Rapid Assessment of Australian MPA's using Satellite Remote Sensing
Part 2: Validation of Biological Response to Physical Environment

Report to Environment Australia

May 7, 2001

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1. Summary

This report describes a field study on the relationship between *in situ* vital signs that can be measured by satellite and one higher order biological variable. Before satellite derived data can be used to make predictions about the biological response to the physical environment, the *in situ* relationships must be validated. The study took place in the Great Australian Bight Marine Protected Area in February, 2001. The *in situ* vital signs were SST and chlorophyll, while the biological variable was zooplankton volume.

No significant relationships between zooplankton volume and SST or chlorophyll were found for day or night samples during this two week sampling period. Insufficient variation in the physical environment was encountered during the cruise for good tests of the relationship between the physical variables and zooplankton. Longer studies that encompass a wider range of variation are required to achieve this understanding.

2. Introduction

Remote sensing via satellite of the marine environment allows large scale temporal and spatial coverage of an area (Joint and Groom, 2000; Santos, 2000). Information from satellites allows a description of the property being considered in an area, such as sea surface temperature (SST) and sea surface colour (SSC, or chlorophyll), to be generated. If these physical patterns are related to higher order processes or patterns in the region, then information about these higher orders can be inferred from satellite derived descriptions. Relationships between satellite derived estimates of SST and SSC and the abundance of higher trophic levels have been found for a variety of taxa (Herron et al., 1989; Podesta et al., 1993; Cole, 1999; 2000). Zooplankton is an important level in the food chain for many marine species. Changes in zooplankton abundance may reflect changes in the phytoplankton (chlorophyll) or SST environment and may in turn be reflected in changes in higher trophic levels, such as fish, birds and marine mammals (Ainley et al., 1995). The generality of relationships between the physical marine environment and organisms in the environment is unknown, however, and region and taxa specific validation studies should be carried out.

Satellite sampling of SST and SSC is limited to the surface of the ocean. Vertically, the ocean can be considered as two layers. The upper layer is known as the mixed layer, because surface driven mixing leads to more homogeneous distribution of physical characteristics, such as temperature and salinity, with depth (Brainerd and Gregg, 1995). Thus, the surface characteristics measured by satellite are somewhat representative of the characteristics throughout the mixed layer. Because animals may occupy a range of depths, it is important to sample the biological community that experience the physical conditions that are measured by the satellite, ie those animals in the mixed layer. Before using the remotely sensed data, the relationship between the *in situ* components should be examined. If no relationship exists, then use of a remote method to measure one of the components may be unjustified.

The goal of this project was to explore, *in situ*, the relationship between the mixed layer zooplankton community and temperature and chlorophyll in the Great Australia Bight Marine Protected Area. The sampling undertaken was designed to collect data that will be used to evaluate whether remote sensing of these properties (SST and CHL) would allow an understanding of the zooplankton biomass in this region, and thus be a technique for rapid assessment of the zooplankton biomass. If a relationship exists between the remotely sensed characters and the *in situ* biological dynamics, then remote sensing may be a suitable method for rapid assessment of zooplankton biomass in Marine Protected Areas (MPA's). Subsequent biological responses to the zooplankton patterns, such as aggregation of marine birds, fish and mammals, could then be explored further based upon this foundation.

3. Methods

Sampling of the zooplankton and physical variables was undertaken aboard the RV Franklin on a voyage between Fremantle and Adelaide in February, 2001. Underway sampling instruments were used to monitor and record SST, salinity and fluorescence. A Bongo net was used to sample the zooplankton community in the mixed layer. This net is actually composed of two hoops, each with a net attached. The diameter of each hoop, or mouth, was 0.7m, and the nets were 4 m long. The mesh size of nets was 505 microns. Detachable cod-ends allowed the collected zooplankton to be easily processed and the next sample initiated. This reduced the ship time required to complete a set of samples. Bongo net sampling stations were occupied opportunistically throughout the cruise track, during both day and night. The physical environment for selecting some of the sampling locations was defined by the underway data readings. A range of these variables and variable combinations were encountered and the waters sampled for zooplankton.

In general a bongo station was composed of three consecutive bongo tows. In each tow, the net was deployed to a depth of 50 meters at a speed of 20 meters per minute, and then recovered at a speed of 10 meters per minute. The ship speed during the tows was approximately 1.5 knots. Depth was calculated using the angle and length of the deployed winch wire. A typical wire angle of 40 degrees required that 80 meters of wire out was needed to allow the net to reach a depth of 50 meters. A flow meter was used in the starboard net to measure the distance travelled by the net mouth. Distance travelled multiplied by the size of the net mouth provided an estimate of the volume of water filtered for each tow.

The settled whole zooplankton volume was found using the sample from the port net, while the sample from the starboard net was preserved for faunal analysis if required in the future. After net recovery, the contents of the port net were washed into a 500 mL graduated cylinder, placed on a gimbled settling table and allowed to settle for between 24-48 hours. This time period was sufficient for constant volume to be obtained without degradation of the zooplankton sample.

