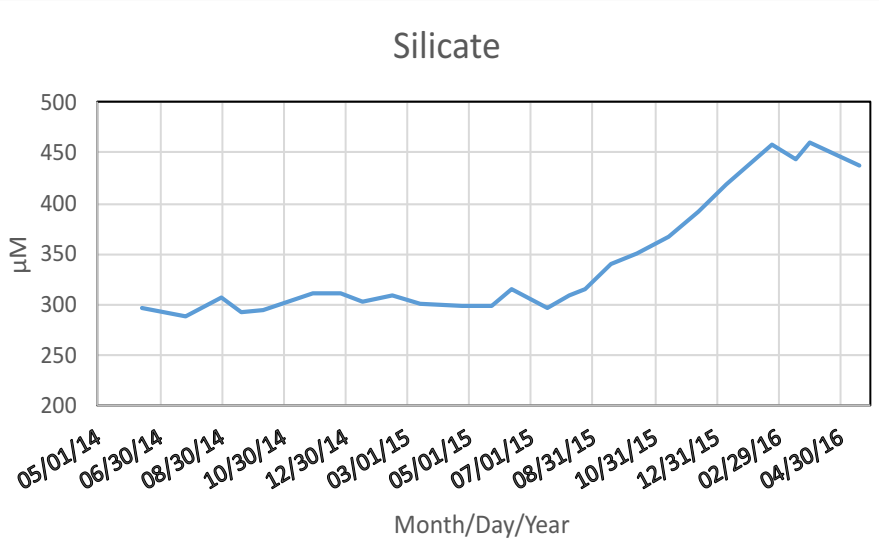



# Wai Kai Lagoon Water Quality Time Series
# Phosphorus & Silicate Nutrients
# (June 2014 - May 2016)

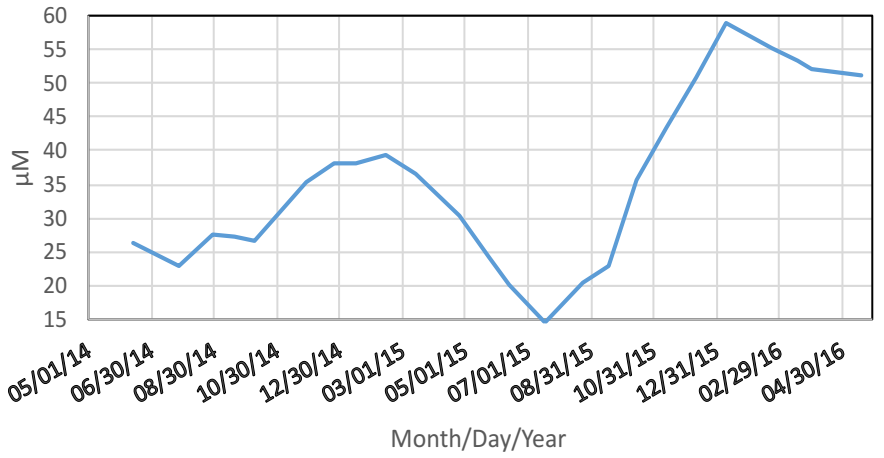


