TIDE Water Quality 2015

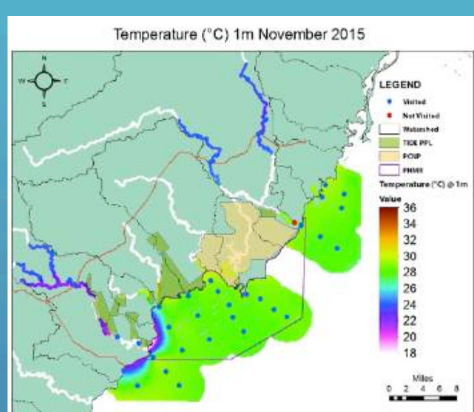
Ridge to Reef Water Quality

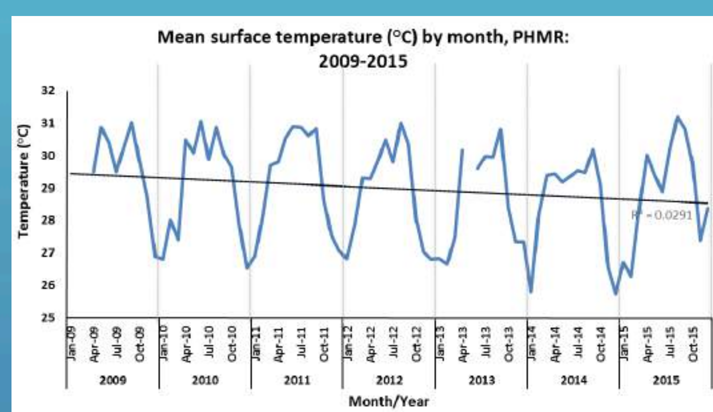
Port Honduras Marine Reserve, Monkey River, Rio Grande

TIDE Annual Report 2015

Foley J, Alvarez M, Barona T, Moore R, Requena E, Warns D

TIDE Research & Monitoring Department 2015





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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
TPPL	TIDE Private Protected Lands
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 2015 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 since 2014), visibility, nitrate, phosphate and sedimentation. Condensed comparisons between each year 2009-2015 are also made. General conclusions about each parameter are located in the last part of each section. Trends are becoming apparent over the years 2009-2015 for temperature and salinity, but not so clearly for dissolved oxygen or visibility. Nutrient concentrations tend to be highest during wet seasons, especially the onset of wet seasons. Higher than previous nitrate levels in Rio Grande suggest increased impact from agricultural runoff in this watershed. Year to year sea surface temperatures exhibited a cessation of the continuous annual mean surface cooling trend from 2009-2014, increasing considerably in 2015. Impact on the Bladen branch of Monkey River from land use change and agriculture appear to be increasing. Particulate organic matter and nutrients are suspected to be of oceanogenic origin rather than from river discharge at certain times of the year. pH may be driven by alkaline river discharge at certain times, counteracting the expected neutralizing effect of dilution of salt water by river discharge. 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 fourth 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.

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

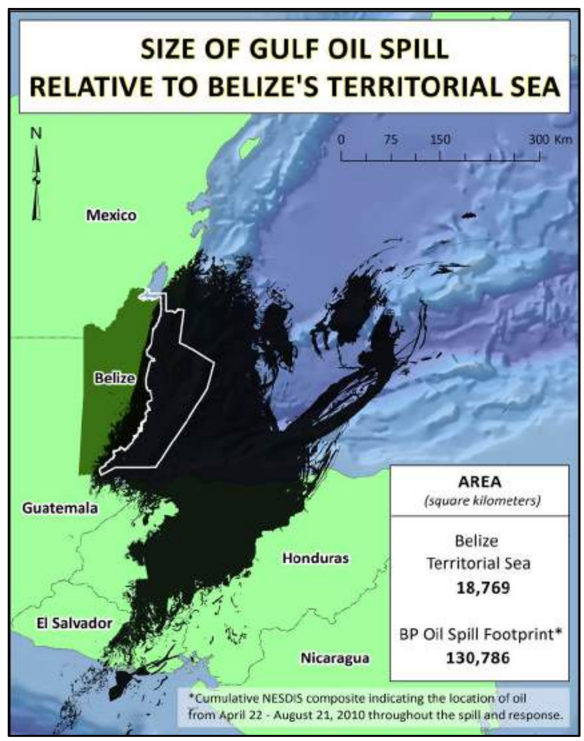
While this occurs on a relatively small scale, cumulatively this could impact nutrient levels in the river, particularly phosphate, potentially increasing risk of eutrophication and subsequent fish die-offs.

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.

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		WGS 84 DD	
				N	W	N	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.

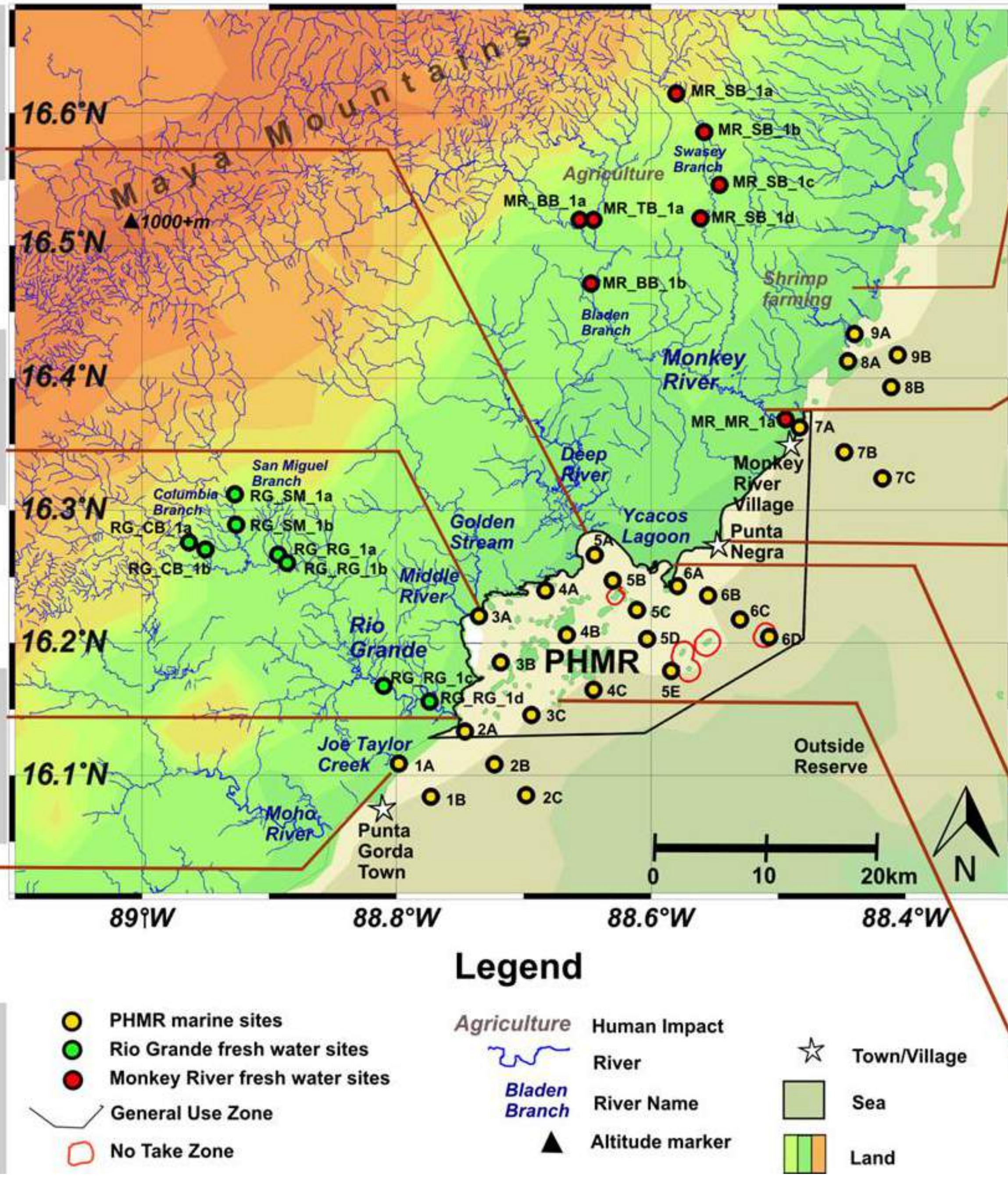
Marine and fresh water monitoring sites 2015
PHMR, Monkey River & Rio Grande

. **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

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.

. **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.

. **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 2015 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.

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*) = $\pi r^2 = 20.268cm^2$
- Volume of trap (*vt*) = $l \times \pi r^2 = 30 \times \pi \times 2.542 = 608.05cm^3$ = 608.05ml
- Proportion trap mouth area is of $1m^2$ (*pa*) = $\frac{10,000}{a} = \frac{10,000}{20.268} = 493.38131035$ 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*

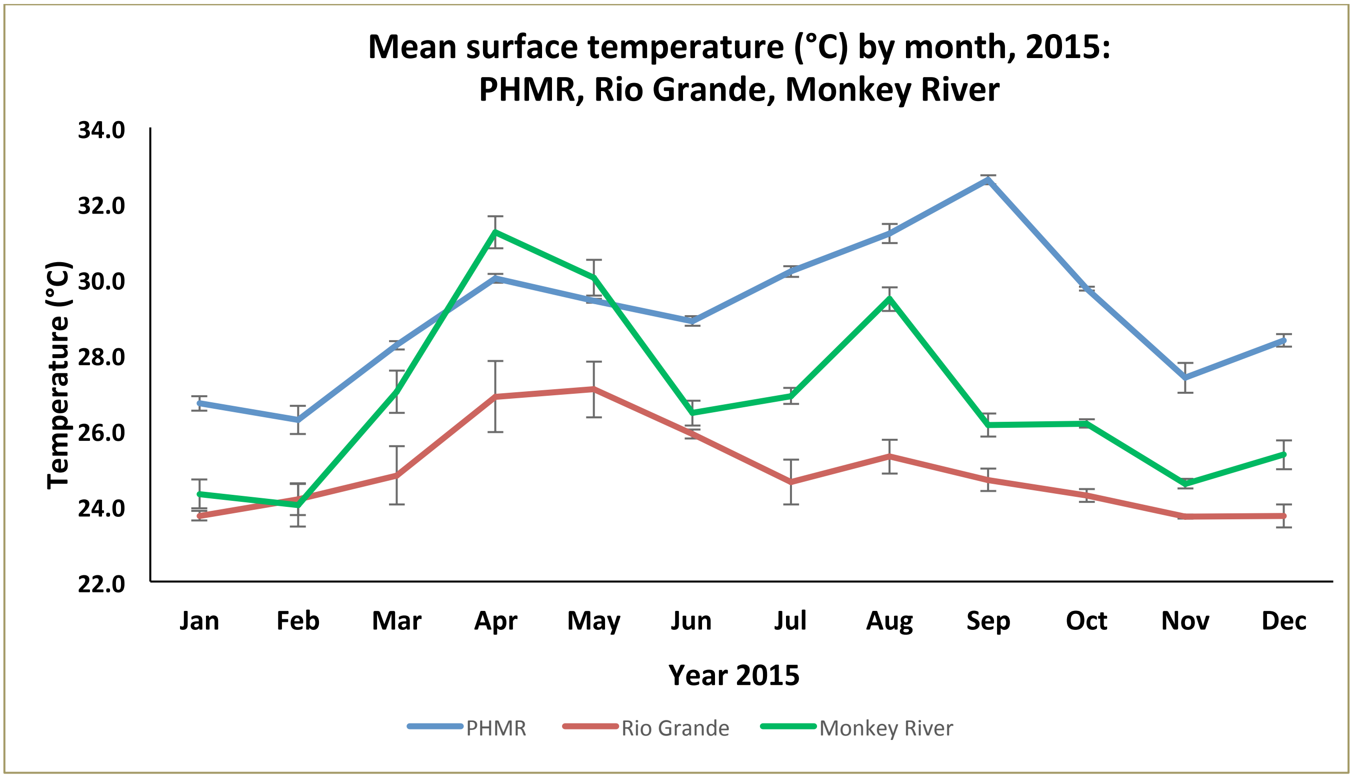
3) Sedimentation Rate (***S***) (g m^{-2} day^{-1}) = $\frac{\text{tw x pa}}{\text{days at sea}}$

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, 2015 – PHMR, Monkey River, Rio Grande (Fig. 1a):



- The 2015 overall trend was similar to 2012 and 2013 (no available data for 2014 rivers April-June), but 2015 had more extreme peaks than ever before in both rivers and the sea. Mean temperatures in all three areas were generally higher in 2015 than previous years, showing a double peaked (bimodal) distribution, the first in March to May and the second around August to September.

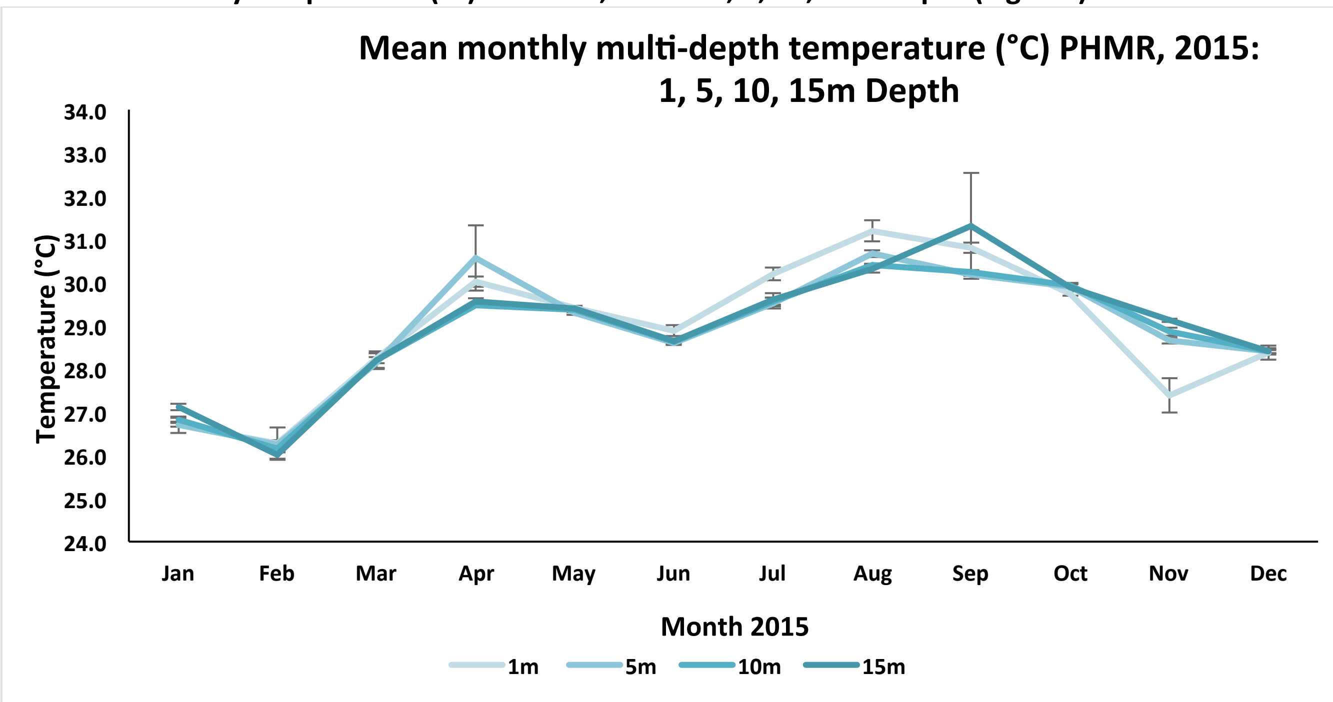
- In the previous year (2014), mean water temperature was consistently higher in PHMR than in either Rio Grande or Monkey River. In 2015 however, mean temperature was lower in PHMR than in Monkey River in both April and May, remaining higher in the remaining months. As in previous years, mean temperatures were generally warmer in Monkey River than in Rio Grande.

- In previous years and this year (2012, 2013, 2014 and 2015) mean ocean surface temperatures peaked in August (2012: 31.0°C ± 0.1SE; 2015: 31.2°C ± 0.25SE) and September (2013: 30.6°C ± 0.03SE; 2014: (30.2°C ± 0.38SE). In all years (2012-2015) there was also a marked and continuous decrease from September to November in PHMR (from 30.8°C ± 0.12SE to 27.4°C ± 0.40SE, in 2015).

- Mean temperature in Rio Grande generally remained lower than PHMR and Monkey River as in previous years. May was the hottest month in Rio Grande in 2015 (27.1°C ± 0.74SE), as it was in 2012 and 2013. The coldest mean temperature in Rio Grande over the past four years was in November 2014 (23.2°C ± 0.2SE).

- Monkey River mean surface temperature increased dramatically and consistently from February to April (from 24.0°C ± 0.56SE to 31.2°C ± 0.42SE), compared with cooler conditions in April 2013 (27.8°C ± 0.31SE).

1.2 Mean monthly temperature (°C) in PHMR, 2015 – 1, 5, 10, 15m depth (Fig. 1.2):



- In contrast to previous years, mean ocean temperature decreased from January (26.8°C ± 0.10SE) to February (26.1°C ± 0.06SE) and thereafter it resumed the general previously observed trend of increasing until April (29.7°C ± 0.14SE). In April, 1m and 5m mean temperatures increased significantly more than 10m and 15m temperatures.

- 2015 was similar to 2014, with most temperatures remaining below 30°C, except for peaking in April, and a sustained period of warming from June to August. In September, surface waters began to cool but warmer temperatures were retained at 15m depth.

- As in 2014, there was a slight increase in temperature with increasing depth in January (26.7°C ± 0.19SE at 1m, 26.7°C ± 0.04SE at 5m, 26.8°C ± 0.05SE at 10 m and 27.1°C ± 0.07SE at 15 m). The opposite was seen in February (26.3°C ± 0.38SE at 1m, 26.2°C ± 0.10SE at 5m, 26.2°C ± 0.09SE at 10 m and 26.0°C ± 0.09SE at 15 m), but increasing temperature with increasing depth occurred again in November and December in both 2014 and 2015.

- The overall pattern illustrated a bimodal distribution, with two peaks, one in April and the other in August/September (August at the surface and September at depth), with subsurface temperatures exhibiting less variability with increasing depth. Notable were the considerably higher temperatures retained at 15m depth relative to the surface in September and October, compared with previous years (2015 Sept mean temperature: 30.8°C ± 0.12SE at 1m and 31.3°C ± 1.23SE at 15m; 2015 Oct mean temperature 29.7°C ± 0.05SE at 1m and 29.9°C ± 0.09 SE at 15m).

- High standard errors for temperatures in September 2014 and 2015 point to greatest variability across PHMR at these times, supported by maps (Figs. 1.3 i1m-i15m).

- In general, temperatures were warmer in 2015 when compared to 2014, and with more extremes.

1.3 Temperature maps, 2015; multi-depth 1m, 5m 10m, 15m – PHMR, Monkey River, Rio Grande:

a. January (Figs. 1.3 a 1m-15m): Temperatures in both Monkey River and Rio Grande were relatively cold (~23°C) with slightly colder temperatures in the upper Swasey branch of Monkey River(~21°C). Sea surface temperature across most of PHMR was uniform and cool, ranging between 26°C and 27°C; however, south of the mouth of Rio Grande was colder (~24°C). Subsurface temperatures were similar to surface temperatures with little change with increasing depth.

b. February (Figs. 1.3 b 1m-15m): Temperatures in Rio Grande remained low (24°C) while Monkey River had slightly colder waters overall (between 22-23°C), but warmer than the previous month. There was a large decrease in temperature in coastal areas north of the mouth of Monkey River, while the majority of PHMR remained stable at around 27-28°C, with colder regions ~25°C located off the coast of Punta Negra. Below the surface, temperature was less variable but cooler than at the surface (~26°C).

c. March (Figs. 1.3 c 1m-15m): Warming continued to be seen in Monkey River, particularly mid-stream in the Swasey Branch (up to 27°C), although the upper section remained cooler (~24°C). The upper stream of Rio Grande continued to be cool (~24°C), while temperatures increased to 25-28°C towards the river mouth. Surface temperatures in PHMR warmed throughout, ranging from 27-30°C with slightly warmer areas around the Snake Cayes and cooler areas in the southern portion of PHMR. At 15m, temperatures were cooler and averaged ~26°C throughout PHMR.

d, e. April, May (Figs. 1.3 d 1m-15m, e 1m-15m): Warming increased dramatically from previous months in the upper reaches of Monkey River with temperatures between 28-33°C. Rio Grande remained a cool 24°C in the upper reaches but warmed to near 30°C downstream. PHMR continued to warm with 1m temperatures around 29°C and higher near the mouth of the Rio Grande and Monkey River (30-31°C). Subsurface temperatures kept a steady 27-28°C at all depths.

f. June (Figs. 1.3 e 1m-15m, f 1m-15m): Monkey River cooled from the previous month to 24-25°C throughout, and Rio Grande showed similar temperatures. In PHMR there were stable surface and subsurface temperatures ranging between 27 and 28°C.

g. July (Figs. 1.3 g 1m-15m): Monkey River warmed once more to 28-29°C but Rio Grande cooled to 23°C in the mid reaches and 24°C in the higher and lower reaches. Waters near PHMR were warmer (26°C) and PHMR averaged 28-29°C. No data available for northern sites.

h. August (Figs. 1.3 h 1m-15m): Monkey River maintained its warmer temperature and Rio Grande warmed considerably in the lower reaches to near 29°C. In PHMR, waters near the mouth of the Payne's Creek lagoon warmed to ~34°C. In other areas of PHMR, both surface and subsurface temperatures increased with temperatures averaging ~31°C.

i, j. September, October (Figs. 1.3 i 1m-15m, j 1m-15m): Both rivers cooled slightly (~24°C and 26°C in the upper reaches of Rio Grande and Monkey River, respectively, and ~26-28°C in the lower reaches). Throughout PHMR waters cooled in September and October to between 29°C and 31°C. September subsurface temperatures were slightly cooler throughout all stations.

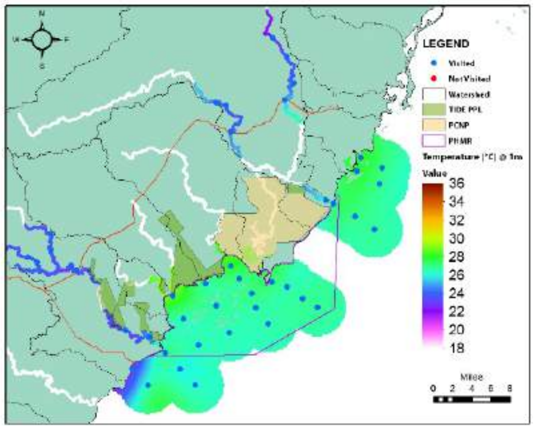
k. November (Figs. 1.3 k 1m-15m): There is no noticeable difference in temperature between upper Rio Grande and Monkey River, ranging from 20-24°C. In PHMR, the average surface temperature (29.7°C) dropped by ~2°C from September, with a significantly cooler region located around both rivers (23°C) while multi-depth temperatures were near ~30°C.

l. December (Figs. 1.3 l 1m-15m): Average surface temperatures continued to decline in PHMR from the previous month to near 26-27°C. The area around the mouth of Monkey River was lower than the rest of PHMR (24-25°C). Temperature at depth was fairly uniform around 26-27°C.

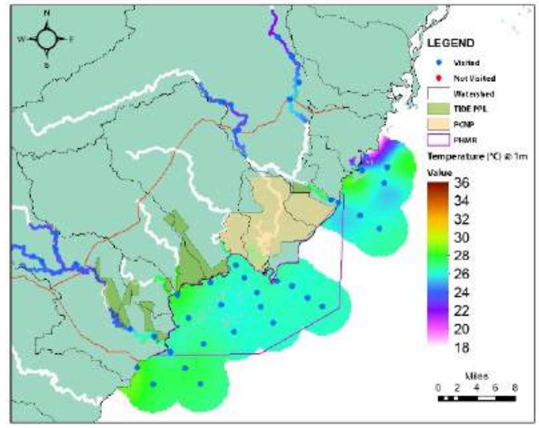
1.3 Temperature (°C) January 2015 (a): February 2015 (b):

1m

Temperature (°C) 1m January 2015

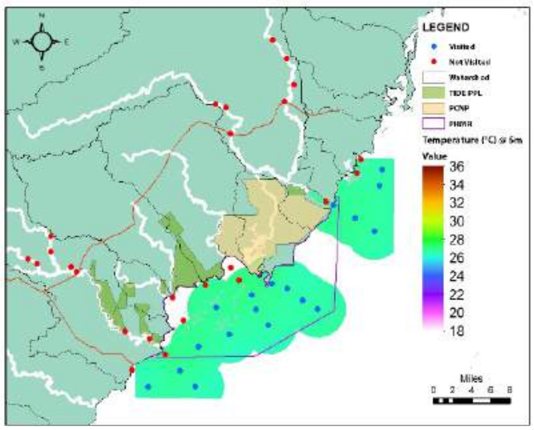


Temperature (°C) 1m February 2015

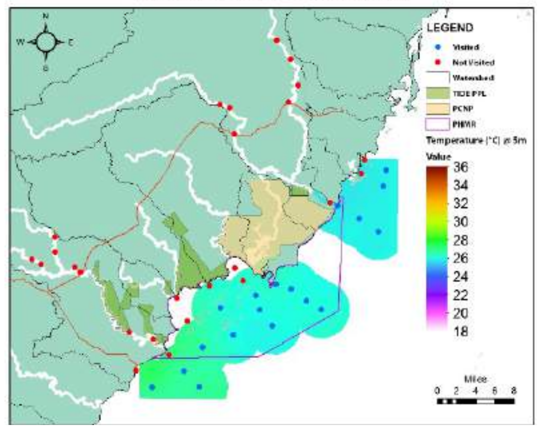


5m

Temperature (°C) 5m January 2015

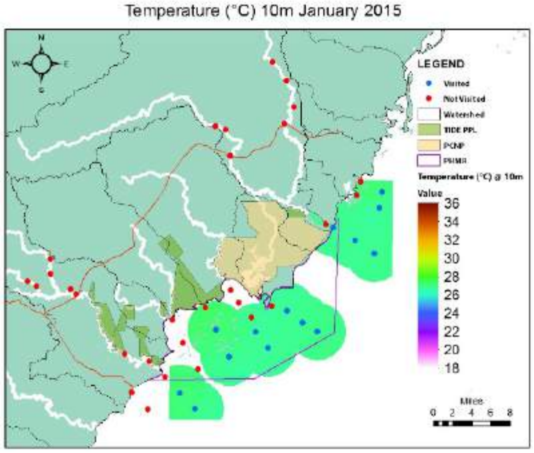


Temperature (°C) 5m February 2015

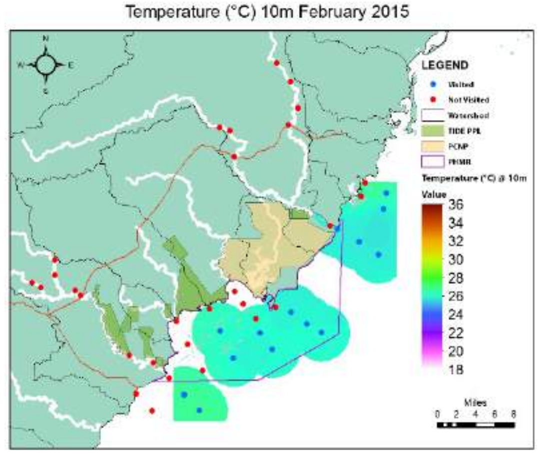


10m

Temperature (°C) 10m January 2015

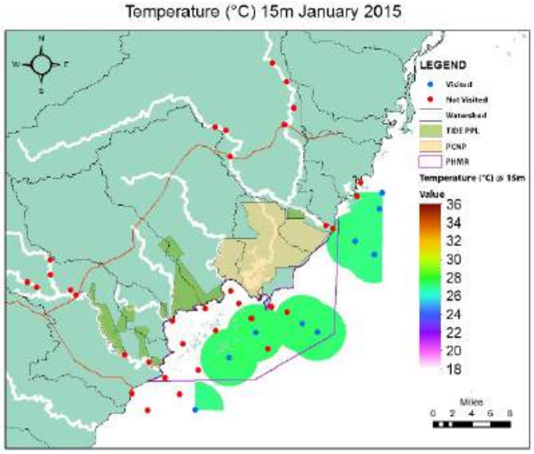


Temperature (°C) 10m February 2015

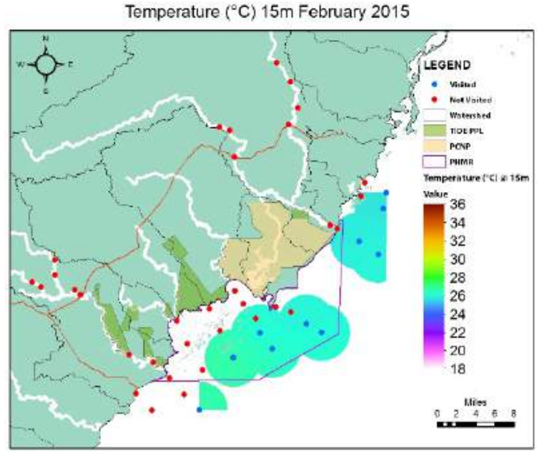


15m

Temperature (°C) 15m January 2015



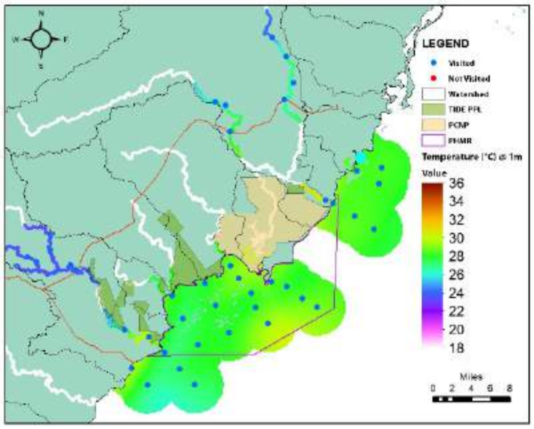
Temperature (°C) 15m February 2015



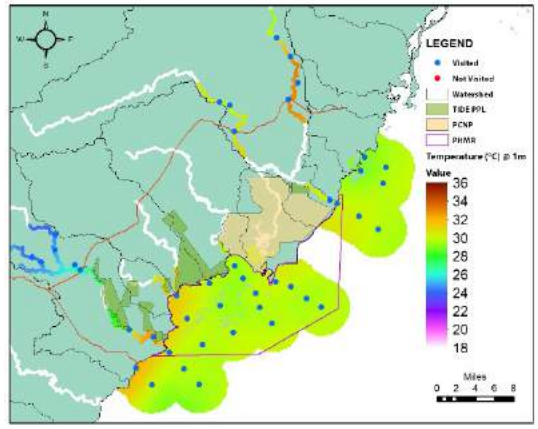
1.3 Temperature (°C): March 2015 (c): April 2015 (d):