Regression analyses were used to test linear relationships between the physical variables and zooplankton volume. Although depth and salinity are not measured by remote sensing, relationships were also tested for these variables. Zooplankton volume was corrected by the volume of water filtered; values reported are mL/m^3.

4. Results and Discussion

A total of 38 tows at 13 stations was completed at locations throughout the cruise track (**Figure 1**, **Table 1**). Nine of the stations were occupied during daylight hours. An average distance of 602 ± 245 m (232 m^3 mean filtered volume) was sampled by all the tows, which lasted an average of 15 minutes each. A total distance of 22.893 km of surface water was filtered during the cruise.

Most stations were spatially and temporally close to CTD casts, allowing determination of the vertical structure of the water column where the zooplankton samples were collected. The mean distance from the closest CTD cast to each bongo station averaged 32 km (or 13.52 km if the first bongo station, is not included). These CTD results showed that the mixed layer depth was approximately 50 meters (mean 48.9 ± 5.25 m, **Table 2**), and so the maximum depth of the tows (50m) meant that the complete mixed layer was sampled for zooplankton.

A range of environmental conditions was encountered during zooplankton sampling (**Table 3**), although these ranges did not completely span the range of conditions encountered throughout the cruise (**Figure 2**). Underway fluorescence data remains uncorrected, and the data is presented for relative comparisons only. Dominant macro-zooplankton taxa collected in the bongo nets included salps, chaetognaths, copepods, crab zoea and megalopea, fish larvae and juveniles, gastropods, stomatopod larvae, euphausids, amphipods, and polychaetes. Occasional cephalopods, cnidarians and a variety of other taxa were also collected. These samples have been retained at CSIRO.

Many zooplankton taxa are known to have a diurnal vertical migration (Ohman, 2000). Thus the zooplankton community and volume may differ between day and night. In addition, there were diurnal differences in the distribution of physical properties (**Figure 3).** The most dramatic differences were for fluorescence with night values greater than day values (**Figure 3)** (see Marra, 1997, for possible explanations for this commonly observed phenomena). The differences were less obvious at the times when zooplankton were sampled (**Figure 5),** although differences in the distributions did occur (**Figure 4)**. Accordingly, zooplankton relationships were analysed separately for the day and night samples. There was one station that was an outlier with regard to zooplankton volume. The western-most station had a large zooplankton volume measurement (**Figure 6**), however, there was a large fraction of gelatinous salps at this station that were not found in other samples. Significant results were obtained, but as an outlier, this station had a large influence on the correlations and statistical tests, and so was removed from the final analysis.

Higher zooplankton volumes were positively related to deeper water during the day ($r=0.46$, $F_{1,20}=5.30$, $p<0.032$), and night ($r=0.39$, $F_{1,20}=1.77$, $p<0.213$) (**Figure 7)** although only the day time relationship was significant. Zooplankton volume was not significantly related to SST for day ($r=0.004$) or night ($r=-0.4$) samples ($p>0.19$ for both). Zooplankton volume was not significantly related to salinity for day ($r=0.19$) or night ($r=-0.37$) samples ($p>0.24$ for both). Finally zooplankton volume was not significantly related to fluorescence for day ($r=-0.084$) or night ($r=0.49$) samples ($p>0.10$ for both) (**Figure 7)**.

Comparisons between *in situ* and satellite SST and fluorescence measurements could not be done at this time, as the satellite data is not yet available.

5. Conclusion

Over the range of physical variables sampled (**Table 3**), zooplankton volume was not related to the SST or fluorescence values for the surface waters in the Great Australian Bight. In each of these relationships examined there was much unexplained variation. Multivariate tests may have explained more variation, but the goal of the study was not to explain variation in zooplankton volume, but to test if univariate measures of the environment, available from satellite, could be used to make inferences about the zooplankton community. This study shows that in the limited range of SST and fluorescence conditions sampled, relationships that would allow predictions about the biomass of zooplankton do not exist. It is apparent from other studies, however, that relationships between physical measures of the environment and biomass or abundance of higher trophic levels do exist. The lack of a relationship here may be due to the small range of physical variables sampled. A program of sampling over many months would see variation in the environment and relationships may be found. For example the range of SST encountered was only 2°C (**Table 3)**, while a range of 10°C is found over the whole year (Hobday, unpublished data). Using zooplankton volume as the response variable may also obscure changes in species composition that occur with changing physical conditions. Enumeration and identification of taxa in the samples would add another layer of complexity to the study, and may not come under the umbrella of rapid assessment. Regular and prolonged sampling programs will be required to uncover the relationships that may exist. Prediction from satellite information may then be investigated more thoroughly.

6. Acknowledgments

Thanks to the captain and crew of the RV Franklin, Chief Scientist Ray Binns, the scientific party and support team, and Marnie Campbell for assistance in carrying out the sampling.

