Phytoplankton Studies in the South Shetland Islands

Guido Bordignon, Stephanie Sexton, and Amy Van Cise

Abstract

Phytoplankton production was measured around the South Shetland Islands as part of the 25th U.S. AMLR field season. Depth discrete and surface water samples were collected for chlorophyll-a (Chl-*a*) biomass (mg m^{-3}), taxonomic determination, and macro-nutrient (NO^{-3}, PO^{-4}, and SiOH) concentrations in relation to water mass properties, including temperature and salinity. Results indicate that:

- During Leg I of the survey, a total of 95 full oceanographic and biological stations were occupied and water samples were collected from 0-200 m depth across the AMLR Survey grid;
- During Leg I, the Chl-*a* concentration averaged over the upper 15 m of the water column varied from 0.43 mg m^{-3} in the West Area to more than 1.3 mg m^{-3} in the South Area. Average Chl-a values for the Elephant Island and West Areas were close to their long term means;
- During the Leg II gear comparison study, only surface (~3 m) water samples were collected from the flow-through thermosalinograph at 59 stations, including stations within the Elephant Island (19), South (19) and Joinville Areas (9), but also within northeastern Gerlache Strait (12). These near-surface samples exhibited higher Chl-*a* concentration in all areas, and ranged from 1.3 mg m^{-3} in the Elephant Island Area to more than 3.2 mg m^{-3} in the South Area. In Gerlache Strait, outside the historical AMLR grid, the mean Chl-*a* concentration was 4.52 ± 3.53 mg $m^{-3\dagger}$; and
- New in situ and incident photosynthetically active radiation (PAR) sensors were calibrated with older sensors, and a high correlation (r^2 > 0.999) between the QCP-200L (sn 4264) sensor and a new QCP2300 (sn 70320) sensor was found. The older sensors, whose maximum operating depth is < 1000 m, will be retired.

Introduction

The U.S. Antarctic Marine Living Resources (AMLR) Program has collected phytoplankton, macro-nutrient, and chlorophyll data since 1990, to determine the factors affecting bottom-up control of krill and zooplankton productivity in the waters around the South Shetland Islands. The amount and quality of food available for zooplankton is fundamental to understanding krill abundance, distribution, and general web food dynamics, especially given the magnitude and rate of climate change in this region. In general, Chl-*a* biomass exhibits significant spatio-temporal variability, reflecting the low biomass within Drake Passage and higher biomass over the continental shelves and around islands. Low biomass is also found on the north side of the Peninsula, within the Bransfield Strait, indicating that mechanisms controlling production are complex. Temporally, Chl-*a* concentration is decreased during El Niño periods and elevated during La Niña periods. This suggests that there is a strong coupling between global scale climate patterns and productivity in this region. Given the impact of climate change on the Peninsula region, continued monitoring and examination of the factors controlling productivity of the system are important to understanding krill dynamics.

Methods

Sample collection

During Leg I, water samples for Chl-*a*, macro-nutrient, and fluoristic determination were collected at fixed stations on the AMLR Survey grid, which is divided into four areas around the South Shetland Islands: the Elephant Island, Joinville Island, West, and South Areas. At each station, water samples were collected with Niskin bottles attached to a conductivity-temperature-depth (CTD) sensor carousel. The depths sampled were 200, 100, 75, 50, 40, 30, 20, 15, 10, and 5 m, with occasional samples taken at 750 m. At shallow stations (< 200 m), samples were collected at standard depths and from 10 m off the bottom.

During Leg II, the CTD was not deployed, owing to a gear comparison study between the Tucker trawl and the IKMT net (see Chapter 4). To assess the Chl-*a* concentrations during Leg II, water samples for Chl-*a* were collected from the clean water outflow of the thermosalinograph (Sea-Bird SBE-21), which gets water from a pump placed in the hull at approximately 3 m depth (see Chapter 1 for thermosalinograph details).

