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Late Summer Plankton Community Variation in Near Shore Environments

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Abstract

Phytoplankton communities have profound impacts on ecosystem health and function. In the Southern California Bight, hydrographic conditions play a key role in determining the composition of phytoplankton communities. This study conducted hydrographic and plankton community analyses of the nearshore environment off Dana Point, California, during late September. Similar to other studies in the SCB during fall, we observed weakly stratified, oligotrophic waters dominated by dinoflagellates under 10 μm. However, the recorded plankton abundances onshore vs. offshore deviated from the "green ribbon" typical of the SCB, in which phytoplankton are much more abundant onshore than offshore. Additionally, while the onshore community was dominated by *Ceratium furca*, the offshore community was dominated by *Lingulodinium polyedra*. *L. polyedra* is known to form Harmful Algal Blooms (HABs), and the presence of this toxic dinoflagellate appears to have impacted community dynamics in the nearshore environment off Dana Point.

Introduction

Phytoplankton rank among the most impactful taxa on Earth, accounting for roughly half of all primary productivity (Field et al., 1998; Falkowski et al., 2004). The importance of phytoplankton community composition cannot be overstated, as the abundance and diversity of these primary producers influences biogeochemical cycles and higher trophic levels (Falkowski et al., 2004). For instance, the size class of phytoplankton in the community has been shown to impact the rate of carbon transport out of the euphotic zone (Krause et al., 2009), with carbon sequestration by diatoms being more efficient due to the mass of their silica frustules (Smetacek,

1999). Additionally, phytoplankton community composition impacts higher trophic levels: the copepod *Arcatia tonsa* demonstrated elevated ingestion rates when fed diatoms as opposed to dinoflagellates, suggesting diatoms were a higher quality energy source (Tirelli and Mayzaud, 2005). Since different phytoplankton taxa possess varying nutritional value, the community composition directly influences zooplankton size structure and the feeding of juvenile fish, both of which impact fishery production (Verity et al., 2002; Rykaczewski and Checkley, 2008). Additionally, certain phytoplankton produce harmful toxins that damage water quality and accumulate in higher trophic levels, emphasizing the critical importance of plankton community composition to ecosystem function and health (Anderson et al., 1998; Huisman et al., 2005).

The ways in which plankton meet their energy demands can also have an impact on the broader ecosystem. Approximately one third of all microzooplankton are mixotrophs, meaning they engage in phototrophy and phagotrophy (Stoecker et al., 2009). Mixotrophy has been shown to boost both primary productivity and biomass transfer to higher trophic levels (Stoecker et al., 2017), indicating that even how plankton meet nutritional demands has broad importance.

The environmental conditions in oceanic ecosystems drive changes in phytoplankton abundance and community composition. Diatoms tend to dominate phytoplankton communities when waters are nutrient rich and highly turbulent, conditions often found in areas of upwelling, while more motile dinoflagellates dominate in stratified conditions (Smayda and Trainer, 2010; Zheng et al., 2023). Given the importance of plankton community composition to ecosystem production, function, and structure, understanding the seasonal trends in an ecosystem and how they affect plankton communities is vastly important.

Primary production by phytoplankton is highest in continental shelf seas (Behrenfeld and Falkowski, 1997). One such region is the California Current System (CCS), which runs along the

Eastern boundary of the North Pacific. The CCS is characterized by seasonal variations in wind-driven upwelling that impact water temperature and nutrient concentrations. Throughout the CCS, there is a strong connection between phytoplankton community structure and these seasonal variations, with diatoms typically dominating during spring upwelling and dinoflagellate blooms occurring with autumnal stratification (Barth et al., 2020) .

The Southern California Bight (SCB) is a sub-section of the CCS stretching from Point Conception to the U.S.-Mexico border. The SCB exhibits the typical seasonal characteristics of the CCS, with diatoms dominating nutrient rich waters during spring upwelling and dinoflagellates dominating during more stratified fall conditions (Goodman et al., 2012). There is also spatial variation in plankton communities in the SCB. Lucas et al. (2011) reported that surface primary production was up to five times greater onshore than it was offshore in the southern SCB. Similarly, Goodman et al. (2012) observed elevated phytoplankton abundances along the inner shelf of the SCB relative to the outer shelf, attributing this gradient to higher nitrate concentrations near-shore (Goodman et. al, 2012). These studies point to a “green ribbon” model of the SCB, where inner shelf abundances and productivity tend to be higher than they are over the outer shelf.

The goal of this study was to determine the relationship between late summer hydrodynamics, trophic relationships, and microplankton community composition in the nearshore environment of the Southern California Bight off the coast of Dana Point. Hydrographic data were collected to determine if the water column has the expected characteristics of a southern SCB ecosystem in September, and whether this varies onshore and offshore. **It was hypothesized that the water column would be weakly stratified and have low surface nutrients both onshore and offshore, as is characteristic of the SCB in late**

summer (Lucas et al., 2011; Goodman et al., 2012; Barth et al., 2020). Plankton community abundances and diversity were studied to determine if September hydrodynamic characteristics influence plankton community composition off Dana Point, and whether the abundances and diversity of plankton differs onshore and offshore. **It was hypothesized that abundances would be higher in onshore waters due to the higher relative nutrient levels characteristic of the SCB, and that dinoflagellates would be dominant at both locations, as has been observed in late summer in the SCB** (Lucas et al., 2011; Goodman et al., 2012; Barth et al., 2020). **Additionally, we predicted that the microplankton community would be dominated by mixotrophic dinoflagellates, as previous studies have indicated that large blooms of mixotrophic dinoflagellates may be able to outcompete strictly phototrophic plankton** (Burkholder et al., 2008). Chlorophyll and cell size fractionation data were collected to determine the relative contribution of distinct size classes to total chlorophyll concentration. **It was hypothesized that plankton less than 10 µm would contribute the majority of chlorophyll concentration since the typical stratified, oligotrophic September conditions in the SCB favor smaller cell sizes** (Barth et al., 2020).

