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Fish Assemblages and Seagrass Condition of the Gippsland Lakes: 2012

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Front cover photo: Black swan in the Gippsland Lakes (T. Daniel).

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Summary

The Gippsland Lakes are one of Australia's largest estuaries, and support unique natural assets and valuable industries, such as tourism and 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. 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 lakes, and undertook to assess the condition of seagrass (and associated fish assemblages). This work has been further supported by the Gippsland Lakes Ministerial Advisory Committee.

This study provides a snapshot of fish assemblage structure and seagrass condition within the Gippsland Lakes during September 2008, April 2009, April 2010, April 2011 and April 2012. In September 2008 the presence and condition of seagrass and the structure of fish assemblages in seagrass habitats was assessed at 30 sites throughout the Gippsland Lakes using an experimental otter trawl and underwater video, respectively. Water quality parameters were recorded at multiple study sites, and light attenuation was measured at selected locations. In April 2009, 2010, 2011 and 2012, 50 sites (including the original 30) were sampled for seagrass and fish were sampled using a small beach seine from selected seagrass sites. Water quality parameters were also measured at selected sites. In July 2010, seining was augmented with a qualitative trial of a new boat-mounted electrofishing unit. This allowed more rigorous comparison of seining and electrofishing was conducted in April 2011 and 2012.

Zostera (including both *Zostera nigricaulis* and *Zostera muelleri*) was the dominant seagrass taxa detected in this study and generally occupied depths 0.5 - 2 m. *Ruppia* was also present, primarily in depths around 0.5 - 1 m. The qualitative condition of seagrass varied during the period of the current study (2008-2012). Seagrass was detected at most sites in September 2008 but condition was generally low (score = 1). The extent and qualitative condition of seagrass within the lakes increased between September 2008 and April 2009 and 2010. In April 2011, seagrass condition was high (score ≥ 4) at a greater proportion of transects (74.4%) than in other sampling rounds. In April 2012, seagrass condition had declined at 42.7% of transects compared with April 2011 and was high (score ≥ 4) at only 21.8% of transects.

In September 2008, video footage indicated there had been some decline in the 'amount' of seagrass within 75% of the sites (video transects) sampled when compared with 1997 Gippsland Lakes seagrass maps (based on aerial photography) of Roob and Ball (1997). The lack of data at finer temporal scales between 1997 and 2008 makes it difficult to ascertain which year seagrass began to decline and the mechanisms generating observed declines are unknown. Differences in seagrass condition through time may reflect, for example, natural cycles in productivity and/or changes in environmental conditions.

The species of fish sampled with netting gears during this study (2008-2012) were generally consistent with those expected in shallow Victorian estuaries and represented a range of functional guilds, including estuarine resident species, species that depend on estuarine habitats to complete their lifecycle and species that use estuaries opportunistically. Relative abundances were highly variable among sampling rounds and variation in percent abundances also varied.

In July 2010, new electrofishing equipment showed great promise in sampling fish within estuarine 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. In April 2011 and 2012 a more rigorous investigation showed that assemblage compositions of seine and electrofishing samples from

seagrass habitats differed and demonstrated that assessments of estuarine fish assemblages will benefit from multiple gears.

Throughout this study, 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 in September 2008 and April 2010, but lower in other regions of the Lakes. Temperature (ºC), dissolved oxygen (Mg/L) and turbidity (NTU) were relatively consistent among sampling locations. Salinity was notably lower in April 2012 (~ 14-18 ppt) than previous occasions following a late summer/autumn characterised by high rainfall.

The four sampling periods of the present study provide a 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 particular, better understanding of cycles of seagrass condition in relation to freshwater flows and catchment landuses and associated implications for fish recruitment will help inform catchment and fisheries management. Moving towards process orientated seagrass monitoring will also facilitate early detection of seagrass stress and better link perceived threats to seagrass condition to help inform management of seagrasses of the Gippsland Lakes.

1 Background

The Gippsland Lakes are one of Australia's largest estuaries, and support unique natural assets and valuable industries, such as tourism and commercial fishing. Seagrass is an important component of the Gippsland Lakes ecosystem that supports a range of ecosystem services. Seagrasses provide valuable invertebrate and fish habitat, stabilise sediments, contribute to estuarine foodwebs and play an important role in nutrient cycling. The proximity of seagrass communities to anthropogenic activity make them particularly susceptible to threats stemming from population increase and catchment modification e.g. altered sediment and nutrient loads, marine pest incursions and alterations of hydrodynamic regimes. Climate change represents an additional broad-scale threat to seagrass ecosystems, which is likely to be exacerbated by population growth and may include, sea level rise (particularly where coastal development impedes shoreline evolution); alteration of ocean chemistry (particularly ocean acidification); changes in circulation patterns of oceanic and nearshore waters; and changes in inputs of flows, nutrients and sediments from catchments (Warry and Hindell 2009).

Phytoplankton blooms are a major feature of the biological activity in the Gippsland Lakes and their development and persistence are influenced by interactions between environmental (e.g. nutrient inputs) and biological (e.g. reproduction of algal spores) factors. Persistent phytoplankton blooms reduce incident light which can negatively impact the productivity of benthic primary producers such as seagrasses. In response to the prolonged 2007-2008 bloom of the blue green alga *Synechococcus* sp., the Gippsland Lakes and Catchment Taskforce undertook to monitor the occurrence and qualitative condition of seagrass within the lakes. Monitoring initially occurred in September 2008 and has occurred annually in April thereafter. Data collected to date provide a strong baseline against which future changes can be assessed. To explore ecosystem level implications of seagrass decline or expansion within the Gippsland Lakes, fish associated with seagrass habitats were also documented during annual monitoring.

Monitoring of seagrass and fish from 2008 – 2011 was supported by the Gippsland Lakes and Catchment Taskforce. The Gippsland Lakes Ministerial Advisory Committee has continued support for these monitoring activities in 2012 and has supported additional work designed to improve understanding of the functional role of seagrass in the ecology of the Gippsland Lakes.

The work documented in this report built upon previous monitoring activities by:

1. Assessing the physical condition of seagrasses in the Gippsland Lakes in April 2012 using underwater video techniques, and compare findings with previous years (2008-2011);
2. Assessing seagrass associated fish assemblages of the Gippsland Lakes in April 2012, and compare findings with previous years (2008-2011).

Additional work supported by the Gippsland Lakes Ministerial Advisory Committee will supplement primary monitoring activities by:

1. Trialling and developing monitoring approaches that target functional aspects of seagrass plants to provide early detection of seagrass stress prior to potential decline;
2. Investigating the role of seagrass in the nutritional support of fish to strengthen understanding of the links between fish and seagrass and potential impacts of fluctuations in seagrass condition on fish assemblages.

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 beds of high or medium density *Zostera* had been observed. Selection of sites in the vicinity of Lakes Entrance was guided by the work of Judd et al. (2008).

The second round of sampling in April 2009 re-sampled the September 2008 sites and an additional 20 sites. This brought the number of seagrass survey sites to 50, increasing the spatial coverage of monitoring and improving the baseline against which future changes in seagrass can be assessed. These 50 sites were re-sampled in April 2010, April 2011 and again in April 2012 (Table 1; Figure 1).

Table 1: Summary of seagrass and fish monitoring activities conducted during this study.

Sampling Occasion	No. of Seagrass sites	No. of Seagrass Transects	Fish Sample Gear/s	No. of Fish Sites
Sep 2008	30	39	Trawl	21
Apr 2009	50	81	Trawl/Seine	8
Apr 2010	50	89	Seine/EF	8
Apr 2011	50	105	Seine/EF	18
Apr 2012	50	110	Seine/EF	19

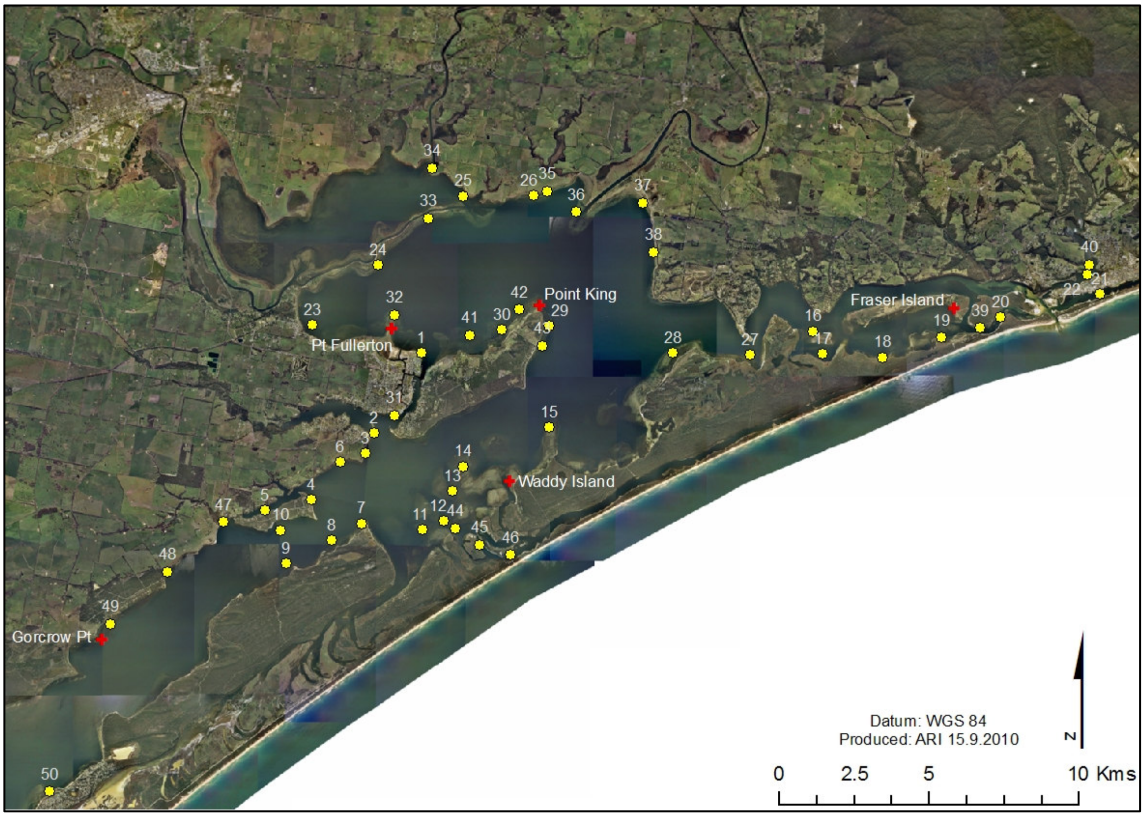

Figure 1. Sites throughout the Gippsland Lakes of seagrass condition assessment during the period 2008-2012.

2.2 Measuring seagrass condition

The distribution of seagrass throughout the Gippsland Lakes was last mapped in 1997 by Roob and Ball (1997). Seagrass close to Lakes Entrance was mapped more recently by Judd et al. (2008). Both these studies used ground-truthed aerial photography. The seagrass monitoring in the current study used underwater video to provide qualitative information on seagrass condition so any comparisons between the different datasets should be made with caution. The work of Roob and Ball (1997) did provide an indicative baseline for the present study, against which the presence/absence of seagrass could be assessed. The continuation of the present study has provided five years of data collected with consistent methods to provide a contemporary baseline against which future changes in seagrass communities of the Gippsland Lakes can be assessed.