Chlorophyll-a

To determine the concentration of Chl-*a* in the water, 100 ml of seawater was filtered through a glass fiber filter (Whatmann 2.5 cm GFF/0.7F) for each depth (between 5 and 200 m). Chl-*a* pigments were extracted from the filters using 9 ml of methanol over 24 hrs. Samples were then shaken, centrifuged, and the clear supernatant placed into a borosilicate tube. Fluorescence was determined using a calibrated Turner-designs model TD-700, fluorometer. After the initial reading, samples were treated with two drops of 1.0 N HCl solution and read again to quantify the phaeopigment concentration (Holm-Hansen et al. 1965; Holm-Hansen and Riemann, 1978).

Chl-*a* (mg m^{-3}) concentration was determined for each sample station using the following equation:

$$(1)\ \text{Chl-}a = Fd\ t/(t-1)^* (Rb-Ra)^*1000/V_1{}^*V_2$$

Phaeopigment concentration (mg m^{-3}) was calculated with the following equation:

$$(2)\ \text{Phaeo} = Fd^*(t^*Ra-Rb)^*1000/V_1{}^*V_2$$

Where Fd (0.0000985) and t (2.802864) are calibration factors for the TD-700 fluorometer, Ra is the Chl-*a* fluorescence reading before addition of HCl, Rb is the phaeopigment fluorescence reading after addition of HCL, V_1 is the volume of water filtered, and V_2 is the volume of methanol used to extract the photosynthetic pigments.

Nutrients

Water samples for macro-nutrient determination were collected in the upper mixed layer from the 15 m water sample at 95 stations. Additionally, samples were collected from the surface to between 100 and 750 m at 5 stations (A18-08, A15-05, A11-01, 17-09, 9-13) during 2011. Further, owing to the earthquake during the AMLR 2010 survey, nutrient samples were not analyzed, and were instead left in a -80°C freezer in Punta Arenas until the end of the 2011 season. In 2010, eight full-cast stations were sampled for nutrients (NO_3, NO_2, SiO_4, PO_4), and 81 surface (10 – 15 m depth) samples were collected over the two legs of that survey. We present the results from both years' data here for comparison of potential quality issues. All samples were collected in acid-washed 100 ml Nalgene nutrient bottles, and immediately frozen until analysis by N. Silva (Universidad Catolica de Valparaiso, Valparaiso, Chile).

PAR

Three *in situ* PAR sensors were attached to the CTD and two mast-mounted incident PAR sensors were used during the 2011 U.S. AMLR field season. The mast-mounted PAR sensors were used to measure incident light continuously during the cruise and also used, in conjunction with the *in situ* sensors, to determine the euphotic zone depth (1%) light level across the survey area. These mast-mounted instruments (BSI model QSR2200) were deployed in two ways. In the first, a QSR2200 (S.N. 70386) was used to determine incident PAR and streamed into the SCS underway data string. In the second, the PAR values were fed directly to the SBE11 Underwater Unit to provide incident PAR for CTD cast data. The three *in situ* PAR sensors were all calibrated by BioSpherical Instruments (BSI Inc., San Diego, CA) prior to the cruise. Each sensor included a model QCP200L (S.N. 4262), which had been used since 1992 and will be retired because of its limited depth range, an early model of the QCP2300 (S.N. 4744) which consistently malfunctioned and will be retired, and a new QCP2300 (S.N. 70320), which had up-to-date electronics, an increased operating depth (2000 m), and will replace both the QCP200L and the older QCP2300. The goal of the comparison was to be able to ensure data continuity when switching to the new instrument. The new QCP2300 PAR is a log output quantum cosine profiling sensor; the single channel analog output voltage is proportional to the log of incident PAR (400-700 nm) irradiance to a depth up to 1500 m. Using BSI supplied calibrations, instrument voltages were converted to μE cm^{-2} sec^{-1}, and the QCP200L and the new QCP2300 were compared using linear regression analysis.

Fluorometry and Transmissometry

Owing to electronic failure on a voltage regulator on the Chelsea fluorometer (S.N. not available), no fluorometric data were collected during the cruise. A new transmissometer (Wetlabs C-Star Red, S.N. CST-1332DR) was used to provide data on optical characteristics of the water column at each station. These data is not reported here.

[†] Except where noted, variation is reported as standard deviation.