Methods

Study Area and Sampling

On September 23, 2023, the R/V *Sea Explorer* was taken from Dana Point to an onshore sampling site and an offshore sampling site, each over the continental shelf in the SCB (Table 1). The position of the onshore site had a bottom depth of 51.2 m. The offshore site had a bottom depth of 182.98 m. The onshore site was sampled before the offshore site, with the cruise lasting a total of 4 hours (1-5 pm PDT).

Hydrography

A Castaway CTD was deployed at both the onshore and offshore sites to measure temperature, density, and salinity following the manufacturer's instructions. The depths of the thermocline and mixed layer were recorded using real-time data from the CTD. CTD data was taken down to 31 m at the onshore site. The offshore collection was not recorded, so archived CalCOFI data collected in the same region in October, 2020 and August, 2022 was used instead.

A Secchi disk was deployed at each site to measure the depth of the euphotic zone, with two people confirming the depth.

Niskin bottles were used to collect water samples at both sampling sites at 6 depths (4, 8, 12, 18, 25, 31-37 m). Water from the Niskin bottles was transferred into acid-washed bottles. Aliquots of 250 mL of the water samples were poured over two different sized filters- GF/F filters and 10 µm filters. The filters were wrapped in foil and frozen for transport back to USD. The filtrate from the GFF filter was collected and used in nutrient analysis following the manufacturer instructions for a Seal Analytical AQ400 nutrient analyzer. One aliquot of seawater from 2 Niskin bottles at different depths at each site was returned refrigerated and unfiltered for particle size fractionation in a Coulter Counter upon return to USD.

Cell and Chlorophyll Size Fractionation

Once at USD, the unfiltered aliquots from the Niskin bottles were run through a Coulter Counter to determine particle size distributions. Additionally, chlorophyll analyses were performed. The GF/F and 10 µm filters were placed into labeled, acid-washed 50 mL conical tubes with 10 mL of 90% acetone for four hours to extract chlorophyll (Arar and Collins, 1997). For each filter in acetone, 1 mL of the liquid was transferred to a glass vial. A fluorometer was used to record the "before" acidification RFU and "after acidification" (30 µL of 0.1 HCl added) RFU. These values were used to calculate the concentration of chlorophyll a in each seawater

sample following the protocol outlined by Arar and Collins (1997). The concentration of chlorophyll a in the 10 µm filter was subtracted from the GF/F concentration to determine the percentage of the total composed of chlorophyll less than 10 µm in size.

Plankton Tow Data

Two five-minute plankton tows were conducted at each sampling site, one with a 300 µm mesh net and the other with a 20 µm mesh net. All tows were conducted at the surface, and the distance of the tow was determined using a flowmeter attached to the net. Ethanol was added to all plankton samples for a final concentration of 70% for preservation.

Both 300 µm mesh tows were divided into eight fractions using a Folsom splitter. All plankton in these fractions were counted and identified under a dissecting microscope. The 20 µm samples were mixed, then 1 mL transferred to Sedgewick-Rafter slides. Using a compound microscope, plankton in five distinct fields of view on the slide were counted and identified at 100x magnification. This was repeated for a total of 35 fields in the offshore sample and 58.155 fields in the onshore sample. The total number counted was divided by the volume counted and multiplied by the volume collected in the tow to determine total abundance. To determine total abundance per m^3 seawater the total abundance was divided by the area of the net openings times the distance recorded by the flowmeter. Shannon-Weiner Diversity, Simpson Diversity, and Margalef's Species Richness calculations were performed for each mesh size and sampling site.

Results

Hydrographic Data

The mixed layer depth at the onshore sampling site was approximately 10 m. The thermocline was recorded by the CTD as just above 10 m. The pycnocline appears to be around 11 m. There is no discernable pattern between salinity and depth at the onshore site (Figure 1). Our CTD data was not recorded at the offshore site. In place of it, we used archived CalCOFI

temperature, salinity, and density data from the same region in October 2020 and August 2022 (Figure 2). On both dates the mixed layer depth was less than 5 m, and the pycnocline and thermocline were around 10 m. The salinity profiles at both CalCOFI sampling times showed an initial decrease in salinity with depth until about 25 m, then a steady increase. The Secchi Depth at the onshore site was 12 m while it was 9 m at the offshore site, indicating a shallower euphotic zone offshore.

Phosphate concentrations were depleted at the surface and generally increased with depth at both the onshore and offshore sites (Figure 3). Nitrate concentrations did not follow the same pattern and were instead close to the lower limits of detection at all depths (Figure 4).