7. References

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8. Figure List

9. Table List

Figure 1. Cruise track of the RV Franklin, January 29-February 15, 2001. The location of the Great Australian Bight Marine Protected Area is indicated. Stars on the cruise track indicate the location of zooplankton sampling stations.

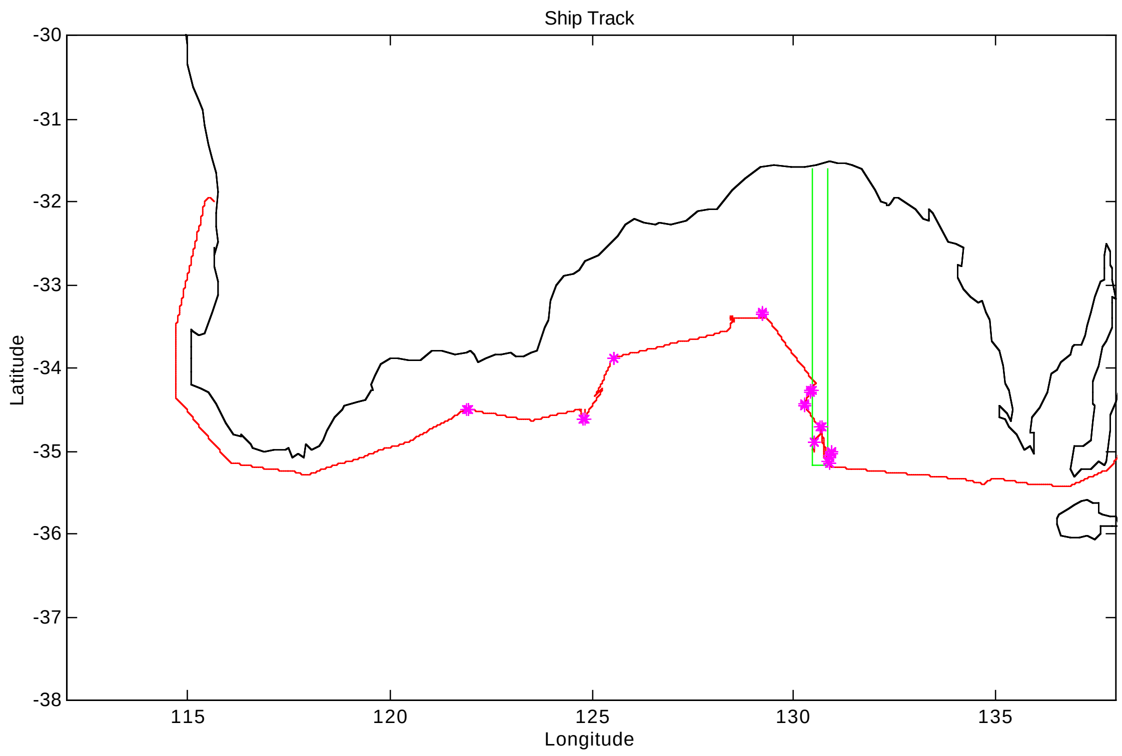

Figure 2. Frequency of environmental conditions (every 5 minutes) throughout the cruise. These are preliminary, uncorrected data, and the distribution should only be compared to the range of conditions sampled during bongo tows.