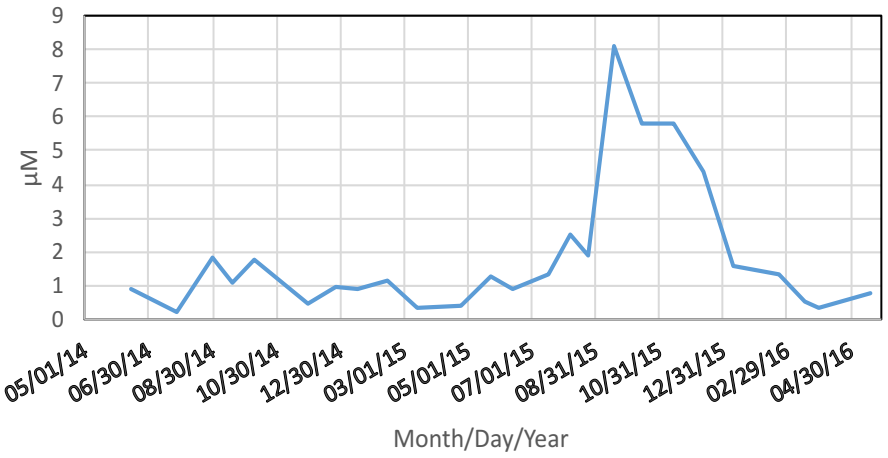



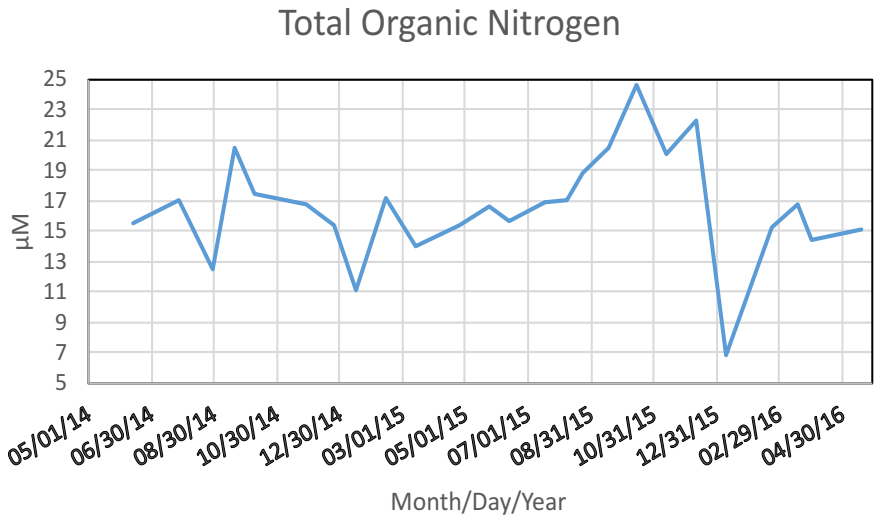



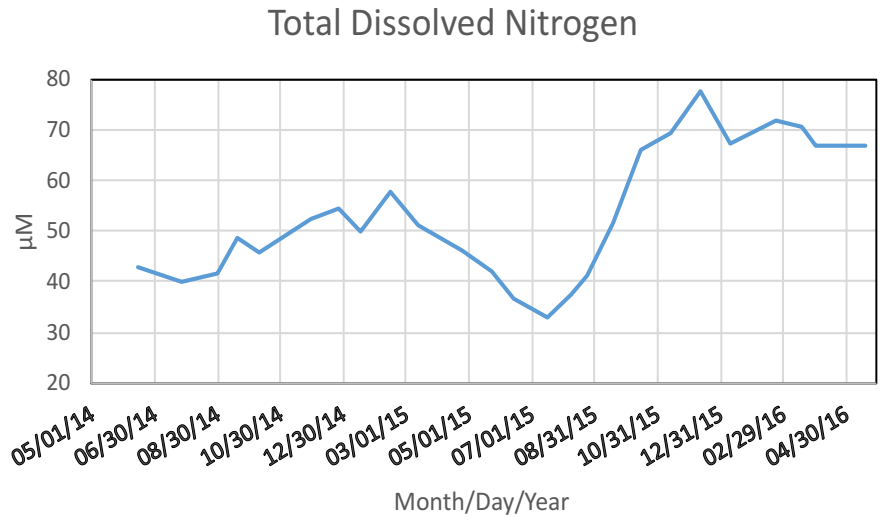



# Wai Kai Lagoon Water Quality Time