Chlorophyll and Cell Size Fractionations

At the onshore site, chlorophyll less than 10 µm made up the majority of chlorophyll a at each of the six depths (Figure 4.) This was least prevalent at 20.3 m where 51% of total chlorophyll was less than 10 µm, and most pronounced at 15.9 m where 89% of chlorophyll a was less than 10 µm. Similarly, the majority of chlorophyll a offshore was less than 10 µm, apart from the sample collected 4.4 m (Figure 5). This majority was most extreme at 30.6 m, with 99% of chlorophyll a being less than 10 µm (ignoring 7.6 m, where the data was incomplete).

Particles under 10 µm were dominant in all the water samples analyzed, both onshore and offshore (Figure 6). More than 99% of particles counted were under 10 µm.

Plankton Community Diversity

In the 20 µm net tows, four more phytoplankton taxa were caught offshore than onshore. The offshore site had a higher Margalef's species richness, but both sites had low values. Both the onshore and offshore phytoplankton communities had similar Shannon-Weiner diversity

values and Simpson diversity/evenness values, each indicating relatively low diversity/evenness relative to the maximum possible (Table 2).

Onshore, the most dominant phytoplankton taxa collected by the 20 µm net were *C. furca,* followed by *L. polyedra, P. micans, C. fusus,* and dinoflagellate cysts (Table 4). Offshore, the most dominant phytoplankton taxa collected by the 20 µm net were *L. polyedra, C. furca, C. fusus, Cochlodinium,* and a species of *Dinophysis* (Table 5). At both sites, dinoflagellates accounted for over 99% of phytoplankton. *C. furca, L. polyedra, and C. fusus* were especially dominant, making up over 85% of the communities. In both communities the top 5 taxa composed over 99% of total abundance. Mixotrophic plankton were more prevalent onshore (accounting for 99.7% of phytoplankton) than offshore (91.5% of total plankton).

Offshore, six more zooplankton taxa were collected in the 20 µm net than onshore (Table 2). While the Margalef's species richness was almost double offshore than it was onshore, both sites had similar, low values for Shannon-Wiener and Simpson diversity/evenness.

Onshore, the most dominant zooplankton taxa collected by the 20 µm net were copepod nauplii, adult calanoid copepods, ostracods, tintinnids, and appendicularians (Table 6). Offshore, the most dominant zooplankton taxa collected by the 20 µm net were copepod nauplii, adult calanoid copepods, *N. scintillans*, fish eggs, and radiolarians (Table 7). At both sites copepod nauplii and adults composed over 50% of the community, but were more dominant onshore, composing over 95% of the community. The top 5 taxa represented a larger share of the total abundance onshore (95.4%) than offshore (84.4%).

In the 300 µm net tows, one more zooplankton taxon was collected than onshore. The offshore zooplankton community had higher Margalef's species richness, Shannon-Wiener diversity, and Simpson diversity/evenness than the onshore community (Table 3).

Onshore, the most dominant zooplankton taxa collected by the 300 µm net were *A. danae*, *A. negligens,* fish eggs, Cladocerans, and Bryozoan larva (Table 8). Offshore, the most dominant zooplankton taxa collected by the 300 µm net were Cladocerans, *A. danae,* fish eggs, *M. pacifica*, and Bryozoan larvae (Table 9). Copepod species were more dominant onshore, with 4 species representing 85.4% of zooplankton, while offshore they only composed 33.4% of the community. *A. danae* was particularly abundant, making up 76.9% of the onshore community and 22.2% of the offshore community. The top 5 taxa composed a larger share of the total abundance onshore (97.8%) than offshore (85.7%).

There were more plankton collected in the 20 µm net per m^3 seawater filtered offshore than onshore (Table 10). Phytoplankton were more abundant than zooplankton in both locations, with this trend most pronounced offshore. However, there was a greater abundance of zooplankton collected in the 300 µm net per m^3 seawater filtered onshore than offshore.

Discussion

This study sought to determine the relationship between late summer hydrodynamics, trophic relationships, and microplankton community composition in the nearshore environment of the SCB near Dana Point.

Hydrographic Characteristics

We expected to observe weak stratification at both the onshore and offshore sites. The onshore CTD data indicated a shallow mixed layer (Figure 1), and archived CALCOFI data from the offshore sampling area in August 2022 and October 2020 also reports a shallow mixed layer (Figure 2). This study assumes that September offshore conditions would be similar. These observations are consistent with those reported in other studies conducted in the SCB during periods of weak stratification (Goodman et al., 2012).

It was also predicted that both sampling sites would have low nitrate and phosphate concentrations at the surface. Phosphates were depleted at surface waters relative to deep waters at both sites (Figure 3), similar to what was observed by Goodman et al. (2012) in the Santa Barbara Channel during fall stratification. The observed shallow mixed layer and depletion of phosphates in surface waters relative to those below the thermocline both indicate our sampling sites were weakly stratified, as is typical in SCB during fall. Nitrate concentrations were close to the lower limits of detection at all depths (Figure 3), indicating both the onshore and offshore sites were characterized by oligotrophic conditions. Nitrate concentrations have been shown to decrease with increasing temperature in the SCB, with previous studies indicating nitrate concentrations approach zero at temperatures exceeding 14^{o}C (Lucas et al., 2011; Zheng et al., 2023). Waters at both sites exceeded 14^{o}C at almost all depths, so our data matches expectations.