1m

Temperature (°C) 1m March 2015

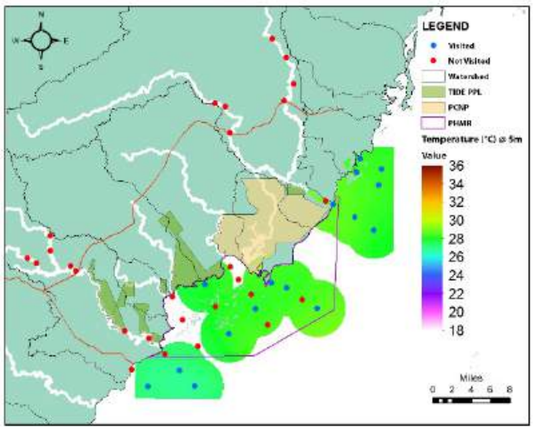


Temperature (°C) 1m April 2015

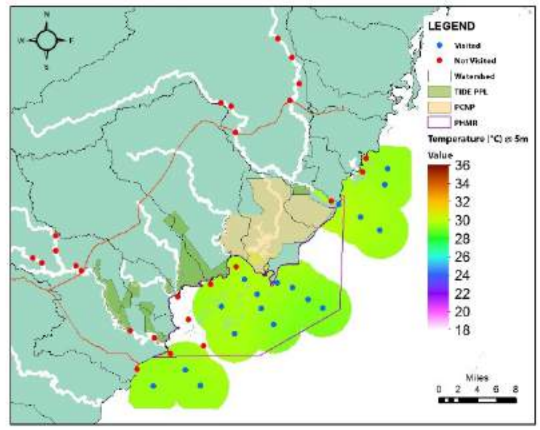


5m

Temperature (°C) 5m March 2015

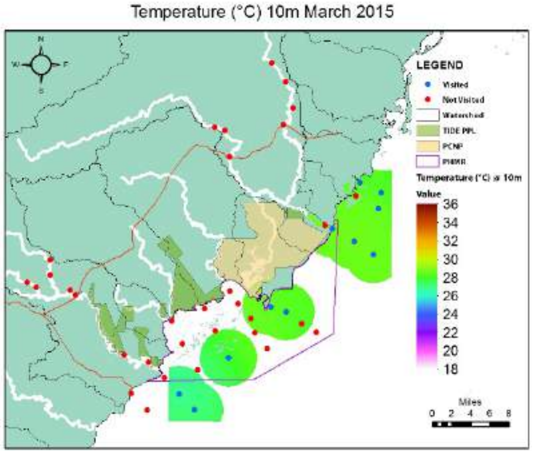


Temperature (°C) 5m April 2015

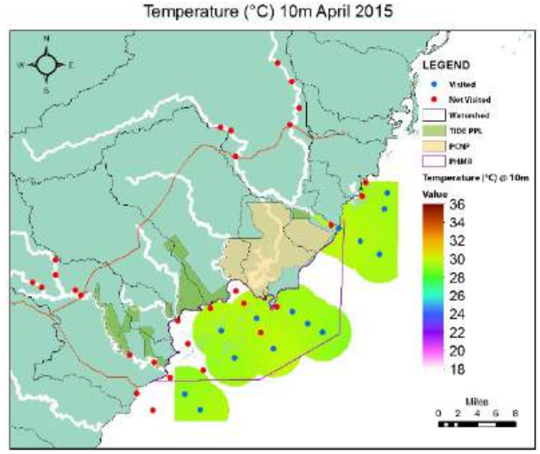


10m

Temperature (°C) 10m March 2015

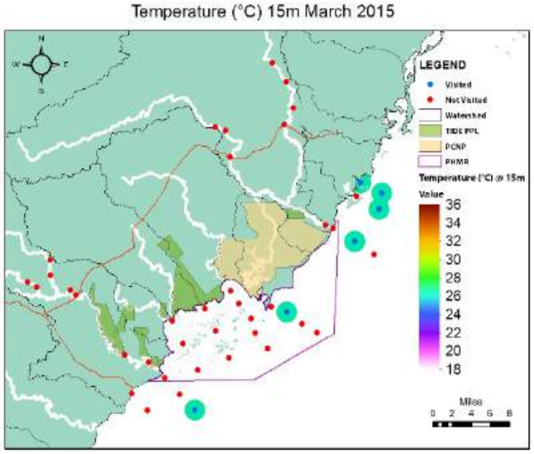


Temperature (°C) 10m April 2015

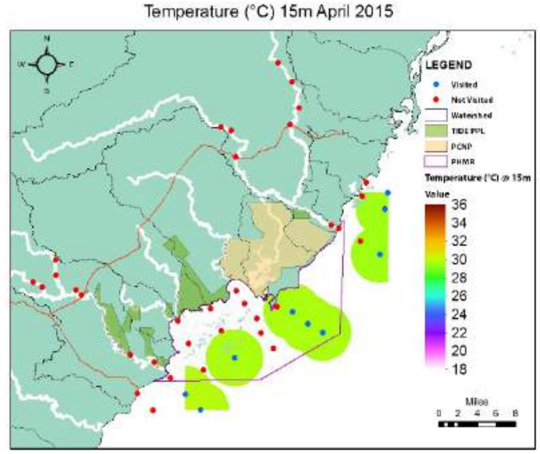


15m

Temperature (°C) 15m March 2015



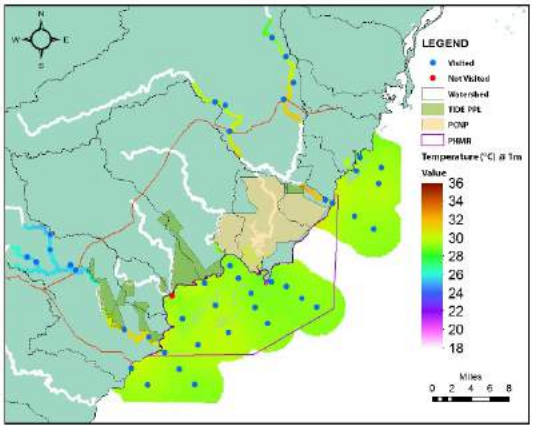
Temperature (°C) 15m April 2015



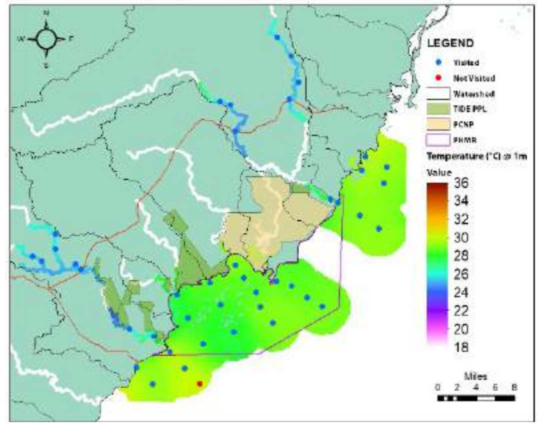
1.3 Temperature (°C) May 2015 (e): June 2015 (f):

1m

Temperature (°C) 1m May 2015

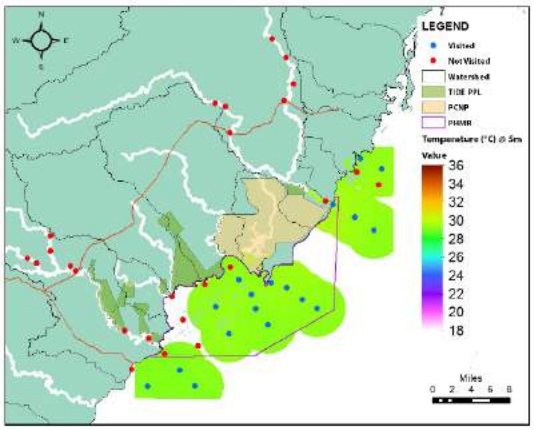


Temperature (°C) 1m June 2015

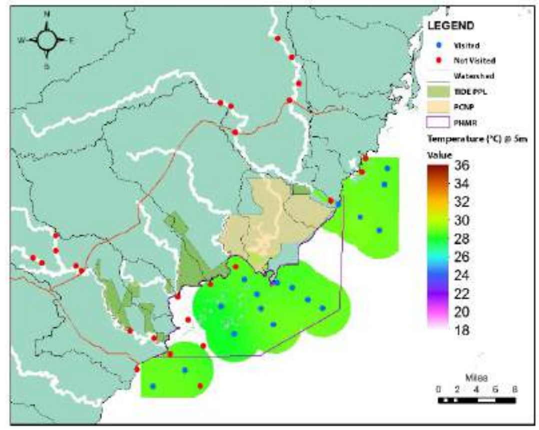


5m

Temperature (°C) 5m May 2015

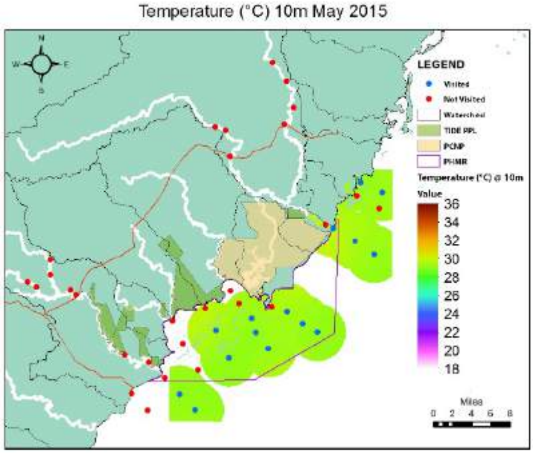


Temperature (°C) 5m June 2015

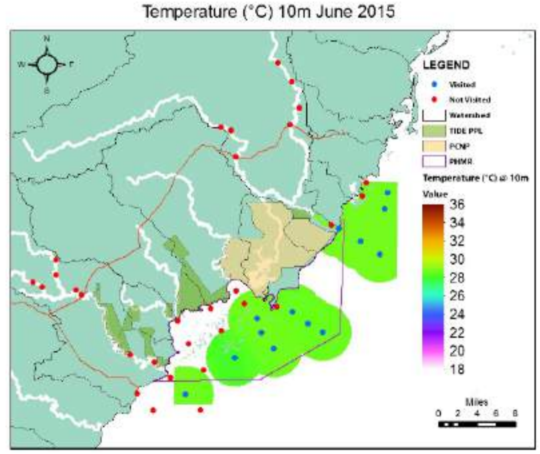


10m

Temperature (°C) 10m May 2015

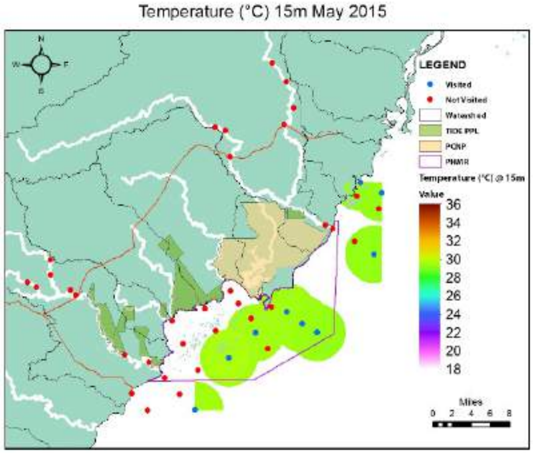


Temperature (°C) 10m June 2015

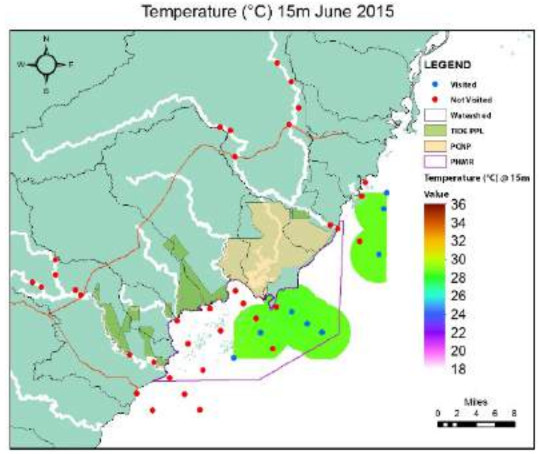


15m

Temperature (°C) 15m May 2015



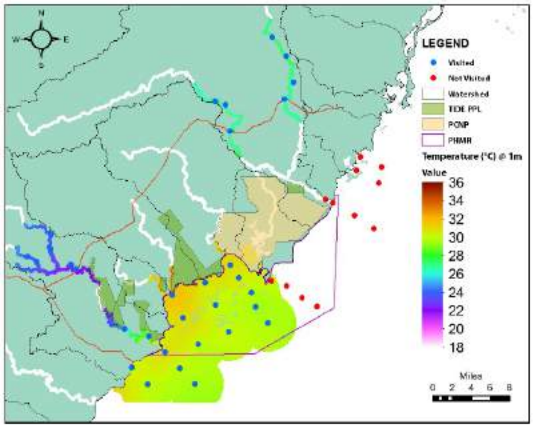
Temperature (°C) 15m June 2015



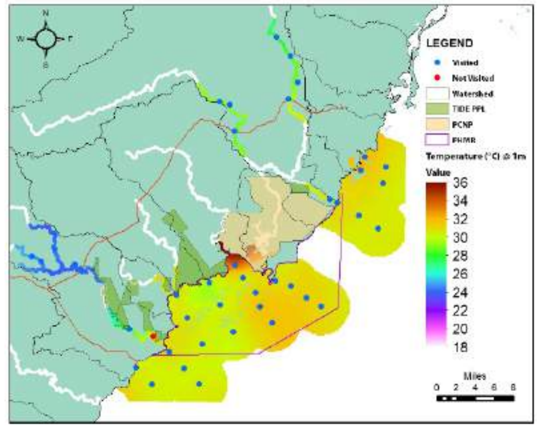
1.3 Temperature (°C) July 2015 (g): August 2015 (h):

1m

Temperature (°C) 1m July 2015

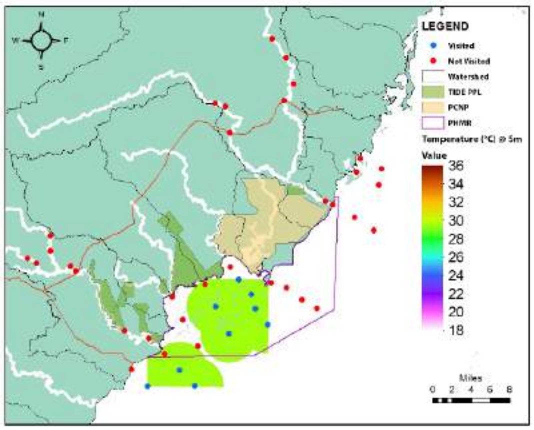


Temperature (°C) 1m August 2015

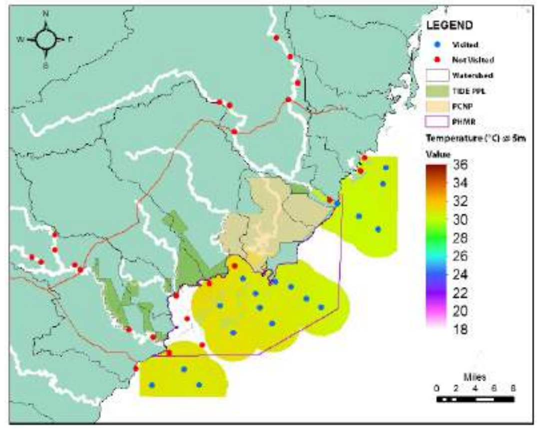


5m

Temperature (°C) 5m July 2015

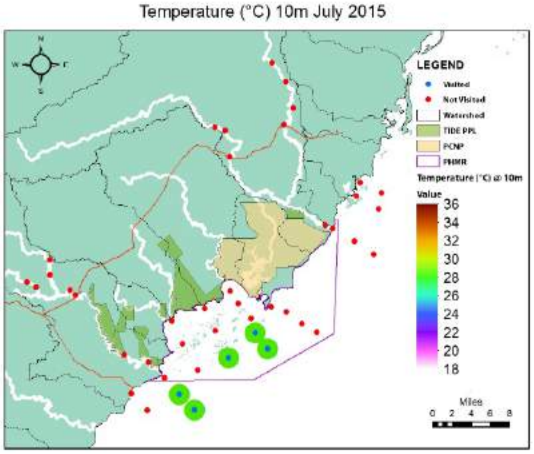


Temperature (°C) 5m August 2015

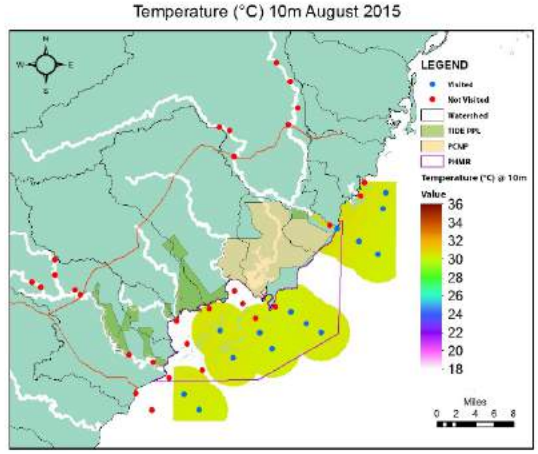


10m

Temperature (°C) 10m July 2015

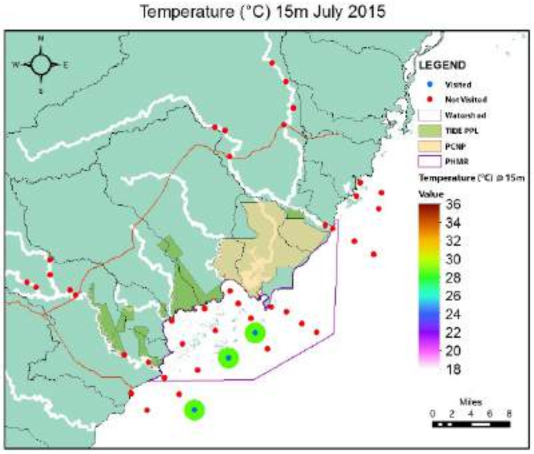


Temperature (°C) 10m August 2015

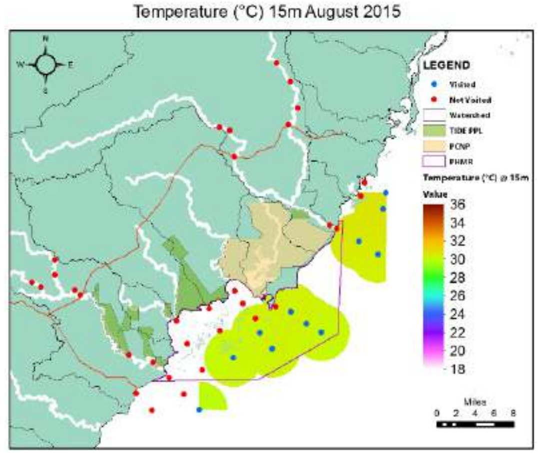


15m

Temperature (°C) 15m July 2015



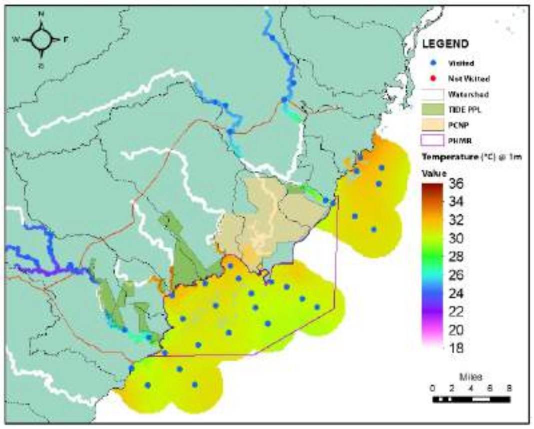
Temperature (°C) 15m August 2015



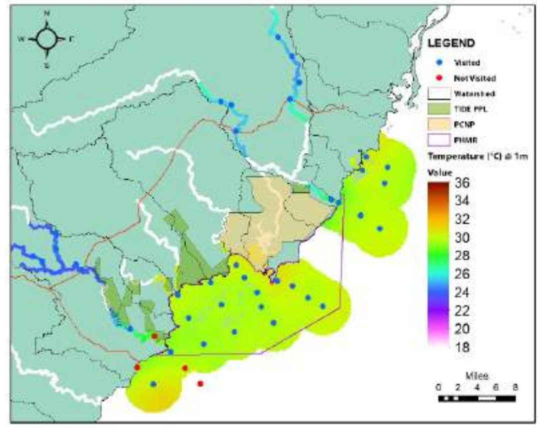
1.3 Temperature (°C) September 2015 (i): October 2015 (j):

1m

Temperature (°C) 1m September 2015

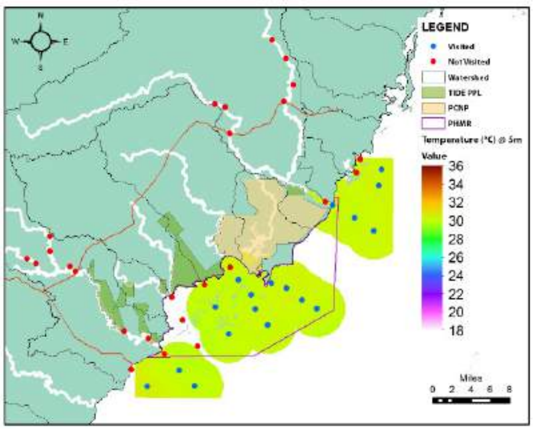


Temperature (°C) 1m October 2015

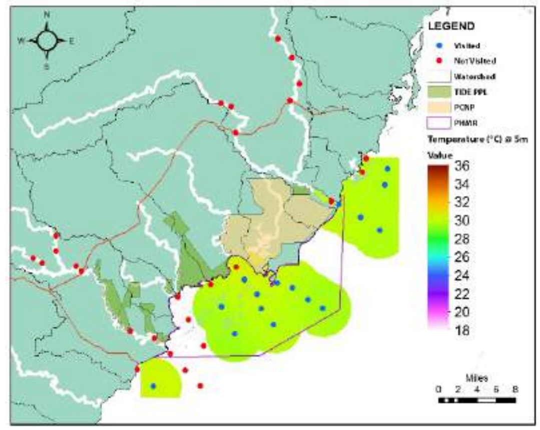


5m

Temperature (°C) 5m September 2015

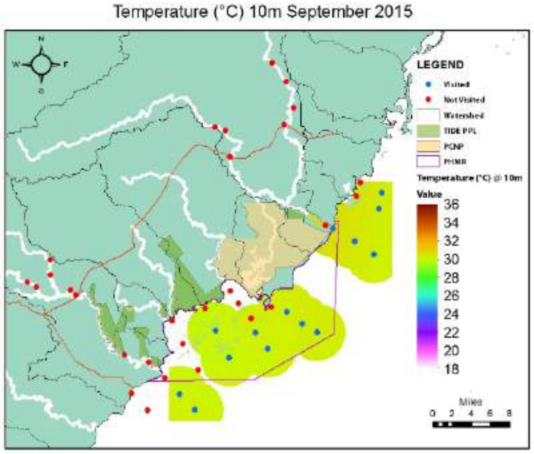


Temperature (°C) 5m October 2015

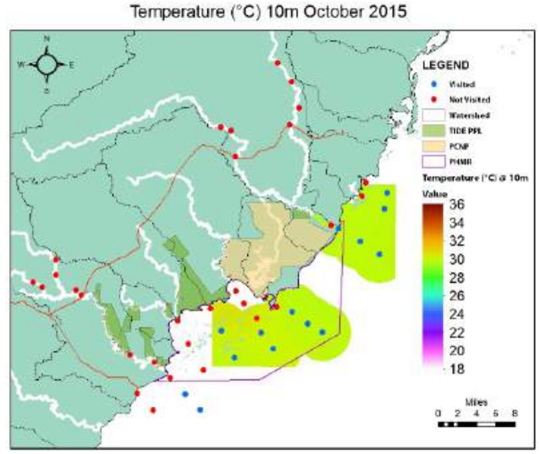


10m

Temperature (°C) 10m September 2015

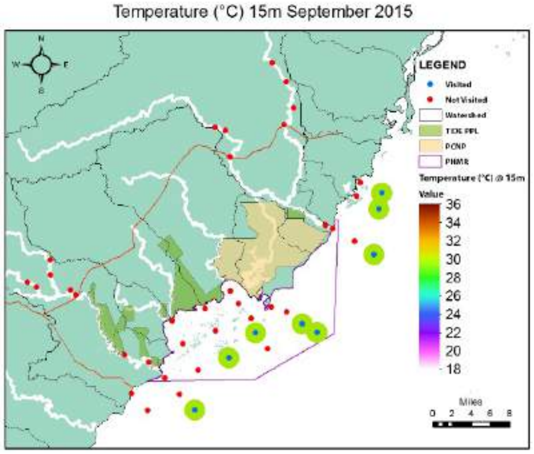


Temperature (°C) 10m October 2015

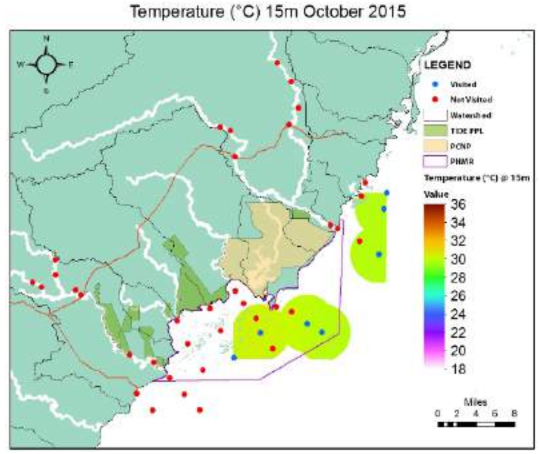


15m

Temperature (°C) 15m September 2015



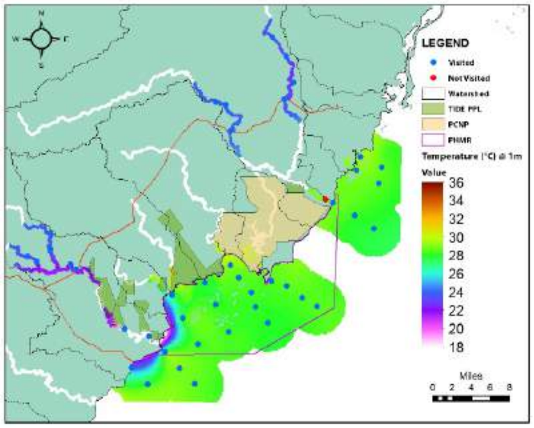
Temperature (°C) 15m October 2015



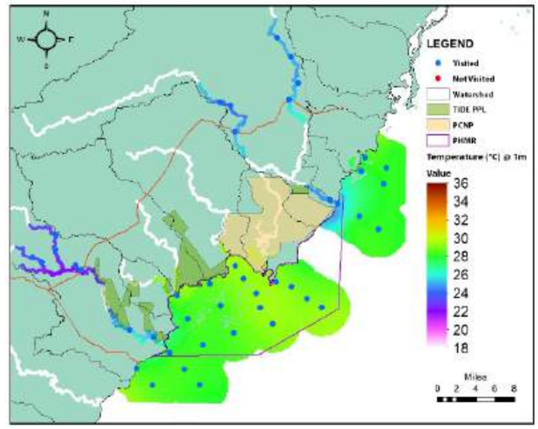
1.3 Temperature (˚C) November 2015 (k): December 2015 (l):