Series
# Nitrogen Nutrients
# (June 2014 - May 2016)

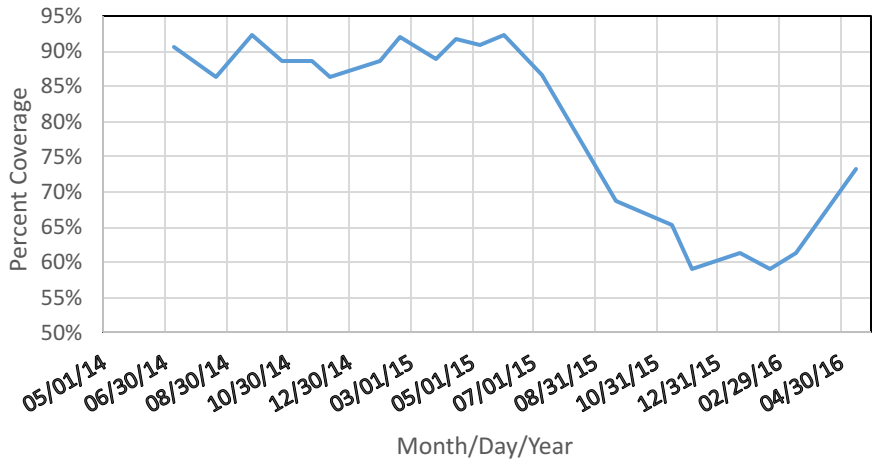


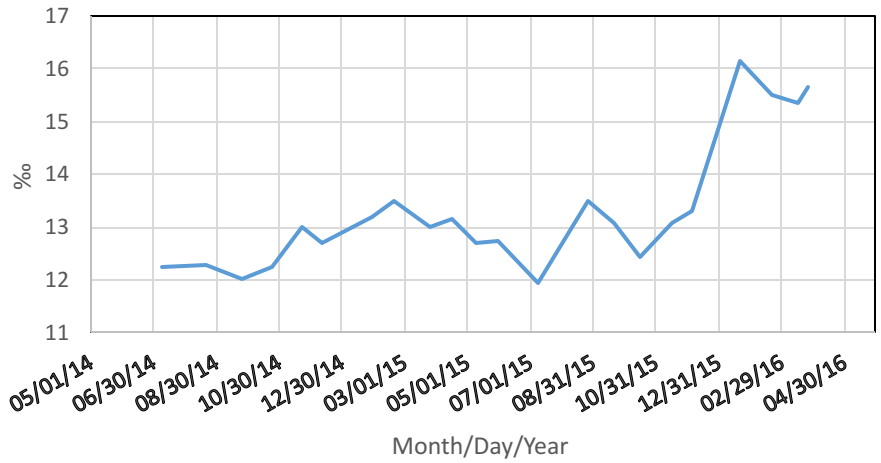



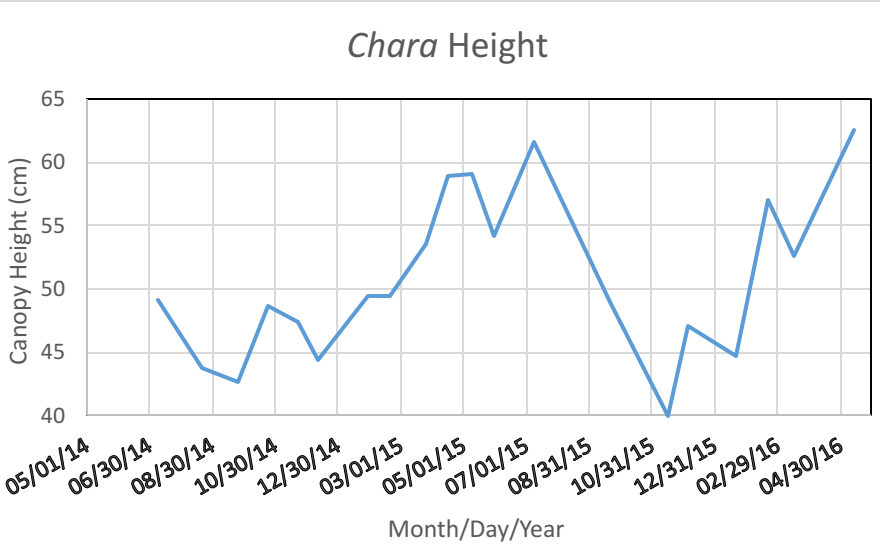