Phytoplankton Size Class

At both sampling sites, Coulter Counter data indicated that over 99% of particles were less than 10 μm (Figure 6), and chlorophyll fractionations revealed that the majority of chlorophyll was contained in cells less than 10 μm (Figures 4, 5). These data support our prediction that plankton less than 10 μm would be dominant at the onshore and offshore sites. The dominance of small cells is consistent with our own hydrographic characterization of the study sites and the results of other studies conducted in the SCB. We reported weakly stratified conditions with low surface nutrients, conditions that favor the growth of smaller phytoplankton taxa, i.e. dinoflagellates, as opposed to larger taxa, i.e. diatoms (Barth et al., 2020).

Plankton Abundance and Community Composition

We hypothesized that dinoflagellates would dominate the phytoplankton community at

both sampling sites. Data from the 20 μm net tows support this hypothesis: both sites had low Margalef's Species Richness, Shannon-Weiner Diversity, and Simpson's Diversity/Evenness values, indicating they were dominated by relatively few species (Table 2). Phytoplankton counts from 20 μm net tows further revealed that both the onshore and offshore sites were characterized by low diversity communities dominated by relatively few dinoflagellate taxa, with only a single diatom taxon identified and accounting for less than 0.1% of total abundance (Tables 4, 5). These low diversity, dinoflagellate dominated communities are similar to those reported in other regions of the SCB during fall (Barth et al., 2020; Goodman et al., 2012; Lucas et al., 2011). Goodman et al. (2012), Barth et al. (2020), and Lucas et al. (2011) attribute the dominance of dinoflagellates to the oligotrophic conditions of stratified fall waters. This is consistent with the nutrient data from our own study sites, which reflected depleted phosphate and nitrate concentrations in the surface waters in which plankton tows occurred. The dinoflagellate dominated communities present in this study are also consistent with Zheng et al.'s (2023) depiction of dinoflagellate dominance in stratified waters resulting from their motile nature, giving them access to both nutrients at depth and food at the surface via vertical migration.

Within these dinoflagellate communities, mixotrophs accounted for the majority of total abundance (Tables 4, 5), supporting the hypothesis they would competitively exclude heterotrophs, as was previously observed by Burkholder et al. (2008). Interestingly mixotrophic plankton were slightly more prevalent onshore. This may have contributed to the larger population of mesozooplankton observed onshore (Table 10), as mixotrophy boosts biomass transfer to higher trophic levels (Stoecker et al., 2017).

However, while the fall phytoplankton community near Dana Point was like other sites in the SCB in that it was dinoflagellate-dominated, the recorded onshore/offshore abundances

deviated from the expected "green ribbon" model. The total abundance of phytoplankton per m^3 seawater filtered was 1.4 times greater offshore than it was onshore (Table 10). These findings stand opposed to those of Lucas et al. (2011) and Goodman et al. (2012), both of which support green ribbon model of the SCB. The green ribbon model proposes that elevated nitrate levels along the inner shelf support more abundant phytoplankton communities. Our study site lacked this nutrient gradient characteristic of a green ribbon, with our phosphate profiles appearing similar at the onshore and offshore sites, and with both sites having near-zero nitrate concentrations. Yet, while the lack of a nutrient gradient might explain why our site was not characterized by a green ribbon, it does not explain why abundances were elevated offshore relative to onshore.

One potential explanation may lie in the abundance and composition of the zooplankton communities collected at each site. In both the 20 µm tow and 300 µm tow, copepod nauplii and adults consisted of a greater percentage of total abundance onshore than offshore (Tables 6-9). Additionally, the total abundance of zooplankton caught with the 300 µm net was greater onshore than offshore: not only were copepods more dominant in the onshore community, but they were also more abundant. Copepods are voracious consumers, capable of grazing up to 40% of the standing stock of phytoplankton blooms (Bautista and Harris, 1992). Thus, higher absolute and relative abundances of copepods may have exerted greater top-down pressure on the phytoplankton community, attributing to lower abundances onshore than offshore.

This explanation is further supported by considerations of the specific taxa observed onshore and offshore. The most dominant phytoplankton taxon onshore was *C. furca* (Table 4). *C. furca* is a non-toxic dinoflagellate (Baek et al., 2006), and copepod species have been observed grazing *C. furca* in other studies (Jansen et al., 2006). Offshore, the most dominant

phytoplankton taxon was *L. polyedra* (Table 5). *L. polyedra* is a toxic dinoflagellate that produces yessotoxins, which have been shown to decrease copepod feeding activity and egg production (Bizani et al., 2023). While the *C. furca* dominated onshore community supported a larger mesoplankton community, the *L. polyedra* dominated offshore community may have suppressed copepod grazing and reproduction, releasing the phytoplankton community from mesozooplankton grazing. This explanation would be consistent with the observed increased phytoplankton and microzooplankton abundances offshore, as well as the observed decrease in mesoplankton offshore. Further, this explanation finds support in the results of Bizani et al. (2023), which linked a bloom of *L. polyedra* to a decrease in copepods off southern Africa.