1m

Temperature (°C) 1m November 2015

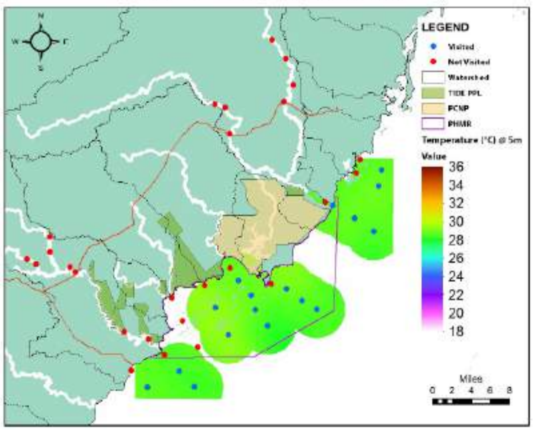


Temperature (°C) 1m December 2015

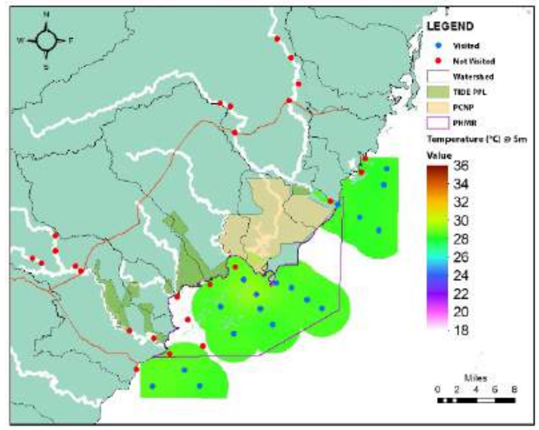


5m

Temperature (°C) 5m November 2015

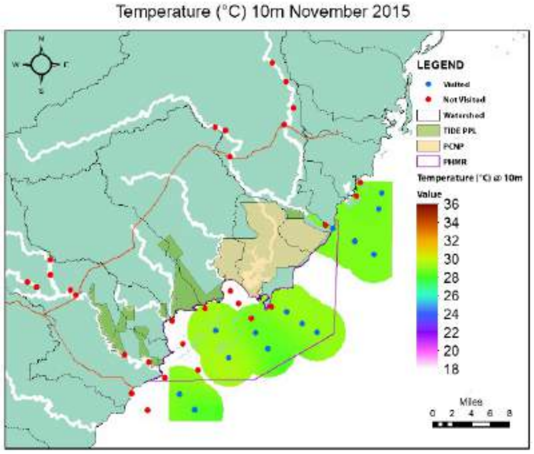


Temperature (°C) 5m December 2015

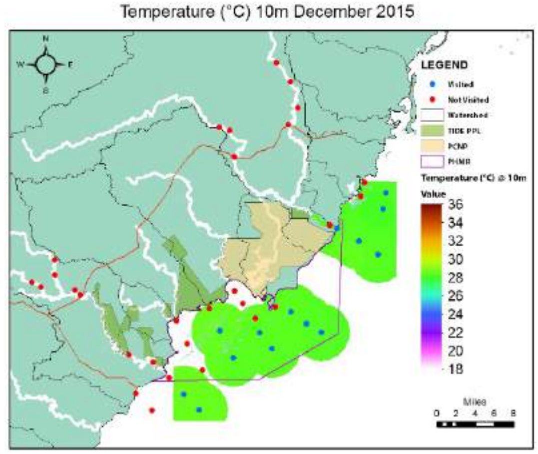


10m

Temperature (°C) 10m November 2015

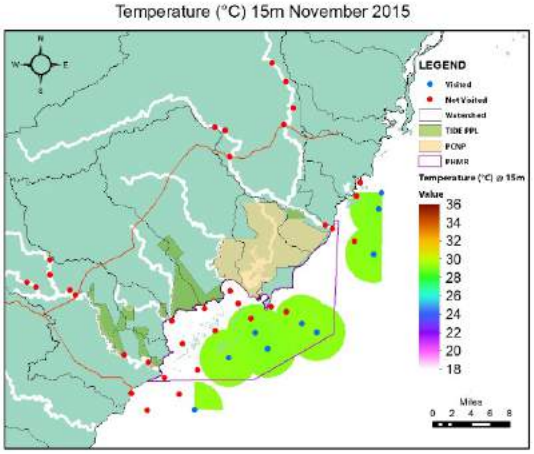


Temperature (°C) 10m December 2015

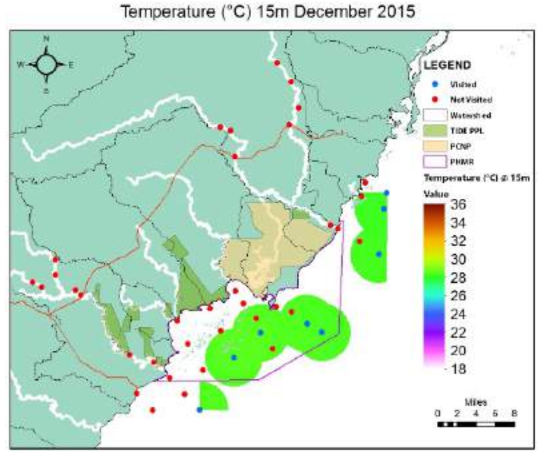


15m

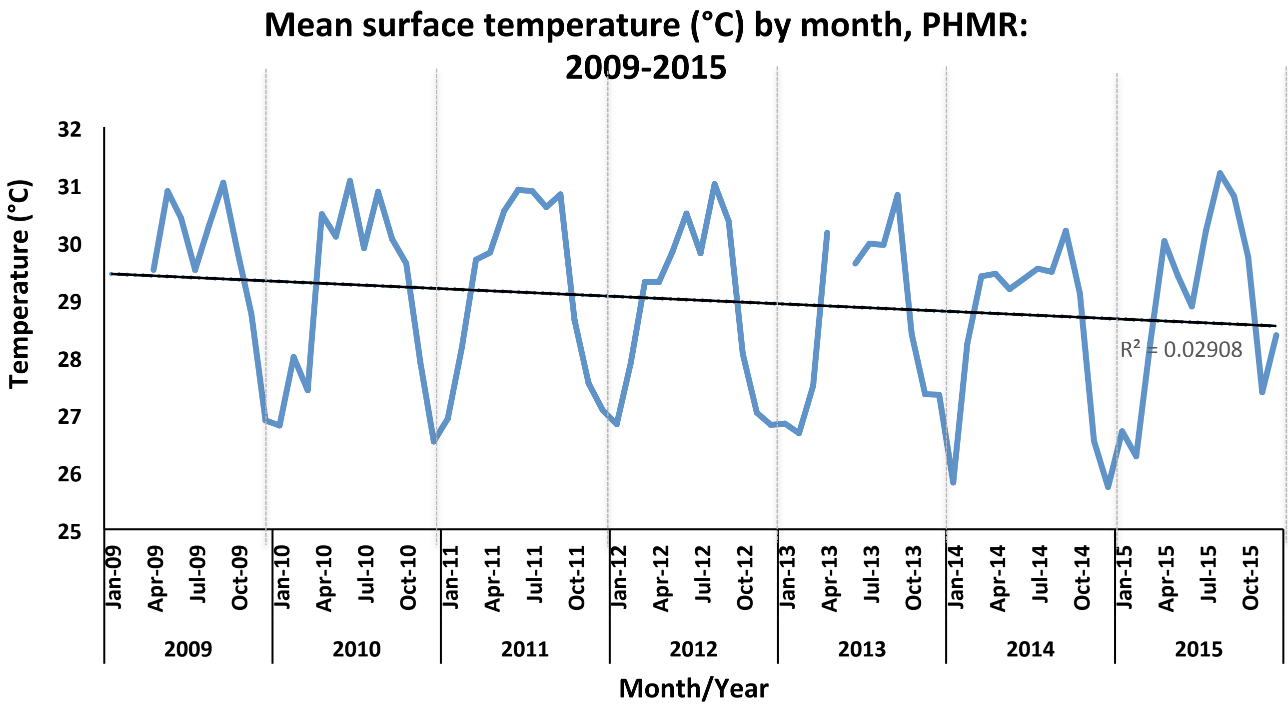
Temperature (°C) 15m November 2015



Temperature (°C) 15m December 2015



1.4 Mean surface temperature by month, PHMR – 2009-2015 (Fig. 1.4):



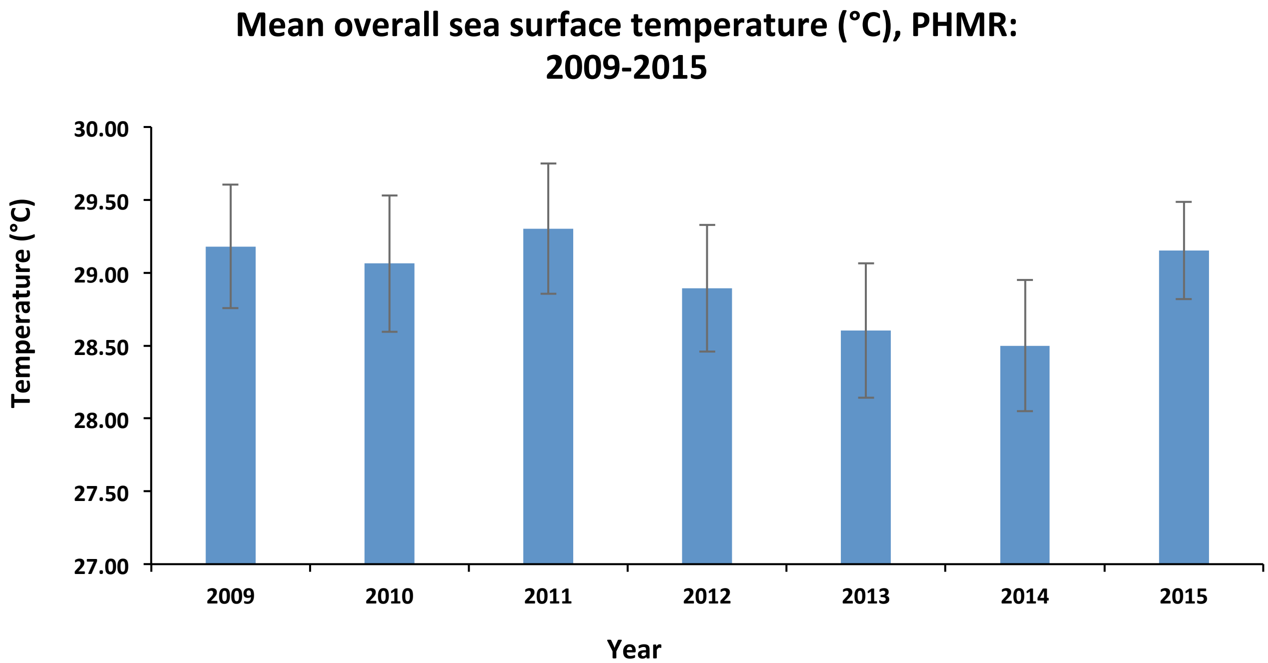
- Mean surface temperatures followed a fairly consistent trend overall in each of the years 2009-2015. In general, temperatures started relatively cool (January in all years approx. 26.8°C), rising steadily to between ~29.3°C to ~30.5°C by April in all years.

- Coldest temperatures for the year 2015 were in January and February (26.7^{o}C ± 0.19SE and 26.3^{o}C ± 0.38SE, respectively). Both were notably similar to previous lowest recorded temperature since 2009 (26.5^{o}C), which was observed in 2014 (25.8°C ± 0.11SE in January and 25.7°C ± 0.13SE in December).

- Temperatures began to rise steadily in February and March, as in previous years. Temperatures from June to August showed an increase similar to previous years. Mean sea surface temperature then decreased continuously from October to December, like in previous years.

- Overall there was a general trend of sea surface temperature cooling in PHMR from 2011- 2014, but sea surface temperature instead increased in PHMR in 2015. This marks the end of the general trend of overall ocean surface cooling in PHMR since 2011. Winters in 2014 and 2015 were markedly colder than any year previous since 2009. However, the greatest summer temperature in 2015 was higher than any previous year and the greatest temperature range within a twelve-month period was observed between December 2014 (25.7^{o}C ± 0.13SE) and September 2015 (30.8^{o}C ± 0.12SE).

1.5 Mean overall sea surface temperatures – 2009-2015 (Fig. 1.5):



- The previously observed continuous declining trend of mean surface temperature for PHMR ended with a notable increase in 2015. 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, an overall gradual cooling was observed between 2009 and 2014, with mean overall temperatures in 2014 being lower than any other year since at least 2010. While highest monthly temperature ever recorded was observed in 2015 (Fig. 1.4), unusually cool temperatures in December 2014, January 2015 and the latter part of 2015 counteracted these high values, bringing overall mean sea surface temperature in 2015 to below that of 2011.

1.6 Temperature – general conclusions:

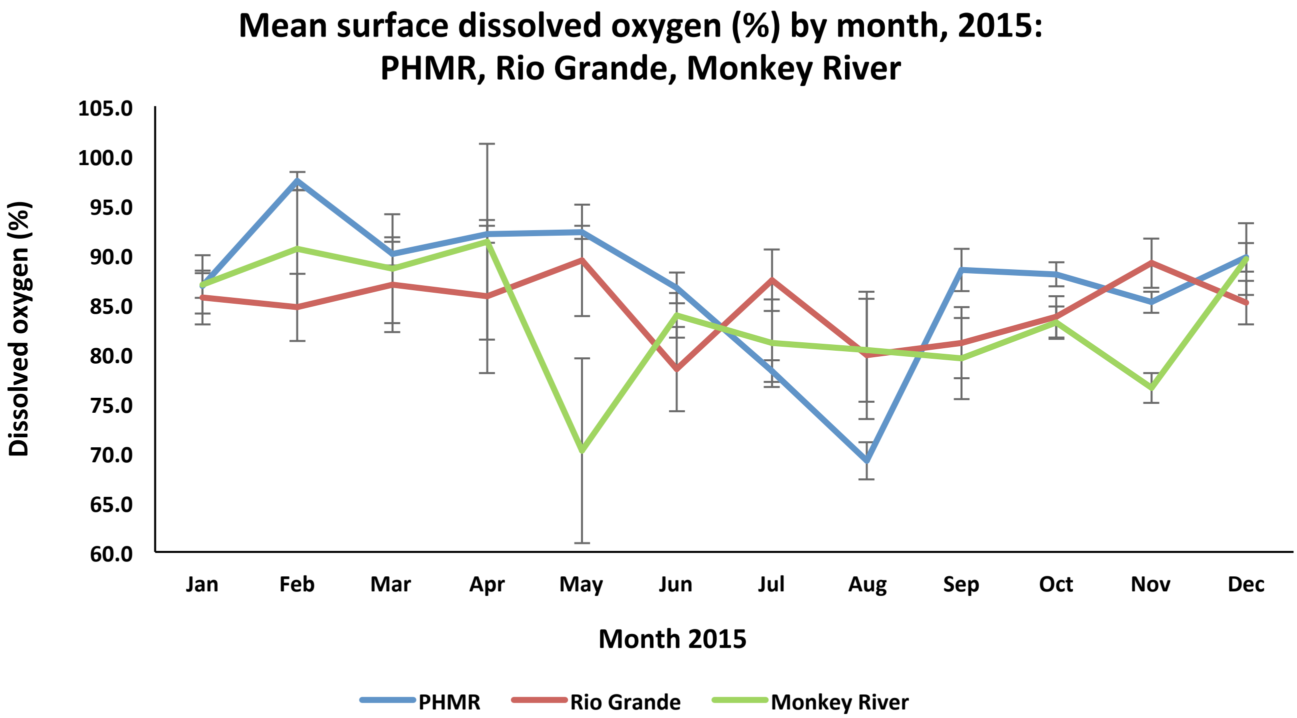
- Mean surface temperature has decreased by 0.8°C from 29.3°C to 28.5°C between 2011 and 2014. In 2015, however, it increased 0.7°C from 28.5°C to 29.2°C.

- April, August and September were the hottest months in PHMR, with warmer than normal summer temperatures reaching above 30°C. On many occasions this also included the multi-depth temperatures.

- As in previous years, Monkey River continues to be warmer than Rio Grande. Rio Grande continues to exhibit overall cooler and more stable temperatures than PHMR and Monkey River.

2. Dissolved Oxygen

2.1 Mean surface Dissolved Oxygen (%) by month, 2015 – PHMR, Monkey River, Rio Grande (Fig. 2.1):



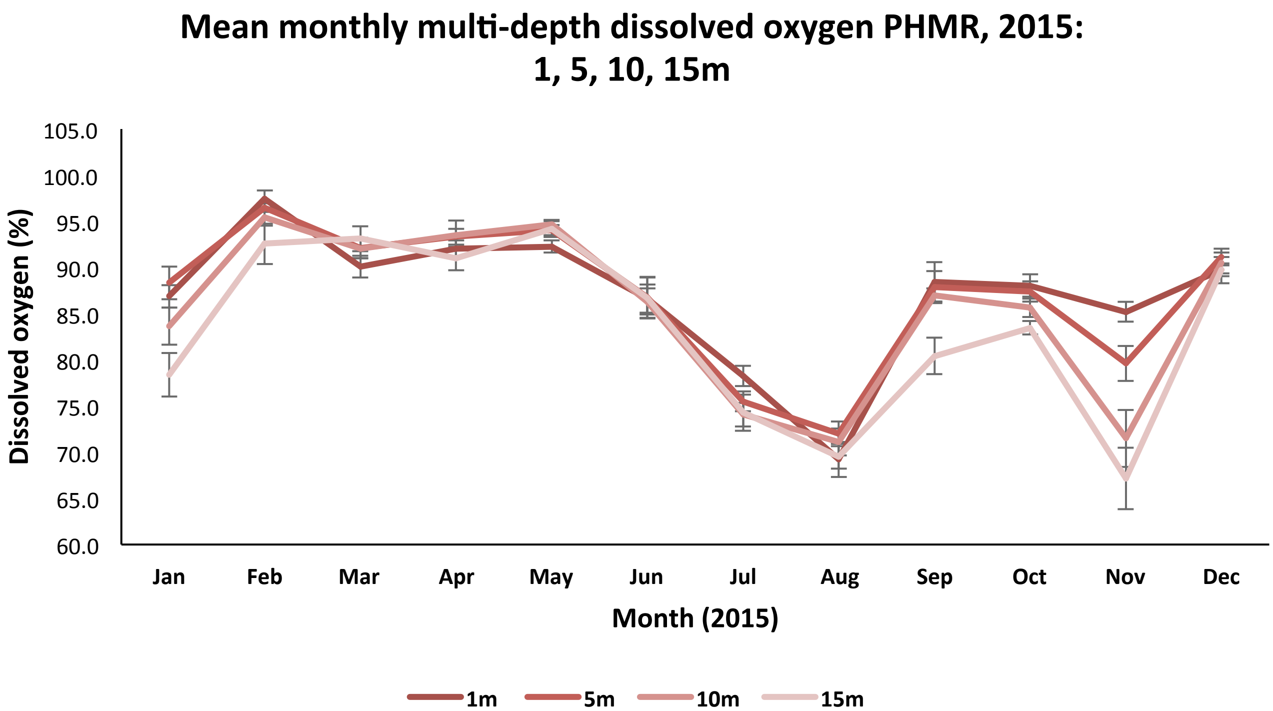
- Overall there is a similar trend in both rivers and the sea of higher mean surface dissolved oxygen levels in early and late ends of the year. In PHMR, mean surface DO was lowest in July and August (78.2% ± 1.08SE and 69.2% ± 1.89SE, respectively), as opposed to May in 2014 (74.7% ± 0.9SE). In Monkey River, mean DO dropped markedly in May (70.2% ± 9.32SE), similarly to 2013 and 2012 as well, though less extreme in 2012. Rio Grande showed a stable pattern throughout the course of the year ranging from 78.5% ± 4.26SE to 89.4% ± 5.64.

- In 2015, the mean DO was highest in February in PHMR (97.4% ± 0.92 SE), May in Rio Grande (89.4% ± 5.64 SE) and April in Monkey River (91.3% ± 9.89 SE).

- Whereas in 2012, PHMR almost always had highest mean 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 generally had lower DO than Rio Grande and surface values in PHMR. In 2015, PHMR almost always had the highest DO, except in July, August and November, and Monkey River and Rio Grande alternated.

- Overall trends in mean surface DO from one year to the next have been quite different, and there have been no identifiable patterns.

2.2 Mean monthly dissolved oxygen, 2015 – 1, 5, 10, 15m depth (Fig. 2.2):



- DO rose significantly at all depths between January and February 2015, peaking above 95% at the surface in February. Conditions remained stable and uniform at all depths from February to May, between about 90-97% at all depths. There was a considerable and continuous drop between May and August at all depths (from 93.8% in May ± 0.53SE to 70.5% ± 0.65SE in May). Mean DO finally rose again to the 80s (%) in September and October before a considerable drop in November and then return to ~90% in December, similar to the previous year.

- DO stratification increased steadily from August until December in 2015, with conditions being similar at all depths until mean DO below 10m becomes lower than at shallower depths, and markedly lower at 15m until November. Conditions became more uniform with depth in December.

- In the last few years there has not been a consistent pattern in DO trends from year to year.

2.3 Dissolved oxygen maps, 2015; multi-depth 1m, 5m 10m, 15m – PHMR, Monkey River, Rio Grande:

a. January (Figs. 2.3 a 1m-15m): In general, DO was similar across PHMR, averaging near 86%. Surface mean DO in PHMR was 86.9% ± 1.23SE. Site 3A in PHMR had the highest single-site DO (108%) while the lowest single site DO was 74% at site 6A. There was little change in DO% with increasing depth throughout PHMR.

b. February (Figs. 2.3 b 1m-15m): DO conditions in the rivers were slightly higher than January but averaged lower than PHMR. There was little spatial variability across PHMR, which had a mean DO of 97.4% ± 0.94SE. Multi depth DO was slightly lower with increasing depth and ranged from 97.4-92.6%.

c, d. March, April (Figs. 2.3 c 1m-15m, d 1m-15m): DO levels were relatively high in the upper reaches of both rivers. Monkey River, however, showed more variability between the upper and lower reaches of the Swasey Branch (~110% to ~80%, respectively). Lower DO was recorded for April than March in the Swasey Branch. March showed similar trends but some stations (Site: MR_TB_1a and RG_RG_1a) recorded DO as low as ~55% in the lower to mid reaches. In PHMR, DO remained relatively constant (March, 90.1% ± 1.18SE; April, 92.1% ± 0.86SE) and showed little spatial variation across sites, both at surface and subsurface levels. Site 5E at 10m recorded the highest April DO (112%) in PHMR.

e. May (Figs. 2.3 e 1m-15m): Both Monkey River and Rio Grande showed a decrease in DO, with only the Columbia Branch of Rio Grande recording a high of 122% in the upper reaches. Site MR_TB_1a in Monkey River recorded an extremely low 29.8%. PHMR showed continuing high DO levels across both surface (92.3% ± 0.68SE) and subsurface (between 94-95%) depths compared to previous months. An increase of ~2% in subsurface water was observed in comparison to surface water.

f. June (Figs. 2.3 f 1m-15m): Rio Grande and Monkey River both had a decrease in average DO. DO was consistent throughout the entire rivers (73.5-90.0%) except for a measurement of 52.4% in the lower reaches of the Rio Grande (RG_RG_1d). PHMR also had a decrease in DO at the surface (86.6% ± 1.55SE), which was very similar to levels recorded in January (86.9% ± 1.23SE at 1m). Similar DO levels were recorded in subsurface waters, also a decrease from previous months.

g. July (Figs. 2.3 g 1m-15m): Rio Grande was the only area to show an increase from the previous month in DO. The average in Monkey River declined another ~2%. PHMR exhibited a similar decline with no spatial variability, but had a greater decrease in the average DO of ~8%. There was little spatial variability in subsurface DO besides a slight decrease with increasing depth.

h. August (Figs. 2.3 h 1m-15m): DO remained low in Monkey River at ~80% and Rio Grande exhibited similar DO. PHMR kept decreasing reaching 69.2% ± 1.89SE, on average at the surface, lower than previous years (DO was ~90% in 2014 in PHMR). There was little subsurface variation, besides a decline in DO with increasing depth.

i, j. September, October (Figs. 2.3 i 1m-15m, j 1m-15m): Rio Grande and Monkey River both kept their low levels of DO, but DO was higher in the upper reaches of both rivers at ~90%. In PHMR, levels recovered from their two-month average lows, reaching 88.4% ± 2.13SE in September, an increase of ~18%. Depths 1m, 5m and 10m showed similar increases with only readings at 15m increasing by a lower percentage.

October showed little to no variation with only a high recorded at site 1a (107.1%). There was little spatial variation in PHMR for the two months.

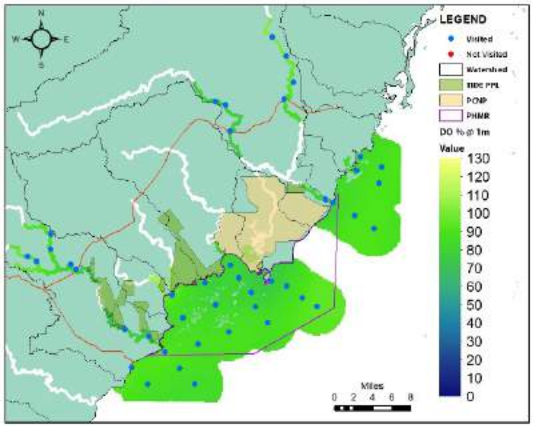
k. November (Figs. 2.3 k 1m-15m): DO levels remained constant in Rio Grande with slightly higher levels in the upper reaches. Monkey River decreased to an average of 76.6% ± 1.51SE. There was very little variability across the reaches. Surface DO in PHMR remained high with little spatial variation; however, DO decreased with increasing depth from ~85% to ~67%.

l. December (Figs. 2.3 l1-l15): DO decreased slightly in Monkey River (89.6% ± 2.21SE) while it increased in Rio Grande (85.2% ± 2.21SE). Both showed little variation between branches. Overall, PHMR had high surface DO (mean 89.7% ± 1.43SE). DO remained high at depth, indicating an end to the stratification observed in November.

