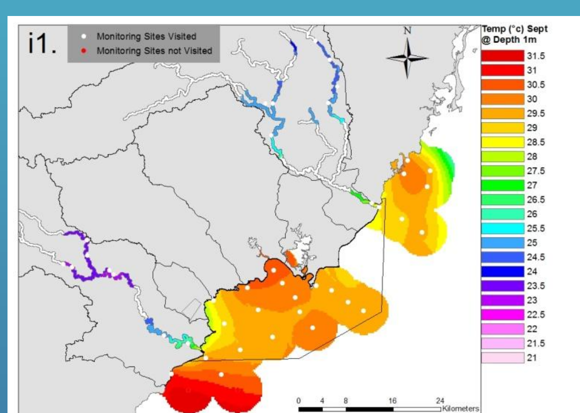
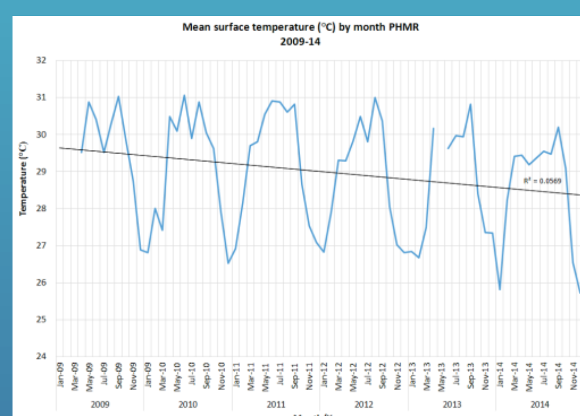
TIDE Water Quality 2014

Foley J, Alvarez M, Barona T, Requena E, O'Connor P, Takahashi M
TIDE Research & Monitoring Department 2015





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Contents

ACRONYM KEY

BFD	Belize Fisheries Department
DO	Dissolved oxygen
EDF	Environmental Defense Fund
GUZ	General use zone
NTZ(s)	No-take zone(s)
OUT	Marine areas close to but outside PHMR
PCNP	Payne's Creek National Park
PHMR	Port Honduras Marine Reserve
PRZ	Preservation zone
TIDE	Toledo Institute for Development and Environment
WCS	Wildlife Conservation Society

Units:

cm	Centimetre
$g\ m^{-2}\ day^{-1}$	Grams per metre squared per day
$mg\ l^{-1}$	Milligrams per litre
ppt	Parts per thousand
SE	Standard error
%	Percent

ABSTRACT

Since 2012, the Toledo Institute for Development and Environment (TIDE) has integrated initially separate marine and fresh water quality monitoring programs in order to improve understanding of hydrological and biophysical interconnectivity between land and sea in the Maya Mountain Marine Corridor (MMMC). Results of 2014 analysis are presented here, comparing seasonal dynamics of Rio Grande and Monkey River, and inferences made on their respective influences on conditions in PHMR. Parameters measured were temperature, dissolved oxygen, salinity, pH (new for 2014), visibility, nitrate, phosphate and sedimentation. Condensed comparisons between each year 2009-2014 are also made. General conclusions about each parameter are located in the last part of each section. Trends are becoming apparent over the years 2009-2014 for temperature and salinity, but not so clearly for dissolved oxygen or visibility. Nutrient concentrations tend to be highest during wet seasons, and higher than previous nitrate levels in Rio Grande suggest increased impact from agricultural runoff in this watershed. Year to year sea surface temperatures continue to decrease since 2009, especially in 2014 dropping by around 1 degree on average compared with 2013. This trend is observed elsewhere in the world. Impact on the Bladen branch of Monkey River from land use change and agriculture appear to be increasing. Finally, recommendations for stakeholder engagement, research and monitoring, reserve management, education and outreach and capacity building are provided in light of this year's monitoring results.

INTRODUCTION

Program integration:

The Toledo Institute for Development and Environment (TIDE) had been implementing both marine and freshwater quality monitoring programs with varying degrees of continuity, and without integration, since 1998 until 2011. In 2011, TIDE expanded its water quality monitoring program to include new sites, multiple depths, new parameters and revised and standardised methods. The 2011 marine and fresh water quality annual report provided recommendations for merging the marine and freshwater quality monitoring programs, with the aims of demonstrating interconnectivity between land and sea and creating a more comprehensive picture of the impacts of terrigenous runoff on the marine ecosystems in Port Honduras Marine Reserve (PHMR). By revising methods for data collection, data entry, database management and data analysis, and visual presentation, this has now been achieved. This report provides the third annual *integrated* marine and fresh water quality monitoring analysis conducted by TIDE. Information derived from this program can inform and facilitate adaptive "ridge-to-reef" management of marine and terrestrial protected areas under TIDE's management.

Threats to water quality:

a. ***Domestic use:*** Local communities in the Rio Grande watershed use this river extensively for domestic purposes such as cooking and cleaning and washing clothes, which often occurs directly in the river.

While this occurs on a relatively small scale, cumulatively this could impact nutrient levels in the river, particularly phosphate, potentially increasing risk of eutrophication and subsequent fish die-offs.

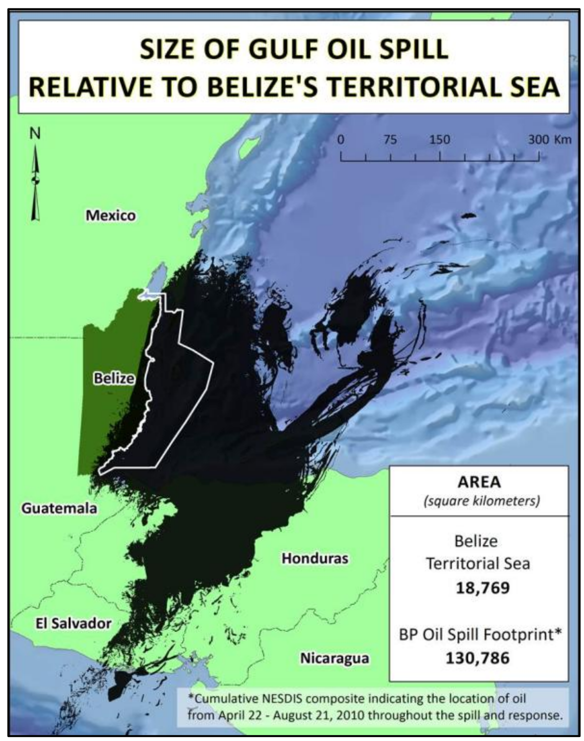
b. ***Fruit plantations*****:** There are extensive banana and citrus plantations in the upper watershed of Monkey River in Swasey and Bladen branches. These sites are known to use large amounts of fertilizers and pesticides, which subsequently leach into the river. It is anticipated that these would contain high levels of nitrates.

Flat stones in the Rio Grande used for washing clothing. Phosphate rich detergents are probably released into the river in this way,

c. ***Shrimp aquaculture*****:** The area North of Monkey River is the northern limit of TIDE's area of interest. In this area there are extensive land based shrimp farming facilities, some in operation and some disused, that may be flushing harmful waste substances into the local marine environment. TIDE monitors the adjacent waters north of PHMR to determine if there are any impacts of these facilities on the ecosystem health of PHMR. While many of the ponds are abandoned, water from them still drains into PHMR, potentially leaching harmful toxic chemicals into the ocean. Some ponds are still in use to commercially produce an Ecuadorian shrimp species, and may periodically release large quantities of nitrate-rich shrimp feed and shrimp faeces, biologically hazardous antibiotics, escaped exotic shrimp and exotic parasites into the surrounding waters close to Monkey River Village and PHMR.

d. Land burning – Land is burned for hunting, clearance for cattle, agriculture or construction. Sometimes fires are started naturally by lightning or intense heat from the sun during hot dry weather. Land may also be burned in a controlled fashion to protect adjacent property as seen in this example, where an area of pine savannah is being burned to protect an adjacent shrimp farm from wildfire. This can be detrimental to rivers if conducted nearby, as soil may wash into rivers, bringing nutrient rich ash with it and elevating nutrient levels and sedimentation in the river. It is important to consider these types of activities when interpreting water quality data.

e. Oil development – currently there is no oil extraction or seismic testing taking place in PHMR, although since US Capital Energy recently set a precedent in Belize by being approved to drill for oil in Sarstoon Temash National Park, the possibility of this happening in one or more of TIDE's protected areas is real, and must be taken seriously. The figure below shows the scale of the BP oil spill superimposed over the Gulf of Honduras and Central America. If a similar oil spill were to occur in PHMR, a very large area of sea, including the entire Mesoamerican Barrier Reef (UNESCO World Heritage Site) and large portions of the territorial waters of Mexico, Guatemala and Honduras would be at high risk of environmental devastation. Even if no accidents were to occur, potential oil development in PHMR could have serious negative impacts on tourism by reducing the pristine aesthetics of the reserve. PHMR is one of the last strongholds for critically endangered goliath grouper, West Indian manatee and hawksbill turtles, and supports a large dolphin population of at least two species. This not only indicates a healthy environment capable of supporting many top end predators, but dolphins are important to future tourism development. There is plenty of research demonstrating the negative effects of acoustic disturbances such as seismic testing on dolphin migration patterns and other behavior (e.g. Castellote et al. 2012). Oil has also directly resulted in mass cetacean deaths (Williams et al. 2011). Water quality standards have been developed for coastal dolphins (Thompson 2007) and need to be applied in the case of future oil development.



BP oil spill footprint superimposed to scale over Belize territorial waters and a large part of Central American and the Gulf of Honduras.

OBJECTIVES

The objectives of TIDE's water quality monitoring program are:

To monitor spatial and temporal variations in multiple water quality parameters in and near Port Honduras Marine Reserve, and associated river catchments, in order to:

1. Establish baseline water quality conditions in PHMR and associated river systems.
2. Understand and determine causes (natural and anthropogenic) of spatial and temporal fluctuations in water quality in PHMR and associated river systems.
3. Understand, characterise and demonstrate water system interconnectivity between terrestrial and marine protected areas managed by TIDE.
4. Provide recommendations in support of an adaptive "management-informed-by-research" approach to TIDE's protected area management and management of the wider MMMC.
5. Inform analysis and interpretation of other TIDE monitoring programs.
6. Demonstrate the importance and vulnerability of water quality in both rivers and the sea for ensuring long term sustainability of river ecosystems and local communities, as well as fisheries and tourism in PHMR.

MONITORING SITES

#	Transect/ Watershed	Site Name	Site Code	NAD27 UTM N	NAD27 UTM W	WGS 84 DD N	WGS 84 DD W
1	1	Joe Taylor Creek	1a	1781833	307682	16.10903	-88.79823
2	1	-	1b	1779038	310370	16.08398	-88.77288
3	2	-	2a	1784468	313282	16.13327	-88.74609
4	2	Rio Grande	2b	1781698	315761	16.10843	-88.72271
5	2	-	2c	1779118	318362	16.08505	-88.69807
6	3	Golden Stream	3a	1794100	314568	16.22041	-88.73483
7	3	Hen & Chicken	3b	1790211	316318	16.18540	-88.71816
8	3	Moho/Stuart	3c	1785783	318890	16.14558	-88.69377
9	4	-	4a	1796168	320109	16.23951	-88.68317
10	4	-	4b	1792449	321864	16.20603	-88.66647
11	4	-	4c	1787860	324113	16.16473	-88.64510
12	5	Deep River	5a	1799120	324355	16.26650	-88.64368
13	5	-	5b	1796974	325754	16.24721	-88.63043
14	5	Man O War	5c	1794495	327860	16.22495	-88.61054
15	5	Wilson Caye	5d	1792062	328604	16.20302	-88.60341
16	5	S. of West Snake Caye	5e	1789373	330680	16.17887	-88.58380
17	6	Punta Ycacos	6a	1796465	331255	16.24300	-88.57893
18	6	S. of Punta Negra	6b	1795445	333825	16.23577	-88.55489
19	6	N. of Middle Snake Caye	6c	1793635	336429	16.21778	-88.53033
20	6	East Snake Caye	6d	1792155	338941	16.20457	-88.50674
21	7	Monkey River Mouth	7a	1809630	341635	16.36267	-88.48273
22	7	-	7b	1807537	345281	16.34399	-88.44846
23	7	-	7c	1805318	348554	16.32415	-88.41768
24	8	-	8a	1815137	345681	16.41270	-88.44522
25	8	-	8b	1812952	349366	16.39319	-88.41058
26	9	-	9a	1817403	346293	16.43322	-88.43964
27	9	-	9b	1815632	349885	16.41744	-88.40589
28	Monkey River	Upper San Pablo	MR_SB_1a	1837392	331439	16.61466	-88.58030
29	Monkey River	Gravel Mining Road	MR_SB_1b	1834166	333790	16.58568	-88.55800
30	Monkey River	Next to Farm 6	MR_SB_1c	1829747	335010	16.54583	-88.54630
31	Monkey River	Swasey Bridge	MR_SB_1d	1826958	333415	16.52052	-88.56100
32	Monkey River	Trio Bridge	MR_TB_1a	1826915	324427	16.51948	-88.64520
33	Monkey River	Upper Trio	MR_BB_1a	1826915	323259	16.51939	-88.65610
34	Monkey River	Bladen Bridge	MR_BB_1b	1821585	324203	16.4713	-88.64690
35	Monkey River	Inside Monkey River	MR_MR_1a	1810318	340397	16.36881	-88.49440
36	Rio Grande	Upper Columbia	RG_CB_1a	1800275	290284	16.27603	-88.96256
37	Rio Grande	Lower Columbia	RG_CB_1b	1799677	291632	16.27074	-88.94990
38	Rio Grande	Upper San Miguel	RG_SM_1a	1804244	294159	16.31222	-88.92670
39	Rio Grande	Lower San Miguel	RG_SM_1b	1801700	294191	16.28924	-88.92610
40	Rio Grande	Upper Big Falls	RG_RG_1a	1799159	297734	16.26658	-88.89280
41	Rio Grande	Big Falls Bridge	RG_RG_1b	1798476	298403	16.26047	-88.88650
42	Rio Grande	Wilson Landing	RG_RG_1c	1786785	310355	16.16764	-88.81030
43	Rio Grande	Esso Landing	RG_RG_1c	1786785	310355	16.15579	-88.77370

Table 1: Marine and fresh water quality monitoring sites 2013: blue: PHMR; red: Monkey River; green: Rio Grande. For PHMR, difference shades denote site groups associated with each transect. For rivers, different shades denote different branches.

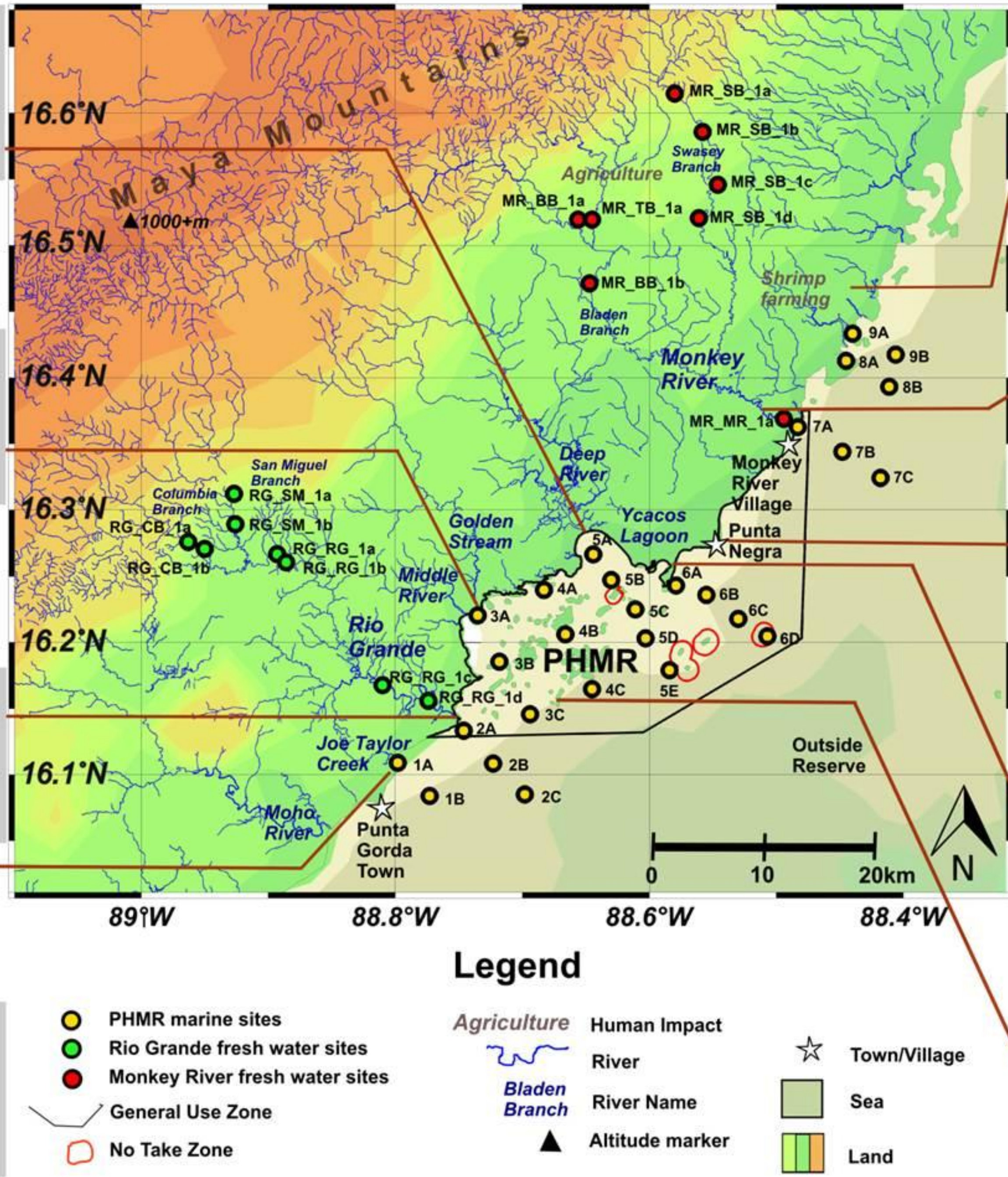
Marine and fresh water monitoring sites 2014
PHMR, Monkey River & Rio Grande

4. *Deep River*: Third longest in study area behind Monkey River and Rio Grande. May be largest by volume. Low impacted. Wide slow, mangrove-lined lower reaches. Western border of PCNP. Farming expanding upstream. Important goliath grouper nursery

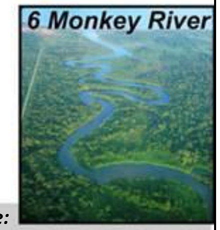
3. *Middle River / Golden Stream*: Small rivers, reach PHMR <1km apart. Low impacted. Important in both providing and buffering nutrient and sediment inputs into PHMR. Good baseline rivers. Drain PLI and Belcampo.

2. *Rio Grande*: Large river, low impacted, some communities upstream. Used for small scale domestic purposes & hicatee hunting. Lower reaches near pristine forest & mangroves. Concern of pollution from nearby dumpsite. Southern boundary of TPPL.

1. *Joe Taylor Creek*: Small river, low impacted until last 1km, where mangrove and forest are disappearing to development. Upstream, dense mangroves remain intact.



5. *North of Monkey River:* Northern marine limit of TIDE's management area. Extensive land based shrimp mariculture including Ecuadorian species. Threats include nutrient rich effluent, eutrophication, fish deaths, invasive parasites.



6. *Monkey River & Village:* Largest river in Toledo. High impacted by fruit plantations, river gravel mining, riparian deforestation, water pumping; linked to coastal erosion; fishing village; key PHMR stakeholders.

7. *Punta Negra:* Smallest buffer community in PHMR. No rivers nearby, but two fresh water lakes behind village. Important turtle nesting beach. Serious coastal erosion in last few years.

8. *Ycacos Lagoon:* Links PHMR to PCNP. Crucial nursery habitat for endangered goliath grouper. Important for migratory birds & endangered yellow-headed parrot. Boat access to PCNP ranger station

9. *PHMR Cayes:* Approx. 138 cayes, mostly mangrove swamps. Critical near pristine environment supporting fisheries, tourism and endangered species manatee, goliath grouper, turtles.

Map features (numbers correspond to map figures):

Left side:

1. **Joe Taylor Creek:** Joe Taylor Creek is a small river which reaches the sea between Punta Gorda and Hopeville. While the upper watershed is relatively non-impacted and thickly fringed with red mangroves, urban development is rapidly spreading upriver from town, with land clearance and mangrove destruction being major threats to water quality both in the river and the adjacent sea in front of Punta Gorda. Riparian zone mangroves are crucial to maintain in this area, not only for ecosystem health in the sea, but also the most popular swimming areas in Punta Gorda are close to the mouth of Joe Taylor Creek.

2. **Rio Grande:** The Rio Grande is a large and relatively low-impacted river, and the lower reaches form the southern boundary of much of TIDE's Private Protected Lands (TPPL). Dense broadleaf forest meets the river on both sides in the lower reaches, with the last 2km before the sea lined by dense red mangroves. Upper reaches have some impact from agricultural and cattle ranching, but such activities are less significant than on Monkey River. The mouth is located in the southern-most part of PHMR. The river is an important source of water for several villages. Hicatee are hunted in the river by local communities and snook fishing is a common activity in the area where the river mouth meets the sea. Water quality may be threatened by the Punta Gorda dumpsite, located in the lower watershed less than 1km south of the river. TIDE conducted a dumpsite impact study in 2014 to quantify impacts of this in order to determine management solutions. Report (Halvorson & Foley 2014) available from TIDE.

3. **Middle River / Golden Stream:** Middle River and Golden Stream are small rivers with smaller catchment areas than Rio Grande or Monkey River, and are currently not monitored by TIDE due to limited funding and difficult access. The mouths of these two rivers are situated close together in the south central coastal area of PHMR. Marine data near to the mouths of these rivers allow inferences to be made about conditions in the watersheds drained by these rivers, and are important to consider when interpreting marine data.

4. **Deep River:** Deep River is a reasonably large watershed, although slightly smaller than Rio Grande and Monkey River. While TIDE does not conduct water quality monitoring in this river, it is an extremely important catchment because the coastal waters adjacent to Deep River mouth are vital nursery grounds for the critically endangered Goliath grouper. The area is also important for bait fishing. There is limited water circulation in this corner of PHMR due to being sheltered from offshore currents, increasing the importance of maintaining good water quality in the river. While the watershed is relatively non-impacted, there are concerns about agricultural impacts further upstream, where some farms have expanded in recent years. The lower reaches form the south western boundary of Payne's Creek National Park.

Right side:

5. **North of Monkey River:** Northern limit of TIDE's management area. Several shrimp farming operations nearby.

6a. **Monkey River:** Monkey River has the largest catchment area in Toledo, and is the 5th largest watershed in Belize. There are two main branches – Swasey branch to the north and Bladen branch to the south. Monkey River has been much more impacted by human activities compared with the other rivers of interest. Extensive banana and citrus plantations have replaced lowland broadleaf forest in the area, leading to soil erosion and excess nutrients from fertilisers entering the water, increasing risk of eutrophication and poor water quality. Deforestation, clearing of riparian zones for subsistence agriculture and water access for cattle, as well as gravel mining in the river have all contributed to changing the shape of the river from a deep rounded profile to a wide shallow profile. This has increased the surface area to volume ratio of the river, rendering it more susceptible to seasonal warming and cooling, and possibly reducing the amount of suspended sediment the river can transport to the sea. This may be a driver of the increased erosion at Monkey River Village, located on the southern bank of the river mouth. The greater seasonal variability in biophysical and hydrological properties of the river water compared with Rio Grande may have reduced species abundance and biodiversity in the river, and ecosystem health is considered to be diminished compared with less impacted nearby rivers. It is important to monitor this river as both the buffer community of Monkey River Village and the health of receiving marine waters around Monkey River depend on its continued health.

6b. **Monkey River Village:** Monkey River is the largest buffer community using PHMR, and is located at the mouth of Monkey River. The settlement was originally established as a hardwood port, when logs were floated down the river for shipment from this village. When the logwood dried up, the community turned to fishing. There has been significant erosion in Monkey River, destroying at least one street and a cemetery. This is thought to be due to changes in sediment load coming from Monkey River watershed as a result of land clearing and river gravel mining. Illegal clearing of the 66ft buffer zone next to river banks upstream is probably a significant cause of a change in river profile, which has become wider and shallower over the years. This will reduce the ability of the river to transport sediment load, possibly contributing to this erosion.

7. **Punta Negra:** Punta Negra is an important buffer community in PHMR, located on the point of a broad sandy headland in the central-northern coastal part of PHMR. No river exists nearby, but there is a fresh water lagoon behind the village, where tarpon have been reported to exist. Water security and coastal erosion are major threats to the long term survival of a permanent community at Punta Negra.

8. **Punta Ycacos Lagoon:** While not technically a river, Punta Ycacos Lagoon is a large area of pristine shallow wetlands draining the southern portion of Payne's Creek National Park. The area is important for many species of bird including the endangered yellow head parrot and several long-distance migratory species. It is also critical nursery habitat for multiple fish species, including the critically endangered Goliath grouper. Many terrestrial fauna species rely on the area for food and water; at least one jaguar has been sighted frequenting the surrounding area in TIDE's camera trapping study. While fishing is prohibited within the lagoon itself, the waterway between the lagoon and PHMR is an important fishing area for local fishers. The area has also revealed important Mayan archaeological sites, with some of the

only Mayan wooden structures and tools ever found preserved in these low-oxygen swamps. TIDE currently does not carry out monitoring in the lagoon, however this is planned to commence in 2015 with support from Ridge to Reef Expeditions. The area serves critical functions to both marine and terrestrial species, demonstrating the interconnectivity between land and sea and the importance of monitoring and managing these areas with a holistic approach.

9. **PHMR cayes:** There are approximately 138 cayes in PHMR, which can be roughly divided into three zones running southwest to northeast. The inner cayes closest to land tend to be waterlogged mangrove swamps surrounded by shallow brown water. A second band of cayes extends through the middle of the reserve the majority of which form the Frenchman Cayes, an extensive labyrinth of again swampy mangroves. The third group is the offshore Snake Cayes, which form some of the few true islands in PHMR with solid dry ground. These are sandy cayes with small beaches and some broadleaf forest in the interior. A brackish lagoon lies in the interior of West Snake Caye. Water tends to be clearer in this offshore environment, more representative of barrier reef conditions. Fringing coral reefs skirt the windward sides of these islands, and some of the healthiest coral reefs in the entire Mesoamerican Barrier Reef (HRI 2010) are found around East Snake Caye. These four cayes are all geographically separate no-take zones. In 2013 TIDE consulted with buffer community stakeholders over a plan to extend the no-take zones to one contiguous zone encompassing all four Snake Cayes to improve fisheries sustainability in the surrounding general use zone and as a means of improving enforcement in the area. This has resulted in consensus to establish a contiguous Replenishment Zone around Middle, South and West Snake Cayes. This will be enforced later in 2014. There is also a further zoning expansion plan underwater in partnership with TNC. See report on RZ expansion published February 2014 for further details (Foley & Baker 2014).

METHODS

Water quality monitoring is conducted at 43 sites in total; 27 in PHMR divided into nine transects (1-9), 8 in Monkey River and 8 in Rio Grande (Table 1, pg. 8).

Marine monitoring in 2014 was completed at the end of each month by TIDE Marine Biologist (Marlon Williams until his departure from TIDE in September 2013, and subsequently by Tanya Barona, who became TIDE's marine biologist in October 2013) and TIDE Community Researchers. Where possible, data were collected at depths of 1m, 5m, 10, and 15m at each monitoring site in the Port Honduras Marine Reserve (PHMR). Fresh water monitoring is conducted by Elmar Requena (TIDE Terrestrial Biologist), with occasional assistance from university students.

Parameters: The following parameters are measured at marine and freshwater monitoring sites. pH monitoring was reiniciated in marine sites in 2014 after several years without due to lack of a functional pH meter. In late 2013 TIDE received a new YSI ProPlus probe capable of measuring pH among a suite of other parameters. Freshwater pH monitoring began in late 2013 and so not enough freshwater pH data was yet available to present in this report. 2013 data for November and December will be utilised in the 2016 report.

Marine:

1. Temperature
2. Salinity
3. Dissolved oxygen
4. pH
5. Turbidity (vertical visibility)
6. Nitrate-nitrogen
7. Orthophosphate-Phosphorus
8. Sedimentation

Freshwater:

1. Temperature
2. Salinity
3. Dissolved oxygen
4. Nitrate-nitrogen
5. Orthophosphate-phosphorus

1. Temperature: Measured at the surface, 5m, 10m and 15m depth at all marine sites (depth permitting) at each site using YSI ProPlus probe. Measured at the surface at fresh water sites (15cm depth).

2. Dissolved Oxygen: Dissolved oxygen (DO) is oxygen that is dissolved in water and is essential for most plants and animals that live in water. Measured with YSI ProPlus probe.

3. Salinity: Salinity refers to the amount of salt in the water, and is currently measured with YSI ProPlus probe.

4. Turbidity (vertical visibility): The term "turbidity" refers to the "cloudiness" of water, measured using a Secchi Disk.

5. Nutrients:

Nitrate - Nitrogenous compounds (e.g. nitrites, nitrates & ammonia) are essential components of life. Nitrogen is recycled continually by plants and animals, and is found in protein in the cells of all living things. Excess nitrate is introduced into a body of water typically as runoff from various sources when it rains. Sources include agricultural fertilizer, livestock, unmanaged or partially managed sewage, animal wastes (including fish and bird waste), aquacultural waste, and discharges from car exhausts and industrial waste (Cushion 2004). In excess amounts they can cause significant water quality problems for the environment and human health. The United States Environmental Protection Agency advises that drinking water is hazardous to human health if nitrate concentrations exceed 10 milligrams per litre (mg l^{-1}) (EPA 2012), citing symptoms of overexposure among affected infants less than 6 months as shortness of breath and death from ‘blue baby syndrome. This it thought to be caused by nitrates impacting the ability of oxygen to bind with haemoglobin in the blood. Lower levels can still be extremely harmful to the environment. Method for analysis is the Cadmium Reduction Method (Method 8039 from Hach Procedures Manual) (Russell 2011) using a Hach DR2800 Spectrophotometer.

Phosphate - Phosphate in water bodies comes from fertilizers, pesticides, wastes from laundries, industry, and cleaning compounds that are leached into the water. Phosphate also occurs naturally from solid or liquid wastes such as human and animal wastes (one human body releases approximately 0.5kg of phosphorus per year (The Hach Company 2006)) and phosphate-rich rocks. TIDE tests for ortho-(reactive) phosphate because it is the form which plants utilize; therefore, the most cost effective way of gauging eutrophication (The Hach Company 2006). Method for analysis is the PhosVer3 Ascorbic Acid Method (Method 8048 from Hach Procedures Manual) (Russell 2011) using a Hach DR2800 Spectrophotometer.

6. **Sedimentation:** Traps are deployed and collected at the described sites once monthly via scuba diving. Sites are located initially by GPS and once close, by markers previously set and attached to underwater buoys. Once located, a dive team collects the sediment-laden traps for laboratory analysis and sets fresh empty traps. Traps are deployed with caps off, secured with zip-ties in groups of three to reference stakes with a concrete base (except the Abalone Caye sites which are single traps per site due to limited materials). For transect water quality sites, three traps are used to derive a mean value, which makes data more statistically robust and reduces error. Setting three traps also reduces that likelihood of no data being collected from a site in the event that one or more traps are knocked down. Traps must be at least a few meters below the water in calm areas and deeper in exposed areas. After approximately one month these traps are capped, removed and replaced with empty ones. The precise number of days that each trap has been underwater is recorded in order to calculate sedimentation rate in grams per m^2 per day.

   ***Sedimentation laboratory methods*:** Dry weight is measured, which is then used to calculate sedimentation rate in grams per m^2 per day (g m^{-2} day^{-1}). To begin the process, a Petri dish and Whatman 0.45µm filter paper are weighed separately on a microbalance and then added to obtain a combined total. This information is recorded in a spread sheet. Traps are scrubbed clean on the outside to avoid contamination of the sample. The contents are shaken vigorously to ensure uniform suspension of the sediment, the lid immediately removed, and the entire contents of the sample immediately poured through a coarse grade filter (mesh size 0.5mm) into a bowl to remove non-sediment debris. After this primary filtration, the sample is again stirred vigorously using a stirring plate to ensure uniform suspension and 100ml poured into a 250ml beaker through a funnel before the sediment settles out again. The remainder of the sample is stored in the bowl until the entire process is complete, in case a sample needs to be rerun for any reason. The sample in the beaker is stirred vigorously and 20ml poured into a graduated cylinder. This sample is passed though the Buchner funnel. 10ml measurements are passed through the Buchner funnel with the intent of getting as close as possible to the saturation point of the filter without actually reaching the saturation point. Once the filter paper is near saturated, the exact amount of sample water that was successfully passed through the filter is recorded. The filter paper is then removed from the Buchner funnel with tweezers to minimize contamination of the sample and placed in a Petri dish. The Petri dish is placed into a drying oven at 70◦C for approximately two hours, or until no weight change can be seen from one hour to the next, indicating that no water remains in the sample. Once the sample is dry, the sample, filter paper and Petri dish are weighed together on the microbalance. The weight of the sample is then derived by subtracting the combined weight of the Petri dish and filter paper. If the sample is found to have no weight or the weight difference is less than the 0.1g resolution of the microbalance, the sample must be re-tested with more water volume until a weight can be detected. The weight of the sample is then entered into a spread sheet. This process is repeated for all of the sediment traps. Finally all equipment and traps are scrubbed clean, and faded site codes are rewritten on the traps.

***Sedimentation data analysis methods*:** The dry weight results are calibrated to the volume of the traps (which are all identical), to account for the varying amounts of water filtered to obtain the dry weight samples. This allows the weights of sediments recorded from each sample to be scaled up to a standard volume of 608.05cm^3. This standard volume has arisen due to the length of the traps being 30cm, while the diameter is two inches, because pipe widths come in imperial measurements in Belize. The area of the trap mouths can be used to standardize the sedimentation rate to grams per m^2 per day, or "g m^{-2} day^{-1}". The sedimentation rate is calculated using the following formulas:

Constants

- Length of trap (*l*) = 30cm
- Diameter of trap mouth (*dt*) = 2 inches = 5.08cm
- Radius of trap mouth (*r*)= 1 inch = 2.542cm
- Area of trap mouth (*a*) = πr^2 = 20.268cm^2
- Volume of trap (*vt*) = l x πr^2 = 30 x π x 2.542 = 608.05cm^3 = 608.05ml
- Proportion trap mouth area is of 1m^2 (*pa*) = —— —— times

1) Proportion of trap contents sampled $(\boldsymbol{pv}) = \frac{\text{Volume of trap } (vt)}{\text{Volume of sample water } (vs)}$

2) Dry weight of total sediment in trap (***tw***) = Dry weight of sediment from sample (*sw*) x *pv*

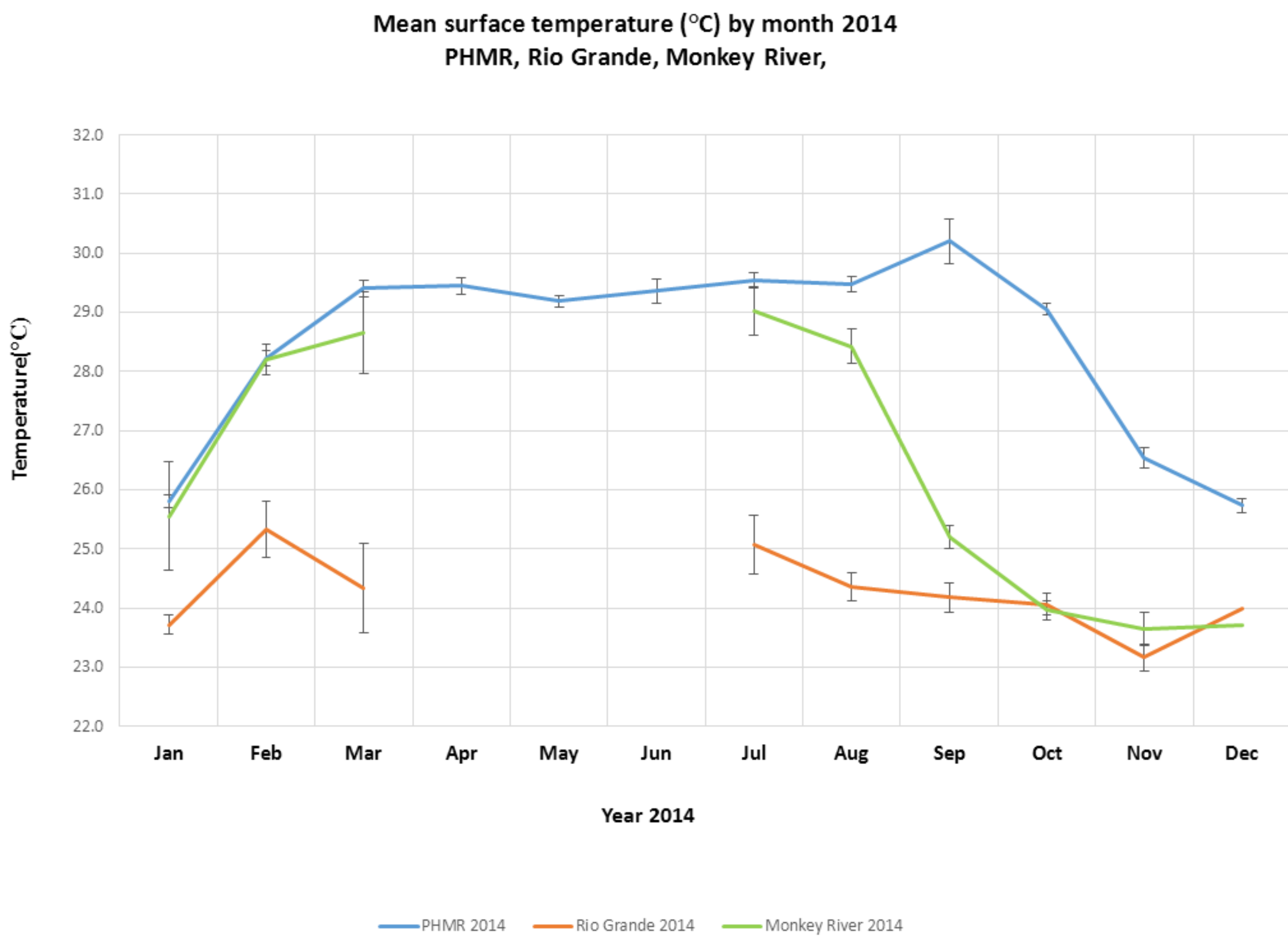
3) Sedimentation Rate (***S***) (g m^{-2} day^{-1}) = $\frac{\text{tw x pa}}{\text{days at sea}}$

The mean is then calculated for the dry weight results from the three traps (if all three remained intact) at each monitoring site.

RESULTS

1. Temperature

1.1 Mean surface temperature (°C) by month 2014 - PHMR, Monkey River, Rio Grande (Fig. 1a):



- Mean water temperature was consistently higher each month in PHMR than in either Rio Grande or Monkey River, a general trend observed in 2012 and 2013.

- Mean temperatures in PHMR were generally higher in the months April to September as in previous years. Mean river temperatures were rising by February, and were still high in July, dropping thereafter. No data is available for the rivers between April-June.

- While no data is available for April-June for rivers, available data for the rest of the year suggests a similar trend to previous years of Monkey River warming more in the summer months than Rio Grande. However, this year Monkey River was considerable colder than normal in the last 2 months of the year, at times even dropping below mean temperatures in Rio Grande, a trend not observed in recent years.

- PHMR: Lowest temperatures were in January (25.8°C) and December (25.7°C), slightly lower than 2013.

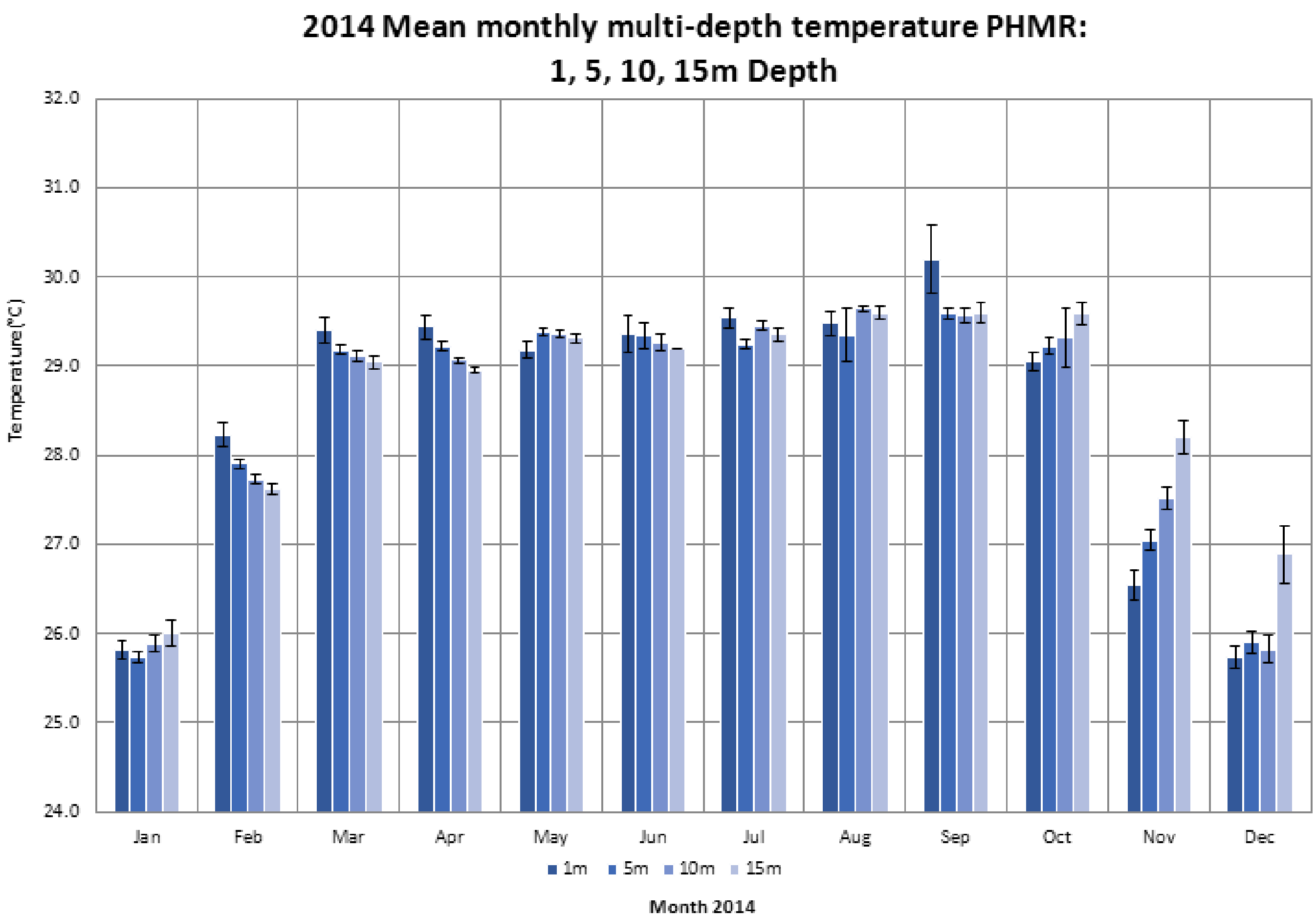
- Highest mean temperature for PHMR was 30.2°C in September. Mean surface temperatures rose rapidly between January to March from 25.8°C to 29.4°C, before stabilizing until August, after which there was a brief increase to 30.2°C in September, followed by a rapid and continuous decrease until December (25.7°C). This pattern is consistent with recent years.