In this study, underwater video was used to observe and record seagrass condition. Underwater video transects are a useful technique for the rapid assessment of seagrass and have been used to document seagrass presence/absence and percent cover elsewhere (see Haag et al. 2008; Schultz 2008). The method is particularly advantageous when depth, turbidity or phytoplankton blooms inhibit the ability of aerial or satellite imaging techniques to penetrate the water and identify benthic habitats (Haag et al. 2008). Other benefits include the low observer error associated with the technique, its non-destructive nature and its capacity to rapidly assess aspects of seagrass condition at high spatial resolution, without the need for SCUBA (Haag et al. 2008; Schultz 2008). In the present study, video was used to document the presence/absence of seagrass and noted broad condition categories based on percent cover and blade density along each transect. These condition categories are outlined in Table x.

Table 2: **Outline of the five condition scoring categories used for the description of seagrass condition.**

Condition Score	Description
0	No seagrass observed along transect
1	Very sparse seagrass, with only a few blades or small plants observed along transect
2	Sparse seagrass throughout < 50% of transect
3	Sparse seagrass present along > 50% of transect
4	Medium – high density seagrass common along transect
5	Dense seagrass present along > 50 % of transect

The video camera was deployed from a boat and gradually lowered to a distance of around 30-40cm from the bottom and the entire transect was recorded. Up to two minutes of footage was recorded. The latitude and longitude were recorded at the beginning of each transect. Transects were typically run perpendicular to the shoreline, shoreward from the GPS marker. On all sampling occasions, video footage was assessed with a view to identifying whether seagrass was present, however, the quality of the footage was adequate to provide some information on percent cover and semi-quantitative estimates of seagrass condition based on blade density. Condition was scored between 0 and 5 (Table 1).

Sites initially assessed in September 2008 were selected based on those areas shown by Roob and Ball (1997) to have dense beds of *Zostera,* in order to maximise detection potential. Thirty sites were selected. Generally one transect was run at each site but an additional transects were run at some sites where seagrass was suspected to be patchy and may have gone undetected with a single transect. The total number of transects conducted in September 2008 was 39. Greatly improved water clarity during April 2009 improved our ability to identify areas of the Gippsland Lakes with seagrass, and we were able to collect video data from an additional 20 sites (and 71 new transects) during the April 2009 sampling round (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 (89 transects), 2011 (105 transects) and 2012 (110 transects).

In this study, as in Roob and Ball (1997), the two species of Zosteraceae (*Zostera nigricaulis* and *Zostera muelleri*) were not easily differentiated by the methods used. Specific species identifications were not undertaken, and the two species were grouped as "Zostera". The seagrass species, *Ruppia spiralis* was also detected by of Roob and Ball (1997) and will hereafter be referred to as *Ruppia.*

2.3 Assessing fish assemblages

The approach to characterising seagrass-associated fish assemblages has been refined throughout this project (see Hindell and Warry 2010a; Warry and Hindell 2011). Work in 2008-2009 supported the use of a small beach seine net and this was the primary sampling approach used in 2009 and 2010. Following the success of pilot study in winter 2010 investigating the potential utility of a new, boat-mounted estuarine electrofishing unit, electrofishing was incorporated into the sampling protocol in April 2011. A more comprehensive comparison of estuarine electrofishing and seining in 2011 showed that electrofishing complemented the seining approach by sampling a different suite of species. Electrofishing was included in the sampling protocol again in April 2012.

In autumn 2011 and 2012, 15 seagrass and 3 unvegetated sites were sampled with the seine net (see section 2.3.1). Each site was also sampled with the electrofisher using an approach that consisted of three 90 second 'shots' (see section 2.3.2).

Fish were identified, measured and returned to the water, where appropriate. Some fish were retained for confirmation of species identifications in the laboratory, or future analyses of stable isotope ratios of tissues. Fish for identification were preserved in 70% ethanol. Fish for stable isotope analyses were frozen.

2.3.1 Seine Netting

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. 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 (see Hindell and Warry 2010a).

2.3.2 Electrofishing

In 2010, a new boat-mounted estuarine electrofishing unit was trialled. The higher salt content of estuarine and marine waters has historically precluded the use of this type of equipment in sampling fish from environments other than freshwater within these types of environment. Senior ARI technicians have recently arranged for a powerful electrofishing unit to be built. Since mid 2010, ARI have been trialling this new unit in a range of conductivities.

The boat team consisted of two people; one to operate the unit and one to net fish. Electrofisher output settings were not standardised but operator judgement was used to select settings based on environmental conditions at each site to maximise gear efficiency. A 'sample' consisted of a 90 second 'shot' (power-on time) during which the boat moved slowly along the estuary with one operator controlling boat and electrofisher settings and a netter at the front controlling the passage of electric current into the water and removing any immobilised fish from the water using a dip-net. Fish were placed in tanks of water on board the boat to recover prior to identification, measurement and release.

Three 'shots' were paired with each seine sample. Fifteen seagrass and three unvegetated sites were sampled.

2.3.3 Statistical Analyses

Fish assemblage composition was assessed among gear types, habitats and years using multi-dimensional scaling (MDS) based on Bray-Curtis dissimilarity indices calculated from presence-absence data and Analyses of Similarity (ANOSIM). Similarity Percentage Analyses (SIMPER) was done to ascertain which species contributed most to the variation among gear types, habitats and years. Analyses were done using PRIMER version 6 (Clarke and Warwick 2001).

2.4 Measuring water quality

The spatial coverage of water quality measurements has varied during this project (see Hindell and Warry 2010a). In April 2011 and 2012 water quality data (see Appendix 4 for a list of attributes) were collected at 1 m depth intervals, from the surface to the bottom using a Hydrolab DataSonde 5x.

2.5 Functional Monitoring of Seagrass Plants

The primary monitoring activities of April 2012 will be supplemented with a preliminary investigation of the utility of functional metrics of seagrass condition. This work will involve analyses of elemental nutrients (C:N:P) and carbon and nitrogen isotope ratios of seagrass leaves. These measures aim provide an integrated picture of environmental conditions in which seagrasses grow e.g. the relative availability of nutrients and light. Such approaches may detect seagrass stress prior to decline and better link the condition of seagrasses to perceived threats including nutrient loading and phytoplankton blooms. This work aims to develop a suite of functional monitoring tools to complement conventional monitoring of physical seagrass attributes.

Seagrass samples were collected from sites in Lake Victoria, Lake King, Jones Bay and in the vicinity of Lakes Entrance during autumn 2012. Samples are being stored at ARI for processing and analyses in 2012-2013.

2.6 Seagrass Contribution to Fish Nutrition

Primary monitoring activities (see section 2.2 and 2.3) and functional monitoring of seagrass plants (see section 2.5) will be supplemented with an assessment of the contribution of seagrass to fish nutrition. This work will use stable isotope approaches to help elucidate the contribution of seagrass versus alternative primary producers (e.g. macroalgae and *Nodularia spumigena*) to the nutrition of fish species that are representative on various functional guilds. Stable isotope approaches can be used to trace nutrients through foodwebs and isotopic signatures of consumers will reflect that of their combined sources of nutrition, thereby providing a time-integrated estimation of assimilated diet (Peterson and Fry 1987). In this way the relative contribution of seagrass vs. other primary producers can be assessed to provide information on the value of seagrass and potential consequences of altered seagrass condition for fish fauna of the Gippsland Lakes.

Replicate samples of fish, seagrass (both *Zostera* and *Ruppia*) and macroalgae were collected from sites in Lake King and in the vicinity of Lakes Entrance in autumn 2012. Fish were collected using seines and electrofishing as described in section 2.3. Samples are being stored at ARI for processing and analyses in 2012-2013.

3 Results and Discussion

3.1 Seagrass condition

Zostera and *Ruppia* were detected during this study. *Zostera* was the most common seagrass taxa occurring across the study area during all sampling occasions. *Ruppia* was detected at some sites and on some occasions (Appendix 1). In this study, the condition of seagrass varied among sites and years (Appendix 1) and the presence/absence of seagrass also varied among years and in comparison to the 1997 mapping done by Roob and Ball (1997).

In September 2008, seagrass was detected at most sites, although condition was generally low (Table 3; Appendix 1). 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 epiphytic algae. For sites where seagrass was not detected during September 2008, the substratum was commonly covered with shells of molluscs. Despite the widespread 'loss' of seagrass, some sites had retained significant areas of seagrass, either as continuous but sparse beds (Figure2c) or dense patches (Figure2d and e).

Table 3: Summary of seagrass video monitoring showing the percent of transects where seagrass was detected, seagrass condition was high (≥ 4), and the percentage of re-sampled transects where condition had increased or decreased compared with the previous sampling occasion.

Sampling Occasion	% Transects with SG detected	% Transects with condition ≥ 4	% Transects with condition increase	% Transects with condition decrease
Sep 2008	74.4	7.7	-	-
Apr 2009	64.2	33.3	50	11
Apr 2010	55.1	16.9	11	48
Apr 2011	74.4	47.6	54.4	6.7
Apr 2012	64.6	21.8	11.8	42.7

Seagrass was detected at most transects sampled in April 2009 and condition had generally improved from September 2008 (Table 3; Appendix 1), demonstrating the importance of short-term variability in seagrass condition. Seagrasses are known to die-back over winter as day-length, solar radiation and water temperatures decline, before re-growing through late spring and summer.

In April 2010 seagrass was again detected at most transects but condition was relatively low (Table 3; Appendix 1). The notable decline in seagrass condition between April 2009 and 2010 (Table 3), corresponds with an increase in epiphytic algal cover at some sites (Appendix 1), particularly those in the vicinity of Waddy Island.

In April 2011 seagrass was detected at 74.4% of transects and condition was high at the greatest proportion (47.6%) of transects during this study (Table 3; Appendix 1) At the broader scale of sites, the coverage and density of seagrass was relatively high in April 2011, with tracts of dense, continuous seagrass apparent (Condition ≥ 4). This was most pronounced near Green Point Hill (site 8), Rotamah Island (site 11) and Corcrow Point (site 49) in Lake Victoria, at Shaving Point (site 27) near Metung and near Lakes Entrance (site 20; Figure 3).

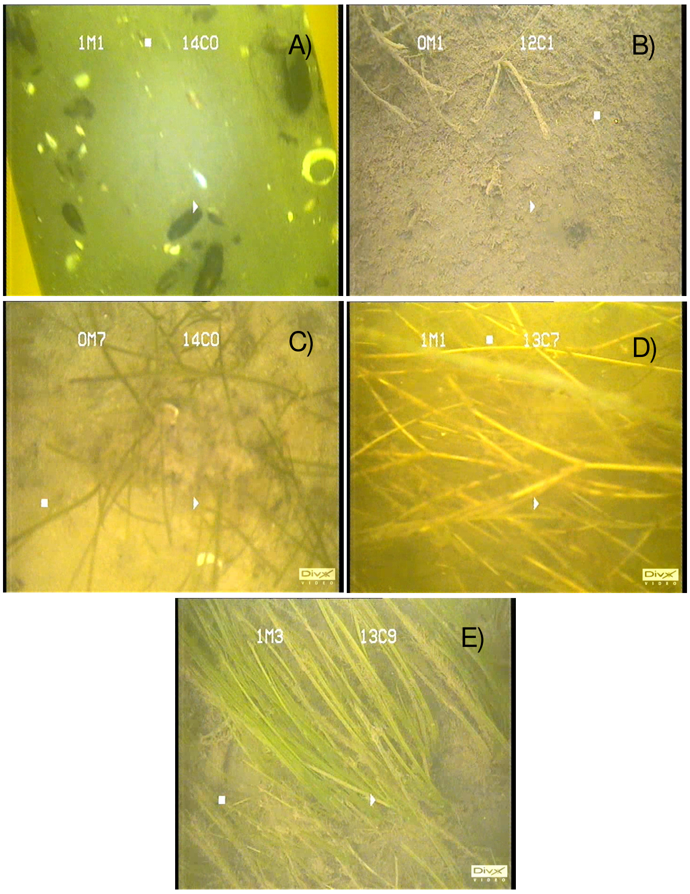

Figure 2: Visual demonstration of the qualitative seagrass condition measures provided in Table 2. A) Condition = 0; B) Condition = 1; C) Condition = 2/3; D) Condition = 4; E) Condition = 5.