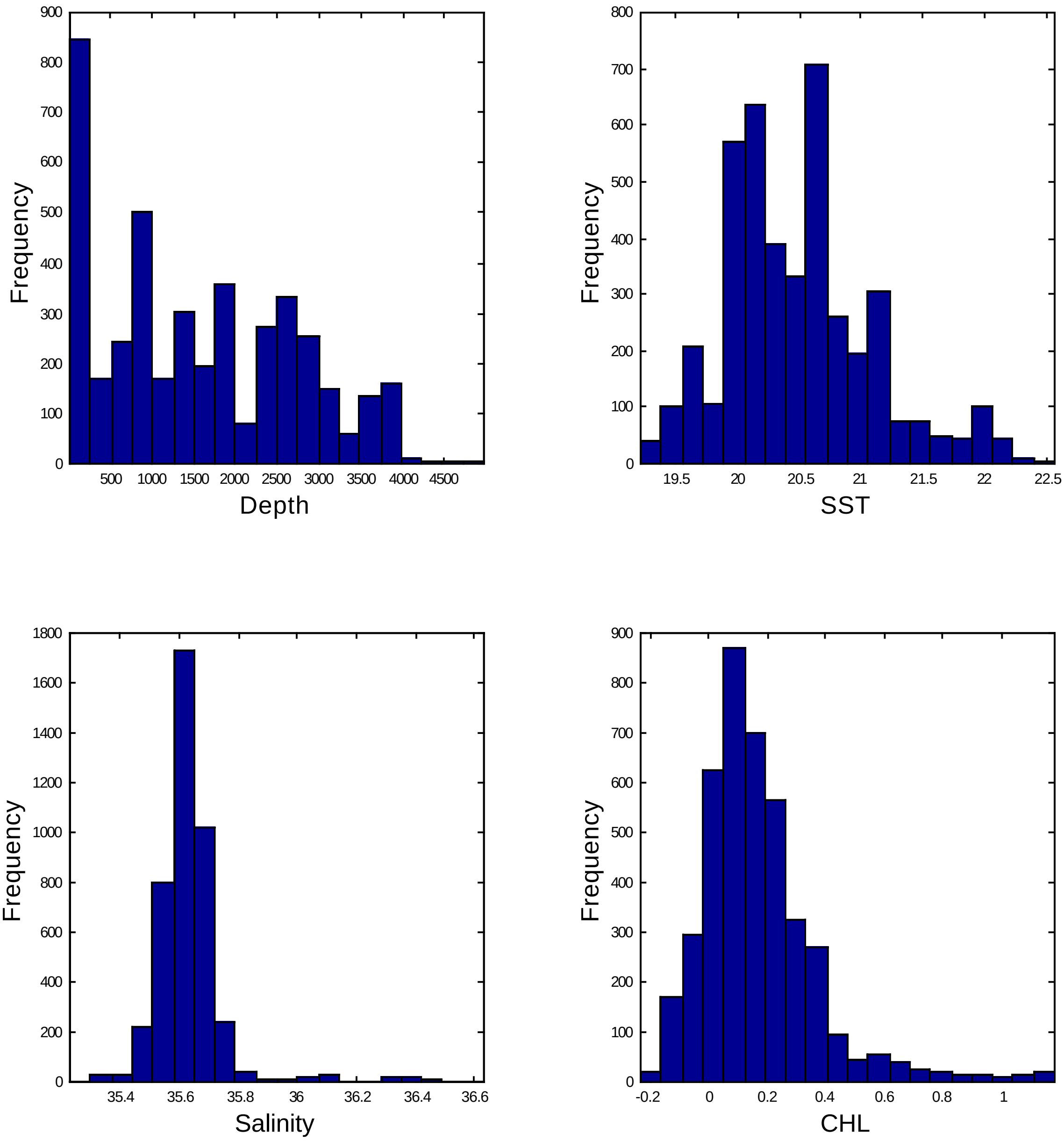

Figure 3. Diurnal variation in underway data. Upper plot. Mean location of ship during the four hours centred on midnight (circles) and noon (stars). Middle left: Diurnal difference in depth by day. Middle right: Diurnal difference in SST by day. Lower left: Diurnal difference in salinity by day. Lower right: Diurnal difference in fluorescence by day.