- While temperatures showed an unusual increase in September of the previous year in all three areas, this trend was observed only in PHMR this year.

- Coldest mean surface temperatures were found in Rio Grande in November (23.2°C).

- Monkey River temperature increased dramatically and consistently in the first two months of the year, from 25.6°C in January to 28.7°C in March, compared with cooler conditions in January 2013 (23.9°C) and marginally warmer conditions in March 2013 (28.9°C).

1.2 2014 PHMR Mean monthly temperature: 1, 5, 10, 15m depth (Fig. 1.2):



- As in the first four months of 2012, 2014 mean ocean temperatures rose and surface temperatures increased significantly more than subsurface temperatures.

- 2014 was a more moderate year than 2012 or 2013 however, with all temperatures remaining below 30°C except for the surface in September, whereas surface temperatures peaked above 30°C often between April and September in 2012 and 2013

- As in 2013, after September, a typical cooling pattern was observed with surface temperatures significantly cooler than subsurface temperatures. Notable were the considerably higher temperatures retained at 15m depth in November and December (Sept mean temperature 1m: 30.2°C $\pm$ 0.38 SE; Oct mean temperature 1m: 29.1.°C $\pm$ 0.09 SE) with subsurface temperatures showing less change the deeper they are (e.g. Sept mean temperature 15m: 29.5°C $\pm$ 0.07 SE; Oct mean temperature 15m: 29.6°C $\pm$ 0.12 SE)

- High Standard Error for surface temperatures in September 2014 point to greatest variability across PHMR, supported by maps (Fig. 1.3 i).

- The hottest month in 2012 was August (2012 August 1m: 31.0°C $\pm$ 0.1 SE), in 2013 was September (2013 September 1m: 30.8°C $\pm$ 0.14 SE), and in 2014 was September (2014 September 1m: 30.2°C $\pm$ 0.38 SE). Coolest month in 2012, 2013 and 2014 was January (2012 January 15m: 26.7°C $\pm$ 0.0 SE; 2013 January 15m 26.3°C $\pm$ 0.09 SE; 2014 January 5m 25.7°C $\pm$ 0.07 SE).

- In general temperatures were cooler in 2014 than recent years, and with fewer extremes. This follows the general trend of overall ocean cooling in PHMR since 2011, and cooler than any other year since at least 2009.

1.3 Temperature map descriptions 2014

a. January (Fig 1.3 a1-a15): Temperature in both Monkey River and Rio Grande are relatively cold (23-24 ^{o}C) with slightly higher temperature in upper Swasey branch (26.5-27.5^{o}C). The sea surface temperature across PHMR is uniform and cool across the region with the range 25-25.5^{o}C. Furthermore, the sea surface temperature at the mouth of Monkey River is warmer than the area to the north of the river mouth by 0.5^{o}C. Sea water temperature increased by 0.5 – 1.0^{o}C in the water column at a depth of 10m and deeper.

b. February (Fig 1.3 b1-b15): The temperature at Rio Grande remained low 24^{o}C while there was a steep rise in the temperature in the upper stream of Monkey River from 24-29^{o}C. There was an overall increase in temperature from January with warmer regions ~29^{o}C located in the bay around Middle River and Golden Stream. Temperature was less variable below the surface than at the surface, ranging between 27.5^{o}C and 28^{o}C.

c. March (Fig 1.3 c1-c15): Considerable warming is seen in the Monkey River, particularly in the mid-stream of the Swasey Branch (up to 31.5^{o}C) although the upper section remains cooler (27^{o}C). The upper stream of Rio Grande continues to be cool (23 - 24^{o}C) while the temperature increases from 25-29^{o}C towards the river mouth. Surface temperatures in PHMR have warmed throughout, ranging from 29-30.5^{o}C with slightly warmer areas around the mouth of Rio Grande. Multi depth temperatures are slightly higher in general than in January and February by 2-3^{o}C.

d,e,f. April-June (Fig 1.3 d1-d15, e1-e15,f1-f15): There is no data available for the rivers for the months April-June due to unavailability of a vehicle and scheduling issues. The temperature of PHMR remained similar over the three months, ranging between 28.5-30^{o}C. There was no significant change in temperature across the multi-depth gradients.

g. July (Fig 1.3 g1-g15): Monkey River, particularly the Swasey Branch (31.5^{o}), had significantly higher temperature than Rio Grande (23-25.5^{o}C). Temperature in Swasey Branch for 2014 was 2-3^{o}C higher compared to 2013. Surface and multi-depth temperatures in PHMR were similar in range to previous months, ranging between 28.5-30^{o}C.

h. August (Fig 1.3 h1-h15): The temperature in upper stream Monkey River (27.5-29^{o}C) showed a decrease from the previous month while the temperature in Rio Grande remained cool. Compared to the previous month in PHMR there is lower surface temperature at the mouth of the Rio Grande (28^{o}C) while a larger area of warm water (30^{o}C) is present around Middle River and Golden Stream. Multi-depth temperature is warmer on average by ~1^{o}C than in July.

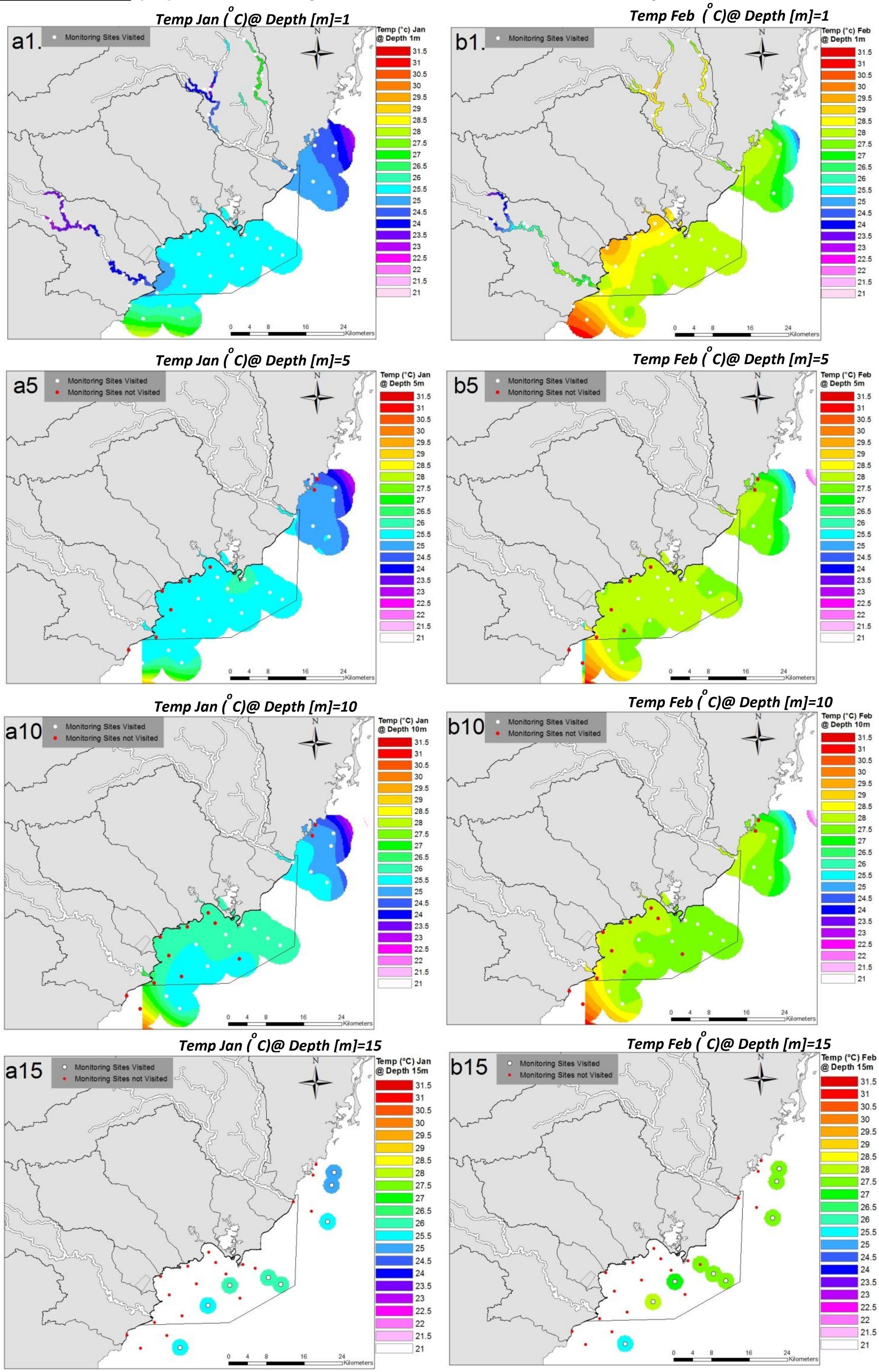
i. September (Fig 1.3 i1-i15): Temperatures continued to decrease in upper Monkey River (24-25.5^{o}C) while the temperatures in Rio Grande remained cool (23-23.5^{o}C). Temperatures in the lower reaches in both rivers reach 27^{o}C. In PHMR the mean surface temperature was highest for 2014 (30.2^{o}C) but the multi depth temperature showed no significant change from the previous months.

j. October (Fig 1.3 j1-j15): There is no noticeable difference in temperature between upper Rio Grande and Monkey River, ranging from 23-24^{o}C. In PHMR, compared to September the average surface temperature (29.1^{o}C) dropped by ~1^{o}C with cooler regions located around both rivers (27.5-28^{o}C) while multi-depth temperature remained constant.

k. November (Fig 1.3 k1-k15): Temperatures at Swasey branch and upper Rio Grande both continue to decline to ~22.5^{o}C. Water temperatures decreased at all depths, with the largest decline (~2.6^{o}C) at the surface compared to October. There was a notable increase in average temperatures with increased water depth from 26.5^{o}C at 5m to 28.2^{o}C at 15m.

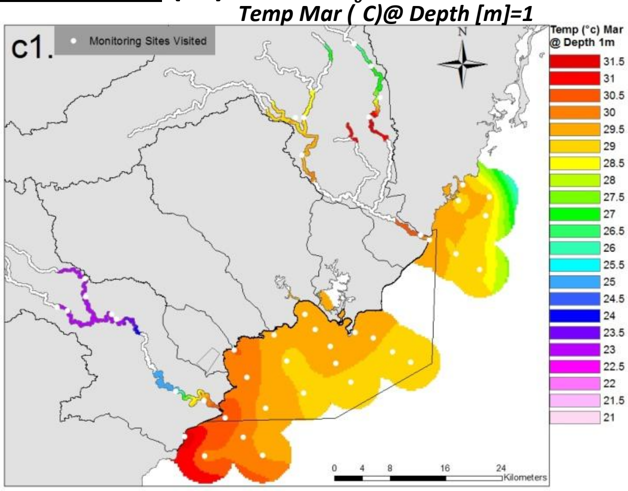
l. December (Fig1.3 l1-l15): Average surface temperatures continue to decline in PHMR from the previous month from 26.5-25.7^{o}C. The area around the mouth of Monkey River (24.5-25^{o}C) was slightly lower than the rest of PHMR (25-26^{o}C). Temperature at depth is fairly uniform from 1-10m with a range of 25.7-25.9^{o}C while a higher temperature was recorded at 15m (~26.9^{o}C).

1.3 a, b: Temperature (°C) January 2014 February 2014

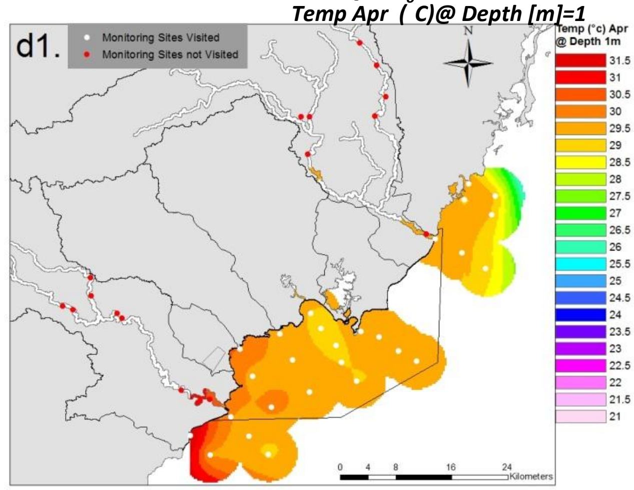


1.3 c, d: Temperature (°C): March 2014 April 2014

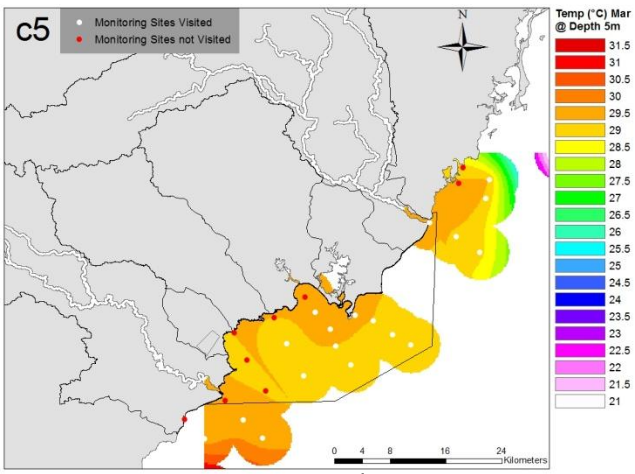
Temp Mar (°C)@ Depth [m]=1



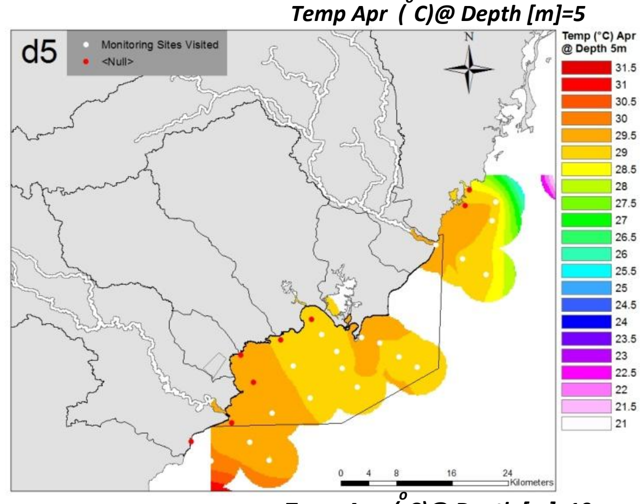
Temp Apr (°C)@ Depth [m]=1



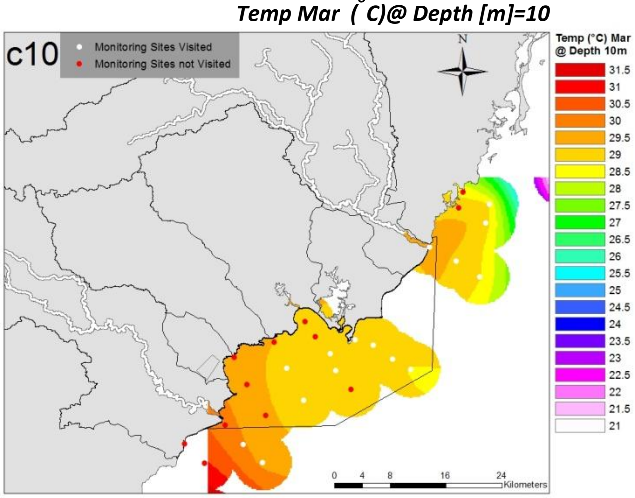
Temp Mar (°C)@ Depth [m]=5



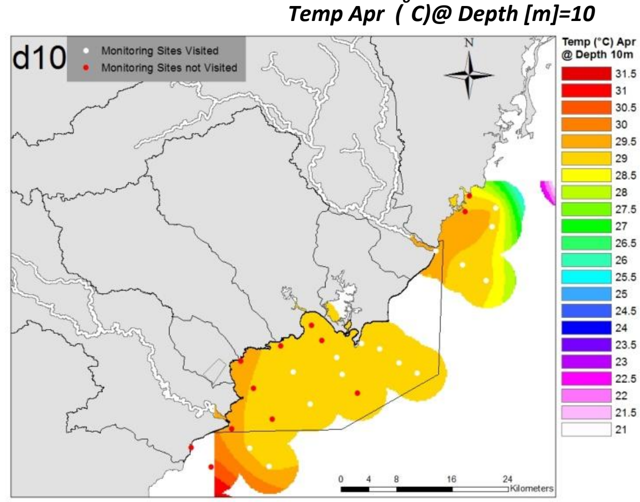
Temp Apr (°C)@ Depth [m]=5



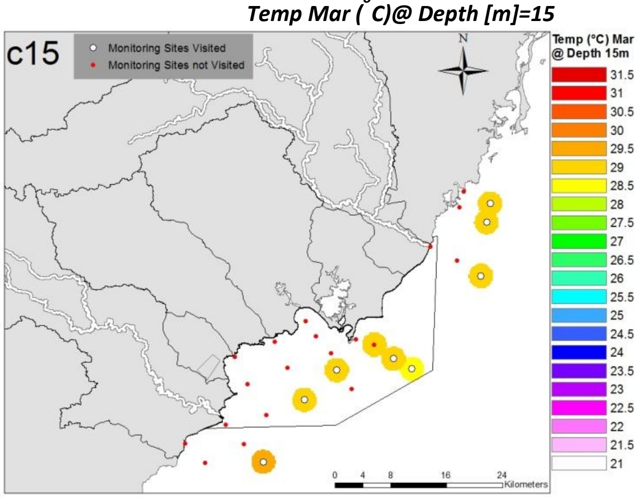
Temp Mar (°C)@ Depth [m]=10



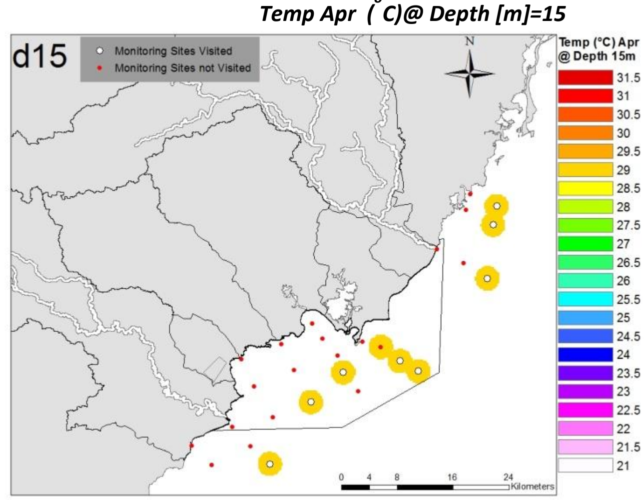
Temp Apr (°C)@ Depth [m]=10



Temp Mar (°C)@ Depth [m]=15

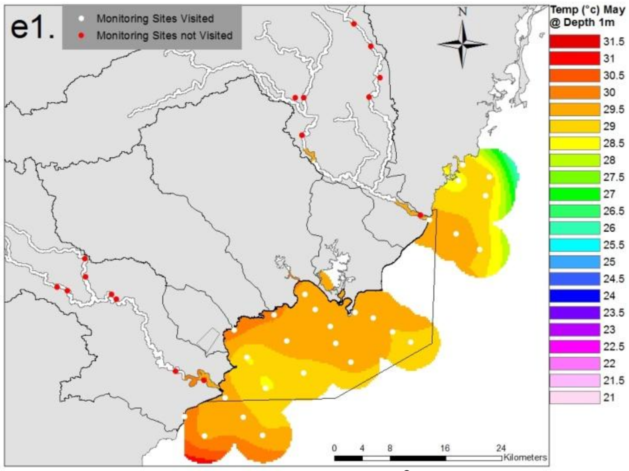


Temp Apr (°C)@ Depth [m]=15

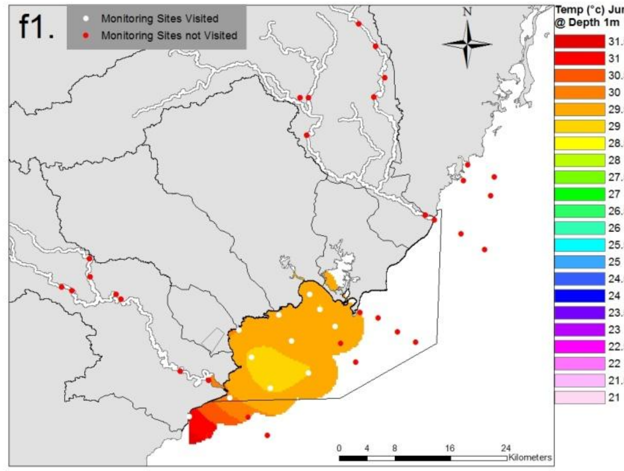


1.3 e, f: Temperature (°C) May 2014 June 2014

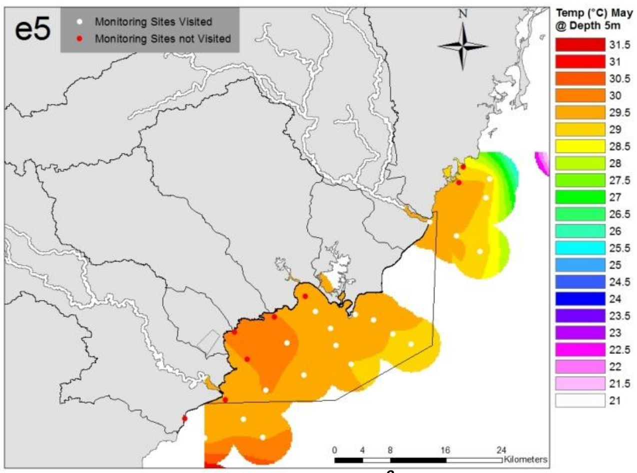
Temp May (°C)@ Depth [m]=1



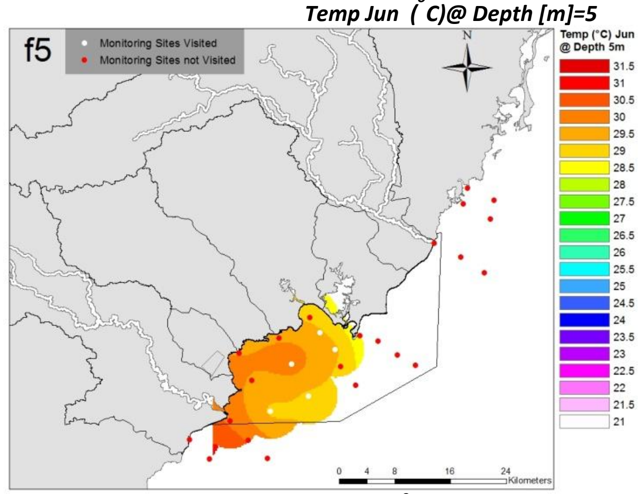
Temp Jun (°C)@ Depth [m]=5



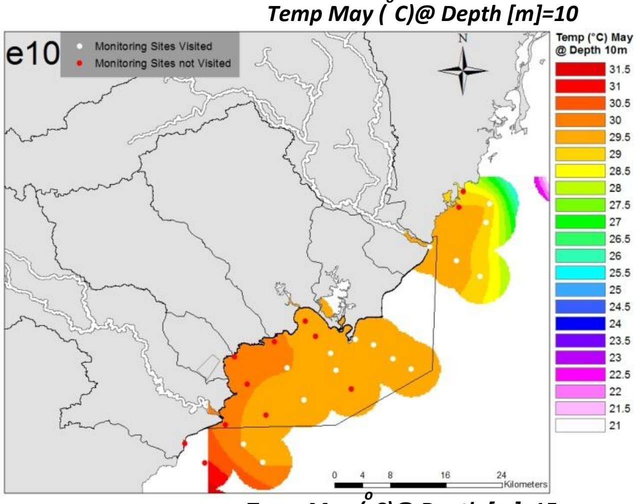
Temp May (°C)@ Depth [m]=5



Temp Jun (°C)@ Depth [m]=5

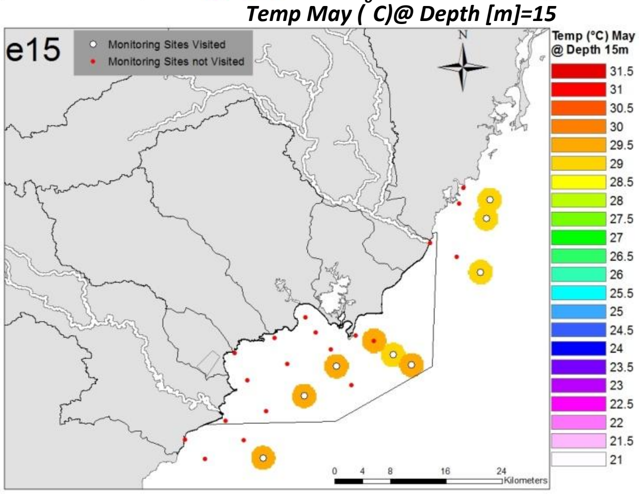


Temp May (°C)@ Depth [m]=10

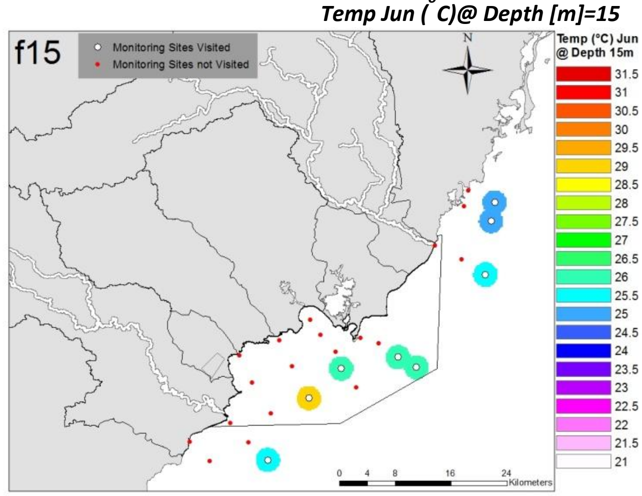


Temp Jun (°C)@ Depth [m]=10

Temp May (°C)@ Depth [m]=15

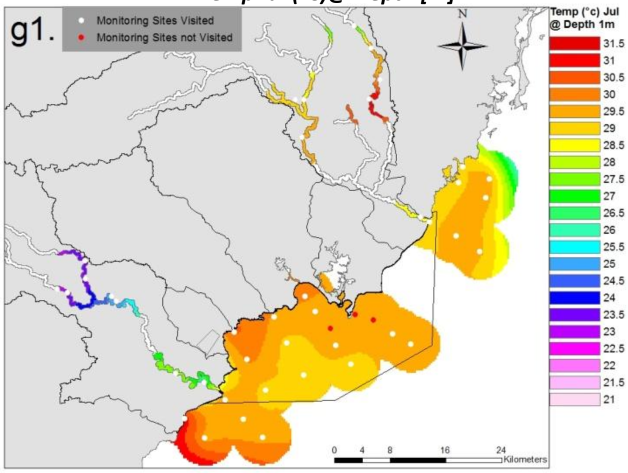


Temp Jun (°C)@ Depth [m]=15

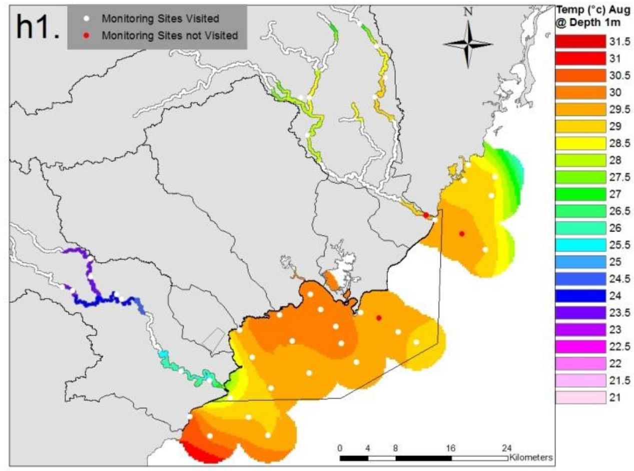


1.3 g, h: Temperature (°C) July 2014 August 2014

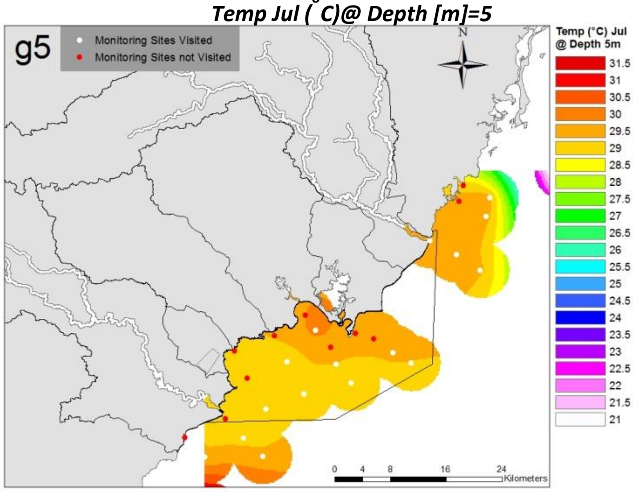
Temp Jul (°C)@ Depth [m]=1



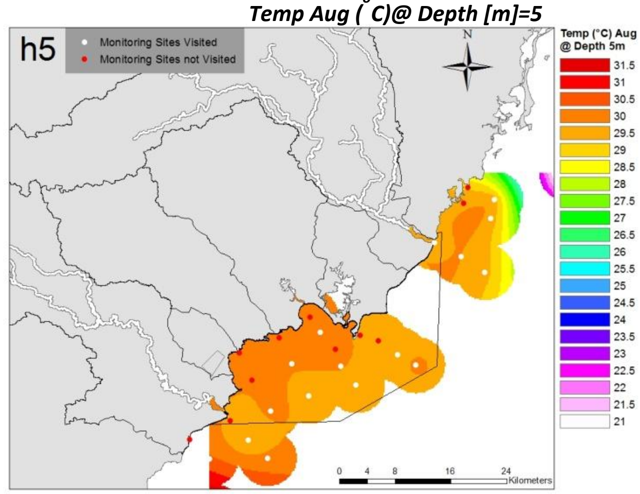
Temp Aug (°C)@ Depth [m]=1



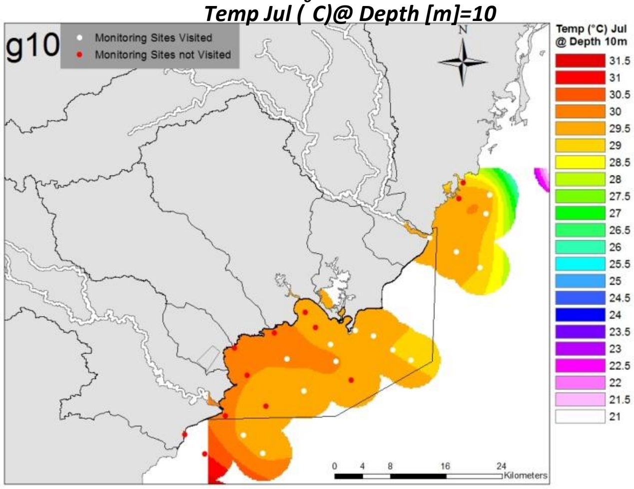
Temp Jul (°C)@ Depth [m]=5



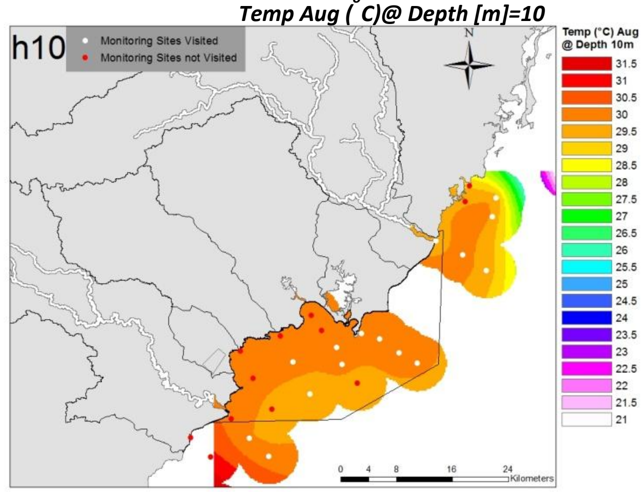
Temp Aug (°C)@ Depth [m]=5



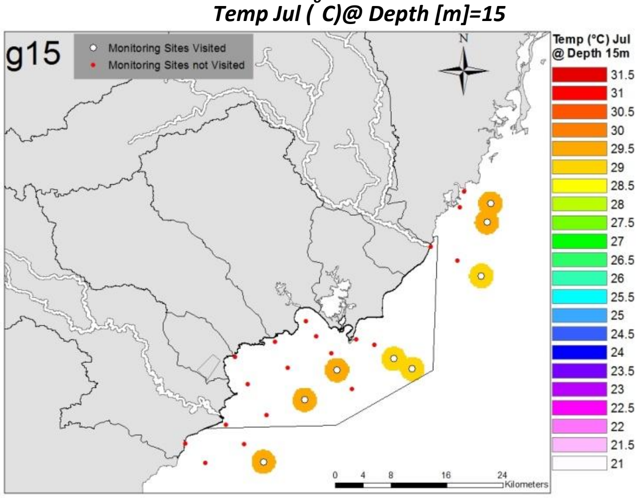
Temp Jul (°C)@ Depth [m]=10



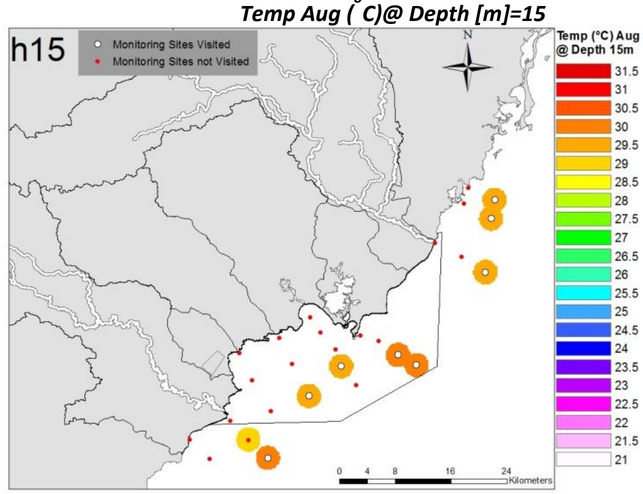
Temp Aug (°C)@ Depth [m]=10



Temp Jul (°C)@ Depth [m]=15

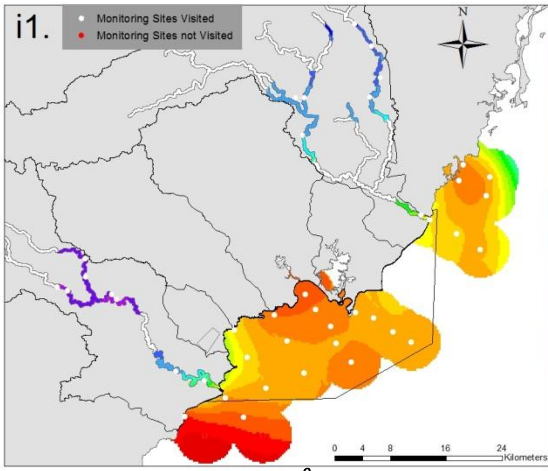


Temp Aug (°C)@ Depth [m]=15

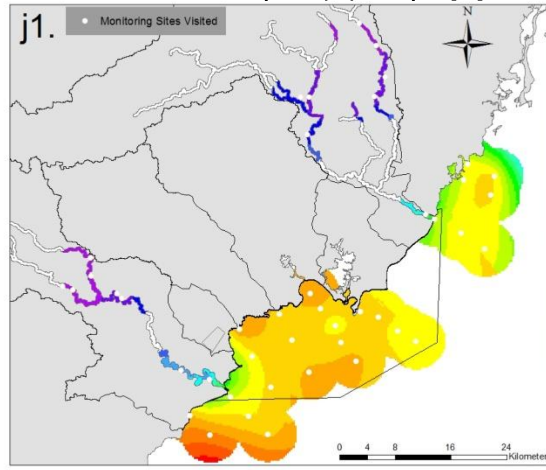


1.3 i, j: Temperature (°C) September 2014 October 2014

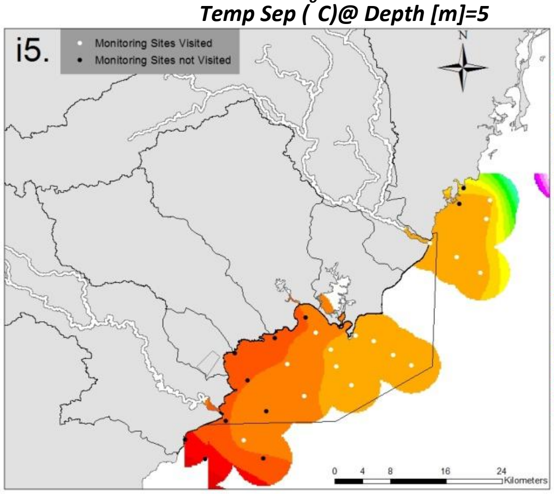
Temp Sep (°C)@ Depth [m]=1



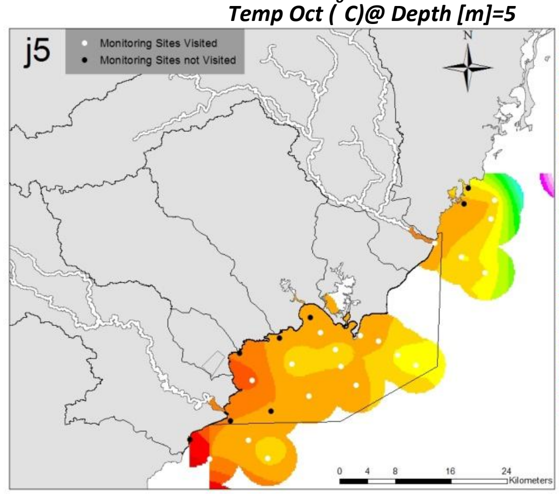
Temp Oct (°C)@ Depth [m]=1



Temp Sep (°C)@ Depth [m]=5



Temp Oct (°C)@ Depth [m]=5



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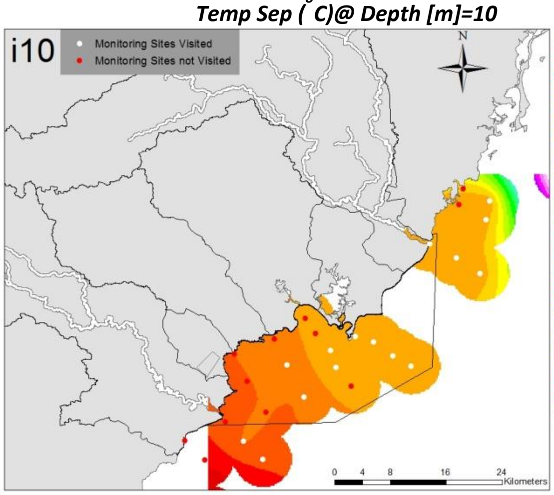
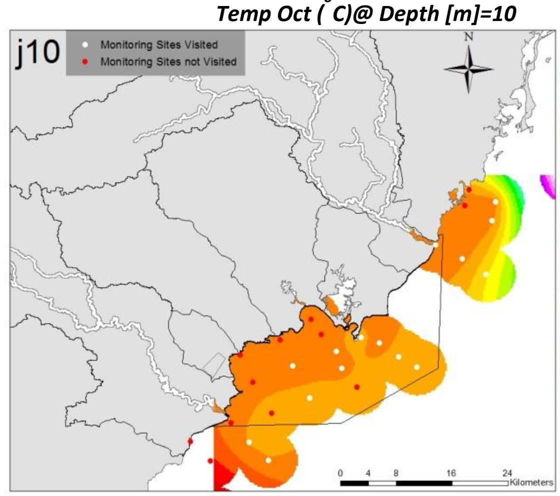


Temp Oct (°C)@ Depth [m]=10



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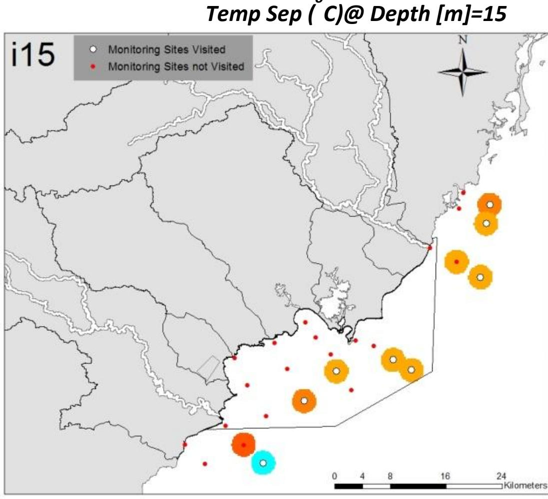
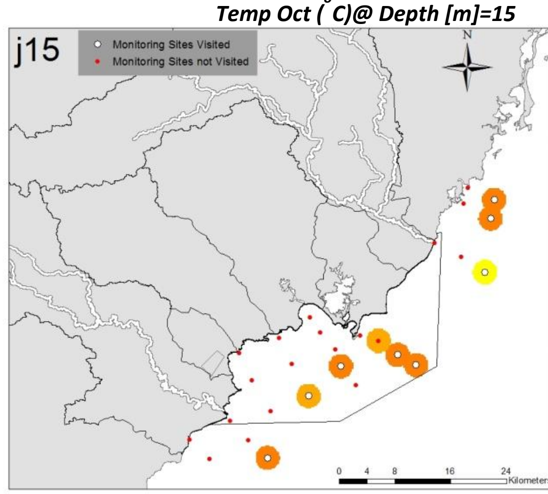
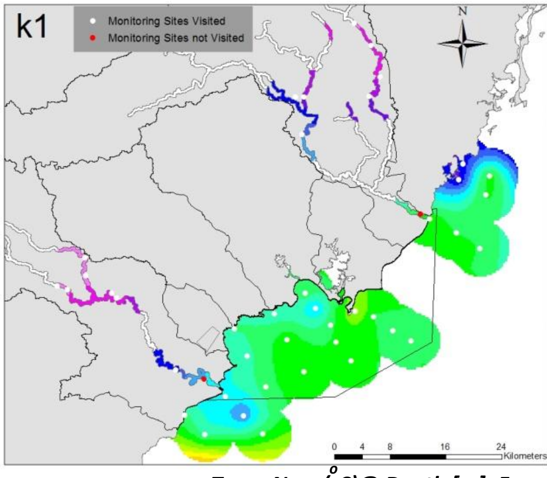


