Gippsland Lakes & Catchment Taskforce

Fish assemblages and seagrass condition of the Gippsland Lakes: 2008 to 2010

Jeremy S. Hindell and Fiona Y. Warry
Arthur Rylah Institute for Environmental Research
Department of Sustainability and Environment

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Jeremy S. Hindell and Fiona Y. Warry

Arthur Rylah Institute for Environmental Research
123 Brown Street, Heidelberg, Victoria 3084

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Arthur Rylah Institute for Environmental Research
Department of Sustainability and Environment
Heidelberg, Victoria

Report produced by: Arthur Rylah Institute for Environmental Research
Department of Sustainability and Environment
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.dse.vic.gov.au/ari

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Executive Summary

The Gippsland Lakes are one of Australia's largest estuaries, and support unique natural assets and valuable industries (e.g. tourism, commercial fishing). A bloom of the blue-green alga *Synechococcus* sp. occurred throughout the Gippsland Lakes in November 2007, and persisted for at least 10 months. This bloom drastically reduced incident light over a large area of the Gippsland Lakes, and anecdotal evidence from local fishers, tourism operators and the general public suggested that there had also been widespread decline of seagrass over the same period. The Gippsland Lakes and Catchment Taskforce were concerned at the potential decline in seagrass within the Gippsland lakes, and undertook to assess the 'condition' of seagrass (and associated fish assemblages) within the Gippsland Lakes.

This study provides a snapshot of fish assemblage structure and seagrass 'condition' within the Gippsland Lakes during September 2008, April 2009 and April 2010. Fish assemblage structure and/or the presence and condition of seagrass were initially assessed during September 2008 at 30 sites throughout the Gippsland Lakes using an experimental otter trawl and underwater video, respectively. Water quality parameters were recorded at all study sites, and light attenuation was measured at selected locations. A second round of sampling was undertaken in April 2009, during which the same 30 sites were (re)sampled for seagrass and water quality parameters, and fish were again collected at selected sites. An additional 20 sites were sampled during April 2009, with a focus on recording seagrass cover and condition. The most recent round of sampling in April 2010 re-sampled fish at a range of sites using a small beach seine net, and trialled a new electrofishing unit. Water quality attributes were again recorded throughout the lakes, and there was some additional sampling of seagrass condition across the Lakes.

Fish assemblages sampled in September 2008 were consistent with those expected in shallow Victorian estuaries during the colder winter and early spring periods. Black bream dominated catches, with juveniles of several other species also common. Seagrass was present at most sites, with two taxa dominating: *Ruppia* at depths around 0.5 to 1 m; and, '*Zostera'* (including both *Heterozostera nigricaulis* and *Zostera muelleri*) in waters 0.5 to 2 m depth. When compared with the habitat maps for seagrass throughout the Gippsland Lakes by Roob and Ball (1997), there appeared to have been some decline in the 'amount' of seagrass within 75% of the sites (video transects) sampled. Water quality variables throughout the Gippsland Lakes were within the ranges commonly observed for this large estuary. Chlorophyll *a* levels were high ($> 10\ \mu g.l^{-1}$) in the vicinity of eastern Lake Victoria, but relatively lower in other regions of the Lakes.

The second round of sampling in April 2009 demonstrated an increase in the overall condition of seagrass. *Ruppia* and *Zostera spp.* again dominated seagrass samples, and 50% of the video transects sampled in September 2008 showed increases in the density of seagrass. There was also an increase in fish abundance and species richness. Samples of fish in April 2009 were dominated by juveniles and species strongly associated with seagrass. Some of the change in overall numbers of fish caught was due to the change in gear used to sample fish. The experimental trawl net was used to sample fish in both periods, but it was increasingly clear that this gear was not effective at sampling fish within the Lakes, and a beach seine net was used to more effectively sample fish within the Lakes. As in September 2008, water quality parameters were within the ranges expected for the Gippsland Lakes during late summer/early autumn. Chlorophyll *a* levels were $\leq 6.0\ \mu g.l^{-1}$ at all sites, which were generally lower than those recorded in September 2008.

The most recent round of sampling in April 2010 showed some decrease in seagrass cover and condition at several sites throughout the Gippsland Lakes. Fish assemblages sampled with the beach seine were similar to those from 2009. The new electrofishing equipment showed great promise in sampling fish within estuarine (and marine) environments. A range of species not previously caught in surveys of the Gippsland Lakes were caught using this equipment, including species that are nocturnal and those which are more commonly found on exposed coastal reefs. Temperature (ºC), salinity (ppt), dissolved oxygen (Mg/L) and turbidity (NTU) in April 2010 were consistent with other years. Chlorophyll *a* values were variable but high (>10Mg/L) at several sites.

The present study suggests that there was some decline in seagrass between the late 1990s and September 2008. Seagrass then returned at 50% of the sites sampled in September 2008. The initial declines can not be linked directly to effects of the phytoplankton bloom of 2007 (i.e. reduction in available light to support seagrass growth) because of a lack of regular seagrass assessment. Sampling in 2010 suggests that seagrass has again declined across a number of sites, with some evidence of smothering by epiphytic algae and slightly higher phytoplankton levels.

The three sampling periods of the present study provide a preliminary baseline of data against which future changes in the Gippsland Lakes can be assessed. There is now an opportunity to build on the present work to improve understanding of where and when areas of seagrass within the Gippsland Lakes change, and how changes in the distribution of seagrass influence local fish assemblages.

In order to understand how changes in the distribution of seagrass influence local fish assemblages, it is recommended that further research is undertaken in developing innovative sampling and methodological approaches in electrofishing and GIS-based modelling for distribution assessments. We also recommend that research should be undertaken to develop our understanding of the value of seagrass ecosystems with regard to processes such as carbon capture and storage, supporting commercial and recreational fisheries, biodiversity and conservation, and nutrient cycling and water quality.

1 Background

Planktonic algal blooms are a major feature of the biological activity in the Gippsland Lakes. Toxic blue-green algal blooms are an ongoing concern due to their deleterious effects on fish and other marine life, water quality for public health, and flow-on impacts on local businesses and tourism (Stephens et al. 2004). Stephens et al. (2004) noted that there were other groups of plankton that have the potential to be toxic and/or disrupt ecosystem function, however, little attention had been paid to these in the past.

A bloom of the blue-green alga *Synechococcus* sp. occurred throughout the Gippsland Lakes in November 2007. *Synechococcus* sp. is a unicellular cyanobacterium that is widespread in the marine environment. Unlike blue-green algae such as *Nodularia* sp., *Microcystis* sp. and *Anabaena* sp., *Synechococcus* sp. is not toxic to marine animals; however, the Department of Human Services advised that high levels of *Synechococcus* sp. may cause skin irritation, mild respiratory and hay-fever like symptoms upon contact.

Unlike previous blue-green algal blooms, the bloom of *Synechococcus* sp. declined only partially through the winter of 2008. One of the most serious consequences of the algal bloom was reduced light penetration of the water. Light levels were severely attenuated throughout the water column by the high cell densities for up to 10 months in areas of the Lakes with the highest densities of *Synechococcus* sp. cells. The ecological effects of the extended bloom conditions were not known, although the extended reduction in light was likely to have negatively impacted the primary productivity of benthic plants such as seagrasses.

The Gippsland Lakes & Catchment Taskforce facilitated an alliance of State Government and University research scientists to assess the ecological impacts of the algal bloom in the Gippsland Lakes. In discussing monitoring needs, there was agreement that investigations should:

- Build on existing data or current/recent monitoring programs
- Provide a snapshot of the present health of fish populations and seagrass
- Integrate impacts of the bloom over the past 10 months
- Outline a robust sampling strategy that builds on logical synergies among ecological processes to better understand impacts of the algal bloom - i.e. link fish populations to seagrass health and food web dynamics.
- Design a sampling strategy that can be done quickly and efficiently - including the collection of all data in a single field trip
- Collect results that can be analysed and written-up within a month of completing the sampling
- Focus on measures that are meaningful and easy to describe to managers and the general public

Four broad activities were put forward to improve understanding of the consequences of algal blooms on fish and seagrass communities within the Gippsland Lakes, and included:

1. Assessing the assemblage structure of fish
2. Documenting seagrass 'condition'
3. Measuring water quality
4. Assessing attenuation of photosynthetically active radiation

These activities were completed for a first round of sampling in September 2008, and then refined for second- and third-round sampling events in April 2009 and April 2010. Sampling in April 2010 further assessed novel equipment (i.e. electrofishing) in sampling fish, and increased the spatial coverage of historical sampling.

2 Materials and Methods

2.1 Study sites

Sites for the first round of sampling in September 2008 were selected between Lake Victoria and Lakes Entrance. The habitat maps of Roob and Ball (1997) were used to select sites where dense or medium beds of *Zostera* had been observed. The work of Judd et al. (2008) was also used to guide the selection of sites in the vicinity of Lakes Entrance.

The second round of sampling in April 2009 re-visited sites sampled in September 2008. An additional 20 sites were added to those sampled in 2008 to increase the spatial coverage of the study and the total number of sites surveyed (for seagrass) to 50. These additional sites strengthened baseline data (including video footage) with which to assess future changes in seagrass health of the Gippsland Lakes. The April 2010 sampling round re-visited these 50 sites (Figure 1).