Results

Chlorophyll-a

Across the West Area, 24 of 25 stations were sampled for a total of 229 samples from various depths. Chl-*a* concentration at 10 m ranged from 0.044 to 1.49 mg m^{-3}. The

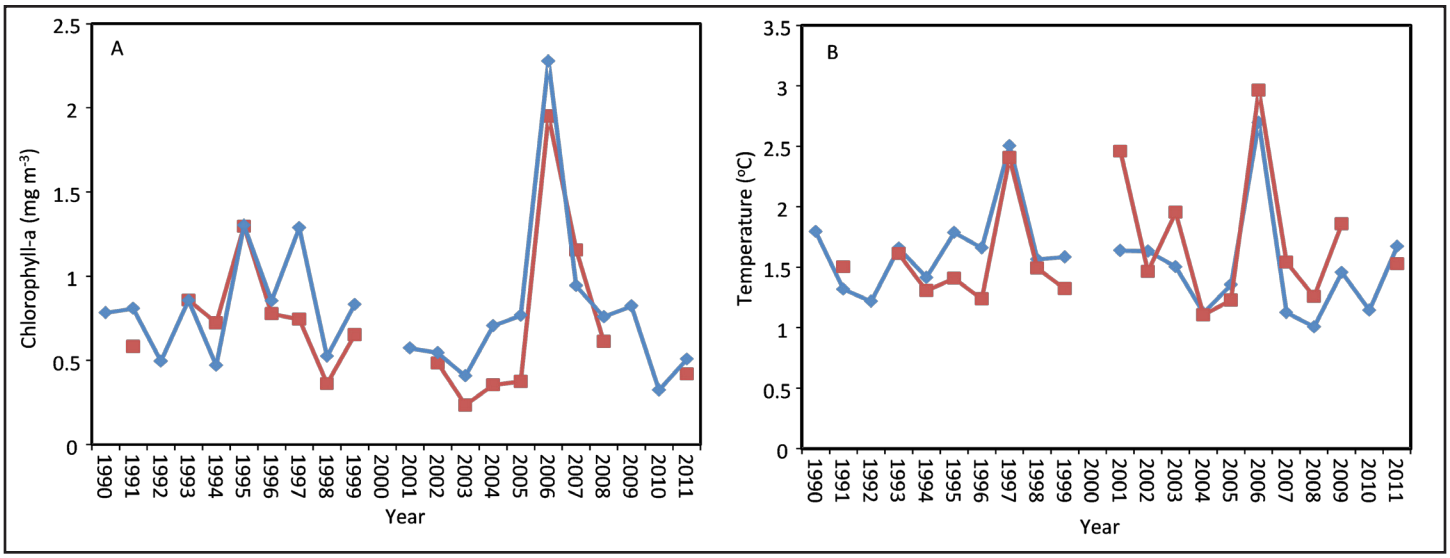


Figure 2.1. Time-series of the mean Chl-*a* (A) and temperature (B) in the West (red) and Elephant Island (blue) Areas of the South Shetland Islands averaged over the upper 15 m of the water column. West Area stations sampled prior to 1997 were not part of the fixed grid currently sampled, so care must be used to infer any differences between areas during that time period.

mean 10 m concentration was 0.48 ± 0.51 mg Chl-*a* m^{-3}. In the Elephant Island Area, 46 stations were sampled and 460 Chl-*a* samples were obtained. Chl-*a* concentrations at 10 m ranged from 0.069 to 2.20 mg Chl-*a* m^{-3}. The mean 10 m Chl-*a* concentration was 0.49 ± 0.43 mg Chl-*a* m^{-3}.

In the Joinville Island Area, only five stations were occupied (owing to ship breakdowns) and 50 Chl-*a* samples were collected. At 10 m, the Chl-*a* concentration ranged from 0.11 to 1.70 mg m^{-3}, with a mean concentration of 1.02 ± 0.75 mg m^{-3}. Finally, in the South Area, 20 stations were occupied and 258 Chl-*a* samples were collected. Chl-*a* concentration at 10 m ranged from 0.28 to 2.65 mg m^{-3}, and the mean concentration was 1.34 ± 0.66 mg m^{-3}, which was the highest among all areas sampled during Leg I.

Time series of Chl-*a* concentration and water temperature averaged over the upper 15 m from 1990 to 2011 for both the West and Elephant Island Areas showed that patterns were similar over time (Figure 2.1). After a peak in production associated with a very warm summer in 2006, both Chl-*a* and water temperature have declined to more average conditions.