Temp Oct (°C)@ Depth [m]=15

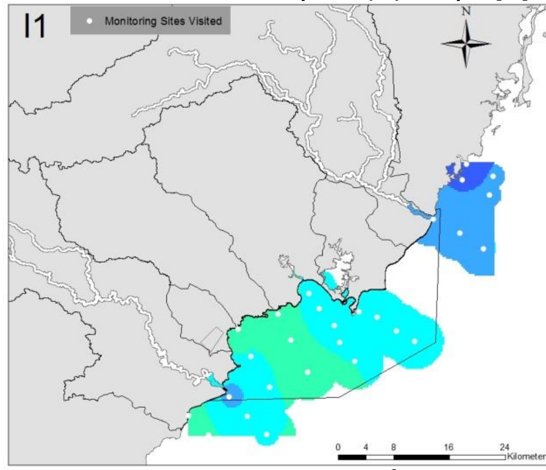


1.3 k, l: Temperature (°C) November 2014 December 2014

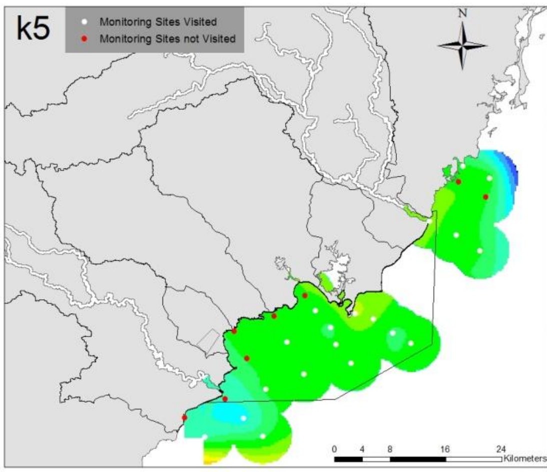
Temp Nov (°C)@ Depth [m]=1



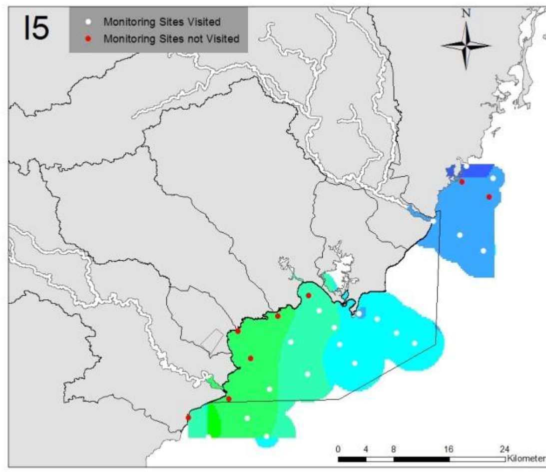
Temp Dec (°C)@ Depth [m]=5



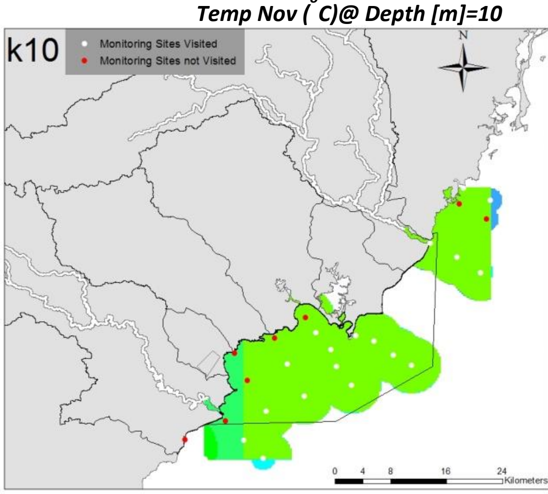
Temp Nov (°C)@ Depth [m]=5



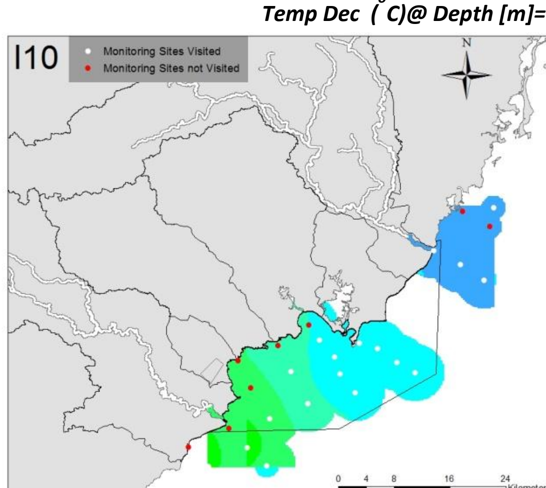
Temp Dec (°C)@ Depth [m]=5



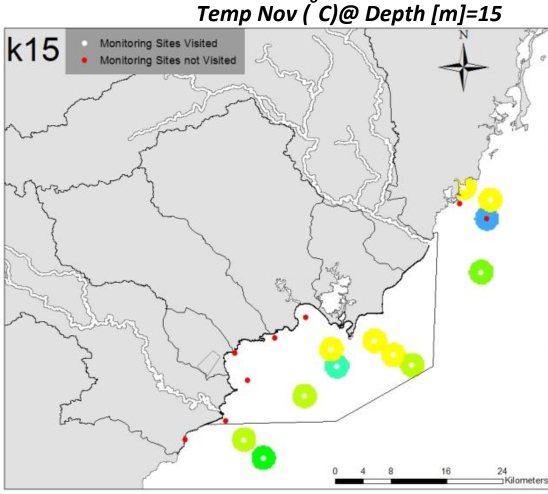
Temp Nov (°C)@ Depth [m]=10



Temp Dec (°C)@ Depth [m]=10



Temp Nov (°C)@ Depth [m]=15



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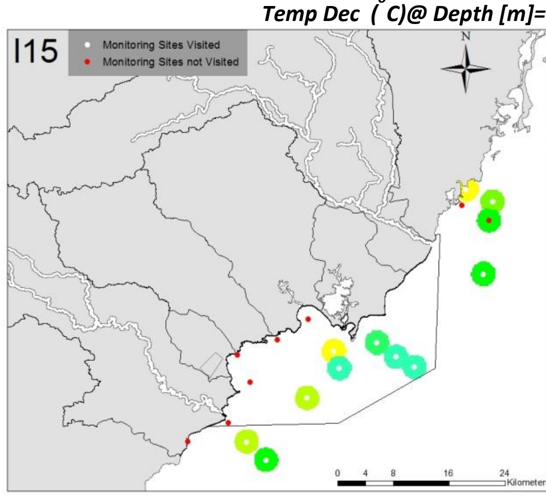
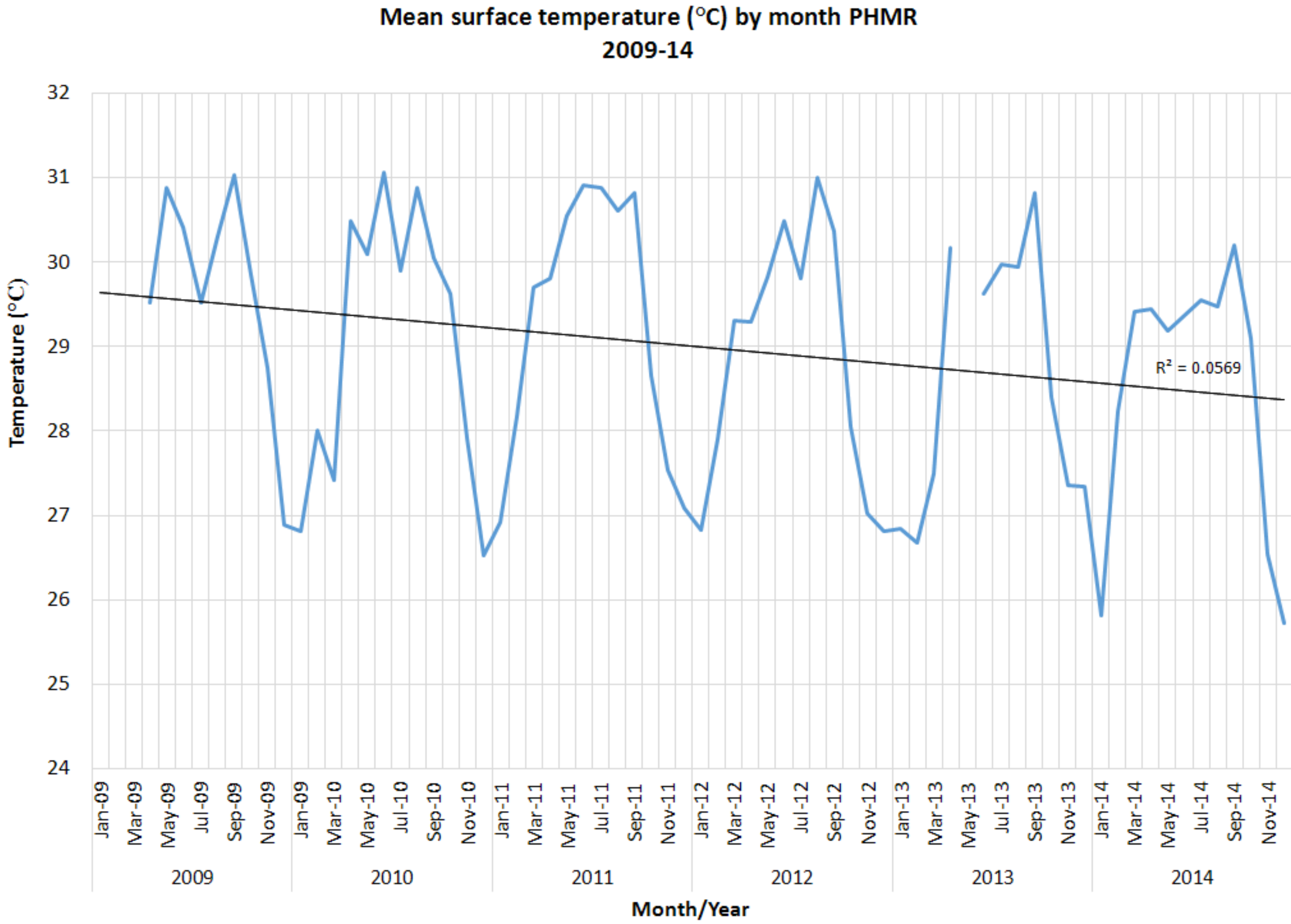


1.4 Mean surface temperature by month PHMR 2009-2014 (Fig. 1.4):



- Mean surface temperatures followed a fairly consistent trend overall in each of the years 2009-2013. In general, temperatures started cool (January in all years approx. 26.8°C, rising steadily to between ~29.3°C to ~30.5°C by April in all years.

- **2014 had mean surface temperatures about a whole degree cooler throughout the year than any other year since 2009.** Coldest temperatures for the year 2014 were in January. Average surface temperatures in January and December of 2014 were 25.8^{o}C and 25.7^{o}C respectively. Both of which were 0.7-0.8^{o}C colder than the previous lowest recorded temperature since 2009 (26.5^{o}C).

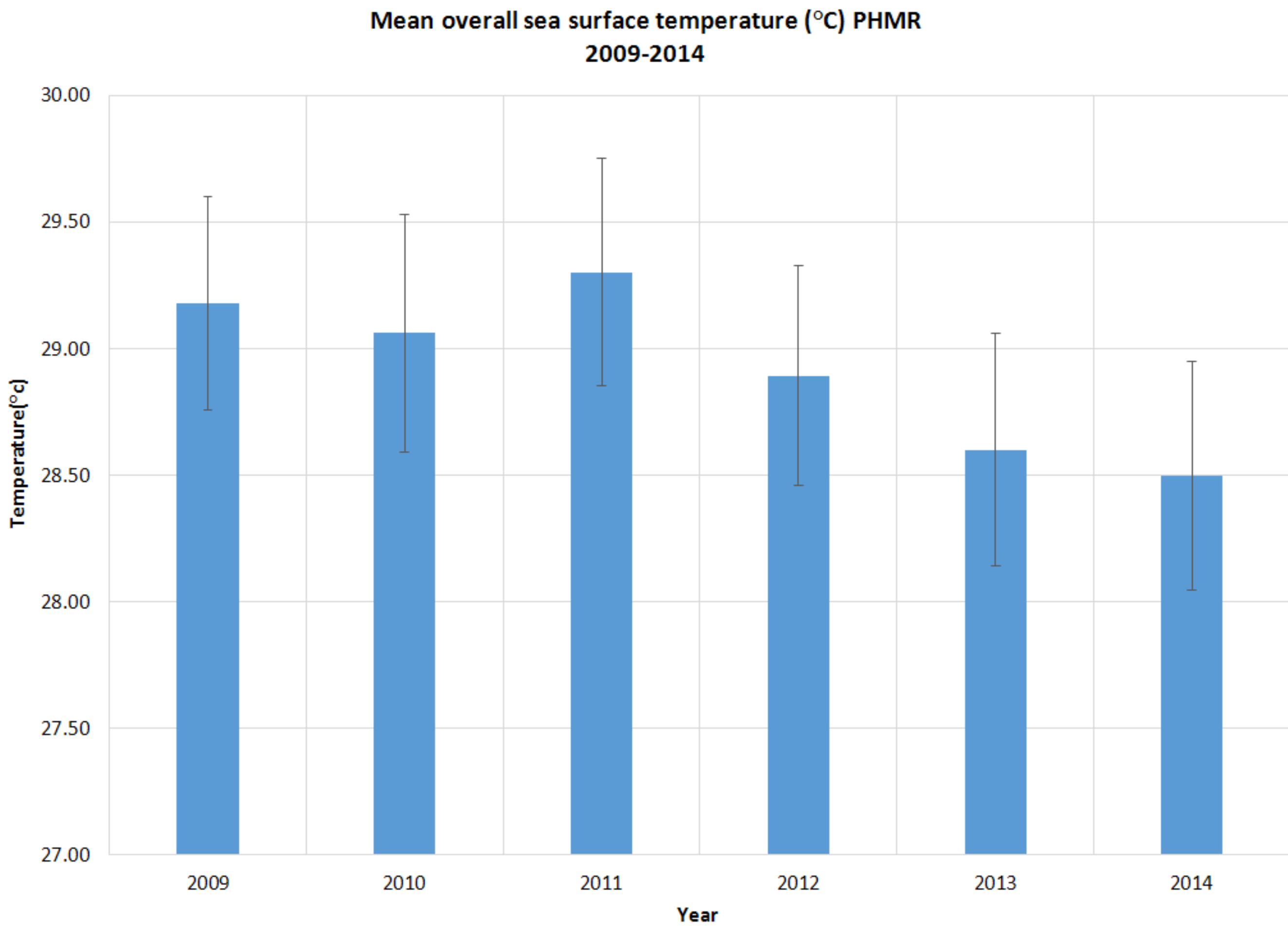
- Temperatures began to rise steadily in February and March which was consistent to previous years. Temperatures from March to August showed minimal variation (29.2-29.5^{o}C) whereas previous years showed continuous increase in temperature until June/July.

- September was the hottest month with a mean temperature of 30.2^{o}C. This was the only month in the year with temperature over 30^{o}C. Whereas in the previous year's most summer months exceeded 30^{o}C.

- After September, temperatures started to decline and followed a fairly predictable trend overall in each of the years 2009-2013.

- Overall there is a general trend of cooling in PHMR since 2009, with 2014 being markedly colder than any year previous since 2009.

1.5 Mean overall sea surface temperatures 2009-2014 (Fig. 1.5):



- Mean overall surface temperatures continue to decline, a pattern seen since 2009 with the exception of 2011. It is important to note that for 2009 there is no temperature data for January, February and March, typically the cooler part of the year, and so the annual mean for 2009 is most likely artificially high. Nonetheless, it appears that overall there has been a gradual cooling of mean ocean temperatures over the last 6 years, with mean overall temperatures in 2014 being lower than any other year since at least 2009. 2011 was an unusually warm year for sea surface temperatures in PHMR, possibly owing to lower than average rainfall in summer 2011.

1.6 Temperature: general conclusions:

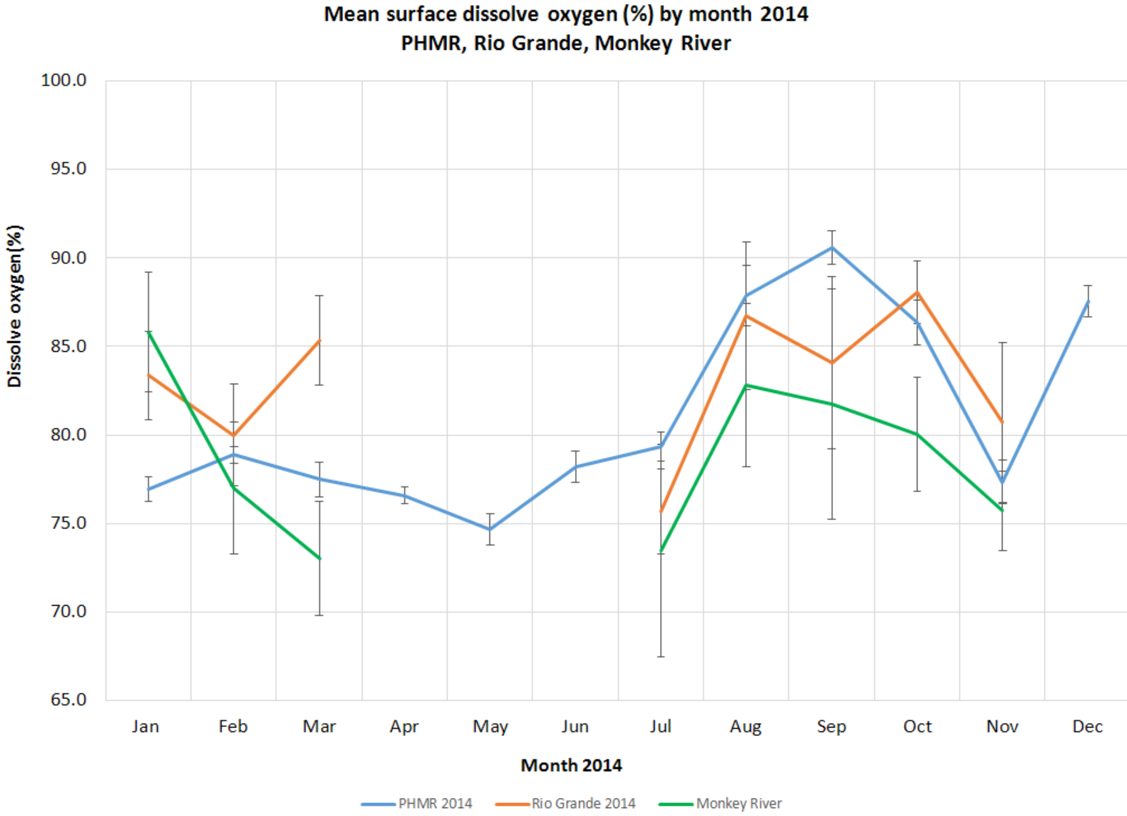
- Mean surface temperature has decreased by 1.3°C from 29.7°C to 28.4°C between 2009 and 2014.

- Peak warming occurred in September in PHMR, but with lower than normal summer temperatures reaching above 30°C only in September and only at the surface unlike other recent years where temperatures rose above 30°C on many occasions including below the surface.

- Monkey River continues to be more susceptible to solar warming during summer months, due to exposure of river to sun from riparian deforestation. Rio Grande continues to exhibit much cooler and more stable temperatures. These more stable and sheltered conditions are likely due to intact nature of riparian forests in Rio Grande, providing shade to the river, retaining bank structure and thereby river profile, and minimizing input of profile-flattening sediment into the river. The human impacts on Monkey River make it a more dynamic and therefore less favourable environment for aquatic life than Rio Grande, demonstrating the impact that land use change has on river ecosystems that support local livelihoods.

2. Dissolved Oxygen

2.1 Mean surface Dissolved Oxygen (%) by month 2014 - PHMR, Monkey Rio Grande (Fig. 2a):



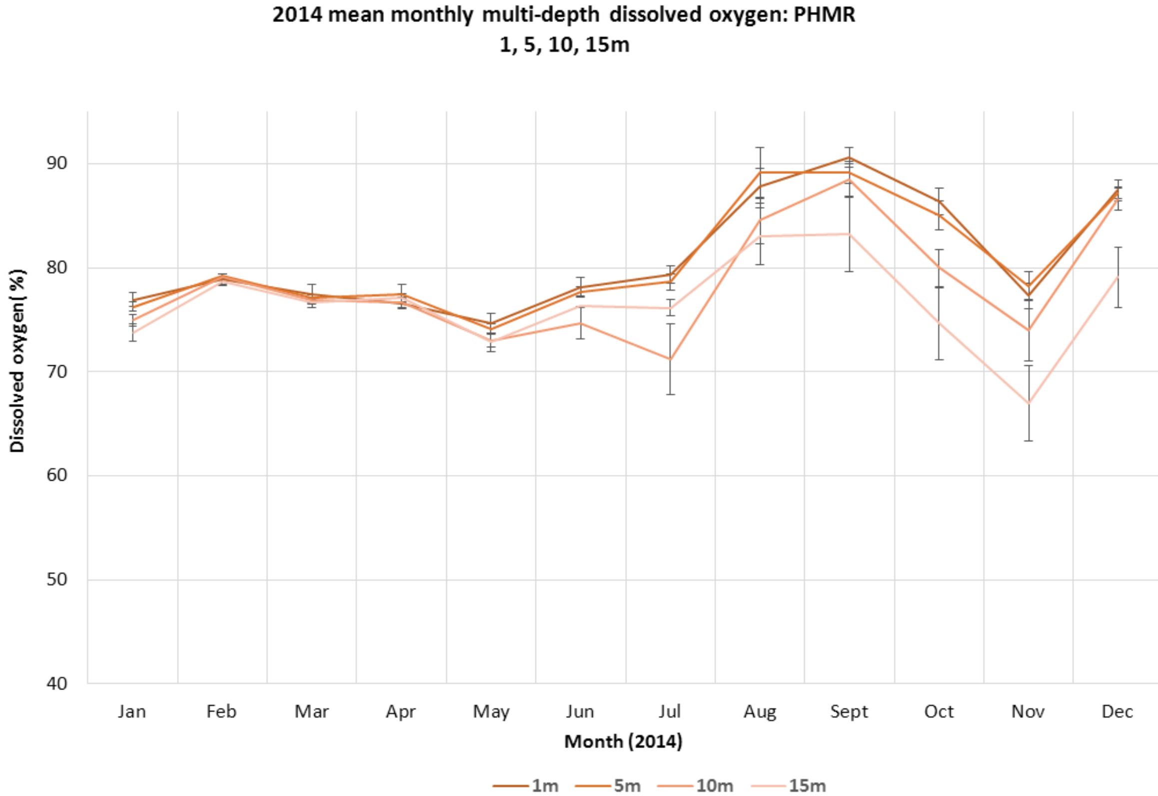
- Overall, a similar trend in both rivers and the sea of higher dissolved oxygen levels in first and third quarters of the year, with lower levels in the March to August period in PHMR (no data April to June for rivers), dropping significantly PHMR in May. Levels drop in November in all areas.

- DO highest in September in all in PHMR, highest between August and October in Rio Grande, high from August to October in Monkey River, but not as high as in January.

- Whereas in 2012, PHMR almost always had highest DO%, Monkey River almost always second highest, and Rio Grande almost always lowest, in 2013, the area with the highest, middle and lowest DO% varied from month to month. **In 2014, where data is available, Monkey River general had lower DO% than Rio Grande and surface values in PHMR.**

- Overall trends from one year to the next have been quite different. No identifiable pattern is exhibited year to year.

2.2 2014 Mean monthly dissolved oxygen: 1, 5, 10, 15m depth (Fig. 2.2):



- Conditions remained stable from January to July, being between about 74-79% at 1m, 5m and 10m throughout this time. DO% increased significantly in August, **peaking in September above 90% at the surface,** before a considerable drop in November to the high 70s (%), and finally rising again to the high 80s (%) at 1m, 5m, and 10m depth in December.

- DO% stratification increased steadily throughout the second half of 2014, with conditions being similar at all depths until DO% below 10m becomes lower than at shallower depths, and markedly lower at 15m for the rest of the year.

- In the last few years there has not been a consistent pattern in DO trends from year to year. **It appears that higher temperatures in general coincide with higher DO, possibly due to increased photosynthesis of marine plants, and/or higher winds causing turbulent water and more atmospheric oxygen to be absorbed into the water.**

2.3 Dissolved oxygen maps 2014: multi-depth 1m, 5m 10m, 15m - PHMR, Monkey River, Rio Grande:

a. **January 2014 (Fig. 2.3 a):** In general DO was higher in the rivers (82-84%) compared to PHMR, which exhibited only modest spatial and temporal variability (70-78%) compared with previous years. Surface mean DO in PHMR was 81.0% ± 0.9 SE with slightly lower surface DO near the mouths of Middle River and Golden Stream. Monkey River had the highest single-site DO (85.8%) while Rio Grande highest single-site DO was 83.4%. There was little change in DO% with depth throughout PHMR.

b. **February 2014 (Fig. 2.3 b):** DO conditions similar to January (February ~78.9%) in PHMR. There was both a decrease throughout Rio Grande watershed (mean 80.0% ± 2.47 SE) and Monkey River, (mean 77.0% ± 3.7 SE) There was little spatial variability across inshore marine sites, but slightly more towards the eastside border of PHMR. DO% increased with increasing distance from the coastline at 1m, 5m and 10m depths. There was also an overall decrease in DO% in the lower reaches of the rivers ranging to about 72%.

c. **March 2014 (Fig. 2.3 c):** DO% rose again in Rio Grande (mean 85.3% ± 2.5 SE) and remained relatively constant throughout PHMR, particularly subsurface. There was little surface DO variability across sites in PHMR, (mean 77.5% ± 1.0 SE). Monkey River DO% dropped considerably (mean 73.0% ± 3.2 SE) compared to that of PHMR and Rio Grande.

d. **April 2014 (Fig. 2.3 d)** No monitoring took place in Rio Grande and Monkey river due to logistical constraints. Like March, in April there was not much variation between 5, 10, and 15m depth, ranging from 72-78% throughout PHMR. However there was an area in front of Rio Grande which appeared to be considerably high (88%) at the 5m depth in April. Cause not known.

e. **May 2014 (Fig. 2.3 e):** No monitoring took place in Rio Grande and Monkey river due to logistical constraints. In PHMR, surface DO% ranged from (72-74%) near the coast and increased to (74- 78%) in the eastern region of PHMR. Lower levels were seen at the surface north of Monkey River mouth (site 9A: 61%), and near Rio Grande mouth at 10m depth (site 3A: 68%).

f. **June 2014 (Fig. 2.3 f):** No monitoring took place in Rio Grande and Monkey river due to logistical constraints. Marine surface DO was fairly similar between Pork 'n Doughboy Point and Punta Ycacos (~77-78%). Higher levels were seen around Rio Grande mouth (site 3C: 80%)

g. **July 2014 (Fig. 2.3 g):** DO% rose in PHMR and in the upper reaches (RG_CB_1) of Rio Grande (~80%) while upper Bladen branch of Monkey River remained lower (~68%). Surface conditions in PHMR were higher than previous months, with greater spatial variability, being higher in the central part of PHMR extending to the coast, and less near Rio Grande mouth, Punta Ycacos and north of Monkey River mouth. Greater stratification was observed than previous months, with sub surface DO generally decreasing with depth, especially at nearshore sites. Subsurface DO at 10m was high around Snake Cayes.

h. **August 2014 (Fig. 2.3 h):** DO% notably higher in Columbia Branch of Rio Grande (~90%), and high throughout all rivers and PHMR. There was a general trend of increasing DO% with increasing distance from shore, with subsurface values lower in inshore areas. There was reduction in DO% with increasing depth in inshore areas of PHMR from 1-15m (similar to 2013) typical of times of warmest ocean temperatures of previous years. DO in offshore areas and north of Monkey River remained high with increasing depth.

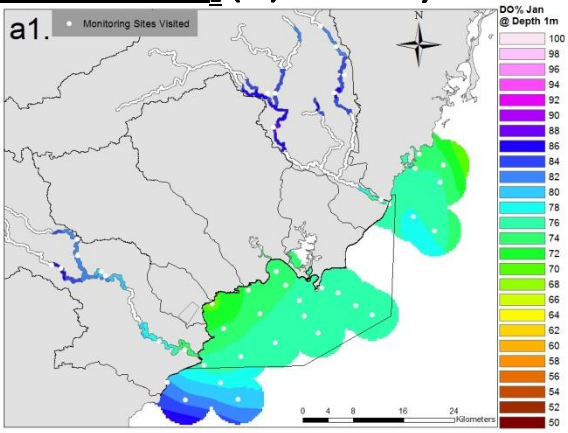
i. **September 2014 (Fig. 2.3 i)** Columbia Branch of Rio Grande and PHMR had high DO. Rio Grande lower reaches moderate (~78%). DO is generally high throughout PHMR (approx. 90-92%) but with higher DO at the surface around Joe Taylor Creek, similar to previous year, slightly lower around mouths of Middle River and Deep River. DO% decreased rapidly with depth in nearshore areas between Middle River and Deep River. Lowest reading occurred outside mouth of Rio Grade at 15m depth (site 2C: 61%)

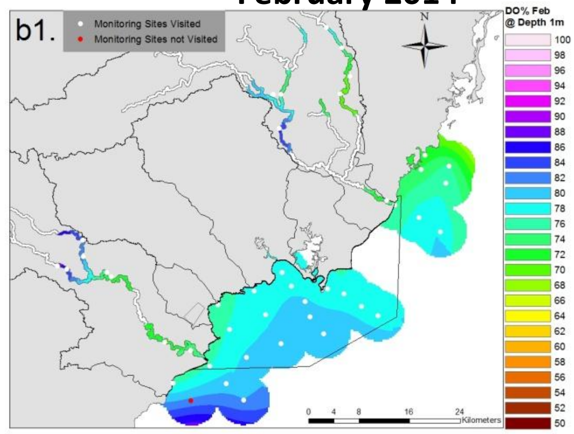
j. **October 2014 (Fig. 2.3 j):** DO was both stable and high in the Rio Grande (mean 88% $\pm$ 1.8 SE). Conditions were moderate in Bladen branch of Monkey River, and high in Swasey branch and lower reaches of Monkey River (MR_SB_1b: 91.9%). In PHMR, conditions were varied, DO decreased with depth in nearshore areas around Middle River mouth. Lowest DO site 6B at 15m depth: 57.6%.

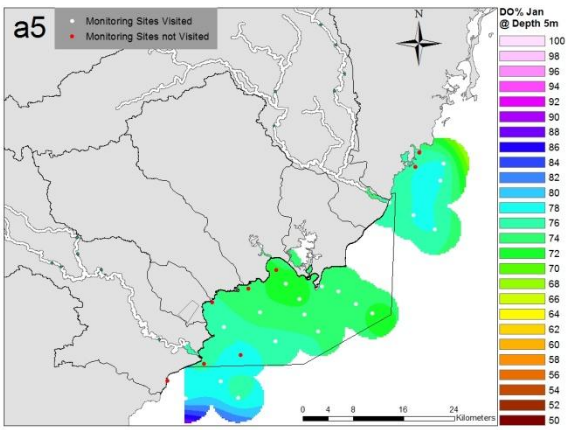
k. **November 2013 (Fig. 2.3 k):** DO levels in Columbia Branch of Rio Grande had higher DO than all other river sites. Surface DO overall in PHMR was less spatially variable than summer months (77.3 $\pm$ 1.2 SE). DO decreased significantly at 10m and below in PHMR, with some patches of higher subsurface DO in central and southern regions of PHMR. Suboxic conditions at 15m in PHMR close to Rio Grande mouth (site 2C 15m depth: 47.5%), the lowest reading of the year across all areas at all depths.

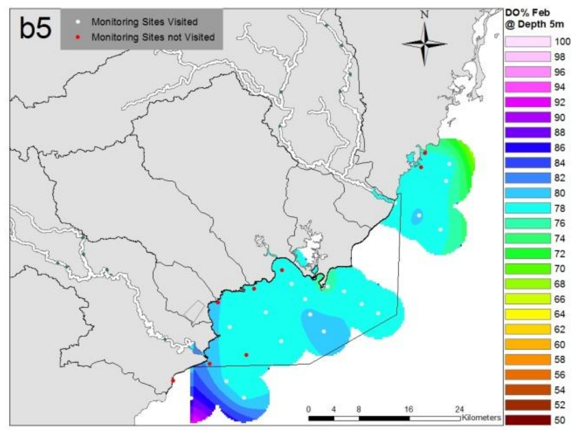
l. **December 2014 (Fig. 2.3 l):** No monitoring took place in Rio Grande and Monkey river due to logistical constraints. Overall PHMR had high surface DO (mean 87.5% $\pm$ 0.9 SE). DO% remained high at depth, indicating and end to warm season stratification.

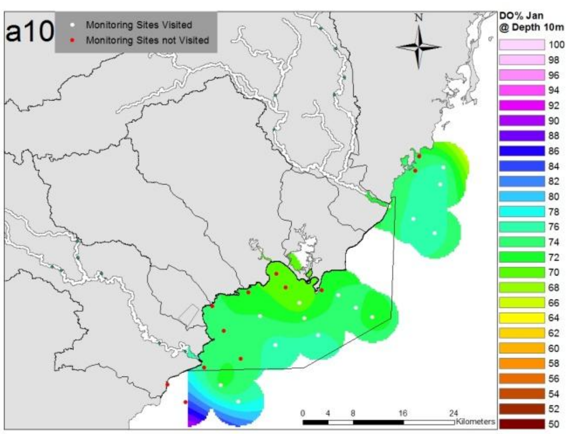
2.3 a,b: Dissolved O_2 (%) January 2014 February 2014

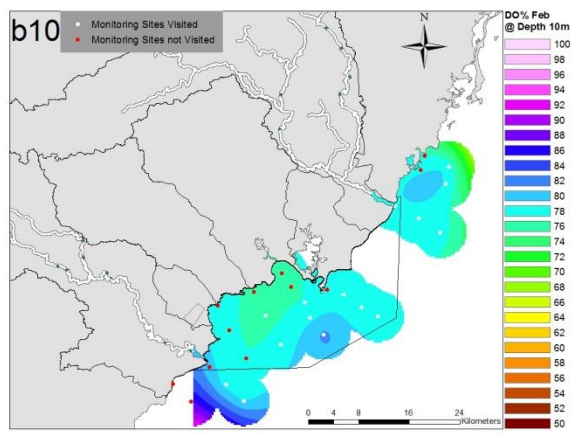


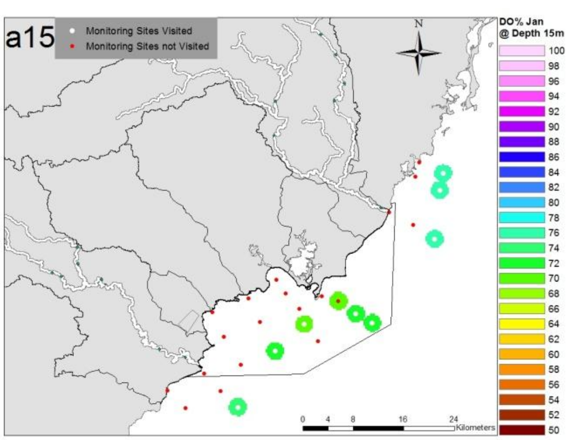


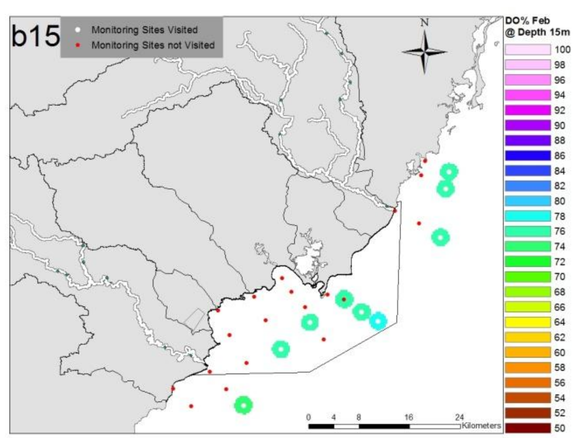




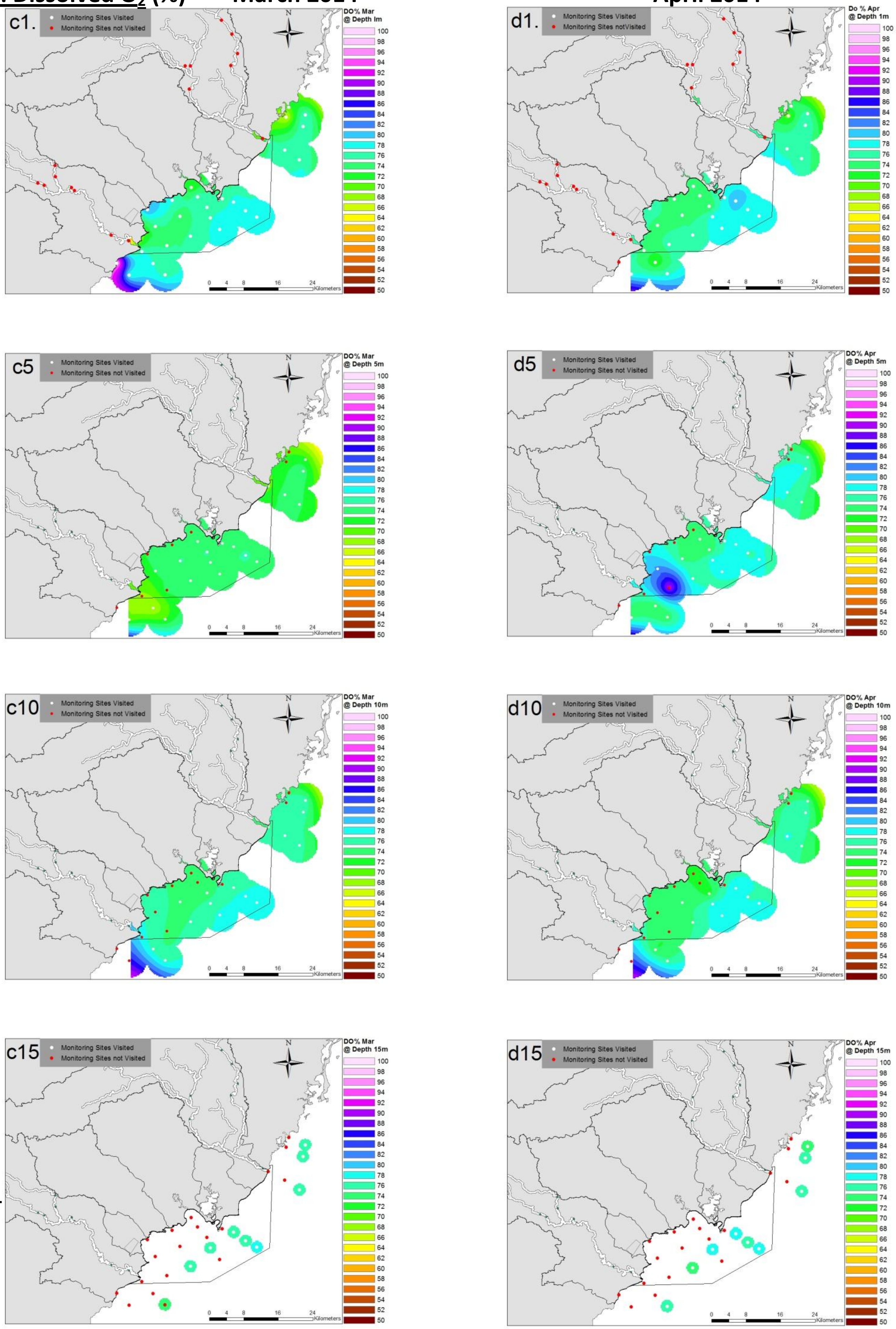




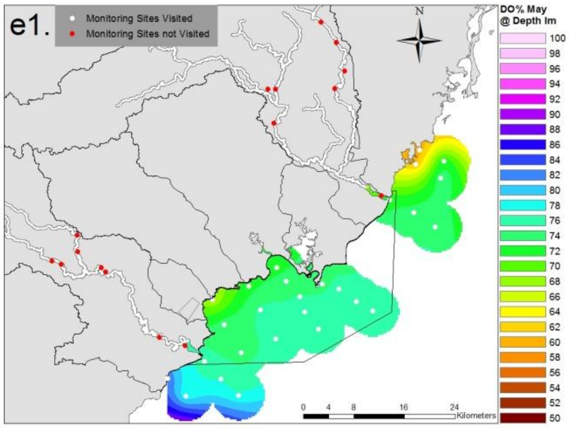


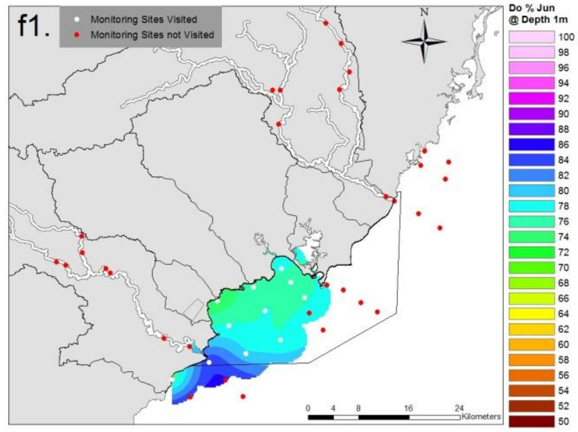


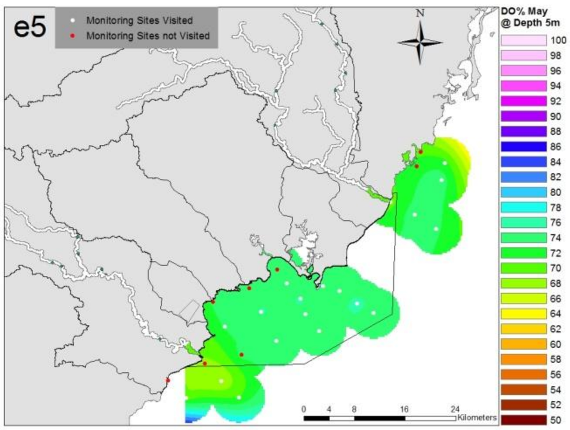
2.3 c,d: Dissolved O_2 (%) March 2014 April 2014

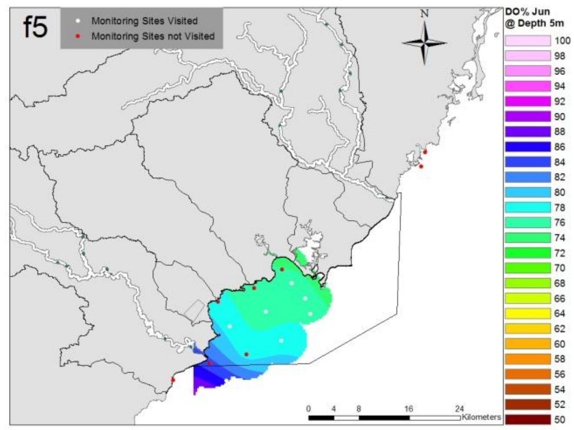


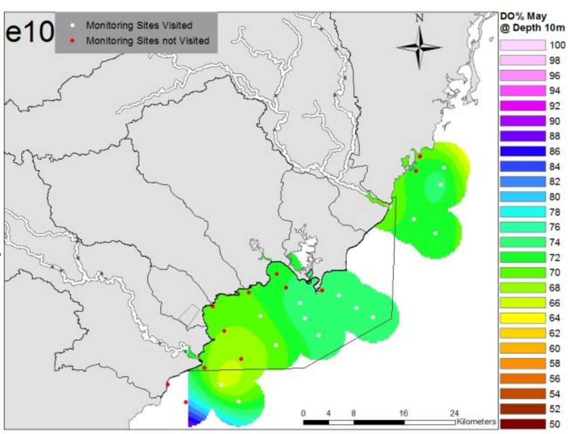
2.3 e, f: Dissolved oxygen (%) May 2014 June 2014