Conclusion

Like other sites in the SCB, the hydrographic conditions off Dana Point shape the plankton communities present over the continental shelf. Weak stratification and depleted surface phosphates favor phytoplankton cells under 10 μm, with dinoflagellate taxa being highly dominant. However, the relative abundance of phytoplankton onshore vs. offshore near Dana Point differed from observations made elsewhere in the SCB. Whereas other studies of the SCB describe a “green ribbon” in which abundances are significantly greater onshore than offshore, we observed elevated phytoplankton abundance and depressed mesozooplankton abundance offshore. This has significance since phytoplankton community composition and abundance have direct impacts on higher trophic levels. For instance, observations made in the present study might suggest the presence of toxic dinoflagellates offshore reduced the presence of mesozooplankton, while elsewhere phytoplankton community composition has been shown to impact the rate of carbon transport out of the euphotic zone (Krause et al., 2009) and impact fishery production (Verity et al., 2002; Rykaczewski and Checkley, 2008).

Future studies near Dana Point might take a closer look at the relationship between the onshore and offshore abundances and nutrient concentrations. Lucas et al. (2011) and Goodman et al. (2012) both related increased abundance to increased nitrate availability, but our nutrient data indicated both sites were highly oligotrophic and did not appear to explain the observed higher phytoplankton abundance offshore. Analyses of additional key nutrients might reveal more context. Additionally, future studies may investigate the presence of *L. polyedra* near Dana Point. *L. polyedra* is known to form Harmful Algal Blooms (HABs) that can result in hypoxic conditions and large fish kills, and HABs are increasing in frequency and intensity globally (Dai et al., 2023). Our data appears to indicate that the oligotrophic conditions in September precipitated a bloom of *L. polyedra*. While a short-lived bloom may have minor consequences, dinoflagellate blooms may persist beyond the fall season due to large-scale changes in climate patterns, i.e. the El Niño Southern Oscillation (Barth et al., 2020), or regional forces, i.e. internal tides (Lucas et al., 2011). If such factors extend *L. polyedra's* presence near Dana Point, it could have major consequences on ecosystem dynamics and damage fishery production.

Figures and Tables

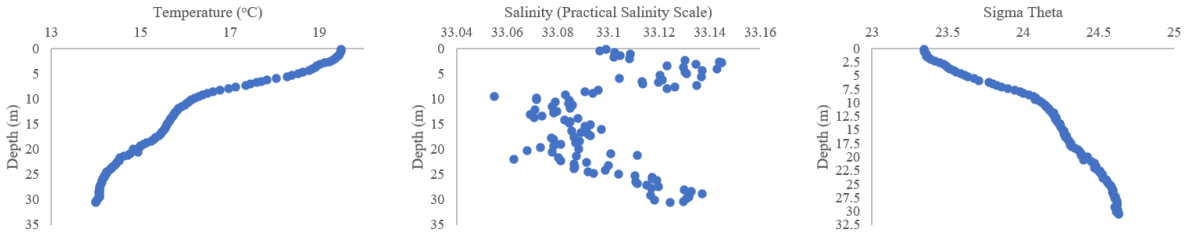

Figure 1. Temperature, salinity, and density depth profiles from Castaway CTD data at the onshore sampling site.

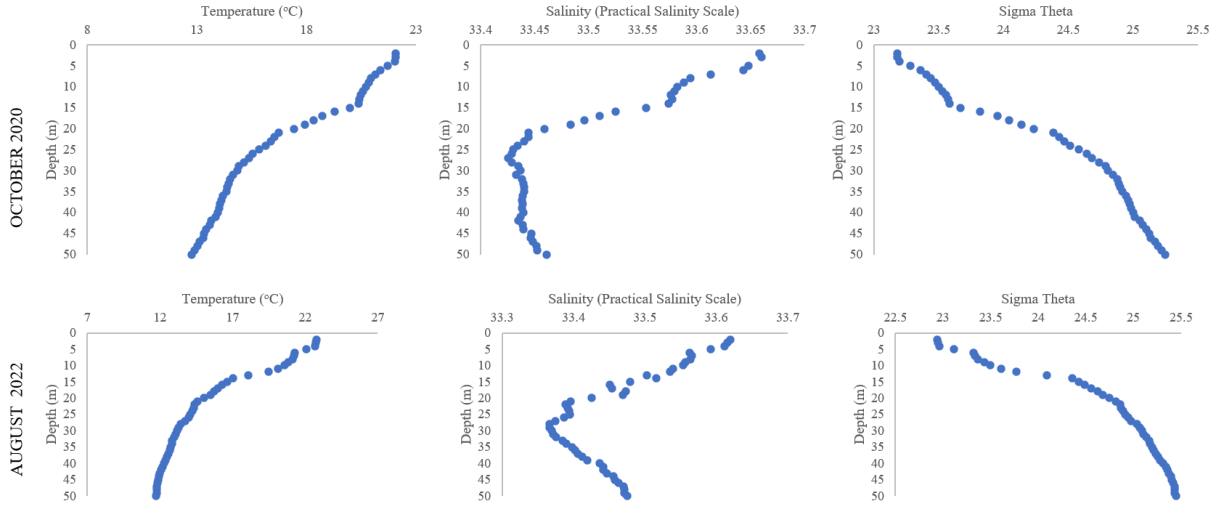

Figure 2. Archived CalCOFI data from the same geographic area as our offshore sampling site. Depth profiles of temperature, salinity, and density are shown for October 2020 and August 2022.