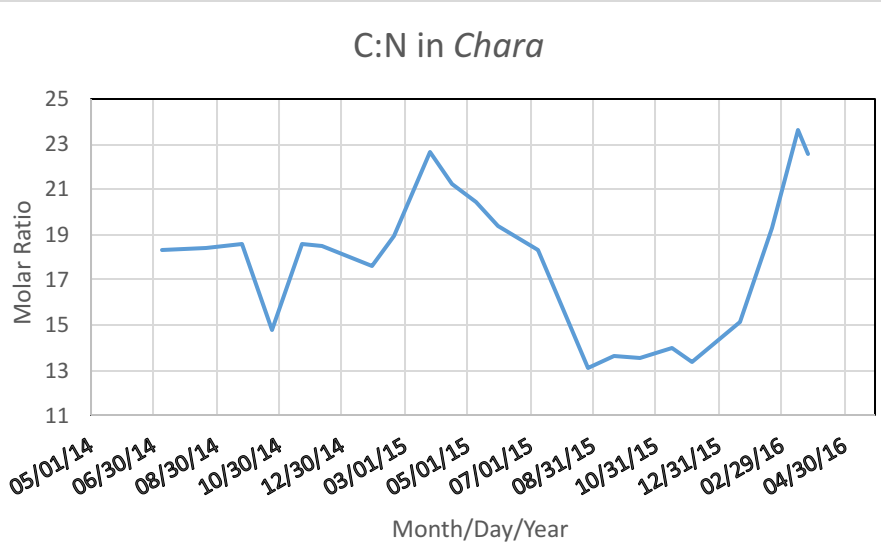



# Wai Kai Lagoon *Chara* Indicators
# (June 2014 - May 2016)

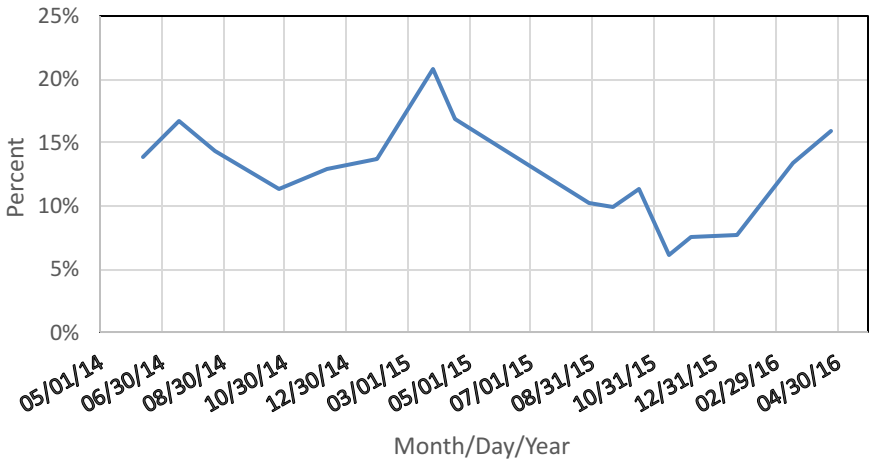


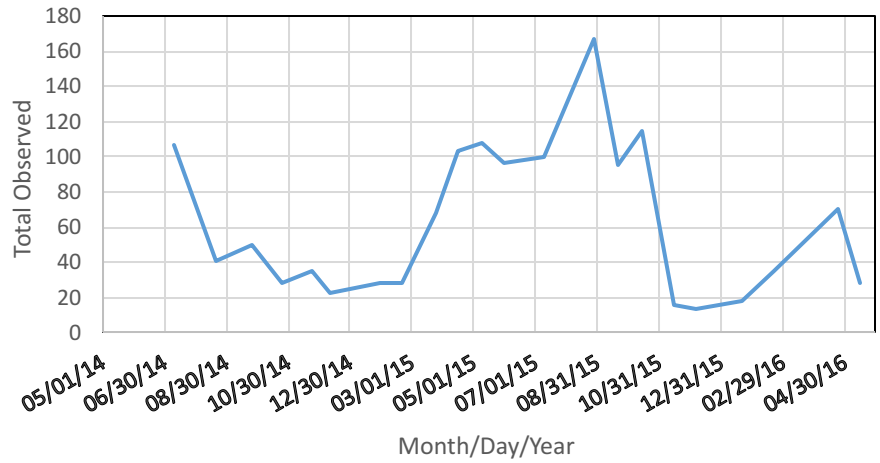



