ADELAIDE DESALINATION PROJECT

PLANKTON CHARACTERISATION STUDY

Preliminary report

September 2009

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Photo courtesy of Simon Bryars, DEH

Introduction

The security of Adelaide's metropolitan water supply is largely affected by climatic variability and by Adelaide's limited water storage capacity (approximately one years' demand). With the impact of severe droughts and anticipated climate change likely to lead to reduced flows and greater variability of flows to local reservoirs, the security of Adelaide's water supply has become an issue of critical significance. In March 2007, the South Australian Minister for Water Security announced the formation of a Desalination Working Group to investigate desalination technology and other potential water security measures for the State in the future. The Adelaide Desalination Project has begun the development of a 100 GL per annum seawater reverse-osmosis desalination plant at Port Stanvac in Gulf St Vincent, which aims to provide a reliable water supply for the city of Adelaide, reducing the need to draw water from the River Murray.

Past studies assessing the impact of desalination plants on marine ecosystems have recognised that the intake of seawater has the potential to entrain a large number of different plankton species. Modern intake designs attempt to minimise the chance of motile species being drawn into the feedwater by not placing intake structures in known nursery areas, covering intake structures with fine mesh (~4 mm^2) and reducing intake velocity, such that it is equivalent to ambient currents. Larger fish or larvae which are able to swim against the current are unlikely to be drawn into the desalination plant. However, smaller, less motile organisms such as phytoplankton and smaller zooplankton are still at risk of entrainment through the mesh of the intake structure, and the removal of these important organisms from the water column may have a detrimental impact on food web structure.

The risk that entrainment will have a detrimental impact on regional commercial and recreational fisheries in the vicinity of the Adelaide Desalination Project requires verification. This study is designed to provide data to assist this verification via:

1) characterisation of the plankton communities in the area around the intake and outlet pipes to be used by the Adelaide Desalination Project,
2) quantifying the temporal variation in these communities and
3) quantifying variation in primary and secondary productivity

This document represents a preliminary report from data collected in the first three months of the study. More detailed conclusions will be drawn following the analysis of all data at the completion of the project.

Methods

Plankton was sampled in June and August 2009 at the site of both the inlet pipe (station IRP) and outlet pipe 4 (station ORP4) (Fig. 1). While sampling is intended to be monthly, poor weather prevented sampling in July 2009. Samples for quarterly studies of primary productivity were collected from station PP, midway between station IRP and station ORP4, in August.

A Seabird SBE 19 plus conductivity, temperature, depth recorder (CTD) fitted with a Chelsea Aquatracka fluorometer was used at each station during each sampling trip to provide information regarding sea surface temperature and surface fluorescence. Full vertical profiles from the CTD will be included in the final report. Samples for pigment analysis, sampling of the phytoplankton community, and samples to examine primary productivity were collected at midday. Zooplankton and

icthyoplankton samples were collected at midday and midnight, recognising that the species composition of these groups in the water column may be highly diurnal.