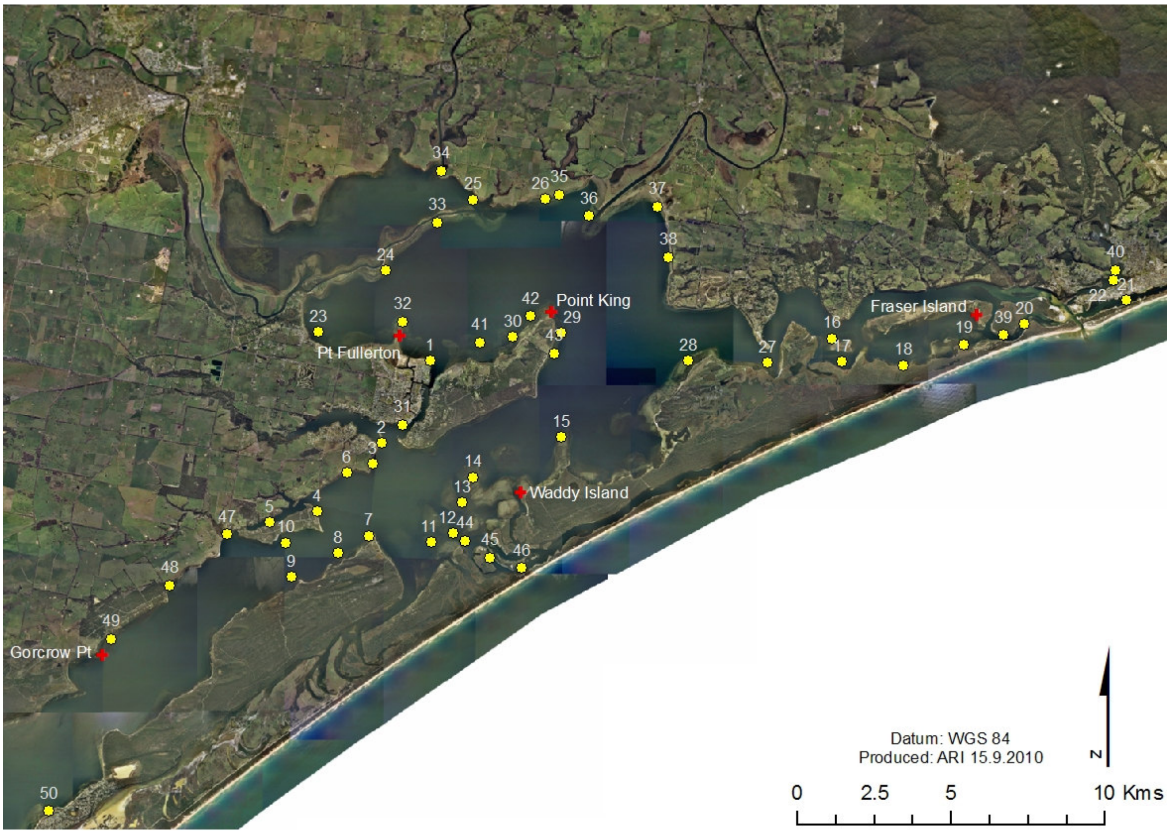

Figure 1. Sites throughout the Gippsland Lakes where seagrass condition assessment was done during April 2010.

2.2 Assessing fish assemblage structure

The original assessment of fish assemblage structure in September 2008 used an experimental otter trawl previously employed effectively by Hindell and colleagues (2008) in the riverine regions of the Gippsland Lakes estuarine system (see Hindell and Warry 2009 for trawl description). Fish catches were low with this gear in the Gippsland Lakes in September 2008 (Hindell and Warry 2009) and further evaluation of the otter trawl showed that catches of fish within the Lakes were significantly lower than those in the rivers (J. Hindell unpublished data), although it is not clear at this stage why this was the case.

Comparison of the otter trawl with a small beach seine net in April 2009 and previously published work (e.g. Guest et al. 2003) indicated the seine captured higher species richness and relative abundances of small and juvenile fishes associated with shallow water habitat such as seagrass. The beach seine was subsequently used exclusively in 2010.

The beach seine net was 20 m long × 2 m deep, with 5 mm knotless mesh and 10 m lengths of rope attached to each end (Figure 3). The seine was deployed by walking the net out from the boat in a wide arc and using a 'pursing' technique to haul the net and its contents into a large bucket. Sampling focused on sites with seagrass coverage to identify those species most likely to use seagrass in the Gippsland Lakes. The seine net representatively sampled fish assemblages of shallow-water habitats making it a considerably more useful technique than the trawl for sampling fish associated with seagrass in the Gippsland Lakes.

In 2010, fish assemblages were quantified using the beach seine net used in 2009. In addition, a new electrofishing unit was trialled. Electrofishing units can usually only be used in freshwater with very low conductivity. The higher salt content of estuarine and marine waters, and concomitant higher conductivities, has historically precluded the use of this type of equipment in sampling fish within these types of environment. Senior ARI technicians (J.McKenzie pers. com.) have recently arranged for a powerful electrofishing unit to be built (the make and model of which can not be published until further testing is completed). ARI are now trialling this new unit in a range of conductivities. The Gippsland Lakes fish survey for this study provided an excellent opportunity to trial this new equipment over a range of salinities (and conductivities) from fresh to marine. The trial of the electrofishing unit in the Gippsland lakes provided additional qualitative information on fish assemblage structure to support the quantitative data collected using the seine net.

2.3 Measuring seagrass condition

Anecdotal reports suggested that seagrass declined throughout the Gippsland lakes during the 2007 to 2008 period, probably because of reduced light as a consequence of the 2007 algal bloom. Roob and Ball (1997) mapped and reviewed the distribution of seagrass throughout the Gippsland Lakes. More recently, Judd et al. (2008) mapped and assessed seagrass habitat close to the Entrance. Originally, the maps of Roob and Ball (1997) and Judd et al. (2008) provided a baseline for the present study, against which the presence/absence of seagrass could be assessed. The continuation of the present study has provided three years of data collected with consistent methodologies to contribute to the current baseline regarding seagrass distribution and condition in the Gippsland Lakes.

In the present study, as in Roob and Ball (1997), the two species of Zosteraceae observed in the Gippsland Lakes (*Zostera nigricaulis* and *Zostera muelleri*) are not easily differentiated by remote sensing techniques, including underwater video. Specific species identifications were not undertaken, and *Zostera nigricaulis* and *Zostera muelleri* were grouped into the single generic category of "Zostera". Roob and Ball (1997) commented that Ducker et al. (1977) had identified *Ruppia spiralis* (hereafter *Ruppia*) and *Lepilaena cylindrocarpa* (hereafter *Lepilaena*) within the Gippsland Lakes. Roob and Ball (1997) found *Zostera* in 38% of the sampling points across the Gippsland Lakes, while *Ruppia* and *Lepilaena*, which generally occur at lower salinities, occurred in 22% and 9% of the sites, respectively.

Figure 2. Electrofishing boat on the Gippsland Lakes estuary

In the present study, underwater video was used to observe and record the seagrass in the Gippsland Lakes. In September 2008, 30 sites (with 41 video transects) were selected for initial assessment based on those areas shown by Roob and Ball (1997) to have dense beds of *Zostera*. Greatly improved water clarity in the April 2009 round of sampling increased our ability to identify areas of the Gippsland Lakes with seagrass, and we were able to collect video data on an additional 20 sites (and 71 new transects) during the April 2009 round of sampling (Figure 1). This brought to 50 the total number of sites where data on seagrass were recorded using the underwater video. These 50 sites were re-visited in April 2010.

The video was gradually lowered to the bottom and the entire transect was recorded. In most cases, 2 to 5 minutes of footage was recorded. The video was lowered to a distance of around 30 to 40 cm from the bottom. The latitude and longitude were recorded at the beginning of each transect.

On all sampling occasions, video footage was assessed with a view to identifying whether seagrass was present, however, the quality of the footage was good enough to be able to provide some semi-quantitative estimates of seagrass condition based on shoot density. Condition was ranked between 0 and 5, with scores of 5 given to video footage showing continuous dense coverage, and 0 given to a complete absence of any seagrass. Notes were also taken on whether any observable seagrass was dead or alive, and the degree to which it was overgrown with epiphytes.

2.4 Measuring water quality

Water quality data (see Appendix 4 for a list of attributes) were collected at 1 m depth intervals, from the surface to the bottom, at all sites using a Hydrolab DataSonde 5x (Table 2, CD for all data) during the September 2008 sampling period. Regional consistency in water quality attributes led us to reduce spatial effort on water quality measures, and the water quality was recorded at fewer sites in the April 2009 round of sampling. The spatial resolution of sampling was again increased in April 2010 due to relatively high spatial variation in chlorophyll *a* values (Appendix 4). Throughout the study, chlorophyll *a* was measured using a fluorescence sensor attached to the water quality instrument.

3 Results and Discussion

3.1 Fish Assemblage Structure

Twelve species of fish were caught during September 2008, including juvenile stages of black bream (*Acanthopagrus butcheri*) and six-spine leatherjacket (*Meuschenia freycineti*; Table 1). The species caught during this period are generally regarded as either estuarine resident (e.g. black bream) or estuarine dependent (e.g. tailor). While all of the species sampled are known to be associated with seagrass at some stage in their life history, we were unable to sample several species that are strongly seagrass associated, including pipefish (various species of the Family Sygnathidae) and cobblers (*Gymnapistes marmoratus*), during September 2008.

Figure 3. Beach seine net being used to sample fish in a shallow (< 2 m depth) estuarine environment.

Fish catches in the trawl net during September 2008 were generally low throughout the Lakes compared with catches recorded in the estuarine reaches of tributaries such as the Nicholson, Mitchell and Tambo Rivers (Appendix 2; Hindell 2008). Catches from the otter trawl during September 2008 were also generally lower than those using this gear in Lake King and Jones Bay during Autumn 2008 (Hindell 2008). Five minute tows of the otter trawl can yield up to 50 bream of 20 to 30 cm in length, but the largest number of fish sampled in any trawl within the Lakes during September 2008 was less than 10. While seasonal movements of fish (e.g. during winter and spring black bream are known to move into the middle and upper reaches of the tributaries, Hindell 2007) may explain low catches within the Lakes during September 2008, subsequent sampling within the Lakes over summer and autumn 2009 suggested that an alternative method may be required to better describe fish assemblages in shallow (<1.5 m depth) water.