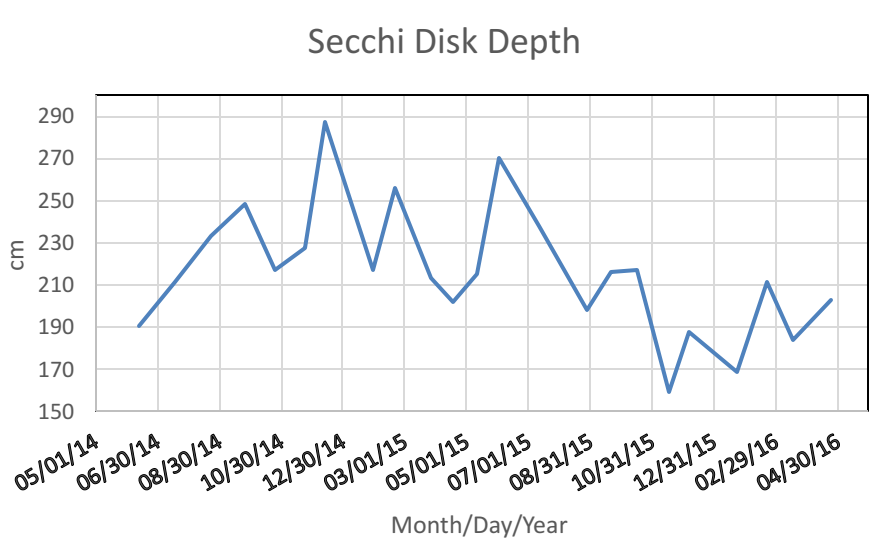



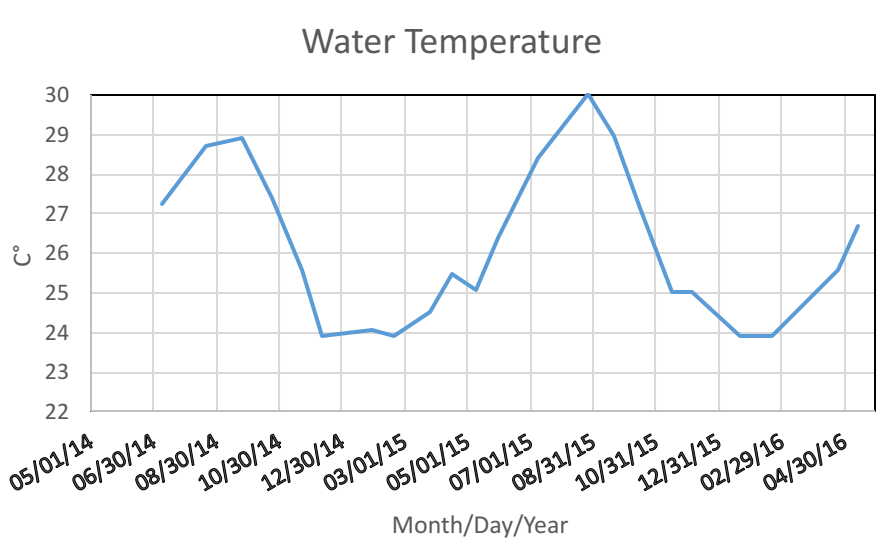



# Wai Kai Lagoon Water Clarity & Tilapia Nests
# (June 2014 - May 2016)