In April 2012 seagrass was again detected at a relatively high proportion of transects however condition was high at only 21.8% of transects; a notable reduction compared to 2011 (Table 3; Appendix 1). Broad regions of seagrass decline include areas in the vicinity of Point King and Eagle Point. Seagrass condition improved at the mouth of the Nicholson River and at some sites in the vicinity of Lakes Entrance. On all sampling occasions, seagrass has been largely absent from sites in the north of Lake King (e.g. sites 24, 32 and 37) and the eastern side of Point King (sites 29 and 41;Figure 3; Appendix 1).

The original 30 sites sampled in September 2008 were chosen based on the mapping work of Roob and Ball (1997) and previously supported dense beds of *Zostera* and other algal species. The first round of video sampling of the present study, in September 2008, indicated that estimated seagrass density had declined at 23 of 30 sites (2 of 4 broad regions) since the mapping, based on 1997 aerial photography, done by Roob and Ball (1997; Table 4

). The different methodologies employed in the present work and that of Roob and Ball (1997) prevent quantification of this decline. The lack of data at finer temporal scales between 1997 and 2008 makes it difficult to ascertain which year seagrass began to decline and the mechanisms generating observed declines are unknown. The present study does, however, demonstrate the temporally dynamic nature of seagrass within the Gippsland Lakes.

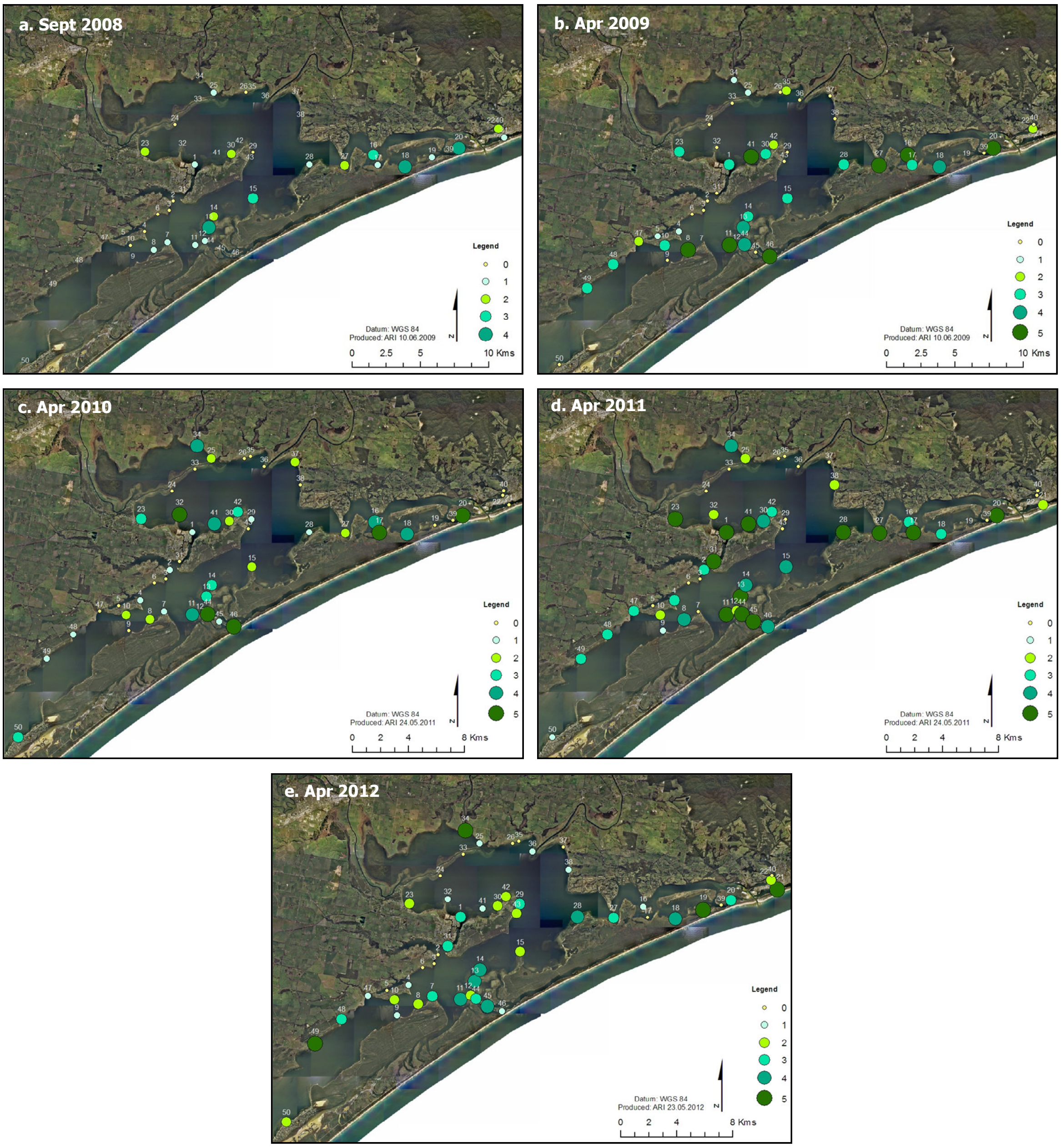

Figure 3: Spatial representation of the qualitative seagrass condition measures provided in Tables 2 and 3 for a) September 2008, b) April 2009, c) April 2010, d) April 2011 and e) April 2012; description of condition scores is provided in Table 2; these maps should be used conservatively as condition was averaged across transects within a site, and seagrass density can be patchy.

The qualitative condition of seagrass has fluctuated at the five broad regions of Roob and Ball (1997) during the period of the current study (2008-2011) and in comparison to the 1997 mapping (Table 4). Video data suggests both increases (e.g. in the vicinity of Fraser Island) and decreases (e.g. near Point King) in seagrass density have occurred within these areas of the Gippsland Lakes since 1997 (Appendix 1). Although video data indicates seagrass presence and qualitative condition has increased in the Gippsland Lakes between September 2008 and April 2012, quantification of areal extent and physical structure would facilitate direct comparison of seagrass condition in 2011 with that recorded by Roob and Ball in 1997, when extensive quantitative mapping was last conducted. Differences in seagrass condition through time may reflect, for example, natural cycles in productivity and/or changes in environmental conditions.

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, 2010, 2011 and 2012 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 4: Summary of estimated changes in the density of seagrass observed in the present study as compared with that documented by Roob and Ball (1997); Adapted from 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	light green				
1966		light green			
1968	dark green				
1969	dark green	dark green	dark green	dark green	light green
1975	mid green				
1976	light green	mid green	light green	mid green	mid green
1979			mid green	mid green	dark green
1984	dark green	light green	light green	light green	light green
1986	light green				mid green
1989			mid green		
1997	mid green	dark green	dark green	light green	dark green
2008*	mid green	light green	light green		dark green
2009*	dark green	mid green	mid green	light green	mid green
2010*	dark green	dark green	mid green	light green	light green
2011*	dark green	mid green	mid green	mid green	dark green
2012*	dark green	light green	light green	dark green	mid green

3.2 Fish Assemblages

Overall, 28 species of fish were sampled during April 2012. Species from several functional groups were sampled, including estuarine resident species (e.g. Eastern bluespot goby) and species that use estuaries opportunistically (e.g. Luderick). Diadromous species that depend on estuarine environments to reproduce (e.g. Tupong and Common galaxids) were also present along with species strongly associated with seagrass habitats including pipefish and cobblers (Table 5). This indicates that seagrass habitats of the Gippsland Lakes are contributing to the support of a functionally diverse fish fauna.

Table 5: Summary of the percent abundance of fish sampled using an experimental otter trawl in September 2008 (S-08), a beach seine in April 2009 (A-09), 2010 (A-10), 2011 (A-11) and 2012 (A-12), and an electrofisher in April 2011 (A-11) and 2012 (A-12); species detected in the qualitative electrofishing pilot in July 2010 are indicated with a tick; samples pooled across all sites; abbreviations, Twl – otter trawl.

Common name	Species name	Twl	Seine				Electrofishing		
		S-08	A-09	A-10	A-11	A-12	Ju-10	A-11	A-12
Australian anchovy	*Engraulis australis*	8.20	5.66	0.00	0.00	0.04	✓	0.00	0.00
Bay prawn	*Metapenaeus bennettae*	1.64	0.00	0.00	0.00	0.00	✓	0.00	0.00
Blue sprat	*Spratelloides robustus*	0.00	0.23	0.00	0.00	0.00	✓	0.00	0.00
Black bream	*Acanthopagrus butcheri*	67.21	13.80	0.82	1.54	0.04	✓	20.25	0.81
Bridled goby	*Arenigobius bifrenatus*	0.00	0.00	0.55	1.72	0.04		3.31	0.00
Cobbler	*Gymnapistes marmoratus*	0.00	0.23	0.68	0.20	1.76		0.41	0.00
Common galaxid	*Galaxias maculatus*	0.00	0.00	0.00	0.13	0.00		0.00	0.00
Dusky flathead	*Platycephalus fuscus*	0.00	0.00	0.00	0.02	0.04	✓	2.07	4.07
Eastern Australian salmon	*Arripis trutta*	0.00	0.00	0.00	0.03	0.00		1.24	0.00
Eastern blue spot goby	*Pseudogobius sp.*	0.00	0.00	0.07	4.87	2.67	✓	0.00	0.00
Eastern fortesque	*Centropogon australis*	0.00	0.00	0.00	0.00	0.13		0.41	0.00
Eastern kelpfish	*Chironemus marmoratus*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Eastern striped trumpeter	*Pelates sexlineatus*	0.00	0.00	0.34	0.00	0.00	✓	0.00	0.00
Eastern wirra	*Acanthistius ocellatus*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Elephant fish	*Callorhinchus milii*	0.00	0.00	0.00	0.00	0.00		0.00	0.81
Estuary perch	*Macquaria colonorum*	0.00	0.68	0.00	0.00	0.00	✓	0.00	0.00
Flathead gudgeon	*Philypnodon grandiceps*	0.00	0.23	0.07	1.92	0.04		0.41	0.00
Glass goby	*Gobiopterus semivestitus*	0.00	7.24	0.20	0.25	6.23	✓	0.00	0.00
Globefish	*Diodon nicthemerus*	0.00	0.23	0.14	0.02	0.00		0.41	0.81
Greenback flounder	*Rhombosolea tapirina*	0.00	0.00	0.00	0.00	0.04	✓	3.72	3.25
Herring cale	*Odax cyanomelas*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Largemouth goby	*Redigobius macrostoma*	0.00	0.00	1.36	3.43	0.47		0.00	0.00
Longfinned goby	*Favonogobius lentiginosus*	0.00	0.00	0.00	0.21	0.00		0.00	0.00
Longsnout flounder	*Ammotretis rostratus*	1.64	0.00	0.00	0.13	0.00		2.89	5.69
Luderick	*Girella tricuspidata*	0.00	9.50	0.89	0.48	0.43	✓	6.20	21.95
Old wife	*Enoplosus armatus*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Oyster blenny	*Omobranchus anolius*	0.00	0.00	0.00	0.03	0.00		0.00	0.00
Pipefish	*Stigmatopora spp.*	0.00	22.17	0.00	0.00	0.04		0.00	0.00
Port Jackson Glassfish	*Ambassis jacksoniensis*	0.00	0.00	0.00	0.61	4.69		0.00	0.00
Pot-belly seahorse	*Hippocampus abdominalis*	1.64	0.45	0.00	0.00	0.04		0.00	0.00
Prickly Toadfish	*Contusus brevicaudus*	0.00	0.00	0.00	0.00	0.04		0.00	0.81
Pug-nose pipefish	*Pugnaso curtirostris*	0.00	0.45	0.34	0.11	4.00		0.41	0.00
Red Gurnard	*Chelidonichthys kumu*	0.00	0.00	0.00	0.00	0.04		0.00	0.00
Rock blackfish	*Girella elevata*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
River garfish	*Hyporhamphus regularis*	0.00	2.26	1.70	1.18	4.51		0.00	0.81
Rock cod	*Pseudophycis spp.*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Rock ling	*Genypterus tigerinus*	0.00	0.00	0.00	0.00	0.00	✓	0.83	0.00
Rough leatherjacket	*Scobinichthys granulatus*	0.00	4.30	0.00	0.00	0.00	✓	0.00	0.00
Sandy sprat	*Hyperlophus vittatus*	0.00	8.37	0.00	0.00	0.13	✓	0.00	0.00
Sea sweep	*Scorpis aequipinnis*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Serpent eel	*Ophisurus serpens*	0.00	0.00	0.00	0.00	0.00		2.07	0.81
Shortfin eel	*Anguilla australis*	0.00	0.00	0.00	0.00	0.00	✓	2.89	5.69
Silver sweep	*Scorpis lineolata*	0.00	0.00	0.00	0.00	0.00		2.48	0.00