Fish density (total fish.m^{-2}) and species diversity recorded with the seine net during April 2009 and 2010 were higher than those using the trawl in September 2008 and April 2009. Although catches of the two gears are not directly comparable, a similar suite of species were caught using the trawl and the seine nets. Trialling different gear types is often necessary in the preliminary phases of a monitoring program, and both the trawl and seine data provide a valuable baseline against which future changes in fish assemblages in the Gippsland Lakes can be measured.

Demersal species such as juvenile black bream (*Acanthopagrus butcheri*), anchovies (*Engraulis australis*), leather-jackets (family Monocanthidae) and tupong (*Pseudaphritis urvilli*) caught using trawls in September 2008 were again caught using the seine in April 2009 and 2010 (Table 1, Appendix 3). The seine net also caught juveniles of estuary perch (*Macquaria colonorum*), luderick (*Girella tricuspidata*) and mullet (family Mugilidae), as well as many smaller, strongly seagrass-associated species such as pipefish (*Stigmatopora spp.* and *Pugnaso curtirostris*) and cobbler (*Gymnapistes marmoratus*).

Two highly transient, pelagic species were caught in eastern Lake Victoria during September 2008 - tailor (*Pomatomus saltatrix*) and anchovy (*Engraulus australis*) and large schools of bait fish were observed on the sonar while trawling. In April 2009 anchovy (*Engraulus australis*) and sandy sprats (*Hyperlophus vittatus*) were again caught in seine nets in Lake Victoria. Anchovy and sprats feed on zooplankton, and are an important prey species for birds and other predatory fish such as Tailor. The 2007-2008 plankton blooms in the Gippsland Lakes may have supported high abundances of grazing zooplankton (which may persist), which in turn support large numbers of planktivorous fish such as anchovy. This food web could then support larger predator fishes (such as tailor), birds and marine mammals. Investigation of trophic pathways (for example through the use of stable isotopes) during the presence and absence of phytoplankton blooms will provide information on how trophic relationships may change during algal blooms and how this may in turn affect fish production.

The ‘condition’ of fish was not formally assessed in the present study, however, no fish were observed with any form of fin rot or external ulcers. Physiological assessments of stress and other hormones, as well as measures of heavy metals and other contaminants in fish tissues could aid in our understanding of fish health and condition throughout the Gippsland Lakes.

The new electrofishing equipment was effective in catching a wide range of fish in salinities from close to freshwater in the Mitchell and Nicholson rivers, through to almost marine waters at the entrance to the Gippsland Lakes. This is one of the first times where an electrofishing unit has successfully caught fish in salinities over 30 ppt. Fish over a range of sizes, from tupong, gobies and estuary perch of less than 5 cm through to eels, black bream and mullet greater than 40 cm in length were caught. The species sampled with the new electrofishing equipment are summarised in Table 1, and included at least 15 new species (shown by * in Table 1). At least two of the new species sampled (rock ling and worm eels) are nocturnal species that were ‘encouraged’ out from their daytime refuges – these species are rarely sampled during daylight hours.

The success in this study in using the electrofishing equipment in estuarine and marine salinities means that this equipment can potentially be used to better understand the nature of fish associations with structurally complex habitats that are almost impossible to sample with traditional fishing equipment. In this study, we caught fish along rock walls, from within large woody debris, and adjacent to river banks with *Phragmites*, tree roots and other overhanging terrestrial vegetation throughout the Lakes system. In addition to the enhanced ability to sample structurally complex environments such as rock walls and large woody debris, the electrofishing equipment is more ‘fish friendly’ than traditional netting equipment. The electrical field stuns fish for only a short period, after which fish can regain movement and are able to swim away naturally.

Figure 4. Species sampled using the electrofishing equipment. From top: Black bream, Cod and Eastern Wirra (the latter two are marine species that were caught at the entrance to the Lakes along the rock walls).

Table 1. Summary of the total number of fish and crustaceans sampled using an experimental otter trawl in September 2008, a beach seine in April 2009, and a beach seine and electrofisher in April 2010. Samples pooled across all sites.

Common name	Species name	Number of fish			Electrofishing
		Sep-08	Apr-09	Apr-10	Apr-10
Australian anchovy	*Engraulis australis*	5	25	-	✓
Bay prawn	*Metapenaeus bennettae*	1	-	-	
Blue sprat	*Spratelloides robustus*	-	1	-	✓
Black bream	*Acanthopagrus butcheri*	41	61	12	✓
Bridled Goby	*Arenigobius bifrenatus*	-	-	8	✓
Cobbler	*Pugnaso curtirostris*	-	1	10	
Rock cod*	*Pseudophycis spp.*				✓
Dusky flathead	*Platycephalus fuscus*				✓
Yank flathead	*Platycephalus speculator*				✓
Eastern blue spot goby	*Pseudogobius sp.*	-	-	1	✓
Eastern kelpfish	*Chironemus marmoratus*				✓
Eastern striped trumpeter	*Pelates sexlineatus*	-	-	5	✓
Eastern wirra	*Acanthistius ocellatus*				✓
Estuary perch	*Macquaria colonorum*	-	3	-	✓
Flathead gudgeon	*Philypnodon grandiceps*	-	1	1	✓
Glass goby	*Gobiopterus semivestitus*	-	32	3	✓
Globefish	*Diodon nicthemerus*	-	1	2	
Greenback flounder	*Rhombosolea tapirina*				✓
Hardyhead	*Atherinosoma microstoma*	-	18	-	✓
Herring cale	*Odax cyanomelas*				✓
Largemouth goby	*Redigobius macrostoma*	-	-	20	
Longsnout flounder	*Ammotretis rostratus*	1	-	-	
Luderick	*Girella tricuspidata*	-	42	13	✓
Old wife	*Enoplosus armatus*				✓
Pipefish	*Stigmatopora spp.*	-	98	-	
Pot-belly seahorse	*Hippocampus abdominalis*	1	2	-	
Pug-nose pipefish	*Pugnaso curtirostris*	-	2	5	
River garfish	*Hyporhamphus regularis*	-	10	25	
Rock blackfish	*Girella elevata*				✓
Rock ling*	*Genypterus tigerinus*				✓
Rough leatherjacket	*Scobinichthys granulatus*	-	19	-	✓
Sand crab	*Ovalipes australis*	2	-	-	
Sandy sprat	*Hyperlophus vittatus*	-	37	-	✓
Sea sweep	*Scorpis aequipinnis*				✓
Six-spine leatherjacket	*Meuschenia freycineti*	1	-	4	✓
Short fin eel*	*Anguilla australis*				✓
Smallmouth hardyhead	*Atherinosoma microstoma*	-	-	1198	
Snapper	*Chrysophrys auratus*				✓
Southern-sea garfish	*Hyporhamphus melanochir*	-	4	1	
Spotted pipefish	*Stigmatopora argus*	-	2	57	
Tailor	*Pomatomus saltatrix*	1	-	-	✓
Tamar Goby	*Afurcagobius tamarensis*	-	-	15	
Tasmanian blenny	*Parablennius tasmanianus*	-	1	-	
Toadfish smooth	*Tetractenos glaber*	5	1	3	✓
Toadfish prickly	*Contusus brevicaudus*	1	-	-	
Tupong	*Pseudaphritis urvillii*	1	1	1	✓
Wide bodied pipefish	*Stigmatopora nigra*	-	-	74	

Common name	Species name	Number of fish			Electrofishing
Worm eel*	*Muraenichthys spp.*				✓
Yellow-eye mullet	*Aldrichetta forsteri*	3	-	-	✓
Zebra fish	*Girella zebra*				✓
Other Gobiids	family *Gobiidae*	-	78	-	
Juvenile mullet	family *Mugilidae*	-	1	-	
Post-larval fish		-	-	7	
Unknown fish spp.		-	1	2	
Shrimp	*Metapenaeus spp.*	-	Present	Present	
Total		63	445	1467	

3.2 Seagrass 'condition'

Ruppia and *Zostera* appeared to be the most common species of seagrass occurring across the study area during all sampling occasions, although it was not always possible to reliably identify seagrass to species from video footage alone. The sites chosen for sampling, based on the mapping work of Roob and Ball (1997), previously supported dense beds of *Zostera* and other algal species. Roob and Ball's (1997) aerial photography for 1997 was taken in June (early-winter), which appears to be the time that they also assessed seagrass cover. The first round of sampling for the present study was completed in September 2008 (post-winter). Underwater video footage from this time suggested that the density of seagrass at 23 of 30 sites (and 2 of 4 broad regions) had declined since the work of Roob and Ball (1997) was published. During the second and third sampling rounds (April 2009 and 2010), seagrass density appeared to have declined in 3 of 5 broad regions since the work of Roob and Ball (1997; Table 3). The reason/s for, and broad timing of observed declines are not known. The lack of data on inter-annual seagrass coverage at finer spatial scales makes it difficult to ascertain which year seagrass began to decline. Where the mapping work of Roob and Ball (1997) was inconsistent with the amount of seagrass documented in the present study, differences could reflect 1) 'natural' cycles in productivity, 2) changes in environmental conditions (which may be independent of the current phytoplankton bloom), and/or 3) our inability to find seagrass within a site when it was really there (i.e. we missed patches of seagrass using the underwater video).

In September 2008, most sites had retained some level of seagrass cover, although the 'condition' of the seagrass at most of these was considered to be low (Condition = 1, Table 2); seagrass at some sites was alive, but there was a large amount of seagrass detritus (dead fronds) and many fronds were covered by significant growth of epiphytes (Figure 6 C). For sites where seagrass had not been detected during September 2008, the substratum was commonly covered with shells of molluscs (Figure 5 B and D). Despite the widespread 'loss' of seagrass, some sites had retained significant areas of seagrass, either as continuous but sparse beds (Figure 5 C and Figure 6 C) or dense patches (Figure 5 D and E, and Figure 6 F).