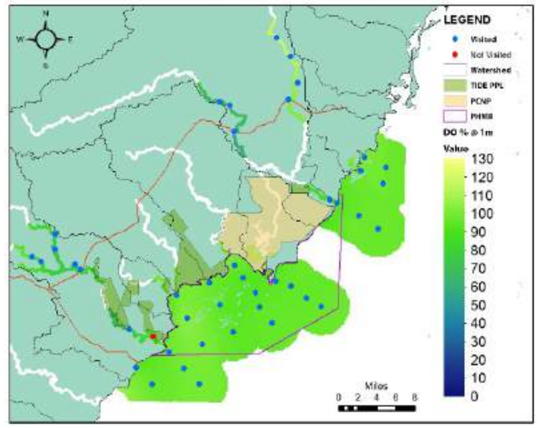
2.3 Dissolved oxygen (%) **January 2015 (a):** **February 2015 (b):**

1m

Dissolved Oxygen % 1m January 2015

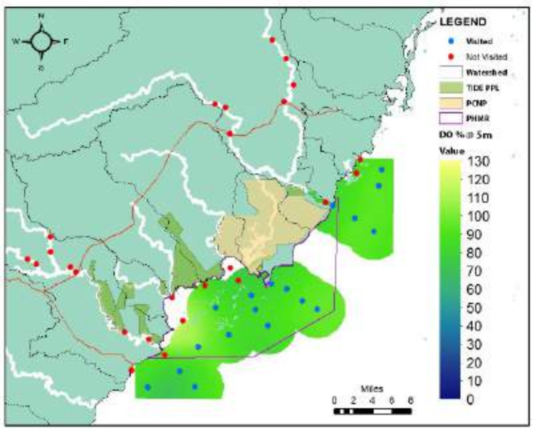


Dissolved Oxygen % 1m February 2015

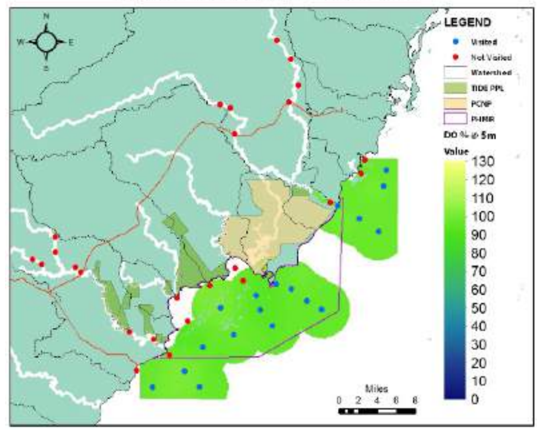


5m

Dissolved Oxygen % 5m January 2015

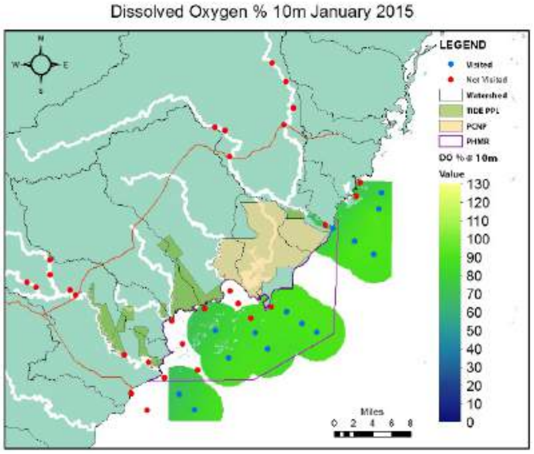


Dissolved Oxygen % 5m February 2015

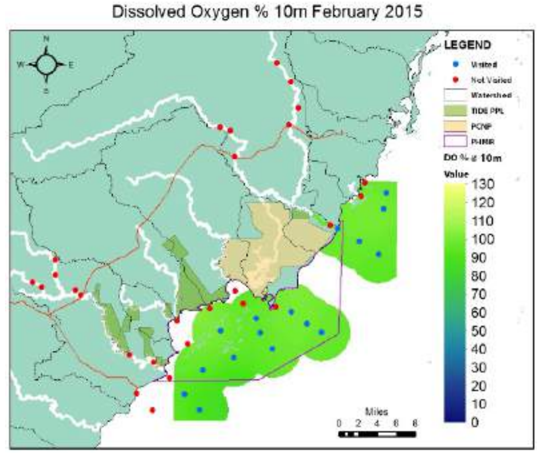


10m

Dissolved Oxygen % 10m January 2015

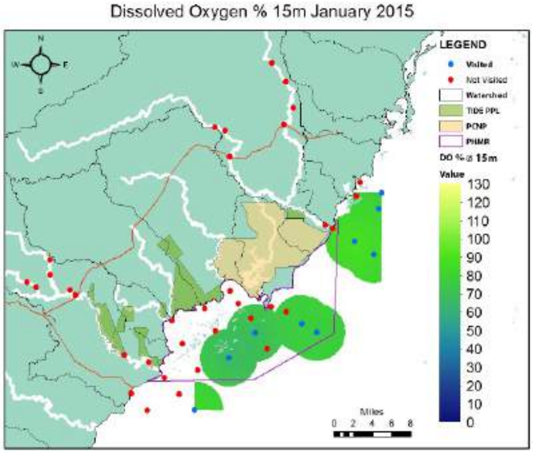


Dissolved Oxygen % 10m February 2015

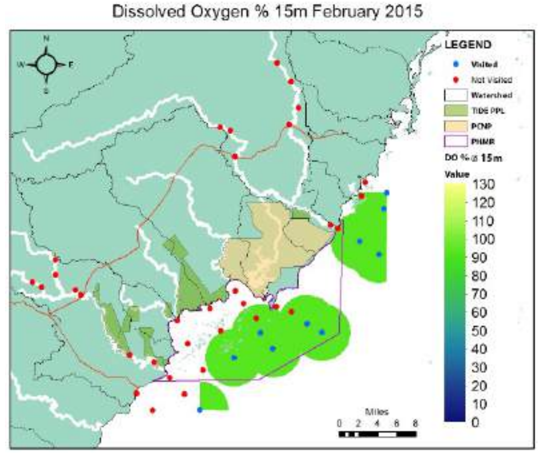


15m

Dissolved Oxygen % 15m January 2015



Dissolved Oxygen % 15m February 2015

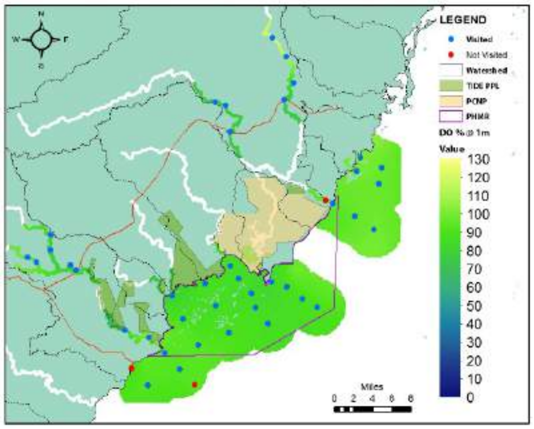


2.3 Dissolve oxygen (%)

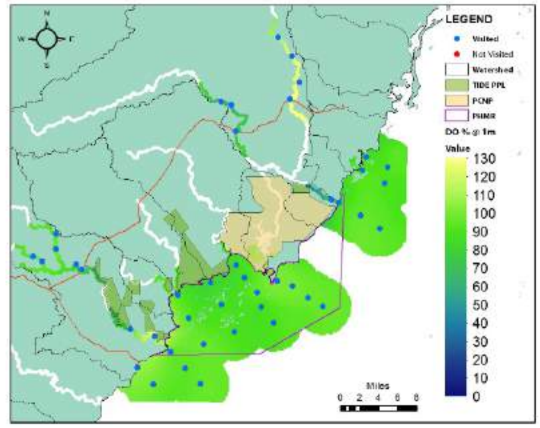
March 2015 (c): **April 2015 (d):**

1m

Dissolved Oxygen % 1m March 2015

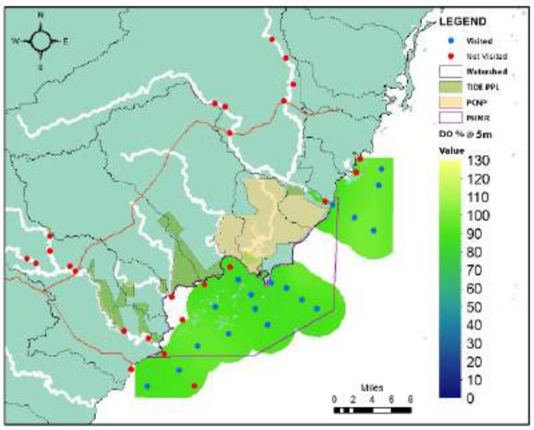


Dissolved Oxygen % 1m April 2015

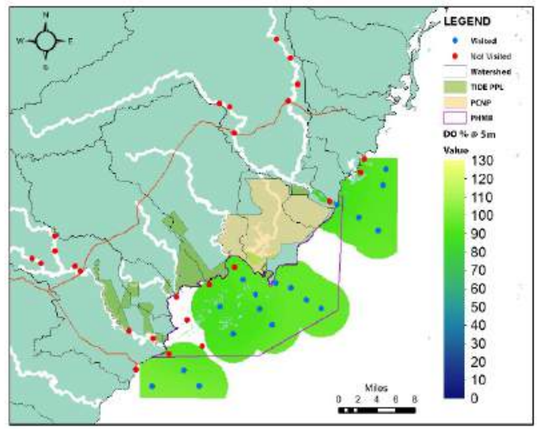


5m

Dissolved Oxygen % 5m March 2015

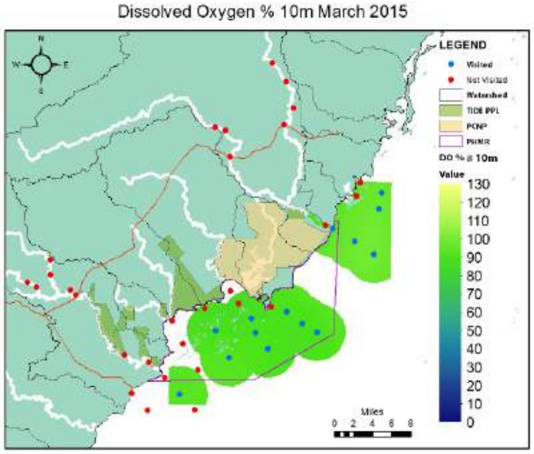


Dissolved Oxygen % 5m April 2015

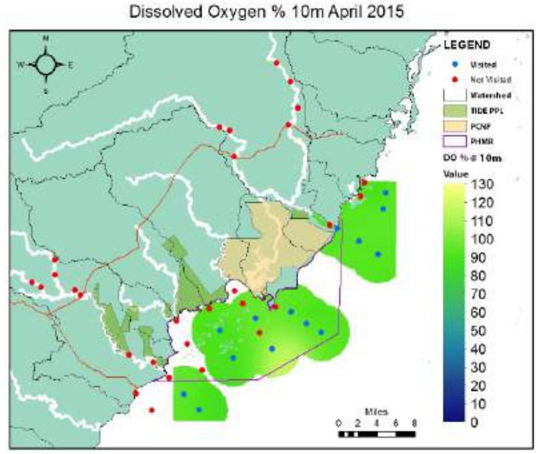


10m

Dissolved Oxygen % 10m March 2015

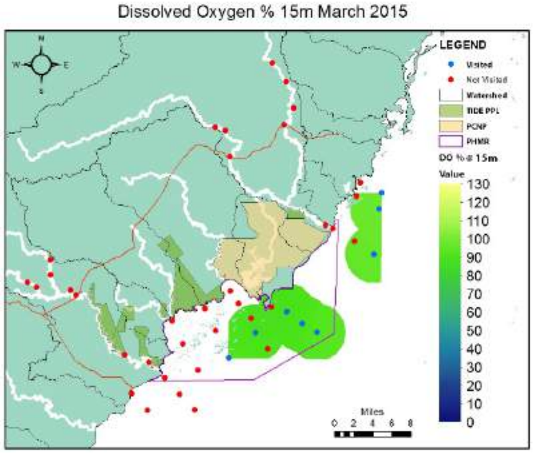


Dissolved Oxygen % 10m April 2015

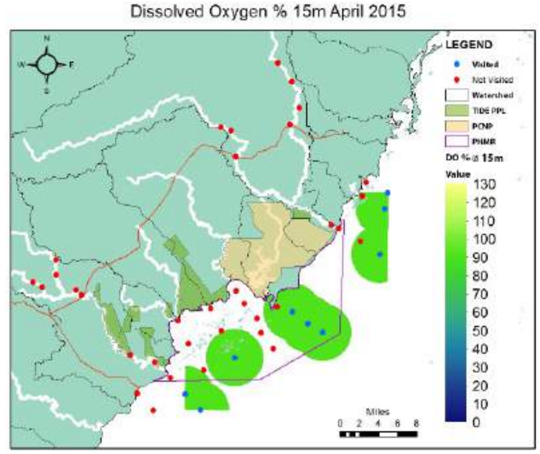


15m

Dissolved Oxygen % 15m March 2015



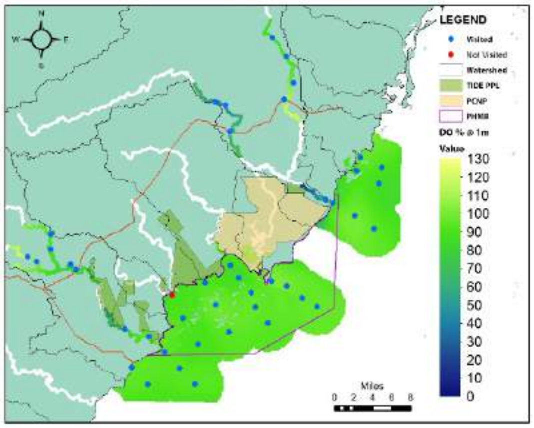
Dissolved Oxygen % 15m April 2015



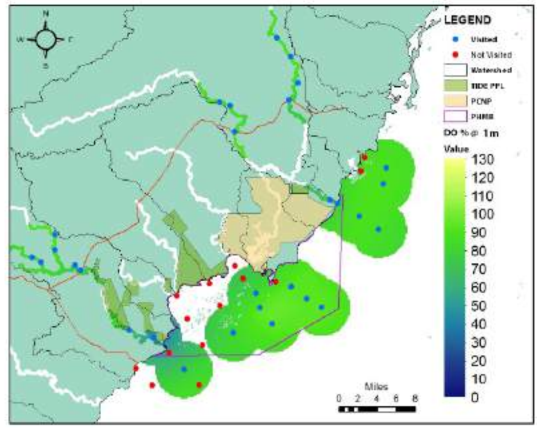
2.3 Dissolved oxygen (%) May 2015 (e): June 2015 (f):

1m

Dissolved Oxygen % 1m May 2015

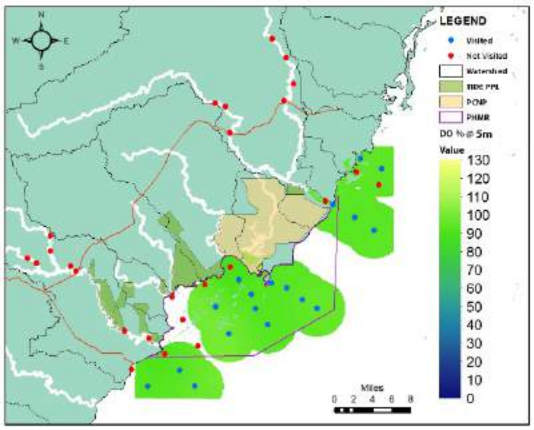


Dissolved Oxygen % 1m June 2015

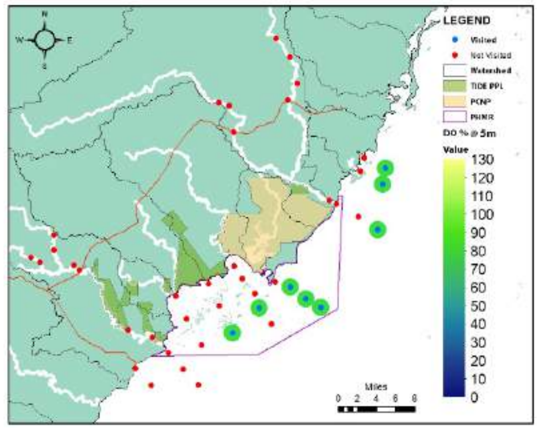


5m

Dissolved Oxygen % 5m May 2015

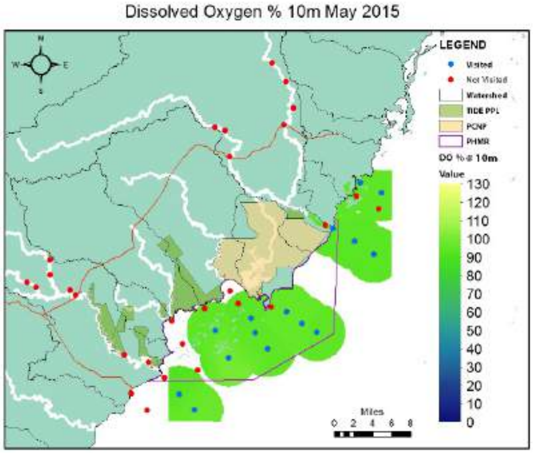


Dissolved Oxygen % 5m June 2015

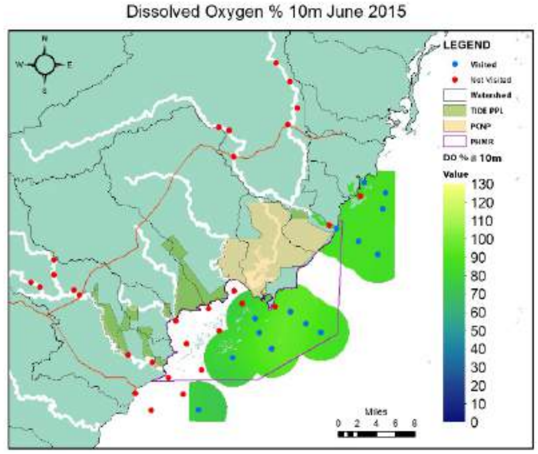


10m

Dissolved Oxygen % 10m May 2015

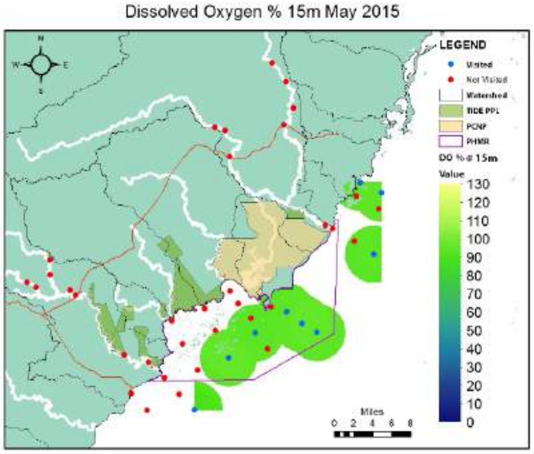


Dissolved Oxygen % 10m June 2015

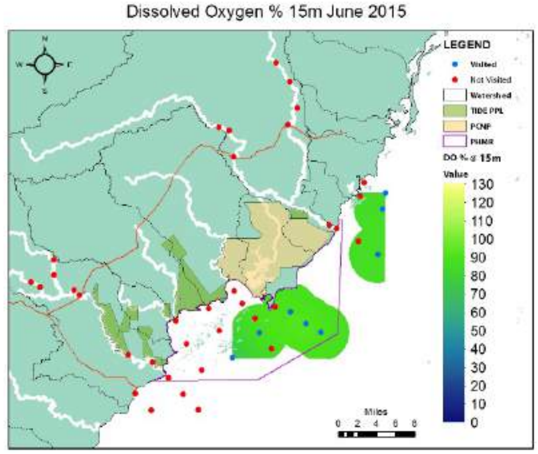


15m

Dissolved Oxygen % 15m May 2015



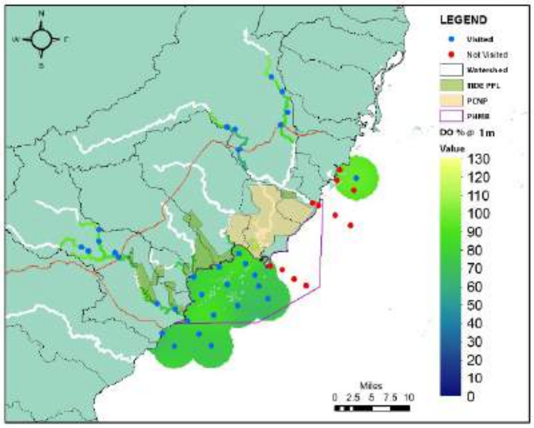
Dissolved Oxygen % 15m June 2015



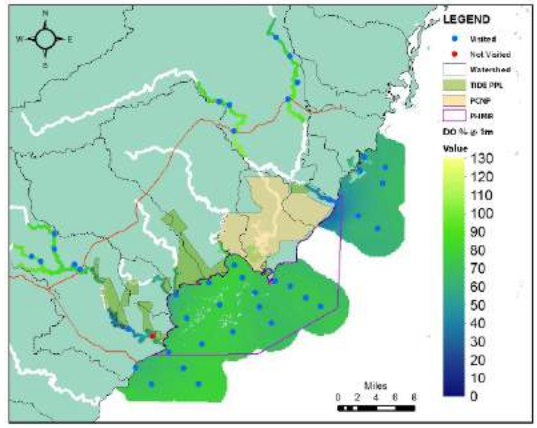
2.3 Dissolved oxygen (%) July 2015 (g): August 2015 (h):

1m

Dissolved Oxygen % 1m July 2015

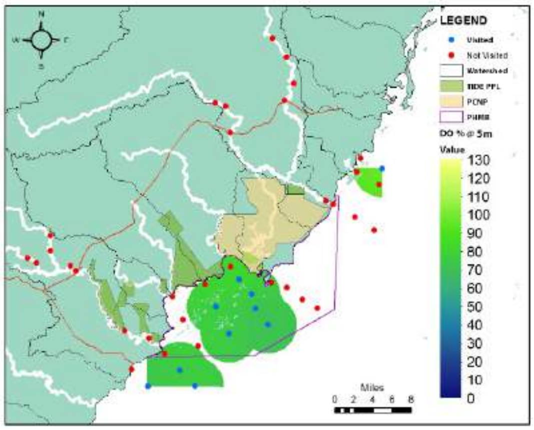


Dissolved Oxygen % 1m August 2015

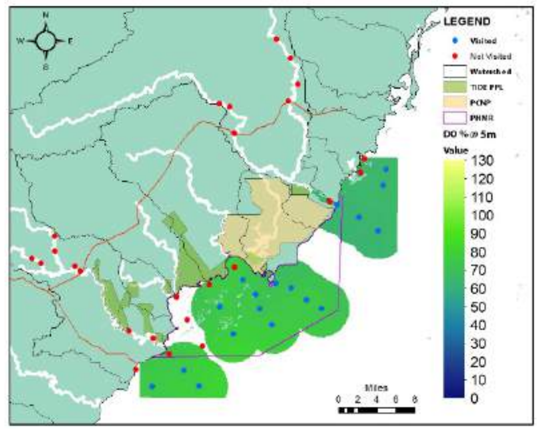


5m

Dissolved Oxygen % 5m July 2015

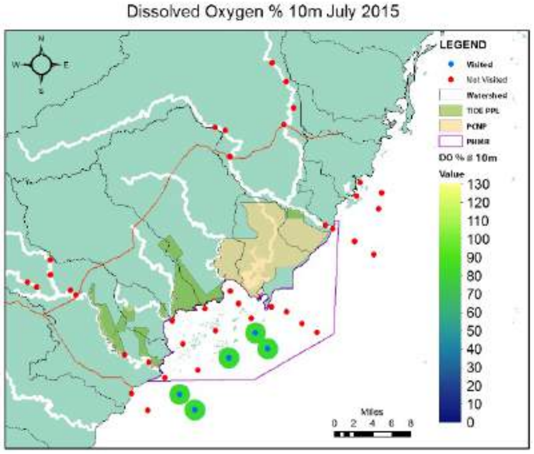


Dissolved Oxygen % 5m August 2015

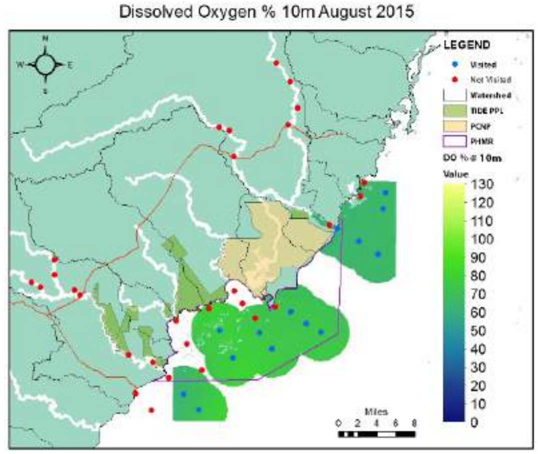


10m

Dissolved Oxygen % 10m July 2015

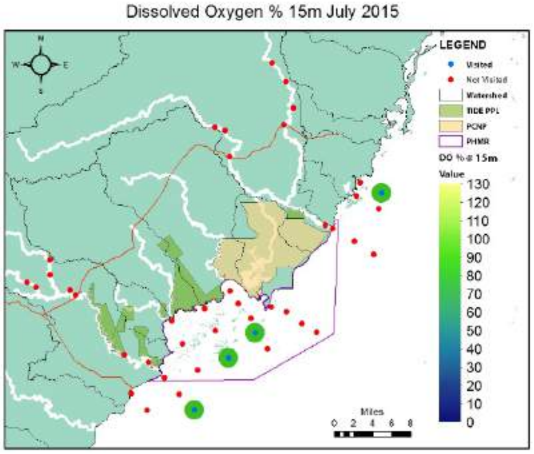


Dissolved Oxygen % 10m August 2015

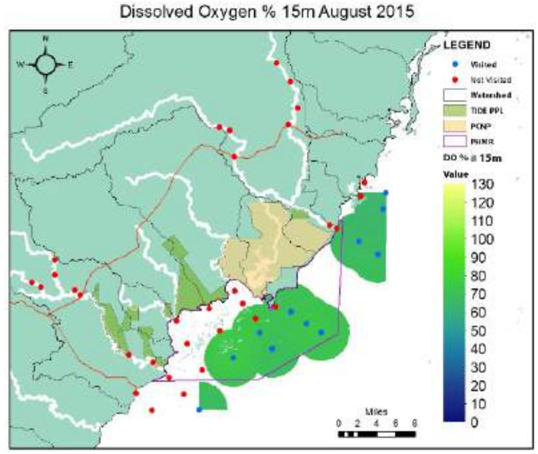


15m

Dissolved Oxygen % 15m July 2015



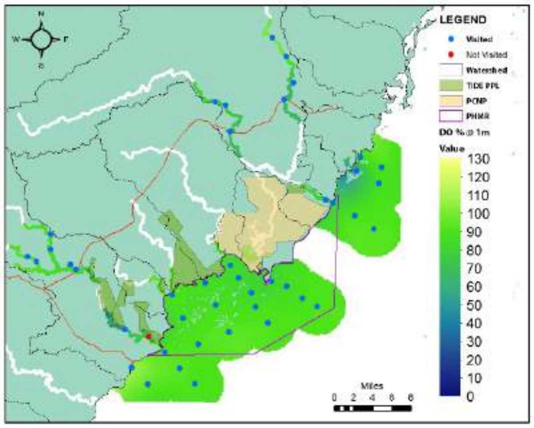
Dissolved Oxygen % 15m August 2015



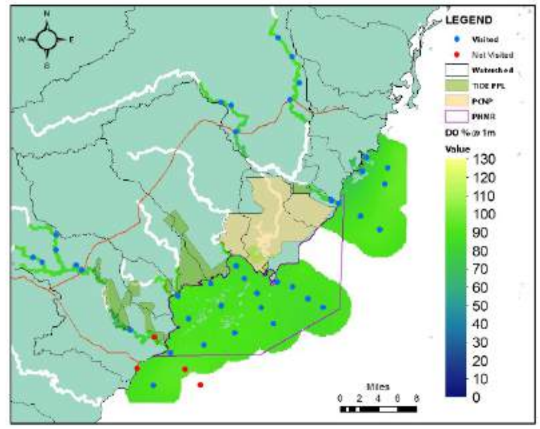
2.3 Dissolved oxygen (%) **September 2015 (i):** **October 2015 (j):**