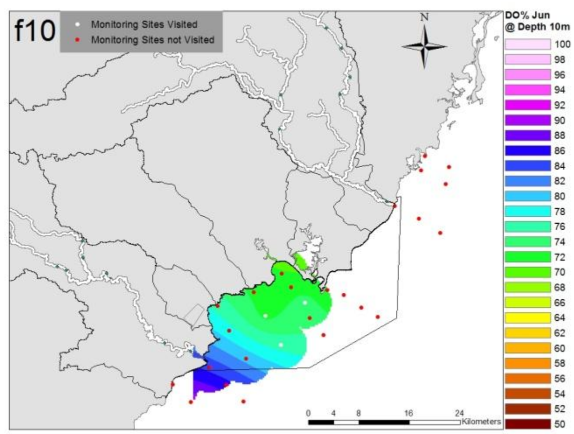


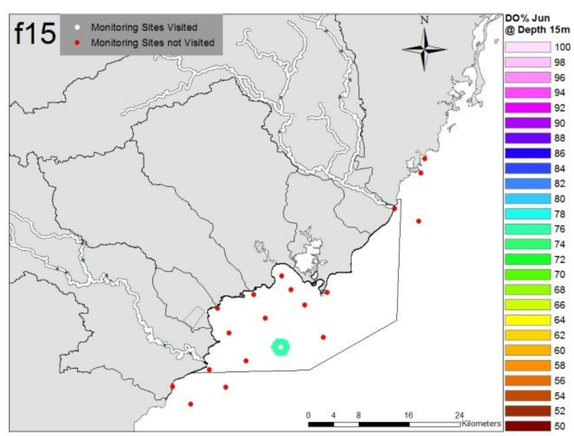




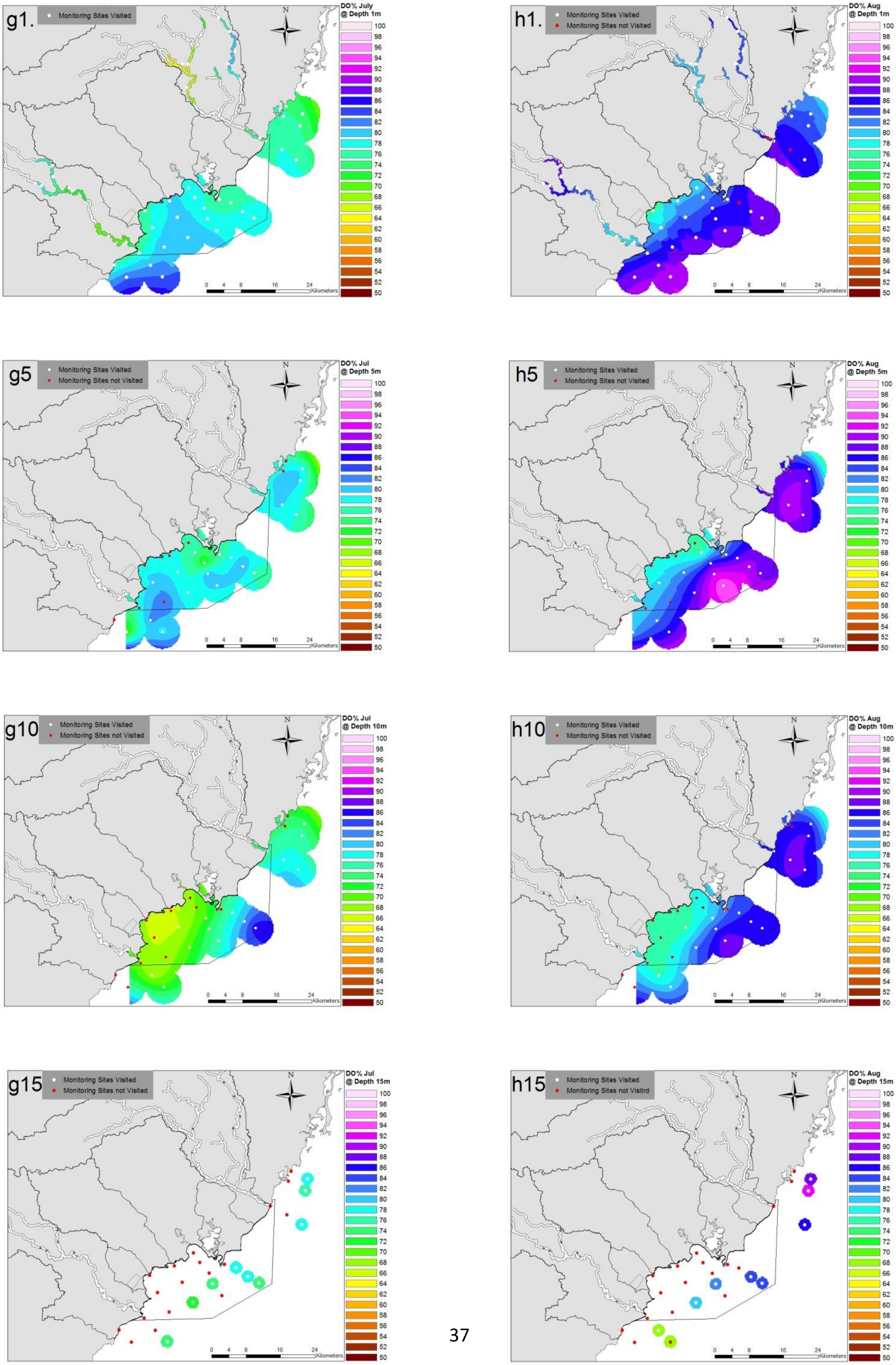




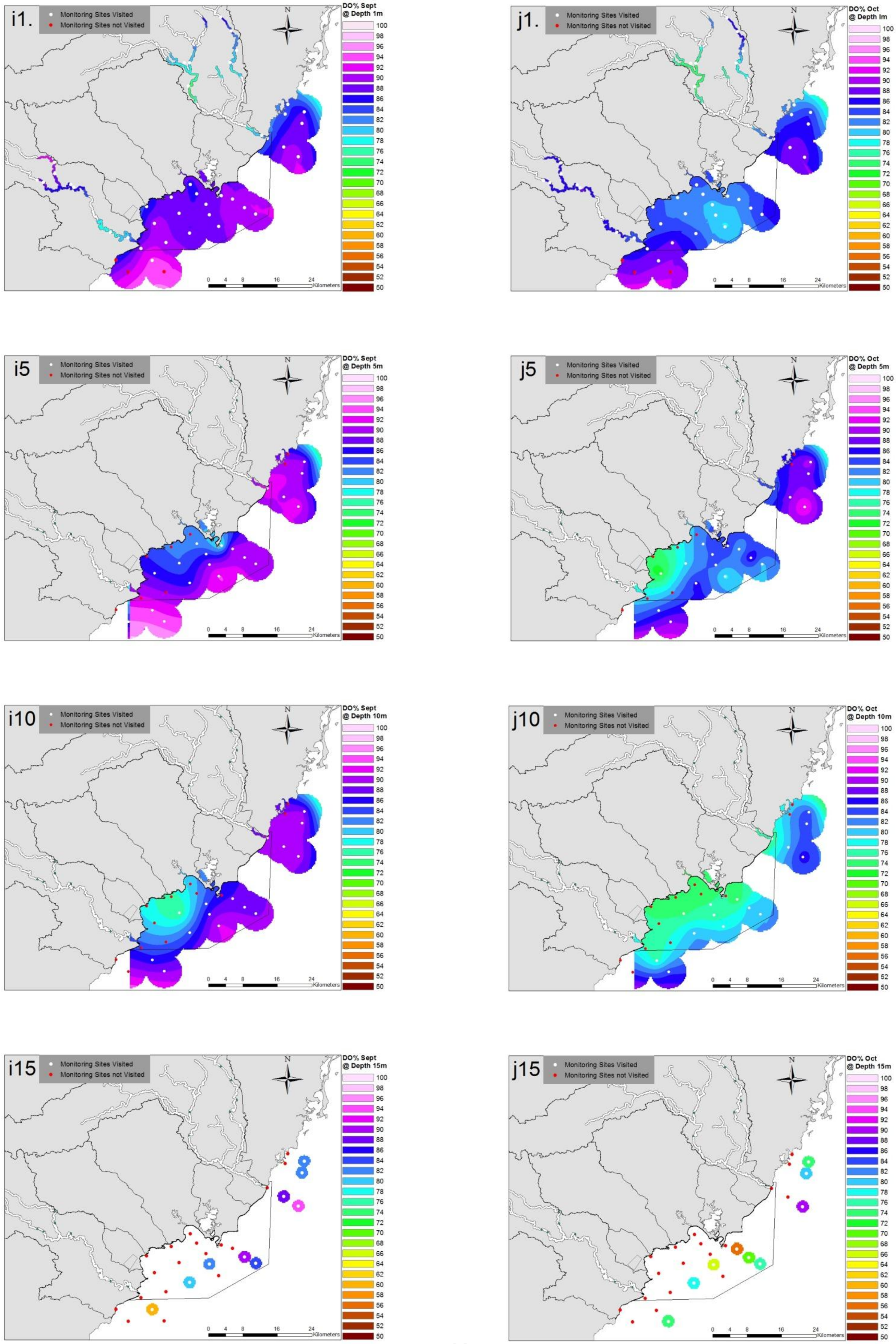




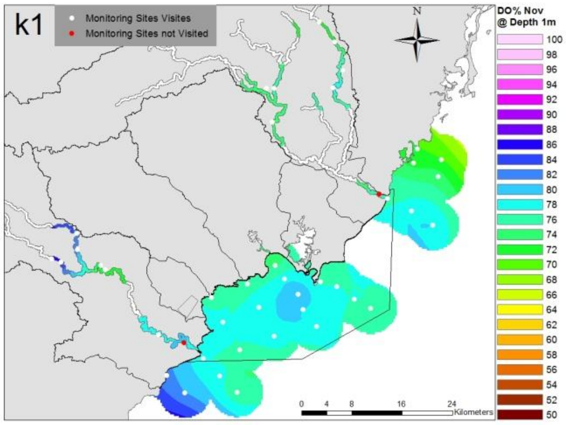
2.3 g, h: Dissolved O_2 (%) **July 2014** **August 2014**

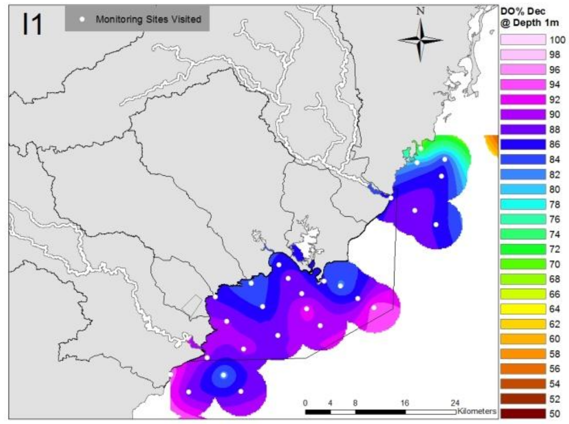


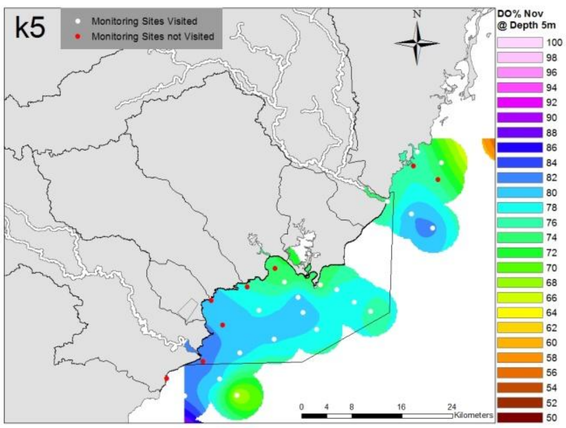
2.3 I, j: Dissolved oxygen (%) September 2014 October 2014

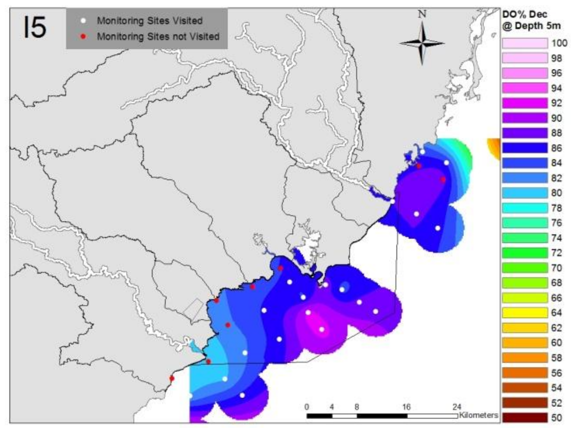


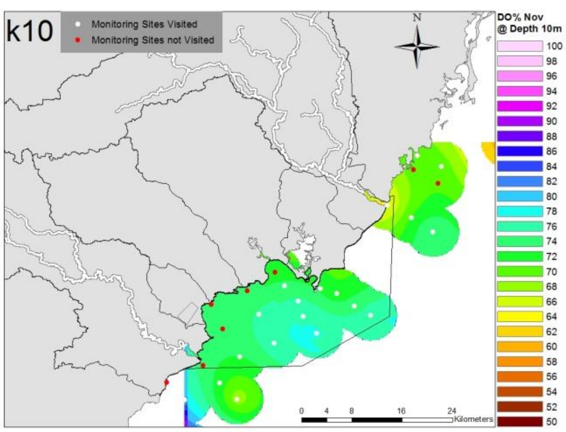
2.3 k, l: Dissolved O_2 (%) November 2014 December 2014

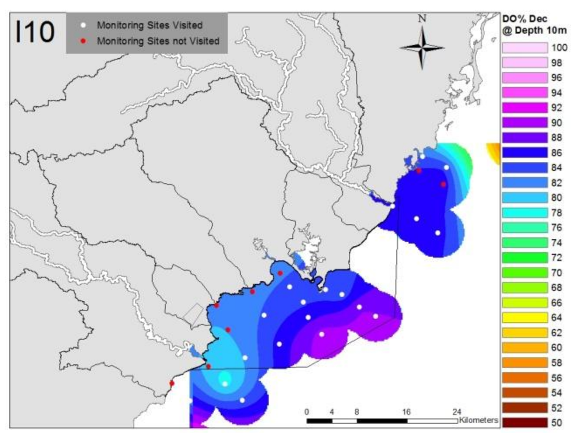


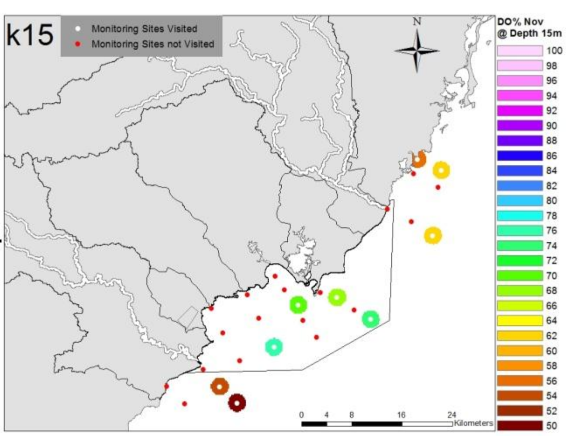




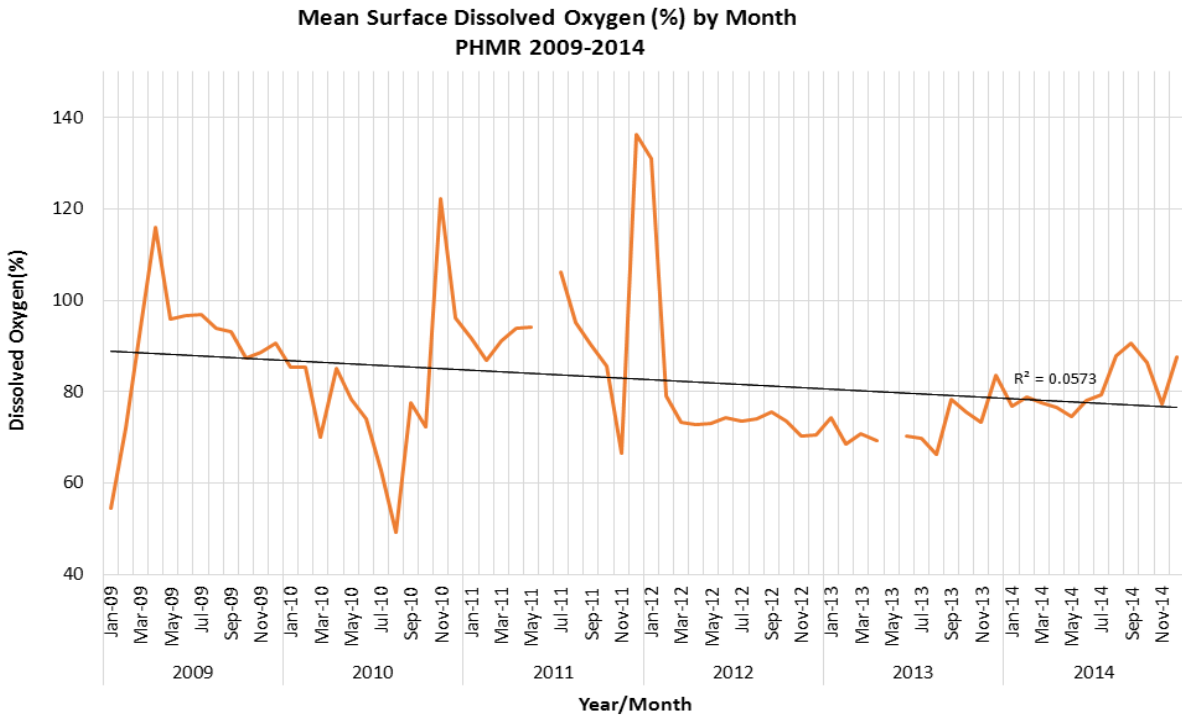








2.4 Mean DO (%) by month PHMR 2009-2014 (Fig 2.4):



- 2014 surface DO was higher on average in PHMR in 2014 compared with 2013, although there has been an apparent slight decrease overall over the past 6 years. More extreme variability was recorded between 2009 and 2011, which may be a result of equipment calibration with the previous YSI probe, which was replaced with the YSI ProPlus probe in 2012. Data post January 2012 is therefore considered to be more reliable.

2.5 Dissolved oxygen - general conclusions:

- In 2014, where data is available, Monkey River general had lower DO% than Rio Grande and surface values in PHMR.

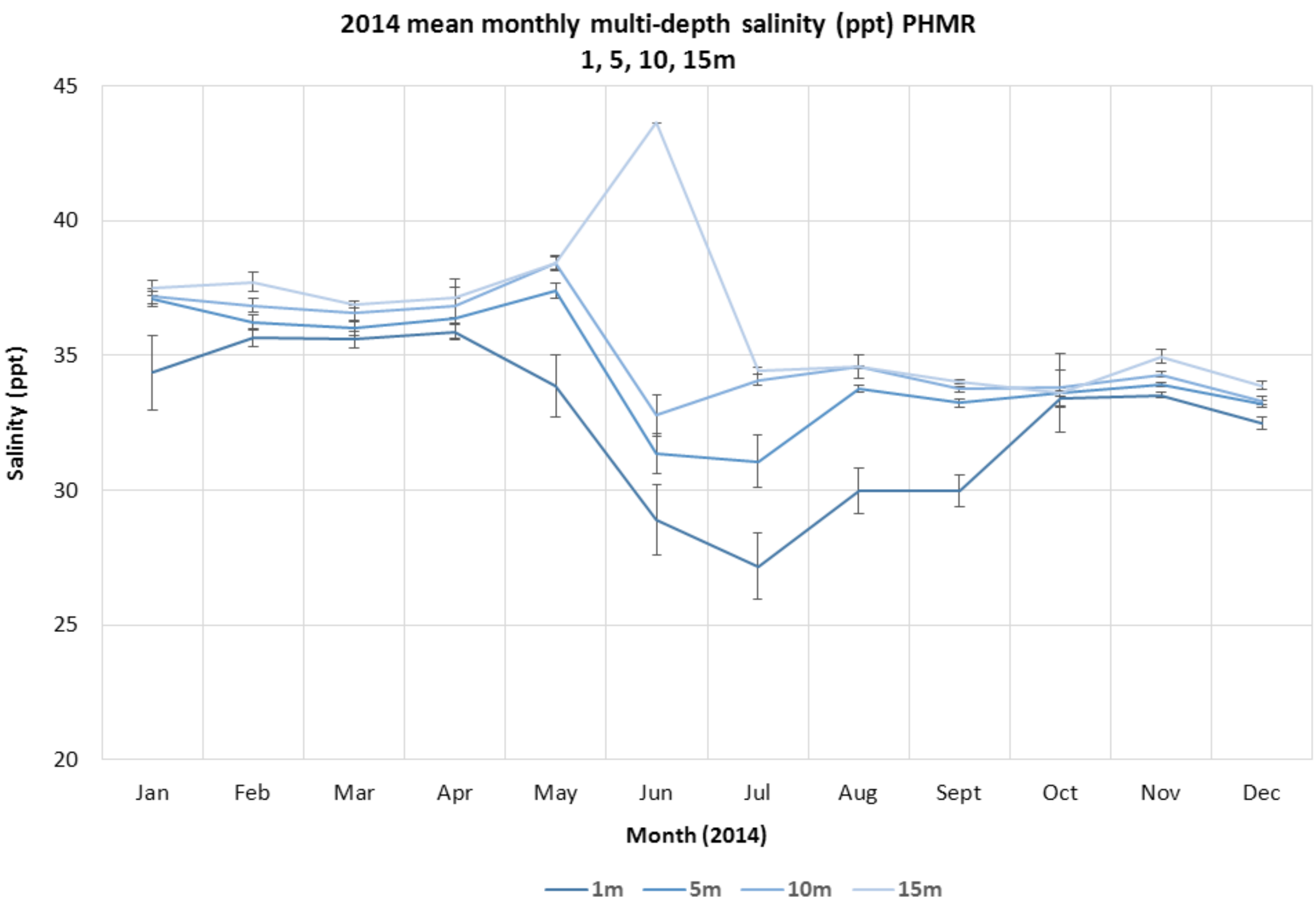
- Conditions were similar at all depths in the first half of the year with minimal stratification. Depth related stratification in PHMR increased between June and December, with DO generally decreasing with depth during this time. Highest DO occurred at the surface between August and October 2014

- DO on average was higher in 2014 than in 2013.

- *Temperature and Dissolved Oxygen*: observations of low subsurface DO coinciding with high subsurface temperatures indicate an inverse relationship between the two under certain conditions, probably due to the reduced capacity of water to retain DO at higher temperatures. This needs to be watched more closely in future years to determine if this is a common event, as the potential for benthic commercial species die-offs e.g. lobster and conch, are higher in such circumstances.

3. Salinity

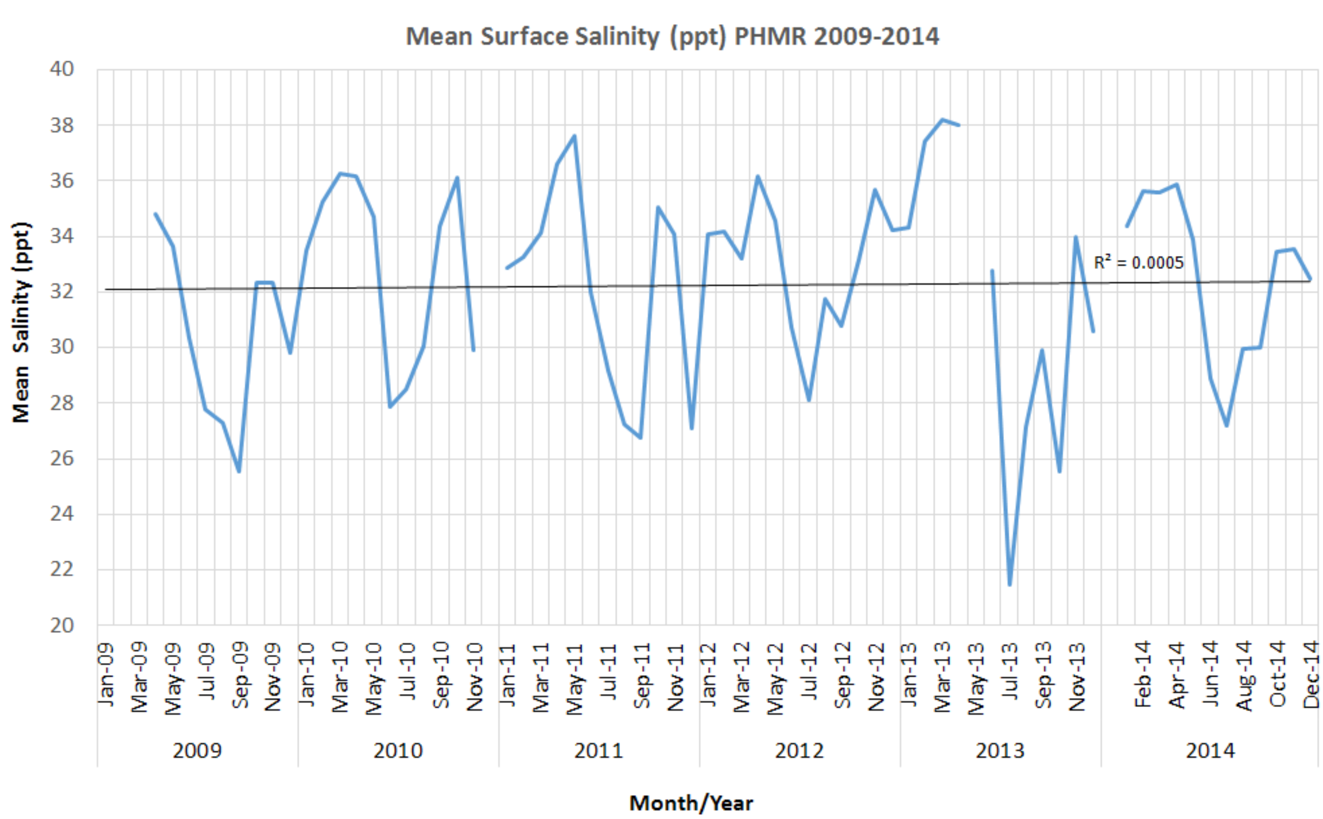
3.1 2014 Mean monthly salinity: 1, 5, 10, 15m depth (Fig. 3.1):



- Overall, salinity trends in 2014 were similar to 2012 and 2013. There is a general trend overall of higher salinity in the first quarter each year, followed by a general decrease with greater stratification in the second and third quarters, followed by a general overall increase with reduced stratification again in the final quarter. These trends reflect typical rainfall levels, which are higher in the second and third quarters of the year.

- Apparent hypersaline conditions in Jun at 15m depth are probably inaccurate. Only one reading is available for June 2014 15m depth, and is likely incorrect possibly due to incorrect calibration of the refractometer because it is far higher than any other reading ever recorded since 2009.

3.2 Mean salinity (ppt) by month 2009-2014 (Fig 3.2):



- Mean monthly salinity trend was similar to previous years 2009 to 2013 in Rio Grande, Monkey River and PHMR. In PHMR there was a general trend of average salinity with values between 28 and 38 ppt. High readings in June of 44 ppt at 15m are based on one data point only and are considered an outlier.

- The general average trend in PHMR during the first 5 months had values between 34 and 38 ppt. Thereafter the salinity decreased to 17 and 35 ppt. In October salinity values increased to values between 28 and 35ppt. There is a general variation in salinity values at the 1m depth. The trend was a general increase in values from the coastline outwards. Less spatial variability was recorded with increased depth.

3.3 Mean Monthly Salinity: 1,5,10 and 15 meters depth (fig 3.2, 3.3)

Note: no salinity data is collected for Rio Grande and Monkey River

a. January 2014 (fig 3.3 a): PHMR had a low surface salinity in northern and southwestern areas, likely due to high freshwater output from Monkey River, Golden Stream, Seven Hills Creek and Rio Grande. Salinity values increased with distance from the coast with values between 28 and 38 ppt. At the 5, 10 and 15 meter depths there was little variation.

b, c, d. February, March and April (fig 3.3 b): There was little vertical, lateral or temporal variation in salinity throughout PHMR as expected of conditions typical of dry season. One exception was April 2014, which exhibited low salinity around Middle River/Golden Stream mouths in PHMR at 5m depth but not at surface. Cause unknown.

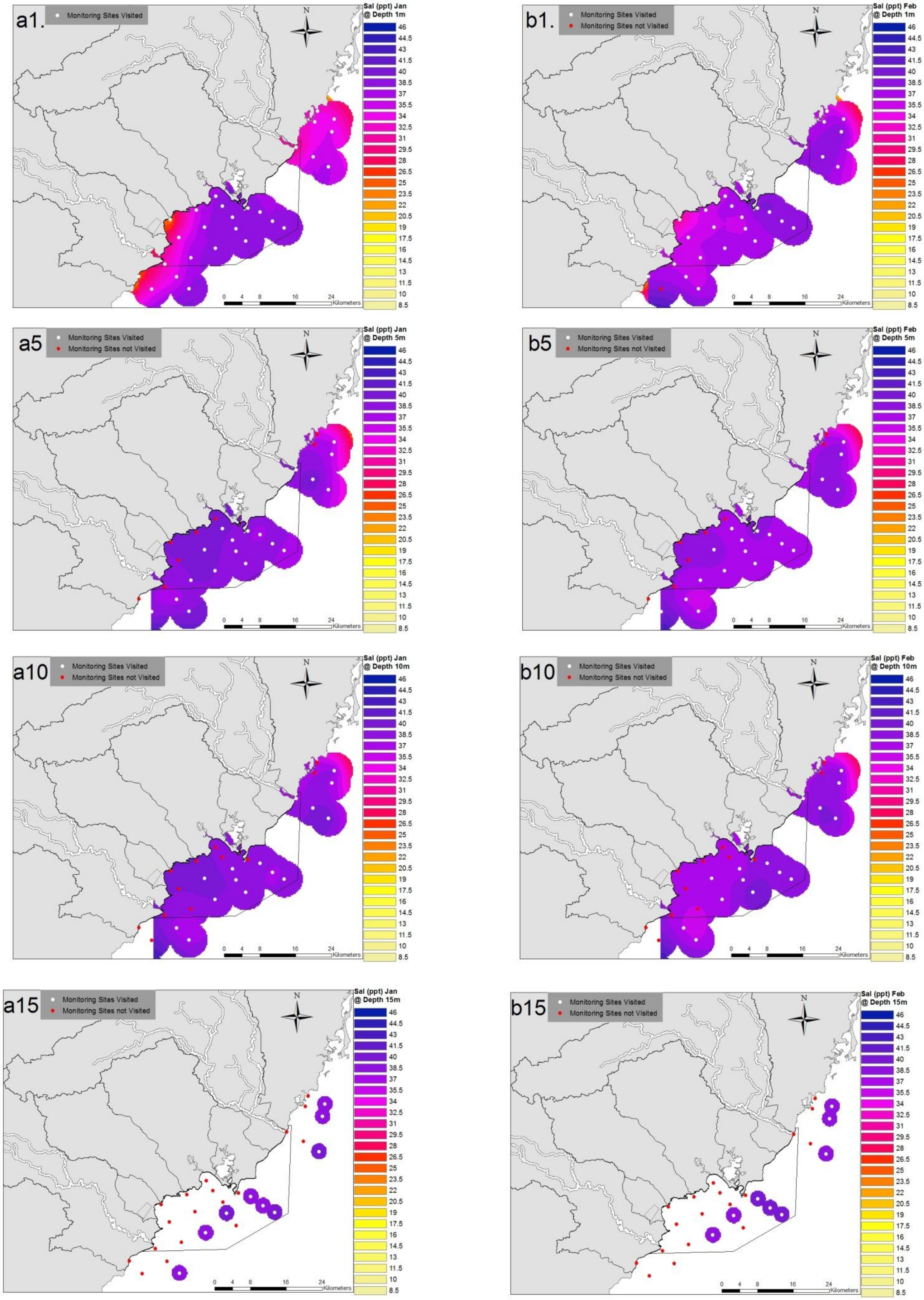
e. May (fig 3.3 e): High river discharge evident in the southern portion of PHMR with a decrease in salinity values to around 25 ppt, extending to 5m depth. The central and northern areas of the reserve during May had similar values to the first four months of the year typically around 35ppt. Values remained similar to the first four months at 10 and 15 meters depth throughout the reserve.

f. June (fig 3.3 f): Surface salinity values remained low in the southern portion of the reserve and decreased further near mouth of Joe Taylor creek (e.g. site 1A: 17 ppt). Data was not collected for the northern portion of the reserve due to rough weather.

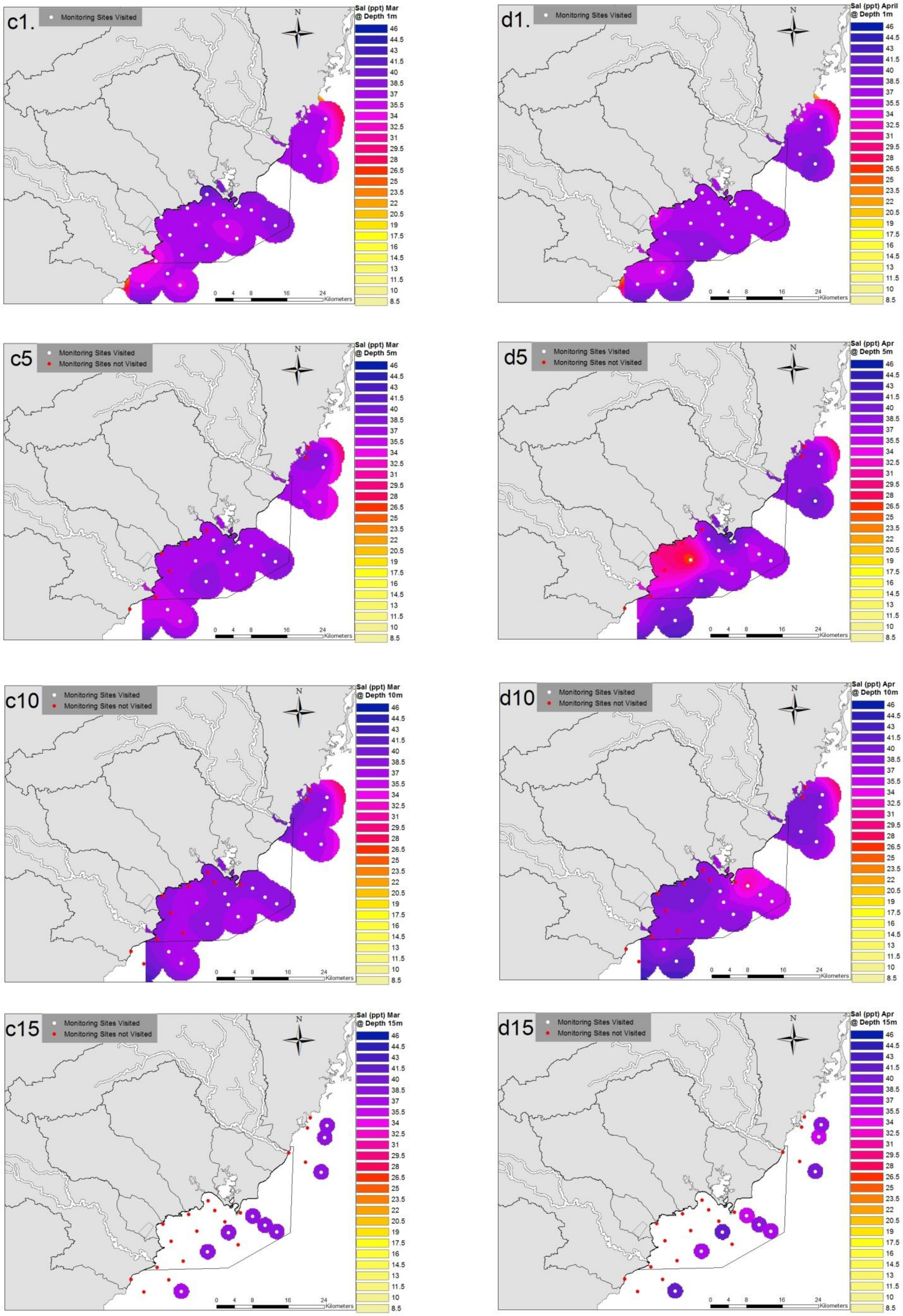
g, h, i. July, August, September 2014 (Figs. 3.3 g, h, i): High freshwater discharge evident from Rio Grande watershed. Subsurface mixing starts off high in July, with low salinity down to 5m depth, decreasing throughout this wet period. Freshwater influence remains significant but diminishing and confined to the surface for August and September in southern PHMR.

j, k, l. October, November and December (fig 3.3 j, k, l): Average salinity more oceanic in influence with values between 31 and 38 ppt, indicating lower rainfall. Average salinity increased with depth and distance from the coast, values were recorded between 32 and 38 ppt.

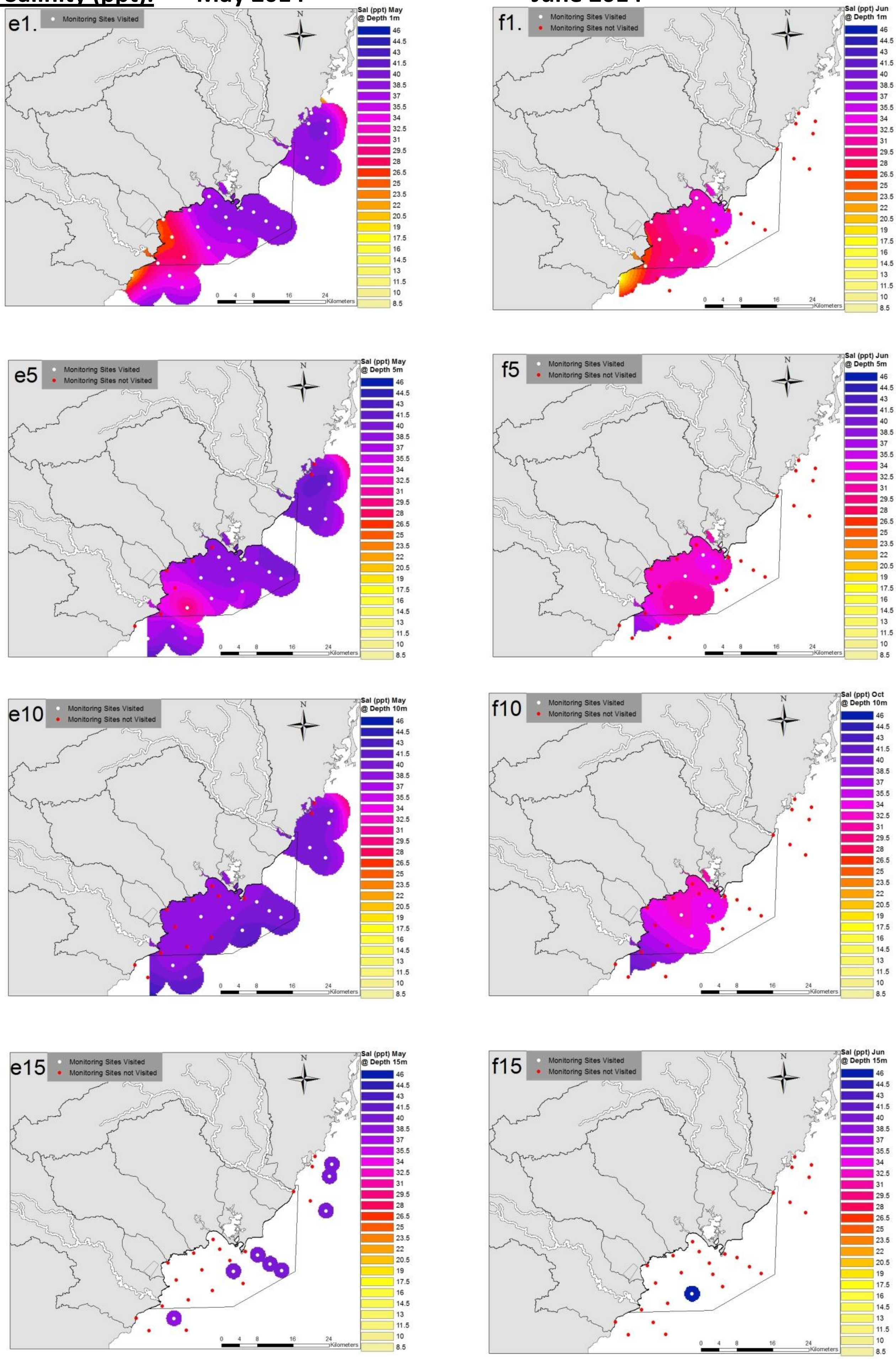
3.3 a, b: Salinity (ppt): January 2014 February 2014



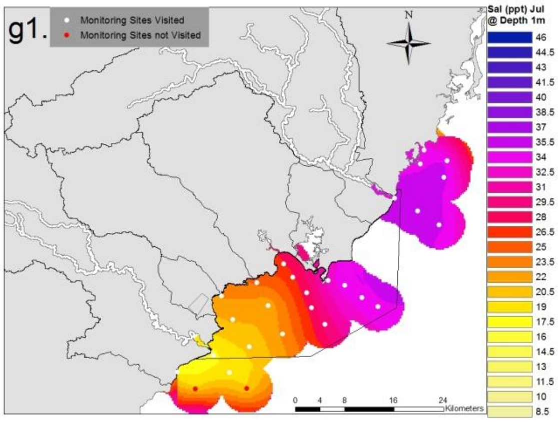
3.3 c, d: Salinity (ppt): March 2014 April 2014

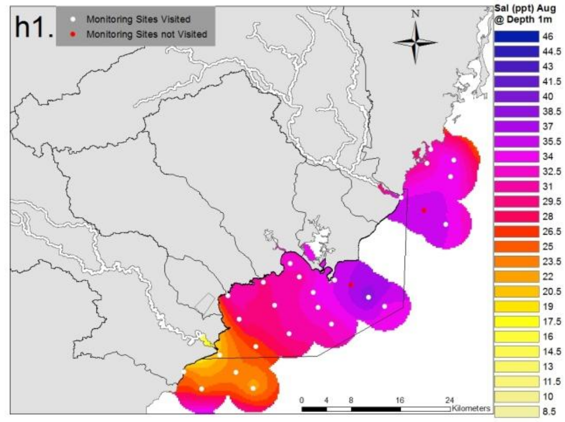


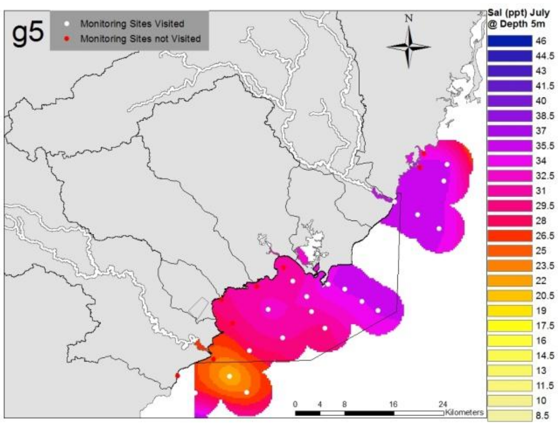
3.3 e, f: Salinity (ppt): May 2014 June 2014

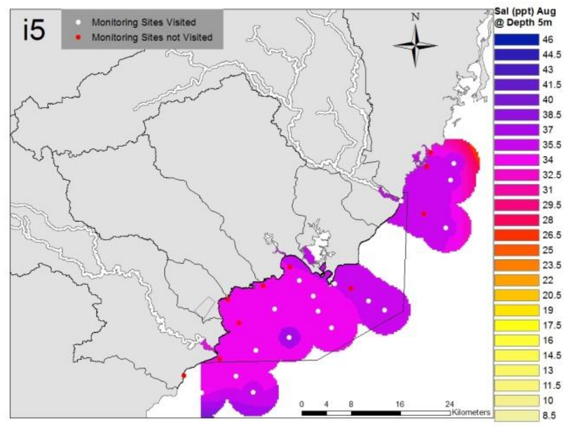


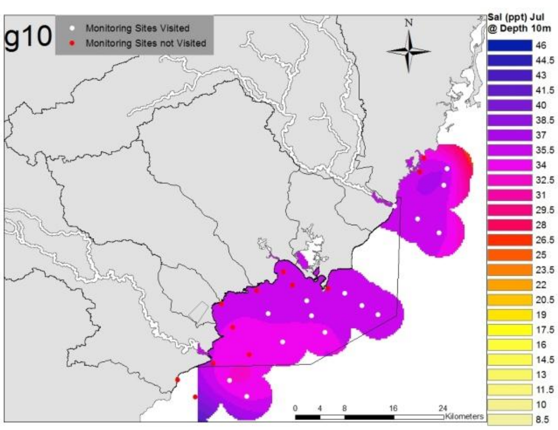
3.3 g, h: Salinity (ppt): July 2014 August 2014