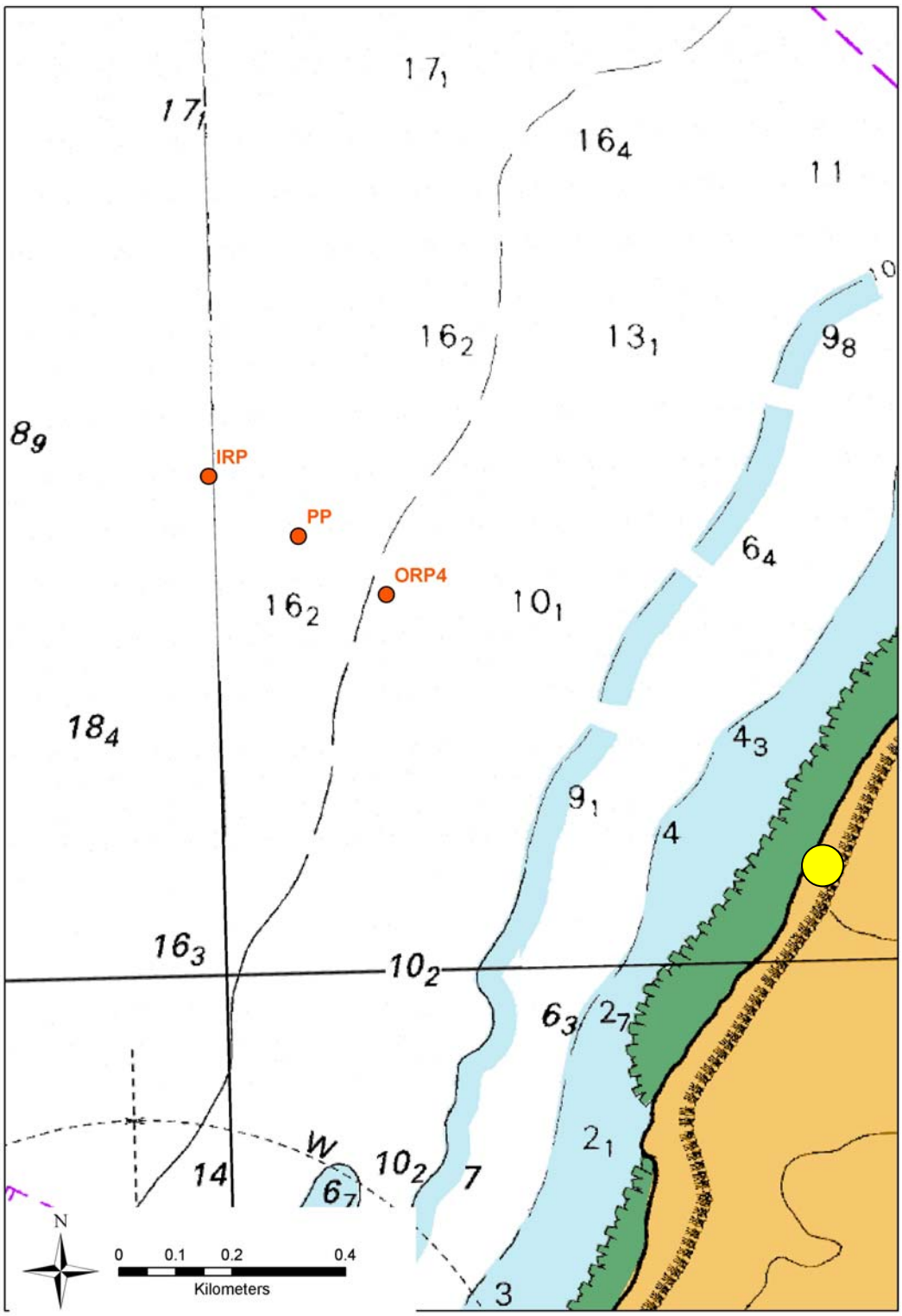

Figure 1. Station locations for sample collection for the plankton characterisation study. IRP = 138.4679 E 35.09059 S; ORP4 = 138.47129 E 35.09255 S; PP = 138.46961 E 35.09158 S (WGS 84). Yellow circle indicates approximate location of ADP site.

HPLC pigment analysis

The pigment composition of water samples was measured using High Pressure Liquid Chromatography (HPLC), to provide an assessment of the biomass distribution between major phytoplankton groups. One litre samples were collected from 3 m depth at each station with a Niskin bottle and kept cool in the dark until returned to the laboratory within 3 hours. Samples were filtered through stacked mesh (to retain cells > 5 μm) and Whatman GF/F filters (to retain cells < 5 μm), allowing the examination of size fractionated phytoplankton biomass. Filters were frozen at -80°C prior to HPLC analysis in the SARDI Aquatic Sciences Environmental Chemistry laboratory.

Phytoplankton community

A detailed inventory of taxa, and their cell abundances, was obtained from one litre samples collected from 3 m depth at each station with a Niskin bottle and fixed with acidified Lugol's iodine solution. Enumeration and identification of phytoplankton to genus or species level was carried out using light microscopy by Microalgal Services, Victoria, Australia.