1m

Dissolved Oxygen % 1m September 2015

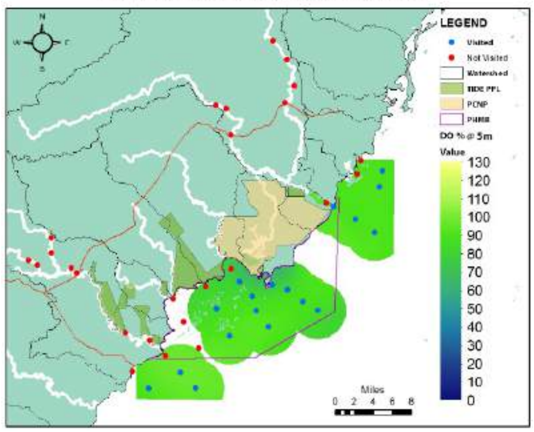


Dissolved Oxygen % 1m October 2015

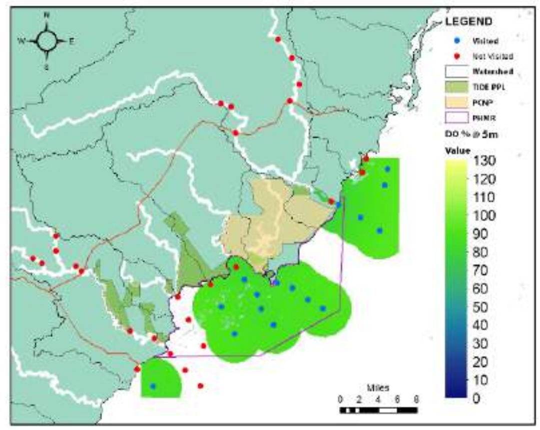


5m

Dissolved Oxygen % 5m September 2015

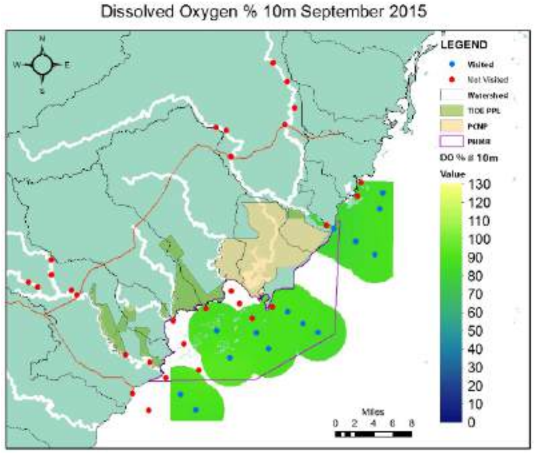


Dissolved Oxygen % 5m October 2015

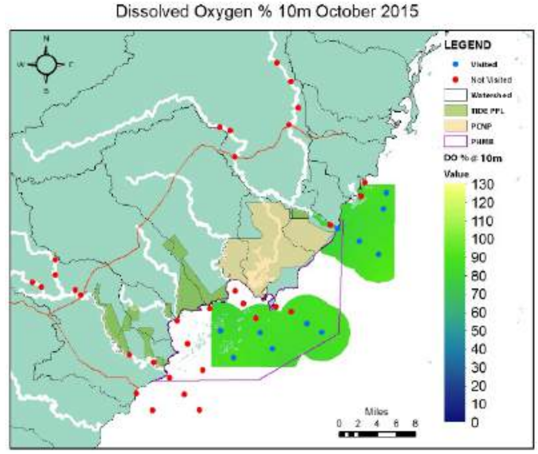


10m

Dissolved Oxygen % 10m September 2015

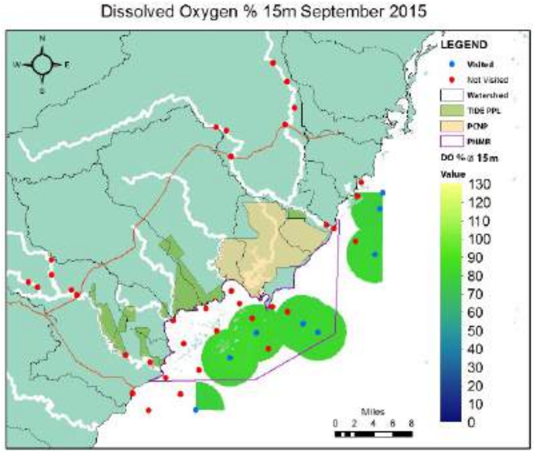


Dissolved Oxygen % 10m October 2015

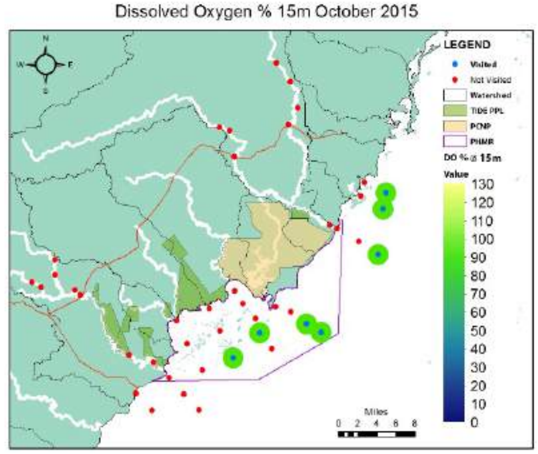


15m

Dissolved Oxygen % 15m September 2015



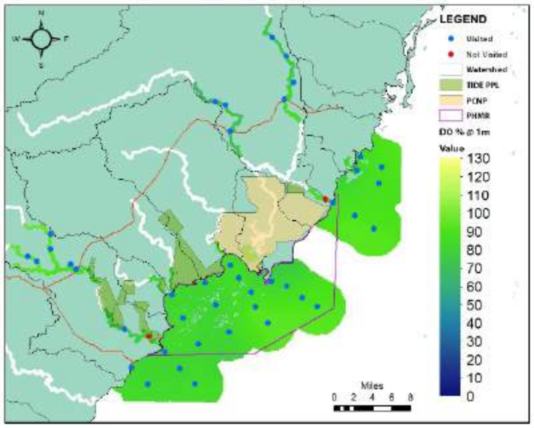
Dissolved Oxygen % 15m October 2015



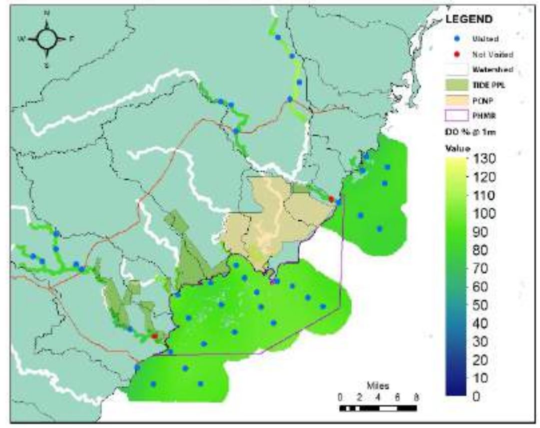
2.3 Dissolved oxygen (%) November 2015 (k): December 2015 (l):

1m

Dissolved Oxygen % 1m November 2015

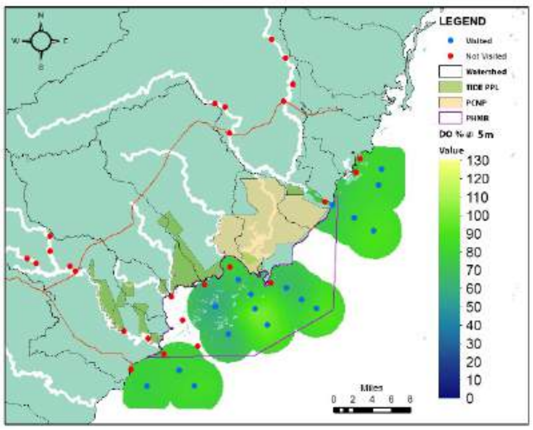


Dissolved Oxygen % 1m December 2015

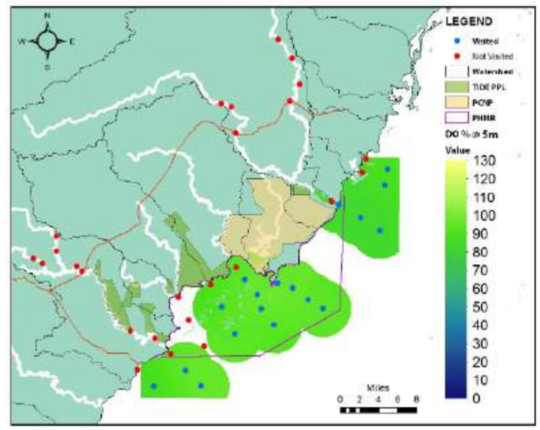


5m

Dissolved Oxygen % 5m November 2015

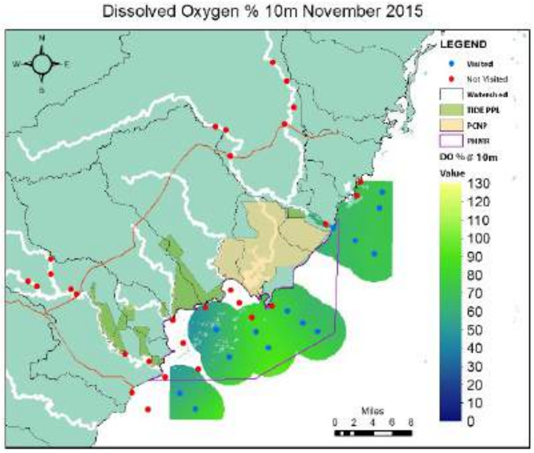


Dissolved Oxygen % 5m December 2015

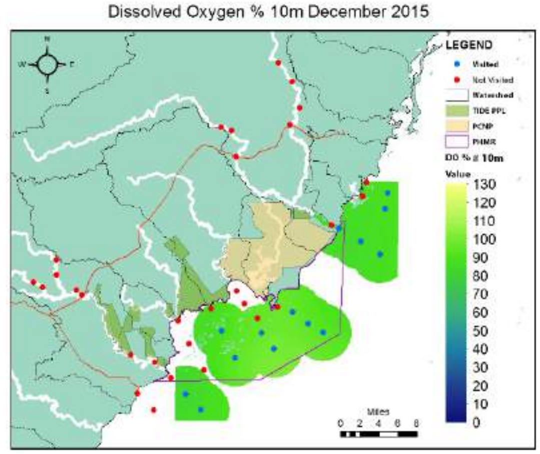


10m

Dissolved Oxygen % 10m November 2015

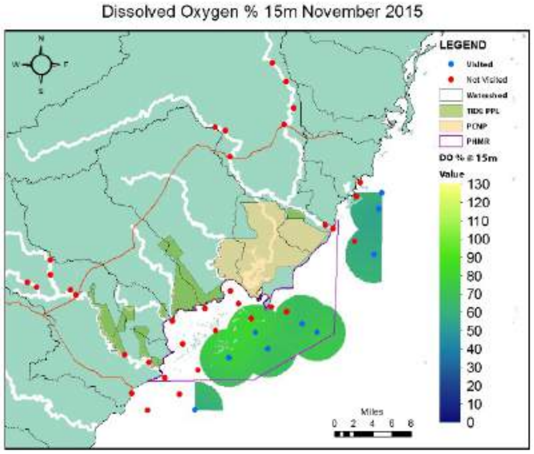


Dissolved Oxygen % 10m December 2015

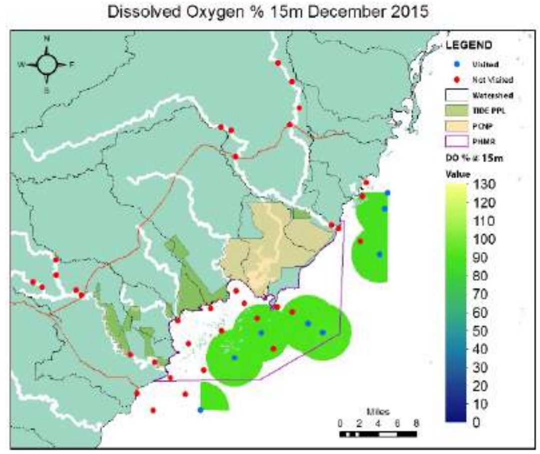


15m

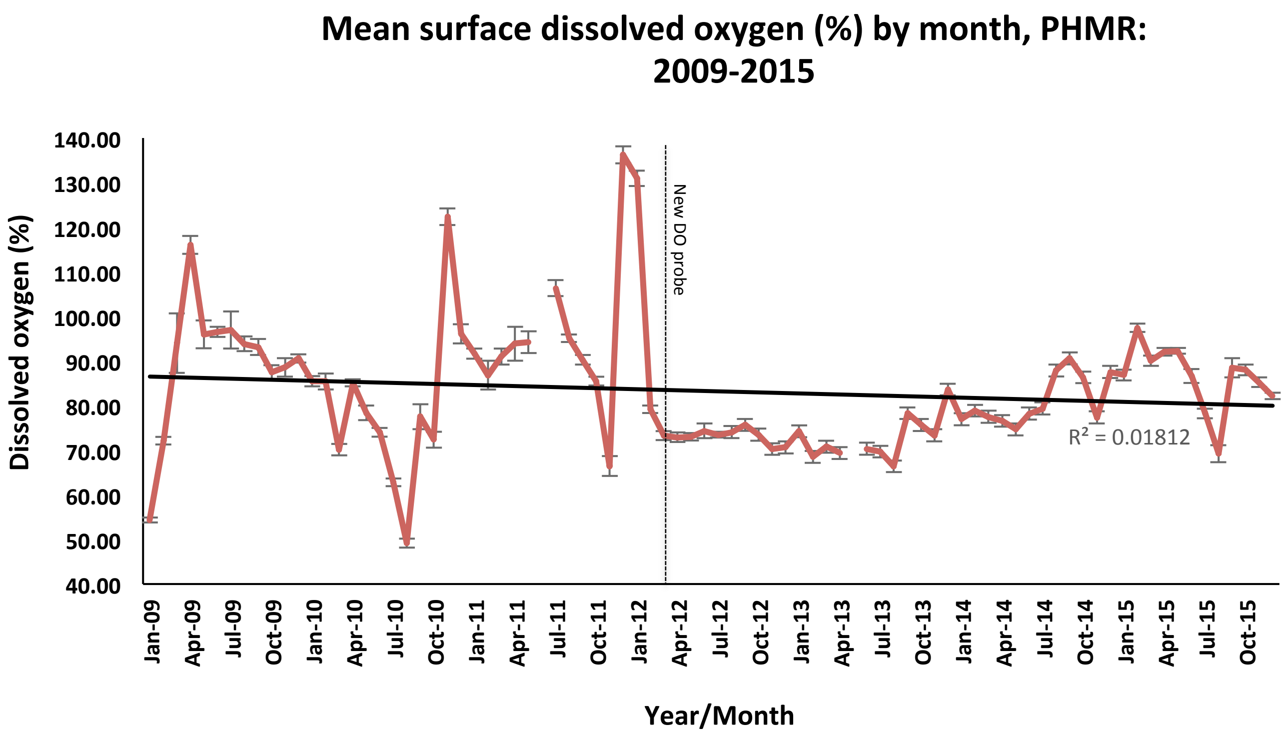
Dissolved Oxygen % 15m November 2015



Dissolved Oxygen % 15m December 2015



2.4 Mean DO (%) by month, PHMR – 2009-2015 (Fig 2.4):



- Mean surface DO exhibited a net increase overall between 2012 and mid-2015, dropping markedly after May 2015. 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 2015, Monkey River and Rio Grande had similar surface values, apart from May and November, in which Monkey River had lower DO.

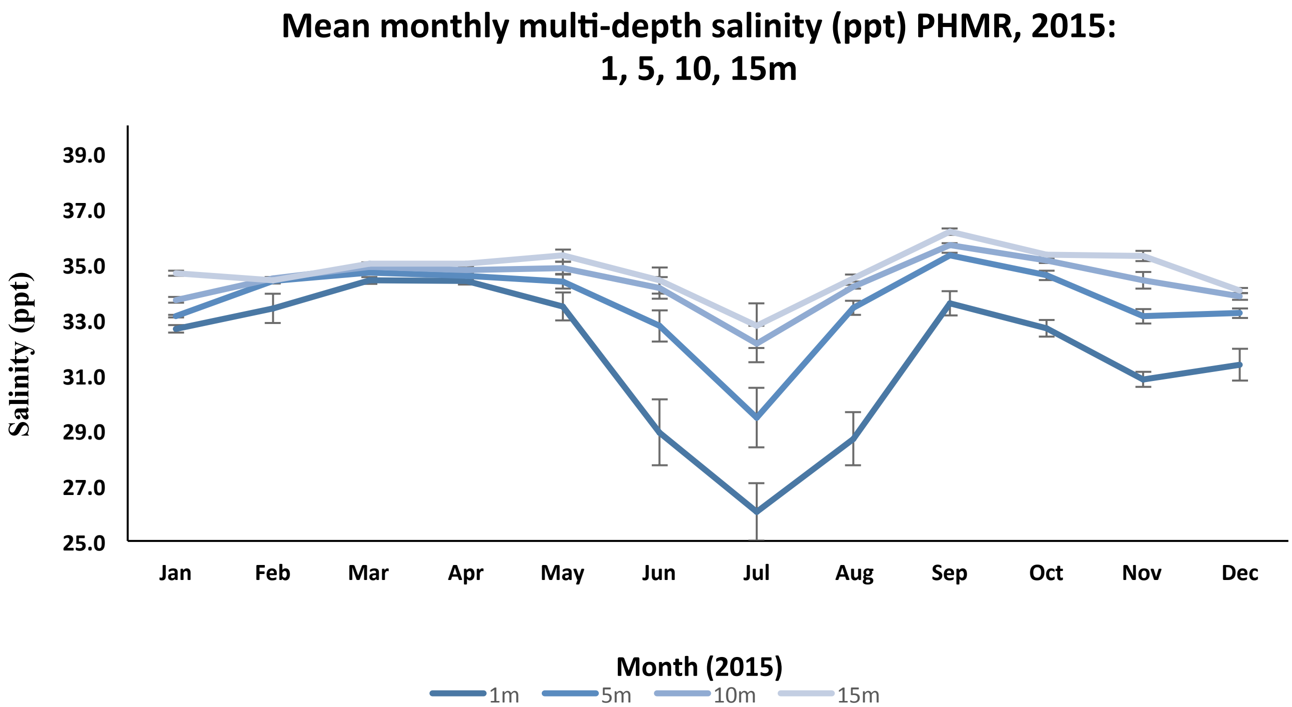
- Conditions were similar at all depths in the first eight months of the year, with minimal stratification. Depth related stratification in PHMR increased between October and December, with DO generally decreasing with increasing depth during this time. Highest DO occurred at the surface between February and May 2015.

- DO on average was higher in 2015 than in 2014 and 2013.

3. Salinity

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

3.1 Mean monthly salinity, 2015 – 1, 5, 10, 15m depth (Fig. 3.1):

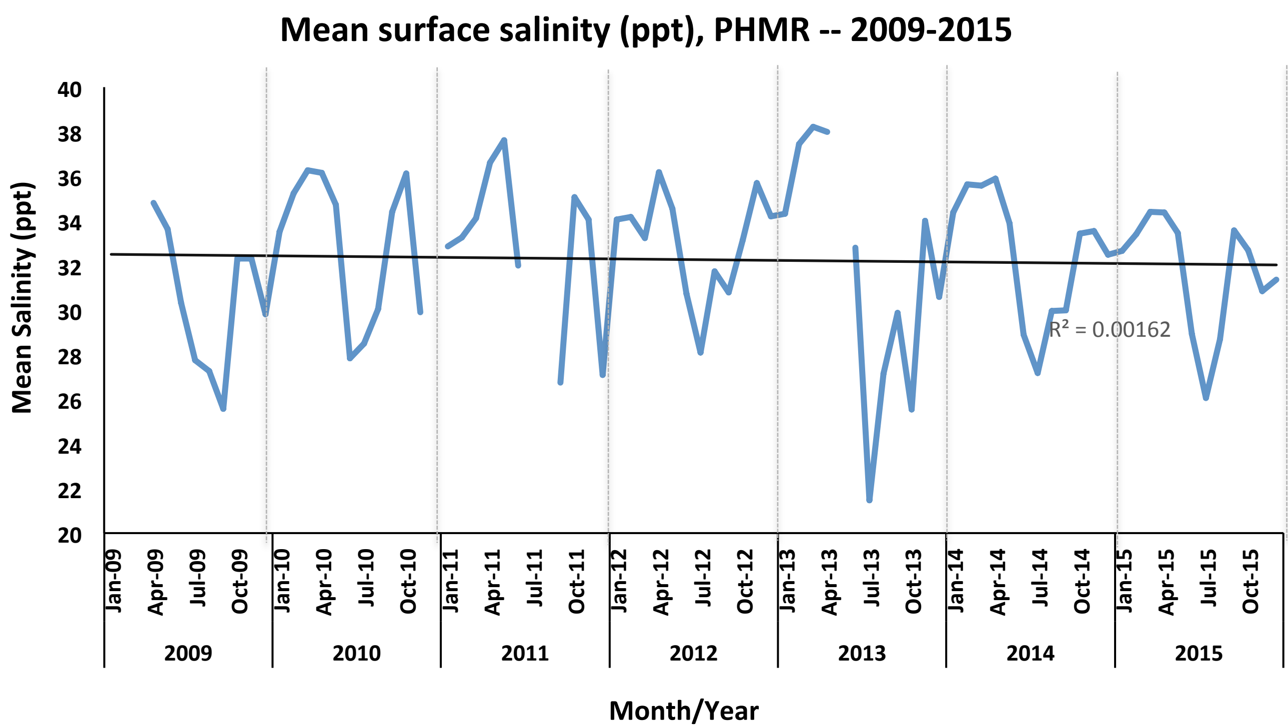


- Overall, salinity trends in 2015 were similar to 2012, 2013, and 2014. There was a general trend of stable salinity in the first quarter each year, followed by a general decrease with greater stratification in the second and third quarters, followed by a general overall increase with reduced stratification again in the final quarter.

- In 2015, there was generally a greater difference in mean salinity between 1m and 5m than between 10m and 15m. The greatest variability over time occurred at the surface (1m), while there was little change in the 5-15m depth range, especially between January and May. Surface readings dropped considerably from June to August in 2015, unlike the previous years in which the drop occurred from June to September.

- Surface values increased after July, until September and subsequently dropped by a small amount up to December.

3.2 Mean surface salinity (ppt) by month, PHMR – 2009-2015 (Fig 3.2):



- In PHMR there was a general trend of average surface salinity from year to year, in which the highest values were observed in the months of April or March. There is a recurring drop in salinity in July during the rainy season where the lowest salinity of each year is observed.

- Less variation than usual was observed between November 2014 and April 2015.

- No data is available in 2009 from January to March, 2010 December, 2011 July to August and 2013 April to May. However, the graph indicates similar trends in each year. It is notable that the highest (38.22ppt) and lowest (21.46ppt) salinity ever recorded in PHMR were both observed in the same year, 2013.

- Over the seven-year period, average surface salinity remained fairly consistent through time decreasing by only 0.002ppt. This is not statistically significant.

3.3 Salinity maps, 2015; multi-depth 1,5,10 and 15m – PHMR, Rio Grande, Monkey River (fig. 3.3):

a. January (Figs. 3.3 a 1m-15m): In PHMR, surface salinity values demonstrated a small rise with increased distance from the coast. Values ranged between 31.1ppt and 33.4ppt. Salinity also progressively increased with depth reaching 35.1ppt at 15m.

b, c. February and March (Figs. 3.3 b 1m-15m, c 1m-15m): There was little vertical, lateral or temporal variation in salinity throughout PHMR as expected of conditions typical of dry season. Values ranged between 33.6ppt and 34.7ppt. Two exceptions, which exhibited low salinity at the surface, were witnessed in February (eg. 6D: 23.9ppt, 9A: 24.2ppt).

d. April (Figs. 3.3 d 1m-15m): Salinity values throughout PHMR remained between 33.1ppt and 35.3ppt at all depths.

e, f. May and June (Figs. 3.3 e 1m-15m, f 1m-15m): Surface salinity values continuously decreased in the southern half of the reserve from May to June, with the lowest recorded level in 2015 being achieved (1B: 16.3ppt). Salinity in PHMR remained fairly stable through June (~33-34ppt at the surface and up to ~35ppt at 15m). In June, salinity began to decrease in southern PHMR, however. June was also the first time in 2015 when lower salinities were observed at depth. The lowest values in June in the 5 and 10m depth range were observed in the southern half of the reserve.

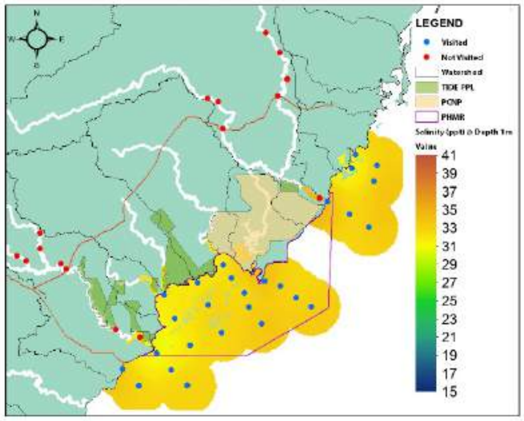
g, h, i, j. July, August, September, October (Figs. 3.3 g 1m-15m, h 1m-15m, i 1m-15m, j 1m-15m): Subsurface mixing starts off high in July, with low salinity in the areas from Joe Taylor Creek to Middle River, down to 5m depth (eg. 2B: 27.5 and 4A: 26.8 ppt, respectively), further decreasing throughout the months leading to October. Freshwater influence remained significant but diminished and was confined to the surface in September and October in southern PHMR.

k, l. November and December (Figs. 3.3 k 1m-15m, l 1m-15m): Surface salinity was patchy in distribution in November with low salinity levels extending down to 10 meters deep in November (5D at 10m: 32.2ppt) and 5 meters in December (2C at 5m: 31.4ppt). Notable drops in surface salinity were seen in the Joe Taylor and Monkey River areas (1B: 21.4 and 9A: 31.4ppt, respectively).