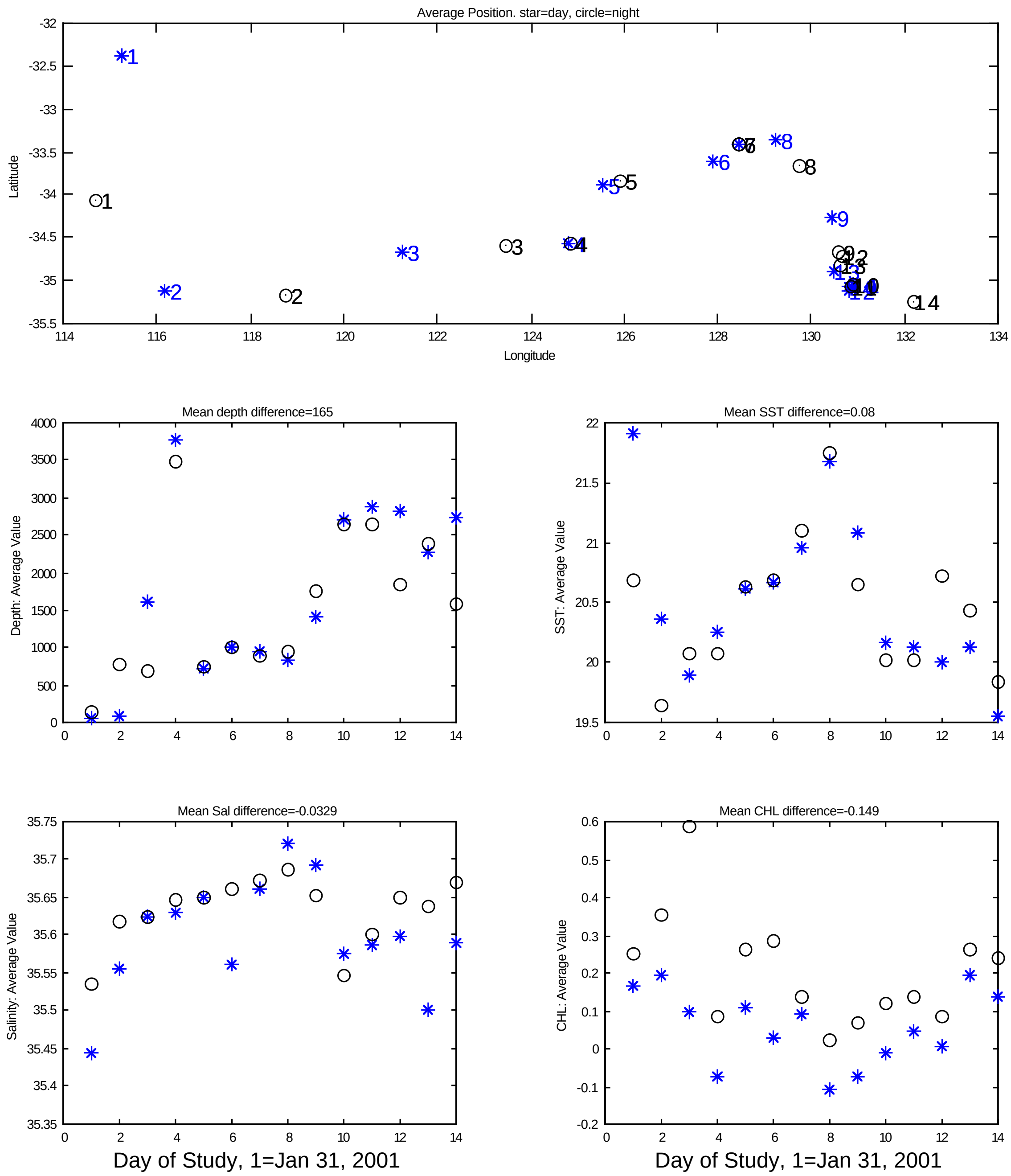

Figure 4. Diurnal variation in physical variables associated with zooplankton sampling. Day (stars) and night (circles) values for each tow are shown.

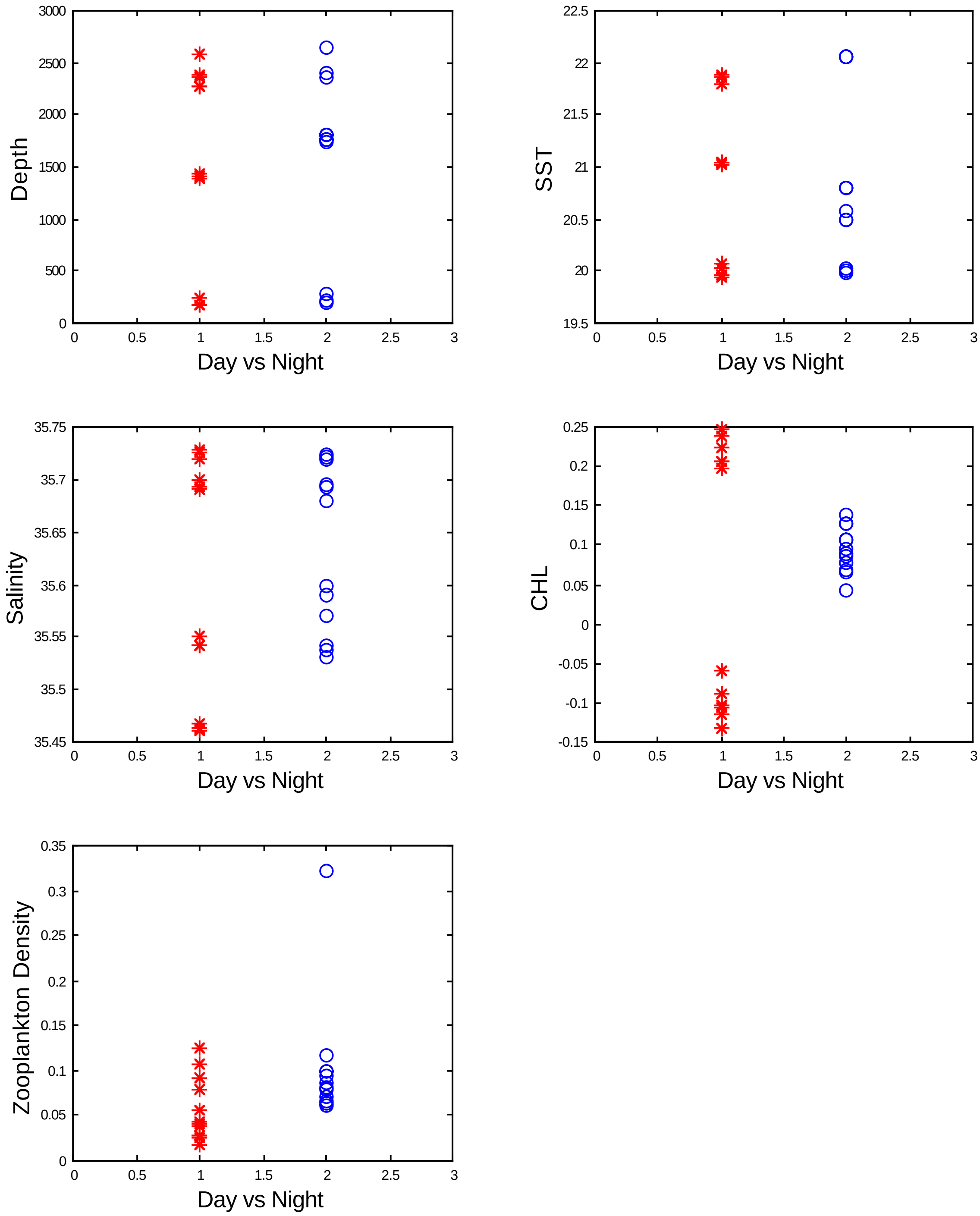

Figure 5. Distribution of the physical properties associated with each bongo tow. Daily tows (stars) and night tows (circles) are indicated separately.