Common name	Species name	Twl	Seine				Electrofishing		
		S-08	A-09	A-10	A-11	A-12	Ju-10	A-11	A-12
Silver trevally	*Pseudocaranx dentex*	0.00	0.00	0.00	0.00	0.09		0.41	0.00
Six-spine leatherjacket	*Meuschenia freycineti*	1.64	0.00	0.27	0.00	0.00	✓	0.00	0.00
Smallmouth hardyhead	*Atherinosoma microstoma*	0.00	4.07	81.66	58.59	65.00	✓	14.05	0.00
Snapper	*Chrysophrys auratus*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Sole	*Brachirus nigra*	0.00	0.00	0.00	0.00	0.00		0.00	2.44
Southern crested weedfish	*Cristiceps australis*	0.00	0.00	0.00	0.18	0.00		0.41	0.00
Southern-sea garfish	*Hyporhamphus melanochir*	0.00	0.90	0.07	0.00	0.00		0.00	0.00
Spinytail Leatherjacket	*Acanthaluteres brownii*	0.00	0.00	0.00	0.00	0.13		0.00	0.00
Spotted pipefish	*Stigmatopora argus*	0.00	0.45	3.89	6.79	1.85		0.00	0.00
Tailor	*Pomatomus saltatrix*	1.64	0.00	0.00	0.00	0.00	✓	0.00	0.00
Tamar river goby	*Afurcagobius tamarensis*	0.00	0.00	1.02	8.17	3.18		2.07	2.44
Tasmanian blenny	*Parablennius tasmanianus*	0.00	0.23	0.00	0.00	0.00		0.00	0.00
Toadfish smooth	*Tetractenos glaber*	8.20	0.23	0.20	0.52	0.00	✓	5.79	0.00
Toadfish prickly	*Contusus brevicaudus*	1.64	0.00	0.00	0.00	0.00		0.00	0.00
Tupong	*Pseudaphritis urvillii*	1.64	0.23	0.07	0.00	0.43	✓	16.12	45.53
Western Australian Salmon	*Arripus truttaceaus*	0.00	0.00	0.00	0.00	0.13		0.00	0.00
Wide bodied pipefish	*Stigmatopora nigra*	0.00	0.00	5.04	2.95	3.31		0.83	0.00
Yank flathead	*Platycephalus speculator*	0.00	0.00	0.00	0.00	0.00	✓	0.00	0.00
Yellow-eye mullet	*Aldrichetta forsteri*	4.92	0.00	0.00	5.92	0.43		10.33	4.07
Gobies	family *Gobiidae*	0.00	17.65	0.00	0.00	0.00		0.00	0.00
Juvenile mullet	family *Mugilidae*	0.00	0.23	0.00	0.00	0.00		0.00	0.00
Post-larval fish		0.00	0.00	0.48	0.00	0.00		0.00	0.00
Unknown fish		0.00	0.23	0.14	0.00	0.00		0.00	0.00
		0.00	0.00	0.00	0.00	0.00		0.00	0.00
N		21	8	8	18	19		54	61
Number of Individuals		61	442	1467	6097	2326	0	242	123
Number of species		11	24	22	25	29	0	24	15

Similar numbers of species were sampled with seines and electrofishing in 2011 and 2012 (Table 5, Appendix 2, 3 and 4). Fish assemblage composition of seine and electrofishing samples from seagrass habitats could be clearly separated in both 2011 and 2012 (Figure 4a and b), with several species contributing to the average dissimilarity of 90.3% between the two groups in 2011 and 97.1% in 2012.

More species were sampled in April 2011 and 2012 than in previous sampling rounds (Table 5) which likely reflects the greater seining effort (18 sites) and inclusion of electrofishing (Table 1). In 2010, 2011 and 2012 species not previously detected with conventional netting gears were sampled with the electrofisher, demonstrating its utility for fish assessment in the Gippsland Lake (see Warry and Hindell 2011 and Table 5). These new species included species that are highly mobile (e.g. Elephant fish) and nocturnal (e.g. Rock ling and Serpent eels).

SIMPER analysis indicated largely small bodied species accounted for 50% of the dissimilarity between electrofishing and seine samples in seagrass in 2011. They included Tamar river goby, Smallmouth hardyhead, Spotted pipefish, Wide-bodied pipefish, Eastern blue spot goby, Largemouth goby and Black bream collectively. Small-bodied species again contributed most to the dissimilarity between electrofishing and seining in 2012; Smallmouth hardyhead, River garfish, Glass goby, Widebodied pipefish, Pugnose pipefish, and Port Jackson glassfish accounted for >50%.

In seagrass habitats, electrofishing techniques were more successful than seines at sampling mobile, larger bodied species (and individuals), including Black bream, adult Tupong which dominated electrofishing samples in 2011 (Table 5). Adult Tupong, Luderick, and Dusky flathead dominated electrofishing samples in 2012. Dusky flathead individuals over 700mm were sampled.

Seine nets were more successful than electrofishing at sampling smaller-bodied, benthic associated species including several gobies, and pipefish (Table 5).

Fish assemblages sampled from sand habitats using seines and electrofishing were more similar than those from seagrass habitats (Figure 4a and b; average dissimilarity 77.95% in 2011 and 80% in 2012). Again, several species contributed to the dissimilarity between assemblages sampled with seines and electrofishing.

The composition of fish assemblages sampled with the electrofisher was relatively consistent between April 2011 and 2012 but the composition of seine samples differed (Figure 4c). SIMPER indicated Black bream, Largemouth goby, River garfish and Pugnose pipefish collectively accounted for >20% of the dissimilarity between seine samples in 2011 and 2012. Black bream were noticeably rare in 2012 samples with only two individuals sampled (one with seines, one with electrofishing), suggesting they may have moved into the river systems. The assemblage composition of seine samples also differed among other years of this study (Figure 4d). Again, several species contributed to this dissimilarity. The environmental and/or population factors generating these differences are yet to be fully understood, but may include shifts in habitat quality and food availability/quality.

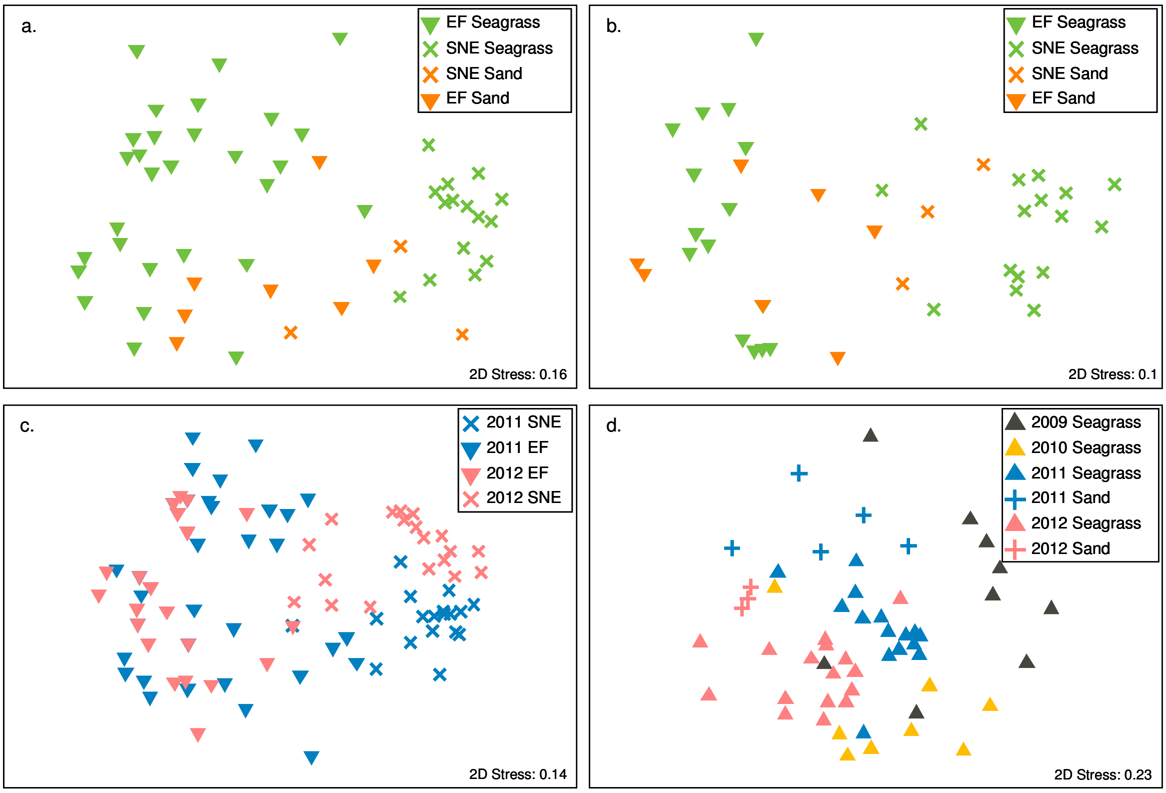

Figure 4: Multidimensional scaling plots based on Bray-Curtis dissimilarity metrics derived from presence-absence fish assemblage data, comparing electrofishing and seine samples in seagrass and sand habitats in a) 2011 and b) 2012 and c) electrofishing and seine samples between 2011 and 2012 and d) seine samples among years 2009 - 2012.

