Monterey Bay, California: A Window into the North Pacific Ecosystem

SEASONAL PHYTOPLANKTON DYNAMICS IN SIXTEEN YEARS OF TIME SERIES DATA

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ABSTRACT

Shipboard occupations of three stations within the coastal upwelling system near Monterey Bay, California, have been made each 2-3 weeks over the past 16 years. The system is characterized by strong spatial and short-term temporal structure. In this poster we smooth temporal variations to explore seasonal phytoplankton dynamics and differences between the three stations. Phytoplankton dynamics are controlled by seasonal upwelling, currents, mixing and phytoplankton:nutrient coupling.

Phytoplankton carbon is dominated by diatoms year-round, and diatom abundance cycles account for most of the seasonal change in phytoplankton carbon. Mar-Jul is an upwelling period rich in nutrients with peak phytoplankton productivity, biomass and centric diatom carbon. Aug-Oct is an 'oceanic' period influenced by the California Current with moderate though declining nutrient, phytoplankton productivity and biomass values, but peak pennate diatom, dinoflagellate and picophytoplankton carbon. A Nov-Feb winter period is influenced by storm-related onshore transport, downwelling and deep mixing, with low macronutrients but high iron, low productivity and biomass, and less but still dominant diatom carbon.

SUMMARY

- Sixteen years of time series data are averaged and smoothed to examine seasonal station to station differences in phytoplankton and nutrient measurements.
- Nearshore during spring and summer are the most productive; offshore during winter is the least productive.
- Diatoms dominate, especially nearshore during the upwelling period.
- Centric diatoms peak several months earlier than pennate diatoms, dinoflagellates and picophytoplankton.
- Surface nitrate averages >3 uM, and phosphate and silicate are present in excess of Redfield.
- The nearshore diatom-dominated flora at C1 may be nitrate limited and show elevated POC sinking, even at 3-5 uM NO_3.
- The offshore picoplankton-domnated flora at M2 does not appear nutrient limited, even at 1-2 nM iron, though there is evidence of iron stress.