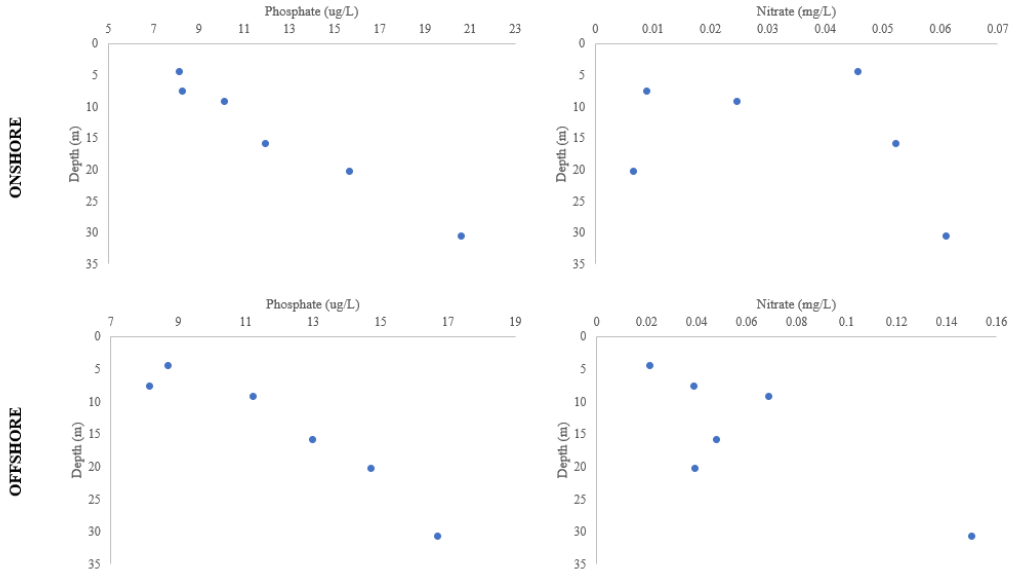

Figure 3. Nutrient profiles for the onshore and offshore sites made using water samples collected at six discrete depths. Phosphate concentrations are in ug/L while nitrate concentrations are reported in mg/L.

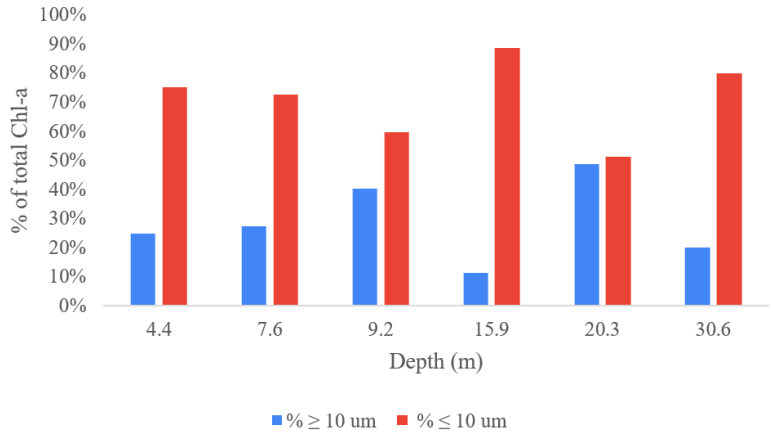

Figure 4. Percentage of chlorophyll-a over and under 10 µm at each of the six discrete depths sampled at the onshore site.

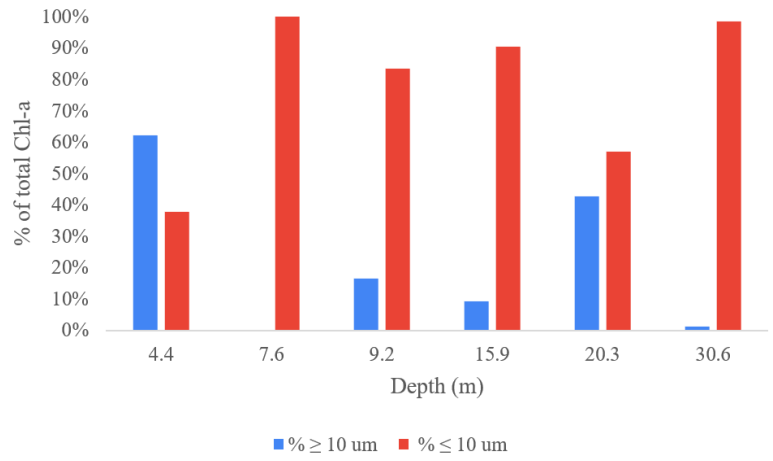

Figure 5. Percentage of chlorophyll-a over and under 10 µm at each of the six discrete depths sampled at the offshore site. The 10 µm filter from 7.6m leaked and was omitted.