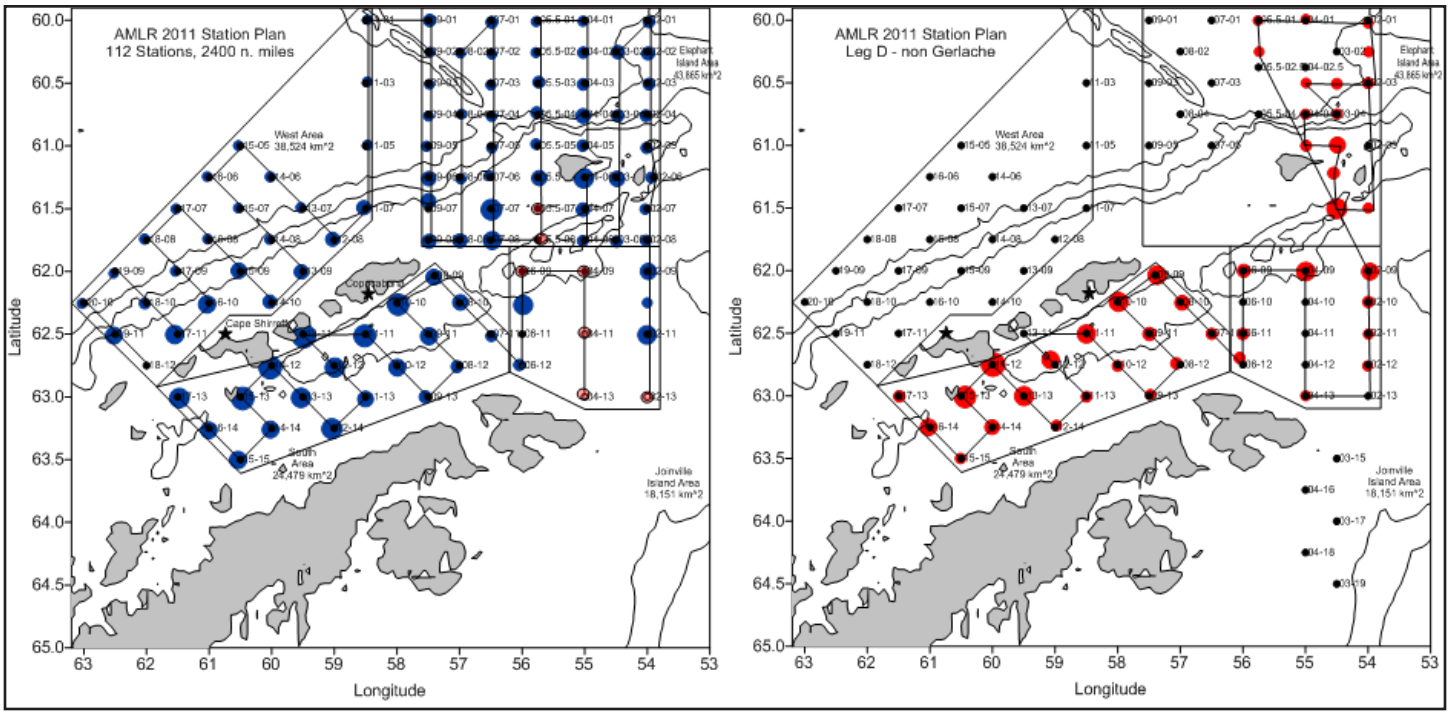
During Leg II, 47 water samples were collected from the clean water outflow of the thermosalinograph. These 47 samples were collected from the Elephant Island, Joinville Island, and South Areas, as well as within Gerlache Strait. The mean Chl-*a* concentration across all stations sampled during the leg was 2.21 ± 0.84 mg m^{-3} . The mean Chl-*a* concentration from the 12 samples collected from Gerlache Strait was much higher than the South and Joinville Island Areas, with a mean Chl-*a* concentration of 4.53 ± 1.02 mg m^{-3}.

Spatially, Chl-*a* concentration was highest near the shelves and coastal waters surrounding the islands during both legs (Figure 2.2). Consistently high concentrations of Chl-*a* were present on the north side of the Bransfield Strait. High Chl-*a* concentration was also associated with intermediate salinity waters (Figure 2.3a), and showed the clear unimodal relationship previously described for the region.