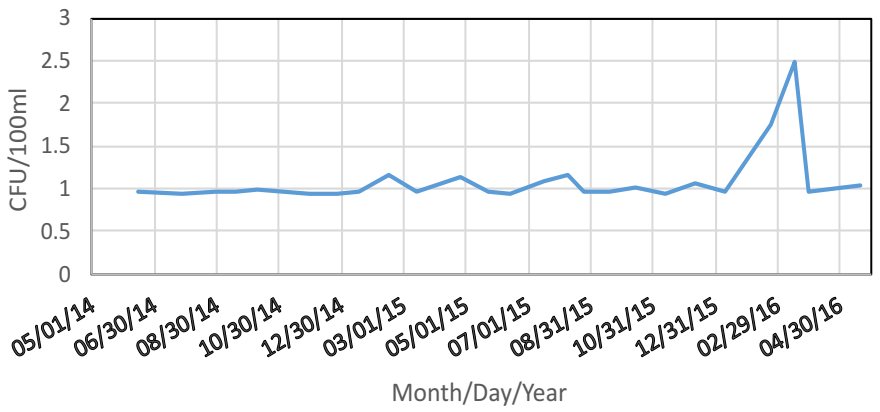


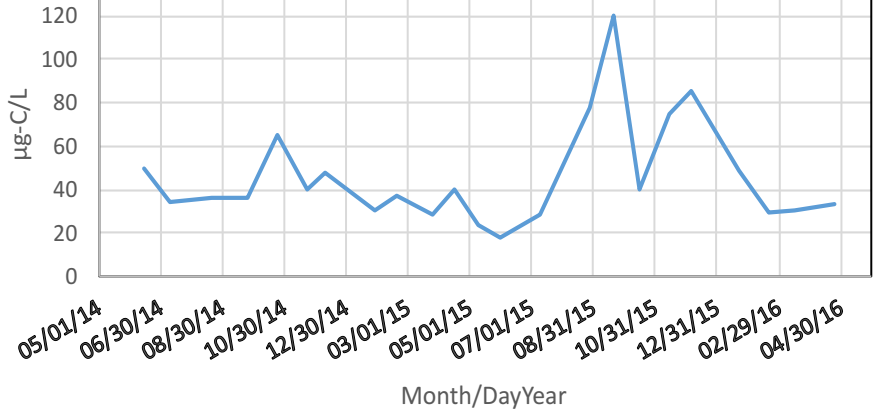



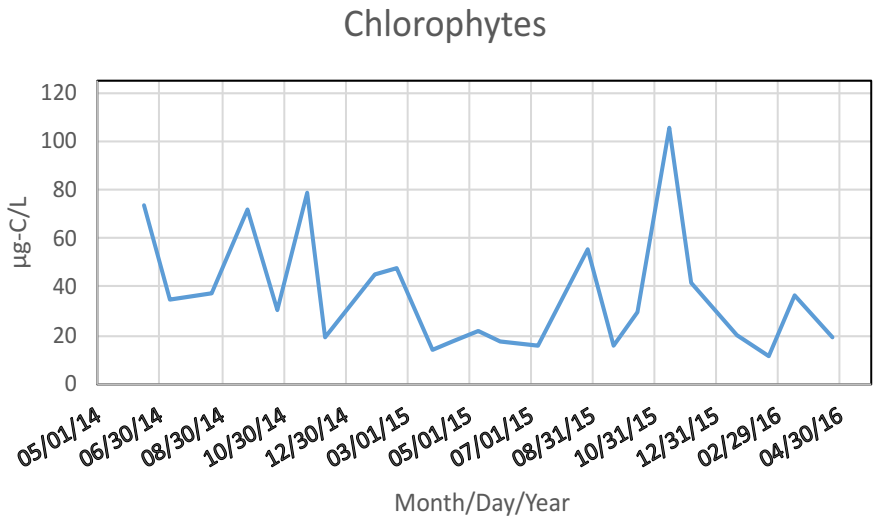



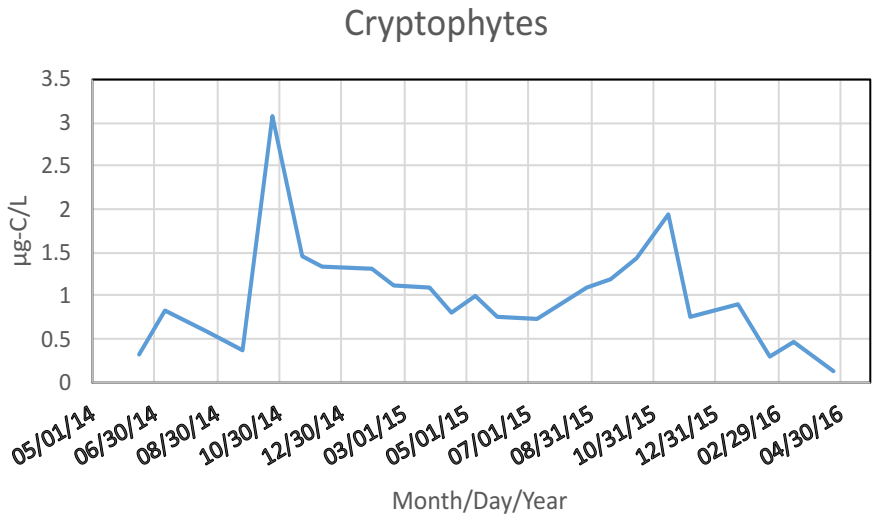