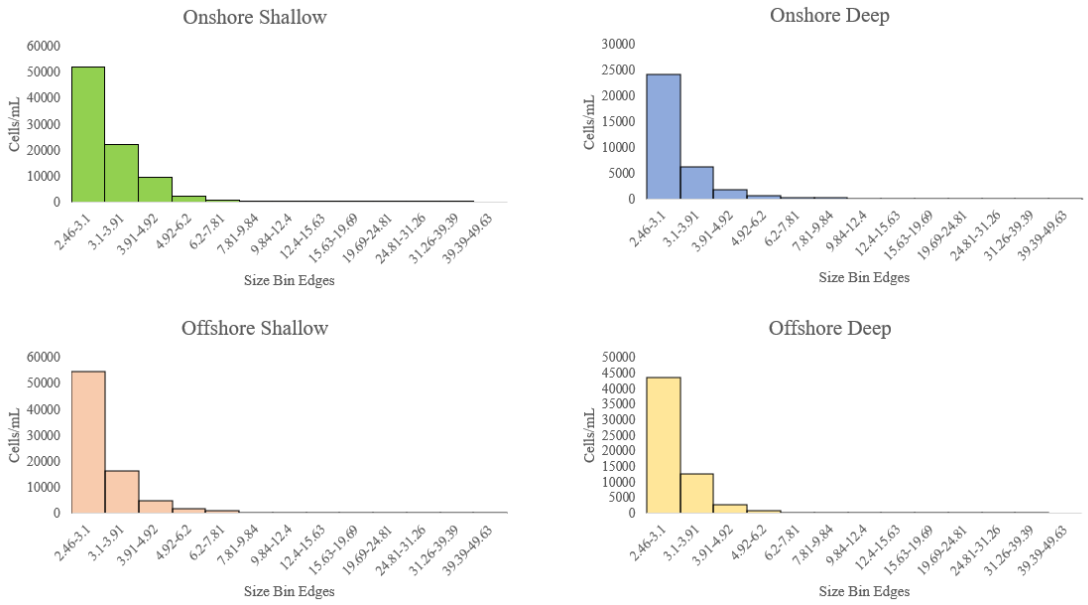

Figure 6. Cell size fractionations for the onshore and offshore sampling sites. Shallow samples were taken from water collected at 4 m and deep samples were taken from water collected at 12 m at each site. Cell abundances are reported in cells/mL and grouped in size bins.

Table 1. Overview of sampling sites.

Sampling Site	Longitude	Latitude	Distance from Shore (km)	Bottom Depth (m)
Onshore	117.682837°W	33.417360°N	4.12	51.2
Offshore	117.694077°W	33.404175°N	6.08	182.98

Table 2. Diversity indices for plankton collected with the 20 µm mesh net.

Tow	# taxa	Shannon Weiner (H')	Max H'	Simpson Diversity	Dmg
20µm Onshore Phytoplankton	7	1.13	1.95	0.62	0.72
20µm Offshore Phytoplankton	11	1.27	2.40	0.67	1.23
20µm Onshore Zooplankton	7	1.40	1.95	0.67	1.43
20µm Offshore Zooplankton	13	1.87	2.56	0.78	3.05

Table 3. Diversity indices for zooplankton collected with the 300 µm mesh net.

Tow	# taxa	Shannon Weiner (H')	Max H'	Simpson Diversity	Dmg
300µm Onshore	11	0.92	2.40	0.40	1.56
300µm Offshore	10	1.66	2.30	0.71	2.17

Table 4. Relative abundance and abundance rank for phytoplankton taxa caught onshore with the 20 µm net. For dinoflagellates, Blue = mixotrophic.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Ceratium furca	Dinoflagellate	51.5%	1
Lingulodinium polyedra	Dinoflagellate	31.9%	2
Prorocentrum micans	Dinoflagellate	12.4%	3
Ceratium fusus	Dinoflagellate	3.8%	4
Spikey Ball (dinoflagellate cyst)		0.3%	8
Ceratium tripos	Dinoflagellate	0.2%	6
Ceratium pentagonum	Dinoflagellate	0.1%	7
Ceratium macroceros	Dinoflagellate	0.2%	5

Table 5. Relative abundance and abundance rank for phytoplankton taxa caught offshore with the 20 µm net. For dinoflagellates, Blue = mixotrophic, yellow = unknown.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Lingulodinium polyedra	Dinoflagellate	47.20%	1
Ceratium furca	Dinoflagellate	29.09%	2
Ceratium fusus	Dinoflagellate	14.04%	3
Cochlodinium	Dinoflagellate	8.37%	4
Dinophysis sp.	Dinoflagellate	0.62%	5
Prorocentrum micans	Dinoflagellate	0.50%	6
Ceratium tripos	Dinoflagellate	0.06%	7
Ceratium pentagonum	Dinoflagellate	0.03%	8
Chaetoceros spp.	Diatom	0.03%	9
Dinoflagellate cyst		0.03%	10
Unknown String of Cells		0.03%	11

Table 6. Relative abundance and abundance rank for zooplankton taxa caught onshore with the 20 µm net.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Copepod Nauplius	Crustacean larvae	51.5%	1
Calanoid Copepod	Copepod	19.7%	2
Protoperidinium divergens	Dinoflagellate	15.2%	3
Ostracod	ostracod	4.5%	4
Tintinid	Ciliate	4.5%	5
Appendicularian	Tunicate	3.0%	6
Protoperidinium oceanicum	Dinoflagellate	1.5%	7

Table 7. Relative abundance and abundance rank for zooplankton taxa caught offshore with the 20 µm net.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Copepod Nauplius	Crustacean larvae	35.3%	1
Calanoid Copepod	Copepod	27.5%	2
Noctiluca scintillans	Dinoflagellate	11.8%	3
Fish egg	Vertebrata: Pisces	7.8%	4
Radiolarians	Radiolarian	2.0%	5
Ostracod	ostracod	2.0%	6
Cladoceran	Cladoceran	2.0%	7
Appendicularian	Tunicate	2.0%	8
Chaetognatha	Chaetognatha	2.0%	9
Mysid Shrimp	Crustacean	2.0%	10
unknown polychaete	Annelid worm: polychaete	2.0%	11
Protoperidinium sp.	Dinoflagellate	2.0%	12
Protoperidinium oceanicum	Dinoflagellate	2.0%	13