Strongly seagrass associated species of pipefish and gobies dominated seine samples in 2009 (Table 5). Smallmouth hardyheads which are a planktivorous, pelagic species were the dominant species caught with seines in April 2010 (81.7%), 2011 (58.6%) and 2012 (65%; Table 5).

Two highly transient, pelagic species were caught in eastern Lake Victoria during September 2008 - Tailor and Australian Anchovy and large schools of bait fish were observed on the sonar while trawling. In April 2009 Australian Anchovy and Sandy Sprats were again caught in seine nets in Lake Victoria however these species were not detected in April 2010 or 2011 when the pelagic Smallmouth hardyhead dominated samples (Table 5). Australian Anchovy and Sandy Sprats feed on zooplankton, and are an important prey species for birds and other predatory fish such as Tailor and Estuary Perch. The 2007-2008 plankton blooms in the Gippsland Lakes may have supported high abundances of grazing zooplankton, 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. Tailor and Anchovy were not detected in 2012 following the *Nodularia spumigena* (phytoplankton) bloom during the 2011-12 spring/summer. Knowledge of the implications of phytoplankton blooms, the species composition of blooms and their persistence on secondary productivity during and after phytoplankton blooms in the Gippsland Lakes, and broader implications for resource dynamics within the estuary, is limited. Investigation of trophic pathways 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 supplementary work described in section 2.6 to investigate the role of seagrass versus other primary producers (e.g. algae and phytoplankton) as will help to improve understanding of these resource dynamics.

The species diversity and fish densities sampled from Gippsland Lakes seagrass habitats, in the present study, are comparable to those sampled from seagrass in other parts of Victoria in recent years, including Port Phillip Bay (Jenkins et al. 1997; Smith et al. 2008) and Corner Inlet (Jenkins et al. 1997). Pre European Reference Conditions for fisH (PERCH) lists (based on historical records and expert consultation), have been developed for inland aquatic systems, but are yet to be developed for Victoria's estuaries. This makes it difficult to compare contemporary estuarine fish assemblages to those expected under undisturbed, pre-European conditions. The development of the Victorian Index of Estuarine Condition (IEC; Arundel et al. 2009; Warry and Reich 2010), which is currently underway, will provide a framework for consistent assessment of estuarine fish fauna within a broader context of estuarine ecological condition. The Victorian IEC will ultimately help to link fish assemblage information collected in the current study (and similar estuarine fish surveys) to estuarine condition and perceived threats.

3.3 Water quality

Basic water quality parameters were measured at multiple sites on each sampling occasion (Appendix 5).

During September 2008 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.

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 south-eastern Lake King, and these figures are similar 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. 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 $\mu g.l^{-1}$.In April 2010, 2011 and 2012 chlorophyll *a* measurements were variable but exceeded September 2008 values at several sites.

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. In April 2011, however, salinities were generally lower than those recorded on previous occasions ranging ~ 21-30 ppt. The high rainfall received throughout Gippsland in the 2010-2011 summer would have increased freshwater inflows to the Gippsland Lakes, thereby reducing salinities. Salinities were reduced further in April 2012, ranging ~ 14-18 ppt. This corresponded with high rainfall in Gippsland Lakes catchments during late summer and early autumn 2012. Turbidity was also noticeably higher in 2012 than previous years. This was likely due to a combination of increased freshwater flows delivering suspended particles to the lakes and the phytoplankton bloom over the summer period. However, it should be noted that sampling in 2012 was conducted under winder conditions than previous years which may have re-suspended sediments.

Concentrations of dissolved oxygen were consistent between the five sampling rounds and showed little spatial variation within the lakes ranging from ~ 6.6 – 12.7 Mg/L.

4 Summary of findings

The present study undertook an assessment of fish assemblage structure and seagrass condition within the Gippsland Lakes during September 2008, and April of 2009, 2010, 2011 and 2012. Key points from the present report include:

- Seagrass was present at most sites. Two seagrass taxa dominated: *Ruppia* in waters mostly around 0.5 to 1 m; and, '*Zostera'* (including both *Zostera nigricaulis* and *Zostera muelleri*) in waters 0.5 to 2 m depth.
- Seagrass condition was high (score ≥ 4) in April 2011 at a greater proportion of transects (74.4%) than in other sampling rounds.
- Seagrass condition had declined at 42.7% of transects in April 2012, compared with April 2011 and was high (score ≥ 4) at only 21.8% of transects.
- In the current study, seagrass condition was variable among sites and years. Differences in seagrass condition through time may reflect, for example, natural cycles in productivity and/or changes in environmental conditions.
- Underwater video footage taken during September 2008 suggested that there had been some decline in the occurrence and semi-qualitative estimates of densities of seagrass within 75% of all sites (video transects) compared with the mapping work of Roob and Ball (1997). The lack of data at finer temporal scales between 1997 and 2008 makes it difficult to ascertain which year seagrass began to decline and the mechanisms generating observed declines are unknown.
- Video data indicated seagrass occurrence and qualitative condition had increased in the Gippsland Lakes between September 2008 and April 2011, however, quantification of areal extent and physical structure would facilitate direct comparison of contemporary seagrass condition with that recorded in 1997, when extensive quantitative mapping was last conducted (see Roob and Ball 1997).
- Fish species sampled with netting gears during this study were generally consistent with those expected in shallow Victorian estuaries and represented a range of functional guilds.

- Estuarine electorfishing was also tested over a range of salinities throughout the Gippsland lakes in July 2010. Several fish species that had not previously been encountered were sampled.
- Work in April 2011 and 2012 showed that the electrofisher sampled different fish assemblages to seining in seagrass habitats. Electrofishing was effective at sampling larger bodied species including Black bream and adult Tupong as well as cryptic species, e.g. Rock ling and Worm eels, rarely sampled from seagrass habitats. Seining sampled more small-bodied benthic associated species including gobies and pipefish. Investigations aiming to characterise assemblages will benefit from using multiple gears.
- Electrofishing shows immense promise for investigating fish associations with structurally complex habitats such as rock walls, large woody debris and *Phragmites* which are difficult to sample directly with conventional sampling gears.
- 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 $\mu g.l^{-1}$.
- Salinity (ppt) was notably lower in April 2012 than on other sampling occasions and ranged ≈ 14-18 ppt.

5 Recommendations

- 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.
- Samples for investigations into process orientated seagrass monitoring and the contribution of seagrass to the nutritional support of fish in the Gippsland Lakes have been collected and will be processed and analysed in 2012-2013.
- 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.

6 Directions for future research

The current study provides a valuable baseline on the distribution and qualitative condition of seagrass within the Gippsland Lakes. Over the period of this study (2008 – 2012), substantial variability in the amount and quality of seagrass had been observed. The ability to better relate seagrass condition to perceived threats and improve understanding of mechanisms generating seagrass distribution and condition changes will help inform management.

6.1.1 Process-orientated seagrass monitoring

Conventional seagrass monitoring approaches, including those employed in the current study, focus on physical attributes of seagrass plants e.g. leaf density and areal extent. A disadvantage of relying exclusively on monitoring physical attributes of plants is that seagrass decline occurs before a stress is detected. Environmental parameters known to influence seagrass growth, including light availability and temperature can be monitored, however, such approaches are only valuable if species-specific responses and critical thresholds are known.

Monitoring functional aspects of seagrass plants, such as concentrations of elemental nutrients and isotope rations can provide an integrated signal of environmental conditions e.g. the relative availability of nutrients and light. Such approaches may detect seagrass stress prior to decline and better link the condition of seagrasses to perceived threats, including nutrient loading and phytoplankton blooms. Similar process-orientated approaches to seagrass monitoring have been employed in the Florida Keys National Marine Sanctuary since the 1990s and have yielded valuable information on the relationships between seagrass condition and human activities in coastal zones (Fourqurean et al. 2005).

Seagrass samples were collected during field activities in autumn 2012 (see section 2.5 above) in order to trial and develop such functional indicators of seagrass conditions in the Gippsland Lakes context. Processing and analyses will occur in 2012-2013.

6.1.2 Seagrass contribution to fish nutrition

Data collected thus far indicate that seagrass supports diverse assemblages of small and juvenile fish within the Gippsland Lakes, but snapshots of fish assemblages are limited in their capacity to explore functional links between seagrass and fish fauna. Investigating the role of seagrass in providing nutritional support to estuarine fish will strengthen the understanding of the value of seagrass for fish and ecosystem function. Stable isotope approaches have been used to trace the transfer of nutrients through foodwebs and demonstrate that seagrass can make a major contribution to the nutrition of fish in Victorian estuarine systems (see Hindell 2006; Hindell and Warry 2010). Identifying fish species (or groups of species) that are nutritionally reliant on seagrass versus those that demonstrate plasticity in feeding habits and the capacity to successfully utilise alternative primary producers e.g. phytoplankton and macroalgae, will improve understanding of potential implications of fluctuations in seagrass condition.

Samples of fish and primary producers were collected during field activities in autumn 2012. Processing and analyses will occur in 2012-2013.

6.1.3 Environmental drivers of seagrass condition

Seagrass condition has varied spatially and temporally throughout the current study. This study now has five years of data which is approaching the replication required to statistically analyse relationships between patterns of seagrass growth and decline and environmental parameters in a meaningful way. Environmental parameters including freshwater flows and catchment land-uses may influence seagrass condition through various mechanisms. For example, freshwater flows are considered important for estuarine function through the delivery of nutrients and sediments to estuaries and by playing an important role in the flushing of estuarine systems. Investigating the links between freshwater flows and seagrass condition will improve understanding of the mechanisms underpinning seagrass health in the Gippsland Lakes and interactions between catchments and estuaries more broadly.

Understanding relationships between seagrass condition and freshwater flows and catchment land-uses will inform management of seagrass habitats and the Gippsland Lakes ecosystem more broadly. An ARC linkage project led by ARI and Monash University commenced last year to investigate functional links between estuaries and their catchments. This project will complement any investigation into relationships between seagrass condition and, catchment landuse practices and freshwater flows in the Gippsland Lakes systems by providing details around the functional links between the dynamics and quantity of catchments inputs and estuarine ecology and biogeochemistry.

6.1.4 Seagrass habitats and Black bream recruitment

Work by Jenkins et al. (2010) found that the recruitment of black bream within the Gippsland Lakes was episodic and that the population was dominated by a few year classes. There was a positive relationship between recruitment and water column stratification within the lakes and highest recruitment occurred during years with moderate freshwater flows. It was noted that spawning within the lakes rather than the rivers of the Gippsland Lakes system would put juvenile bream in close proximity of seagrass habitats which may be beneficial for survival. Information on seagrass condition, however, was not incorporated into their analyses. Improved understanding of relationships among black bream productivity, freshwater flows and seagrass condition would help inform management of the Gippsland Lakes black bream fishery in the face of climate change and increasing catchment modification.