# Wai Kai Lagoon *Enterococcus* & Plankton(1)
# (June 2014 - May 2016)

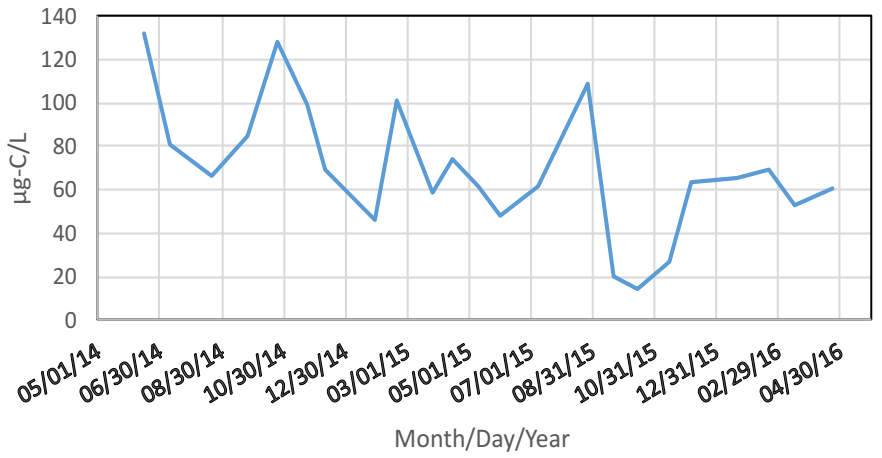


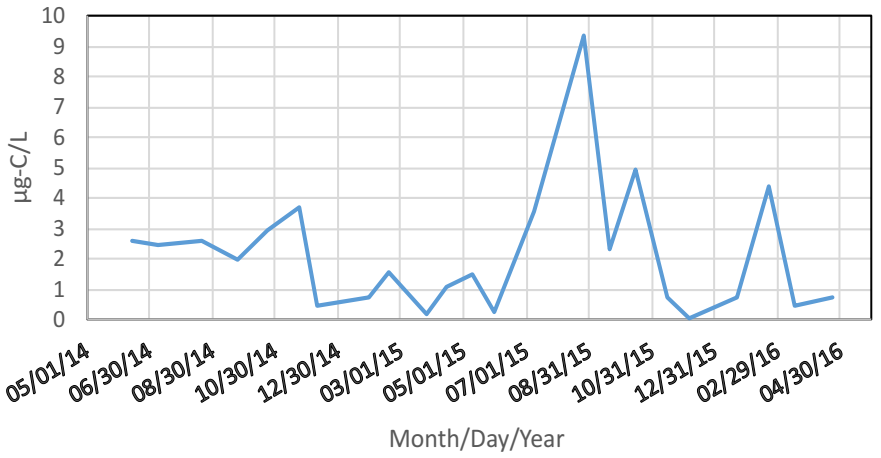