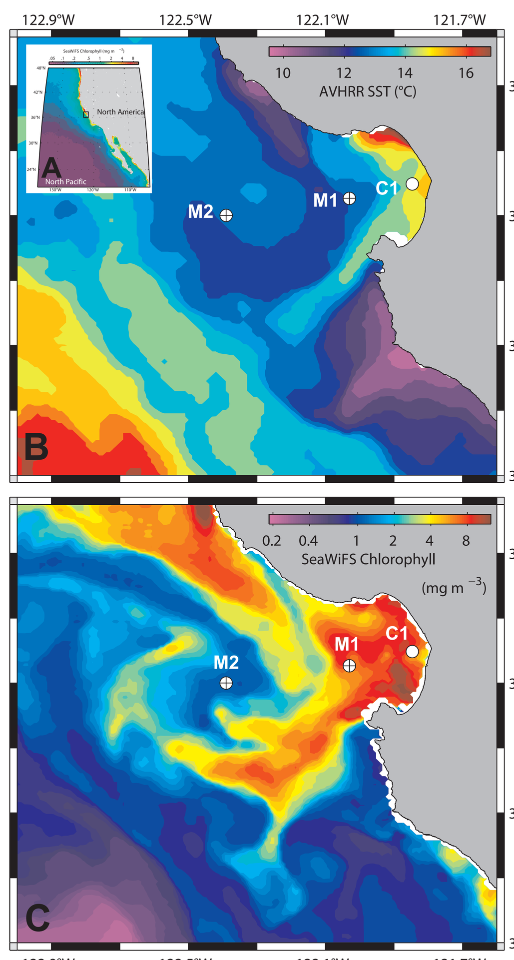

Figure 1

INTRODUCTION

The coastal upwelling system (CUS) off western North America lies within an eastern boundary current region, as shown in the SeaWIFS **(Figure 1A, inset, and C)** and AVHRR **(Figure 1B)** images. Off Monterey Bay, nearshore hydrography can be divided into three regions and seasons. In spring and summer, northwesterly winds drive a near-surface coastal upwelling jet across the mouth of Monterey Bay. Inside the bay, a cyclonic eddy recirculates upwelled water. Offshore, CUS and CC waters mix across a region of fronts and eddies called the coastal transition zone (CTZ). In fall, coastal upwelling relaxes and CC influence increases in all three areas. In winter, with onset of southerly storm winds that drive onshore transport and downwelling, surface waters are influenced by the CC and deep mixing. Cruises to these regions were conducted every 2-3 weeks (**Figure 1B - C**). In spring and summer the upwelling jet station (M1) experiences nearly fresh upwelled water (1-3 da). The in-Bay station (C1) receives aged upwelled water (1-3 wk). Offshore station (M2) has upwelled water mixed with CC water. During the fall and winter, station to station differences are less pronounced. Time series for selected parameters, **Figure 2**, with stations averaged. The series are characterized by strong short-term fluctuations (blue dots), seasonal cycles (red line), interannual fluctuations (red line), and small residual trends (green line). We collapse the years and smooth the data to focus on (1) seasonal pattern and (2) station to station differences. We place emphasis on (3) phytoplankton taxa and (4) phytoplankton:nutrient coupling.