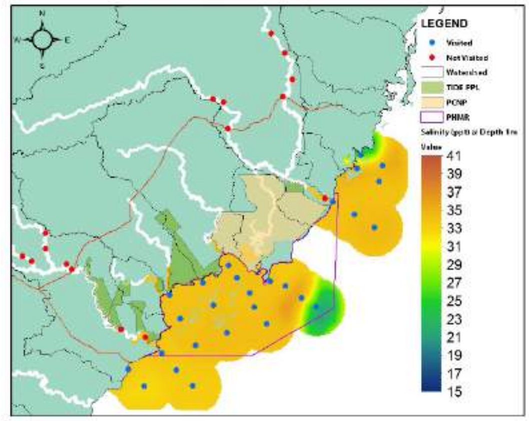
3.3 Salinity (ppt) **January 2015 (a):** **February 2015 (b):**

1m

Salinity (ppt) 1m January 2015

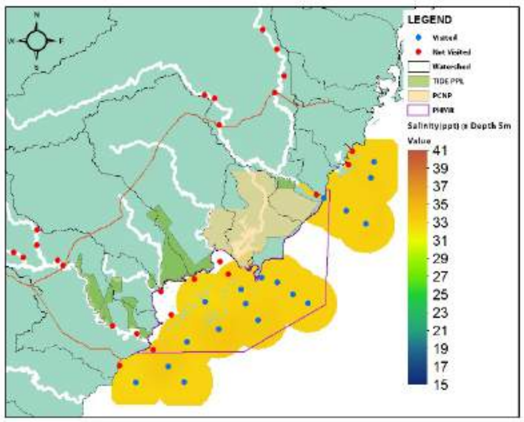


Salinity (ppt) 1m February 2015

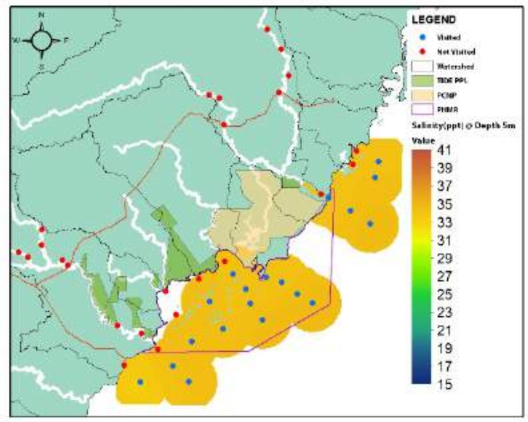


5m

Salinity (ppt) 5m January 2015

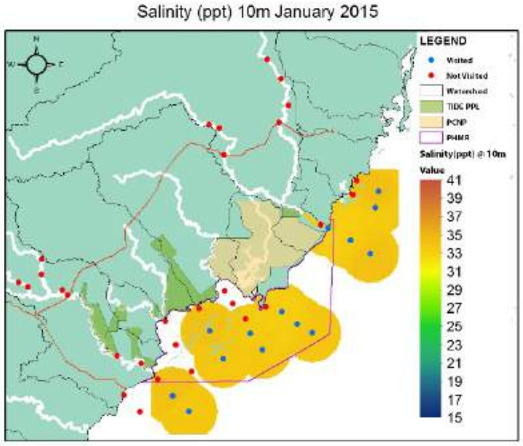


Salinity (ppt) 5m February 2015

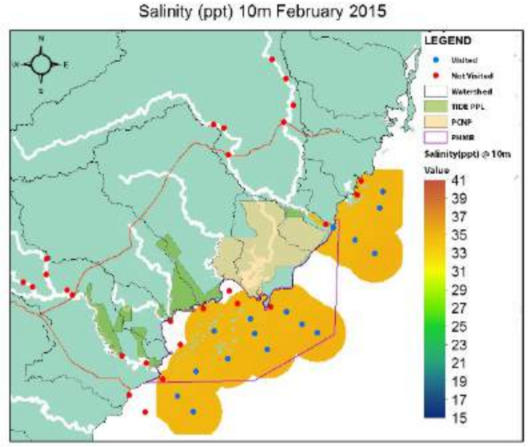


10m

Salinity (ppt) 10m January 2015

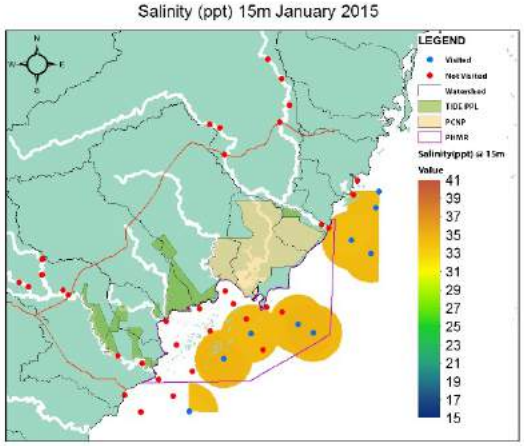


Salinity (ppt) 10m February 2015

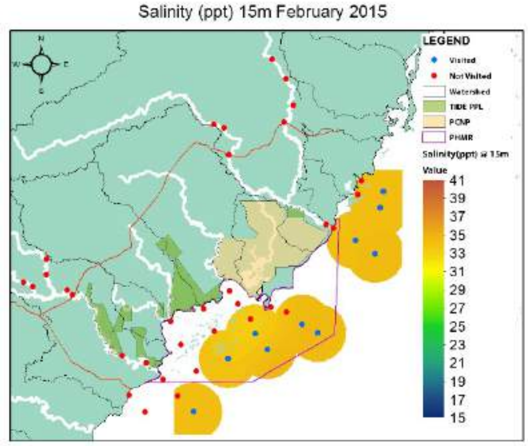


15m

Salinity (ppt) 15m January 2015



Salinity (ppt) 15m February 2015

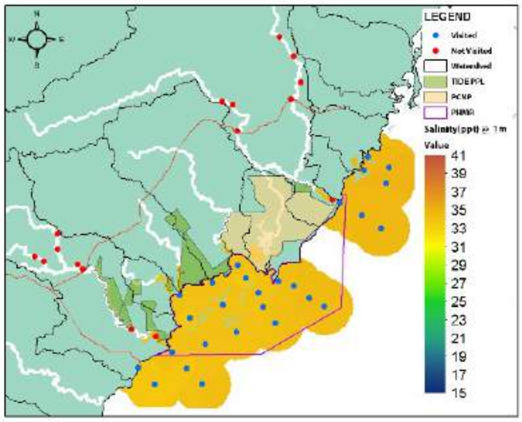


3.3 Salinity (ppt)

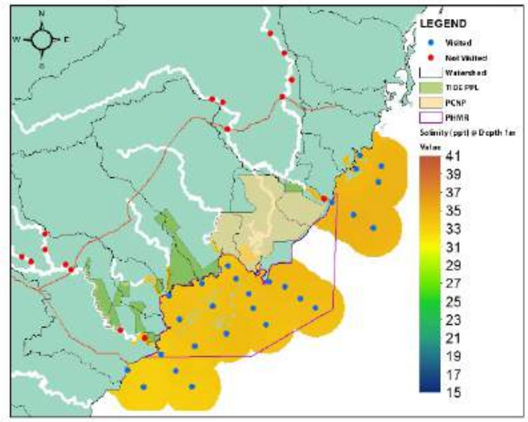
March 2015 (c): **April 2015 (d):**

1m

Salinity (ppt) 1m March 2015

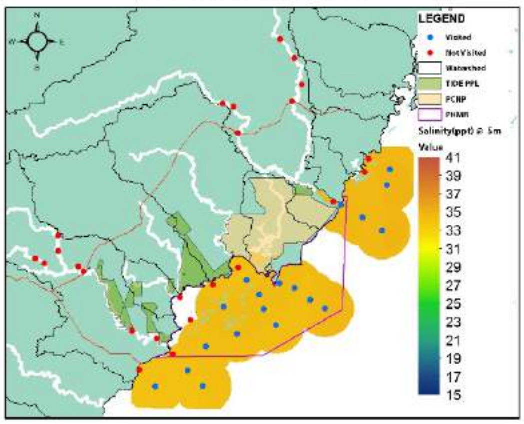


Salinity (ppt) 1m April 2015

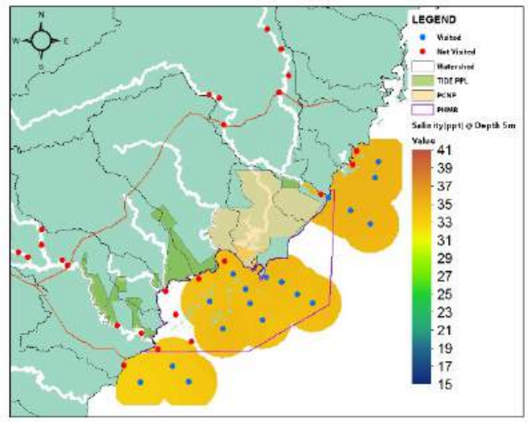


5m

Salinity (ppt) 5m March 2015

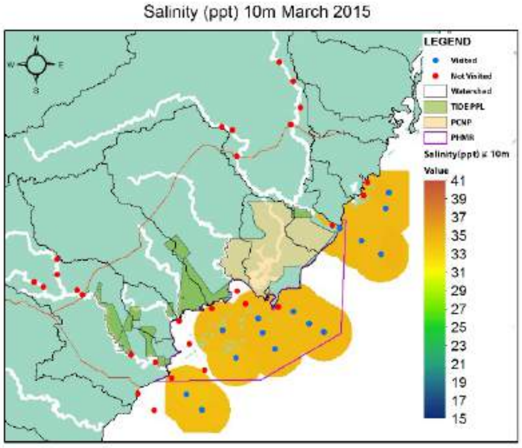


Salinity (ppt) 5m April 2015

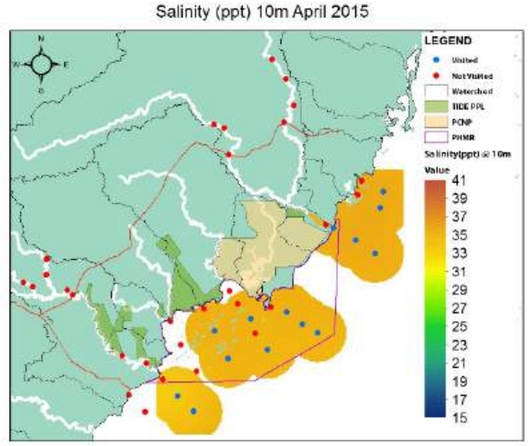


10m

Salinity (ppt) 10m March 2015

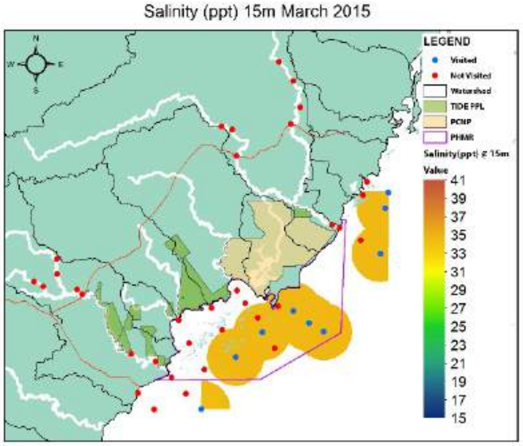


Salinity (ppt) 10m April 2015

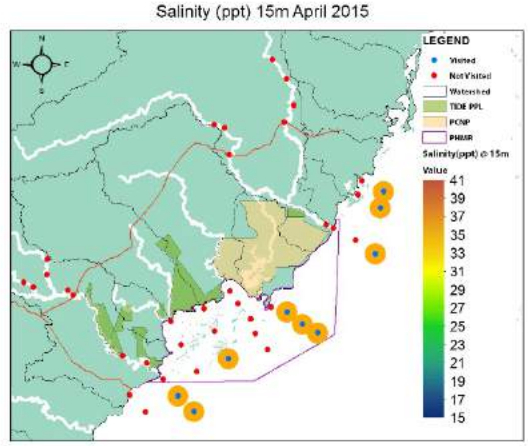


15m

Salinity (ppt) 15m March 2015



Salinity (ppt) 15m April 2015

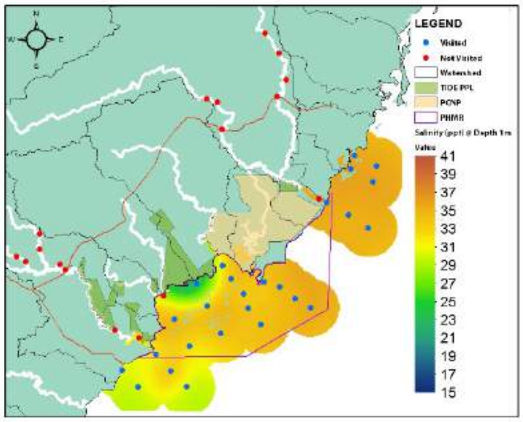


3.3 Salinity (ppt)

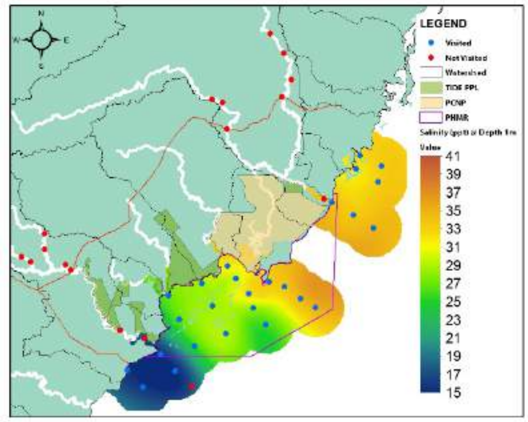
May 2015 (e): | **June 2015 (f):**

1m

Salinity (ppt) 1m May 2015

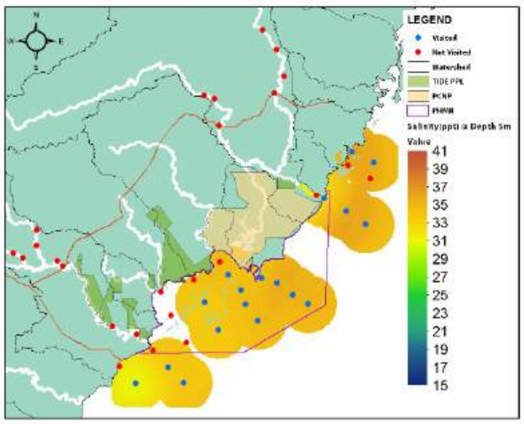


Salinity (ppt) 1m June 2015

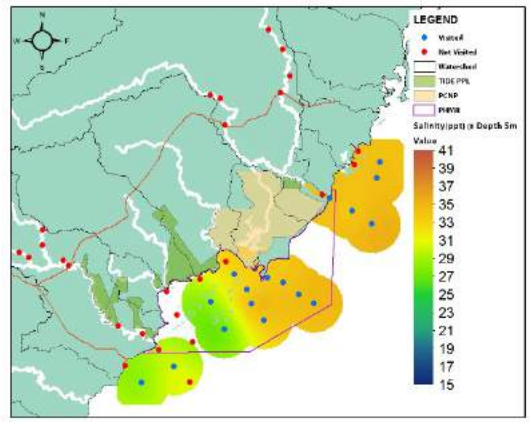


5m

Salinity (ppt) 5m May 2015

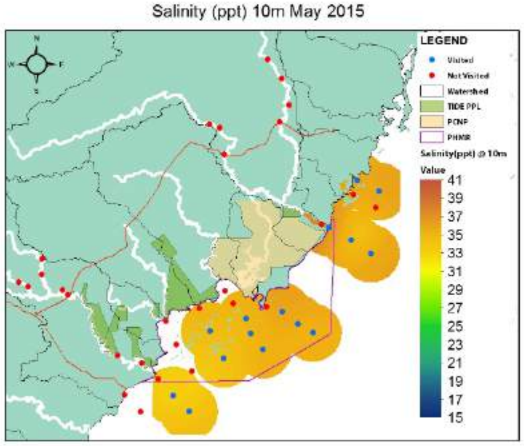


Salinity (ppt) 5m June 2015

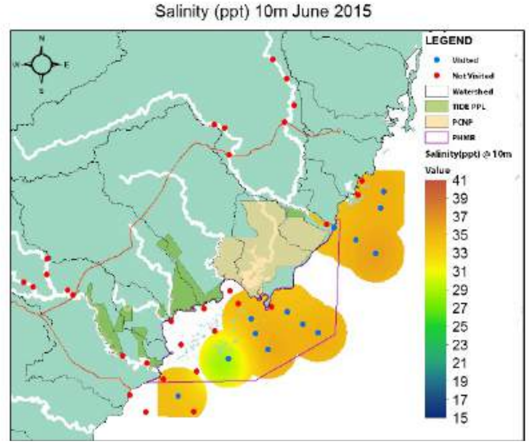


10m

Salinity (ppt) 10m May 2015

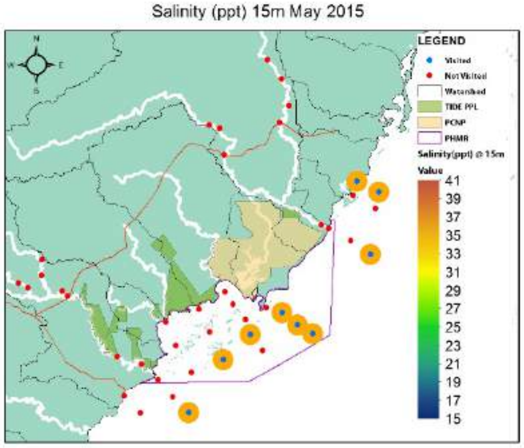


Salinity (ppt) 10m June 2015

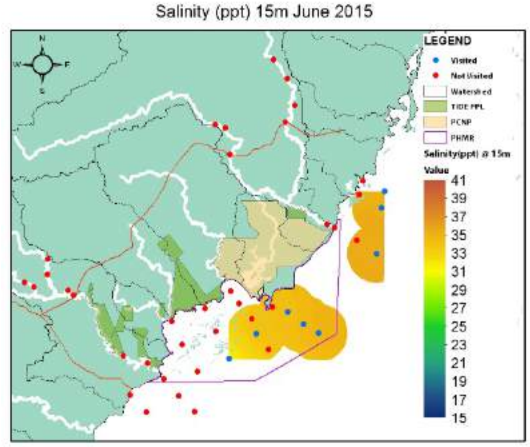


15m

Salinity (ppt) 15m May 2015



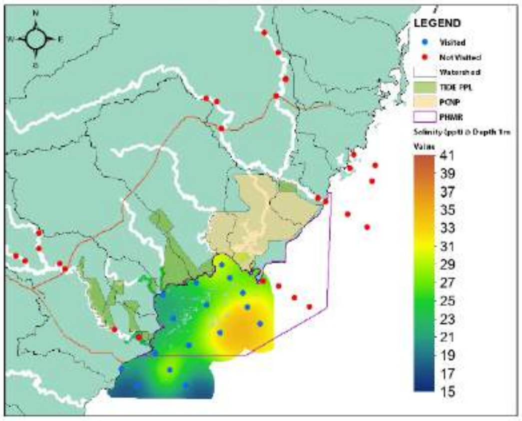
Salinity (ppt) 15m June 2015



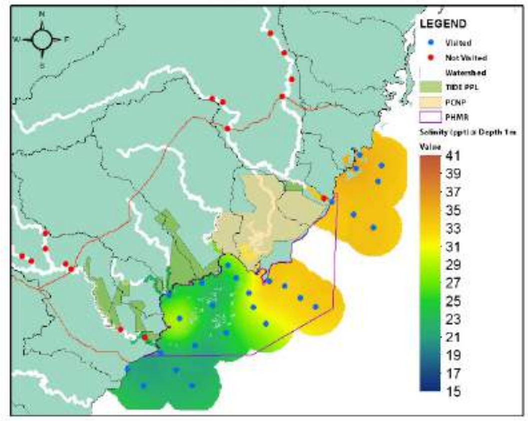
3.3 Salinity (ppt) July 2015 (g): August 2015 (h):

1m

Salinity (ppt) 1m July 2015

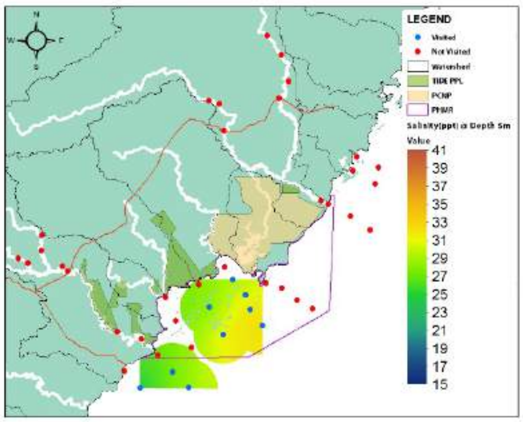


Salinity (ppt) 1m August 2015

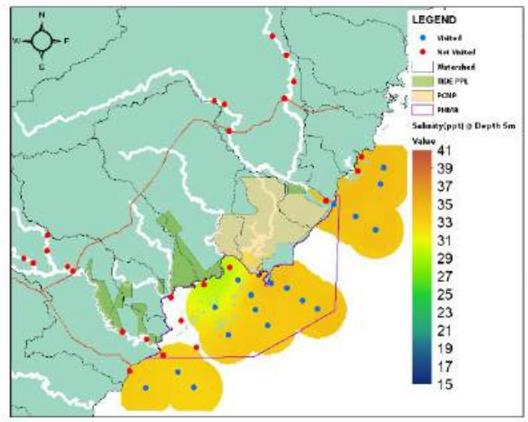


5m

Salinity (ppt) 5m July 2015

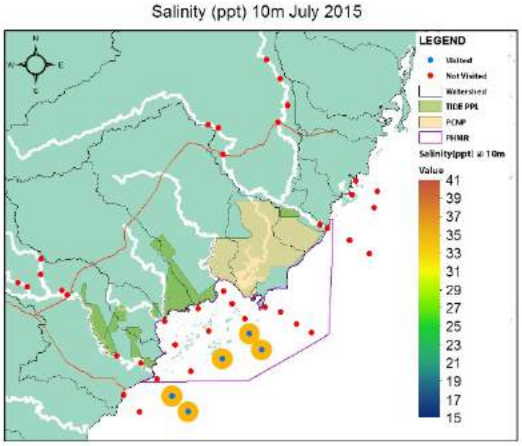


Salinity (ppt) 5m August 2015

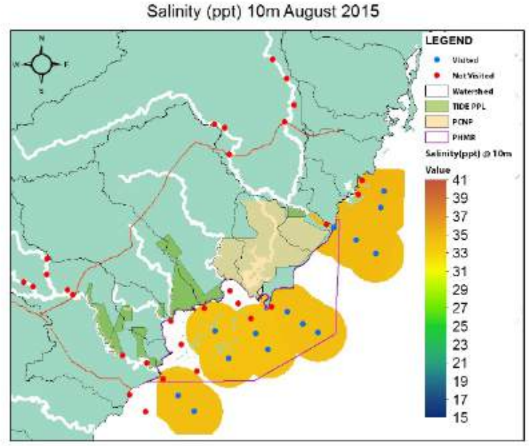


10m

Salinity (ppt) 10m July 2015

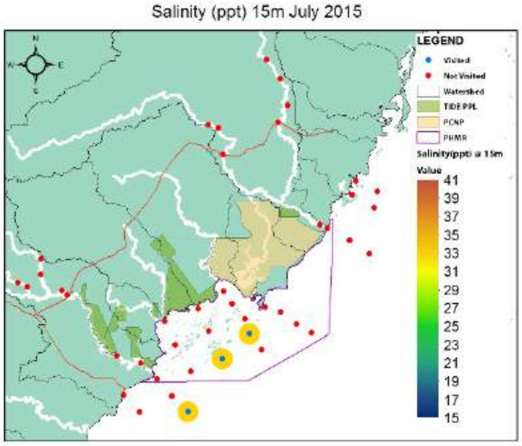


Salinity (ppt) 10m August 2015

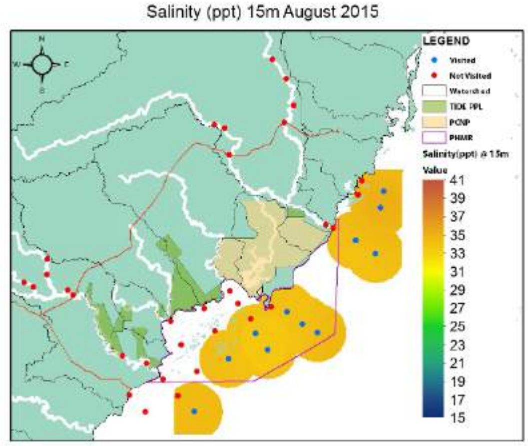


15m

Salinity (ppt) 15m July 2015



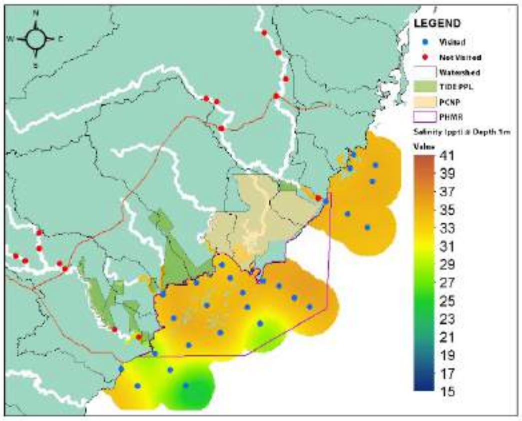
Salinity (ppt) 15m August 2015



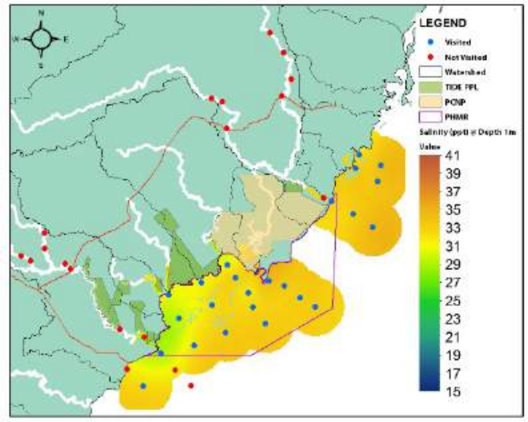
3.3 Salinity (ppt) September 2015 (i): October 2015 (j):

1m

Salinity (ppt) 1m September 2015

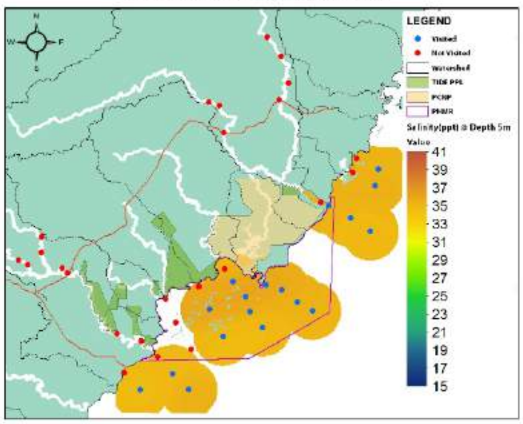


Salinity (ppt) 1m October 2015

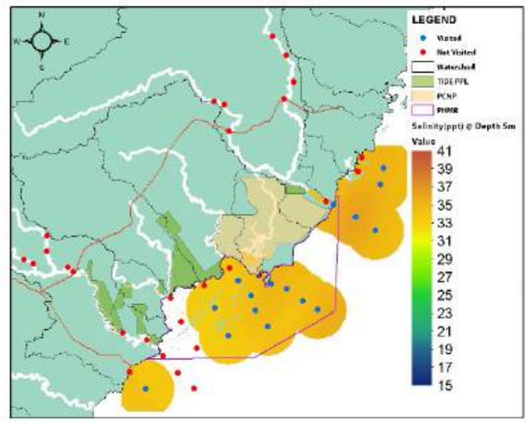


5m

Salinity (ppt) 5m September 2015

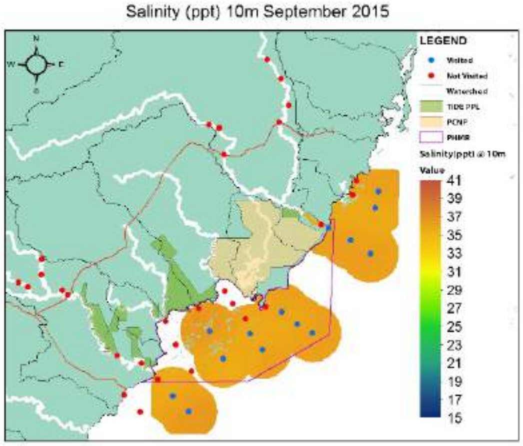


Salinity (ppt) 5m October 2015

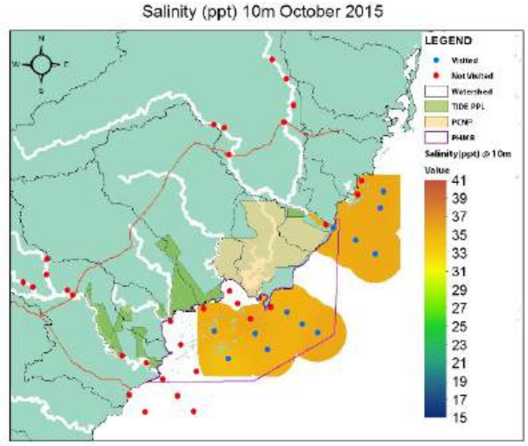


10m

Salinity (ppt) 10m September 2015

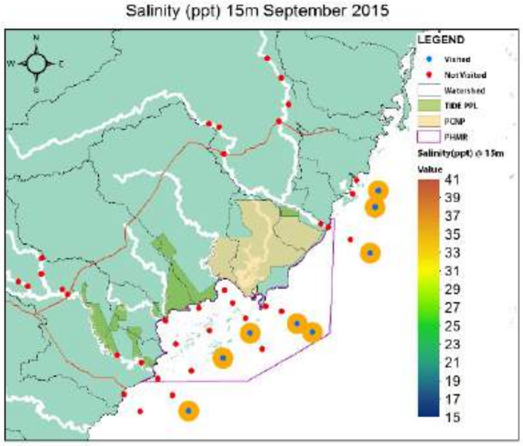


Salinity (ppt) 10m October 2015

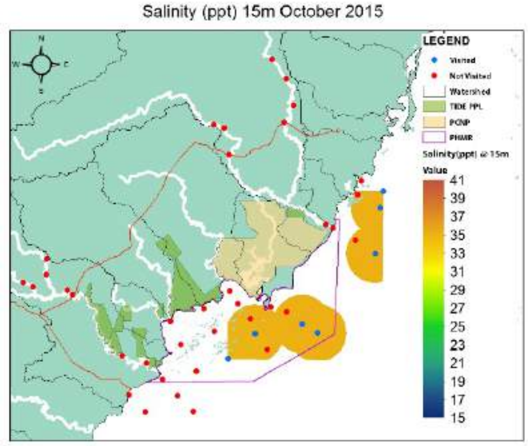


15m

Salinity (ppt) 15m September 2015



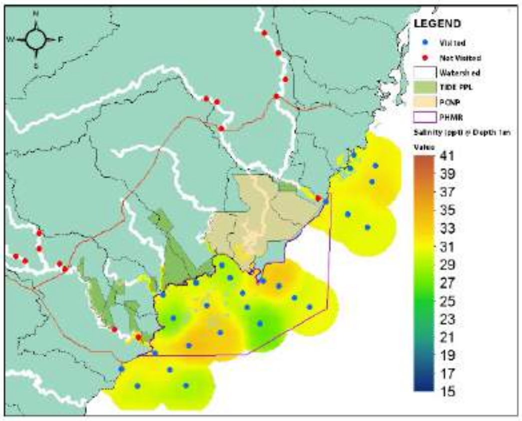
Salinity (ppt) 15m October 2015



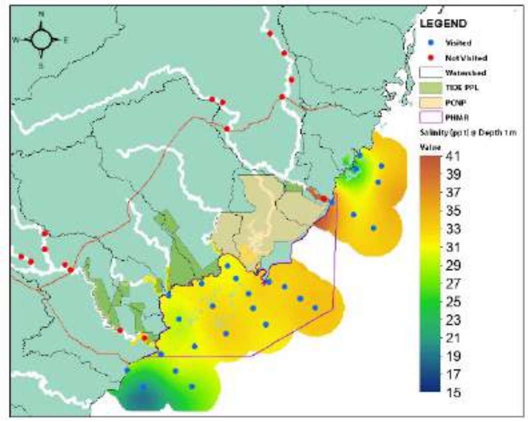
3.3 Salinity (ppt) November 2015 (k): December 2015 (l):