Seagrasses are known to die-back (to various degrees) over winter as day-length, solar radiation and water temperatures decline, before re-growing through late spring and summer. Seagrass increased between September 2008 and April 2009 at 50 % (9 of 18) of the re-sampled video transects (Table 3), demonstrating the importance of short-term (months) variability in seagrass 'condition'. Thirty-nine percent (7 of 18) of re-sampled transects showed no change in seagrass 'condition' between the first and second rounds of sampling, and 6 of these transects had no visible signs of seagrass (condition = 0, Table 3, Figure 5 A). Seagrass 'condition' declined at 11 % (2 of 18) of re-sampled transects between September 2008 and April 2009.

Between April 2009 and April 2010, seagrass 'condition' declined at 48% (38 of 80) of the re-sampled video transects. Forty-one percent (33 of 80) of re-sampled transects showed no changes in seagrass 'condition' between the second and third sampling rounds while 'condition' increased at 11 % (9 of 80) transects. The notable decline in seagrass condition between April 2009 and 2010 corresponds with an increase in epiphytic algal cover at some sites (Table 2), particularly those in the vicinity of Waddy Island and high chlorophyll *a* measurements at some sites (see section 3.3; Appendix 4). Reduced water clarity was also observed at sites in the vicinity of Waddy Island and within Lake Victoria. High epiphytic algal cover, high chlorophyll *a* values and reduced water clarity at some sites may indicate nutrient enrichment, but specific nutrient testing of water and sediments would be required to confirm this.

At the broader scale of sites, the coverage and density of seagrass generally increased between September 2008 and April 2009, with tracts of dense, continuous seagrass apparent (Condition = 4 and 5, Figure 5 D and E). This was most pronounced near Green Point Hill (site 8), Elbow Point (site 10) and Rotamah Island (site 11) in Lake Victoria, and at Shaving Point (site 27) near Metung (Figure 7). There was, however, often considerable variability in seagrass 'condition' among video transects within a site which again reflects the patchy nature of seagrass in the Gippsland Lakes.

Six sites had no visible signs of seagrass in any transect during the first or second rounds of sampling. These included sites near Bluff Head, Lake Victoria (sites 2, 3 and 6) and in the north east of Lake King (sites 24 and 26). Live seagrass was also absent from site 29, on the eastern side of Point King, in both sampling rounds, although the presence of detrital material suggests that seagrass may have grown here in recent times (years). Seagrass was absent from 50% of new sites sampled in April 2009 (Table 3, Figure 7 B). Many of these were again in the vicinity of Bluff Head, Point King and northern Lake King (Figure 7 B).

The initial assessment of seagrass presence and (qualitatively) condition at 30 sites for two periods of time (September 2009 and April 2008), plus additional sites in the April 2009 and April 2010 rounds of sampling, establish a baseline of data against which future changes in seagrass cover and extent can be assessed. The establishment of geo-referenced visual records of seagrass distribution are critical in determining the impacts of, for example, algal blooms, during which determining where to look for seagrass is made difficult by the almost zero visibility through water.

Table 2: Summary of the 'condition' of seagrass at each site in 2010 compared with condition values recorded in 2008 and 2009. Condition = 0, No seagrass observed; Condition = 1, Very sparse seagrass, with only a few shoots or small plants observed along a transect; Condition = 2, Sparse seagrass throughout < 50% of the transect; Condition = 3, Sparse seagrass present along > 50% of transect; Condition = 4, seagrass common along transect, medium or dense seagrass ; Condition = 5, dense seagrass along > 50% of the transect. Highlighted cells correspond to the nature of change in seagrass condition at a given transect: green = increase; blue= no change; orange = decrease of 1 condition ranking; red = decrease > 1 condition ranking.

Site	Wpt	Lat.	Long.	Depth (m)	Condition (2008)	Condition (2009)	Condition (2010)	Seagrass Species Observed at This Site	Substratum	Comments (2010)
1	2	S37 54.047	E147 43.908			5	1	*Ruppia/Zostera*	sand/silt/	Thick coverage of epiphytic and various alga throughout.
1	24	S37 54.084	E147 44.449	0.8		3	1	*Zostera*	sand/shell	Significant numbers of bivalves.
1	363	S37 54.202	E147 44.007	3.0		0	0		sand/silt/shell	Various algae cover bottom consistently.
1	364	S37 54.114	E147 43.936		1			*Zostera*	sand/shell	
2	367	S37 55.530	E147 42.845	0.5	0	0	1	*Zostera*	sand/rock/shell	Only a couple of fronds observed. Cover mostly by benthic algae.
3	372	S37 55.950	E147 42.637	1.2	0	0	0		sand/shell	Cover of benthic algae, with some *Codium*.
4	375	S37 56.766	E147 41.419	1.2	0	1	1	*Zostera*	sand/silt/shell	
4	378	S37 56.963	E147 40.478	3.0		2	0		sand/silt/shell	
5	140	S37 57.017	E147 40.258	3.0		0	0		sand/silt/shell	
6	386	S37 56.071	E147 42.188	0.7		0	0			Some ascidian, benthic algae.
6	387	S37 56.085	E147 42.169		0				sand	
7	398	S37 57.275	E147 42.473	5.6	1		1	*Zostera*	sand/silt	
8	56	S37 57.628	E147 41.854	1.0		5	2	*Zostera/Ruppia*	sand/silt	Mix of *Zostera* and *Ruppia*.
8	59	S37 57.565	E147 41.957	0.8			2	*Zostera/Ruppia*	sand	Significant coverage by epiphytic algae.
8	401	S37 57.541	E147 41.929	0.7	1	5	0	*Zostera*	sand/silt	Mussel reef with some algal cover.
8	404	S37 57.923	E147 40.888		1			*Zostera*	sand/shell	
9	403	S37 57.930	E147 40.882	2.3		0	0		sand/silt/shell	
9	405	S37 57.944	E147 40.927	0.5			0			
10	45	S37 57.146	E147 40.848	1.0		4	3	*Zostera*	sand/silt/shell	Significant coverage by benthic algae.
10	144	S37 57.117	E147 41.114	2.5		0	0		sand/silt/shell	Sand covered with benthic algae.
10	145	S37 57.143	E147 40.878	1.5		4	2	*Zostera*	sand/shell	Some benthic algae.

Site	Wpt	Lat.	Long.	Depth (m)	Condition (2008)	Condition (2009)	Condition (2010)	Seagrass Species Observed at This Site	Substratum	Comments (2010)
10	147	S37 57.200	E147 40.646	1.5		3	0	*Zostera*	sand/silt/shell	Benthic algae throughout.
10	409	S37 57.180	E147 40.696	1.5	0	3	0	*Zostera*	sand/silt/shell	
11	44	S37 57.249	E147 44.212	1.5		5	4	*Zostera/Ruppia*	sand/silt/shell	
11	159	S37 57.201	E147 44.033	0.7		4	3	*Zostera/Ruppia*	sand/silt/shell	Dense cover of filamentous algae.
11	417	S37 57.303	E147 43.993		1			*Zostera*	sand/silt/shell	
11	420	S37 57.282	E147 44.148		1			*Zostera*	sand	
12	39	S37 56.852	E147 44.320	3.0			0		sand/shell	Seagrass detritus over benthic algae with significant coverage of bivalve shells.
12	424	S37 57.136	E147 44.454		1			*Zostera*	sand/silt	
12	425	S37 57.131	E147 44.460		1			*Zostera*	sand/silt	
12	426	S37 57.130	E147 44.483		1			*Zostera*	sand/silt	
13	37	S37 56.505	E147 44.527	1.3		4	4	*Zostera*	sand/silt	Some cover by epiphytic algae.
13	38	S37 56.551	E147 44.356	1.0		4	2	*Zostera*	sand/silt	Much filamentous algae.
13	431	S37 56.599	E147 44.666		3			*Zostera*	sand	
13	436	S37 56.583	E147 44.741		4			*Ruppia*	sand	
14	35	S37 56.049	E147 44.857	1.0		2	2	*Zostera*	sand/silt	Thick cover by filamentous algae.
14	36	S37 56.099	E147 44.754	1.1		4	3	*Zostera*	sand/silt/shell	Thick cover by filamentous algae.
14	438	S37 56.152	E147 44.901	0.8	2	4	3	*Zostera*	sand/mud	Thick mat of algae.
14	439	S37 56.139	E147 44.895		2			*Zostera*	sand/mud	
15	33	S37 55.415	E147 47.032	0.5		3	2	*Zostera*	sand/silt/shell	Thick cover of benthic algae.
15	34	S37 55.422	E147 46.937	1.0		5	1	*Zostera*	sand/silt/shell	Thick cover by filamentous algae.
15	156	S37 55.447	E147 46.942	0.7		0	3	*Zostera/Ruppia*	sand	Dense cover of filamentous algae.
15	443	S37 55.427	E147 46.825	1.2	3	2	0	*Ruppia/Zostera*	sand/mud	
16	447	S37 53.717	E147 52.949	0.5	3	5	4	*Zostera*	sandy/mud	
17	450	S37 54.179	E147 53.071	0.7	1	5	5	*Zostera*	sand/silt	
18	18	S37 53.950	E147 54.311	2.5		4	0	*Zostera/Ruppia*	sand/silt	Thick algal cover over sand.
18	19	S37 53.950	E147 54.929	0.6		5	5	*Zostera/Ruppia*	sand/silt	
18	452	S37 54.116	E147 54.427	1.2	4	3	3	*Zostera/Ruppia*	sand/silt	
18	453	S37 54.105	E147 54.425		3			*Ruppia/Zostera*	silt	
19	457	S37 53.751	E147 55.771	1.1	1		0	*Ruppia/Zostera*	silt	Some drift algae and detritus.
20	21	S37 53.432	E147 57.103	1.0		5	5	*Zostera/Ruppia*	sand/silt/shell	
20	460	S37 53.368	E147 57.114	1.3	4	4	4	*Zostera*	sand/silt	
21	464	S37 52.927	E147 59.485	1.1	1		0	*Ruppia/Zostera*	silt/mud	Sand covered by thick mat of benthic algae.