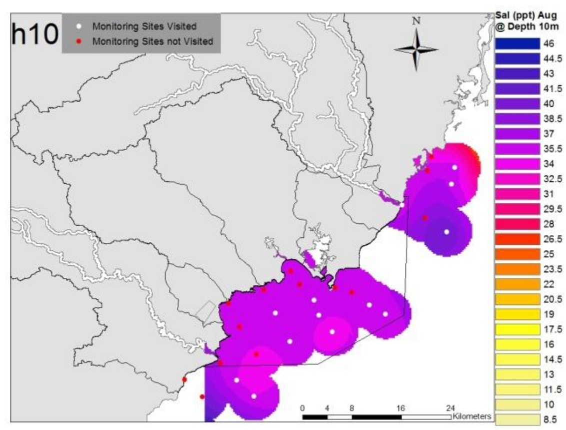


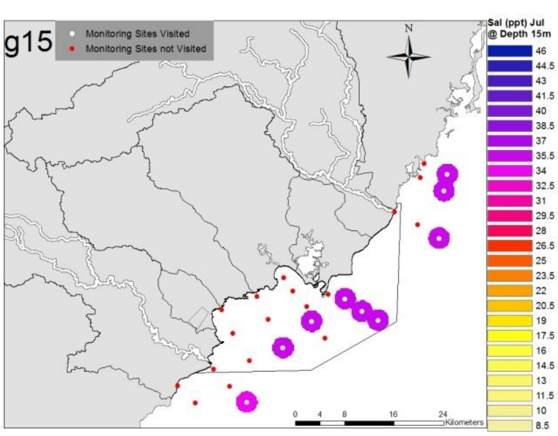


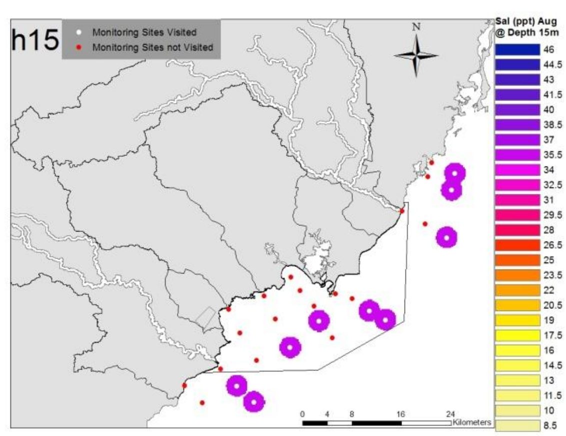




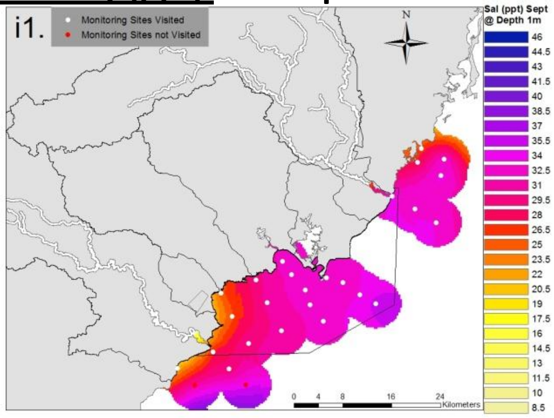


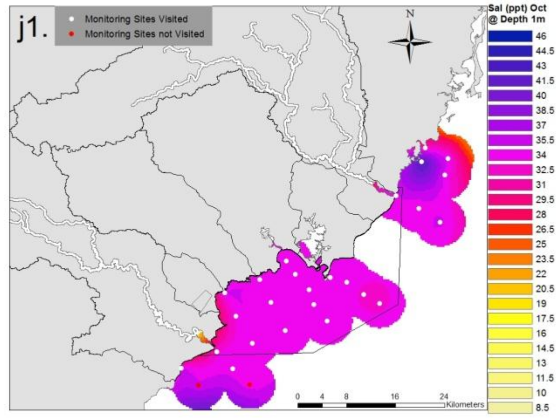


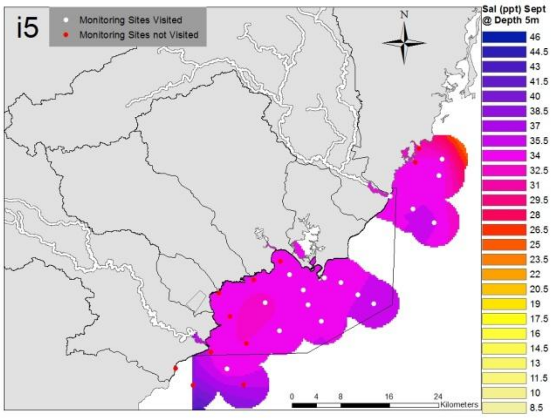


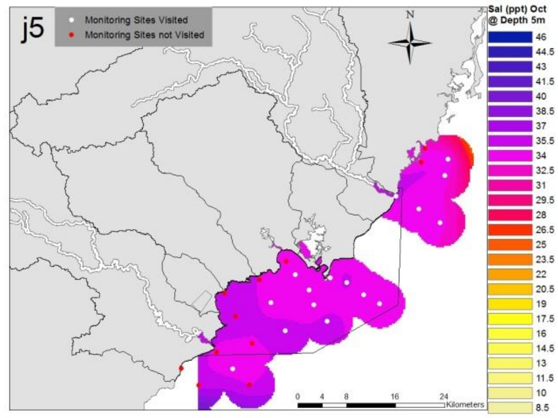


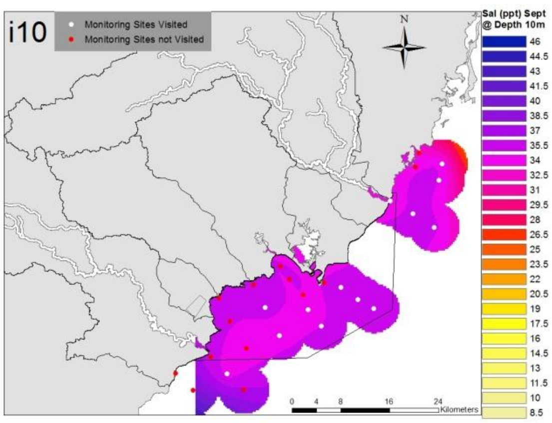
3.3 i, j: Salinity (ppt): **September 2014** **October 2014**

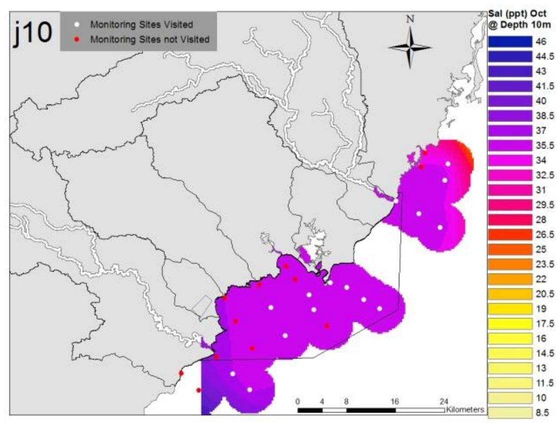


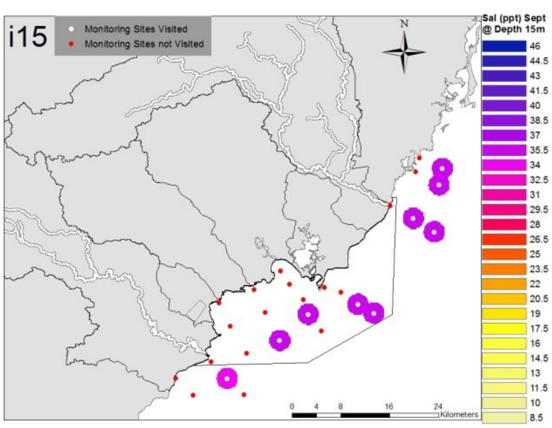


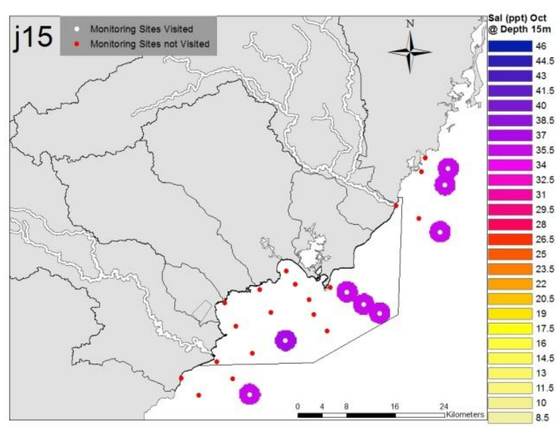




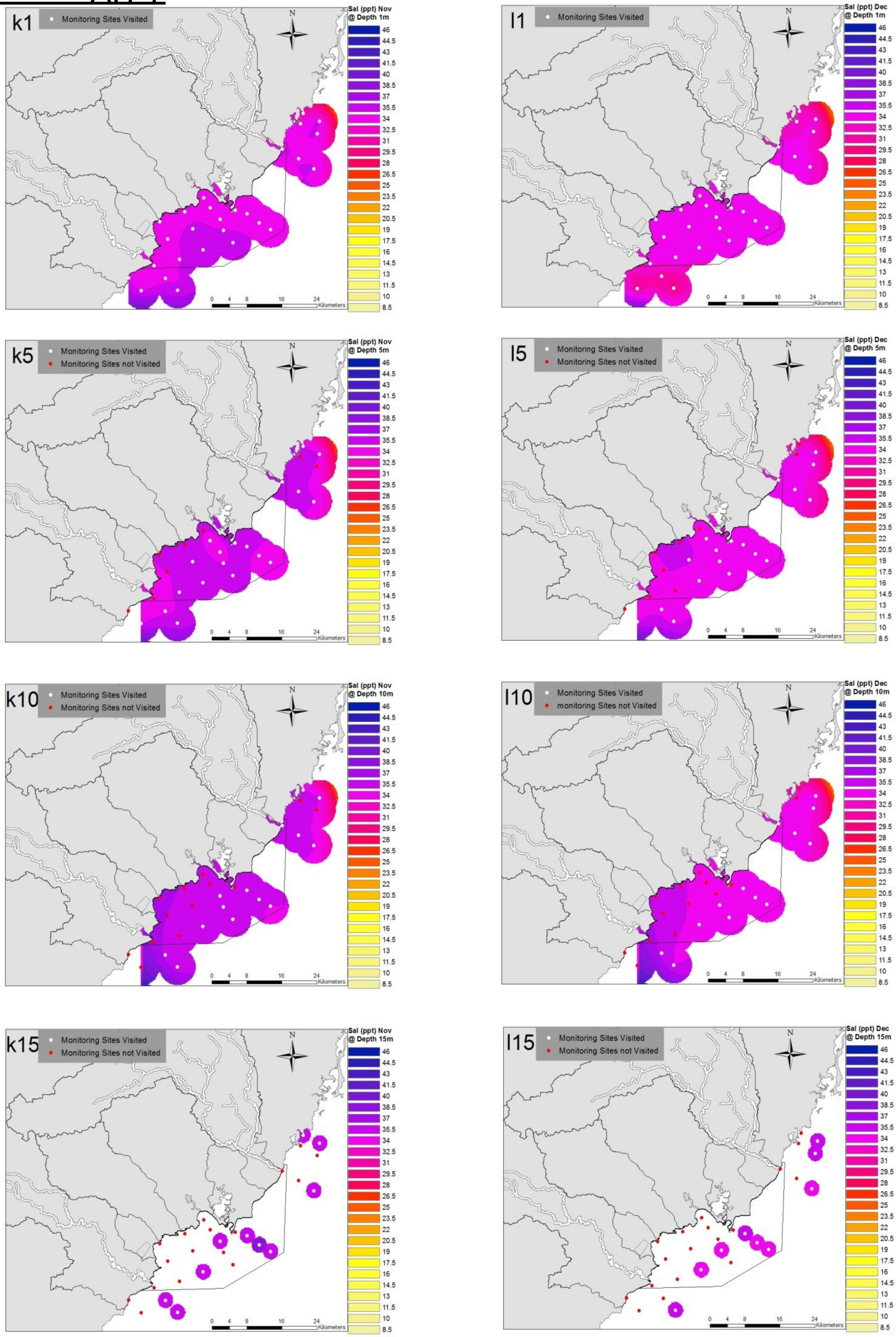








3.3 k, l: Salinity (ppt): November 2014 December 2014



3.4 Salinity - general conclusions:

- Wettest months were June to September becoming drier in November and December.

- Greatest stratification by depth for salinity occurred between June and September 2014

- During wet periods across the region, Rio Grande and Monkey River watersheds discharge larger volumes of freshwater and earlier than the smaller water sheds in between, probably due to their larger catchment areas.

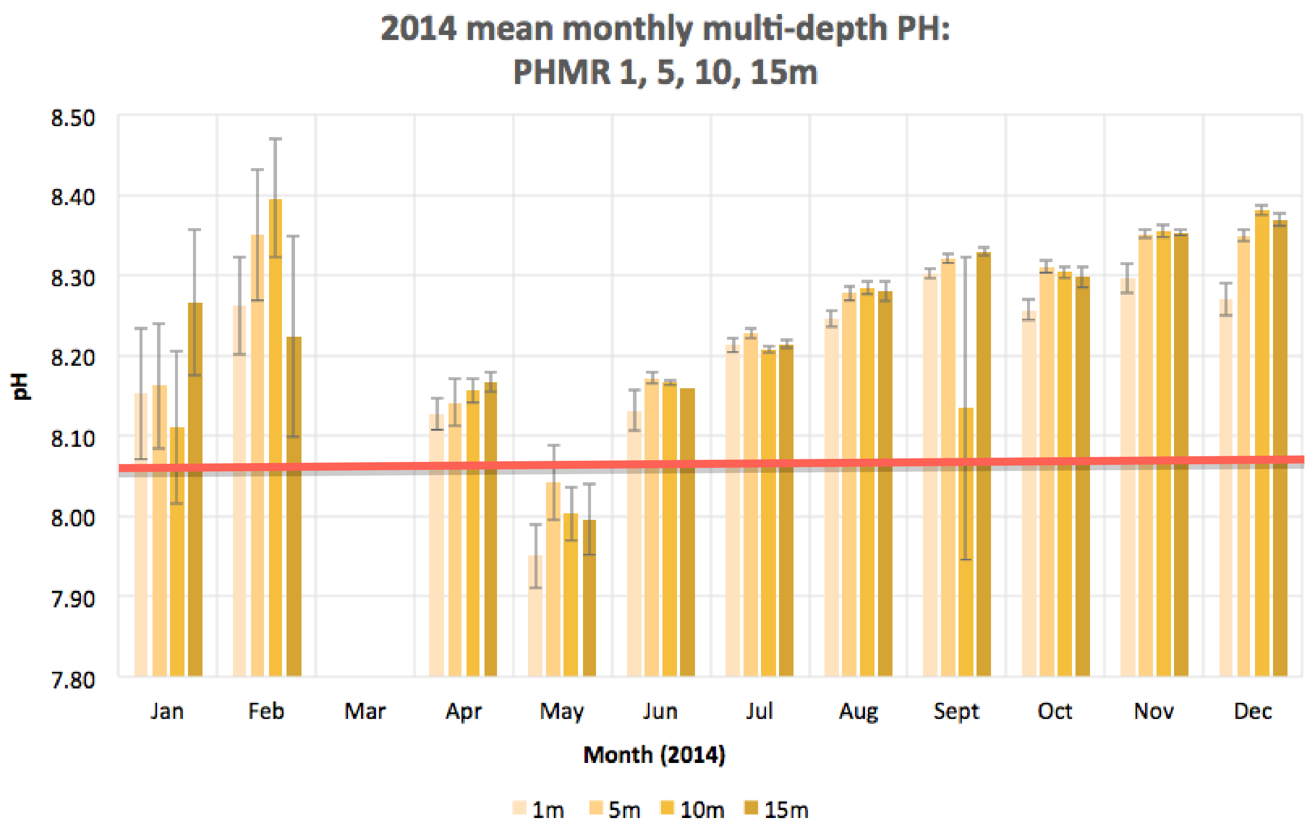
- Except for areas immediately adjacent to river mouths, impacts of freshwater input from rivers and from rain falling directly onto the sea are mainly limited to the top few meters of the water column.

- Higher rainfall in Rio Grande watershed is evident and may be due to higher forest cover there.

- In PHMR, 2014 had less freshwater impact than in 2013.

4. pH

4.1 2014 PHMR Mean monthly pH: 1, 5, 10, 15m depth (Fig. 4.1):



- There is greater variability in pH spatially and at all depths in PHMR from January to May 2014, with conditions becoming more uniform from June to December.

- In general pH is lower (more neutral) with decreasing salinity. Salt water is naturally more alkaline.

- May had by far the lowest mean monthly pH, being considerably lower than other months, especially at the surface, but significant at depth also. This occurred at the same time as significant salinity stratification occurred (Fig 3.1).

- There was greater variability in the first 5 months of the year at all depths throughout PHMR, with mean values increasing steadily from May to December with little depth related variability. One exception is unusually low mean pH at 10m in September. Cause unknown.

4.2 pH maps 2014: multi-depth 1m, 5m 10m, 15m - PHMR, Monkey River, Rio Grande:

a. **January (Fig. 4.2 a):** pH values were highly variable ranging from 7.2 to 8.6 at all depths, with the largest variation recorded in the deepest water (15m). At the surface, pH values were relatively lower near the river mouths of both Monkey River and Rio Grande, as fresh water is more neutral in pH whereas salt water is more alkaline (high pH). pH values in PHMR were higher than those around the mouth of Monkey River at all depths.

b. **February (Fig. 4.2 b):** pH at 1, 5, 10m significantly increased from January to February at the river mouths of both Monkey River (from 7.7 to 8.5) and Rio Grande (from 8.1 to 8.5). The spatial gradients in pH at 5 m and 10m were very similar to each other; the pH values gradually declined from the river mouth towards offshore. At 15m, high pH (8.6) was recorded around Monkey River mouth while PHMR had a lower range (7.5 - 8.2). High pH was observed in Bladen branch of Monkey River.

c. **March (Fig. 4.2 c):** There is no pH data available in March due to equipment problems.

d. **April (Fig. 4.2 d):** Overall, pH was less (more neutral) than earlier in the year across PHMR at all depths. pH values at 1m and 5m ranged from 7.7 to 8.2, with the lowest values recorded around Middle River and Golden Stream. The pH values are less variable at deeper water (10 and 15m) ranging from 8.1 to 8.3.

e. **May (Fig. 4.2 e):** The pH values sharply decreased to more neutral values from the previous month at all depths, with the majority of the areas recording lower than 8.0. Spatial variations are more homogeneous at deeper water (10-15m) than shallower (1-5m).

f. **June (Fig. 4.2 f):** Data is available only in the southern part of PHMR at 1 – 10m. pH at the surface increased from 7.7 to 8.2 (more alkaline) compared to May. pH values were more uniform at all depths shallower than 10m compared to the previous months.

g. **July (Fig. 4.2 g):** There was less spatial variability (both horizontal and vertical) in pH, ranging between 8 and 8.2.

h. **August (Fig. 4.2 h):** Seawater pH values in August were very similar to those in the previous month, with a small spatial variation (8.1 - 8.4) across all depths. pH values in upper streams of Rio Grande and Swasey Branch (7.4-7.7) were higher than those at upper stream of Bladen Branch (~7). pH increased towards lower stream in both rivers, reaching to 8.3 at the mouth of Monkey River.

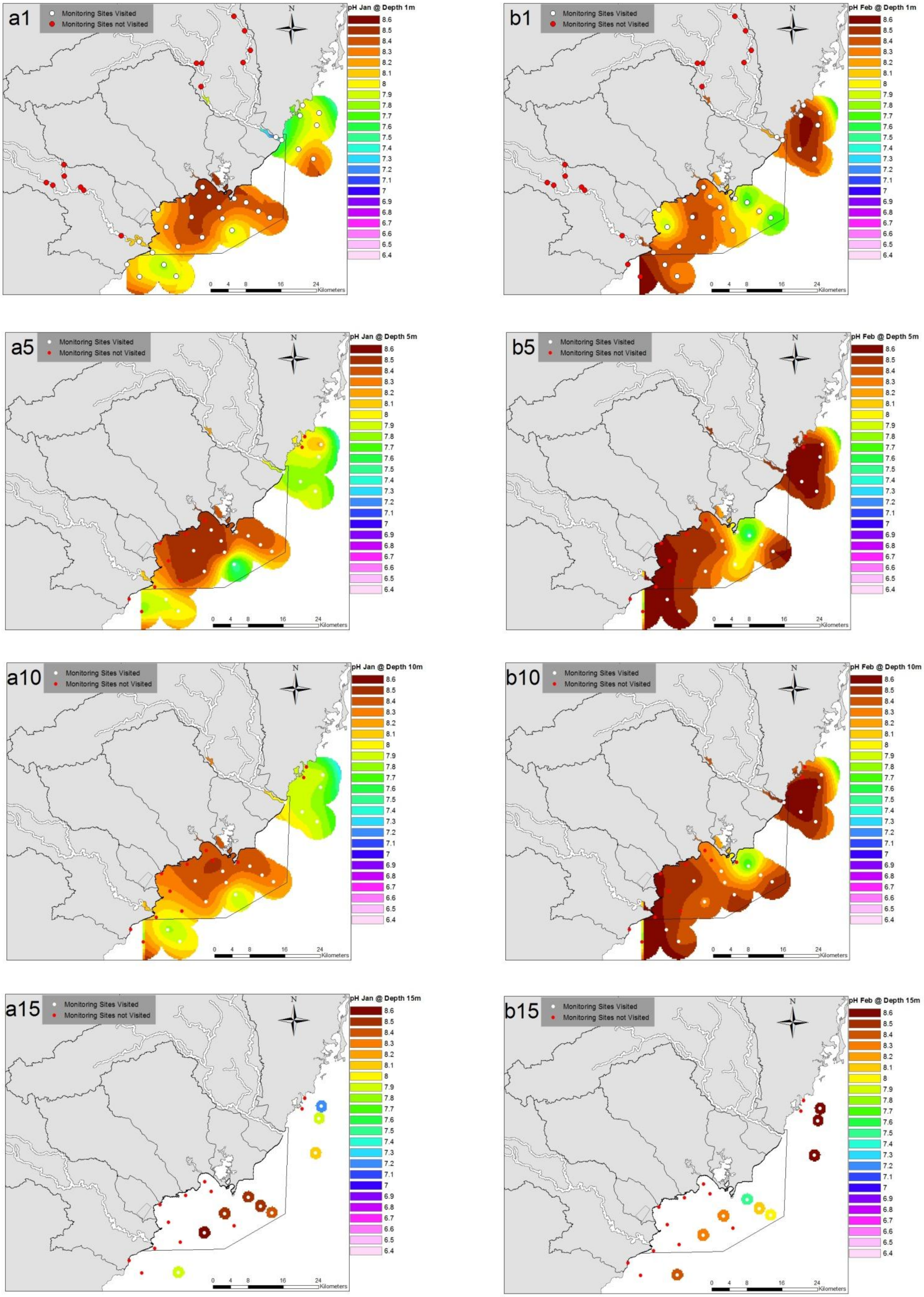
i. **September (Fig. 4.2 i):** pH values in the upper reaches of both Monkey River and Rio Grande were near neutral (7.2 – 7.5). Seawater pH was uniform (8.2-8.3) across PHMR at all depths.

j. **October (Fig. 4.2 j):** pH values in the upper reaches of Rio Grande and Bladen Branch (7.4- 7.9) increased slightly compared to the previous month. pH in Swasey Branch remained low (~7), except for the upper most site (MR_SB_1a) where pH was 8.1. Seawater pH remained consistent with the previous month.

k. **November (Fig. 4.2 k):** pH in the upper reaches of Rio Grande was higher than October (7.8 – 8.1 in the upper stream), and increased continuously towards the lower reaches (RG_RG_1c: 8.4). There was little difference in pH values in Monkey River between October and November. pH in the central part of PHMR increased slightly at the surface from the previous month. Multi-depth pH was uniform and higher than summer months, ranging between 8.3-8.4.

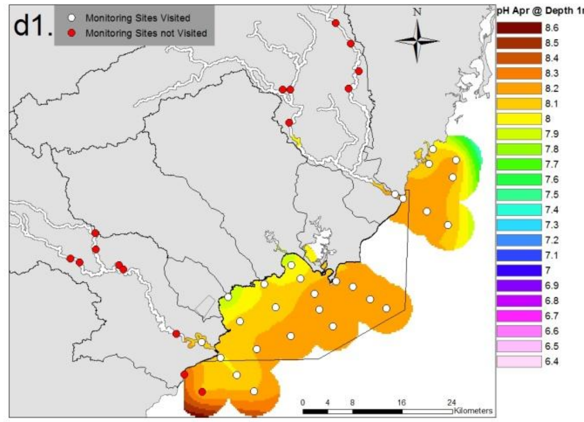
l. **December (Fig. 4.2 l):** Marginally lower pH was recorded around the mouth of Rio Grande compared to the rest of PHMR. The mean pH at 1m was 8.3, which was slightly lower than the rest of the water column (5-15m). The uniformity also slightly increased with depth, being slightly higher at greater depths.

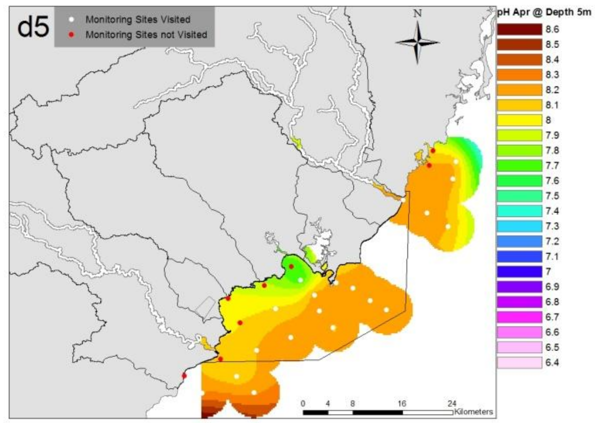
4.2 a,b: pH: January 2014 February 2014

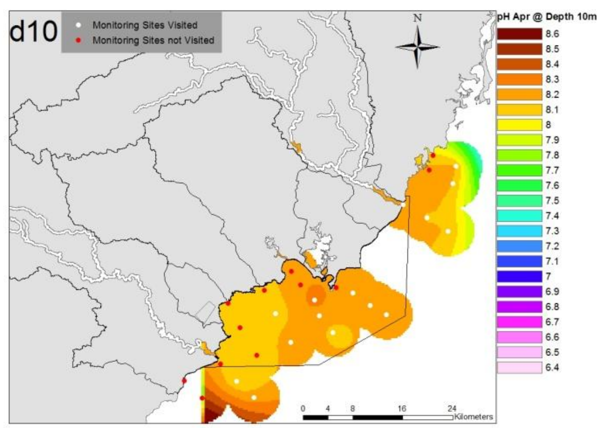


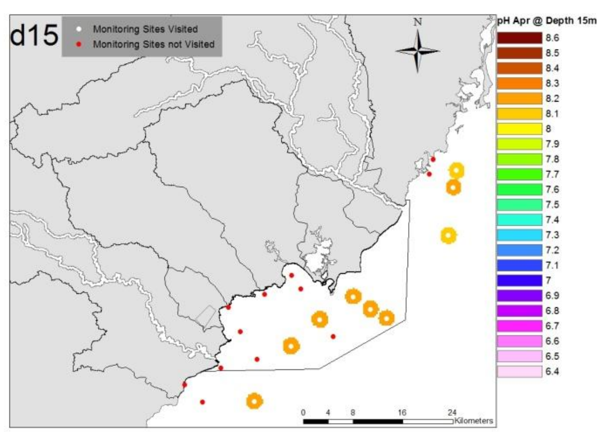
4.2 c, d: pH:

March 2014 **April 2014**

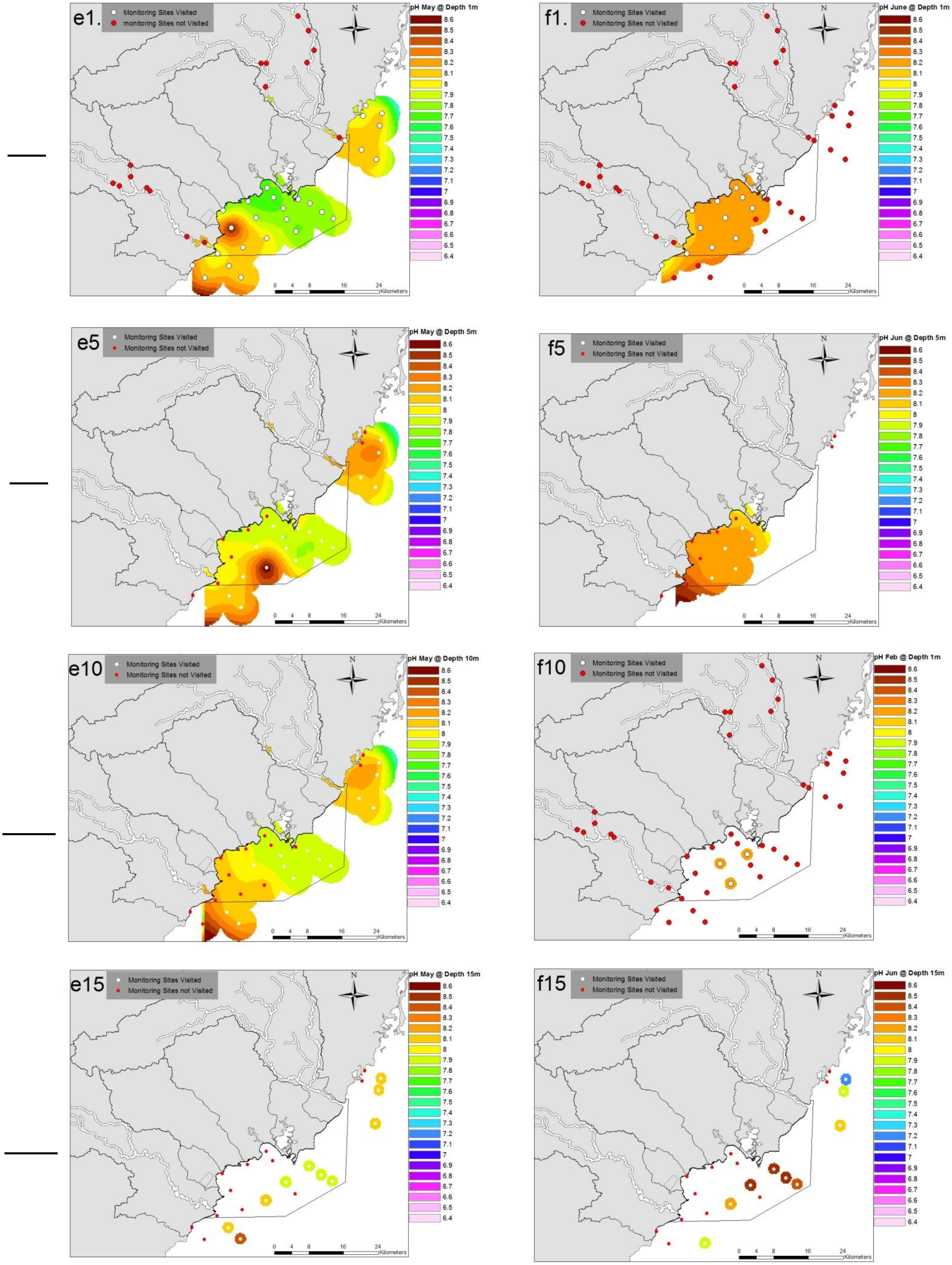




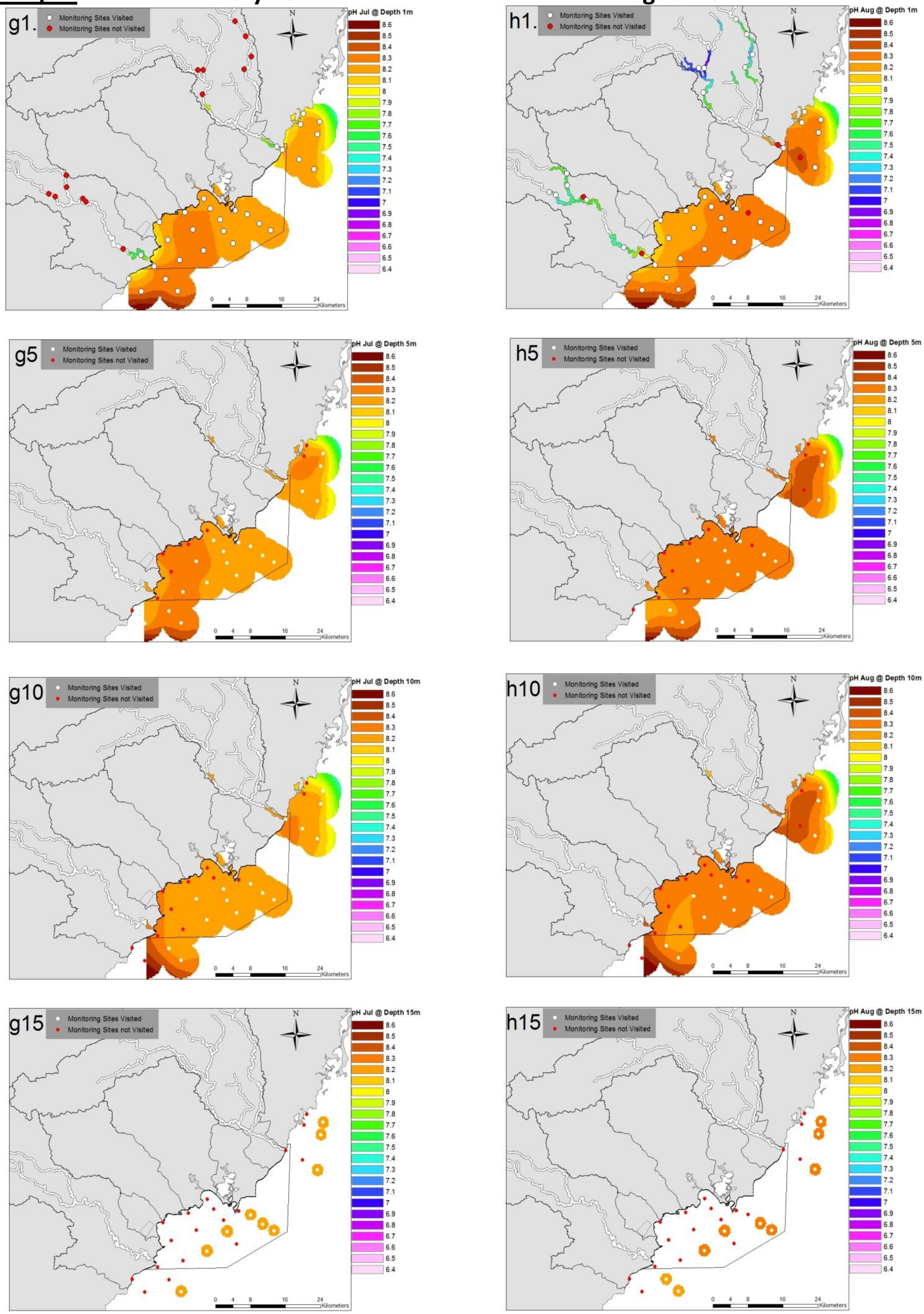




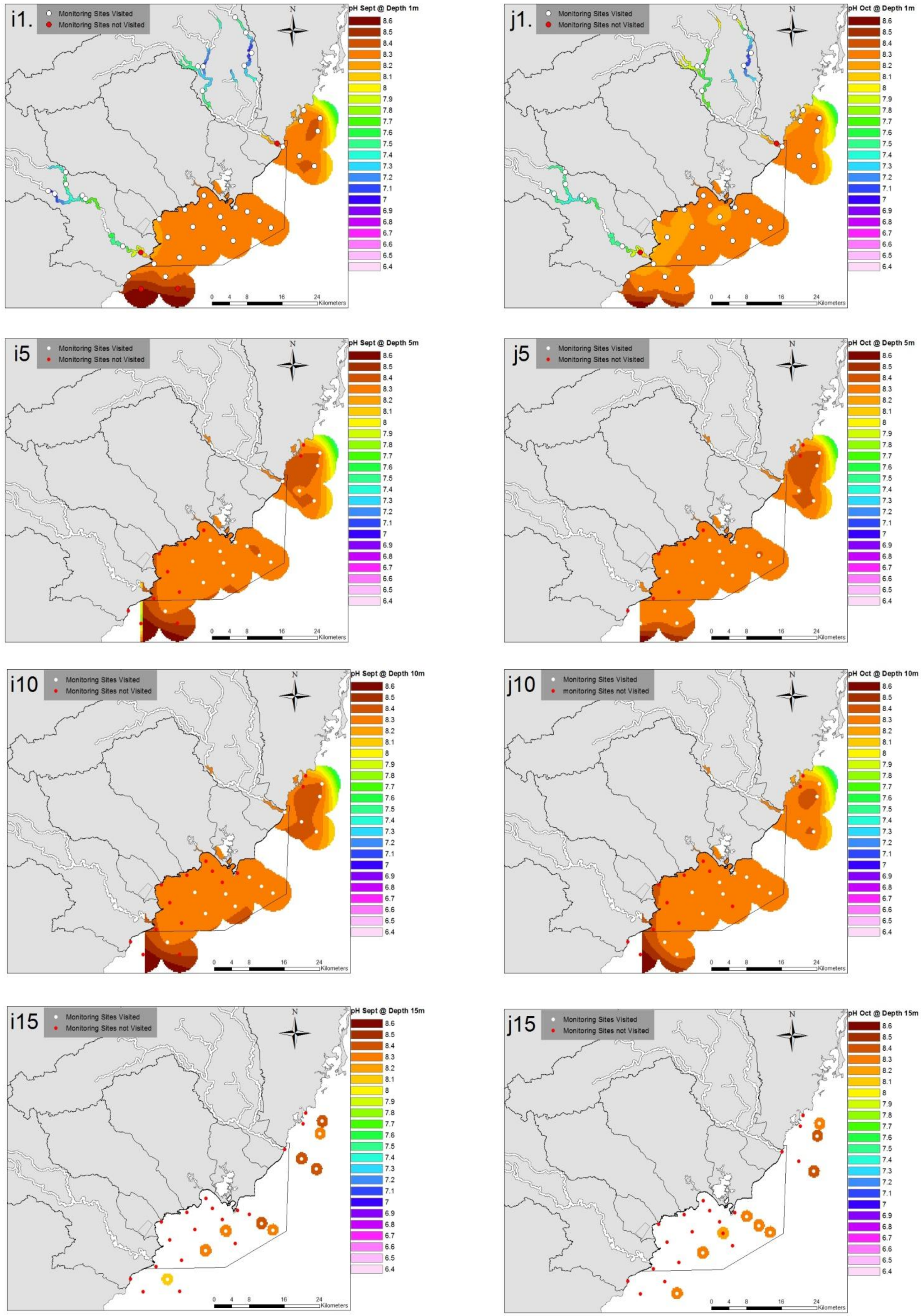
4.2 e,f : pH: May 2014 June 2014



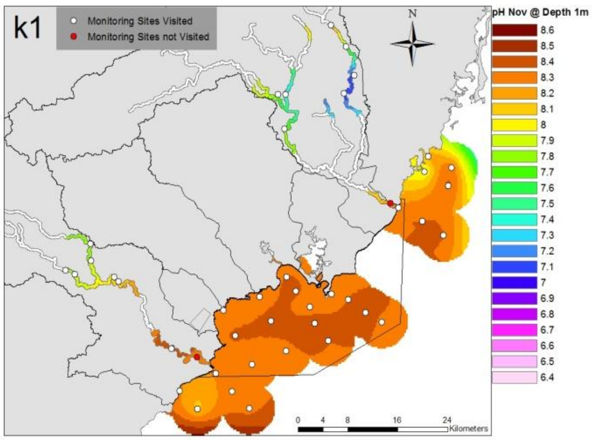
4.2 g, h : pH: July 2014 August 2014

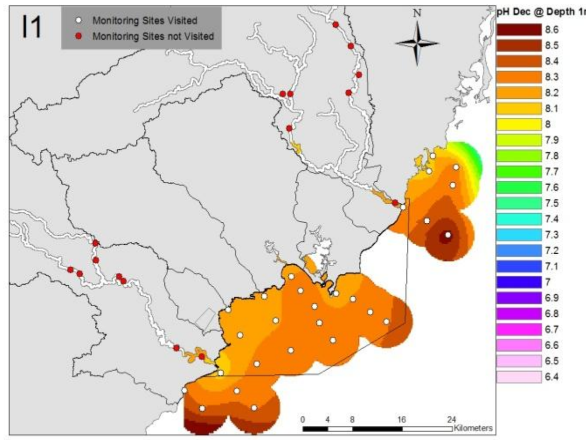


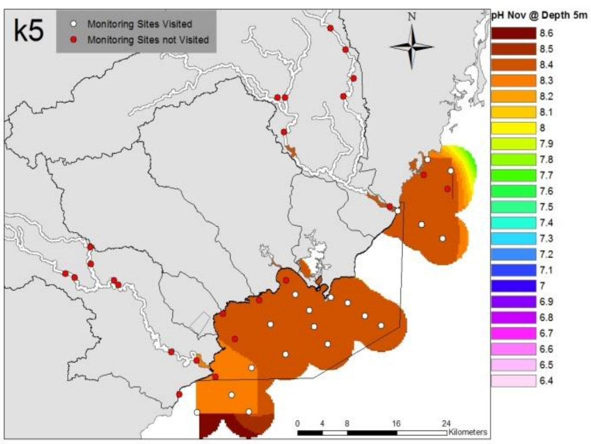
4.2 i, j : pH: September 2014 October 2014

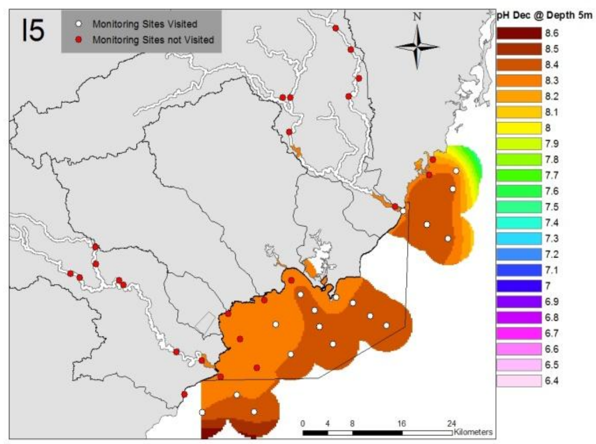


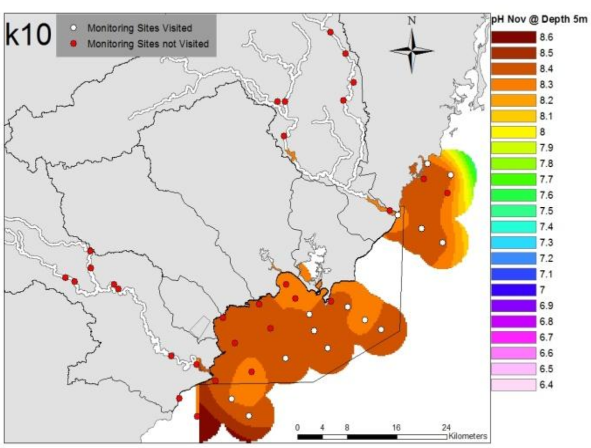
4.2 k, l: pH: November 2014 December 2014

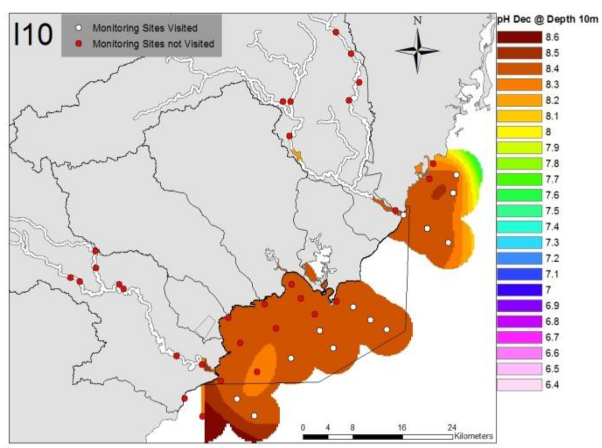


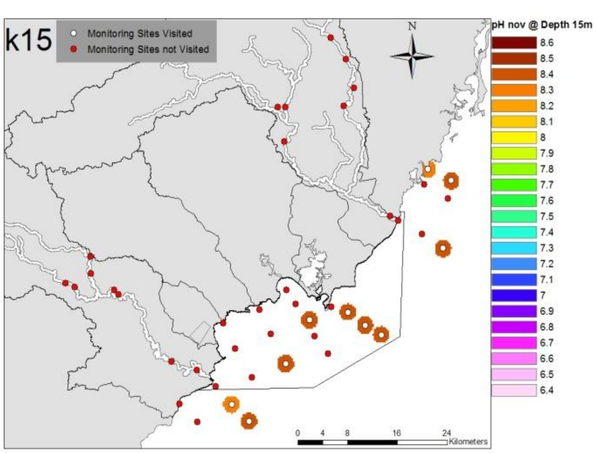


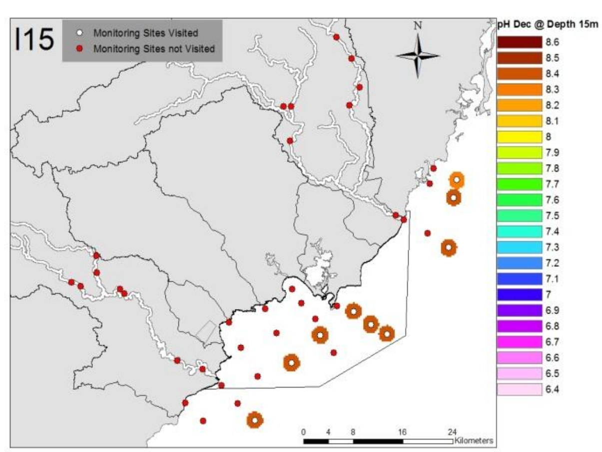












4.3 pH - General conclusions:

- pH values in PHMR dropped significantly in May, 2014 and gradually increased throughout the rest of 2014.