Nutrient concentrations

Concentrations of macro-nutrients were similar between 2010 and 2011, but some differences in the variability in macro-nutrient concentrations were observed (Figure 2.3). In 2010, the mean nitrate concentration was 26.9 ± 2.6 µMol kg^{-1} and ranged from 22.5 to 35.9 µMol kg^{-1}. In 2011, the mean nitrate concentration was 25.8 ± 1.4 µMol kg^{-1}, which was smaller and had a lower variance than the mean in 2010, and ranged from 23 to 35.7 µMol kg^{-1}, which was narrower than the range of values found in 2010.. Phosphate concentrations exhibited a similar pattern to nitrate, with mean concentrations of 1.96 ± 0.22 µMol kg^{-1} and 1.93 ± 0.18 µMol kg^{-1} in 2010 and 2011, respectively. Mean silicate concentrations, which are potentially more affected by long-term storage, were 43 ± 0.12 µMol kg^{-1} in 2010 and 45 ± 0.20 µMol kg^{-1} in 2011. Silicate concentrations in 2010 ranged from 19 to 80 µMol kg^{-1}, which was much narrower than the range of 12 to 84 µMol kg^{-1} observed during 2011.

Silicate and salinity were more strongly correlated in 2011 than in 2010, reflecting the overall range of sili-



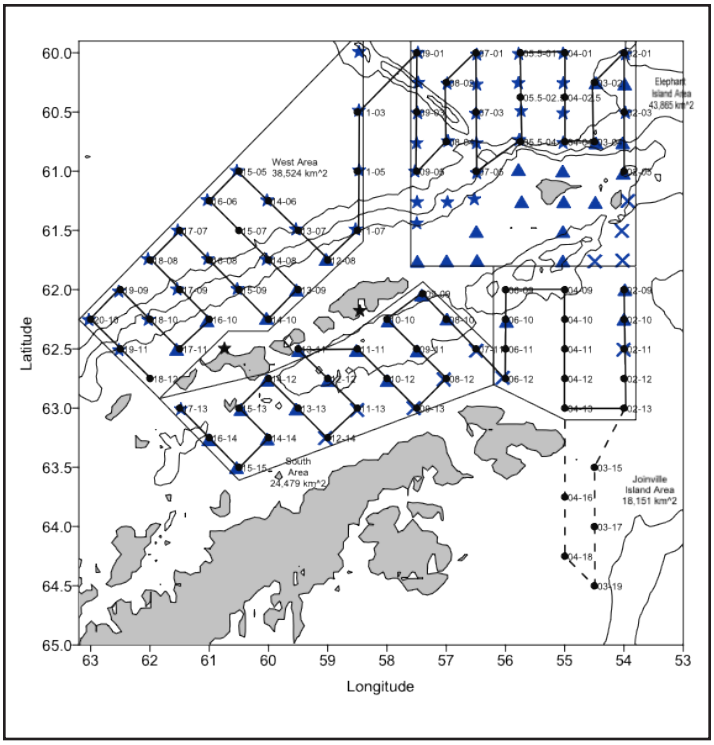


Figure 2.2. Top: Near-surface (5 m) Chl-*a* (mg m^{-3}) concentrations during Leg I (left panel) and Leg II (right panel) of the AMLR 2011 Survey. High concentrations of Chl-*a* are present near the islands and on the shelves. Bottom: Salinity during AMLR 2011 Leg I at 10 m depth. Stars indicate salinities ranging from 33.8 to 34; triangles indicate salinities ranging from 34 to 34.3; crosses indicate salinities ranging from 34.3 to 34.5. Black circles - historical stations not sampled on this survey.

cate observed in 2011, but also the lower variance. Patterns of correlation between salinity and both nitrate and phosphate concentrations were similar. Low but variable concentrations were present at salinities between approximately 33.7 and 34 , and then concentrations of both nutrients increased linearly with salinity.