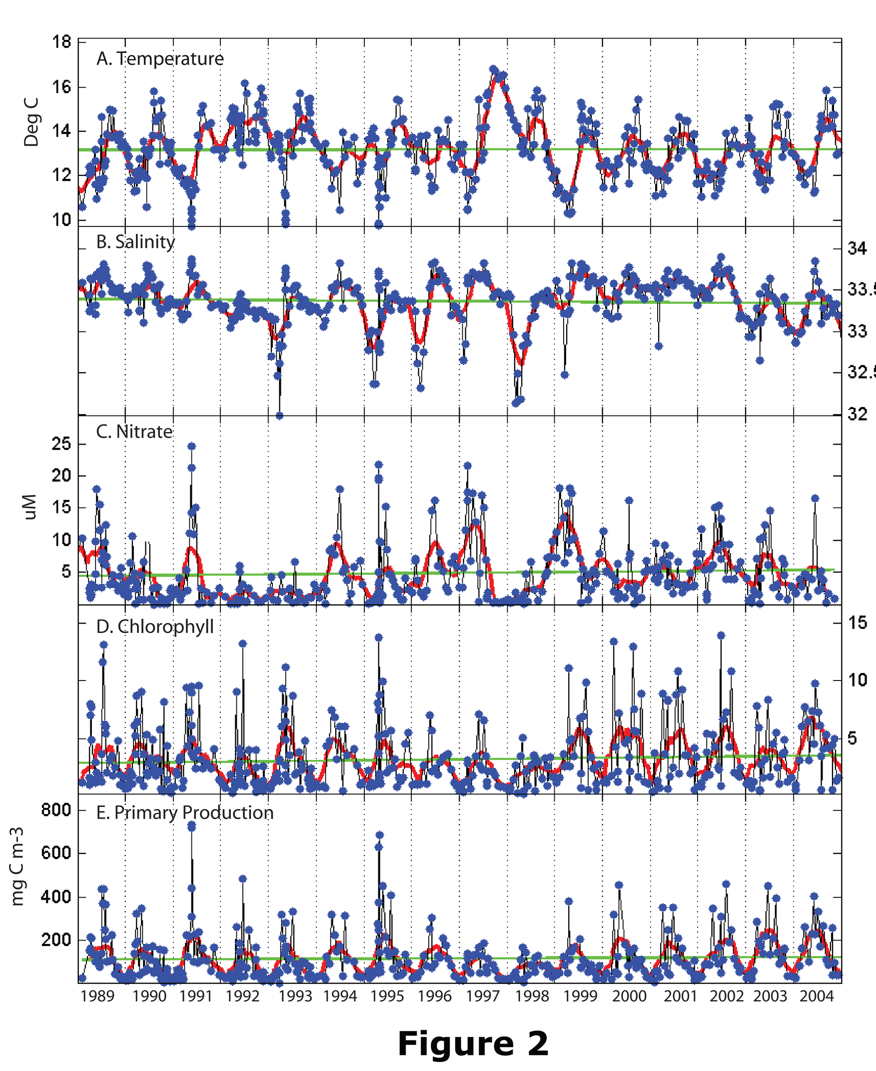

Figure 2

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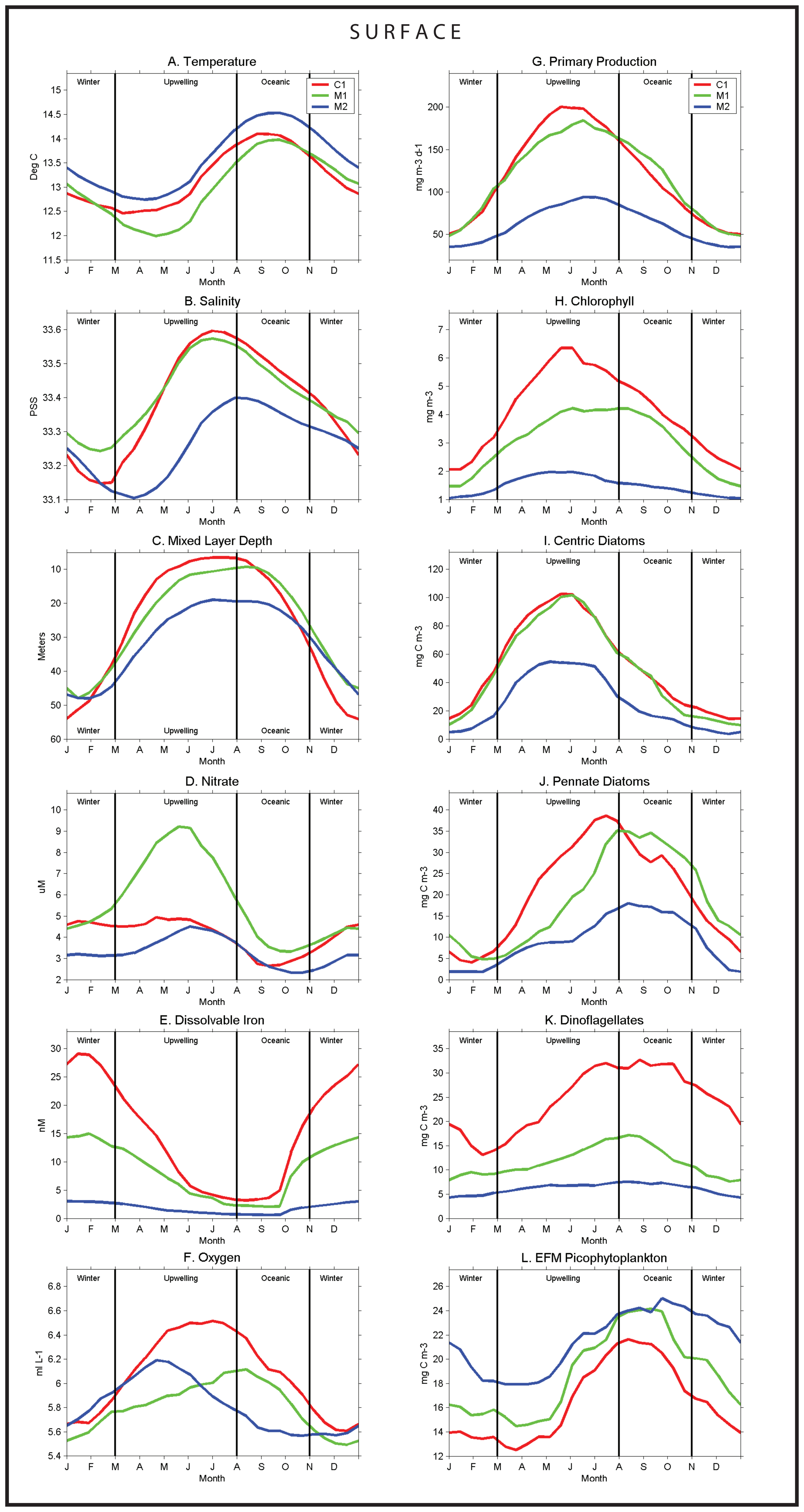