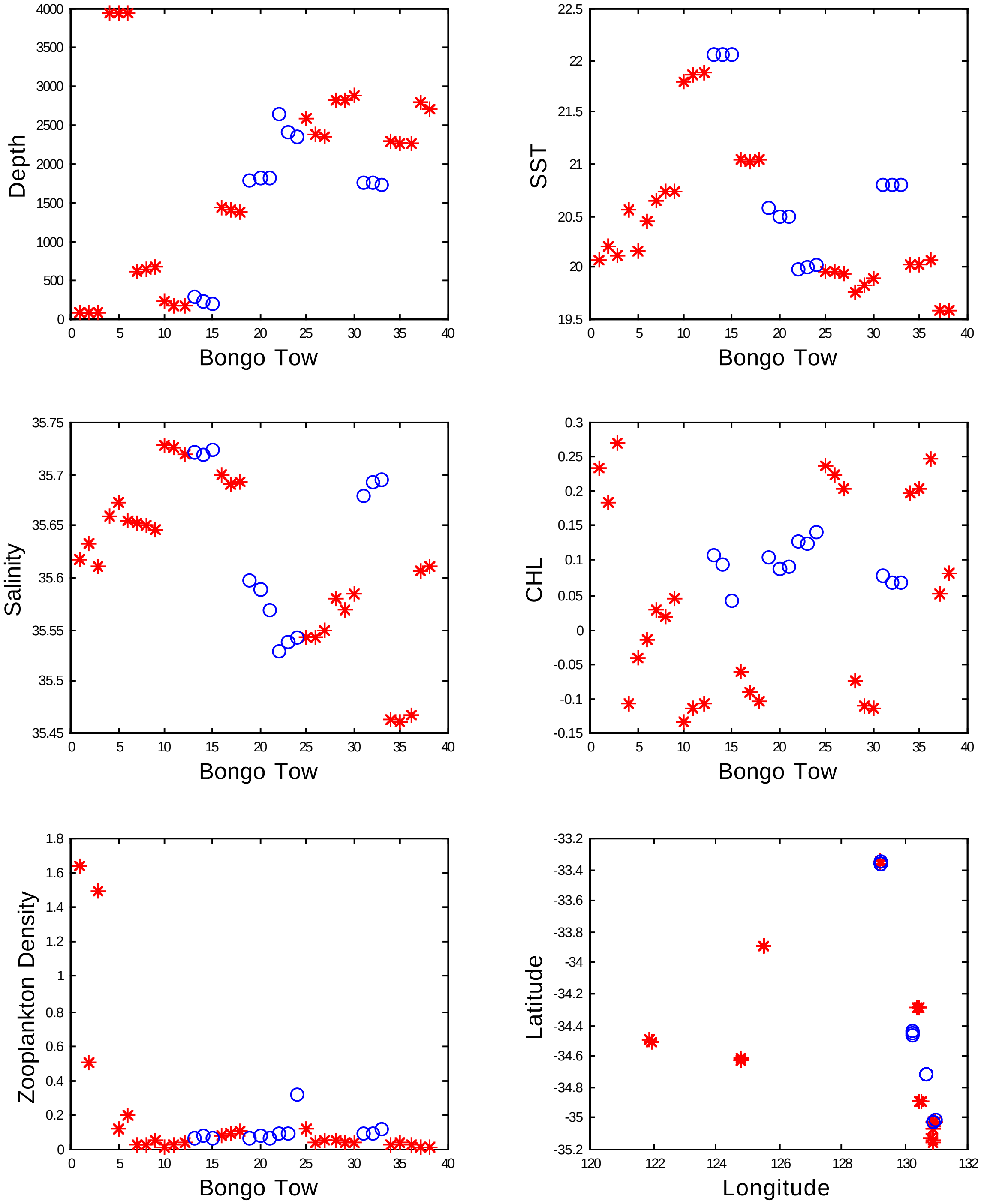

Figure 6. Relationship between the physical properties associated with each bongo tow and the zooplankton volume from each tow. Daily tows (stars) and night tows (circles) are indicated separately.