1m

Salinity (ppt) 1m November 2015

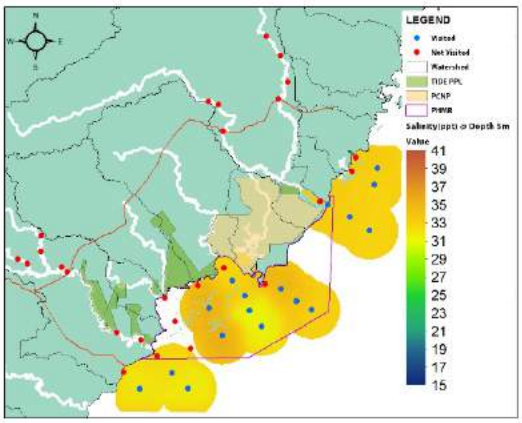


Salinity (ppt) 1m December 2015

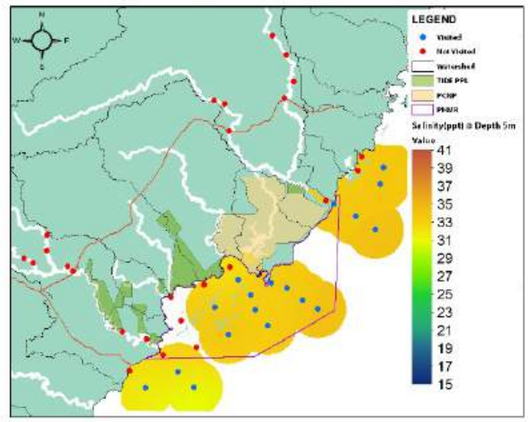


5m

Salinity (ppt) 5m November 2015

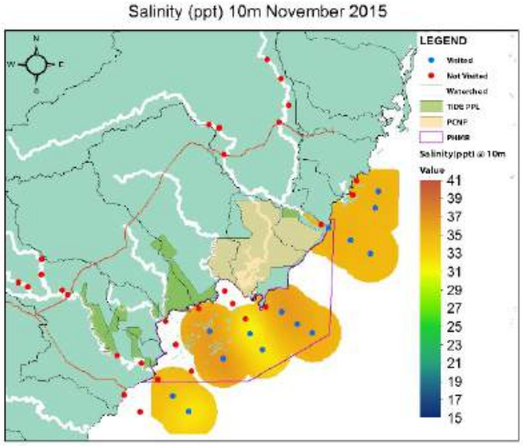


Salinity (ppt) 5m December 2015

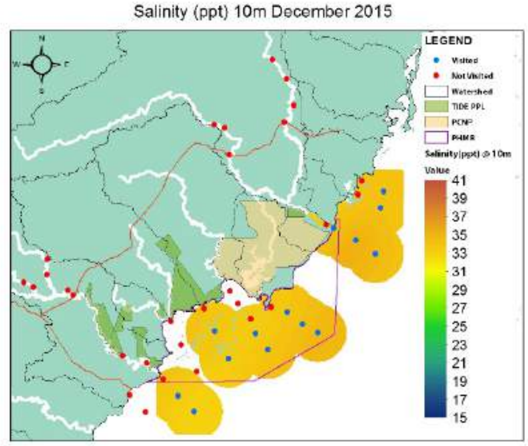


10m

Salinity (ppt) 10m November 2015

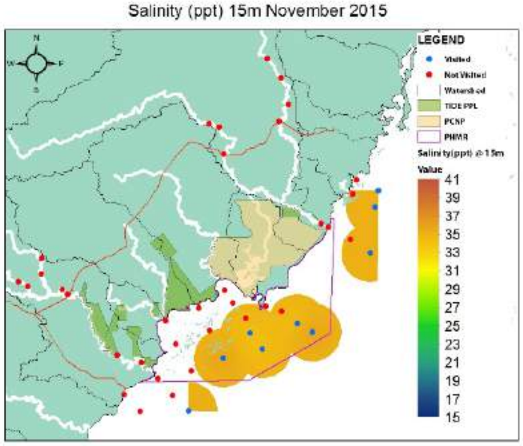


Salinity (ppt) 10m December 2015

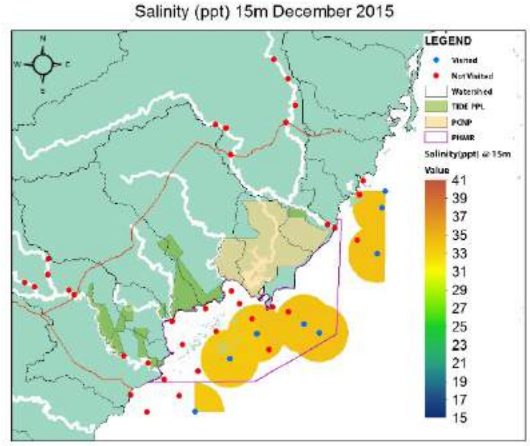


15m

Salinity (ppt) 15m November 2015



Salinity (ppt) 15m December 2015

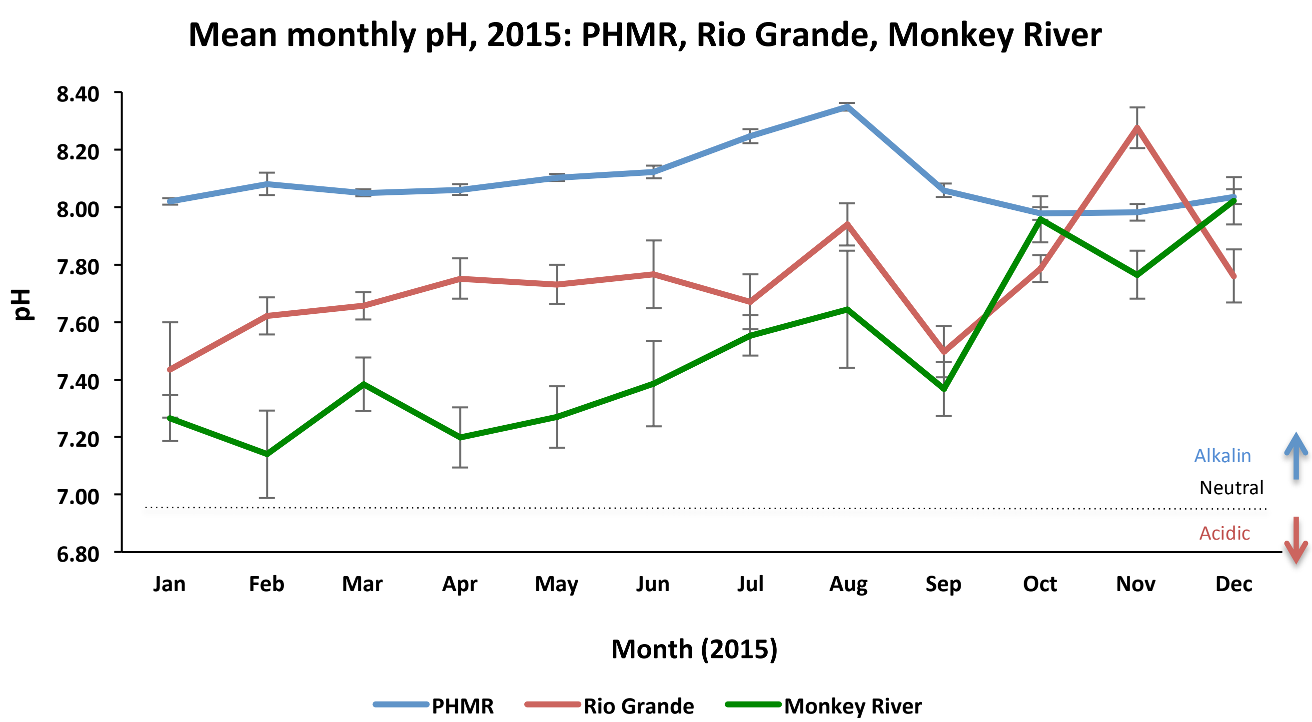


3.4 Salinity - general conclusions:

- Higher salinity and weaker stratification, signs of low freshwater input, occurred from January to May. The opposite was seen from June to September, and then previous conditions resumed in November and December.
- Greatest stratification by depth for mean salinity occurred between June and September 2015.
- 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.
- In PHMR, 2015 had more freshwater impact than in 2014, however this extended over a shorter period of time (3 months) than in 2014 (4 months).

4. pH

4.1 Mean surface pH by month, 2015 – PHMR, Monkey River, Rio Grande (Fig. 4.1):

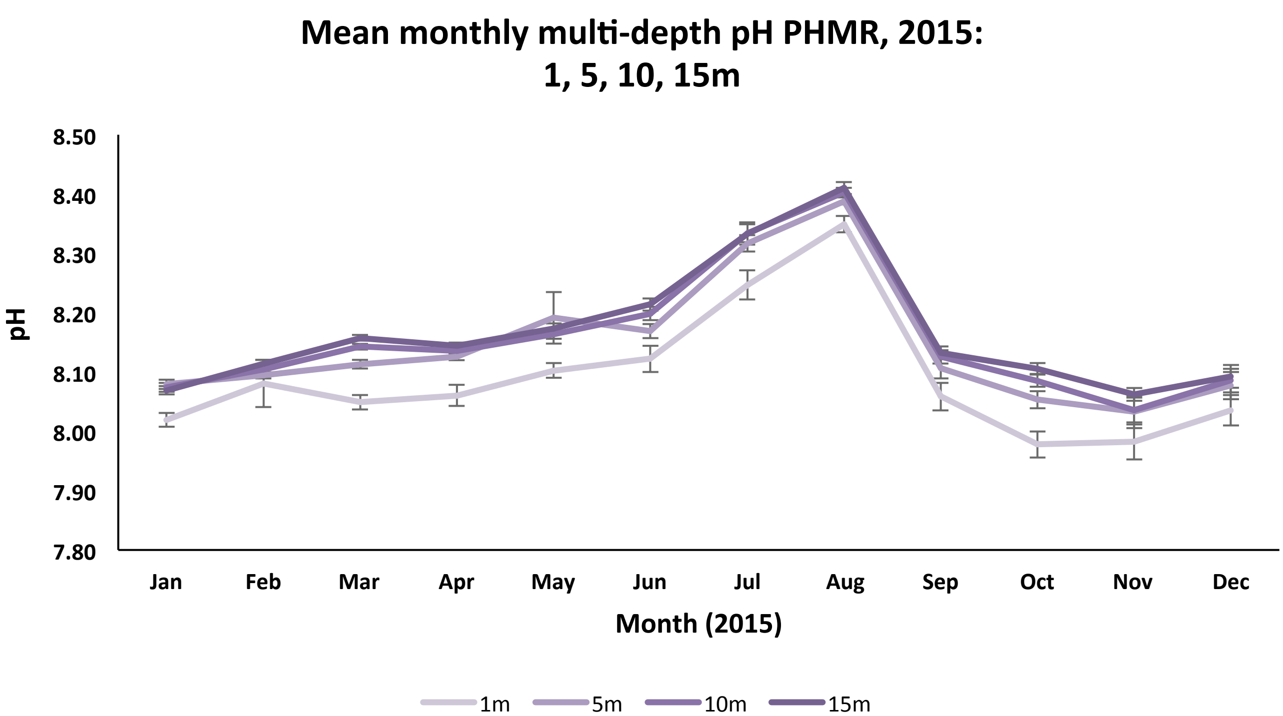


- In general, mean pH in Rio Grande and Monkey River remained lower than PHMR for the duration of 2015. This is the expected trend due to saline conditions typically being more alkaline; however, one unusual significantly high value 8.28 ± 0.07SE was observed in November in Rio Grande.

- Rio Grande experienced the lowest recorded value (pH 7.43 ± 0.17SE) for 2015 in January. This marginally rose in February where values remained fairly constant up to July, with values ranging from pH 7.62 ± 0.07SE to pH 7.77 ± 0.12SE. In August, there was a slight increase to pH 7.94 ± 0.07SE, followed by a decrease in September back to average values. Subsequently, the highest pH value (pH 8.28 ± 0.07SE) for 2015 on Rio Grande was recorded in November, which decreased again to similar levels witnessed in the first seven months of 2015.

- Monkey River pH fluctuated from January to April. The values ranged from pH 7.14 ± 0.15SE to pH 7.38 ± 0.09SE. Thereafter pH slightly increased through August, from pH 7.20 ± 0.10SE to pH 7.64 ± 0.20SE. September experienced a dip to pH 7.37 ± 0.09SE. In October pH increased sharply to pH 7.96 ± 0.08SE, temporarily decreased in November and finally peaked in December at pH 8.02 ± 0.08SE.

4.2 Mean monthly pH PHMR, 2015 – 1, 5, 10, 15m depth (Fig. 4.2):



- There were uniform pH conditions in PHMR from January to May throughout all depths, averaging pH 8.11 ± 0.01SE, followed by an increase in alkaline conditions from June to August and returning to uniform conditions in pH spatially and at all depths in PHMR from September to December.

- In theory, pH should be lower (more neutral) with decreasing salinity, because salt water is naturally more alkaline. In 2014 and 2015, however, a reversal of this trend was observed. In 2015, during the months in which salinity levels drop from May to July, pH rises (Figs. 3.1, 4.2). While salinity increases in August, pH continues to rise, reaching a peak for 2015.

- In 2015 the mean monthly multi-depth pH data vastly contrasts from the previous year (see 2014 Water Quality Monitoring Annual Report). 2014 shows 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 (pH 8.13 ± 0.19SE in 2014). pH also dropped considerably in September 2015 in PHMR, but remained low thereafter, in contrast to 2014.

4.3 pH maps, 2015; multi-depth 1m, 5m 10m, 15m – PHMR, Monkey River, Rio Grande (Fig. 4.3):

a. January (Figs. 4.3 a 1m-15m): pH values in Rio Grande were higher at the river mouth than all upstream sites. pH values in upper reaches ranged from pH 7.25 to pH 7.75, while the lower reaches fluctuated between pH 6.44 at Wilson Landing and pH 8.01 downstream near the river mouth. The upper and lower reaches of Monkey River were fairly consistent, with values ranging from pH 7.20 to pH 7.49; however, site MR_TB_1a had a lower value of pH 6.8. pH values in PHMR were variable, ranging from pH 7.87 to pH 8.12 at all depths, with the largest variation recorded in the shallowest water (1m).

b. February (Figs. 4.3 b 1m-15m): Trends in Rio Grande were similar to January. In Monkey River, pH decreased from January in the Swasey Branch. The Bladen Branch and lower reaches demonstrated higher values ranging from pH 7.2 to pH 7.7. In PHMR the spatial gradients in pH at 1m were variable; the value at site 2C significantly rose to pH 9.09 from January to February. pH remained between pH 8.07 and pH 8.14 at 5, 10, and 15m.

c, d. March and April (Figs. 4.3 c 1m-15m, d 1m-15m): pH trends in Rio Grande for both months were more consistent and closer to neutral when compared to the previous months, with values from pH 7.41 to pH 7.98. Monkey River also exhibited closer to neutral values overall for both months. Swasey Bridge, however, had a slightly acidic value of pH 6.75 in April. In PHMR values were variable, ranging from pH 7.88 to pH 8.18 in March and pH 7.84 to pH 8.14 in April at all depths. The largest variation was recorded in the 1 m depth at offshore site 4C and in coastal areas north of Monkey River.

e, f. May and June (Figs. 4.3 e 1m-15m, f 1m-15m): Values remained close to neutral in May in Rio Grande at an average pH 7.73 ± 0.07SE, with marginal increase at the river mouth in June to pH 8.58 (Site RG_RG_1c). In Monkey River, values ranged between pH 7.04 and pH 7.75 in May. In June, Monkey River produced more variable values between the upper and lower reaches. Average values were between pH 7.15 and pH 7.60; however, differences were seen at site MR_SB_1c, which had a lower pH 6.66, and the river mouth, where pH rose to 8.16. Surface pH values in PHMR were more alkaline at 5m depth in May (8B: pH 8.91) and at 1m depth in June (8A: pH 7.93). The pH values are less variable in deeper water (10m and 15m), ranging from pH 8.11 to pH 8.24 in both months.

g, h. July, August (Figs. 4.3 g 1m-15m, h 1m-15m): In Rio Grande, similar spatial trends seen in June were again observed in July with overall more alkaline conditions seen in August. The average pH rose from pH 7.67 ± 0.10SE in July to pH 7.94 ± 0.07SE in August. In July a similar trend seen in June was also seen in the upper reaches of Monkey River with slightly elevated values ranging from pH 7.32 to pH 7.77. There was a decrease and more variability in the Swasey Branch from July to August, while values rose at the river mouth from June to August. Data is available only for the southern part of PHMR in July. In this region pH values on average gradually increased (became more alkaline) across all depths, (eg.1m: pH 8.35 ± 0.01SE) in August compared to June's average (1m: pH 8.12 ± 0.02SE). pH progressively increased with depth as well, with the exception being observed at 15m, where average values dropped to around pH 6 in August, showing acidic conditions.

i, j. September and October (Figs. 4.3 i 1m-15m, j 1m-15m): No data is available for the Rio Grande river mouth in October. A minimal decrease in pH, compared to the previous three months, was seen in September with an average value of pH 7.50 ± 0.09SE. In October, average pH values rose to pH 7.79 ± 0.05SE. In September, pH values increased to more stable alkaline conditions along the entire Monkey River, with average values of pH 7.37 ± 0.09SE, then further rose in October to average values of pH 7.96 ± 0.08SE. In PHMR, September mean pH values drop from the previous month across all depths with the most variable conditions remaining at the 1m depth. Marginally lower surface pH was recorded in areas near the Rio Grande and Deep River mouth, south of Punta Ycacos and north of Monkey River when compared to the rest of PHMR. Values here ranged from pH 7.85 – 7.96.

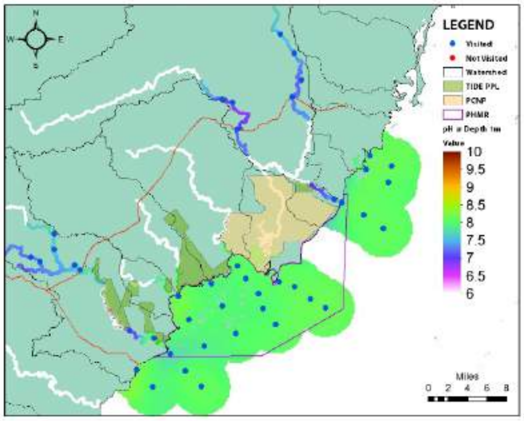
k, l. November and December (Figs. 4.3 k 1m-15m, l 1m-15m): There is no data available for both river mouths in November. Average pH in Rio Grande rose to pH 8.28 ± 0.07SE in November, the highest value recorded in 2015 for this watershed. Values subsequently returned to normal average conditions of pH 7.76 ± 0.09SE in December. In November the upper reaches of Monkey River produced a similar trend as observed in October, while December produced higher pH values averaging pH 8.02 ± 0.08SE, with most variability in the Swasey Branch. During November in PHMR there was a slight increase in pH from October to December. Mean values climbed above pH 8 in November and December. This change is seen across all depths, with the most variability occurring at the 1m depth.

4.3 pH

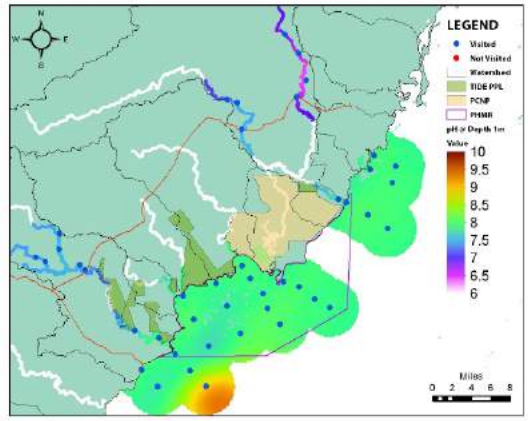
January 2015 (a): **February 2015 (b):**

1m

pH 1m January 2015

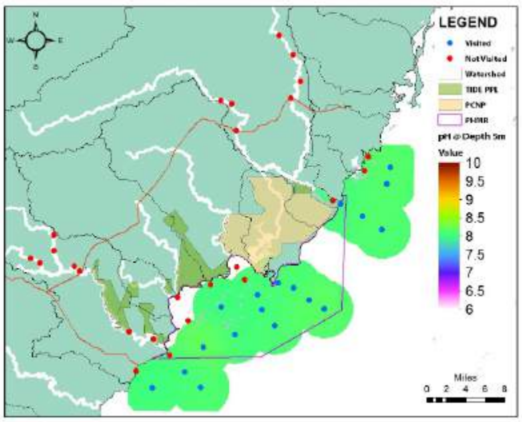


pH 1m February 2015

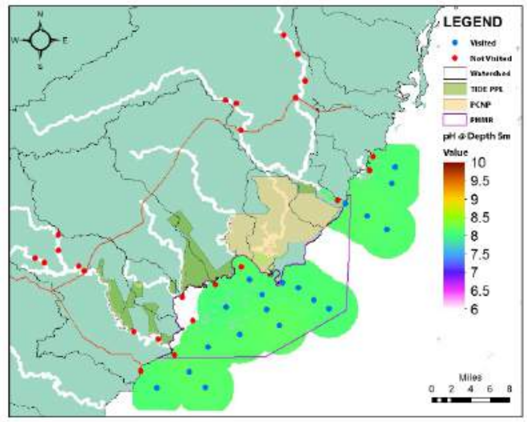


5m

pH 5m January 2015

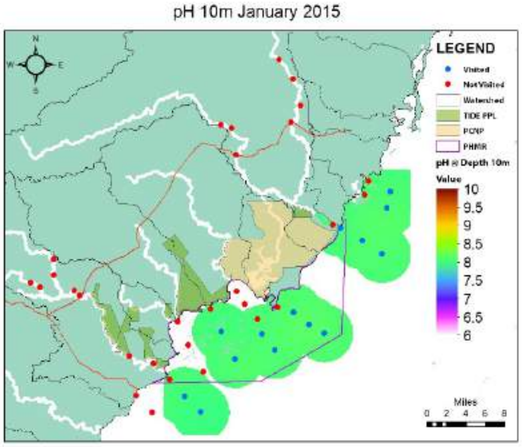


pH 5m February 2015

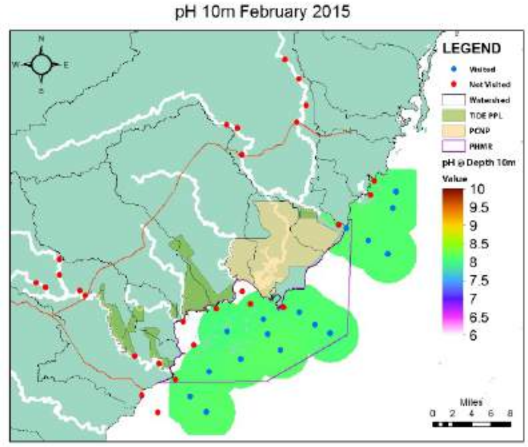


10m

pH 10m January 2015

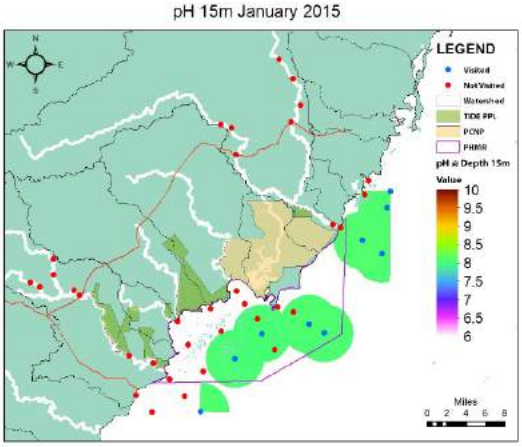


pH 10m February 2015

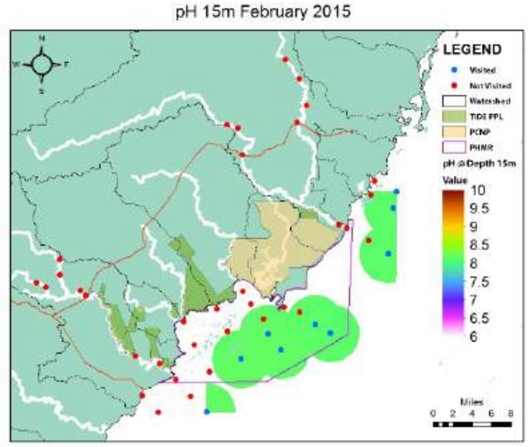


15m

pH 15m January 2015



pH 15m February 2015



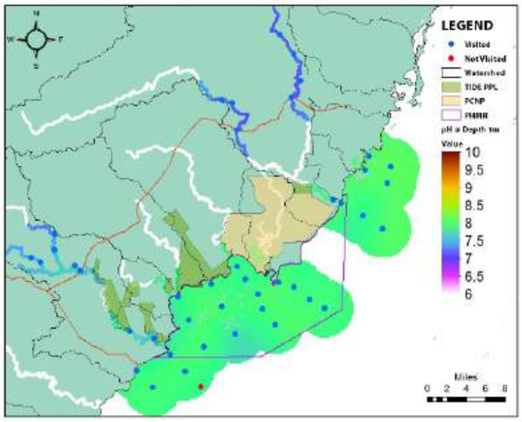
4.3 pH

March 2015 (c):

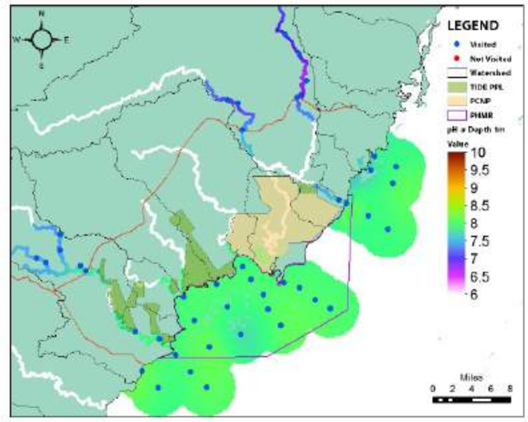
April 2015 (d):