Primary productivity

Primary productivity in the water column was measured based on methods outlined by Parsons et al. (1984), Lohrenz et al.(1992), and Mackey et al. (1995). Three independent 2 litre samples were collected from 3 m depth in opaque bottles and kept cool in the dark until return to the laboratory within x hours. Seven irradiance levels were used, by modifying the amount of natural sunlight reaching the experimental bottles via shading with shade cloth. Irradiances included 0% (dark), 0.4%, 1.2%, 1.5%, 6.5%, 50%, and 100% of natural sunlight. From each independent water sample, 1 x 250ml polycarbonate bottle was prepared for each irradiance level. A known quantity of $NaH^{14}CO_3$ (20 μCi) was added to each replicate bottle. Bottles were then incubated in a flow-through water bath for 24 hours at *in-situ* water temperatures in natural sunlight. Irradiance was measured every minute with a Licor Li-1400 data logger and underwater quantum sensor, with the mean irradiance logged every 30 minutes over the 24 hour period, then integrated to provide daily integral irradiances. Post-incubation, samples were filtered at low vacuum pressure through 25mm Whatman GF/F filters, rinsed with filtered seawater, placed into 5ml scintillation vials and frozen until further analysis. Filters were thawed at room temperature and exposed to 200μl of 5N HCl for 12 hours to drive off any remaining $^{14}CO_2$. Four millilitres of scintillation fluid (Ultima Gold high flashpoint LSC cocktail) was then added to each vial and, after 24 hours, radioactivity was determined as disintegrations per minute using a scintillation counter (Packard Tricarb 2100TR). Total CO_2 concentration in samples was estimated from salinity using the method of Parson et al. (1984). Measured photosynthetic rates were fit to the hyperbolic tangent equation of Jasby and Platt (1976) in Microsoft Excel using Solver to provide estimates of photosynthetic efficiency (α), and maximum biomass specific photosynthetic rates (P^b_{max}), and irradiances corresponding to the onset of light saturation of photosynthesis (I_k).

Zooplankton community

The structure of the zooplankton community was detemined in five samples collected via net tows with a 50 µm mesh net (30 cm net mouth diameter) lowered to within 1 m of the bottom and towed vertically to the surface. The contents of the net was washed into a sample jar, topped up to 1 litre, and fixed with formalin (5% final volume). Samples were pooled during rinsing through a 35 µm mesh sieve. The contents of the sieves were rinsed into 100ml measuring cylinders and allowed to settle for 24 hours, after which settling volumes were recorded (ml). Samples were then decanted into 120 ml jars and resuspended in 100ml of water (i.e. concentrated 50x). Identification and enumeration was done via light microscopy. After gently resuspending the sample, a 1 ml aliquot was taken for counting using a Sedgewick-Rafter chamber. Counts were continued until 100 specimens of the dominant group were counted. Organism numbers were recorded as individuals m^{-3} in the water column using the volume swept by the net, calculated as the depth of the tow multiplied by the area of the net mouth.

Secondary productivity

Meso-zooplankton grazing pressure was estimated from zooplankton settling volumes, which were converted into biomass (mg C). Settling volumes were first converted into displacement volumes using a factor for samples without gelatinous zooplankton (0.35, (Wiebe *et al.* 1975; Wiebe 1988)). Displacement volumes were converted to biomass (mg C) using a factor of 21 for samples with displacement volumes < 1 cm^3, and a factor of 41 for samples with displacement volumes 1-10cm^3 (Bode *et al.* 1998). Potential growth of the meso-zooplankton was estimated via the empirical relationship of Huntley and Boyd (1984) (equation 1):

$$G'_{\max} = 0.0542e^{(0.110T)} \qquad (1)$$

Where T is temperature (CTD measured sea surface temperature) and G'_{max} is the maximum mass-specific food-saturated growth rate, which can be used to estimate the assimilative capacity (AC) of the meso-zooplankton community via equation 7:

$$AC = 0.7G'_{\max} \qquad (2)$$

Where 0.7 is the estimate of 70% assimilative efficiency proposed by Conover (1978). The assimilative capacity was multiplied by biomass to give an estimate of the potential grazing rate of the meso-zooplankton community.

Icthyoplankton community

To assess abundance of fish larvae and eggs, five samples were collected via net tows with a 350 µm mesh bongo net (30 cm net mouth diameter) lowered to within 1 m of the bottom and towed 50 m horizontally then brought to the surface. The contents of the nets were pooled into a sample jar, topped up to 1 litre and fixed with formalin (5% final volume). Samples were pooled during rinsing through a 35 µm mesh sieve. The entire sample was sorted under a dissection microscope at 5x magnification. Egg and larvae numbers were recorded as individuals m^{-3} in the water column using the volume swept by the net, calculated using distances travelled by the

net (recorded by flow meters suspended in the mouth of each net) multiplied by the area of the net mouth.