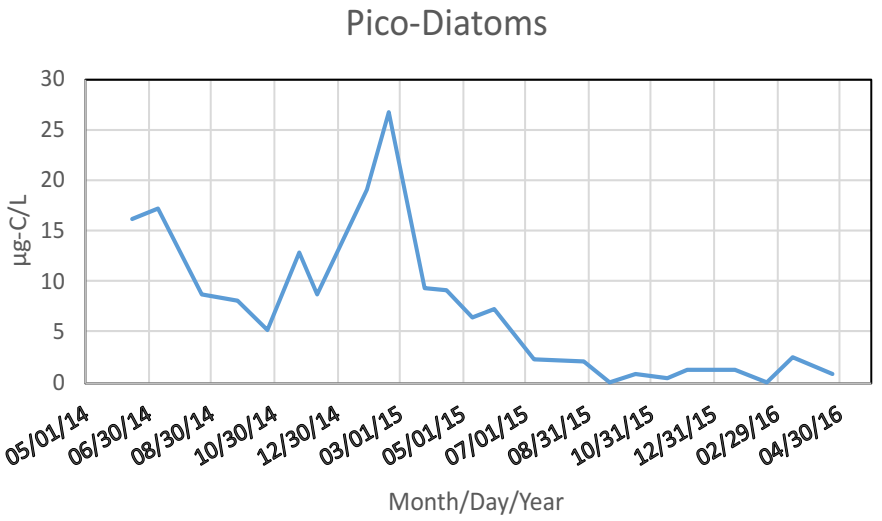



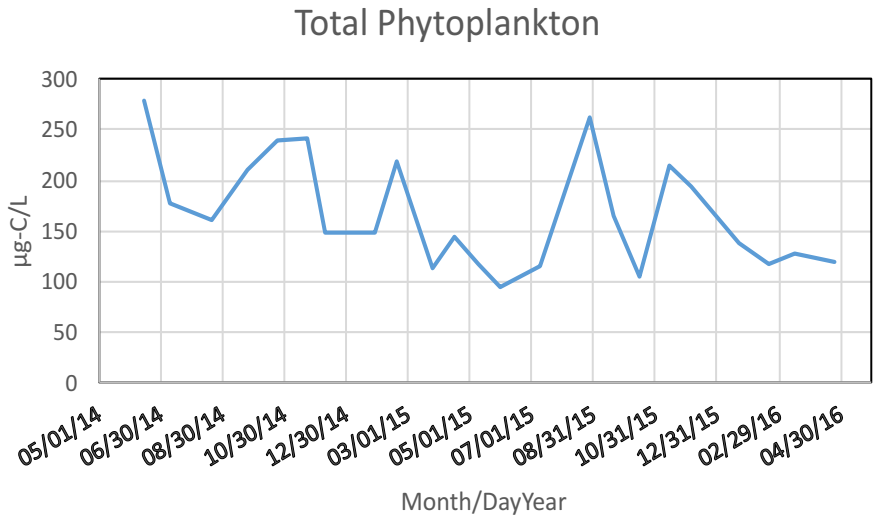



# Wai Kai Lagoon Plankton(2)
# (June 2014 - May 2016)



# Wai Kai Lagoon  Plankton(3)
# (June 2014 - May 2016)