Figure 3

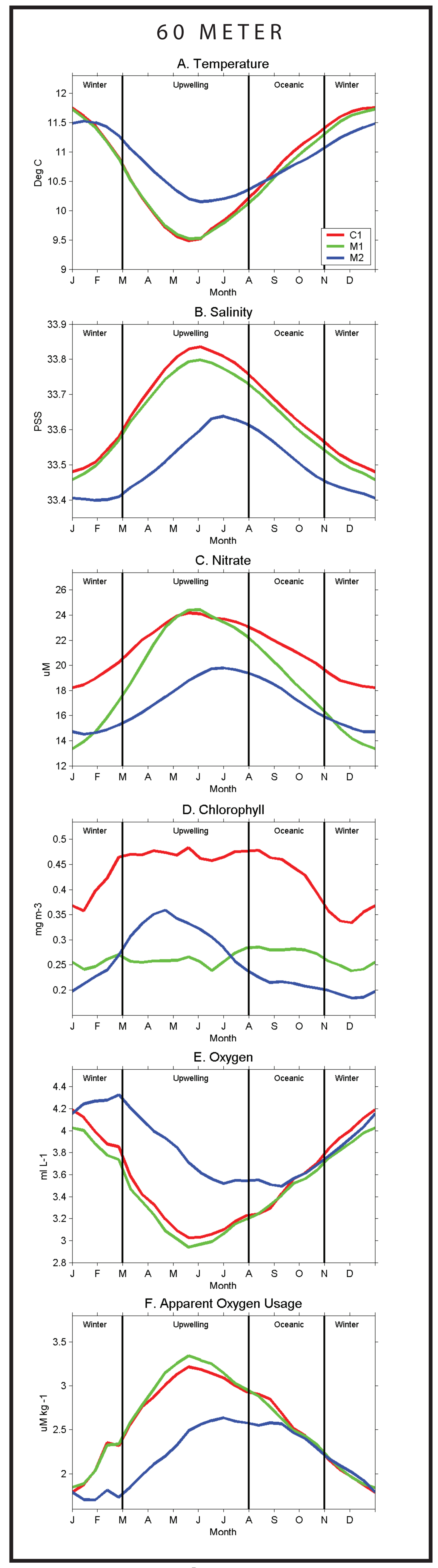

Figure 4

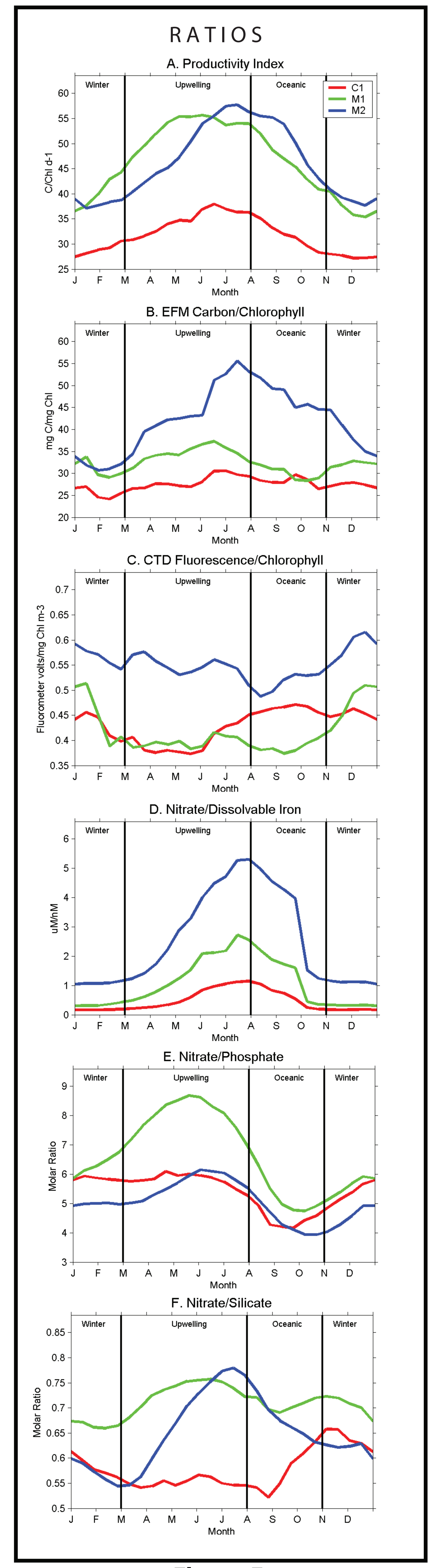

Figure 5

RESULTS

Figures 3, 4, and 5 Average annual cycles with upwelling jet station (M1) in green, the in-bay station (C1) in red, and the offshore station (M2) in blue. The raw data were averaged as a canonical year then smoothed with a 14 day Stineman interpolation followed by a 9 point moving average. The vertical black lines divide the upwelling, fall oceanic and winter periods. Surface temperature **(3A)** is coldest during the upwelling period and warmest during fall at all stations. Temperature at 60 m **(4A)** however is warmest in winter. Peak surface salinity occurs in Jul-Aug **(3B)**, well after the coldest temperatures, and the CC-influenced M2 is much fresher than the inshore stations which are very similar. Freshwater runoff is seen as a winter and spring freshening of C1 versus M1 surface salinity **(3B)**. 60 m salt **(4B)** cycles similarly, but 2 months in advance of the surface at all three stations. Mixed layer depth **(3C)** is deepest in winter/offshore and shallowest in summer/onshore. Nitrate exhibits strong seasonal cycles at 60 m at all stations **(4D)**, but not at C1 or M2 at 0 m **(3D)**, apparently due to biological drawdown at C1 and drawdown and mixing at M2. Average surface nitrate **(3D)** is usually >3 uM, even offshore at M2. At all stations dissolvable iron **(3E)** is highest in winter, declines over the upwelling period and is lowest during the late upwelling and fall oceanic period. C1 iron shows the strongest seasonal cycle reflecting winter input from the shelf or shore, while M2 iron is low year-round and only 1 nM in Jul-Sep. Surface primary production and chlorophyll **(3G-H)** peak late in the upwelling period, with the highest values at C1, M1 and M2, respectively. Primary production peak occurs offshore later. This 'offshore later' trend can be seen inin several parameters and apparently