Comparison of PAR Sensors

PAR measured by both the QCP200L and the QCP2300 were highly correlated (Figure 2.4). The intercept for all comparisons was not significantly different from 0, and the slopes of all relationships to the QCP200L were quite good over the range 0 to 0.05 µE cm^{-2} sec^{-1}. However, visual analysis of the residuals shows some deviation from a purely linear response over this range. Beginning at approximately 0.03 µE cm^{-2} sec^{-1}, the QCP2300 underestimated PAR by up to 0.004 µE cm^{-2} sec^{-1}. Inclusion of other data also showed similar deviations, and in some cases by much more than the equation described. However, detailed analysis of those data is beyond the scope of this Field Season Report.

Discussion

During Leg I of the AMLR 2010-11 field season, Chl-*a* samples were collected from various depths at 95 stations throughout all four areas of the survey grid. Chl-*a* concentrations in the upper 5 m were similar to those recorded in 2010, with high Chl-*a* concentrations present around the shallow water of the South Shetland Islands, especially in

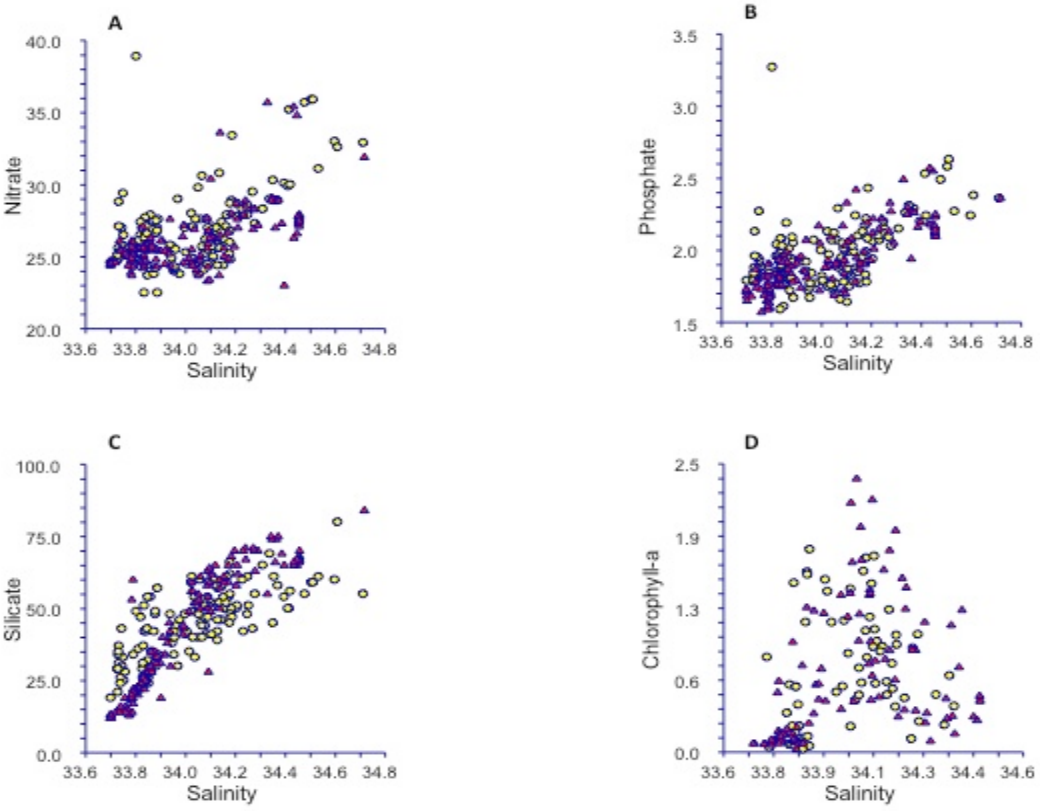


Figure 2.3. Nutrients and Chl-*a* versus salinity; comparison between AMLR 2010 and 2011.

the Bransfield Strait and the southwestern region of the Elephant Island Area. During Leg II, Chl-*a* sampling was restricted to the surface layer through the outflow of the thermosalinograph. Chl-*a* in these surface waters was higher on this leg than during Leg I, but was also highly variable. In the Gerlache Strait Area, extremely high Chl-*a* values (≥ 8 mg Chl-*a* m^{-3}) at stations GS04 and GS13 and very low Chl-*a* values (i.e., 0.08 mg Chl-*a* m^{-3} at station D05.501) were found.