Site	Wpt	Lat.	Long.	Depth (m)	Condition (2008)	Condition (2009)	Condition (2010)	Seagrass Species Observed at This Site	Substratum	Comments (2010)
21	466	S37 52.917	E147 59.556	1.0	1		0	*Ruppia/Zostera*	silt/mud	Sand covered by thick mat of benthic algae.
21	472	S37 52.594	E147 59.066	1.4	1		0	*Zostera*	silt/mud	Sand covered by thick mat of benthic algae.
22	22	S37 52.830	E147 59.610			4		*Ruppia*	silt/mud	
22	471	S37 52.590	E147 59.071			0			silt/mud	
22	483	S37 54.029	E147 43.868		2			*Zostera*	sand/silt	
23	4	S37 53.522	E147 41.189			1		*Zostera*	sand/silt/shell	
23	63	S37 53.661	E147 41.315	0.8			4	*Zostera/Ruppia*		Significant coverage of algae.
23	158	S37 53.707	E147 41.294			5		*Zostera*	sand/silt	
23	489	S37 53.642	E147 41.312	1.0	2		1	*Zostera*	sand/silt	Significant coverage by *Codium*, over sand shell.
24	495	S37 52.483	E147 42.929	1.4	0	0	0		sand	Silt/sand covered with benthic algal mat.
25	7	S37 51.486	E147 44.382	0.5		0	1	*Zostera*	sand/silt	Thick coverage of epiphytic and various algae throughout.
25	8	S37 51.408	E147 44.291	1.2		1	0	*Zostera*	sand/silt	Sparse and patch cover of benthic algae.
25	9	S37 51.430	E147 44.094	1.0		5	4	*Zostera*	sand/silt	Dense *Zostera* with significant epiphytic coverage in water less than 1 m depth. Unvegetated sand at greater depths.
25	12	S37 51.177	E147 44.838	1.0		0	0		sand/silt/rubble	Patches of red algae. High densities of bivalve shells, and a few live mussels.
25	501	S37 51.229	E147 44.856	0.8	0	0	0		sand/rocks	Mussel reef covered with algae in places.
25	503	S37 51.412	E147 44.420		1			*Zostera*	sand	
26	509	S37 51.230	E147 46.459	0.7	0	0	0		sand/silt	Rubble reef with patches of sand, shell cover and smaller patches of algae.
27	61	S37 54.072	E147 49.639	0.6			2	*Zostera/Ruppia*		Significant algal coverage.
27	516	S37 54.191	E147 51.500	0.7	2	5	2	*Zostera*	sand/silt/shell	Significant seagrass detritus.
28	32	S37 54.007	E147 49.558	3.0		2	1	*Zostera*	sand/silt	Thick cover of benthic algae.
28	520	S37 54.070	E147 49.644			3		*Zostera*	sand	
28	522	S37 54.074	E147 49.621		1			*Zostera*	sand	

Site	Wpt	Lat.	Long.	Depth (m)	Condition (2008)	Condition (2009)	Condition (2010)	Seagrass Species Observed at This Site	Substratum	Comments (2010)
29	526	S37 53.641	E147 46.798	0.8	0	0	0		sand	Cover of green algae, lots of filamentous.
30	26	S37 53.610	E147 45.781			4	2	*Zostera*	sand	Consistent cover of epiphytic algae.
30	27	S37 53.556	E147 45.743	2.3		1	1	*Zostera*	sand/silt/shell	
30	532	S37 53.635	E147 45.754	1.5	0	5	3		sand/silt	
30	534	S37 53.703	E147 45.797		3	3		*Zostera/Ruppia*	sand	
31	1	S37 55.244	E147 43.330			0	0	*Zostera*	sand/silt/shell	Consistent cover of benthic algae.
32	3	S37 53.430	E147 43.306			0	0		sand/shell	Very little macrophytic vegetation, high density of bivalve shells.
32	64	S37 53.539	E147 43.155	0.5			5	*Zostera/Ruppia*		
33	5	S37 51.673	E147 44.050			0	0		sand	High density of invertebrate burrows, consistent coverage of benthic microalgae.
33	6	S37 51.697	E147 44.404			0	0		sand/silt/shell	High density of bivalve shells, consistent coverage of benthic microalgae.
34	10	S37 50.767	E147 44.146	1.0		2	4	*Zostera*	sand/silt	Dense *Zostera* with significant epiphytic coverage in water less than 1 m depth.
34	11	S37 50.728	E147 44.098	1.0		0	3		sand/silt	Sparse seagrass consistent throughout with significant cover of epiphytic algae.
35	13	S37 51.167	E147 46.758	0.7		2	0	*Ruppia*	sand/rubble	Patches of algae over sand.
36	14	S37 51.543	E147 47.424	1.3		0	0		sand/silt	
37	15	S37 51.372	E147 48.933	0.7		0	2	*Zostera*	sand/silt	Sparse and inconsistent coverage of *Zostera* over sand.
38	16	S37 52.599	E147 49.178	0.5		0	0		rubble/sand/silt	Some patches of green/red algae
38	153	S37 52.256	E147 49.186	0.6		0	0		sand/silt/rubble	Patches of *Codium*.
39	20	S37 53.645	E147 56.715	2.0			0		silt	Some smaller patches of algae.
40	23	S37 52.403	E147 59.114	1.0		0	0		silt/mud	Thick benthic algal mat.
41	25	S37 53.779	E147 45.020	1.5		5	4	*Zostera*	sand/shell	Significant shell coverage.
42	28	S37 53.401	E147 46.102	1.0		3	3	*Zostera/Ruppia*	sand/silt/shell	Thick coverage of epiphytic algae.
42	30	S37 53.148	E147 46.384	1.0		1	0	*Zostera*	sand/silt	Significant patches of seagrass detritus.
43	31	S37 53.964	E147 46.673	2.3		0	0		sand/silt/shell	Significant coverage of detritus.
44	40	S37 57.221	E147 44.580	1.5		4	5	*Zostera/ruppia*	sand/silt	A little epiphytic algae.

Site	Wpt	Lat.	Long.	Depth (m)	Condition (2008)	Condition (2009)	Condition (2010)	Seagrass Species Observed at This Site	Substratum	Comments (2010)
45	42	S37 57.567	E147 45.284	2.0		0	1	*Zostera*	sand/silt	Thick coverage of benthic algae.
46	43	S37 57.745	E147 45.994	1.5		5	5	*Zostera/Ruppia*	sand/silt	Some cover of seagrass by epiphytic alga.
47	46	S37 57.139	E147 39.608	1.5		2	0	*Zostera*	sand/silt/shell	Thick coverage by benthic algae throughout.
47	58	S37 57.267	E147 39.853	1.0			0		sand/shell	Sand shell substratum.
47	141	S37 57.076	E147 39.918			2			sand/silt/shell	
48	48	S37 58.097	E147 38.164	0.6		3	1	*Zostera*	sand/silt/shell	Significant cover by benthic algae.
49	49	S37 59.005	E147 36.933	1.0		2	1	*Zostera*	sand	Thick cover by benthic algae. Seagrass in this transect looks to have very wide blades? *Posidonia* sp. not previously noted in Gippsland Lakes. Worth re-checking.
49	50	S37 59.019	E147 36.906	0.6		3	1	*Zostera*	sand	
49	51	S37 59.044	E147 36.885	0.7		3	1	*Zostera*	sand	
50	53	S38 02.162	E147 35.334	1.2		0	0		sand/silt	
50	54	S38 02.082	E147 35.509	1.0		0	0		sand/rubble	Some algal coverage
50	55	S38 01.505	E147 36.636	0.5			4	*Zostera/Ruppia*	sand	Mix of *Zostera* and *Ruppia*.
Total Transects					**39**	**81**	**89**			

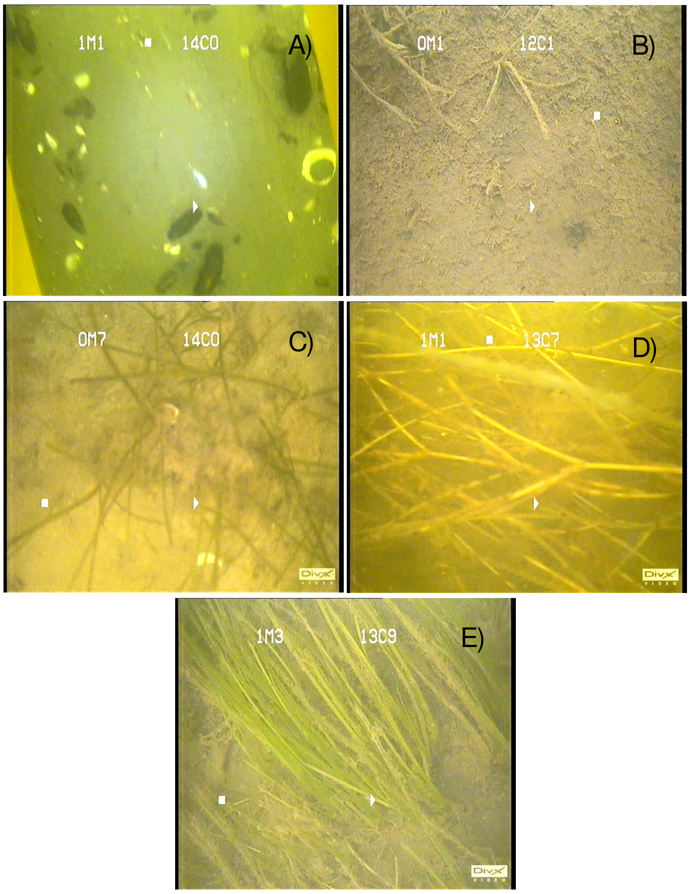

Figure 5. Visual demonstration of the qualitative seagrass condition measures provided in Table 2. A) Condition = 0, No seagrass observed; B) Condition = 1, Very sparse seagrass, with only a few shoots or small plants observed along a transect; C) Condition = 2, Sparse seagrass throughout < 50% of the transect; C) Condition = 3, Sparse seagrass present along > 50% of transect; D) Condition = 4, seagrass common along transect, medium or dense seagrass ; E) Condition = 5, dense seagrass along > 50% of the transect.