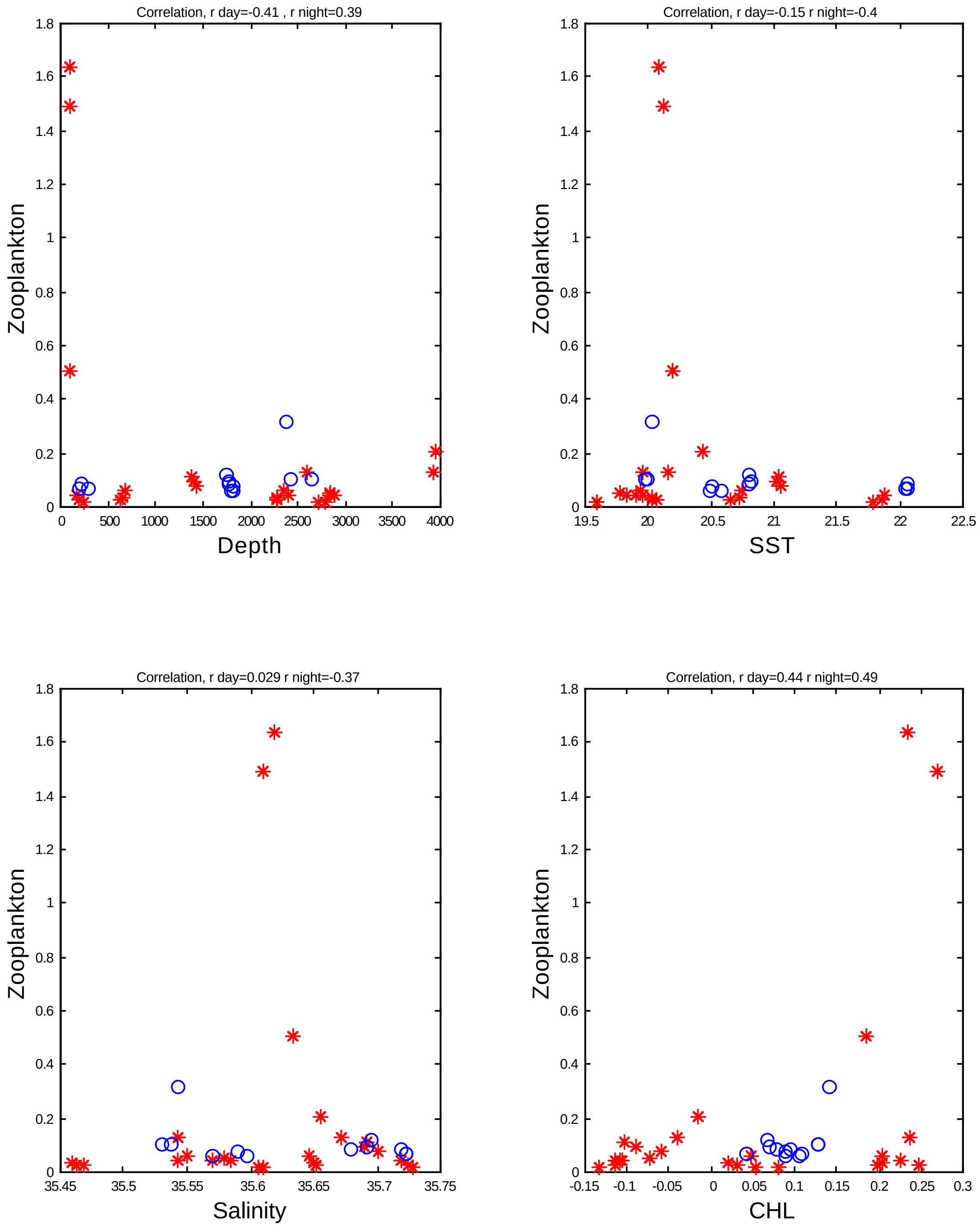

Figure 7. Relationship between the physical properties associated with each bongo tow and the zooplankton volume from each tow. Daily tows (stars) and night tows (circles) are indicated separately. Same as Figure 6, but with the first, western-most station removed.