- Variability between sites was greater in the first half of 2014, which was observed at all depths. However, the spatial variability stablised after June 2014.

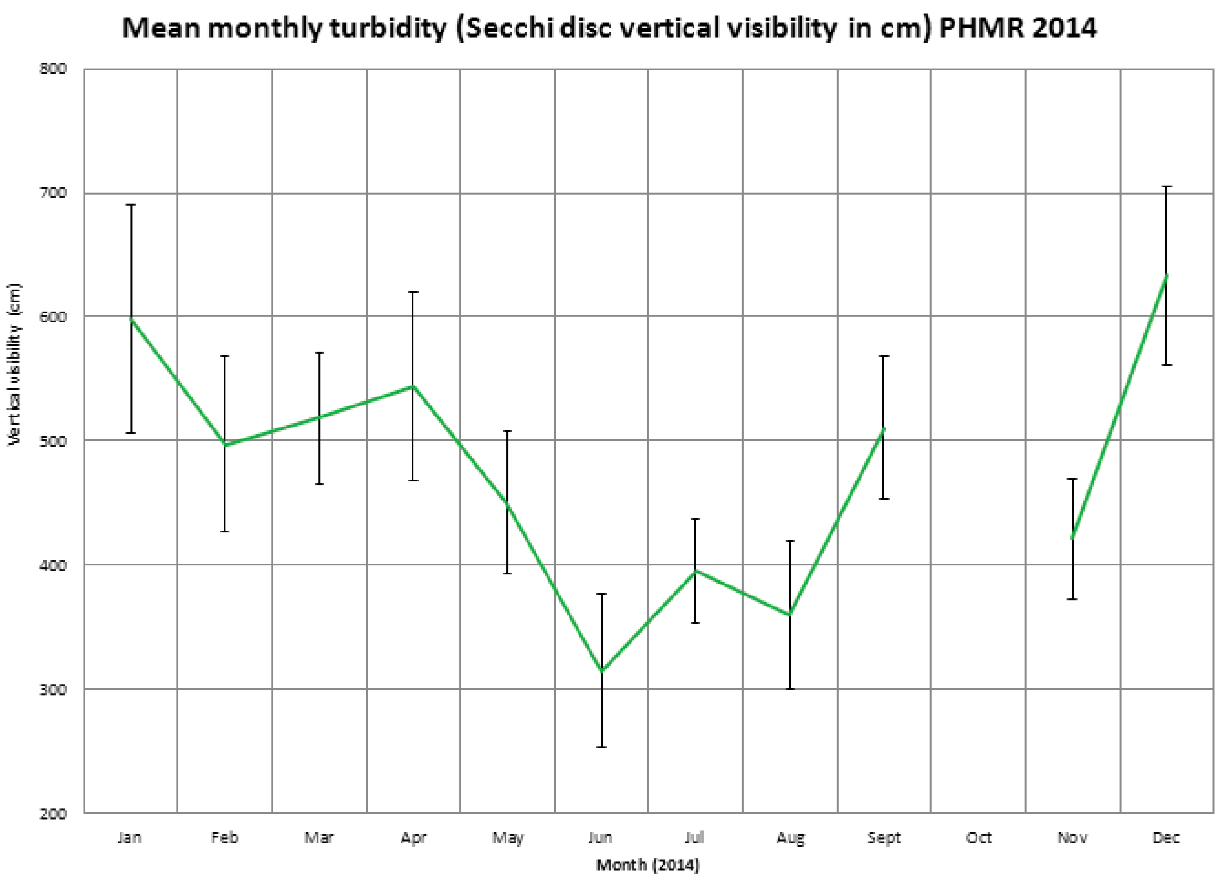
- Times of high river discharge coincided with lower (more neutral) pH in PHMR close to river mouths.

- In general pH is considerably more neutral in the upper streams of the rivers than lower streams and in the sea.

5. Visibility

5.1 2014 Mean monthly visibility (Fig. 4.1):

Note, no visibility data is collected for Rio Grande and monkey River



- Overall there was a loose trend of higher mean visibility in PHMR in January (598.1cm + 92.3 SE) and December (633.3cm + 72.5 SE), dropping steadily from April (513.6cm + 64.6 SE) to June (315cm +61.9 SE), and rising again thereafter, although no data is available for October 2014.

- Spatial variability in visibility across PHMR was similar each month.

5.2 Visibility 2014 PHMR (Fig. 5.2: Maps a-l):

- **January (Fig. 5.2 a):** Visibility increased with increasing distance from shore, being poorest around Middle River/ Golden Stream mouths (~100cm), and greatest at furthest offshore sties south of PHMR and around Snake Cayes (>1800cm).

- **February (Fig. 5.2 b):** Visibility was poor (100-200cm) in nearshore areas from Joe Taylor Creek mouth to Deep River mouth, and north of Monkey River mouth. Conditions improved with increasing distance from shore in all areas, but less so than January. Best visibility again at Snake Cayes (>1800cm).

- **March (Fig. 5.2 c):** Visibility again increased throughout PHMR with increasing distance from shore. There was less spatial variability than previous months, with nearshore conditions better than before (~200-300cm) and poorer than previous months offshore (Snake Cayes 800-900cm).

- **April (Fig. 5.2 d):** Visibility again increased throughout PHMR with increasing distance from shore. Poorer visibility extended out from the coast further than previous months, with only East Snake Caye and sites offshore adjacent to Monkey River mouth exceeding 1000cm.

- **May (Fig. 5.2 e):** Conditions very similar to March, with conditions slightly improved in central regions of PHMR compared with April. Snake Cayes visibility ~900cm.

- **June (Fig. 5.2 f):** No data available for northern part of reserve due to bad weather. Visibility worsened in southwestern regions of PHMR, but conditions improved more rapidly than May with increasing distance from shore.

- **July (Fig. 5.2 g):** July did not exhibit the typical trend observed in previous months. Conditions were poorest in the southwestern parts of PHMR, with better conditions in the central regions of PHMR extending from Frenchman Cayes to the coast between Middle River and Deep River mouths. Conditions did not exhibit much improvement with increasing distance from shore. Conditions in the north were more uniform than previous months also.

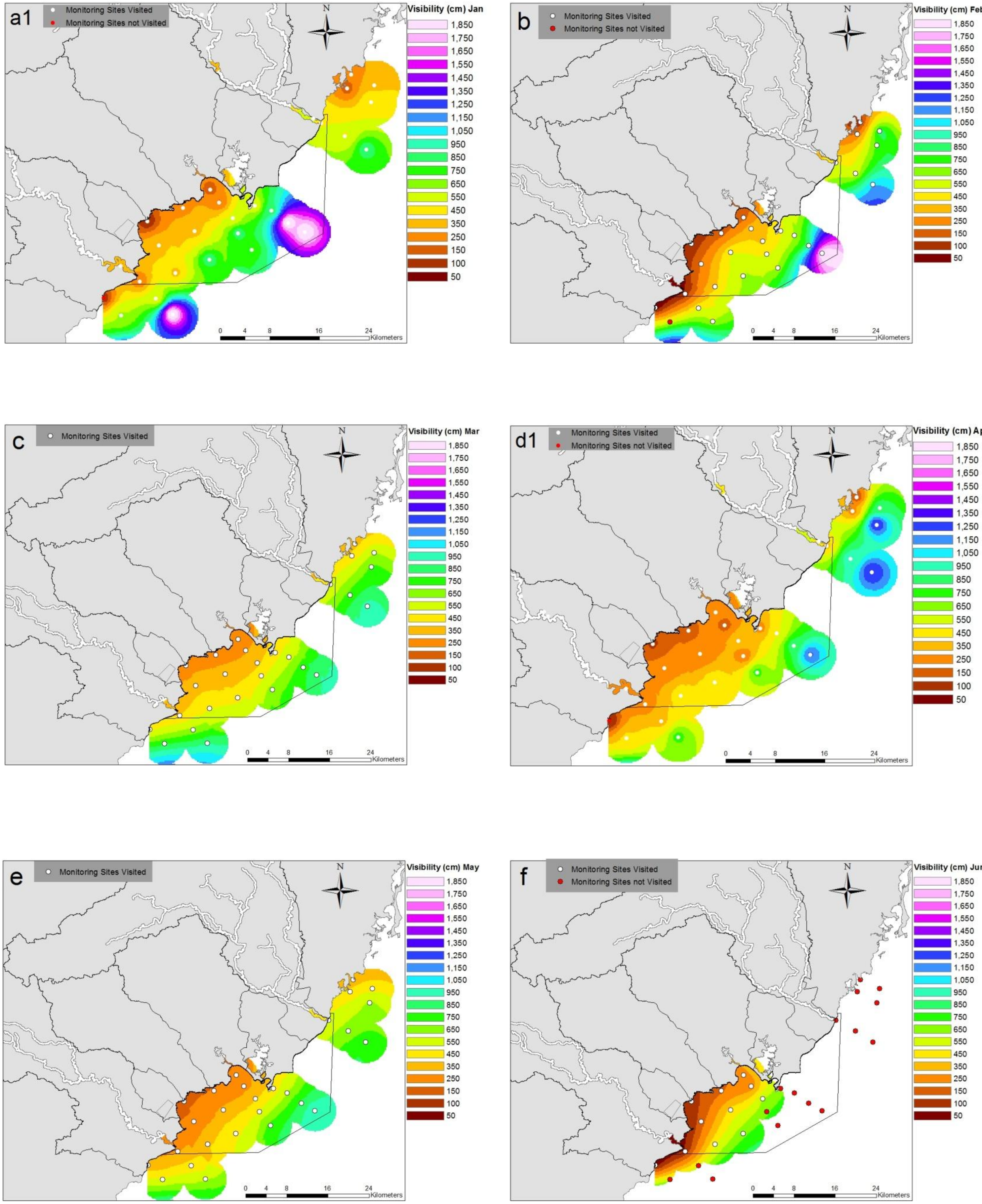
- **August (Fig. 5.2 h):** There was greater spatial variability with isolated pockets of better and poorer visibility throughout PHMR. Poorest conditions were seen outside Rio Grande mouth, Deep River mouth and coastal areas north of Monkey River mouth. Best visibility around Snake Cayes (~1400cm).

- **September (Fig. 5.2 i):** Conditions improved in the central region of PHMR (~600-700cm) with poorest visibility confined to coastal nearshore areas between Rio Grande mouth and Middle River mouth. Generally better visibility than previous months in nearshore areas.

- **October (Fig. 5.2 j):** No data is available for October 2014 visibility due to technical constraints.

- **November (Fig. 5.2 k):** Typical gradient increasing from nearshore to offshore sites throughout the reserve, with coastal areas 100-200cm, and furthest offshore sites 600-700cm.

- **December (Fig. 5.2 l):** Low visibility confined to coastal areas throughout the reserve (100-200cm), with much improved conditions throughout offshore sites from Frenchman to Snake Cayes (~1200-1300cm).



a1
Monitoring Sites Visited
Monitoring Sites not Visited
Visibility (cm) Jan
b
Visibility (cm) Feb
c
Visibility (cm) Mar
d1
Visibility (cm) Apr
e
Visibility (cm) May
f
Visibility (cm) Jun
1,850
1,750
1,650
1,550
1,450
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1,250
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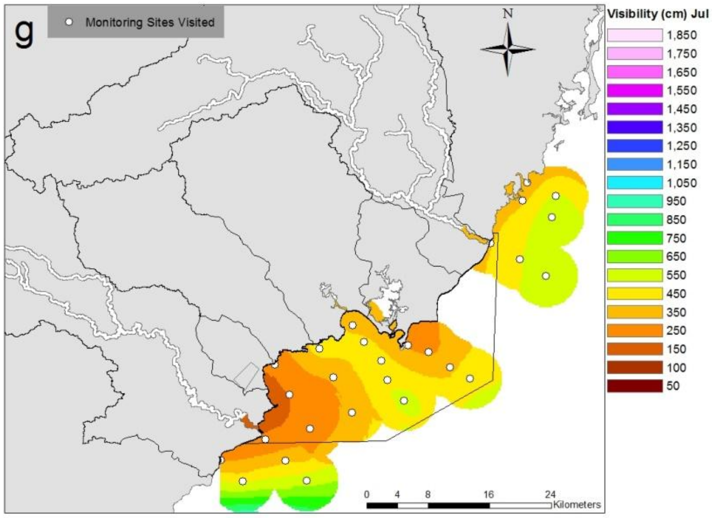
g
Monitoring Sites Visited
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Visibility (cm) Jul
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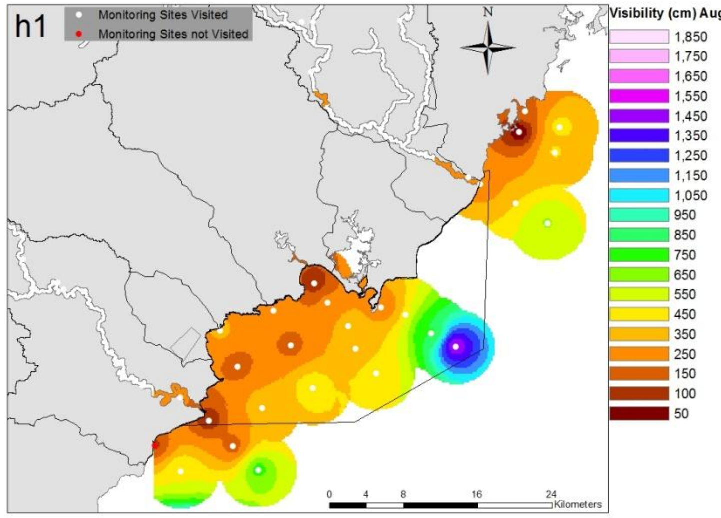
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Monitoring Sites Visited
Monitoring Sites not Visited
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Visibility (cm) Aug
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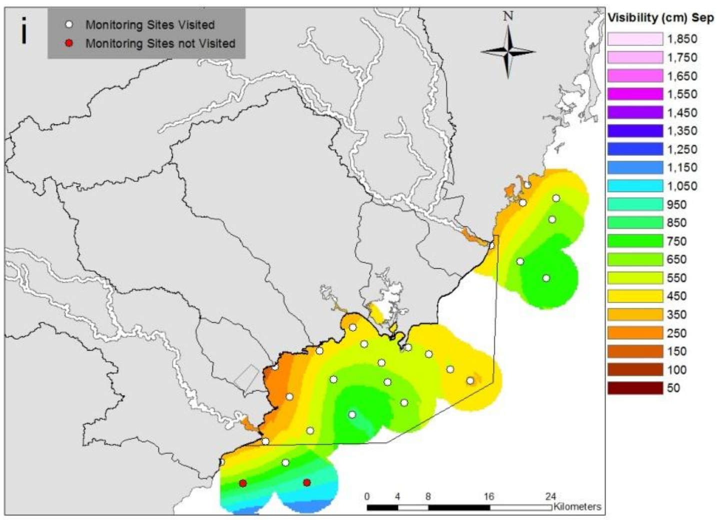
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Monitoring Sites Visited
Monitoring Sites not Visited
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Visibility (cm) Sep
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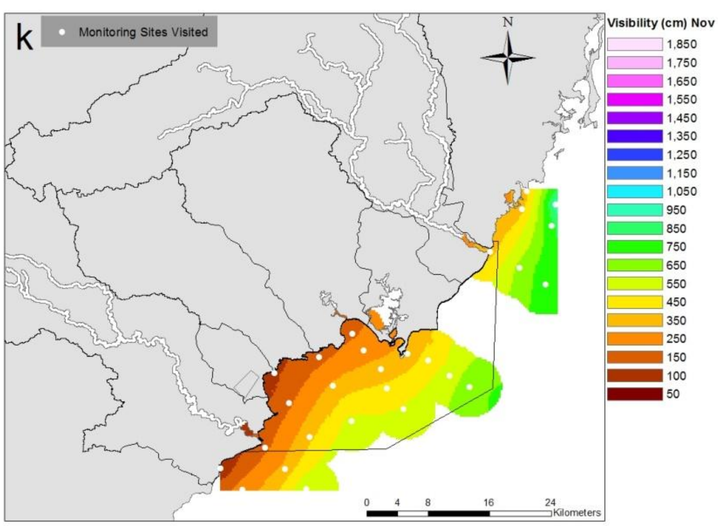
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Monitoring Sites Visited
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Visibility (cm) Nov
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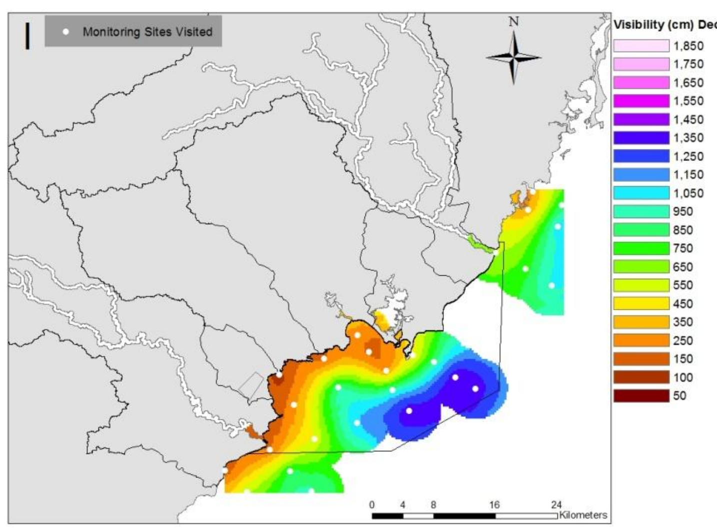
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Monitoring Sites Visited
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Visibility (cm) Dec
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950
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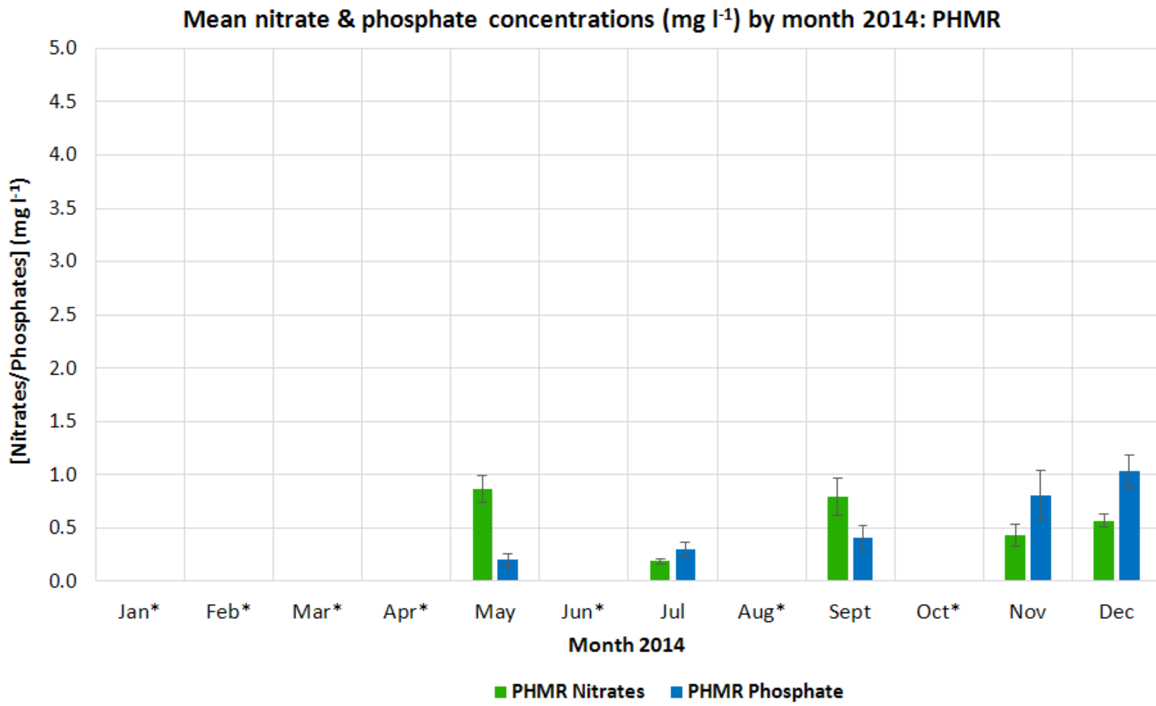
0 4 8 16 24 Kilometers

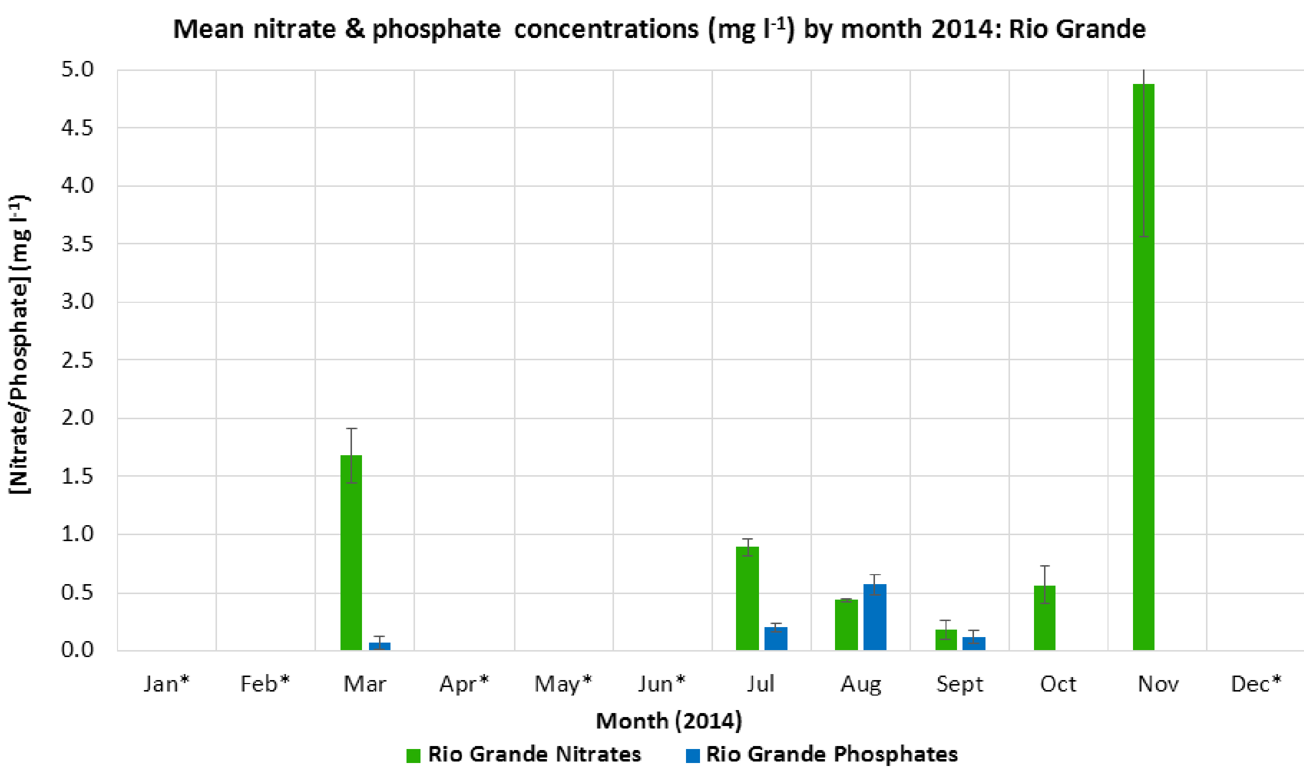
5.3 Visibility – General Conclusions:

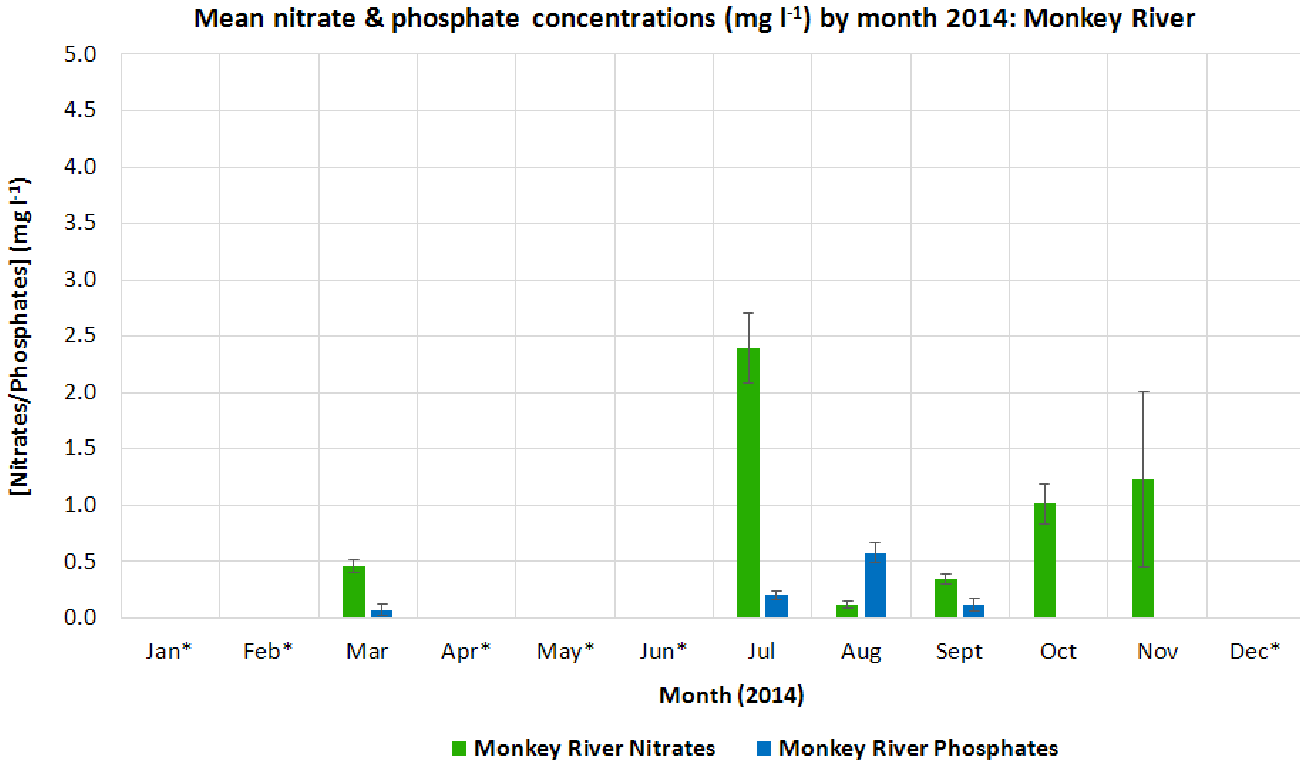
- Overall there is not an obvious trend in mean visibility over each year 2009-2014. Visibility can be influenced by many factors on a daily basis.. The general trend is that visibility increases further from shore, with offshore visibility worsening and becoming more like inshore areas during periods of high river discharge, rainfall or wind.

6. Nutrient Analysis: Nitrate & Phosphates:

6.1 Mean surface nutrient concentrations (nitrates and phosphates) by month 2014, PHMR, Rio Grande, Monkey River:







For both phosphates and nitrates, no data is available for the following months in the following locations:

- *PHMR: January, February, March, April, June August or October.*
- *Rio Grande: January, February, April, May, June, November and December.*
- *Monkey River: January, February, April, May, June, November and December.*

- **PHMR (Fig. 6.1a):** Phosphates increased over May-December, while nitrates were highest in May and September.

- **Rio Grande (Fig 6.1b): Nitrate values decreased from March-September followed by a significant increase in November to 4.88 mgl^{-1} $\pm$ 1.32 SE.** Phosphates were relatively low in March July and September, however there was an increase in November to a value greater than 0.5 mgl^{-1}.

- **Monkey River (Fig 6.1c):** Nitrate levels were low in March, rising in July to 2.39 mgl^{-1} $\pm$ 0.31 SE. This was followed by a decrease in August to less than 0.5 mgl^{-1} and a continued increases in the following months leading up to November (1.23 mgl^{-1} $\pm$ 0.8 SE). Phosphate levels were generally low with the exception of August (0.57 mgl^{-1} $\pm$ 0.1 SE).

6.2 Nitrate 2014 PHMR (Fig. 6.2: Maps a-l):

- **March 2014 (Fig 6.2c):** Nitrate levels were high on the Columbia Branch of Rio Grande at RG_CB_1b with levels ~1.60 mgl^{-1} and higher at RG_SM_1b and RG_RG_1c with levels between 1.61 and 2.00 mgl^{-1}. Higher than usual levels were also seen in lower reaches of Rio Grande. Monkey River had low levels. No data was available for PHMR.

- **May 2014 (Fig 6.2e):** No data available for the Rio Grande and Monkey Rivers. Nitrate levels were low in PHMR ranging from 0.41 to 0.81 $mg\ l^{-1}$.

- **July 2014 (Fig 6.2g):** The highest nitrate levels recorded for the year were seen in both the Bladen and Swasey branches of Monkey River at MR_TB_1a, MR_BB_1b, and MR_SB_1d with values between 2.01 and 3.00 and mgl^{-1}. Levels in PHMR were low.

- **August 2014 (Fig 6.2h):** Nitrate levels were low in Rio Grande (0.41 and 0.80 mgl^{-1}) and very low in Monkey River (0.41 and 0.80 mgl^{-1}). No data available for PHMR due to logistical constraints.

- **September 2014 (Fig 6.2i):** Low levels were observed in both fresh water and marine monitoring sites. The exception being at site 5E in PHMR where levels were notably higher, at a value between 1.21 and 1.60 mgl^{-1}.

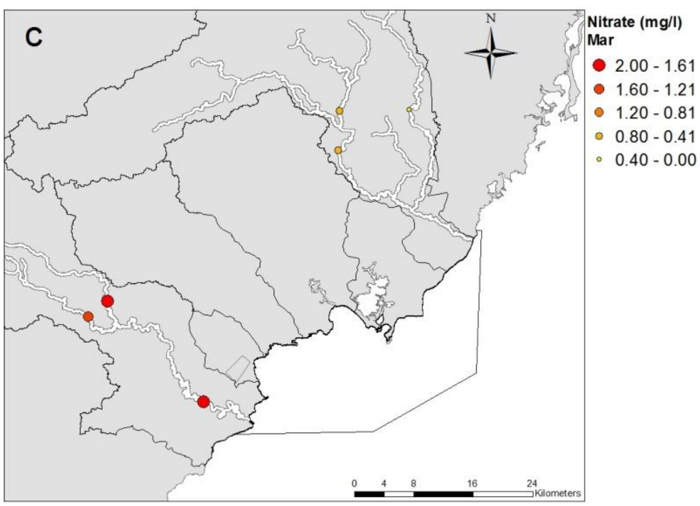
- **October 2014 (Fig 6.2j**): Nitrate levels increased from the previous two months on both Rio Grande and Monkey River. However only MR_TB_1a (Trio branch) rose higher than 1.21 mgl^{-1}. No data available for PHMR.

- **November 2014 (Fig 6.2k):** No data available for Rio Grande and Monkey River. Levels of nitrate in PHMR were low.

- **December 2014 (Fig 6.2l**): No data available for Rio Grande and Monkey River. Levels of nitrate in PHMR were low.

Spectrophotometer sent away for servicing

Spectrophotometer sent away for servicing



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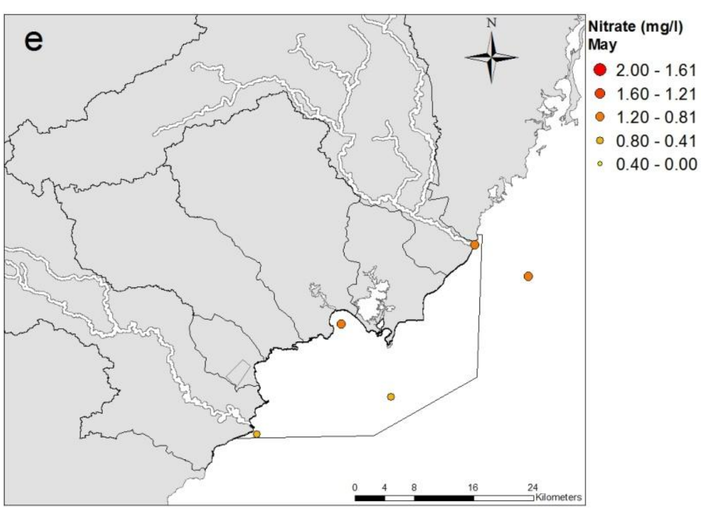
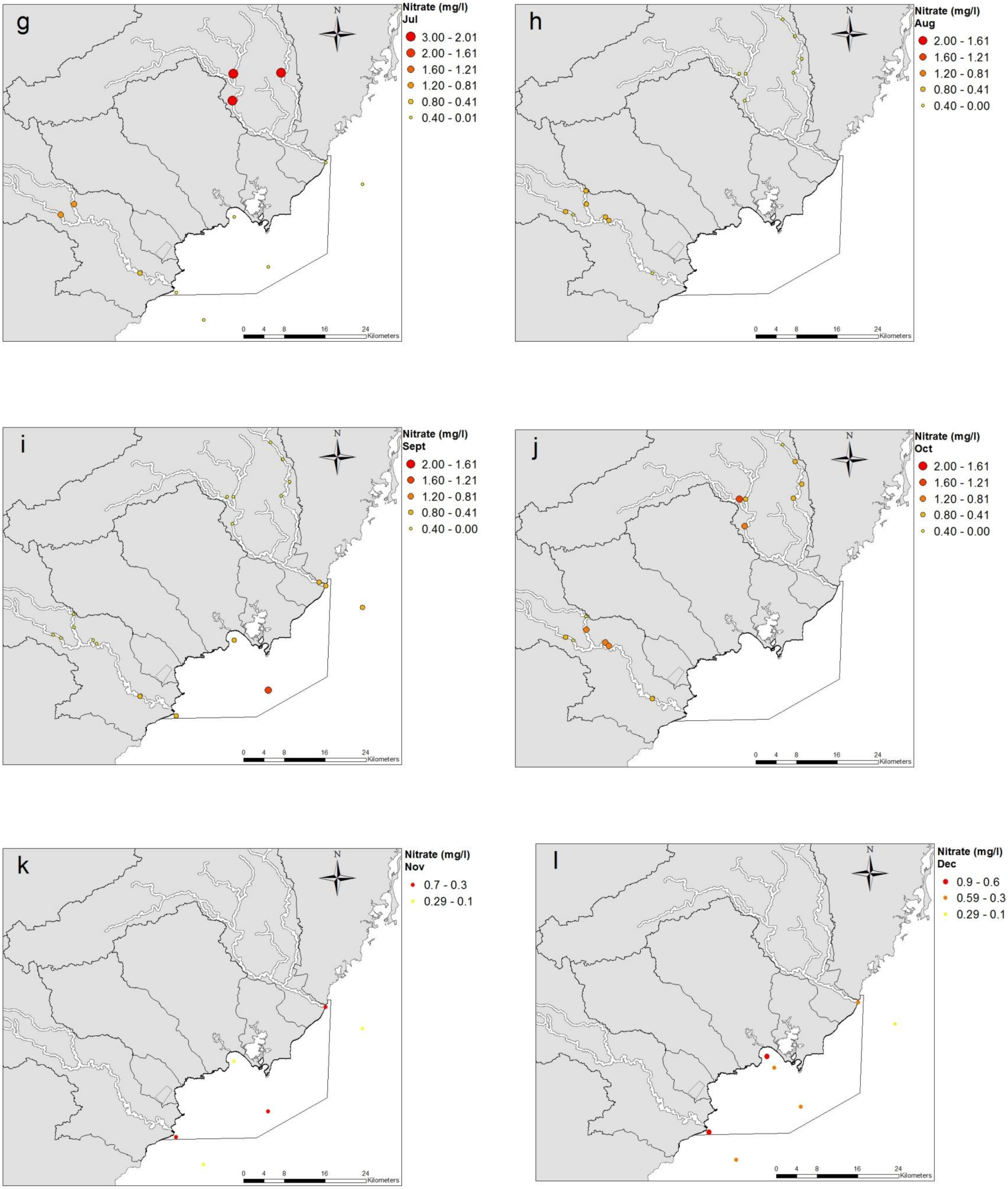
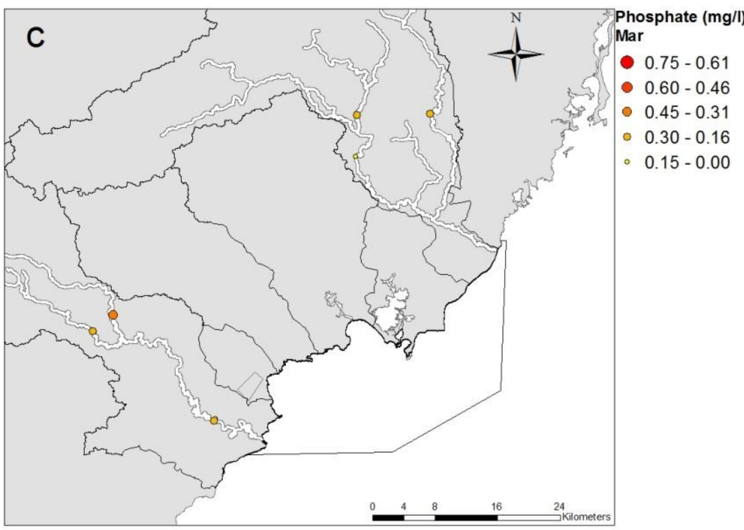


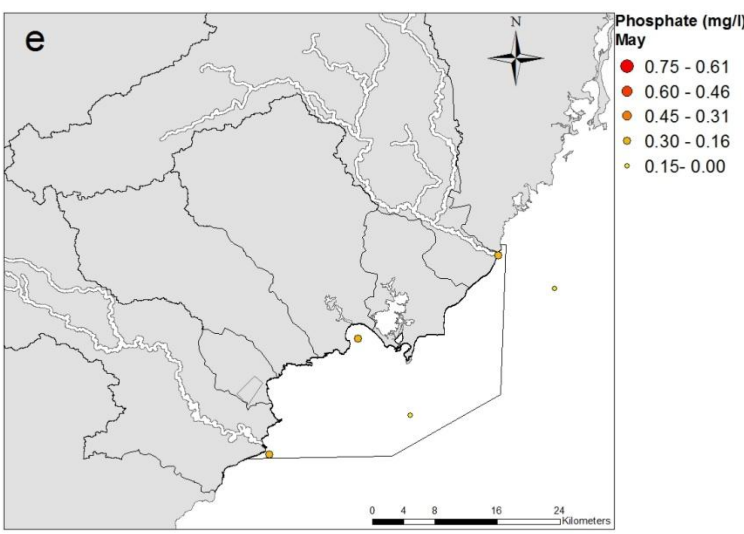
Spectrophotometer sent away for servicing

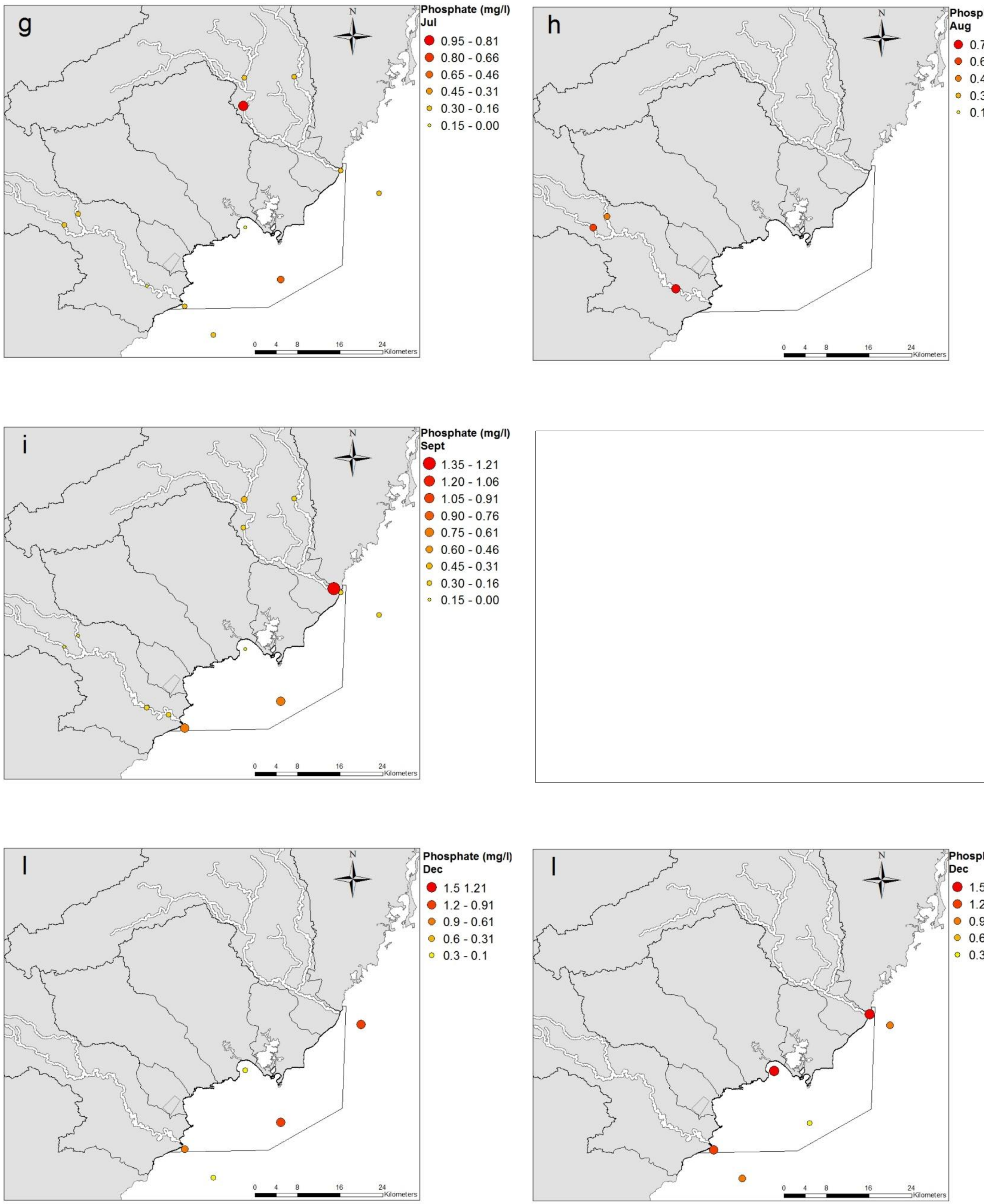

g
Nitrate (mg/l)
Jul
3.00 - 2.01
2.00 - 1.61
1.60 - 1.21
1.20 - 0.81
0.80 - 0.41
0.40 - 0.01
h
Nitrate (mg/l)
Aug
2.00 - 1.61
1.60 - 1.21
1.20 - 0.81
0.80 - 0.41
0.40 - 0.00
i
Nitrate (mg/l)
Sept
2.00 - 1.61
1.60 - 1.21
1.20 - 0.81
0.80 - 0.41
0.40 - 0.00
j
Nitrate (mg/l)
Oct
2.00 - 1.61
1.60 - 1.21
1.20 - 0.81
0.80 - 0.41
0.40 - 0.00
k
Nitrate (mg/l)
Nov
0.7 - 0.3
0.29 - 0.1
l
Nitrate (mg/l)
Dec
0.9 - 0.6
0.59 - 0.3
0.29 - 0.1
N
0 4 8 16 24
Kilometers

6.3 Phosphate 2014: Surface - PHMR, Monkey River, Rio Grande:

- **March 2014 (Fig 6.3c):** Phosphate levels were relatively low and constant at the fresh water monitoring sites. This excludes RG_SM_1b (San Miguel branch of Rio Grande) which had a value between 0.31 and 0.45 mgl^{-1}. No data available for PHMR.
- **May 2014 (Fig 6.3e):** No data available for the Rio Grande and Monkey Rivers. Phosphate levels in PHMR were low.
- **July 2014 (Fig 6.3g):** Phosphate levels were high at a value between 0.81 to 0.95 mgl^{-1} at MR_BB_1b (Bladen branch of Monkey River). Other fresh water sites monitored were normal. Site 5E in PHMR is the only marine site that had values exceeding 0.46 mgl^{-1} for the month.
- **August 2014 (Fig 6.3h):** Data only available for Rio Grande. RG_CB_1b and RG_RG_1c had levels between 0.46 and 0.60 mgl^{-1} and 0.61 and 0.75 mgl^{-1} respectively. Moderate.
- **September 2014 (Fig 6.3i):** Relatively low levels of phosphate were seen in the fresh water monitored site, with the exception of lower Monkey River (MR_MR_1a 1.21 to 1.35 mgl^{-1}). PHMR sites 5E and 2A also had unusually high levels ranging from 0.61 to 0.75 mgl^{-1}.
- **November 2014 (Fig 6.3k):** No data available for both the Rio Grande and the Monkey Rivers. In PHMR, levels ranging from 0.61 to 1.20 mgl^{-1} were observed at 2A, 5E, and 7C with the latter two having the higher recorded values.
- **December 2014 (Fig 6.3l):** No data available for both the Rio Grande and the Monkey rivers. In general high levels of phosphate were seen in nearshore sites in PHMR close to river mouths - 2A, 5A, 7A had the highest values, ranging from 0.91 to 1.50 mgl^{-1}. Offshore sites were lower - sites 7C and 2C had values ranging from 0.61 to 0.90 mgl^{-1}.


c
N
Phosphate (mg/l)
Mar
0.75 - 0.61
0.60 - 0.46
0.45 - 0.31
0.30 - 0.16
0.15 - 0.00
0 4 8 16 24
Kilometers


e
N
Phosphate (mg/l)
May
0.75 - 0.61
0.60 - 0.46
0.45 - 0.31
0.30 - 0.16
0.15- 0.00
0 4 8 16 24
Kilometers


g
Phosphate (mg/l)
Jul
0.95 - 0.81
0.80 - 0.66
0.65 - 0.46
0.45 - 0.31
0.30 - 0.16
0.15 - 0.00
h
Phosphate (mg/l)
Aug
0.75 - 0.61
0.60 - 0.46
0.45 - 0.31
0.30 - 0.16
0.15 - 0.00
i
Phosphate (mg/l)
Sept
1.35 - 1.21
1.20 - 1.06
1.05 - 0.91
0.90 - 0.76
0.75 - 0.61
0.60 - 0.46
0.45 - 0.31
0.30 - 0.16
0.15 - 0.00
l
Phosphate (mg/l)
Dec
1.5 1.21
1.2 - 0.91
0.9 - 0.61
0.6 - 0.31
0.3 - 0.1
l
Phosphate (mg/l)
Dec
1.5 - 1.21
1.2 - 0.91
0.9 - 0.61
0.6 - 0.31
0.3 - 0.1
0 4 8 16 24 Kilometers

6.4 Nitrate and Phosphate: general conclusions:

- Nitrate levels in Rio Grande have increased notably compared with previous years. This could be a sign of increased human impact on Rio Grande watershed. In particular, higher than normal nitrate levels were seen throughout Rio Grande in March.