Results and discussion

HPLC pigment analysis

Pigment samples have yet to be processed through the HPLC. It is more cost effective to process a large number of samples in one go than the few that have been collected in this project so far. Full analysis of pigment samples will be presented in the final report.

Phytoplankton community

Phytoplankton abundances were greater in June than August (Fig. 2). The phytoplankton community at both stations was dominated by small flagellates which were present in total numbers > 80,000 cells L^{-1}, peaking in June at ~350,000 cells L^{-1} (Fig. 2). The flagellates were dominated by the Prymnesiophyte *Chrysochromulina spp.*, Cryptophytes *Hemiselmis sp.* and *Plagioselmis prolonga*, and Prasinophytes *Pyramimonas spp.* and *Tetraselmis spp.* Total diatom abundances were ~50,000 cells L^{-1} in June, decreasing in August (Fig. 2), with the community dominated by *Chaetoceros spp.*, *Cylindrotheca closterium*, *Miniduscus trioculatus*, *Nitzschia spp.*, and *Thalassiosira cf mala*. Dinoflagellate abundances were 30,000-50,000 cells L^{-1} in June, falling to 10,000-20,000 cells L^{-1} in August. Dominant dinoflagellates included Gymnodinioid *spp.*, *Gyrodinium spp.*, *Heterocapsa rotunda*, and *Scripsiella spp.*

Total phytoplankton abundances in the Port Lincoln Tuna Farming Zone in June 2007 were ~200,000 cells L^{-1}, with diatoms dominating the community at ~100,000 cells L^{-1}. August abundances were ~100,000 cells L^{-1}, with diatoms ~40,000 cells L^{-1} (van Ruth et al. 2008a)

Primary productivity

Calculations of primary productivity made use of CTD measured fluorescence (0.2 µg L^{-1}) due to the absence of HPLC pigment data. Values will be re-calculated to provide more accurate estimates when pigment analysis is completed, though they are not expected to change significantly.

The modelled rate of primary productivity agreed well with measured results (Fig. 3). Maximum specific photosynthetic rate (P^b_{max}) in August was 3.00 mg C (mg chl *a*)$^{-1}$ hr^{-1}, the photosynthetic efficiency (α) was 0.06 mg C (mg chl *a*)$^{-1}$ hr^{-1} (µmol m^{-2} s^{-1})$^{-1}$, and the irradiance corresponding to the onset of light saturation of photosynthesis (I_k) was 52 µmol m^{-2} s^{-1} (Fig. 3). Similar values were reported for the waters in the Port Lincoln Tuna Farming Zone in south western Spencer Gulf in July 2007 (P^b_{max} = 1.27-2.04 mg C (mg chl *a*)$^{-1}$ hr^{-1}, α = 0.06-0.11 mg C (mg chl *a*)$^{-1}$ hr^{-1} (µmol m^{-2} s^{-1})$^{-1}$, I_k = 14-25 µmol m^{-2} s^{-1}, van Ruth et al. 2008b).