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Appendix 1:

Summary of the condition of seagrass at each site in 2012 compared with condition values recorded in 2008, 2009, 2010 and 2012. 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)	Cond. (2008)	Cond. (2009)	Cond. (2010)	Cond. (2011)	Cond. (2012)	Species Observed	Substratum	Notes
1	2	S37 54.047	E147 43.908			5	1	5	0	-	Silt/Shell	unvegetated silt, bivalve shells present
1	24	S37 54.084	E147 44.449	0.8		3	1	4	5	Zostera	Sand/Silt/Shell	moderate epiphytic coverage
1	363	S37 54.202	E147 44.007	3.0		0	0	5	0	-	Silt	unvegetated
1	364	S37 54.114	E147 43.936		1			4	4	Zostera	Sand/Silt	high to medium density, unvegetated patches interspersed
2	367	S37 55.530	E147 42.845	0.5	0	0	1	3	0	-	Silt/Shell	unvegetated
3	372	S37 55.950	E147 42.637	1.2	0	0	0	0	0	-	Sand/Silt/Shell	unvegetated
4	375	S37 56.766	E147 41.419	1.2	0	1	1	2	0	-	Sand/Silt	unvegetated
4	378	S37 56.963	E147 40.478	3.0		2	0	4	1	Zostera	Silt/Shell	few small isolated plants
5	140	S37 57.017	E147 40.258	3.0		0	0	0	0	-	Sand/Silt	bivalve shells present
6	386	S37 56.071	E147 42.188	0.7		0	0	0	0	-	Silt/Shell	unvegetated
6	387	S37 56.085	E147 42.169		0			0	0	-	Silt/Shell	unvegetated
7	398	S37 57.275	E147 42.473	5.6	1		1	0	-	-	No visible bottom	
7	551	S37 57.324	E147 42.494						3	Zostera	Sand/Silt	epiphytes present, bivalve shells present
8	56	S37 57.628	E147 41.854	1.0		5	2	4	1	Zostera	Sand/Silt/Shell	bivalves present
8	59	S37 57.565	E147 41.957	0.8			2	5	3	Zostera	Sand/Silt	epiphytes present, bivalve shells present
8	401	S37 57.541	E147 41.929	0.7	1	5	0	4	0	-	Silt/Shell	unvegetated, bivalve shells present
8	404	S37 57.923	E147 40.888		1			2	0	-	Sand/Silt	unvegetated, bivalve shells present
8	581	S37 53.831	E147 45.057						4	Zostera	Sand/Silt	medium density throughout transect, epiphytes present
9	403	S37 57.930	E147 40.882	2.3		0	0	2	0	-	Sand/Silt/Shell	unvegetated, bivalve shells present
9	405	S37 57.944	E147 40.927	0.5			0	0	0	-	Sand/Silt	unvegetated, bivalve shells present
9	584	S37 54.106	E147 43.924						3	Zostera	Sand/Silt	epiphytes present
10	45	S37 57.146	E147 40.848	1.0		4	3	3	3	Zostera	Sand/Silt	sparse seagrass, medium in places, unvegetated tracts interspersed
10	144	S37 57.117	E147 41.114	2.5		0	0	0	0	-	Silt/Shell	unvegetated, bivalve shells present
10	145	S37 57.143	E147 40.878	1.5		4	2	3	3	Zostera	Silt	sparse seagrass consistently along transect, medium denisty in places

Site	Wpt	Lat.	Long.	Depth (m)	Cond. (2008)	Cond. (2009)	Cond. (2010)	Cond. (2011)	Cond. (2012)	Species Observed	Substratum	Notes
10	147	S37 57.200	E147 40.646	1.5		3	0	0	1	Zostera	Silt/Shell	one small plant observed
10	409	S37 57.180	E147 40.696	1.5	0	3	0	2	0	-	Sand/Silt	unvegetated, bivalve shells present
11	44	S37 57.249	E147 44.212	1.5		5	4	4	4	Zostera	Silt	medium density seagrass present along transect, epiphytes present
11	159	S37 57.201	E147 44.033	0.7		4	3	5	4	Zostera	Sand/Silt	medium density, sparse in places, blades long
11	417	S37 57.303	E147 43.993		1			4	3	Zostera	Sand/Silt	epiphytes present, blades long in places
11	420	S37 57.282	E147 44.148		1			5	3	Zostera	Sand/Silt/Shell	epiphytes present, blades long in places
12	39	S37 56.852	E147 44.320	3.0			0	0	2	Zostera/Ruppia	Silt	sparse patches present, bottom not visible for parts of transect
12	424	S37 57.136	E147 44.454		1			3	1	Zostera	Silt	some plants present, no visible bottom in places
12	425	S37 57.131	E147 44.460		1			1	1	Zostera	Silt/Shell	few blades evident, bivalve shells present
12	426	S37 57.130	E147 44.483		1			5	1	Zostera	Sand/Silt	few blades evident, bivalve shells present
13	37	S37 56.505	E147 44.527	1.3		4	4	4	4	Zostera	Sand/Silt	medium density seagrass present along transect, epiphytes present
13	38	S37 56.551	E147 44.356	1.0		4	2	5	5	Zostera	Sand/Silt/Shell	dense seagrass, medium density in places, epiphytes present
13	431	S37 56.599	E147 44.666		3			5	4	Zostera	Sand/Silt	medium density, long blades, epiphytes present
13	436	S37 56.583	E147 44.741		4			4	3	Zostera	Sand/Silt	epiphytes present
14	35	S37 56.049	E147 44.857	1.0		2	2	4	4	Zostera	Sand/Silt	medium density seagrass present along transect, epiphytes present
14	36	S37 56.099	E147 44.754	1.1		4	3	4	4	Zostera	Sand/Silt	medium density seagrass present along transect, epiphytes present
14	438	S37 56.152	E147 44.901	0.8	2	4	3	4	3	Zostera	Sand/Silt	epiphytes present
14	439	S37 56.139	E147 44.895		2			4	4	Zostera	Sand/Silt	epiphytes present, bivalve shells present
15	33	S37 55.415	E147 47.032	0.5		3	2	5	2	Zostera	Sand/Silt/Shell	small patches present, unvegetated tracts interspersed
15	34	S37 55.422	E147 46.937	1.0		5	1	4	2	Zostera	Sand/Silt	small patches present, unvegetated tracts interspersed
15	156	S37 55.447	E147 46.942	0.7		0	3	4	3	Zostera	Sand/Silt	blades generally short, shells present
15	443	S37 55.427	E147 46.825	1.2	3	2	0	3	0	-	Sand	unvegetated
16	447	S37 53.717	E147 52.949	0.5	3	5	4	3	1	Zostera	Silt	few seagrass blades present, green filamentous algae common
17	450	S37 54.179	E147 53.071	0.7	1	5	5	5	0	-	Silt	macroalgae observed, no visible bottom in places
18	18	S37 53.950	E147 54.311	2.5		4	0	0	0	-	Sand/Silt	unvegetated
18	19	S37 53.950	E147 54.929	0.6		5	5	5	5	Zostera/Ruppia	Sand/Silt	epiphytes present, Zostera blades long
18	452	S37 54.116	E147 54.427	1.2	4	3	3	2	5	Zostera	Sand/Silt	moderate-high epiphytic coverage
18	453	S37 54.105	E147 54.425		3			5	5	Zostera	Sand/Silt	moderate-high epiphytic coverage
18	454	S37 54.096	E147 54.402						3	Ruppia	Silt	small medium density patches
19	457	S37 53.751	E147 55.771	1.1	1		0	-	5	Zostera/Ruppia	Silt	epiphytes present, sparse areas interspersed within dense patches
20	21	S37 53.432	E147 57.103	1.0		5	5	5	-			
20	460	S37 53.368	E147 57.114	1.3	4	4	4	4	3	Zostera	Sand/Silt	small dense patches in places
21	464	S37 52.927	E147 59.485	1.1	1		0	0				

Site	Wpt	Lat.	Long.	Depth (m)	Cond. (2008)	Cond. (2009)	Cond. (2010)	Cond. (2011)	Cond. (2012)	Species Observed	Substratum	Notes
21	466	S37 52.917	E147 59.556	1.0	1		0	4	5	Zostera/Ruppia	Sand/Silt	epiphytes present
21	472	S37 52.594	E147 59.066	1.4	1		0	-				
22	22	S37 52.830	E147 59.610			4		-	3	Ruppia	Silt/Shell	patchy along transect, moderate-high epiphytic coverage
22	471	S37 52.590	E147 59.071			0		0	0	-	Silt	unvegetated
22	483	S37 54.029	E147 43.868		2			-				
23	4	S37 53.522	E147 41.189			1		0	0	-	Sand/Silt/Shell	bivalve shells present
23	63	S37 53.661	E147 41.315	0.8			4	5	2	Zostera	Sand/Silt	very patchy Zostera
23	158	S37 53.707	E147 41.294			5		5	3	Zostera	Sand/Silt	Zostera patchy, low epiphytes
23	489	S37 53.642	E147 41.312	1.0	2		1	4	2	Zostera	Sand/Silt	moderate epiphytic coverage, numerous bivalve shells
24	495	S37 52.483	E147 42.929	1.4	0	0	0	0	0	-	Sand/Silt	unvegetated
25	7	S37 51.486	E147 44.382	0.5		0	1	3	-			
25	8	S37 51.408	E147 44.291	1.2		1	0	0	0	-	Sand/Silt/Shell	bivalve shells present
25	9	S37 51.430	E147 44.094	1.0		5	4	4	0	-	Silt/Shell	bivalve shells present
25	12	S37 51.177	E147 44.838	1.0		0	0	0	0	-	Cobbles/Silt/Shell	bivalve shells present
25	501	S37 51.229	E147 44.856	0.8	0	0	0	0	0	-	Cobbles/Silt/Shell	unvegetated
25	503	S37 51.412	E147 44.420		1			3	2	Zostera	Sand/Silt	small patch at beginning of transect, bivalve shells present
26	509	S37 51.230	E147 46.459	0.7	0	0	0	0	0	-	Silt/Shell	unvegetated
27	61	S37 54.072	E147 49.639	0.6			2	-	3	Zostera	Sand/Silt	few medium density patches present, bivavle shells present
27	516	S37 54.191	E147 51.500	0.7	2	5	2	5	2	Zostera	Silt	bivalve shells present
28	32	S37 54.007	E147 49.558	3.0		2	1	5	-	-	No visible bottom	-
28	520	S37 54.070	E147 49.644			3		5	3	Zostera	Sand/Silt	epiphytes presnet, seagrass appears senescent in places
28	522	S37 54.074	E147 49.621		1			5	4	Zostera	Sand/Silt	high epiphytic cover, seagrass appears senescent in places
29	526	S37 53.641	E147 46.798	0.8	0	0	0	0	3	Zostera	Sand/Silt	bivalve shells present
30	26	S37 53.610	E147 45.781			4	2	5	1	Zostera	Sand/Silt	few small plants observed
30	27	S37 53.556	E147 45.743	2.3		1	1	2	0	-	Sand/Silt	unvegetated, bivalve shells present
30	532	S37 53.635	E147 45.754	1.5	0	5	3	4	1	Zostera	Sand/Silt/Shell	few small plants present
30	534	S37 53.703	E147 45.797		3	3		5	3	Zostera	Sand/Silt	epiphytes present, bivalve shells present
31	1	S37 55.244	E147 43.330			0	0	5	3	Zostera	Silt/Shell	low epiphitic coverage, blades moderate to long, bivalve shells present
32	3	S37 53.430	E147 43.306			0	0	0	0	-	Sand/Silt/Shell	lots of bivalve shells present
32	64	S37 53.539	E147 43.155	0.5			5	4	2	Zostera	Sand/Silt	sparse seagrass present, no visible bottom for parts of transect
33	5	S37 51.673	E147 44.050			0	0	0	0	-	Sand/Silt/Shell	lots of bivalve shells present
33	6	S37 51.697	E147 44.404			0	0	0	0	-	Silt/Shell	bivalve shells present
34	10	S37 50.767	E147 44.146	1.0		2	4	4	4	Zostera	Silt/Shell	epiphytes present,