Values in Gerlache Strait are not directly comparable to any AMLR historical data, and these values are higher than normally "high" values found in the AMLR study area. Previous research in southern Bransfield Strait near Gerlache Strait has shown that the area is often more productive than other areas (Holm-Hansen and Mitchell 1991). They found massive blooms in Gerlache Strait and in coastal waters of the Antarctica Peninsula region; typical conditions in these areas are close proximity to meltwater and reduced exposure to storm systems.

Comparisons of nutrient data collected during 2010 and 2011 showed that there was considerably more variability in the data from 2010. It is unclear whether the variability is a consequence of the unusual oceanographic and atmospheric conditions during 2009-10, or whether the variability is related to sample storage. Despite the variability, the overall patterns are similar between years, and suggest that the data quality is sufficient to include in the U.S. AMLR database.

New instruments for recording *in situ* PAR were compared to existing instruments that have long restricted the ability of the U.S. AMLR Program to sample the water column to depths greater than 750 m. Instruments were highly correlated; therefore, beginning in 2012, new PAR sensors with greater depth ranges will be used.

Protocol Deviations

During the AMLR 2011 field season, no fluorometric data was collected owing to an electronic failure on the Chelsea Aquatracka III fluorometer. Most stations were sampled on Leg I with the exception of stations in the Joinville Area.