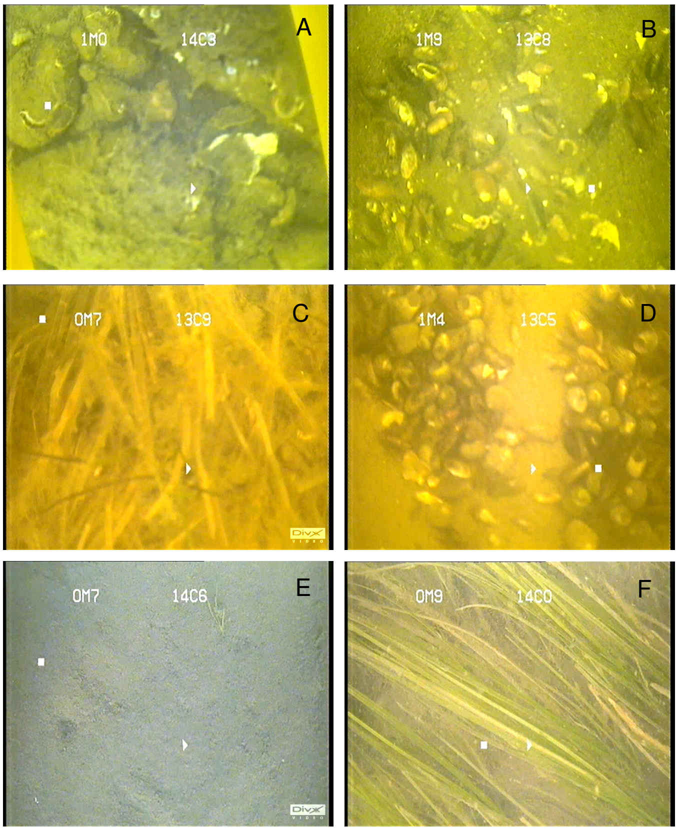

Figure 6. Pictures taken from the underwater video showing A) rubble reef, B) sand with deposits of mussels, C) *Zostera* with fouling by epiphytes, D) sand covered by deposits of mollusc shells, E) silt sediments with a single seagrass plant, and F) healthy *Zostera* with a few dead fronds.

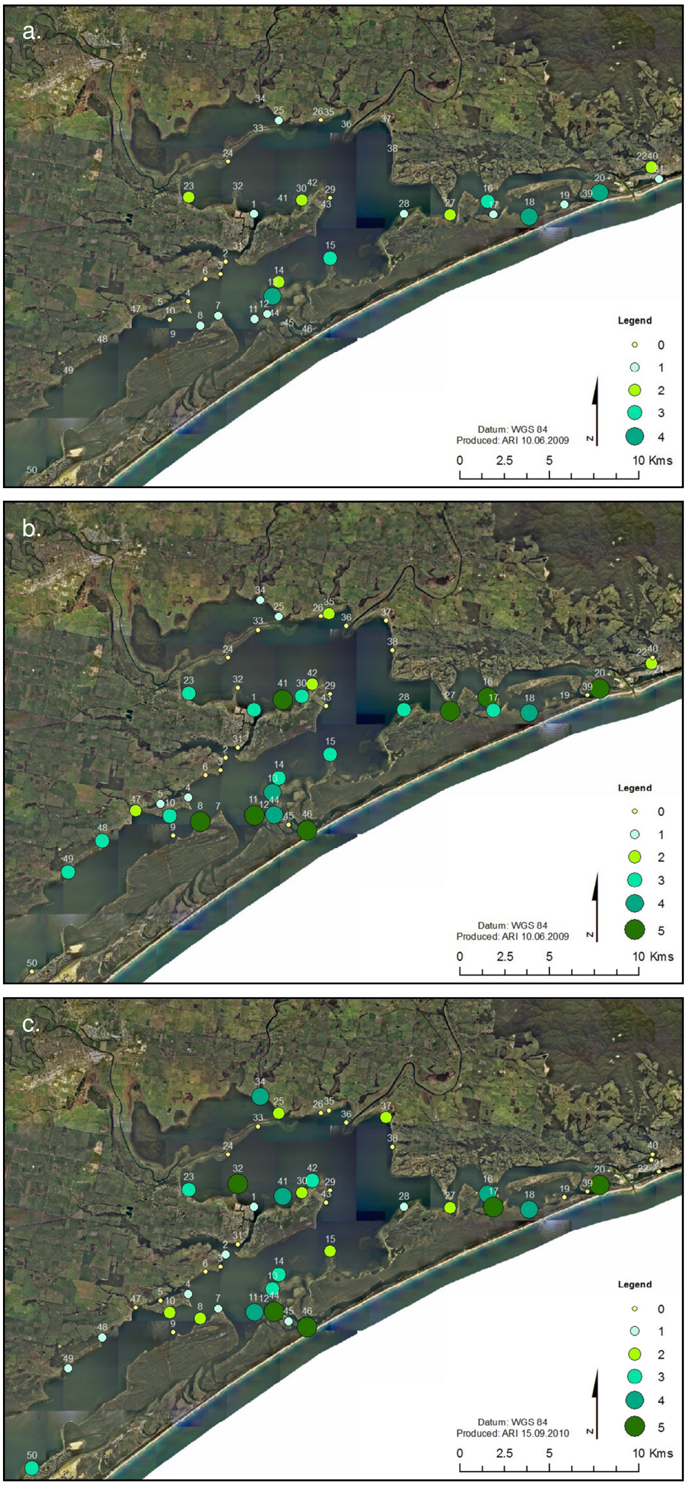

Figure 7. Spatial representation of the qualitative seagrass condition measures provided in Tables 2 and 3 for a) September 2008, b) April 2009 and c) April 2010. Condition = 0, No seagrass observed; Condition = 1, Very sparse seagrass, with only a few shoots or small plants observed along a transect; Condition = 2, Sparse seagrass throughout < 50% of the transect; Condition = 3, Sparse seagrass present along > 50% of transect; Condition = 4, seagrass common along transect, medium or dense seagrass ; Condition = 5, dense seagrass along > 50% of the transect. These maps should be used conservatively as condition was averaged across transects within a site, and seagrass density can be patchy.

Table 3. Adapted from Roob and Ball 1997. Summary of estimated changes in the density of seagrass observed in the present study as compared with that documented by Roob and Ball (1997). Dark green = dense seagrass; mid green = medium density seagrass; light green = sparse seagrass; no fill = no seagrass. * the present study did not use the same methods of Roob and Ball (1997) to estimate seagrass density, so this table should be used conservatively.

Year	Fraser Island	Point Fullerton	Point King	Corcrow Point	Waddy Island
1959					
1966					
1968					
1969					
1975					
1976					
1979					
1984					
1986					
1989					
1997					
2008*					
2009*					
2010*					

3.3 Water quality

A range of basic water quality parameters was measured at each site (Appendix 4) during the September 2008 round of sampling. During this period, salinity, temperature, dissolved oxygen and pH were all within a range that could support ecosystem processes (including the subsistence of seagrasses) within estuaries, although salinities were higher than expected given the time of the year. The spring period is generally one of high rainfall throughout eastern Gippsland, with high rainfall increasing freshwater inflows to the Gippsland Lakes and thereby reducing salinities.

While the algal bloom of 2007/08 was widely regarded to be decreasing throughout the Gippsland Lakes at the time of the September 2008 round of sampling, measurements of chlorophyll *a* were greater than 10 $\mu g.l^{-1}$ at several sites in eastern Lake Victoria and southeastern Lake King, and these figures are consistent with those described by the EPA monitoring program of 2006-2007 (EPA 2008). Turbidity levels were generally low throughout most of the sampling sites, despite being measured following several days of winds in excess of 20 knots.

The lack of strong variability in water quality parameters within regions from the first round of sampling led us to refine measurements of water quality during the April 2009 round of sampling. During the April 2009 round of sampling, depth integrated water quality attributes were recorded at broader spatial scales (100s to 1000s of meters). However, in April 2010 some water quality parameters (namely chlorophyll a) were observed to vary among sites so the spatial resolution of water quality measurements was increased (Appendix 4).

Summer and early autumn are generally periods of higher air temperatures and lower rainfall than winter and spring. Expectedly, temperature and salinity values were higher in April 2009 and 2010 than September 2008. Concentrations of dissolved oxygen were consistent between the three sampling rounds and showed little spatial variation within the lakes ranging from c.a. 7.7 – 12.7 Mg/L. During the April 2009 sampling round, measurements of chlorophyll *a* did not exceed 6.0 $\mu g.l^{-1}$ at any site and were typically 1.0 - 4.0 $\mu g.l^{-1}$ (Appendix 4). During the April 2010 sampling round, chlorophyll *a* measurements were variable but high at many sites and exceeded September 2008 values at 16 of the 27 sites that were sampled in both 2008 and 2010. In 2010 chlorophyll *a* values were generally highest in Lake Victoria, in the region south-west of Waddy Island (Appendix 4).

3.4 Directions for future research

The present study provides a ‘snap shot’ in time of fish assemblage structure and seagrass ‘condition’ within the Gippsland Lakes. In doing so, the present study establishes a baseline of data, upon which monitoring and research programs can be built in the future. Specific project details are beyond the scope of the present study, but the following broad areas for investigation are thought to be critical in understanding and managing seagrass habitat and fish assemblages throughout the Gippsland Lakes.