Site	Wpt	Lat.	Long.	Depth (m)	Cond. (2008)	Cond. (2009)	Cond. (2010)	Cond. (2011)	Cond. (2012)	Species Observed	Substratum	Notes
34	11	S37 50.728	E147 44.098	1.0		0	3	-	5	Zostera	Silt/Shell	high to medium density patches, epiphytes present
35	13	S37 51.167	E147 46.758	0.7		2	0	0	0	-	Sand/Silt/Shell	lots of bivalve shells present
36	14	S37 51.543	E147 47.424	1.3		0	0	0	1	Zostera	Sand/Silt	only a few blades observed
37	15	S37 51.372	E147 48.933	0.7		0	2	0	0	-	Sand/Silt	unvegetated, few shells present
38	16	S37 52.599	E147 49.178	0.5		0	0	0	0	-	Sand/Silt	unvegetated
38	153	S37 52.256	E147 49.186	0.6		0	0	4	3	Zostera	Silt	blades short, shells present
39	20	S37 53.645	E147 56.715	2.0			0	0	0	-	Sand/Silt	largely unvegetated, a few tufts of macroalgae
40	23	S37 52.403	E147 59.114	1.0		0	0	0	0	-	Mud/Silt	unvegetated
41	25	S37 53.779	E147 45.020	1.5		5	4	5	1	Zostera	Sand/Silt	few small plants observed
42	28	S37 53.401	E147 46.102	1.0		3	3	5	4	Zostera	Sand/Silt	medium density seagrass present along transect
42	30	S37 53.148	E147 46.384	1.0		1	0	1	0	-	Silt/Shell	lots of shells present
43	31	S37 53.964	E147 46.673	2.3		0	0	0	0	-	Silt/Shell	lots of shells present
43	573	S37 53.985	E147 46.581						3	Zostera	Sand/Silt	bivalve shells present
44	40	S37 57.221	E147 44.580	1.5		4	5	5	3	Zostera	Sand/Silt	low epiphitic coverage, blades moderate to long, bivalve shells present
45	42	S37 57.567	E147 45.284	2.0		0	1	5	4	Ruppia/Zostera	Silt	macroalgae interspersed, bottom not visible for parts of transect
46	43	S37 57.745	E147 45.994	1.5		5	5	4	1	Ruppia/Zostera	Silt	few blades and small plants observed
47	46	S37 57.139	E147 39.608	1.5		2	0	3	1	Zostera	Silt	few small plants observed, bottom not visible for parts of transect
47	58	S37 57.267	E147 39.853	1.0			0	2	1	Zostera	Sand/Silt	cobbles present, bivalves present
47	141	S37 57.076	E147 39.918			2		3	1	Zostera	Cobbles/Silt/Shell	few small plants present
48	48	S37 58.097	E147 38.164	0.6		3	1	3	3	Zostera	Sand/Silt	low epiphitic coverage, bivalve shells present
49	49	S37 59.005	E147 36.933	1.0		2	1	3	3	Zostera	Sand/Silt	moderate epiphyty coverage
49	50	S37 59.019	E147 36.906	0.6		3	1	3	5	Zostera/Ruppia?	Sand/Silt	moderate-high epiphytic coverage, some areas of sparse seagrass
49	51	S37 59.044	E147 36.885	0.7		3	1	3	5	Zostera	Sand/Silt	moderate-high epiphytic coverage,
50	53	S38 02.162	E147 35.334	1.2		0	0	0	0	-	Sand/Silt	unvegetated, bivalve shells present
50	54	S38 02.082	E147 35.509	1.0		0	0	0	0	-	Sand/Silt/Shell	unvegetated, bivalve shells present
50	55	S38 01.505	E147 36.636	0.5			4	3	4	Zostera	Sand/Silt/Shell	medium density seagrass present along transect, epiphytes present
Total Transects					**39**	**81**	**89**	**105**	**110**			

Appendix 2

Summary of sites and waypoints of electrofishing and seining in April 2011 and 2012.

Site	WPT	Lat	Long	Method	Habitat
1	772	S37 57.276	E147 44.022	Electrofisher	Seagrass
1	774	S37 57.369	E147 44.013	Electrofisher	Seagrass
1	775	S37 57.400	E147 44.141	Electrofisher	Seagrass
1	770	S37 57.227	E147 44.148	Seine	Seagrass
2	776	S37 57.279	E147 44.568	Electrofisher	Seagrass
2	777	S37 57.319	E147 44.452	Electrofisher	Seagrass
2	778	S37 57.366	E147 44.364	Electrofisher	Seagrass
2	779	S37 57.344	E147 44.317	Seine	Seagrass
3	781	S37 57.165	E147 44.689	Electrofisher	Seagrass
3	782	S37 57.105	E147 44.782	Electrofisher	Seagrass
3	783	S37 57.067	E147 44.764	Electrofisher	Seagrass
3	784	S37 57.083	E147 44.743	Seine	Seagrass
4	786	S37 56.878	E147 44.916	Electrofisher	Seagrass
4	787	S37 56.866	E147 44.940	Electrofisher	Seagrass
4	788	S37 56.882	E147 44.951	Electrofisher	Seagrass
4	785	S37 56.919	E147 44.848	Seine	Seagrass
5	790	S37 57.016	E147 45.202	Electrofisher	Seagrass
5	791	S37 56.921	E147 45.180	Electrofisher	Seagrass
5	792	S37 56.918	E147 45.107	Electrofisher	Seagrass
5	793	S37 56.926	E147 45.091	Seine	Seagrass
6	795	S37 53.697	E147 52.748	Electrofisher	Seagrass
6	796	S37 53.679	E147 52.807	Electrofisher	Seagrass
6	797	S37 53.663	E147 52.788	Electrofisher	Seagrass
6	447	S37 53.717	E147 52.949	Seine	Seagrass
7	799	S37 54.105	E147 51.287	Electrofisher	Seagrass
7	800	S37 54.110	E147 51.340	Electrofisher	Seagrass
7	801	S37 54.098	E147 51.384	Electrofisher	Seagrass
7	317	S37 54.280	E147 51.453	Seine	Seagrass
8	803	S37 53.871	E147 50.275	Electrofisher	Seagrass
8	804	S37 53.859	E147 50.290	Electrofisher	Seagrass
8	805	S37 53.886	E147 50.263	Electrofisher	Seagrass
8	316	S37 53.955	E147 50.210	Seine	Seagrass
9	807	S37 54.033	E147 49.732	Electrofisher	Seagrass
9	808	S37 54.062	E147 49.671	Electrofisher	Seagrass
9	809	S37 54.053	E147 49.710	Electrofisher	Seagrass
9	315	S37 54.046	E147 49.777	Seine	Seagrass
10	812	S37 54.420	E147 49.434	Electrofisher	Seagrass
10	813	S37 54.359	E147 49.504	Electrofisher	Seagrass
10	814	S37 54.355	E147 49.407	Electrofisher	Seagrass
10	314	S37 54.388	E147 49.500	Seine	Seagrass
11	818	S37 53.337	E147 57.173	Electrofisher	Seagrass
11	819	S37 53.338	E147 57.152	Electrofisher	Seagrass
11	820	S37 53.328	E147 57.138	Electrofisher	Seagrass
11	319	S37 53.472	E147 56.365	Seine	Seagrass
12	822	S37 53.554	E147 56.934	Electrofisher	Seagrass
12	823	S37 53.528	E147 56.895	Electrofisher	Seagrass
12	824	S37 53.520	E147 56.921	Electrofisher	Seagrass
12	320	S37 53.513	E147 56.887	Seine	Seagrass
13	826	S37 53.352	E147 56.355	Electrofisher	Sand
13	827	S37 53.421	E147 56.344	Electrofisher	Sand
13	828	S37 53.369	E147 56.344	Electrofisher	Sand
13	318	S37 53.488	E147 57.078	Seine	Sand
14	829	S37 53.252	E147 56.436	Electrofisher	Sand
14	830	S37 53.188	E147 56.446	Electrofisher	Sand
14	831	S37 53.245	E147 56.433	Electrofisher	Sand
14	321	S37 53.323	E147 56.401	Seine	Sand
15	324	S37 53.223	E147 46.283	Electrofisher	Seagrass

Site	WPT	Lat	Long	Method	Habitat
15	325	S37 53.217	E147 46.280	Electrofisher	Seagrass
15	326	S37 53.254	E147 46.227	Electrofisher	Seagrass
15	327	S37 53.273	E147 46.223	Seine	Seagrass
16	328	S37 53.673	E147 45.785	Electrofisher	Seagrass
16	329	S37 53.643	E147 45.777	Electrofisher	Seagrass
16	330	S37 53.721	E147 45.749	Electrofisher	Seagrass
16	331	S37 53.726	E147 45.771	Seine	Seagrass
17	332	S37 53.878	E147 45.187	Electrofisher	Seagrass
17	334	S37 53.916	E147 45.158	Electrofisher	Seagrass
17	336	S37 53.888	E147 45.132	Electrofisher	Seagrass
17	335	S37 53.918	E147 45.156	Seine	Seagrass
18	337	S37 55.394	E147 42.783	Electrofisher	Sand/Rubble
18	338	S37 55.424	E147 42.809	Electrofisher	Sand/Rubble
18	339	S37 55.400	E147 42.788	Electrofisher	Sand/Rubble
18	340	S37 55.372	E147 42.771	Seine	Sand/Rubble

Appendix 3

Summary of the total number of fish sampled from each site using the electrofishing unit in April 2012; data pooled across the three 'shots' within each site.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Acanthopagrus butcheri											1								
Afurcagobius tamarensis														2				1	
Ammotretis rostratus								1				1	2				1		
Anguilla australis							1	1			1	1			1				1
Brachirus nigra														1		2			
Callorhinchus milii													1						
Contusus brevicaudus																			1
Diodon nicthemerus																			1
Girella tricuspidata												4							18
Hyporhamphus regularis														1					
Ophisurus serpens														1					
Platycephalus fuscus	2																	1	2
Pseudaphritis urvilli	1	5		5	11		4	1			2	1	1		2	2	3	10	5
Rhombosolea tapirina							3						1						
Total Fish	3	5	0	5	11	0	8	3	0	0	4	7	5	5	3	4	4	12	28

Appendix 4

Summary of the number of fish sampled from each site using the beach seine net in April 2012.

Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Acanthaluteres brownii							1				1	1							
Acanthopagrus butcheri							1												
Afurcagobius tamarensis	1	1			1		1		3	4	2	1	13	8		4	13	10	12
Aldrichetta forsteri					1						2							7	
Ambassis jacksoniensis			1	1	34		3	6	22	3	4				5			1	29
Arenigobius bifrenatus												1							
Arripus truttaceaus											3								
Atherinosoma microstoma		19	67	352	204	12		5	111	73	78	99	24	16	1	142	16	157	136
Centropogon australis																3			
Chelidonichthys kumu											1								
Contusus brevicaudus											1								
Engraulis australis												1							
Girella tricuspidata																			10
Gobiopterus semivestitus	1	2	11	8	20		18	11	6						53	9			6
Gymnapistes marmoratus							4			10	2	3			4	2			16
Hippocampus bleekeri											1								
Hyperlophus vittatus		1							2										
Hyporhamphus regularis	3	5	1	14	6	1	13			1	5	4	3	1	10	10	13	14	1
Philypnodon grandiceps															1				
Pipefish sp.																	1		
Platycephalus fuscus																	1		
Pseudaphritis urvilli	2	3			1				1				1			1	1		
Pseudocaranx georgianus							2												
Pseudogobius sp. 9		12	2	2	10		5			4						14	11		2
Pugnaso curtirostris		7	10	5	1		14		2	4	2	3			4	21	15		5
Redigobius macrostoma			1		5		1										4		
Rhombosolea tapirina				1															
Stigmatopora argus		4	23	2					1		2	4			1		1		5
Stigmatopora nigra	2	1	12		7		9		1	1	3	4			3	5	15		14
Total Fish	9	55	128	385	290	13	72	22	149	100	107	121	41	25	82	211	91	189	236

Appendix 5

Summary of water quality parameters recorded during September 2008, April 2009, 2010 and 2011 at a given site.

Site	Temp (°C)					Salinity (ppt)					Dissolved Oxygen (Mg/L)					Chlorophyll a (Mg/L)					Turbidity (NTU)				
	S-08	A-09	A-10	A-11	A-12	S-08	A-09	A-10	A-11	A-12	S-08	A-09	A-10	A-11	A-12	S-08	A-09	A-10	A-11	A-12	S-08	A-09	A-10	A-11	A-12
1	12.8	19.4	18.8	17.2	17.8	27.7	32.1	29.9	22.5	17.2	8.5	32.1	8.9	7.0	7.4	8.1	2.8	14.4	3.1	6.1	2.9	-	0.1	3.8	983.3
2	12.9	19.7	19.6	16.6	17.2	27.6	32.1	29.0	21.4	14.5	8.7	32.1	9.8	6.8	8.6	9.5	3.5	3.6	3.4	17.6	1.4	-	3.9	2.3	843.7
3	13.1	-	18.8	15.8	17.1	27.5	-	29.7	14.3	14.7	8.3	-	9.5	8.3	8.5	10.6	-	14.6	6.0	17.7	2.4	-	0.1	30.7	832.7
4	13.4	-	18.4	16.5		27.8	-	29.7	21.2		7.8	-	9.5	7.3		12.9	-	14.7	7.5		3.1	-	0.1	2.4	
5	-	-	20.6	17.0	17.6	-	-	30.6	21.7	16.3	-	-	8.3	8.5	10.2	-	-	3.1	14.9	19.3	-	-	5.1	1.7	834.8
6	12.9	-	18.8	16.5	17.1	27.4	-	29.7	21.3	18.9	8.4	-	9.8	6.6	7.0	9.5	-	15.4	4.9	22.3	3.4	-	0.1	2.6	839.0
7	12.2	19.8	18.7	17.1	16.3	27.3	32.0	29.7	20.9	14.5	8.7	6.9	8.7	10.1	8.5	1.5	-	15.1	2.4	4.7	5.3	-	0.1	2.8	815.5
8	12.2	-	18.8		16.2	26.9	-	27.4	-	13.9	8.5	-	9.9	-	9.2	18.4	-	20.8	-	15.8	12.7	-	0.0	-	810.7
9	-	19.3	17.7	17.2		-	31.8	30.1	20.7		-	7.8	10.7	8.3		-	4.5	14.2	3.0		-	-	0.1	2.0	
10	12.1	20.3	18.0	17.8	16.6	27.7	31.2	29.5	21.2	14.0	8.1	6.2	9.1	8.7	10.0	17.9	5.0	15.7	3.8	12.0	12.2	-	0.1	3.7	833.7
11	12.4	-	18.7	17.3	17.6	27.3	-	29.9	21.5	16.7	8.2	-	8.6	9.9	8.2	6.7	-	15.6	2.2	19.4	5.1	-	0.1	3.2	1311.7
12	12.0	19.6	18.0	16.6	17.4	27.0	32.5	30.7	21.7	16.8	8.3	6.9	10.6	9.0	8.9	8.1	1.5	3.8	1.7	12.9	7.2	-	3.3	2.1	721.3
13	12.5	19.4	-	16.7	17.4	27.3	32.5	-	21.6	16.8	8.1	7.6	-	8.6	8.2	7.0	2.2	-	7.4	8.1	19.2	-	-	1.8	349.3
14				17.0	17.3	-	-	-	21.6	16.9	-	-	-	9.6	8.6	-	-	-	12.7	13.8	-	-	-	28.4	358.2
15	13.2	21.5	-	16.7	17.1	27.4	32.7	-	22.0	17.9	7.9	10.2	-	10.4	8.3	3.7	1.5	-	2.0	24.5	7.4	-	-	0.7	563.0
16	12.8	-	19.3	17.8	18.5	29.0	-	29.4	23.4	18.1	8.1	-	8.9	7.8	6.4	3.5	-	16.5	4.4	2.8	5.9	-	0.2	2.3	820.0
17	12.6	20.3	19.8	18.7		30.6	34.2	31.5	24.4		9.7	6.3	10.2	9.9		2.6	-	9.6	2.3		1.9	-	6.8	6.1	
18	12.6	20.0	20.2	18.5	18.3	30.8	35.2	31.7	24.5	19.9	8.3	6.4	10.7	8.5	6.9	2.1	6.0	4.8	2.1	13.3	1.4	-	9.6	24.5	1335.8
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	18.0		33.0	-	33.1	25.0		8.0	-	9.8	8.7		4.8	-	5.8	3.1		21.8	-	8.4	11.5	
21				17.5	18.2	-	-	-	30.4	31.9	-	-	-	8.4	5.6	-	-	-	7.2	9.6	-	-	-	229.9	835.7
22	12.0	-	18.5	18.5		26.5	-	0.0	27.5		9.1	-	112.4	7.5		4.7	-	32.9	8.2		0.5	-	0.0	29.0	
23	12.5	-	18.4	17.6	18.3	27.1	-	32.8	23.4	17.8	8.6	-	9.9	8.1	6.7	5.5	-	4.8	3.2	7.3	1.0	-	5.8	2.8	950.5
24	12.0	-	20.0	17.8	18.0	26.5	-	30.4	23.1	17.0	8.5	-	7.9	7.6	6.9	3.8	-	2.4	3.8	5.5	1.2	-	48.7	2.6	831.0
25	11.7	20.3	20.5	17.0	18.6	17.4	32.2	23.8	19.3	15.7	9.0	7.3	7.8	8.6	5.8	5.1	3.8	6.0	8.0	9.4	5.3	-	8.5	3.3	918.0
26	12.7	21.5	19.8	17.4	17.8	24.3	31.7	27.9	20.1	17.2	8.5	7.7	8.0	8.4	5.6	2.9	0.9	1.8	5.9	3.1	4.2	-	5.8	3.3	856.0
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	18.4	17.1	26.9	-	29.7	22.2	17.7	8.9	-	9.2	9.6	10.0	2.6	-	11.8	2.7	5.1	3.1	-	9.2	159.0	784.0
29	13.1	-	-	16.0	17.2	27.6	-	-	22.3	16.4	8.4	-	-	7.3	7.3	3.4	-	-	1.2	4.2	3.6	-	-	1.0	801.5
30	13.0	-	18.7	16.1	17.6	27.1	-	30.5	22.2	16.9	8.4	-	8.7	7.9	6.9	3.2	-	2.3	2.5	4.5	3.6	-	3.6	46.3	794.7
31				16.8		-	-	-	21.6		-	-	-	7.9		-	-	-	8.9		-	-	-	272.5	
32	-	-	19.2	17.5		-	-	29.7	22.7		-	-	8.8	8.1		-	-	7.0	2.6		-	-	7.6	3.7	
33	-	-	19.5	17.3	18.0	-	-	30.2	19.9	17.3	-	-	7.7	8.3	6.3	-	-	1.9	11.4	15.5	-	-	5.8	110.0	848.2
34	-	-	19.4	17.3	18.7	-	-	30.1	17.9	12.4	-	-	8.3	8.9	6.4	-	-	2.8	27.1	8.1	-	-	18.9	177.4	859.0
35					17.8	-	-	-	-	17.2	-	-	-	-	5.7	-	-	-	-	2.9	-	-	-	-	863.5
36	-	-	19.8	17.3	17.9	-	-	24.5	23.0	15.6	-	-	8.1	7.5	6.4	-	-	3.0	11.5	14.6	-	-	12.3	4.9	854.7
37	-	-	19.2		17.8	-	-	28.2	-	17.9	-	-	8.2	-	6.4	-	-	3.1	-	12.3	-	-	6.3	-	995.0
38	-	-	19.7	17.4		-	-	29.8	22.9		-	-	7.8	8.6		-	-	2.0	10.5		-	-	7.5	2.9	
39	-	-	20.2	18.1		-	-	29.1	25.0		-	-	8.7	8.4		-	-	1.4	3.3		-	-	1.8	3.3	
40	-	-	18.3	18.6	18.5	-	-	33.0	27.9	23.4	-	-	10.0	9.0	5.8	-	-	5.8	17.6	10.0	-	-	6.9	6.5	1036.7

Site	Temp (°C)					Salinity (ppt)					Dissolved Oxygen (Mg/L)					Chlorophyll a (Mg/L)					Turbidity (NTU)				
	S-08	**A-09**	**A-10**	**A-11**	**A-12**	**S-08**	**A-09**	**A-10**	**A-11**	**A-12**	**S-08**	**A-09**	**A-10**	**A-11**	**A-12**	**S-08**	**A-09**	**A-10**	**A-11**	**A-12**	**S-08**	**A-09**	**A-10**	**A-11**	**A-12**
41	-	-	18.7	16.5	17.6	-	-	0.0	21.6	17.2	-	-	117.0	7.8	7.3	-	-	33.0	18.0	7.6	-	-	0.0	7.6	823.3
42	-	-	17.9	16.2	17.5	-	-	30.6	20.3	16.9	-	-	8.6	8.4	7.1	-	-	4.0	4.3	5.9	-	-	4.8	10.6	815.7
43	-	-	18.8	17.1	17.5	-	-	30.5	21.1	16.9	-	-	8.7	8.4	7.2	-	-	2.3	3.3	9.8	-	-	3.7	3.0	818.3
44	-	-	18.8	16.5		-	-	29.5	22.1		-	-	10.1	9.5		-	-	4.7	2.3		-	-	3.0	2.9	
45					18.3	-	-	-	-	17.4	-	-	-	-	7.5	-	-	-	-	30.2	-	-	-	-	1611.7
46				16.0		-	-	-	23.8		-	-	-	8.5		-	-	-	2.3		-	-	-	1.7	
47	-	-	19.6	18.3	17.6	-	-	29.6	21.0	14.5	-	-	10.4	9.5	8.3	-	-	3.0	3.2	14.9	-	-	15.6	2.7	893.0
48				17.0	17.7	-	-	-	20.5	14.3	-	-	-	8.9	10.7	-	-	-	18.5	5.1	-	-	-	5.2	773.5
49	-	-	19.1	17.8		-	-	29.2	20.9		-	-	10.2	9.4		-	-	16.0	3.1		-	-	0.0	2.7	
50	-	-	19.6	16.7	16.5	-	-	26.4	19.3	16.6	-	-	12.7	7.6	6.8	-	-	15.6	6.7	17.2	-	-	0.1	4.9	1410.0

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