reflects seasonal development of the CUS. Centric diatom carbon **(3I)** is highest during the upwelling period when it dominates phytoplankton carbon at all stations. Pennate diatom **(3J)**, dinoflagellate **(3K)** and picophytoplankton **(3L)** carbon are all highest during the late upwelling or oceanic periods. 60 m chlorophyll **(4D)** is much higher at C1 than M1 or M2, perhaps indicating elevated POC export at this station. Surface oxygen **(3F)** is highest while 60 m oxygen is lowest **(4E)** during the upwelling and oceanic periods, reflecting oxygen evolution during photosynthesis at the surface and seasonal shoaling of the oxygen minimum at 60 m. The curves for 60 m apparent oxygen usage **(4F)** are essentially the inverse of those for 60 m oxygen and are very similar to 60 m salinity and nitrate, suggesting that AOU in this environment is controlled by upwelling and seasonal shoaling of the oxygen minimum rather than remineralization. **Figure 5** ratios phytoplankton and nutrient parameters. Productivity indices (productivity/chlorophyll) **(5A)** are much higher at M1 and M2, suggesting that growth of phytoplankton at C1 is limited. C1 has the lowest nitrate/iron ratio **(5D)** of the three stations, which could be nitrate limited. M2 carbon/chlorophyll ratios **(5B)** are higher than at C1 and M1 and peak Jul-Sep, possibly reflecting iron stress which does not depress the M2 productivity indices **(5A)**. Interestingly, CTD fluorescence/chlorophyll **(5C)** is also higher at M2, perhaps again suggesting iron stress. Nitrate:phosphate and nitrate:silicate ratios **(5E-F)** are always below Redfield (106C:16N:P:Si), indicating phosphate and silicate are not limiting. **Figure 6** seasonal phytoplankton epifluorescence microscopy by station. Abundances decrease from spring/nearshore to winter/offshore, with non-diatom carbon relatively more important in winter and offshore.

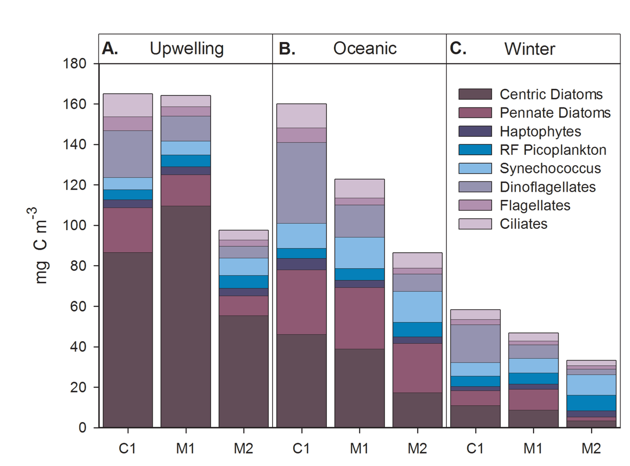

Figure 6