Table 8. Relative abundance and abundance rank for zooplankton taxa caught onshore with the 300 μm net.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Acartia danae	Copepod	76.9%	1
Acartia negligens	Copepod	7.5%	2
Fish egg	Vertebrata: Pisces	7.0%	3
Cladoceran	cladocera	3.9%	4
Bryozoan larva	Bryozoa	2.5%	5
Calanus pacifica	Copepod	0.7%	6
Oikopleura diocia	Appendicularian/larvacean	0.7%	7
Metridia pacifica	Copepod	0.3%	8
Unknown Large Crustacean	Crustacean	0.2%	9
Mysid	Crustacean	0.2%	10
Hyperiid Amphipods	amphipod	0.2%	11

Table 9. Relative abundance and abundance rank for zooplankton taxa caught offshore with the 300 µm net.

Taxa	Type	Relative Abundance (%)	Abundance Rank
Cladoceran	cladocera	47.6%	1
Acartia danae	Copepod	22.2%	2
Fish egg	Vertebrata: Pisces	6.3%	3
Metridia pacifica	Copepod	4.8%	4
Bryozoan larva	Bryozoa	4.8%	5
Acartia negligens	Copepod	3.2%	6
Calanus pacifica	Copepod	3.2%	7
Mysid	Crustacean	3.2%	8
Hyperiid Amphipods	amphipod	3.2%	9
Unknown Crustacean	Crustacean	1.6%	10

Table 10. Abundance of phytoplankton and zooplankton/heterotrophic dinoflagellates per m^3 seawater for the onshore and offshore 20 µm nets, and the abundance of zooplankton per m^3 seawater for the onshore and offshore 300 µm nets.

	Onshore 20 um	Offshore 20 um	Onshore 300 um	Offshore 300 um
Phytoplankton* m^{-3} seawater	1608695	2268886	-	-
Zooplankton * m^{-3} seawater	26751	34346	71	8
Total Abundance % Phytoplankton	98.36%	98.51%	-	-

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Reflective Essay

When I first began the research process for BIOL-451 (Biological Oceanography), I was frankly intimidated by the scale of the project ahead of me. At the time, I had little research experience, and the specific field of biological oceanography was a new area of learning for myself. I believed I would have my hands full with the task of learning and understanding new methods, terminology, and systems such as "plankton net tow," "CTD," and "diel vertical migration," let alone interpreting the results of the research and integrating them into a comprehensive research paper.

However, this intimidation was not paralyzing. Instead, it was motivating. With a research area as vast, grand, unwieldy, and fascinating as the ocean, I wanted to not only understand the research I did in BIOL-451, but to synthesize its key points into discernable, comprehensive takeaways. I wanted to make the research that intimidated myself approachable, but I also wanted to make sure I did not discredit or forget the impressive scale and importance of the ocean ecosystems just down the road from USD.

I initially pictured an hourglass approach, in which I funneled the vast context of the research into a few key ideas and results, then expanded these key points by connecting them to the literature and an overall broader significance. Yet, I was unsure where to begin. Fortunately, Dr. Lowery provided guidance at these crucial first steps, offering advice in proper research strategies and suggesting resources for understanding oceanographic techniques. My first goal was to understand the methods I used in the research and the specific region of the California coast the class studied. To achieve this, I read Goodman et. al (2012), Lucas et. al (2011), and Barth et. al (2020), each of which detailed the typical conditions and plankton community compositions of the Southern California coast. After reading these papers, I wrote an annotated bibliography for each,

distilling their essential takeaways regarding offshore ecosystems in Southern California. Then, I wrote a short synthesis paper weaving the three sources together. This provided me with essential practice synthesizing and integrating the details of specific studies while not losing sight of large-scale themes in biological oceanography.

This initial practice at writing annotated bibliographies and synthesizing papers both expanded my knowledge of biological oceanography and grew my skillset as a researcher. Reading Goodman et. al (2012), Lucas et. al (2011), and Barth et. al (2020) expanded my knowledge of field-specific terminology, enabling me to move beyond the papers and journal articles provided in class and begin using resources such as Google Scholar, JSTOR, and the Copley Library to search for key words I noticed in common across articles I had read. In another research-based class, BIOL-490, I learned about Zotero, a reference management software, and LitMaps, a literature review assistant. Both of these resources proved helpful when keeping track of my citations for BIOL-451 and how they connected with one another.

As I progressed through BIOL-451, I learned how to ask better questions and more effectively use the resources available to me as a researcher. I learned that no source read was wasted time even if I ultimately did not use it in my own paper. Each paper or article I read expanded my own background and knowledge in the field, enabling me to think more critically about my own results. This in turn made it possible for me to sift through a mountain of data, extract meaning from it, and synthesize it with existing literature.

Ultimately, I believe the evolution of my research process informed how my paper was written nearly as much as the results themselves. Going from having no knowledge of the field to being able to write a comprehensive paper about biological oceanography made it clear to me that a well-written paper in the field balances distilling key points into digestible, understandable, and

meaningful takeaways with recognizing the inherent complexity, scale, and importance of ocean ecosystems. Understanding the importance of this balance, learning from Dr. Lowery, and exploring resources on my own all led to a final paper I can be proud of, as it reflects not only my success in one course, but my growth as a researcher.