- Higher than normal nitrate levels were also seen in July 2014 in upper reaches of Monkey River, indicative of increased impact from agriculture in Bladen and Swasey branch areas.

- High phosphate levels were recorded at most river mouths in December. This may suggest high domestic waste input, with agriculture as another possible source.

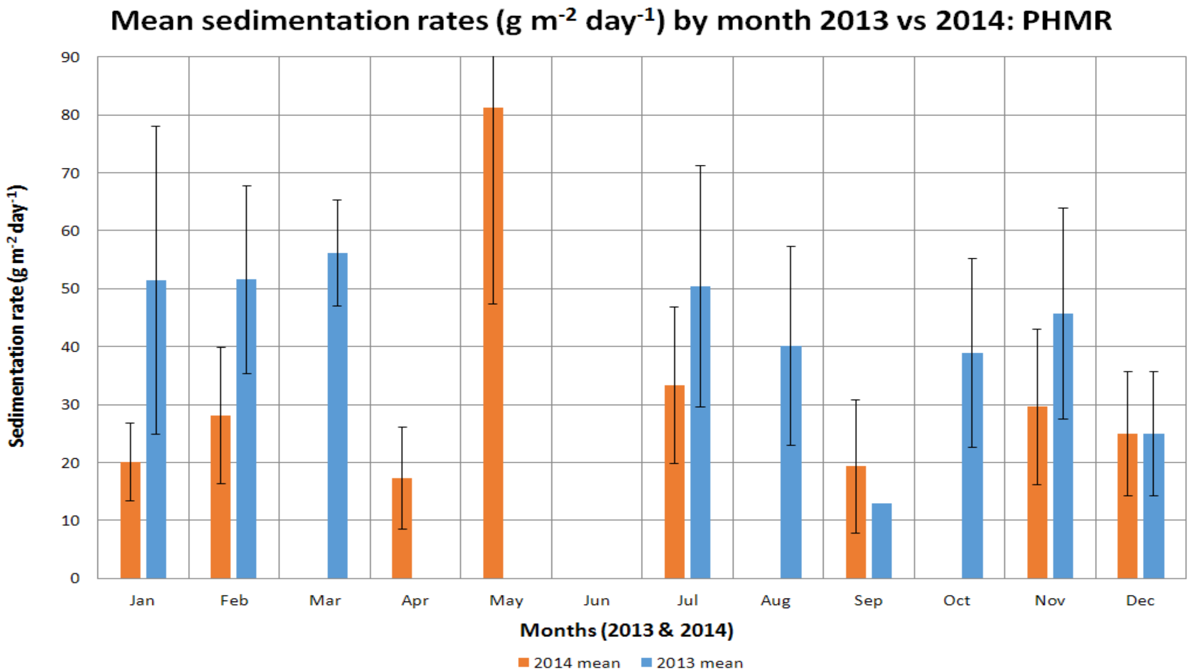
- There was a general increase in phosphate levels in PHMR throughout the second half of 2014. Phosphate levels were very high at mouths of Rio Grande, Deep River and Monkey River in December 2014.

- Higher nitrate levels occurred in both rivers in July and November. Phosphate levels peaked in August in both rivers according to available data.

7. Sedimentation

Note: no sedimentation data is collected for Rio Grande or Monkey River.

7.1 Mean sedimentation 2014 vs 2013 - PHMR:



- No data available for March, June, August or October due to technical issues.

- In general, sedimentation rates were significantly lower in 2014 than in 2013 throughout the year, with the exception of September 2014 which was higher than September 2013.

- Sedimentation rates were relatively low from January to April 2014, followed by a significant increase in May 2014 to over 80g m^{-2} day^{-1}. This may be due to rivers being flushed of the sediment that has accumulated in watersheds during the dry season, which gets washed out in the first major rains of the year in May.

- From July to December, sedimentation rates remained less than 35g m^{-2} day^{-1}, although this is higher than the period January to April. In 2013 the opposite trend was seen, with higher levels in the early part of the year.

7.2 Sedimentation maps 2014 – PHMR:

- **January 2014 (fig 6.2 a):** Sedimentation rates were low at offshore sites, with moderate levels seen at the mouth of Deep River.

- **February 2014 (Fig. 6.2 b):** Conditions very similar to January, with higher levels seen at mouth of Monkey River also.

- **March 2014 (Fig 6.2 c):** Only one data point available for PHMR – site 4C in centre of reserve – sedimentation levels low.

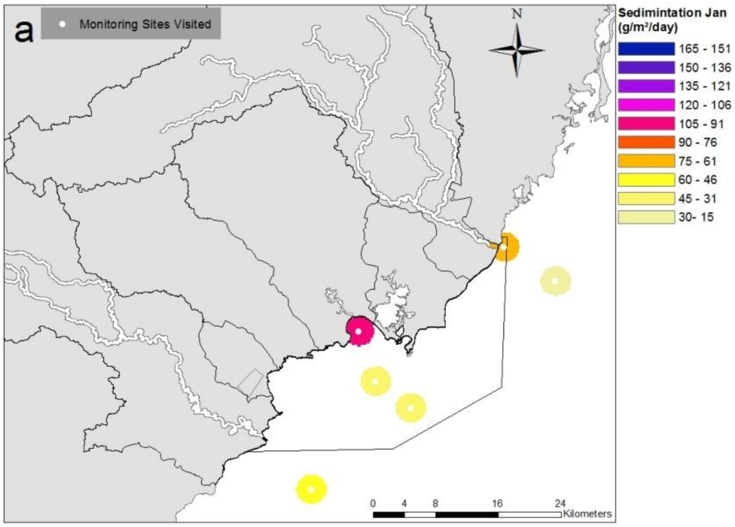
- **April 2014 (Fig 6.2 d):** Only one data point available for PHMR – site 4C in centre of reserve – sedimentation levels very low.

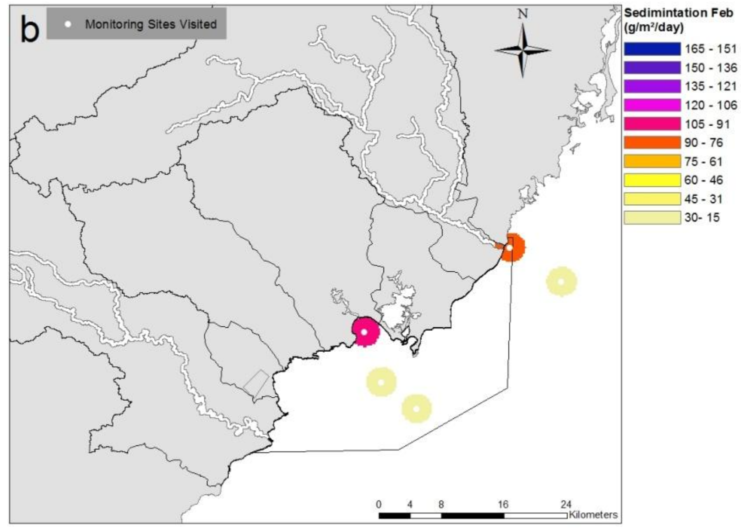
- **May 2014 (Fig 6.2 e):** Sedimentation rates higher than previous months, with moderately high levels seen outside mouths of Deep River and Monkey River. Exceptionally high levels offshore at site 5E are suggestive of an offshore, oceanic source of sedimentation, perhaps as a result of rougher weather depositing oceanic sediments in areas of outer PHMR.

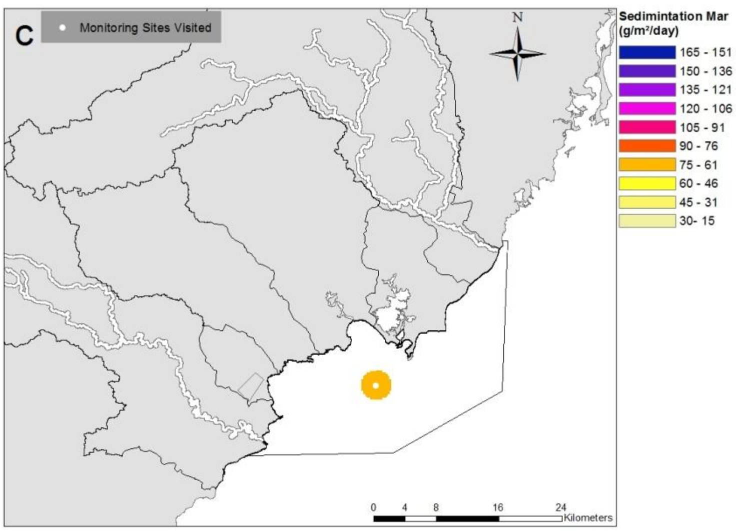
- **July 2014 (Fig 6.2 g):** Very high levels outside mouth of Monkey River, indicative of high sedimentation in Monkey River watershed at this time.. Central PHMR low, southern areas moderate.
- **September 2014 (Fig 6.2 i):** Moderate levels outside Monkey river mouth. Low in offshore areas of central PHMR. No data for other areas.

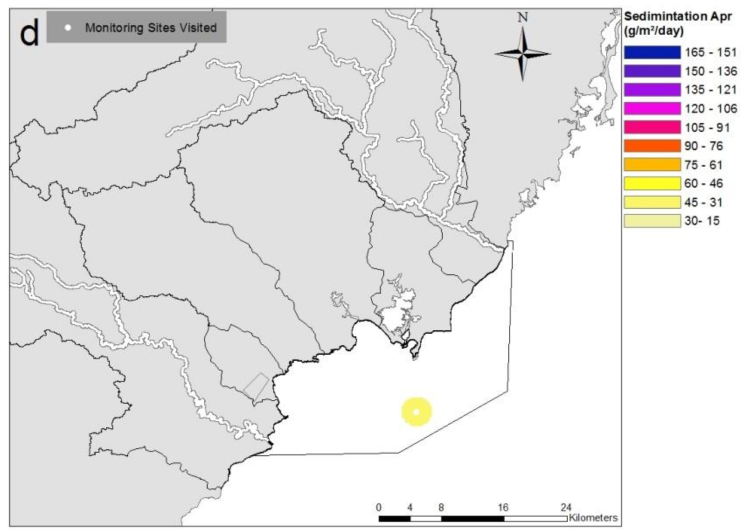
- **November 2014 (Fig 6.2 k):** Sedimentation levels low throughout PHMR where data available.

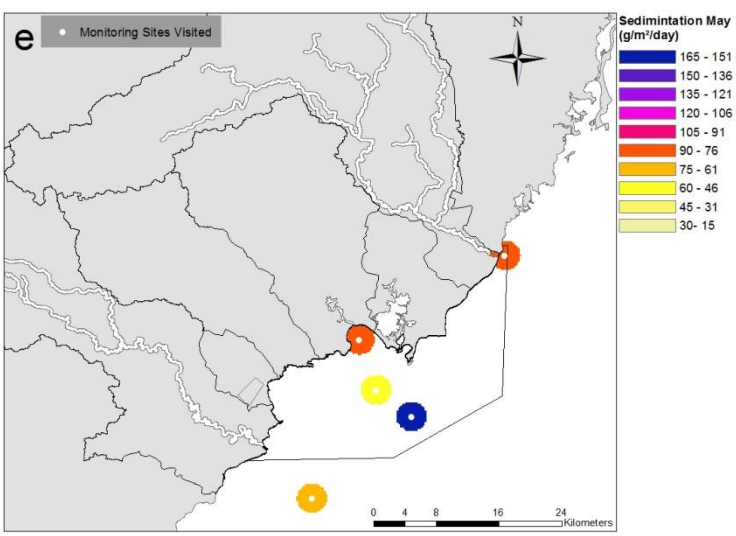
- **December 2014 (Fig 6.2 l):** Very low sedimentation levels outside mouths of Monkey River and Deep River. Higher levels at offshore sites adjacent to Monkey River and Rio Grande, more moderate in the south.

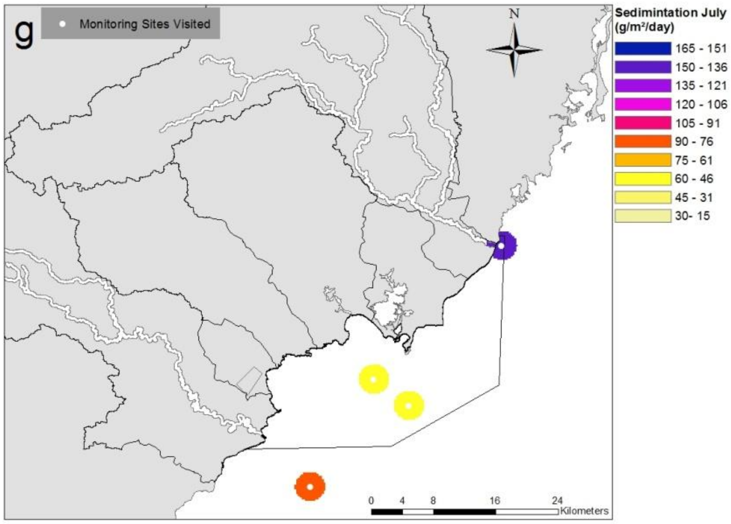

a
Monitoring Sites Visited
Sedimintation Jan
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
N
0 4 8 16 24
Kilometers

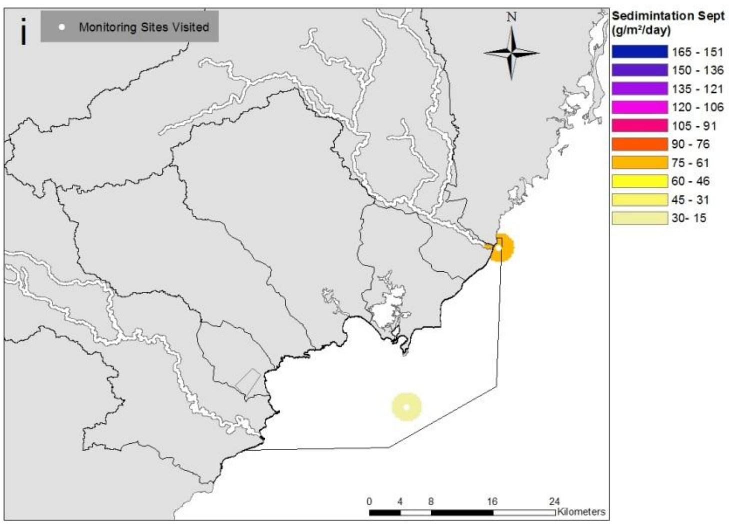

b
Monitoring Sites Visited
Sedimintation Feb
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
N
0 4 8 16 24
Kilometers

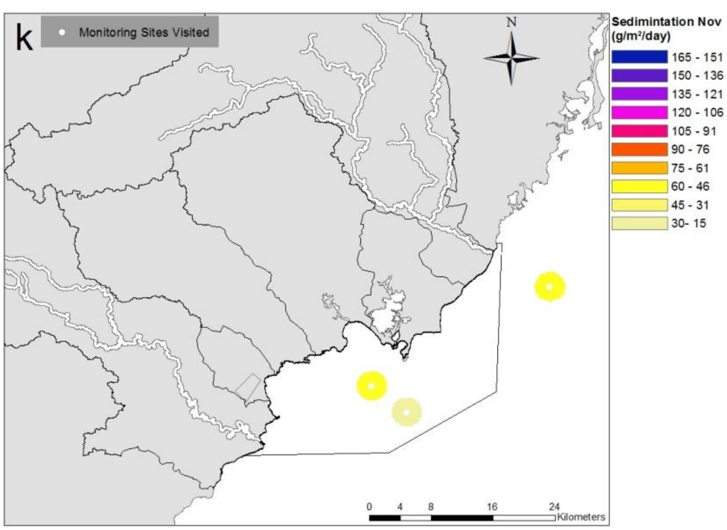

c
Monitoring Sites Visited
Sedimintation Mar
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
N
0 4 8 16 24
Kilometers

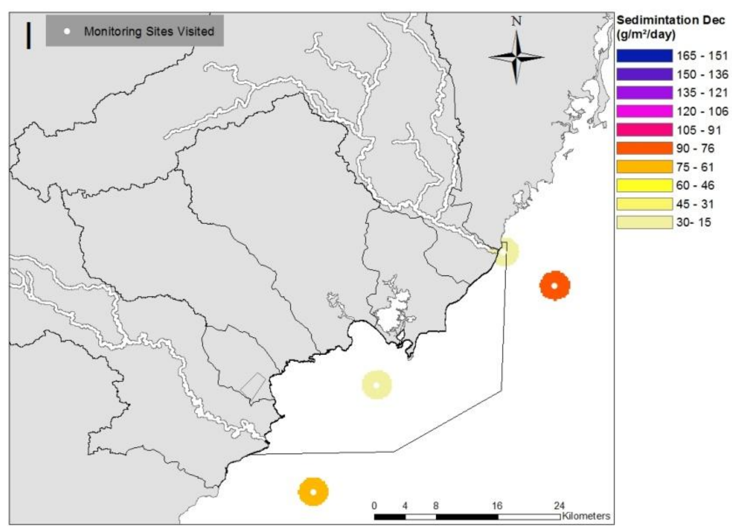

d
Monitoring Sites Visited
Sedimintation Apr
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
N
0 4 8 16 24
Kilometers


e
Monitoring Sites Visited
Sedimintation May
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
N
0 4 8 16 24
Kilometers


g
Monitoring Sites Visited
N
Sedimintation July
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
0 4 8 16 24
Kilometers


i
Monitoring Sites Visited
N
Sedimintation Sept
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
0 4 8 16 24
Kilometers


k
Monitoring Sites Visited
N
Sedimintation Nov
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
0 4 8 16 24
Kilometers


l
Monitoring Sites Visited
N
Sedimintation Dec
(g/m²/day)
165 - 151
150 - 136
135 - 121
120 - 106
105 - 91
90 - 76
75 - 61
60 - 46
45 - 31
30- 15
0 4 8 16 24
Kilometers

DISCUSSION

One objective of the water quality monitoring program is to determine baseline trends in water quality by comparing data over multiple years.

Overall sea surface cooling

- There has been a gradual decrease in mean overall temperature of PHMR since 2009 to 2013, which accelerated in 2014 (Fig.1.4).

- In the years 2009-2014, there were clear trends in temperature in PHMR (Fig. 1.4). Each year 2009-2014, mean surface temperature was low in January (~26.8°C), typically increasing each month to April. During April to September each year, temperatures remained relatively stable, fluctuating from ~30°C to~31°C from 2009 to 2012. After September, temperatures decreased to the end of each year, reaching ~27°C in December 2009 to 2012. While a similar trend is seen since 2012, overall conditions have started to cool since 2013, and 2014 had mean surface temperatures about a whole degree cooler throughout the year than any other year since 2009. Over the entire period, mean surface temperature has decreased by 1.3°C from 29.7°C to 28.4°C between 2009 and 2014. High rainfall and greater cloud cover may have been responsible for less warming effect on the sea surface in 2014.
- Cooler temperatures in recent years may have an impact on ecosystem dynamics, reproduction, spatial distribution and migration of fish including commercial species. Close monitoring alongside fisheries data is necessary to understand the effects this may cause.

- Interestingly, a similar cooling trend has been observed in Pacific waters in recent years: http://www.nature.com/nclimate/journal/v4/n3/full/nclimate2106.html.
 Further comparison with regional Caribbean and global ocean data is needed to affirm this observation.

- In general, PMHR is warmer than the rivers with few exceptions. Rio Grande has a much lower mean temperature than Monkey River. Both rivers tend to reach a low mean temperature at approximately 24.0°C in January or December. Both Rio Grande and Monkey River reach a high temperature around May in previous years (unfortunately no data available for rivers in April, May and June of 2014) however the increase is more pronounced in Monkey River, in 2013 reaching 29.1°C while the Rio Grande reached a high of 25.9°C.

Dissolved Oxygen higher on average in 2014

- Dissolved oxygen was less stratified by depth in the first part of 2014 than previous years. This could be as a result of less solar warming in the early part of the year than normal, as it is known that warmer conditions promote greater DO stratification, generally diminishing with increased depth. Overall however, DO concentrations were higher at the surface in 2014 than 2013 or 2012.

Salinity higher overall in 2014 than 2013, with typical stratification trends. Signs of increased discharge from Rio Grande.

- Salinity exhibited typical trends in 2014, being generally greatest and least stratified in the first quarter of the year. As conditions became warmer and wetter in the second and third quarters of the year, surface salinity dropped significantly, with freshwater influencing down to 10m depth at times.

There were signs of high discharge impacting a larger area with freshwater around the mouth of Rio Grande than previously observed. Signs of increased nitrate loading on Rio Grande in 2014 coincide to suggest higher impact from agricultural runoff. Higher discharge may be due to greater deforestation in the Rio Grande watershed.

Dissolved Oxygen and Visibility:

- No clear trends were observed over the last five years in dissolved oxygen or visibility. For visibility, this could be due to several factors including variable cloud cover, sun angle, eyesight of different observers and sea state. TIDE has recently purchased a new YSI ProPlus meter which is capable of measuring total dissolved solids, a more reliable parameter upon which to infer turbidity. While this was not tested in 2014 due to field staff still learning how to use the equipment, it is hoped that this will elucidate trends in visibility in coming years. DO trends are thought to be more reliable now that the DO sensor cap is being regularly maintained. It is unknown whether this was being done regularly before 2011 but may be the cause of much greater fluctuation in DO readings prior to this time.

Natural or anthropogenic?

- A second objective of the water quality monitoring program is to understand and determine causes (natural and anthropogenic) of spatial and temporal fluctuations in water quality in PHMR and associated river systems. Monkey River continues to be more susceptible to seasonal changes compared to Rio Grande with respect to temperature increase. Both rivers reach a similar low temperature in January but Monkey River temperature was 4.3°C higher than Rio Grande in March, and continued in May at 4.0°C higher in July. This is possibly due to greater anthropogenic influences which have led to wider shallow profile compared to Rio Grande, supporting observations made in 2012 and 2013. See 2012 and 2013 TIDE water quality reports for further details. The effects of this on the ecosystem have yet to be assessed but warrant further targeted research to compare biodiversity of the two rivers. A baseline study of fish biodiversity and water quality by Esselman in 2001 could be used as a comparison, and Halvorson's (2014) ecosystem study of the Rio Grande can also help to inform this research question, to compare biodiversity between the two rivers and changes in each river over time.

- One point of concern in 2014 continues to be Bladen branch of Monkey River, which exhibited high levels of nitrates in July of 2014 during wet conditions. While this could be attributed to geology, it is known that this area is subject to rapid land use change and therefore closer attention is recommended, supporting research with outreach and education to communities in this area. Additionally, there appears to have been an increase in phosphates in Rio Grande since 2012, and a more recent increase in nitrates. Increased phosphates could be due to population increase in riparian zone buffer communities of Rio Grande watershed. Increased nitrates could be due to increased agriculture and clearing of land in the Rio Grande catchment area.

2014 RECOMMENDATIONS

A series of recommendations for stakeholder engagement, research and monitoring, reserve management, education and outreach and capacity building are provided below in light of the findings outlined in this report.

Stakeholder engagement:

- In order for TIDE's large amount of environmental data to be considered in EIAs and development plans, it is important to maintain good communication with the Department of Environment and industry stakeholders. This will enable TIDE to empower affected local communities by putting the tools and information in their hands to know what the long and short term environmental and socioeconomic impacts are, so that **stakeholders may participate in public consultations empowered with factual information upon which to base sound and ethical decision making for the betterment of livelihoods and the environment.**

- Engage with communities in the Bladen branch area and upper reaches of Rio Grande about riparian zone management, low impact farming methods and good sanitation.

- Consult with farmland owners in Bladen area to encourage transparent testing of waste water from their land, particularly in the second half of the year.

Research & Monitoring recommendations:

- **Include Deep River and Punta Ycacos in the fresh water quality monitoring program.** This large and near-flat basin contains vast amounts of water. Given the sheltered nature of the receiving marine environment around Deep River mouth, this area of PHMR may be more vulnerable to riverine impacts than areas around more exposed Monkey River and Rio Grande mouths. Furthermore, it is the **closest watershed to the Snake Cayes and associated Replenishment Zones (RZs)**, **an area of high ecological and economic importance due to its demonstrated function as a commercial species spawning, nursery and larval propagation site, and important for tourism as well. This is now more critical as Providence Energy's oil exploration plans may directly impact Deep River and Punta Ycacos lagoon in the near future. Capacity for achieving these objectives can be developed with TIDE's approaching group volunteer program "Ridge to Reef Expeditions",** which should also increase financial self-sustainability of watershed scale water quality monitoring and of TIDE as a whole. This is expected to begin mid-2014.

- The addition of pH to the suite of parameters measured in 2014 provided invaluable information about the impact of freshwater runoff and river discharge on the acidity of the sea, which may have important implications for calcareous shell building animals such as lobster and conch. It is recommended to increase parameters to include biological and chemical oxygen demand (BOD and COD), conductivity, total suspended solids, total dissolved solids and enterococci in accordance with template requirements for EIAs relating to oil development in protected areas. Monitoring frequency should also be increased.

- Excess nutrients can be devastating for sensitive coastal marine ecosystems. Continued monitoring is needed to determine principal sources of nutrients and other contaminants into PHMR, and how these change over time, especially in light of impending oil development plans in the area.

- TIDE began using the YSI ProPlus multiparameter meter in 2014. This has enabled increased accuracy, and greater ease of data management. Also the new probe can monitor for total dissolved solids, a better parameter to measure than Secchi disc-based visibility, which is influenced by weather conditions, time of day, light conditions, user subjectivity etc. This will be implemented in 2015.

- Increase external collaboration to incorporate data from Middle River / Golden Stream with Ya'axche to improve understanding of marine data from close to the mouths of these rivers. The National Coral Reef Monitoring Network (NCRMN) is now spearheading the development of this plan on behalf of the CCCCC. As chair of the NCRMN for 2014, TIDE is guiding the development of the national level water qualty monitoirng strategy based on its experiences with water quality monitoing in PHMR and associated watersheds.

Management / outreach recommendations:

- Potential oil development is a new threat to PHMR, and with oil exploration concessions held by Providence Energy in PHMR and Payne's Creek, **TIDE must prepare for increased pressure to drill inside the boundaries of PHMR and other protected areas in the region by increasing water quality monitoring in the Deep River / Payne's Creek Lagoon area.**

- Educate inland communities about wide reaching downstream impacts of upstream unsustainable activities, using this report and satellite images of sediment plume from Monkey River.

- Education and outreach activities aimed at reducing watershed impacts can use the findings of this report to develop holistic ridge-to-reef educational courses and community based action projects. Improved understanding of environmental and socioeconomic interconnectivity can improve compliance and instill a sense of stewardship among key watershed stakeholder communities.

- Timely reporting of unusual water quality related phenomena, such as dissolved oxygen dead zones, eutrophication, fish die-offs, sargassum rafts and anything else that may occur, in order to improve awareness of TIDE's monitoring, and demonstrating its effectiveness at informing management, outreach and enforcement.

Fundraising / capacity building recommendations:

- This empirically based demonstration of the interconnectivity between land and sea can be useful in attracting funding into currently underfunded terrestrial monitoring activities. Marine monitoring has historically been better funded in Belize, probably because Belize is best known worldwide for its reef, even though it is one of the last strongholds for intact rainforests in Central America. If funders understand the impacts faced by the marine environment by land based activities, it may encourage more funding to address these impacts from parties most interested in marine affairs. TIDE is better positioned than other organisations managing marine reserves to manage land based impacts because adjacent watershed areas are also managed by TIDE (PCNP and PLI. Also, through cooperation with other local NGOs such as Ya'axché, human resource and site access issues could be resolved with partnerships. For example, Ya'axché are better positioned to monitor Deep River because their rangers routinely patrol Deep River Forest Reserve. A partnership would not only provide TIDE with data on currently unmonitored watersheds, but increase the utility of Ya'axché's monitoring, enabling both organisations to benefit from the larger scale context of their findings.

LIMITATIONS OF STUDY

- Sediment, nitrate and phosphate programs need to be expanded to improve statistical confidence and spatial interpretation of the data. Mid-sections of both rivers are currently under-represented. Site access is a limiting factor. A field visit is necessary to identify new sites in these sections. Further funding is needed to achieve this.

- While pH was added in 2014 to the suite of parameters measured, some important parameters are not currently being monitored under this program, e.g. conductivity, chemical oxygen demand, BOD, total suspended solids, total dissolved solids, enterococci. Some of these could be monitored easily with little extra cost besides purchasing inexpensive equipment, e.g. conductivity and suspended solids. The other parameters are a bit more complex to monitor, but very important as these are often required during an EIA process. If TIDE is to stand resilient against future development pressure inside PHMR and other protected areas, it needs to begin monitoring these as soon as possible. TIDE has now purchased a YSI ProPlus water quality meter to help address this.

- Fresh water monitoring of Deep River and Punta Ycacos lagoon is needed to better understand their relationship with PHMR, especially in light of the impending Providence Energy oil exploration proposal for the area.

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Appendix

Tables

Table 1a. Mean monthly temperature (°C) PHMR 1m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	27.0	30.0	32.0	32.0	30.0	31.0	31.0	31.0	31.0	30.0	26.6	27.2
1B	26.0		30.0	30.0	30.0		30.0	30.0		30.0	26.3	26.1
2A	26.0	28.0	31.0	30.0	29.0	30.0	30.0	29.0	30.0	29.0	26.0	24.0
2B	26.0	28.0	30.0	29.0	29.0		29.0	29.0	30.0	29.0	25.1	25.8
2C	26.0	28.0	30.0	29.0	29.0		30.0	29.0		29.0	26.9	26.1
3A	27.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	29.0	30.0	26.5	26.7
3B	25.0	29.0	30.0	30.0	29.0	29.0	30.0	30.0	29.0	29.0	26.1	25.9
3C	26.0	28.0	29.0	30.0	29.0	29.0	29.0	29.0	29.0	29.0	26.8	26.2
4A	25.0	29.0	29.0	29.0	30.0	29.0	30.0	30.0	30.0	29.0	26.2	26.2
4B	26.0	28.0	29.0	29.0	30.0	29.0	29.0	30.0	30.0	29.0	27.3	
4C	26.0	28.0	29.0	30.0	29.0	29.0	29.0	29.0	29.0	29.0	27.1	
5A	26.0	29.0	29.0	29.0	30.0	29.0	30.0	30.0	31.0	30.0	26.9	26.0
5B	26.0	28.0	29.0	29.0	29.0	29.0	29.0	30.0	30.0	29.0	25.4	25.7
5C	26.0	28.0	30.0	29.0	29.0	29.0		30.0	30.0	28.0	26.8	25.7
5D	26.0	28.0	29.0	29.0	29.0		29.0	30.0	39.0	29.0	27.0	25.9
5E	26.0	28.0	29.0	29.0	29.0		29.0	30.0	30.0	29.0	27.0	26.1
6A	26.0	28.0	29.0	30.0	29.0			30.0	30.0	29.0	28.0	25.8
6B	26.0	28.0	29.0	29.0	29.0				29.0	29.0	26.9	25.8
6C	26.0	28.0	29.0	29.0	29.0		29.0	29.0	29.0	28.4	26.8	25.9
6D	26.0	28.0	29.0	29.0	29.0		30.0	29.0	30.0	29.0	26.9	25.7
7A	26.0	28.0	29.0	30.0	29.0		29.0	29.0	30.0	29.0	27.3	25.4
7B	25.0	28.0	29.0	29.0	29.0		30.0		30.0	29.0	26.9	25.5
7C	26.0	27.0	29.0	29.0	29.0		29.0	29.0	30.0	29.0	26.9	25.5
8A	25.0	28.0	29.0	29.0	28.0		29.0	28.0	30.0	28.0	24.1	24.7
8B	25.0	28.0	29.0	29.0	29.0		30.0	29.0	30.0	29.0	27.0	25.2
9A	25.0	28.0	29.0	30.0	29.0		29.0	29.0	30.0	29.0	24.4	25.0
9B	25.0	28.0	29.0	29.0	29.0		30.0	29.0	30.0	29.0	27.2	25.2
Count	27	26	27	27	27	11	24	25	25	27	27	25
Mean	**25.8**	**28.2**	**29.4**	**29.4**	**29.2**	**29.4**	**29.5**	**29.5**	**30.2**	**29.1**	**26.5**	**25.7**
SD	0.56	0.65	0.75	0.70	0.48	0.67	0.59	0.65	1.91	0.49	0.88	0.63
SE	**0.11**	**0.13**	**0.14**	**0.13**	**0.09**	**0.20**	**0.12**	**0.13**	**0.38**	**0.09**	**0.17**	**0.13**

Table 1b. Mean monthly temperature (°C) PHMR 5m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1B	25.8		29.4	29.8	29.4		29.3	30.2		29.7	26.3	27.0
2B	25.9	28.1	29.5	29.3	29.5		29.1	29.2	29.9	29.3	25.8	26.8
2C	25.8	27.8	29.4	29.2	29.6		29.3	29.8		29.0	26.8	26.5
3B										30.3		
3C	25.7			29.7	29.7	29.1	29.1	29.8			27.1	
4B	26.0	28.2	29.1	29.1	29.8	29.9	28.9	29.7	30.1	28.9	27.4	26.3
4C	25.9	27.8	29.1	29.1	29.5	29.1	29.2	29.5	29.8	29.6	27.3	26.3
5B	25.7	27.9	29.3	29.0	29.4	29.3	29.8	29.9	30.1	29.5	27.2	26.4
5C	26.1	28.3	29.4	29.0	29.4	29.3		29.8	29.5	29.1	26.8	26.2
5D	25.9	28.0	29.2	29.2	29.4		29.2	29.7	29.6	29.2	27.0	25.7
5E	25.9	28.0	29.0	29.2	29.2		28.8	29.5	29.3	29.4	27.1	25.8
6A	26.2	28.1	29.3	29.4	29.5			29.6	29.6	29.3	28.0	25.5
6B	26.0	27.8	29.2	29.2	29.4				29.5	29.4	27.5	25.7
6C	25.6	27.8	28.9	29.2	29.2		29.3	24.6	29.3	28.6	26.8	25.7
6D	25.6	27.9	28.8	29.2	29.2		29.2	29.7	29.4	28.7	27.0	25.6
7A	25.6	28.0	29.4	29.4	29.4		29.2	29.5	29.5	29.7	27.5	25.4
7B	25.3	27.7	29.1	29.1	29.2		29.4		29.4	28.7	27.1	25.4
7C	25.6	27.6	28.9	29.0	29.1		29.3	29.4	29.6	28.8	27.0	25.5
8B	25.2	27.6	29.1	29.1	29.1		29.4	29.5	29.4	29.0		25.1
9B	25.1	27.7	29.2	29.1	29.1		29.4	29.5	29.4	29.1	27.2	25.2
Count	19.0	17.0	18.0	19.0	19.0	5.0	16.0	17.0	16.0	19.0	18.0	18.0
Mean	**25.7**	**27.9**	**29.2**	**29.2**	**29.4**	**29.3**	**29.2**	**29.3**	**29.6**	**29.2**	**27.1**	**25.9**
SD	0.3	0.2	0.2	0.2	0.2	0.3	0.2	1.2	0.3	0.4	0.5	0.6
SE	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**

Table 1c. Mean monthly temperature (°C) PHMR 10m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B	25.9	28.1	29.7	29.1	29.6		29.5	29.7	30.1	29.6	27.8	27.2
2C	25.7	27.8	29.4	29.2	29.5		29.5	29.8		29.7	27.0	26.7
4B	26.0	27.8	29.0	29.1	29.7	29.4	29.7	29.8	30.0	29.8		
4C	26.0	27.9	29.0	29.0	29.4	29.1	29.6	29.5	30.1	29.6	27.4	26.2
5C	26.4	27.9	29.2	29.0	29.5	29.3		29.7		29.7	28.2	
5D	26.2	27.7	29.1	29.0	29.4		29.7	29.8	29.3	29.7	27.7	25.7
5E	25.9	27.5	28.9	29.1	29.4		29.6	29.5	29.4		27.2	25.9
6B	26.1	27.5	29.1	28.9	29.4				29.4	24.8	28.4	26.0
6C	26.1	27.5	28.9	29.0	29.2		29.2	29.8	29.3	29.5	27.2	25.6
6D	26.4	27.7	28.7	29.1	29.3		29.2	29.7	29.4	29.6	27.2	25.7
7A	25.8	28.0	29.3	29.3	29.4		29.3	29.5	29.5	30.0	28.3	25.5
7B	25.5	27.7	29.1	29.0	29.3		29.4		29.4	29.8	27.5	25.4
7C	25.7	27.6	28.9	29.0	29.1		29.2	29.5	29.5	28.8	27.0	25.4
8B	25.3	27.6	29.1	29.1	29.1		29.5	29.6	29.4	29.8		25.2
9B	25.3	27.7	29.2	29.1	29.1		29.5	29.5	29.5	29.8	27.2	25.2
Count	15	15	15	15	15	3	13	13	13	14	13	13
Mean	**25.9**	**27.7**	**29.1**	**29.1**	**29.4**	**29.3**	**29.5**	**29.6**	**29.6**	**29.3**	**27.5**	**25.8**
SD	0.35	0.17	0.24	0.10	0.18	0.15	0.18	0.13	0.30	1.32	0.49	0.59
SE	**0.09**	**0.04**	**0.06**	**0.03**	**0.05**	**0.09**	**0.05**	**0.04**	**0.08**	**0.35**	**0.14**	**0.16**