3.4.1 Evaluating electrofishing as a method for sampling estuarine and marine fish species within small coastal systems

The present study documents for the first time the potential value in using electrofishing methods to sample fish in estuarine and marine waters. The range of species sampled with the electrofishing, and the ease with which species such as black bream and estuary perch were caught, compared with previous sampling of these species over the past 8 years (Hindell et al. unpublished data), suggests this equipment is a significant advance in sampling estuarine fish. Further testing of this equipment needs to be undertaken, however, to assess how efficiency varies with the strength and nature of stratification (freshwater over salt water), and how changes in conductivity as a consequence of temperature (conductivity increases as water temperature increases). The Gippsland Lakes provides a unique opportunity to further test this equipment while providing additional data on fish-seagrass associations.

3.4.2 GIS-based modelling of seagrass distribution

Researchers from NSW and Tasmania are using GIS-based modelling applications to understand where different habitats occur within estuaries in relation to geomorphological and environmental features. Water depth and turbidity, substratum type, fetch and shoreline orientation and bathymetry are currently being modelled to understand which are most important determinants of the structure and distribution of estuarine habitats such as saltmarsh and seagrass. Spatial scientists at ARI have also used these GIS-based modelling approaches to model distributions of terrestrial flora and fauna in Victoria. These models could be adapted to the Gippsland Lakes to understand how current seagrass distributions are likely to change with changes in the environment.

3.4.3 Aerial mapping and ground-truthing

Roob and Ball (1997) last mapped the Gippsland Lakes more than 10 years ago. In completing the assessments of seagrass for the present study 1) the distribution of seagrass was shown to have changed considerably, and 2) it is unclear when broad-scale changes have occurred; is it recent, or was seagrass lost from some of the sites years ago? Periodic mapping of the distribution of seagrasses throughout the Gippsland Lakes at intervals of between 3 and 5 years would enable a more accurate assessment when and for how long seagrass habitats decline and recover. Specific sites throughout the Gippsland lakes should be ground-truthed in association with remote sensing to assess the species and condition of seagrass present. These data would be useful in refining the GIS-based modelling approaches identified above, and could be used to populate some form of resource condition assessment (e.g. report carding).

3.4.4 Valuing seagrasses (and links with estuarine ecosystems)

Understanding the ‘value’ of seagrass ecosystems is critical in their management and conservation. There are several areas of research on seagrass ecosystems that would support valuing these important habitats, including:

- Determining the role of seagrasses in the sequestration of carbon
- Determining the importance of seagrasses in supporting fisheries species – e.g. through the provision of habitat and shelter, as a base for nutritional support
- Determining the role of seagrasses in supporting biodiversity and conservation values (e.g. assemblages of fish and birds)
- Determining the role of seagrasses in estuarine nutrient cycling

3.4.5 Environmental determinants of seagrass health

Determining how changes in the environment impact on the sustainability of seagrass ecosystems is important in future management scenarios, including in the catchments. Key research areas to support management of the environment to support (and secure) seagrass habitats in the future include:

- Determining the resilience of seagrass habitats to light attenuation (caused by turbidity and algal blooms)
- Understanding the strength and nature of links between seagrass health and freshwater flows

- Understanding the strength and nature of links between seagrass health and the offsite, downstream consequences of fire (including increased nutrients, sediment, and other contaminants).

3.5 Summary of findings

The present study undertook an assessment of fish assemblage structure and seagrass 'condition' within the Gippsland Lakes during September 2008, April 2009 and April 2010. Key points from the present report include:

- Fish assemblage structure and or the presence and condition of seagrass were initially assessed at 30 sites throughout the Gippsland Lakes using standard trawls of an experimental otter trawl and underwater video, respectively, during September 2008. Water quality parameters were recorded at all study sites, and light attenuation data was collected at selected locations.
- A second round of sampling was undertaken in April 2009, during which the same 30 sites were (re)sampled for seagrass, and fish and water quality parameters were again collected from strategic sites. An additional 20 sites were sampled during April 2009, with a focus on recording seagrass cover and condition.
- The most recent round of sampling in April 2010 added to the baseline data on seagrass condition by sampling more sites, and also trialled new electrofishing equipment for sampling fish for the first time in Australia.
- Seagrass was present at most sites. Two seagrass taxa dominated: *Ruppia* in waters mostly around 0.5 to 1 m; and, '*Zostera'* (including both *Heterozostera nigricaulis* and *Zostera muelleri*) in waters 0.5 to 2 m depth.
- Underwater video footage taken during September 2008 suggested that there had been some decline in the 'amount' of seagrass within 75% of all sites (video transects) compared with the mapping work of Roob and Ball (1997).
- Underwater video footage taken during April 2009 suggested there had been a general increase in the 'amount' and 'condition' of seagrass at 13 of the 30 sites between the first and second rounds of sampling.
- Underwater video footage from April 2009 suggested a decline in the 'amount' of seagrass within 60 % of broad regions, an increase in 20 % and no change in 20 % of broad regions, compared with the mapping work of Roob and Ball (1997).
- The species of fish sampled using an otter trawl during September 2008 were generally consistent with those expected in shallow Victorian estuaries during winter and early spring periods, although overall numbers of fish were low. Black bream were the most common species sampled.
- An otter trawl and small beach seine net were used to sample fish in the April 2009 round of sampling. Species diversity and overall fish abundances were higher than in September 2008. This is likely due to an increase in seagrass coverage and recruitment of many species over the summer, but may also reflect the shift in sampling gears. Samples were numerically dominated by gobies, baitfish, pipefish, luderick and black bream.
- The beach seine net was again used to sample fish in April 2010. Additionally, an electrofishing unit was also tested over a range of salinities throughout the Gippsland lakes. Several species that had not previously been encountered were sampled. Structurally

complex habitats such as rock walls and large woody debris were significantly easier to sample with the electrofishing unit than any other equipment used previously. The new electrofishing equipment requires further testing, but, based on initial sampling, is likely to revolutionise our understanding of fish-habitat associations in estuaries.

- Water quality variables throughout the Gippsland Lakes were within the ranges commonly observed for this large estuary during both sampling periods. Chlorophyll *a* levels were > 10 $\mu g.l^{-1}$ in the vicinity of eastern Lake Victoria during the September 2008 and again in April 2010 sampling periods. In April 2009 chlorophyll *a* levels were generally < 4 $\mu g.l^{-1}$.
- It is recommended that future seagrass monitoring activities are conducted at the end of summer (March/April) prior to seasonal decline over winter. Sampling in March/April will maximise chances for detection of seagrass and allow investigation of the links between fish and seagrass at a time when a wide range of fish species are present in the Gippsland Lakes.
- More explicit seagrass mapping and GIS based modelling activities are recommended to better understand the distribution of seagrass within the Gippsland Lakes and provide decision support tools for environmental resource managers.
- Process based investigations of fish and seagrass assemblages are recommended to tease out relationships of cause and effect thereby improving capabilities to predict the consequences of environmental change in the Gippsland Lakes.

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Appendix 1

Summary of the total number of fish caught and the catch per unit effort at each site sampled using the otter trawl. Note that only total numbers of fish for each site have been adjusted for effort (area of trawl based on a net width of 1.5 m).

	Effort			Catch																
Site	Speed (km/h)	Depth (m)	Area (m)	Total Fish	Total Fish (m^{-2})	Anchovy	Black bream	Flathead gudgeon	Globefish	Gobies	Longsnout flounder	Pipefish	Potbelly seahorse	Bay prawn	Sand Crab	Six-spine leatherjacket	Tailor	Toad fish	Tupong	Yellow-eye mullet
1	3.3	1.5	412.5	0	0.0000															
1*	2.0	0.7	150	18	0.1200		10	1		1		5			1					
2	3.5	2	437.5	0	0.0000															
3	2.7	2.3	337.5	0	0.0000															
4	3.2	1.6	400	0	0.0000															
5	3.9	2.6	487.5	14	0.0287		14													
6	3.7	2.4	462.5	2	0.0043		1												1	
9	3.2	3.3	400	8	0.0200		5										1			2
10	4.0	2.7	500	17	0.0340	5	12													
12	3.6	2.7	450	1	0.0022				1											
13	3.3	1.6	412.5	3	0.0073		2													1
19	3.3	1.6	412.5	0	0.0000															
20	4.1	2.1	512.5	3	0.0059										1			2		
21	4.1	2.1	512.5	0	0.0000															
22	3.8	1.6	475	6	0.0126								1		1	1		3		
23	3.9	1.5	487.5	4	0.0082		4													
24	3.1	2	387.5	0	0.0000															
25	3.0	1.6	375	0	0.0000															
26	3.4	1.4	425	0	0.0000															
27	3.2	1.4	400	2	0.0050		1				1									
29	3.2	1.2	400	1	0.0025									1						
30	3.7	1.9	462.5	2	0.0043		2													
Total						5	51	1	1	1	1	5	1	1	3	1	1	5	1	3

* Trawl taken in April 2009

Appendix 2

Summary of the total number and (n) density (n.m^{-2}) of fish collected from each site sampled in a) April 2009 and b) April 2010 with a seine net. The area sampled by the seine was estimated at 50 m^{-2}. Electrofishing data from 2010 not included in these summaries.