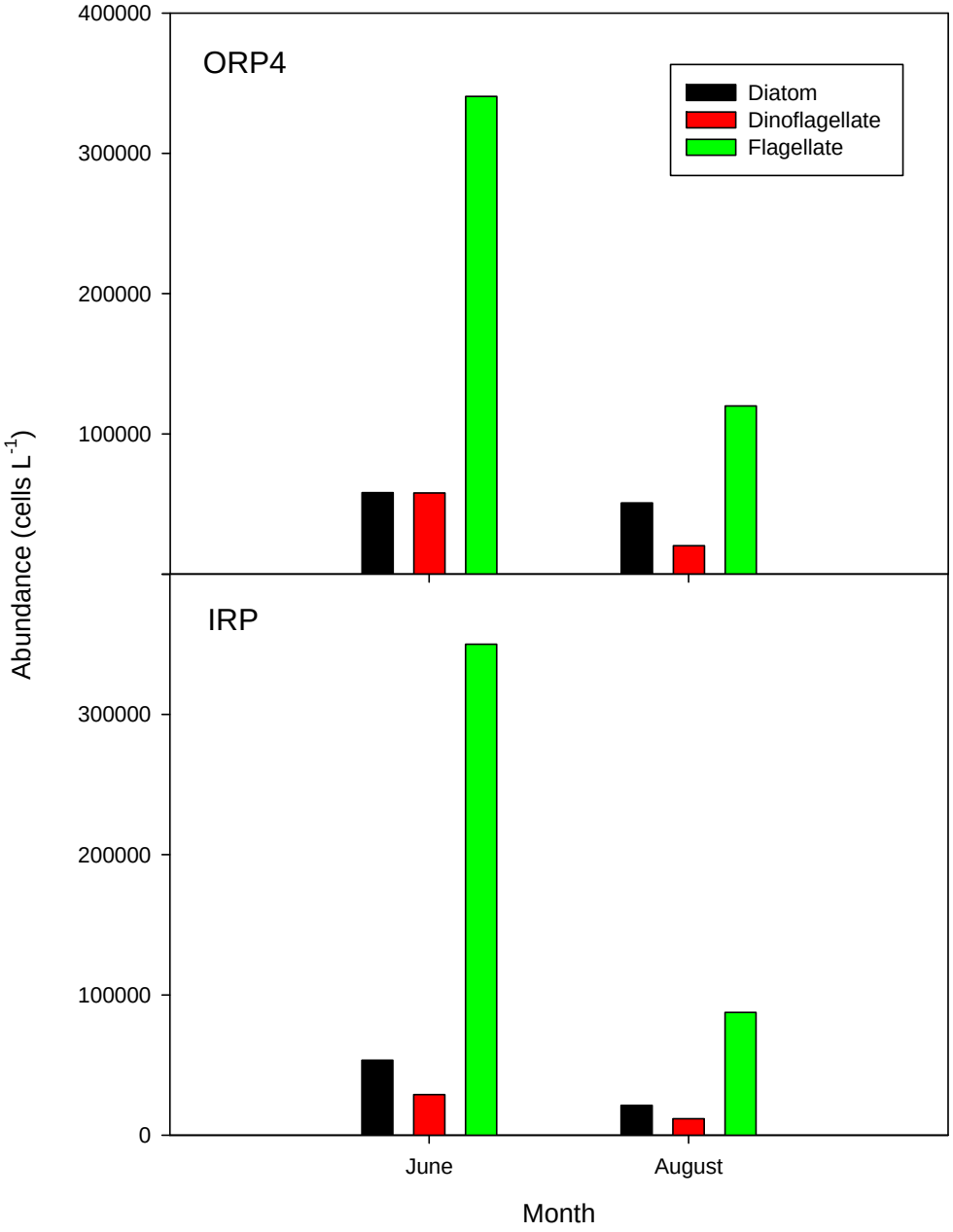

Figure 2. Phytoplankton abundances at stations IRP and ORP4 in June and August 2009. See figure 1 for station locations.