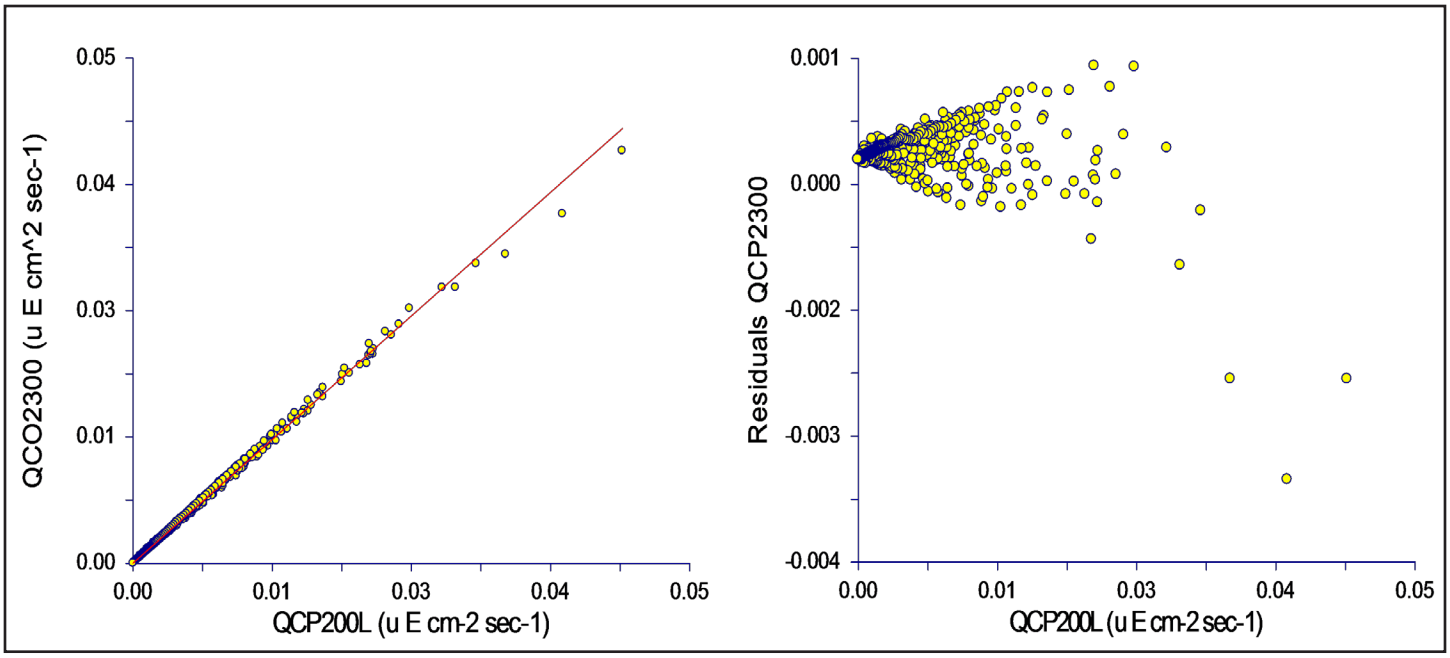


Figure 2.4. Correlations between *in situ* PAR sensors deployed during the 2011 U.S. AMLR Survey. From 1992 to 2011, a BSI QCP200L PAR sensor was used to measure PAR during the surveys. Lines are least squares fits to data collected over the upper 200 m of the water column, and between 0900 and 1600 hours UTC, during January 2011. The equation of relationship is 0.9787*QCP2300, $r^2 = 0.9995$ in microeinsteins cm^{-2} sec^{-1}.

Mechanical failure of the rudder required sampling to be halted and repairs made. This year, only 9 ml instead of 10 ml of methanol was used to extract Chl-*a* from the filters.

Disposition of Data

All Chl-*a*, primary productivity, and macro-nutrient data are available from Dr. Christian S. Reiss, NOAA Fisheries, Antarctic Ecosystem Research Division, 8901 La Jolla Shores Dr., La Jolla, CA 92037. Ph. 858-546-7127; Fax 858-546-7003.

Acknowledgements

We express our gratitude and appreciation to Captain John Seville and the crew of the R/V *Moana Wave*, whose support was fundamental in the success of the 2011 AMLR field season.

References

Goericke, R. and D.J. Repeta. 1993. Chlorophylls a and b and divinyl chlorophylls a and b in the open subtropical North Atlantic Ocean. Mar. Ecol. Prog. Ser. 101:307-313.

Holm-Hansen, O., C.J. Lorenzen, R.W. Holmes, and J.D.H Strickland. 1965. Fluorometric determination of chlorophyll. J. Cons. Perm. Int. Explor. Mer 30: 3-15.

Holm-Hansen, O. and B. Riemann. 1978. Chlorophyll-α determination: improvements in methodology. OIKOS 30: 438-447.

Holm-Hansen, O. and B. G. Mitchell. 1991. Spatial and temporal distribution of phytoplankton and primary production in the western Bransfield Strait region. Deep-Sea Research 38: 961-980.

Hewes, C.D., O. Holm-Hansen, J.L. Iriarte, N. Sanchez Puerto, D. Krause, and N. Silva. 2009. Phytoplankton Studies in the South Shetland Islands. In: Van Cise, A.M., (ed.) AMLR 2010 Field Season Report. NOAA-TM-NMFS-SWFSC-427. NMFS Southwest Fisheries Science Center, La Jolla, CA.

Hewes, C.D., C.S. Reiss, and O. Holm-Hansen, 2009. A quantitative analysis of sources for summertime phytoplankton variability over 18 years in the South Shetland Islands (Antarctica) region. Deep-Sea Research Part I: Oceanographic Research Papers 56: 1230-1241.

Reiss, C.S, G. Bordignon, T. Clemente, and A. Van Cise. 2010. Phytoplankton studies in the South Shetland Islands. In: Van Cise, A.M., (ed.) AMLR 2010 Field Season Report. NOAA-TM-NMFS-SWFSC-427. NMFS Southwest Fisheries Science Center, La Jolla, CA.

Trees, C.C., D.K. Clark, R.R. Bidigare, M.E. Ondrusek, and J.L. Mueller. 2000. Accessory pigments versus chlorophyll a concentrations within the euphotic zone: a ubiquitous relationship. Limnol. Oceanogr. 45: 1130-1143.

NOAA Technical Memorandum NMFS
This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. The TMs have not received complete formal review, editorial control, or detailed editing.

FEBRUARY 2014

AMLR 2010-2011 FIELD SEASON REPORT

Editor, Jennifer G. Walsh,

National Marine Fisheries Service
Southwest Fisheries Science Center
8901 La Jolla Shores Dr.
La Jolla, CA 92037

NOAA-TM-NMFS-SWFSC-524

U. S. DEPARTMENT OF COMMERCE
Penny Pritzker, Secretary of Commerce
National Oceanic and Atmospheric Administration
Dr. Kathryn D. Sullivan, Acting Administrator
National Marine Fisheries Service
Eileen Sobeck, Assistant Administrator for Fisheries