Table 1d. Mean monthly temperature (°C) PHMR 15m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B					29.5			29.2	30.3		27.9	
2C	25.9		29.5	29.1			29.6	29.8		29.7	27.0	27.1
4C	26.0	27.9	29.1	28.9	29.4	29.2	29.4	29.6	29.9	29.5	28.2	26.2
5D	26.4	27.3	29.1	28.9	29.4		29.6	29.6	29.5	29.8		26.1
6B	26.4	27.5	29.1	28.9	29.4					29.6	28.5	26.9
6C	26.4	27.5	28.9	28.9	29.2		29.2	29.8	29.3	29.7	28.4	26.4
6D	26.4	27.7	28.7	28.9	29.4		29.1	29.7	29.3	29.7	28.2	26.1
7B									29.4			
7C	25.9	27.6	28.8	28.9	29.2		29.2	29.5	29.4	28.7	27.7	27.0
8A												
8B	25.4	27.8	29.1	29.0	29.1		29.4	29.6	29.6	29.8		27.0
9A											28.5	
9B	25.3	27.7	29.1	29.1	29.2				29.7	29.8	29.1	29.2
Count	9.0	8.0	9.0	9.0	9.0	1.0	7.0	8.0	9.0	9.0	9.0	9.0
Mean	**26.0**	**27.6**	**29.0**	**29.0**	**29.3**	**29.2**	**29.4**	**29.6**	**29.6**	**29.6**	**28.2**	**26.9**
SD	0.4	0.2	0.2	0.1	0.1		0.2	0.1	0.2	0.3	0.6	1.0
SE	**0.1**	**0.1**	**0.1**	**0.0**	**0.0**		**0.1**	**0.0**	**0.1**	**0.1**	**0.2**	**0.3**

Table 1e. Mean monthly temperature (°C) Rio Grande 1m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
RG_CB_1a	23.0	24.0	23.0				24.0	24.0	24.0	24.0	22.6	
RG_CB_1b	24.0	24.0	23.0				24.0	24.0	24.0	23.0	22.8	
RG_SM_1a	24.0	24.0	23.0				24.0	24.0	24.0	24.0	22.7	
RG_SM_1b	24.0	24.0	24.0				24.0	24.0	24.0	24.0	22.8	
RG_RG_1a		27.0	24.0				25.0	24.0	24.0	24.0	22.9	
RG_RG_1b		26.0	23.0				25.0	24.0	23.0	24.0	23.1	
RG_RG_1c	24.0	27.0	25.0				28.0	26.0	25.0	25.0	24.4	
RG_RG_1d	23.3	26.6	29.7				26.6	24.8	25.4	24.5	24.0	
Count	6.0	8.0	8.0				8.0	8.0	8.0	8.0	8.0	
Mean	**23.7**	**25.3**	**24.3**				**25.1**	**24.4**	**24.2**	**24.1**	**23.2**	
SD	0.4	1.4	2.1				1.4	0.7	0.7	0.5	0.6	
SE	**0.2**	**0.5**	**0.8**				**0.5**	**0.2**	**0.2**	**0.2**	**0.2**	

Table 1f. Mean monthly temperature (°C) Monkey River 1m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MR_SB_1a	26.0	27.0	26.0				27.0	27.0	25.0	23.0	22.7	
MR_SB_1b	27.0	28.0	27.0				29.0	29.0	25.0	24.0	23.3	
MR_SB_1c	28.0	29.0	27.0				30.0	29.0	25.0	24.0	23.3	
MR_SB_1d	28.0	29.0	32.0				31.0	29.0	25.0	24.0	23.7	
MR_TB_1a	20.0	29.0	29.0				29.0	29.0	25.0	24.0	23.7	
MR_BB_1a	26.0	28.0	29.0				29.0	28.0	25.0	24.0	24.4	
MR_BB_1b	25.0	28.0	29.0				29.0	28.0	25.0	24.0	25.1	
MR_MR_1a	24.4	27.6	30.2				28.2		26.6	24.7	22.9	
Count	8	8	8				8	7	8	8	8	
Mean	**25.6**	**28.2**	**28.7**				**29.0**	**28.4**	**25.2**	**24.0**	**23.6**	
SD	2.6	0.7	1.9				1.2	0.8	0.6	0.5	0.8	
SE	**0.9**	**0.3**	**0.7**				**0.4**	**0.3**	**0.2**	**0.2**	**0.3**	

Table 2a. Mean monthly dissolved oxygen (%) PHMR 1m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1A	84.3	75.3	98.0	78.0	83.7	76.0	73.3	95.0	102.5	108	82.6	95.2
1B	80.0		78.0	75.7	78.3		90.0	97.0		86.8	78.4	88.7
2A	78.3	78.7	78.0	72.0	77.0	85.7	81.0	100.7	95.3	89.1	74.8	90.3
2B	79.0	81.0	78.0	77.3	77.7		82.0	95.7	97.0	88.6	82.6	82.7
2C	78.3	79.7	76.7	77.7	78.0		81.0	88.0		91.8	65.7	88.3
3A	64.0	76.3	82.3	75.0	68.0	74.0	78.0	72.3	85.1	88.7	73.5	87.5
3B	75.0	78.7	75.7	77.0	75.0	78.0	81.3	76.7	96.7	80.6	80.3	90
3C	78.7	80.7	75.7	74.3	74.7	80.0	82.3	97.3	89.0	91.9	78.4	90.7
4A	77.0	78.7	78.3	75.3	73.0	77.3	81.0	78.7	91.0	80.4	77.6	83.6
4B	76.0	79.3	74.3	76.3	76.3	78.0	81.3	86.3	86.0	81.0	78.9	85.7
4C	78.0	80.7	76.3	74.7	76.7	78.0	83.7	87.0	86.0	86.5	79.1	88.8
5A	74.0	80.7	71.7	74.7	73.3	78.3	81.7	66.7	87.0	85.6	66.9	86.5
5B	75.3	79.3	77.3	73.7	74.7	77.0	80.0	90.0	87.0	84.6	83.6	89.1
5C	76.3	80.7	77.7	79.0	76.0	77.7	76.3	82.7	87.0	77.6	94.2	88.8
5D	75.3	81.0	77.7	79.0	76.7		79.3	94.7	91.0	82.6	77.3	93.0
5E	76.7	82.3	79.0	79.3	77.7		81.0	91.3	89.0	74.0	78.2	91.1
6A	79.3	76.0	76.0	81.0	75.0		67.7	81.7	89.0	87.7	71.4	86.2
6B	74.0	80.0	79.0	79.0	77.0		79.0		93.0	77.1	79.9	83.3
6C	77.3	79.3	78.0	79.0	76.7		78.3	90.3	92.0	85.9		87.7
6D	76.0	79.3	78.7	78.0	77.0		79.0	87.7	92.0	88.0	71.5	95.1
7A	80.0	78.3	76.3	77.3	73.0		77.7	93.0	89.0	89.0	76.1	87.4
7B	79.7	80.0	77.0	77.3	74.7		80.3		92.0	90.0	83.2	89.9
7C	78.3	80.0	77.3	70.7	75.0		80.0	96.0	92.0	91.0	84.7	87.1
8A	71.3	72.3	67.0	78.3	61.7		76.7	86.7	80.0	83.0	67.8	82.1
8B	81.0	80.0	78.0	74.7	75.0		80.0	87.0	94.0	89.0	79.5	87.1
9A	75.7	72.0	72.0	76.7	61.0		70.7	78.3	88.0	79.0	71.9	71.8
9B	78.3	80.3	78.0		73.3		79.7	96.3	94.0	94.0	72.8	85.5
Count	27.0	26.0	27.0	26.0	27.0	11.0	27.0	25.0	25.0	27.0	26.0	27.0
Mean	**76.9**	**78.9**	**77.5**	**76.6**	**74.7**	**78.2**	**79.3**	**87.9**	**90.6**	**86.4**	**77.3**	**87.5**
SD	3.7	2.5	5.0	2.4	4.7	2.9	4.1	8.5	4.7	6.7	6.2	4.6
SE	**0.7**	**0.5**	**1.0**	**0.5**	**0.9**	**0.9**	**0.8**	**1.7**	**0.9**	**1.3**	**1.2**	**0.9**

Table 2b. Mean monthly dissolved oxygen (%) PHMR 5m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1B	79.0		78.0	75.3	70.7		71.0	79.0		84.6	81.7	82
2B	78.3	79.3	76.7	74.3	68.0		82.7	83.3	94.0	85.1	84.1	81.6
2C	77.0	79.3	76.3	74.0	71.7		79.0	86.0		90	59.9	86.4
3B										71.3		
3C	79.0			91.3	74.7	78.7	83.7	120.3			82.5	
4B	74.3	78.3	75.3	75.3	76.0	76.7	79.0	83.0	84.0	80	79	86.2
4C	77.0	78.7	78.0	77.0	74.7	79.0	77.7	87.3	87.0	87.7	80.8	86.7
5B	73.7	79.7	77.0	75.0	75.0	77.0	76.7	71.3	83.0	83.7	72.5	86.2
5C	73.0	79.3	77.3	74.0	76.0	77.0	71.7	89.0	86.0	83.8	84.6	85.6
5D	75.0	80.3	77.3	79.0	75.7		81.3	94.7	90.0	85.1	81.6	92.6
5E	75.7	80.3	78.3	78.3	75.3		80.0	97.7	94.0	77.3	79.5	92.3
6A	74.7	76.7	75.7	77.7	75.0		77.0	82.3	79.0	88.4	70.7	89.1
6B	75.0	79.7	78.3	79.7	75.0		78.3		91.0	78.4	79.9	85.0
6C	76.0	79.7	77.3	77.7	76.3		82.0	93.7	91.0	91.5	81.2	88.5
6D	73.0	79.0	78.3	78.0	75.3		77.3	86.3	90.0	79.7	74.6	89.4
7A	76.0	79.0	76.3	78.0	71.0		79.3	89.3	93.0	83.0	73.4	87.7
7B	78.0	80.0	77.0	78.0	75.0		80.0		91.0	89.0	83.1	88.1
7C	78.0	79.0	77.3	76.0	74.3		78.0	90.7	93.0	96.0	84.3	86.6
8B	78.3	78.7	77.0	78.0	75.0		80.0	91.3	90.0	88.0		88.7
9A											79.6	
9B	78.3	79.7	77.3	76.0	72.7		79.3	90.0	90.0	94.0	73.1	86.0
Count	19.0	17.0	18.0	19.0	19.0	5.0	19.0	17.0	16.0	19.0	19.0	18.0
Mean	**76.3**	**79.2**	**77.2**	**77.5**	**74.1**	**77.7**	**78.6**	**89.1**	**89.1**	**85.1**	**78.2**	**87.2**
SD	2.0	0.9	0.9	3.8	2.2	1.1	3.2	10.2	4.3	6.1	6.2	2.9
SE	**0.5**	**0.2**	**0.2**	**0.9**	**0.5**	**0.5**	**0.7**	**2.5**	**1.1**	**1.4**	**1.4**	**0.7**

Table 2c. Mean monthly dissolved oxygen (%) PHMR 10m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B	73.3	79.0	77.0	74.0	67.0		60.3	70.7	86.0	71.5	74.1	77.1
2C	77.0	79.7	77.0	76.3	71.0		69.0	78.0		87.2	50.3	84.2
4B	74.0	77.3	75.7	75.7	71.3	71.7	65.0	71.0	72.0	74		
4C	77.0	78.7	76.0	75.7	70.7	76.7	71.7	87.7	85.0	84.1	81.4	87.1
5C	70.0	78.0	74.7	73.0	75.7	75.7	66.3	75.3		76.3	78.6	
5D	73.3	79.3	76.7	78.7	75.3		79.3	89.0	89.0	75	80.7	86.9
5E	76.3	82.3	78.3	79.3	75.0		77.3	94.7	94.0		81.7	91.6
6A										78.5		
6B	74.3	79.3	77.7	79.7	75.0		78.0		88.0	69.4	65	83.3
6C	74.3	78.0	78.0	77.7	75.3		78.7	87.0	89.0	84.2	81.8	90.4
6D	73.0	78.7	78.7	78.0	74.7		29.7	85.0	89.0	79.8	80.0	90.0
7A	73.3	79.7	75.7	74.3	69.7		72.7	86.3	90.0	73.0	50.5	86.4
7B	77.3	79.3	76.7	78.3	73.0		81.7		91.0	80.0	76.1	87.2
7C	77.3	79.0	76.7	76.0	73.7		79.7	90.3	92.0	91.0	83.3	87.2
8B	77.3	79.7	77.0	77.3	75.0		79.3	92.3	92.0	86.0		88.1
9A											78.5	
9B	76.3	79.3	77.3	76.0	73.3		79.7	92.0	93.0	90.0	74.3	86.5
Count	15.0	15.0	15.0	15.0	15.0	3.0	15.0	13.0	13.0	15.0	14.0	13.0
Mean	**75.0**	**79.2**	**76.9**	**76.7**	**73.0**	**74.7**	**71.2**	**84.6**	**88.5**	**80.0**	**74.0**	**86.6**
SD	2.2	1.1	1.1	2.0	2.6	2.6	13.2	8.1	5.6	6.8	11.0	3.7
SE	**0.6**	**0.3**	**0.3**	**0.5**	**0.7**	**1.5**	**3.4**	**2.3**	**1.6**	**1.8**	**2.9**	**1.0**

Table 2d. Mean monthly dissolved oxygen (%) PHMR 15m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2C	75.3		74.3	76.0	70.0		75.7	69.0	61.0	74.2	47.5	78.4
4C	73.7	80.0	76.0	75.7	68.0	76.3	73.0	80.7	81.0	78.2	76.4	87.1
5C											71.5	
5D	71.0	77.7	76.3	78.3	75.0		74.3	82.0	82.0	66.9		86.7
6B	71.0	77.0	77.0	78.7	74.3		78.0			57.6	69.9	69.2
6C	72.0	78.7	77.7	77.3	75.0		78.3	85.7	91.0	71.6	75.3	84.1
6D	73.3	79.0	78.3	78.0	73.0		74.0	84.7	85.0	77.5	75	86.8
7B									89.0			
7C	76.7	79.3	76.0	77.3	72.3		78.7	87.3	94.0	90	63.1	70.7
8B	77.3	79.3	77.3	77.3	75.0		77.3	92.0	83.0	81.0		69.7
9B	76.0	79.3	76.3	75.7	75.3		79.3	89.0	82.0	75.0	62.0	62.0
Count	9.0	8.0	9.0	9.0	9.0	1.0	9.0	8.0	9.0	9.0	8.0	9.0
Mean	**74.0**	**78.8**	**76.6**	**77.1**	**73.1**	**76.3**	**76.5**	**83.8**	**83.1**	**74.7**	**67.6**	**77.2**
SD	2.4	1.0	1.2	1.1	2.6	0.0	2.3	7.0	9.5	9.1	9.8	9.5
SE	**0.8**	**0.3**	**0.4**	**0.4**	**0.9**	**0.0**	**0.8**	**2.5**	**3.2**	**3.0**	**3.5**	**3.2**

Table 2e. Mean monthly dissolved oxygen (%) Rio Grande: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
RG_CB_1a	78.3	80.3	78.0				79.7	96.3	94.0	94.0	92.0	
RG_CB_1b	89.3	94.7	89.7				88.3	89.3		89.5	89.0	
RG_SM_1a	91.3	85.3	87.3				80.7	95.3	95.0	87.2	86.4	
RG_SM_1b	83.7	84.7	94.0				75.0	96.0	96.0	86.4	87.0	
RG_RG_1a	77.7	82.3	79.3				76.3	91.4	81.1	84.2	62.6	
RG_RG_1b	70.3	71.5	92.3				70.3	83.6	83.0	79.0	61.6	
RG_RG_1c	91.7	69.3	89.3				69.7	83.6	83.3	96.0	86.3	
RG_RG_1d	84.7	71.7	72.7				65.3	58.3	56.0	88.0		
Count	8.0	8.0	8.0				8.0	8.0	7.0	8.0	7.0	
Mean	**83.4**	**80.0**	**85.3**				**75.7**	**86.7**	**84.1**	**88.0**	**80.7**	
SD	7.0	8.1	7.2				6.8	11.8	12.9	5.0	11.9	
SE	**2.5**	**2.9**	**2.5**				**2.4**	**4.2**	**4.9**	**1.8**	**4.5**	

Table 2f. Mean monthly dissolved oxygen (%) Monkey River: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
MR_SB_1a	80.7	83.7	74.0				68.0	99.6	97.0	86.7	68.7	
MR_SB_1b	81.0	75.3	68.7				86.3	88.8	87.0	91.9	71.3	
MR_SB_1c	89.3	70.7	73.7				87.3	68.7	76.0	88.2	82.0	
MR_SB_1d	89.3	67.3	90.0				93.3	93.0	67.0	71.8	81.7	
MR_TB_1a	70.3	66.3	62.3				50.3	85.7		72.4	81.4	
MR_BB_1a	94.7	82.3	69.7				68.7	76.0		75.3	74.6	
MR_BB_1b	95.3	93.3	72.7				60.3	67.9		74.0	70.3	
Count	7.0	7.0	7.0				7.0	7.0	4.0	7.0	7.0	
Mean	**85.8**	**77.0**	**73.0**				**73.5**	**82.8**	**81.8**	**80.0**	**75.7**	
SD	9.0	9.9	8.5				15.9	12.2	13.0	8.5	5.9	
SE	**3.4**	**3.7**	**3.2**				**6.0**	**4.6**	**6.5**	**3.2**	**2.2**	

Table 3a. Mean monthly salinity (ppt) PHMR 1m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1A	15.0	36.0	33.0	35.0	17.0	17.2	17.1	23.7	22.1	34.0	33.8	31.3
1B	36.0		34.0	35.0	34.0		18.7	23.9		33.9	33.5	30.3
2A	34.0	35.0	32.0	35.0	20.0	26.7	18.0	21.5	27.2	32.3	32.8	33.1
2B	30.0	35.0	36.0	33.0	34.0		19.5	23.7	28.5	33.3	33.6	30.2
2C	37.0	35.0	33.0	37.0	32.0		18.4	21.8		32.9	34.1	29.2
3A	11.0	30.0	36.0	33.0	25.0	28.2	23.1	30.6	25.1	33.8	33.1	33.1
3B	37.0	35.0	36.0	37.0	25.0	27.9	21.7	28.6	25.4	32.9	33.5	33.2
3C	39.0	35.0	36.0	36.0	25.0	29.6	20.1	26.0	29.3	33.6	33.8	33.4
4A	38.0	35.0	36.0	36.0	36.0	30.9	24.7	29.4	29.1	32.9	33.2	33.6
4B	38.0	35.0	35.0	36.0	36.0	31.5	20.7	29.7	30.1	33.0	34.1	33.8
4C	38.0	36.0	37.0	38.0	35.0	29.3	22.9	30.1	30.1	33.6	34.3	33.2
5A	38.0	35.0	40.0	36.0	35.0	32.0	26.8	32.1	31.6	33.0	33.8	33.1
5B	39.0	36.0	36.0	35.0	38.0	31.9	26.4	30.2	31.2	32.4	33.4	32.9
5C	37.0	35.0	36.0	36.0	37.0	32.7	27.5	32.9	32.0	32.6	33.5	32.6
5D	37.0	35.0	34.0	35.0	37.0		27.6	32.1	31.4	33.8	33.8	33.2
5E	36.0	36.0	35.0	36.0	35.0		28.7	31.4	31.8	33.7	34.0	32.9
6A	38.0	38.0	37.0	36.0	37.0		32.0	33.9	31.6	33.2	33.5	33.0
6B	38.0	38.0	36.0	36.0	38.0		34.2		32.0	33.5	33.7	32.9
6C	37.0	37.0	37.0	35.0	38.0		33.1	37.6	32.4	31.9	33.6	33.4
6D	38.0	37.0	37.0	36.0	37.0		33.8	33.5	34.3	32.3	33.7	33.3
7A	20.0	36.0	36.0	38.0	35.0		34.0	33.7	32.5	33.6	33.9	32.6
7B	38.0	38.0	35.0	37.0	37.0		34.6		31.9	32.7	33.5	32.8
7C	38.0	36.0	36.0	39.0	38.0		34.6	34.1	32.3	34.2	33.9	32.9
8A	33.0	35.0	36.0	34.0	38.0		32.7	30.1	27.2	41.7	32.3	31.2
8B	37.0	38.0	35.0	38.0	39.0		34.8	33.4	32.7	32.9	33.8	32.4
9A	35.0	35.0	35.0	34.0	37.0		33.3	32.2	26.2	31.3	31.4	31.7
9B	36.0	35.0	36.0	37.0	40.0		34.9	33.4	31.8	33.3	33.9	32.3
Count	27	26	27	27	27	11	27	25	25	27	27	27
Mean	**34.4**	**35.7**	**35.6**	**35.9**	**33.9**	**28.9**	**27.2**	**30.0**	**30.0**	**33.4**	**33.5**	**32.5**
SD	7.23	1.60	1.55	1.48	6.01	4.34	6.37	4.27	2.97	1.79	0.60	1.15
SE	**1.39**	**0.31**	**0.30**	**0.28**	**1.16**	**1.31**	**1.23**	**0.85**	**0.59**	**0.34**	**0.12**	**0.22**

Table 3b. Mean monthly salinity (ppt) PHMR 5m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1B	37.0		35.0	35.0	36.0		27.0	33.1		34.5	33.6	33.8
2B	36.0	35.0	35.0	38.0	37.0		19.9	33.3	32.6	33.3	33.6	33.6
2C	38.0	35.0	34.0	39.0	36.0		23.7	33.4		33.7	34.2	33.2
3C	38.0			35.0	38.0	29.7	28.0	32.8		34.6	34.2	
4B	39.0	38.0	36.0	25.0	37.0	31.4	32.2	33.7	32.1	33.4	34.1	33.8
4C	38.0	36.0	38.0	38.0	35.0	29.7	29.9	33.5	32.9	34.1	34.5	33.6
5B	39.0	35.0	36.0	38.0	37.0	32.7	28.9	33.7	33.8	33.7	33.7	33.7
5C	37.0	36.0	37.0	38.0	37.0	33.4	32.2	33.6	33.1	33.7	33.6	33.7
5D	37.0	35.0	36.0	35.0	38.0		30.5	33.2	33.1	33.1	33.8	33.2
5E	37.0	36.0	35.0	35.0	35.0		28.9	33.1	33.5	34.1	34.0	33.3
6A	37.0	38.0	37.0	40.0	37.0		33.9	33.9	33.0	33.5	34.2	33.1
6B	36.0	36.0	35.0	35.0	38.0		34.2		33.2	34.0	34.2	33.2
6C	38.0	36.0	37.0	35.0	38.0		33.8	34.1	33.8	33.1	33.6	33.4
6D	36.0	36.0	37.0	36.0	38.0		34.2	34.5	34.4	33.1	33.7	33.4
7A	37.0	36.0	36.0	37.0	39.0		34.4	34.7	33.1	33.9	34.0	32.7
7B	39.0	37.0	35.0	37.0	39.0		34.7		33.7	33.0	33.9	32.8
7C	36.0	38.0	35.0	40.0	38.0		34.6	34.5	34.1	33.1	34.0	32.2
8B	35.0	37.0	36.0	37.0	39.0		34.8	34.3	33.4	33.0	33.8	32.5
9B	35.0	36.0	38.0	38.0	39.0		34.9	34.6	32.2	33.4	33.9	32.6
Count	19	17	18	19	19	5	19	17	16	19	19	18
Mean	**37.1**	**36.2**	**36.0**	**36.4**	**37.4**	**31.4**	**31.1**	**33.8**	**33.2**	**33.6**	**33.9**	**33.2**
SD	1.24	1.03	1.14	3.24	1.26	1.70	4.21	0.59	0.64	0.49	0.26	0.48
SE	**0.29**	**0.25**	**0.27**	**0.74**	**0.29**	**0.76**	**0.97**	**0.14**	**0.16**	**0.11**	**0.06**	**0.11**

Table 3c. Mean monthly salinity (ppt) PHMR 10m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B	36.0	35.0	36.0	36.0	37.0		32.2	33.8	33.3	35.2	34.8	34.8
2C	36.0	36.0	35.0	40.0	39.0		33.2	33.8		35.0	34.3	33.8
4B	39.0	36.0	36.0	39.0	37.0	31.6	34.1	34.1	34.1	34.3		
4C	38.0	36.0	38.0	37.0		32.5	33.5	34.2	33.5	34.7	34.6	33.7
5C	37.0	36.0	37.0	38.0	37.0	34.2	34.1	34.1		34.5	34.7	
5D	38.0	37.0	37.0	35.0	38.0		33.9	34.0	33.7	34.6	34.5	33.4
5E	37.0	39.0	35.0	38.0	40.0		33.7	33.4	33.8		34.1	33.5
6B	38.0	38.0	37.0	30.0	38.0		34.4		33.9	34.8	34.8	33.5
6C	36.0	37.0	37.0	35.0	39.0		34.5	34.5	33.9	34.4	33.9	33.4
6D	37.0	37.0	37.0	34.0	39.0		34.3	34.5	34.4	34.3	33.8	33.5
7A	36.0	36.0	39.0	38.0	39.0		34.5	34.2	33.1	34.3	34.5	32.7
7B	38.0	38.0	35.0	39.0	39.0		34.7		34.0	24.5	34.2	32.8
7C	39.0	38.0	36.0	38.0	39.0		34.6	39.7	34.2	34.6	34.0	32.9
8B	36.0	37.0	37.0	38.0	38.0		34.9	34.8	33.8	34.4	33.9	32.7
9B	37.0	37.0	37.0	38.0	39.0		35.0	34.7	33.4	33.4	33.9	32.7
Count	15	15	15	15	14	3	15	13	13	14	14	13
Mean	**37.2**	**36.9**	**36.6**	**36.9**	**38.4**	**32.8**	**34.1**	**34.6**	**33.8**	**33.8**	**34.3**	**33.3**
SD	1.08	1.06	1.12	2.53	0.94	1.35	0.74	1.59	0.38	2.70	0.36	0.60
SE	**0.28**	**0.27**	**0.29**	**0.65**	**0.25**	**0.78**	**0.19**	**0.44**	**0.10**	**0.72**	**0.10**	**0.17**

Table 3d. Mean monthly salinity (ppt) PHMR 15m: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B									33.7		34.6	
2C	37.0		36.0	40.0	37.0		33.8	34.5		35.2	34.3	34.3
4C	37.0	37.0	37.0	36.0		43.6	34.3	34.4	34.0	35.3	35.0	33.8
5C											35.1	
5D	38.0	37.0	37.0	40.0	38.0		34.2	34.4	33.9			33.6
6B	37.0	39.0	37.0	35.0	38.0		34.6			35.1	35.0	34.2
6C	37.0	38.0	37.0	37.0	39.0		34.6	34.5	33.9	35.0	37.0	33.8
6D	38.0	39.0	37.0	36.0	39.0		34.4	34.6	34.2	24.9	34.7	33.6
7B									33.9			
7C	39.0	37.0	37.0	38.0	39.0		34.6	34.8	34.3	34.9	34.4	33.2
8B	37.0	37.0	37.0	35.0	39.0		34.9	34.8	34.3	34.9	34.7	34.6
9B	37.0	37.0	37.0	37.0	39.0		34.0	34.8	34.6	34.9	34.0	
Count	9	8	9	9	8	1	9	8	9	8	10	8
Mean	**37.4**	**37.6**	**36.9**	**37.1**	**38.5**	**43.6**	**34.4**	**34.6**	**34.1**	**33.8**	**34.9**	**33.9**
SD	0.73	0.92	0.33	1.90	0.76		0.33	0.18	0.28	3.58	0.80	0.44
SE	**0.24**	**0.32**	**0.11**	**0.63**	**0.27**		**0.11**	**0.07**	**0.09**	**1.26**	**0.25**	**0.15**

Table 4a. Mean monthly pH 1m: PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1A	8.16			8.36	8.25	7.88	8.11	8.22	8.38	8.34	8.25	8.35
1B	7.95			8.13	8.11		8.29	8.30		8.28	8.11	8.35
2A	6.95	8.44		8.04	7.88	8.16	8.25	8.16	8.32	8.23	8.25	8.08
2B	7.53	8.38		8.04	8.11		8.27	8.19	8.29	8.24	8.32	8.31
2C	7.77	8.21		8.14	8.05		8.26	8.28		8.26	8.30	8.32
3A	7.82	7.99		7.85	7.77	8.14	8.19	8.17	8.27	8.28	8.30	8.17
3B	8.39	7.73		8.09	8.60	8.16	8.21	8.17	8.27	8.19	8.35	8.20
3C	8.49	8.48		8.16	8.08	8.16	8.25	8.26	8.30	8.26	8.31	8.27
4A	8.48	8.40		8.06	7.71	8.16	8.24	8.22	8.28	8.23	8.32	8.19
4B	8.44	8.50		8.06	7.80	8.17	8.28	8.18	8.31	8.24	8.35	8.22
4C	8.60	8.40		8.21	8.04	8.16	8.26	8.27	8.30	8.30	8.33	8.30
5A	8.49	8.44		7.93	7.75	8.16	8.20	8.21	8.30	8.30	8.34	8.24
5B	8.49	8.18		8.04	7.70	8.14	8.24	8.27	8.27	8.30	8.35	8.30
5C	8.50	8.40		8.23	7.75	8.15	8.21	8.27	8.29	8.15	8.30	8.29
5D	8.43	8.16		8.22	7.78		8.22	8.29	8.29	8.30	8.38	8.30
5E	7.48	8.18		8.15	7.73		8.21	8.30	8.31	8.27	8.34	8.32
6A	8.41	7.98		8.17	7.85		8.18	8.23	8.30	8.26	8.31	8.16
6B	8.45	7.46		8.18	7.76		8.22		8.34	8.29	8.34	8.25
6C	8.42	8.29		8.19	7.79		8.22	8.31	8.29	8.25	8.37	8.31
6D	8.38	7.53		8.18	7.84		8.23	8.28	8.32	8.25	8.33	8.33
7A	7.88	8.40		8.20	8.12		8.18	8.32	8.29	8.29	8.28	8.23
7B	7.95	8.54		8.17	8.08		8.21		8.32	8.27	8.34	8.36
7C	8.60	8.49		8.15	8.09		8.19	8.31	8.34	8.32	8.35	8.59
8A	7.49	8.53		8.05	7.90		8.13	8.19	8.22	8.02	7.90	8.07
8B	8.01	8.51		8.18	8.10		8.20	8.27	8.35	8.25	8.36	8.33
9A	8.40	8.48		8.06	7.96		8.11	8.19	8.27	8.20	8.19	8.14
9B	8.16	8.44		8.19	8.06		8.19	8.29	8.33	8.36	8.33	8.30
Count	27	25		27	27	11	27	25	25	27	27	27
Mean	**8.15**	**8.26**		**8.13**	**7.95**	**8.13**	**8.21**	**8.25**	**8.30**	**8.26**	**8.30**	**8.27**
SD	0.42	0.31		0.10	0.21	0.08	0.05	0.05	0.03	0.07	0.10	0.10
SE	**0.08**	**0.06**		**0.02**	**0.04**	**0.03**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**

Table 4b. Mean monthly pH 5m: PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1B	7.78			8.24	8.11		8.18	8.24		8.30	8.31	8.34
2B	7.94	8.58		8.07	8.10		8.30	8.21	8.30	8.28	8.34	8.34
2C	7.93	8.51		8.21	8.11		8.25	8.26		8.29	8.35	8.36
3B										8.25		
3C	8.49			8.15	8.07	8.18	8.25	8.36			8.30	
4B	8.46	8.50		8.06	7.95	8.17	8.28	8.26	8.31	8.30	8.37	8.29
4C	8.49	8.38		8.21	8.65	8.19	8.23	8.27	8.31	8.32	8.35	8.34
5A												
5B	8.50	8.41		7.66	7.88	8.15	8.22	8.25	8.28	8.30	8.36	8.35
5C	8.48	8.39		8.19	7.83	8.17	8.21	8.28	8.29	8.25	8.34	8.35
5D	8.50	8.40		8.21	7.87		8.22	8.23	8.31	8.32	8.39	8.35
5E	7.42	7.93		8.13	7.85		8.23	8.31	8.33	8.30	8.36	8.37
6A	8.35	7.80		8.19	7.98		8.21	8.25	8.30	8.31	8.31	8.30
6B	8.42	7.39		8.18	7.86		8.23		8.34	8.30	8.35	8.35
6C	8.44	8.25		8.20	7.86		8.23	8.30	8.34	8.35	8.38	8.37
6D	8.31	8.56		8.18	7.86		8.22	8.27	8.33	8.31	8.35	8.38
7A	7.81	8.57		8.22	8.18		8.23	8.31	8.34	8.30	8.33	8.32
7B	7.74	8.56		8.19	8.11		8.21		8.32	8.33	8.36	8.39
7C	7.91	8.58		8.14	8.12		8.20	8.31	8.34	8.35	8.38	8.41
8B	7.90	8.57		8.16	8.30		8.21	8.30	8.36	8.37		8.38
9B	8.21	8.57		8.10	8.10		8.21	8.31	8.33	8.38	8.37	8.30
Count	19	17		19	19	5	19	17	16	19	18	18
Mean	**8.16**	**8.35**		**8.14**	**8.04**	**8.17**	**8.23**	**8.28**	**8.32**	**8.31**	**8.35**	**8.35**
SD	0.34	0.34		0.13	0.20	0.01	0.03	0.04	0.02	0.03	0.03	0.03
SE	**0.08**	**0.08**		**0.03**	**0.05**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

Table 4c. Mean monthly pH 10m: PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B	7.59	8.54		8.04	8.11		8.17	8.23	8.30	8.28	8.33	8.35
2C	7.85	8.38		8.19	8.13		8.18	8.26		8.29	8.36	8.38
4B	8.46	8.55		8.08	7.85	8.17	8.19	8.24	8.28	8.31		
4C	8.51	8.27		8.20	8.09	8.17	8.20	8.27	8.30	8.32	8.37	8.35
5C	8.45	8.32		8.28	7.87	8.16	8.19	8.27		8.27	8.34	
5D	8.50	8.31		8.20	7.87		8.20	8.30	8.32	8.30	8.38	8.36
5E	7.46	8.50		8.12	7.87		8.21	8.32	8.33		8.37	8.39
6A										8.33		
6B	8.46	7.44		8.17	7.88		8.23		8.33	8.28	8.35	8.36
6C	8.46	8.34		8.16	7.88		8.23	8.30	8.34	8.32	8.30	8.39
6D	8.34	8.49		8.18	7.88		8.21	8.27	8.33	8.31	8.37	8.39
7A	7.91	8.57		8.19	8.13		8.23	8.31	8.29	8.28	8.30	8.37
7B	7.79	8.56		8.13	8.10		8.22		8.34	8.29	8.35	8.40
7C	7.94	8.55		8.13	8.13		8.21	8.31	8.34	8.35	8.39	8.41
8B	7.75	8.56		8.13	8.13		8.22	8.31	8.36	8.35		8.40
9A											8.38	
9B	8.19	8.56		8.14	8.12		8.22	8.31	5.88	8.27	8.38	8.40
Count	15	15		15	15	3	15	13	13	15	14	13
Mean	**8.11**	**8.40**		**8.16**	**8.00**	**8.17**	**8.21**	**8.28**	**8.13**	**8.30**	**8.36**	**8.38**
SD	0.37	0.29		0.06	0.13	0.01	0.02	0.03	0.68	0.03	0.03	0.02
SE	**0.10**	**0.07**		**0.01**	**0.03**	**0.00**	**0.00**	**0.01**	**0.19**	**0.01**	**0.01**	**0.01**

Table 4d. Mean monthly pH 15m: PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2B					8.12			8.21	8.05		8.26	
2C	7.88			8.20			8.19	8.21		8.30	8.36	8.37
4C	8.61	8.25		8.16	8.08	8.16	8.21	8.25	8.31	8.31	8.36	8.39
5C											8.36	
5D	8.49	8.23		8.20	7.87		8.20	8.28	8.31	8.23		8.36
6B	8.45	7.53		8.18	7.89		8.23			8.27	8.34	8.34
6C	8.46	8.14		8.20	7.89		8.23	8.30	8.34	8.29	8.36	8.38
6D	8.36	7.98		8.18	7.87		8.20	8.27	8.32	8.30	8.35	8.39
7B									8.35			
7C	8.10	8.57		8.11	8.12		8.21	8.31	8.34	8.34	8.36	8.40
8B	7.88	8.55		8.16	8.13		8.22	8.31	8.33	8.34		8.35
9A											8.33	
9B	8.16	8.54		8.11	8.12		8.24	8.31	8.33		8.36	8.34
Count	9	8		9	9	1	9	9	9	8	10	9
Mean	**8.27**	**8.22**		**8.17**	**8.01**	**8.16**	**8.21**	**8.27**	**8.30**	**8.30**	**8.34**	**8.37**
SD	0.27	0.35		0.04	0.12		0.02	0.04	0.09	0.04	0.03	0.02
SE	**0.09**	**0.12**		**0.01**	**0.04**		**0.01**	**0.01**	**0.03**	**0.01**	**0.01**	**0.01**

Table 5a. Mean monthly visibility (cm) PHMR: 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1A	120	20	175	75	75	50	100	150	175		25	150
1B	600		800	425	350		300	500			325	600
2A	250	100	200	250	225	100	150	100	175		200	200
2B	500	500	600	400	475		450	200	800		300	800
2C	1800	600	900	700	400		500	700			700	850
3A	100	100	230	150	125	125	150	35	150		125	125
3B	400	250	475	250	250	200	200	200	250		200	300
3C	400	400	520	475	425	500	185	390	430		400	500
4A	300	190	275	200	200	225	750	300	400		175	175
4B	400	500	375	250	400	450	220	200	850		375	900
4C	800	600	375	500	550	650	220	500	1000		600	1000
5A	200	200	130	290	206	290	350	100	300		200	300
5B	230	400	350	200	225	275	500	250	600		300	200
5C	500	400	350	400	350	600	525	375	550		350	250
5D	800	500	400	250	400		600	350	600		450	900
5E	700	600	800	700	975		750	450	700		500	1300
6A	500	500	450	300	25		125	25	525		300	500
6B	800	600	450	500	550		200		550		500	800
6C	1800	800	850	800	825		275	750	600		500	1300
6D	1800	1800	900	1100	1200		600	1400	110		725	1300
7A	500	500	400	400	450		400	300	100		325	600
7B	500	530	700	875	650		500		900		700	700
7C	800	1000	1100	1200	800		600	600	900		700	950
8A	200	250	250	300	300		280	25	250		250	300
8B	500	700	900	1200	1050		800	425	800		700	1000
9A	250	100	250	1700	250		250	225	200		250	300
9B	400	800	800	800	425		700	450	850		1200	800
Count	27	26	27	27	27	11	27	25	25		27	27
Mean	**598.1**	**497.7**	**518.7**	**544.1**	**450.2**	**315.0**	**395.6**	**360.0**	**510.6**		**421.3**	**633.3**
SD	479.7	360.7	274.3	393.3	297.6	205.4	215.7	295.2	287.5		251.3	376.5
SE	**92.3**	**70.7**	**52.8**	**75.7**	**57.3**	**61.9**	**41.5**	**59.0**	**57.5**		**48.4**	**72.5**

Table 6a. Mean monthly nitrates (mg l-1) PHMR 2014

Site Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2A					0.70		0.27		0.63		0.70	0.80
2C							0.23				0.30	0.56
5A					1.10		0.23		0.63		0.10	0.73
5B												0.53
5E					0.50		0.10		1.50		0.70	0.50
7A					0.83		0.13		0.57		0.50	0.56
7C					1.20		0.17		0.63		0.30	0.30
Count					5		6		5		6	7
Mean					**0.87**		**0.19**		**0.79**		**0.43**	**0.57**
SD					0.29		0.07		0.40		0.24	0.16
SE					**0.13**		**0.03**		**0.18**		**0.10**	**0.06**

Table 6b. Mean monthly nitrates (mg l-1) Rio Grande: 2014

Site Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RG_CB_1a								0.44	0.03	0.50	2.55	
RG_CB_1b			1.27				0.84	0.40	0.34	0.04	3.34	
RG_SM_1a								0.48	0.26	0.05	3.34	
RG_SM_1b			2.07				1.03	0.47	0.03	1.01	2.55	
RG_RG_1a								0.41	0.02	1.00	3.34	
RG_RG_1b								0.44	0.02	0.90	11.96	
RG_RG_1c			1.70				0.80	0.39	0.55	0.45	7.10	
Count			3				3	7	7	7	7	
Mean			**1.68**				**0.89**	**0.43**	**0.18**	**0.56**	**4.88**	
SD			0.40				0.12	0.03	0.21	0.42	3.49	
SE			**0.23**				**0.07**	**0.01**	**0.08**	**0.16**	**1.32**	

Table 6c. Mean monthly nitrates (mg l-1) Monkey River: 2014

Site Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MR_SB_1a								0.06	0.13	0.05	6.25	
MR_SB_1b								0.09	0.20	0.59	0.85	
MR_SB_1c								0.22	0.17	0.80	0.70	
MR_SB_1d			0.37				2.15	0.09	0.26	0.72	0.82	
MR_TB_1a			0.57				3.00	0.01	0.30	0.68	0.46	
MR_BB_1a								0.10	0.28	1.58	2.38	
MR_BB_1b			0.43				2.03	0.24	0.31	1.06	1.25	
MR_MR_1a									0.57			
Count			3				3	7	8	7	7	
Mean			**0.46**				**2.39**	**0.12**	**0.28**	**0.78**	**1.82**	
SD			0.10				0.53	0.08	0.13	0.47	2.05	
SE			**0.06**				**0.31**	**0.03**	**0.05**	**0.18**	**0.78**	

Table 7a. Mean monthly phosphates (mg l-1) PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Nun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2A					0.30		0.28		0.67		0.70	1.01
2C							0.29				0.30	0.71
5A					0.30		0.16		0.13		0.10	1.26
5B												1.60
5E					0.09		0.60		0.70		1.00	0.56
7A					0.30		0.28		0.24		1.60	1.44
7C					0.00		0.17		0.31		1.16	0.65
Count					5		6		5		6	7
Mean					**0.20**		**0.30**		**0.41**		**0.81**	**1.03**
SD					0.14		0.16		0.26		0.56	0.41
SE					**0.06**		**0.07**		**0.12**		**0.23**	**0.16**

Table 7b. Mean monthly phosphates (mg l-1) Rio Grande 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
RG_CB_1b			0.18				0.27	0.56	0.06			
RG_SM_1b			0.01				0.20	0.43	0.01			
RG_RG_1c			0.02				0.14	0.73	0.16			
RG_RG_1d									0.23			
Count			3				3	3	4			
Mean			**0.07**				**0.20**	**0.57**	**0.12**			
SD			0.10				0.07	0.15	0.10			
SE			**0.06**				**0.04**	**0.09**	**0.05**			

Table 7c. Mean monthly phosphates (mg l-1) Monkey River 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
MR_SB_1d			0.22				0.20		0.19			
MR_TB_1a			0.12				0.32		0.33			
MR_BB_1b			0.13				0.98		0.16			
MR_MR_1a									1.40			
Count			3				3		4			
Mean			**0.16**				**0.50**		**0.52**			
SD			0.06				0.42		0.59			
SE			**0.03**				**0.24**		**0.30**			

Table 8a. Mean monthly sedimentation (g m-2 day-1) PHMR 2014												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2C	27.4				54.6		24.2		0.0		58.4	7.4
5A	26.5	55.1			151.9							
5E	26.5	20.3		28.7	118.1		23.7				28.4	34.9
7A				23.3			81.7		45.7		61.2	22.3
7C		36.8					36.8		31.7		0.0	60.1
Count	3	3		2	3		4		3		4	4
Mean	**26.8**	**37.4**		**26.0**	**108.2**		**41.6**		**25.8**		**37.0**	**31.2**
SD	0.5	17.4		3.8	49.4		27.4		23.4		28.8	22.3
SE	**0.3**	**10.0**		**2.7**	**28.5**		**13.7**		**13.5**		**14.4**	**11.1**