A: April 2009

Species	site 1		site 7		site 8		site 13		site 14		site 15		site 27		site 47	
	n	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}	*n*	*n*.m^{-2}
Australian anchovy					91	1.82					4	0.08				
Bigbelly seahorse					1	0.02							1	0.02		
Blue spot goby			2	0.04	1	0.02									15	0.30
Blue Sprat					1	0.02										
Bluespot goby	1	0.02														
Bream	27	0.54			5	0.10			8	0.16	3	0.06	8	0.16		
Cobbler	1	0.02														
Crab			1	0.02	1	0.02										
Estuary Perch	1	0.02									1	0.02	1	0.02		
Flathead gudgeon																
Southern-sea garfish	2	0.04							1	0.02			1	0.02		
Glass Goby	5	0.10	4	0.08									90	1.80	3	0.06
Globefish													1	0.02		
Gobies	1	0.02	4	0.08	10	0.20	11	0.22	1	0.02	1	0.02	54	1.08	1	0.02
Hardyhead			18	0.36												
Juvenile Mullet			1	0.02												
Luderick	1	0.02					12	0.24	3	0.06	6	0.12	55	1.10		
Pipefish	10	0.20	24	0.48	5	0.10	1	0.02	14	0.28	16	0.32	31	0.62	4	0.08
Pug-nose pipefish			1	0.02											1	0.02
River garfish															10	0.20
Rough leatherjacket	1	0.02			3	0.06			1	0.02	4	0.08	5	0.10	5	0.10
Sandy sprat					201	4.02					16	0.32				
Shrimp	1	0.02	1	0.02			1	0.02			1	0.02				
Tasmanian Blenny							1	0.02								
Smooth toadfish									1	0.02						
Tupong			1	0.02												
Unknown													1	0.02		
Total	51	1.02	57	1.14	319	6.38	26	0.52	29	0.58	52	1.04	248	4.96	39	0.78

B: April 2010

Species	Site 8		Site 11		Site 13		Site 15		Site 16		Site 27		Site 32		Site 42	
	n	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2	*n*	*n*.m-2
Australian Whitebait	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02
Black Bream	-	-	-	-	-	-	-	-	-	-	10	0.2	2	0.04	-	-
Blue Sprat	-	-	-	-	-	-	-	-	-	-	13	0.26	-	-	-	-
Bridled Goby	-	-	1	0.02	2	0.04	4	0.08	-	-	1	0.02	-	-	-	-
Cobbler	-	-	-	-	-	-	-	-	-	-	9	0.18	1	0.02	-	-
Eastern Blue Spot Goby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02
Eastern Striped Trumpeter	-	-	-	-	-	-	4	0.08	1	0.02	-	-	-	-	-	-
European Shore Crab	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02	-	-
Flathead Gudgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.02
Glass Goby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.06
Globe Fish	-	-	-	-	-	-	-	-	-	-	-	-	2	0.04	-	-
Largemouth Goby	-	-	-	-	-	-	6	0.12	1	0.02	-	-	-	-	13	0.26
Luderick	-	-	-	-	-	-	-	-	6	0.12	5	0.1	2	0.04	-	-
Post Larval a	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-
Post Larval b	-	-	-	-	-	-	3	0.06	-	-	-	-	-	-	-	-
Post Larval d	-	-	-	-	-	-	-	-	3	0.06	-	-	-	-	-	-
Pugnose Pipefish	-	-	1	0.02	1	0.02	-	-	1	0.02	1	0.02	1	0.02	-	-
River Garfish	-	-	-	-	1	0.02	1	0.02	20	0.4	3	0.06	-	-	-	-
Sixspine Leatherjacket	-	-	-	-	-	-	-	-	-	-	3	0.06	-	-	1	0.02
Smallmouth Hardyhead	96	1.92	84	1.68	84	1.68	163	3.26	-	-	750	15	-	-	-	-
Smooth Toadfish	-	-	-	-	-	-	-	-	2	0.04	1	0.02	-	-	-	-
Southern Garfish	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-	-	-
Spotted Pipefish	3	0.06	2	0.04	3	0.06	-	-	1	0.02	2	0.04	34	0.68	12	0.24
Tamar Goby	-	-	-	-	-	-	13	0.26	2	0.04	-	-	-	-	-	-
Tupong	-	-	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-
Unidentified Pipefish	-	-	-	-	-	-	-	-	-	-	-	-	2	0.04	-	-
Widebody Pipefish	6	0.12	17	0.34	3	0.06	-	-	3	0.06	4	0.08	28	0.56	13	0.26
Total	105	2.1	105	2.1	95	1.9	194	3.88	41	0.82	803	16.06	73	1.46	45	0.9

Appendix 3

Summary of water quality parameters recorded during September 2008, April 2009 and April 2010 at a given site.

Site	Temp (°C)			Salinity (ppt)			Dissolved Oxygen (Mg/L)			Chlorophyll a (Mg/L)			Turbidity (NTU)		
	Sep-08	Apr-09	Apr-10	Sep-08	Apr-09	Apr-10	Sep-08	Apr-09	Apr-10	Sep-08	Apr-09	Apr-10	Sep-08	Apr-09	Apr-10
1	12.8	19.4	18.8	27.7	32.1	29.9	8.5	32.1	8.9	8.1	2.8	14.4	2.9	-	0.1
2	12.9	19.7	19.6	27.6	32.1	29.0	8.7	32.1	9.8	9.5	3.5	3.6	1.4	-	3.9
3	13.1	-	18.8	27.5	-	29.7	8.3	-	9.5	10.6	-	14.6	2.4	-	0.1
4	13.4	-	18.4	27.8	-	29.7	7.8	-	9.5	12.9	-	14.7	3.1	-	0.1
5	-	-	20.6	-	-	30.6	-	-	8.3	-	-	3.1	-	-	5.1
6	12.9	-	18.8	27.4	-	29.7	8.4	-	9.8	9.5	-	15.4	3.4	-	0.1
7	12.2	19.8	18.7	27.3	32.0	29.7	8.7	6.9	8.7	1.5	-	15.1	5.3	-	0.1
8	12.2	-	18.8	26.9	-	27.4	8.5	-	9.9	18.4	-	20.8	12.7	-	0.0
9	-	19.3	17.7	-	31.8	30.1	-	7.8	10.7	-	4.5	14.2	-	-	0.1
10	12.1	20.3	18.0	27.7	31.2	29.5	8.1	6.2	9.1	17.9	5.0	15.7	12.2	-	0.1
11	12.4	-	18.7	27.3	-	29.9	8.2	-	8.6	6.7	-	15.6	5.1	-	0.1
12	12.0	19.6	18.0	27.0	32.5	30.7	8.3	6.9	10.6	8.1	1.5	3.8	7.2	-	3.3
13	12.5	19.4	-	27.3	32.5	-	8.1	7.6	-	7.0	2.2	-	19.2	-	-
15	13.2	21.5	-	27.4	32.7	-	7.9	10.2	-	3.7	1.5	-	7.4	-	-
16	12.8	-	19.3	29.0	-	29.4	8.1	-	8.9	3.5	-	16.5	5.9	-	0.2
17	12.6	20.3	19.8	30.6	34.2	31.5	9.7	6.3	10.2	2.6	-	9.6	1.9	-	6.8
18	12.6	20.0	20.2	30.8	35.2	31.7	8.3	6.4	10.7	2.1	6.0	4.8	1.4	-	9.6
19	13.9	-	19.4	31.1	-	32.9	8.3	-	9.8	1.9	-	2.7	2.1	-	8.8
20	13.1	-	18.7	33.0	-	33.1	8.0	-	9.8	4.8	-	5.8	21.8	-	8.4
22	12.0	-	18.5	26.5	-	0.0	9.1	-	112.4	4.7	-	32.9	0.5	-	0.0
23	12.5	-	18.4	27.1	-	32.8	8.6	-	9.9	5.5	-	4.8	1.0	-	5.8
24	12.0	-	20.0	26.5	-	30.4	8.5	-	7.9	3.8	-	2.4	1.2	-	48.7
25	11.7	20.3	20.5	17.4	32.2	23.8	9.0	7.3	7.8	5.1	3.8	6.0	5.3	-	8.5
26	12.7	21.5	19.8	24.3	31.7	27.9	8.5	7.7	8.0	2.9	0.9	1.8	4.2	-	5.8
27	12.2	20.4	18.4	28.2	33.5	29.6	8.4	8.7	9.3	4.3	4.2	14.9	2.9	-	0.1
28	12.9	-	18.9	26.9	-	29.7	8.9	-	9.2	2.6	-	11.8	3.1	-	9.2
29	13.1	-	-	27.6	-	-	8.4	-	-	3.4	-	-	3.6	-	-
30	13.0	-	18.7	27.1	-	30.5	8.4	-	8.7	3.2	-	2.3	3.6	-	3.6

Site	Temp (℃)			Salinity (ppt)			Dissolved Oxygen (Mg/L)			Chlorophyll a (Mg/L)			Turbidity (NTU)		
32	-	-	19.2	-	-	29.7	-	-	8.8	-	-	7.0	-	-	7.6
33	-	-	19.5	-	-	30.2	-	-	7.7	-	-	1.9	-	-	5.8
34	-	-	19.4	-	-	30.1	-	-	8.3	-	-	2.8	-	-	18.9
36	-	-	19.8	-	-	24.5	-	-	8.1	-	-	3.0	-	-	12.3
37	-	-	19.2	-	-	28.2	-	-	8.2	-	-	3.1	-	-	6.3
38	-	-	19.7	-	-	29.8	-	-	7.8	-	-	2.0	-	-	7.5
39	-	-	20.2	-	-	29.1	-	-	8.7	-	-	1.4	-	-	1.8
40	-	-	18.3	-	-	33.0	-	-	10.0	-	-	5.8	-	-	6.9
41	-	-	18.7	-	-	0.0	-	-	117.0	-	-	33.0	-	-	0.0
42	-	-	17.9	-	-	30.6	-	-	8.6	-	-	4.0	-	-	4.8
43	-	-	18.8	-	-	30.5	-	-	8.7	-	-	2.3	-	-	3.7
44	-	-	18.8	-	-	29.5	-	-	10.1	-	-	4.7	-	-	3.0
47	-	-	19.6	-	-	29.6	-	-	10.4	-	-	3.0	-	-	15.6
49	-	-	19.1	-	-	29.2	-	-	10.2	-	-	16.0	-	-	0.0
50	-	-	19.6	-	-	26.4	-	-	12.7	-	-	15.6	-	-	0.1