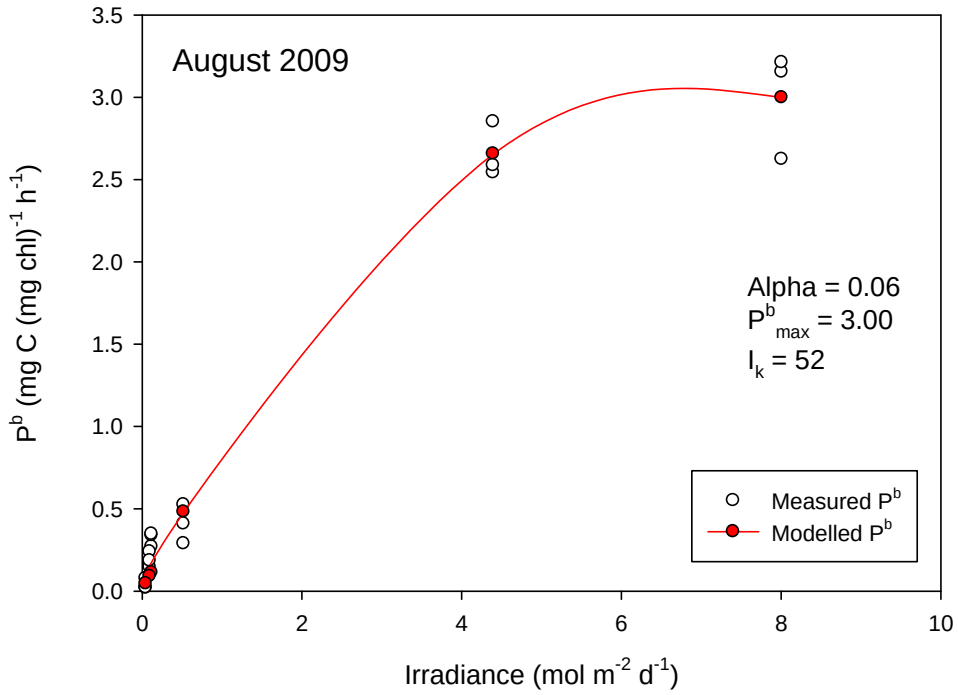

Figure 3. Photosynthesis – irradiance curve from ^{14}C experiment conducted in August 2009 on water collected from station PP (see figure 1 for station location). Units for α = mg C (mg chl *a*)$^{-1}$ hr^{-1} (µmol m^{-2} s^{-1})$^{-1}$, P^b_{max} = mg C (mg chl *a*)$^{-1}$ hr^{-1}, I_k = µmol m^{-2} s^{-1}.

Zooplankton community

Zooplankton abundances were generally higher in June (40,000-80,000 organisms m^{-3}) than August (20,000 to 50,000 organisms m^{-3}, Fig. 4). In June, day-time abundances were higher than night-time abundances. The pattern was reversed in August, reflecting the more typical diel variation in abundances brought about by the vertical migration of zooplankton from the sediments to the surface in the hours of darkness, a common behaviour that allows zooplankton to avoid visual predators during the day and feed in more productive surface waters at night (Haney 1988). Similar patterns were observed in settling volumes (Table 1).

The zooplankton community was dominated by copepod nauplii, which were present in abundances between 5,000 and 35,000 organisms m^{-3}. Copepods were also highly abundant, with numbers between 2000 and 9000 organisms m^{-3}. Other abundant zooplankton included veliger larvae (2,000-10,000 organisms m^{-3}), ostracods (300-14,000 organisms m^{-3}), and bivalves (700-4000 organisms m^{-3}). Zooplankton abundances observed in the Port Lincoln Tuna Farming Zone in July 2007 were ~15,000 organisms m^{-3}, with the community dominated by copepods and cladocerans (van Ruth et al. 2008b).