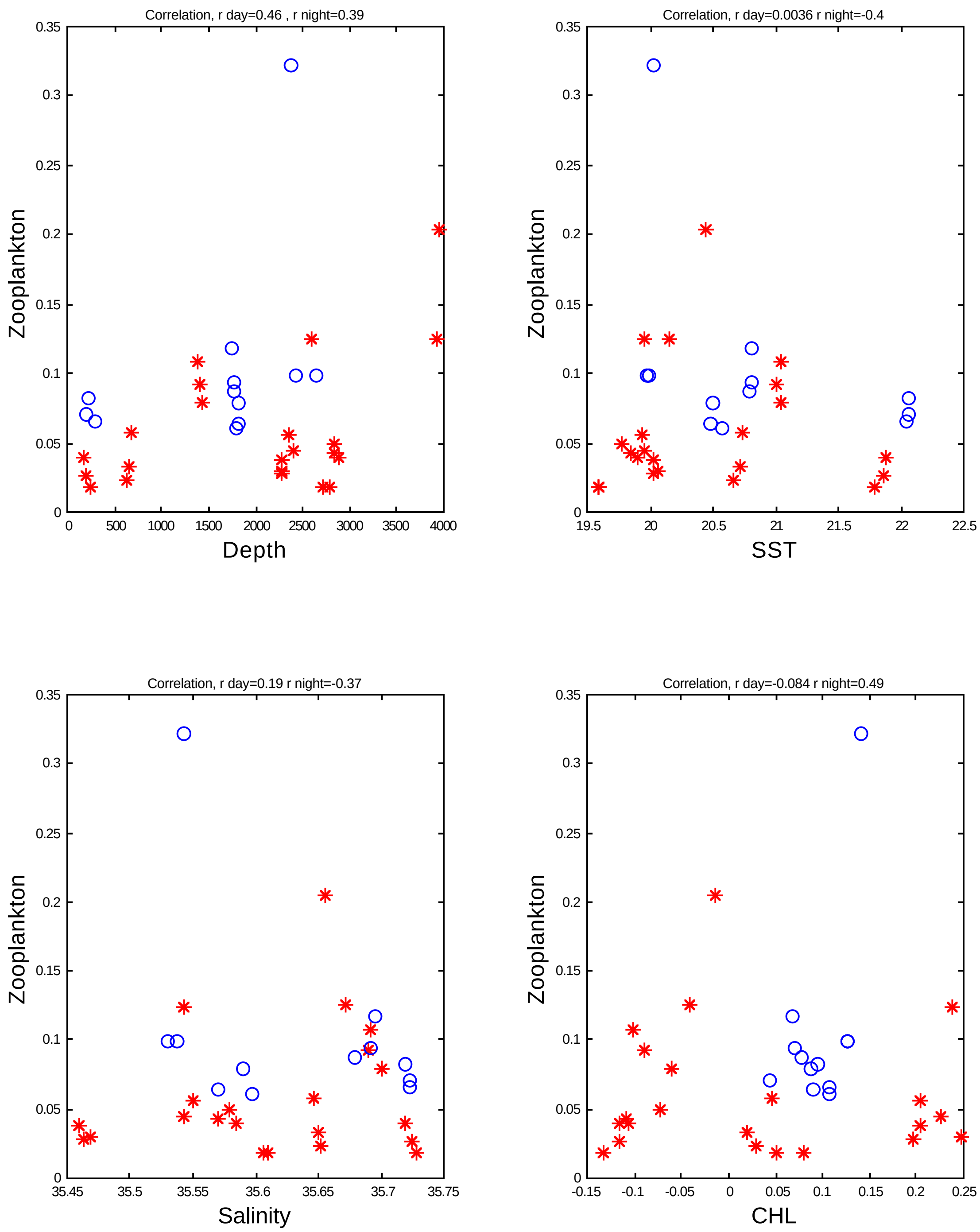

Table 1. Station locations for bongo tows in the GAB, February 1-12 2001.

Station	Tow	Lat (°S)	Long (°E)
1	1	-34.50	121.91
1	2	-34.50	121.94
1	3	-34.51	121.96
2	4	-34.61	124.81
2	5	-34.62	124.81
2	6	-34.63	124.81
3	7	-33.89	125.54
3	8	-33.89	125.55
3	9	-33.89	125.56
4	10	-33.36	129.25
4	11	-33.35	129.25
4	12	-33.34	129.26
5	13	-33.36	129.25
5	14	-33.36	129.25
5	15	-33.35	129.24
6	16	-34.29	130.44
6	17	-34.29	130.45
6	18	-34.28	130.46
7	19	-34.44	130.27
7	20	-34.45	130.27
7	21	-34.46	130.28
8	22	-35.03	130.93
8	23	-35.02	130.94
8	24	-35.02	130.95
9	25	-35.02	130.93
9	26	-35.02	130.94
9	27	-35.02	130.95
10	28	-35.15	130.88
10	29	-35.14	130.87
10	30	-35.13	130.87
11	31	-34.71	130.67
11	32	-34.72	130.68
11	33	-34.72	130.69
12	34	-34.89	130.50
12	35	-34.89	130.50
12	36	-34.89	130.52
13	37	-35.07	130.89
13	38	-35.07	130.90

Table 2. Mixed layer depth estimated using SST and salinity profiles for each CTD station in the GAB, February 1-12 2001.

CTD station	Mixed Layer Depth (m)
1	45
2	55
3	50
4	45
5	50
6	50
7	55
8	50
9	50
10	45
11	55
12	55
13	40
14	40

Table 3. Range of environmental variables that were encountered during zooplankton sampling in the GAB, February 1-12 2001 (n=38 tows).

	Depth (m)	SST (°C)	Salinity (psu)	Fluorescence (relative)
Average	1680	20.61	35.62	0.06
Standard deviation	1172	0.71	0.08	0.13
maximum	3954	22.06	35.73	0.27
minimum	97	19.77	35.46	-0.13