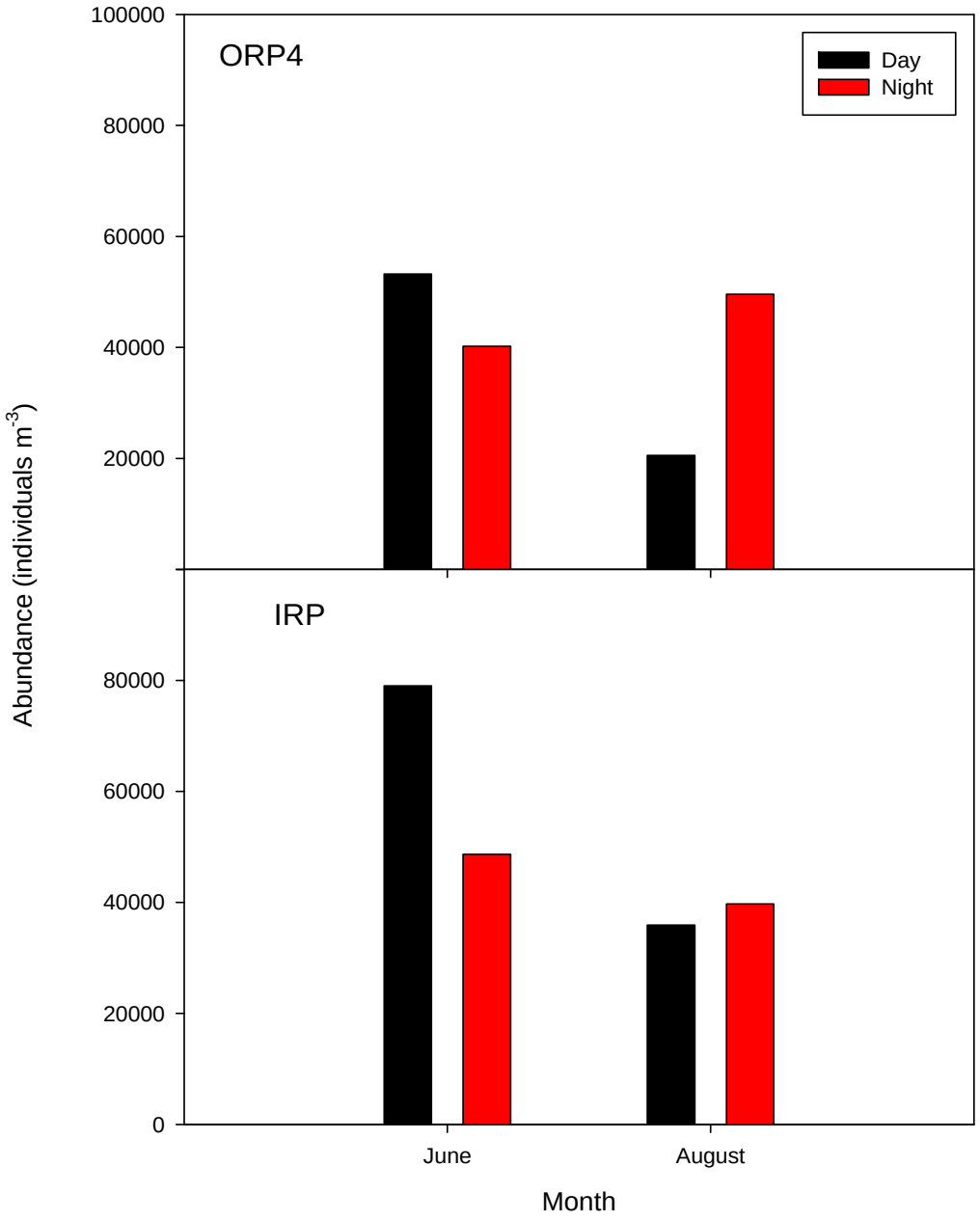

Figure 4. Zooplankton abundances at stations IRP and ORP4 in June and August 2009. See figure 1 for station locations.

Secondary productivity

Potential zooplankton growth rates (G'_{max}) were marginally higher in June than in August (Table 1). Grazing impact was generally higher in June than in August. In similar patterns to those observed in zooplankton abundances and settling volumes, in June, day-time grazing impact was higher than night-time grazing impact, with the pattern reversed in August.

For comparison, grazing impacts in the Port Lincoln Tuna Farming Zone in July 2007 were between 4.0 and 13.5 mg C m^{-3} (van Ruth et al 2008b). Sea surface temperatures and potential zooplankton growth rates were similar to those measured

in this study, but settling volumes (2.1-5.1 ml m^{-3}) and biomass (11.0-37.5 mg C m^{-3}) were much higher in the Tuna Farming Zone in July 2007.

Table 1. Temporal variation in settling volume (ml m^{-3}) meso-zooplankton biomass (mg C m^{-3}) and grazing rate (mg C m^{-3} d^{-1}). SST = CTD measured sea surface temperature (°C), G'_{max} = potential growth rate (d^{-1}). See figure 1 for station locations.

Station	Month	Time	Settling vol	Biomass	SST	G'max	Grazing impact
IRP	June	Day	1.41	10.35	14.7	0.27	0.55
IRP	June	Night	1.01	7.43	14.7	0.27	0.39
ORP4	June	Day	1.41	10.35	14.7	0.27	0.55
ORP4	June	Night	1.27	9.31	14.6	0.27	0.49
IRP	August	Day	0.85	6.21	14.0	0.25	0.31
IRP	August	Night	1.19	8.72	14.0	0.25	0.43
ORP4	August	Day	0.45	3.29	14.1	0.26	0.16
ORP4	August	Night	1.34	9.83	14.0	0.25	0.48

Icthyoplankton community

Results are only currently available for June samples. Full analysis of icthyoplankton samples will be presented in the final report.

Egg numbers present in night samples were ~ double the numbers found in day samples, with 2.4 eggs m^{-3} at night at station IRP, and 1.5 eggs m^{-3} at night at station ORP4. Sardine eggs dominated the samples, with some unidentified eggs also present. There were few larvae found in June samples (< 0.3 larvae m^{-3}). Most larvae were leatherjackets, with some unidentified larvae also counted.

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