1m

pH 1m March 2015

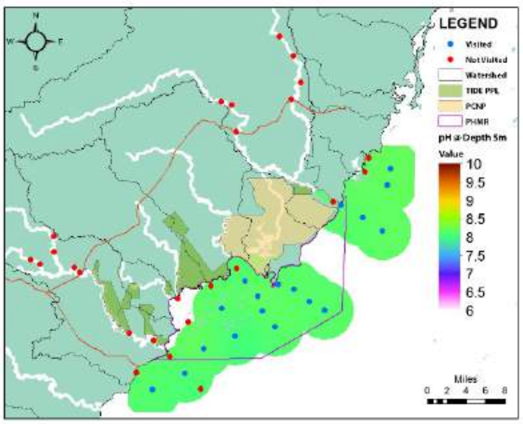


pH 1m April 2015

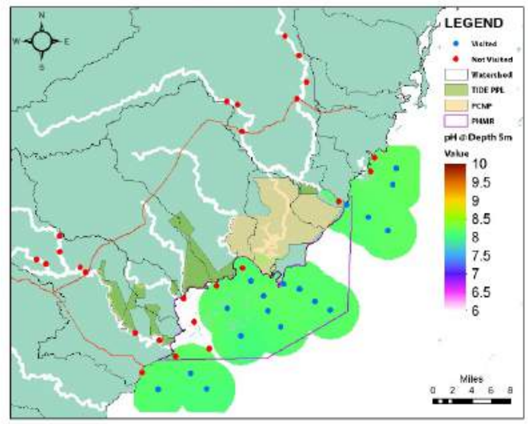


5m

pH 5m March 2015

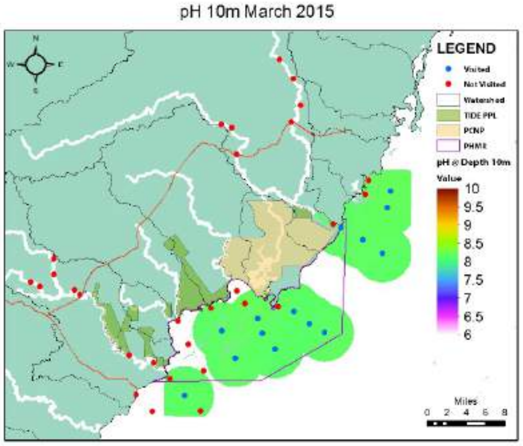


pH 5m April 2015

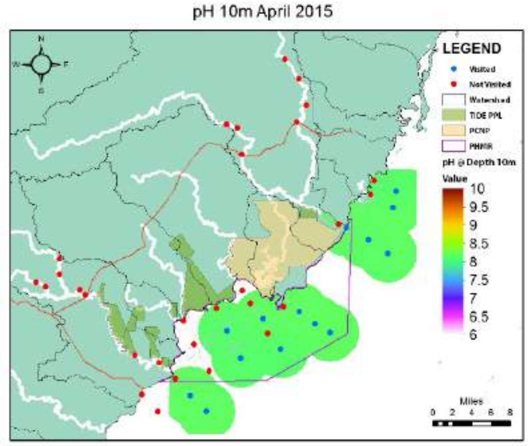


10m

pH 10m March 2015

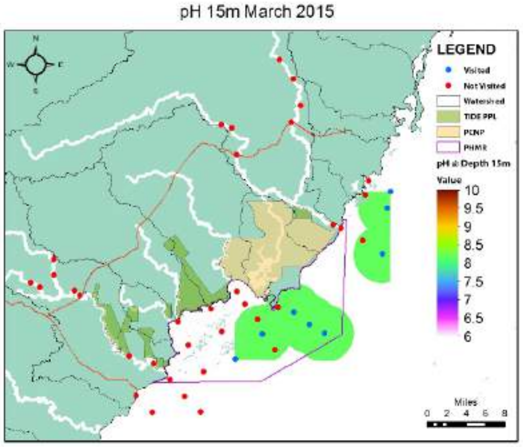


pH 10m April 2015

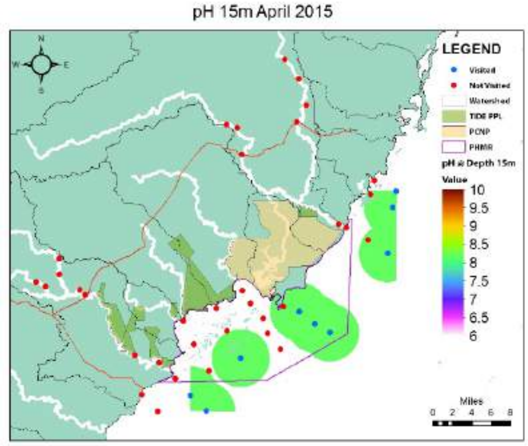


15m

pH 15m March 2015



pH 15m April 2015

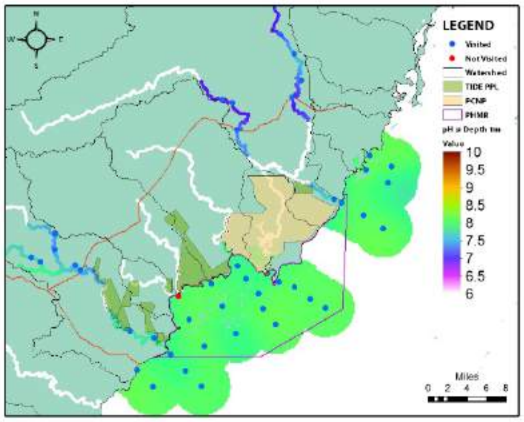


4.3 pH

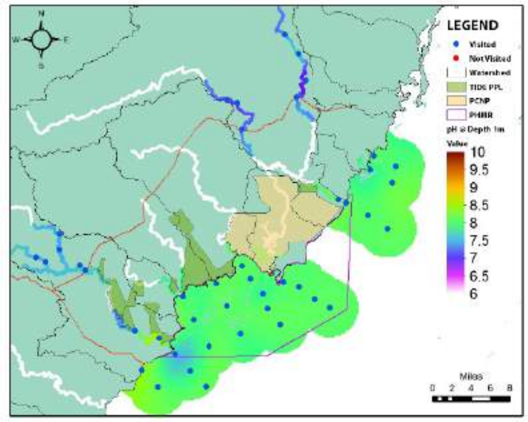
May 2015 (e): | **June 2015 (f):**

1m

pH 1m May 2015

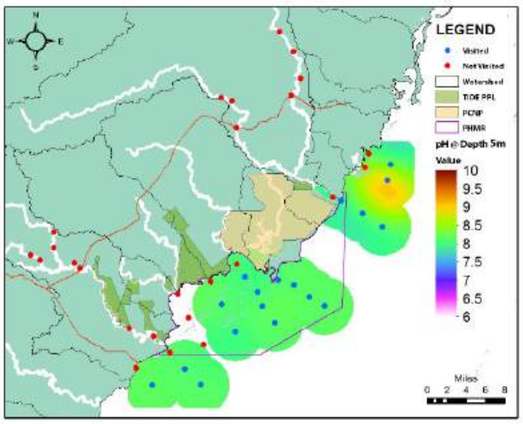


pH 1m June 2015

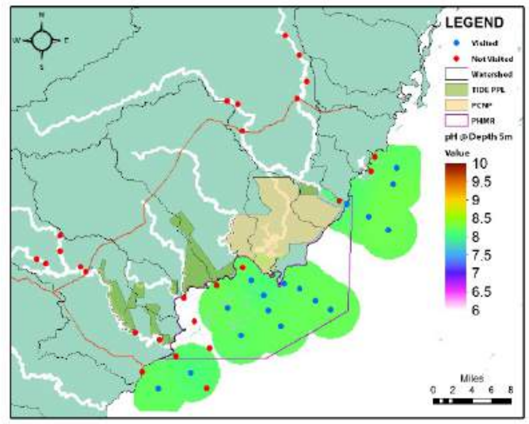


5m

pH 5m May 2015

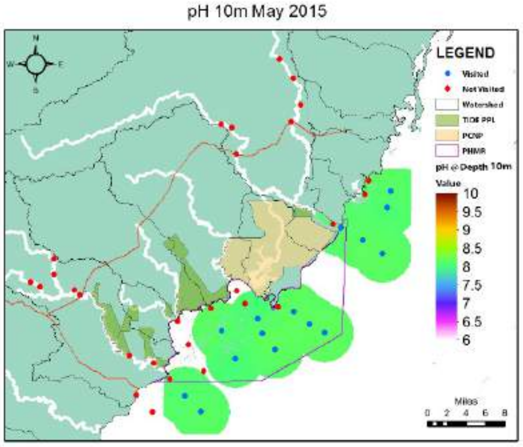


pH 5m June 2015

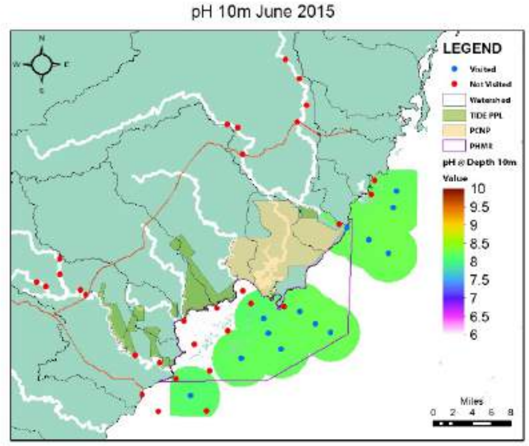


10m

pH 10m May 2015

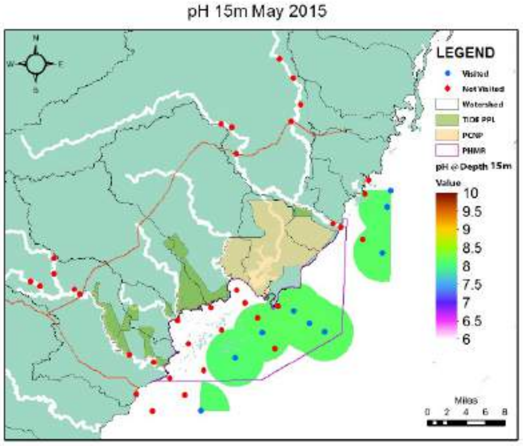


pH 10m June 2015

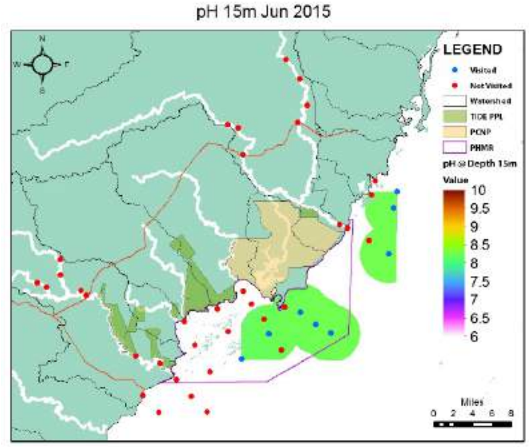


15m

pH 15m May 2015



pH 15m Jun 2015



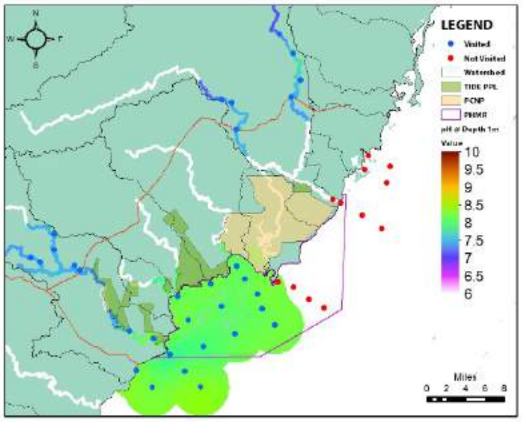
4.3 pH

July 2015 (g):

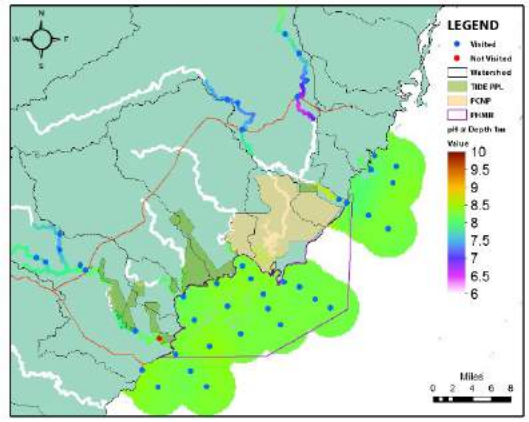
August 2015 (h):

1m

pH 1m July 2015

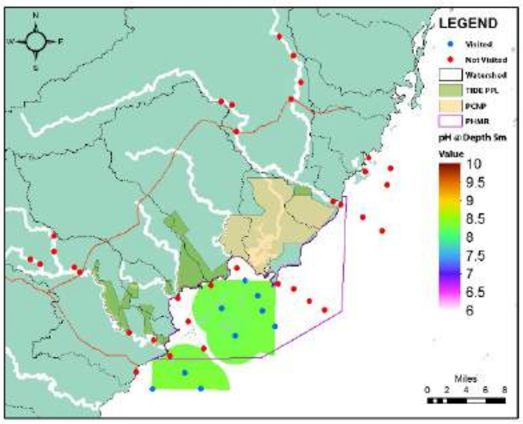


pH 1m August 2015

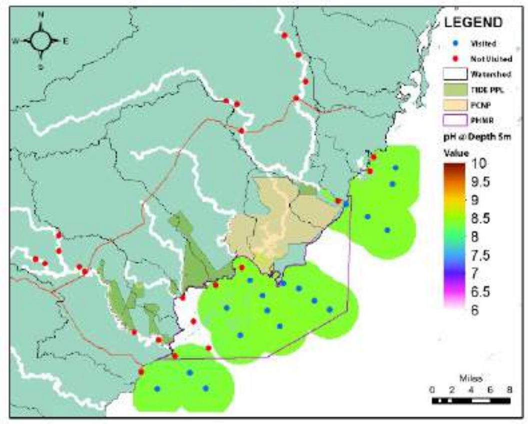


5m

pH 5m July 2015

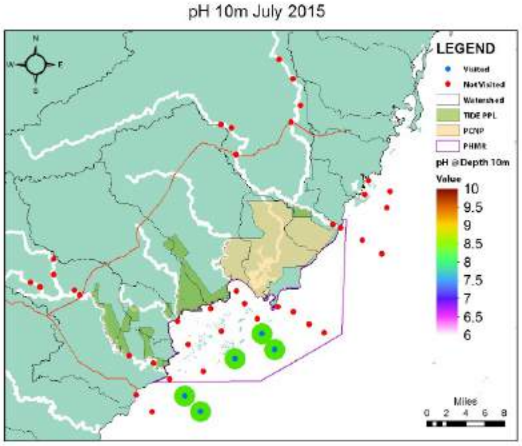


pH 5m August 2015

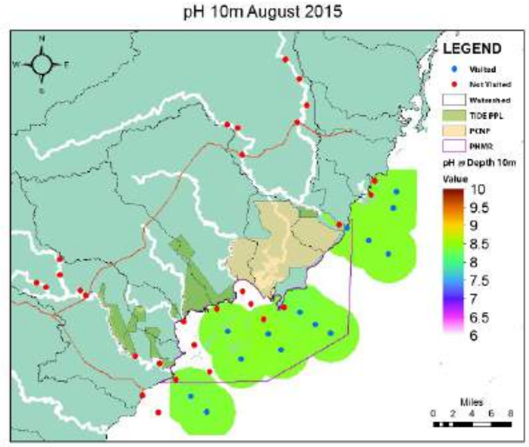


10m

pH 10m July 2015

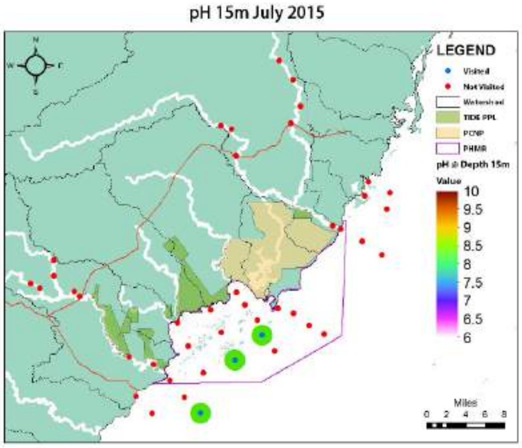


pH 10m August 2015

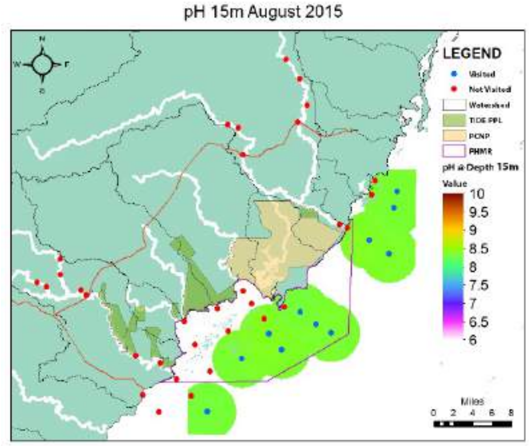


15m

pH 15m July 2015



pH 15m August 2015

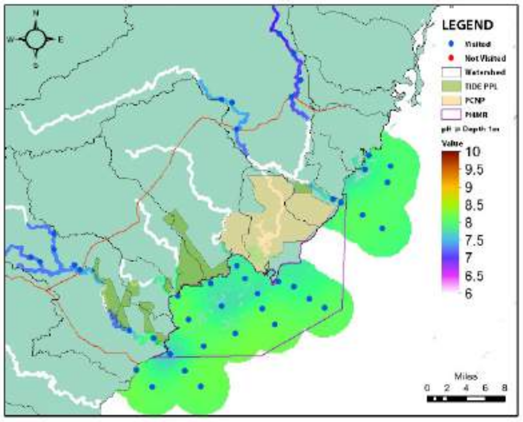


4.3 pH

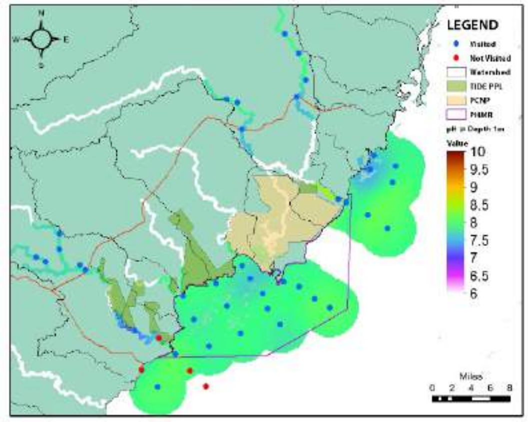
September 2015 (i): | **October 2015 (j):**

1m

pH 1m September 2015

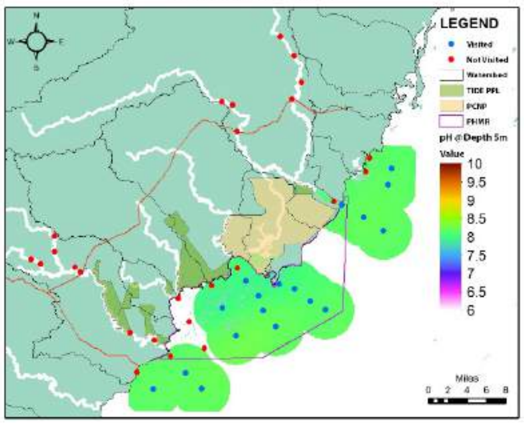


pH 1m October 2015

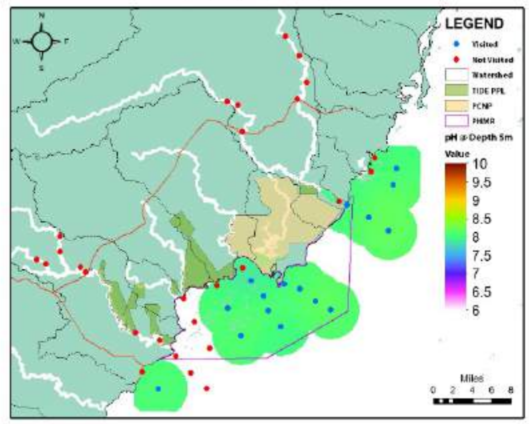


5m

pH 5m September 2015

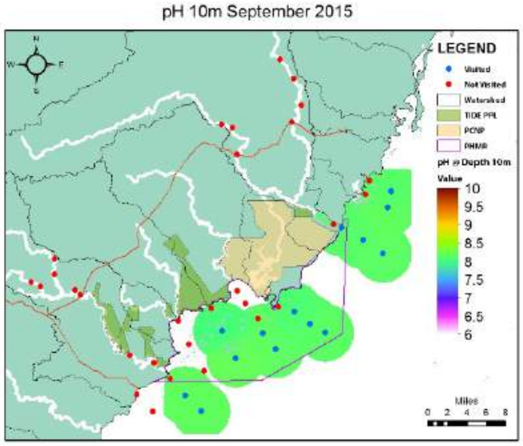


pH 5m October 2015

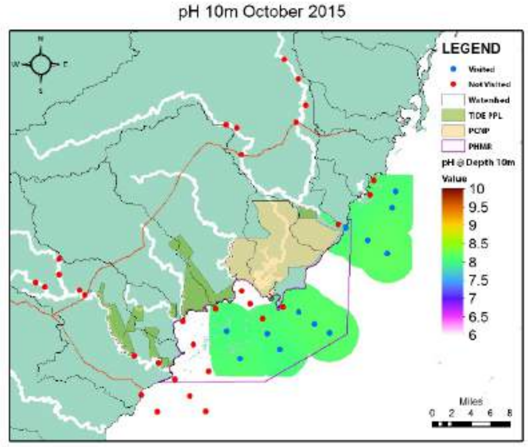


10m

pH 10m September 2015

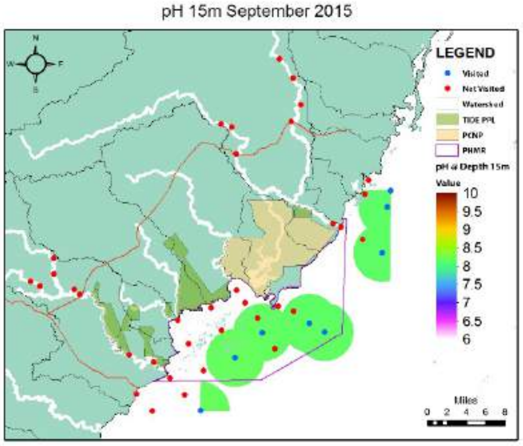


pH 10m October 2015

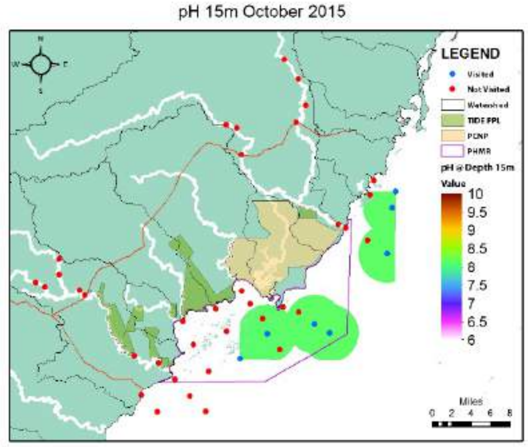


15m

pH 15m September 2015



pH 15m October 2015

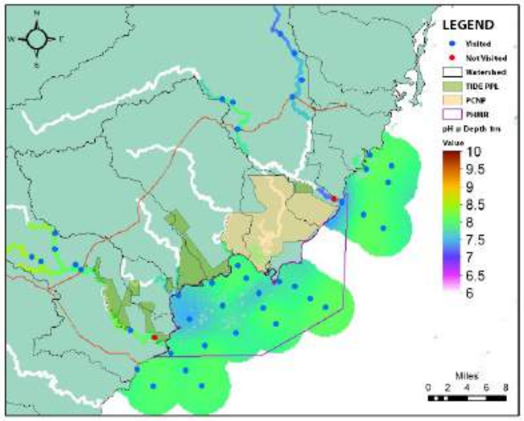


4.3 pH

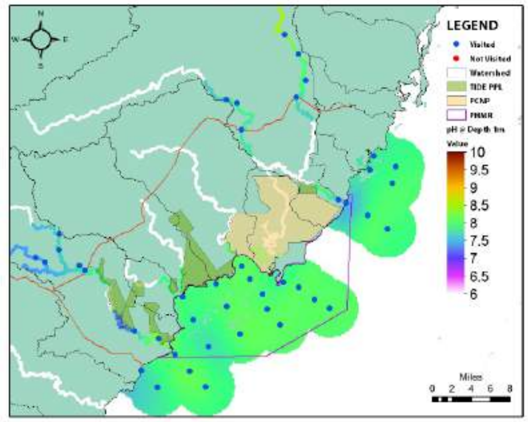
November 2015 (k): **December 2015 (l):**

1m

pH 1m November 2015

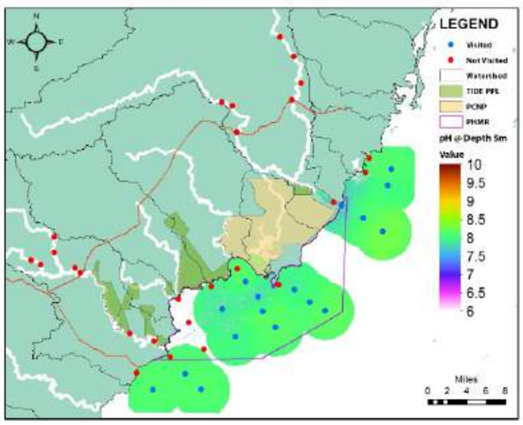


pH 1m December 2015

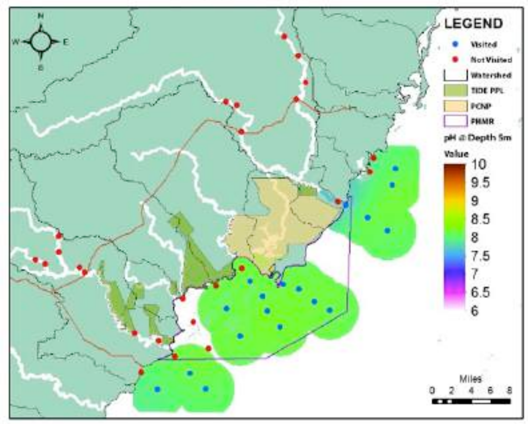


5m

pH 5m November 2015

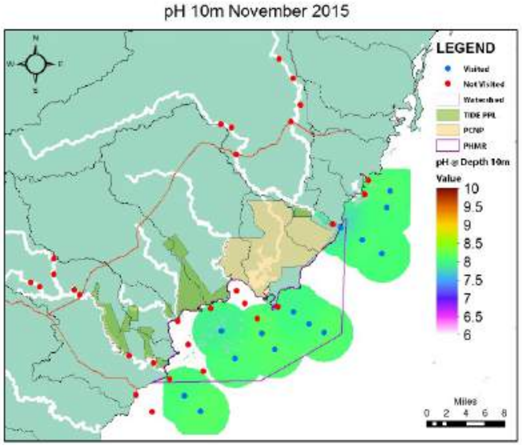


pH 5m December 2015

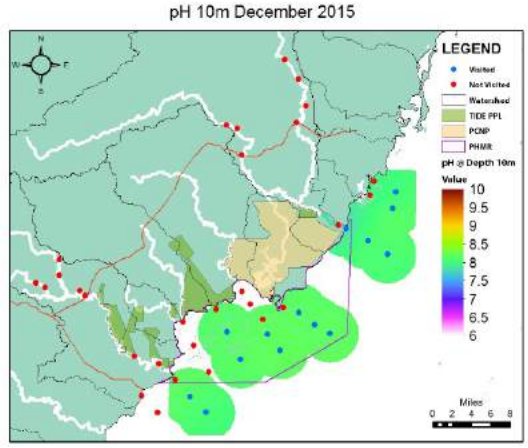


10m

pH 10m November 2015

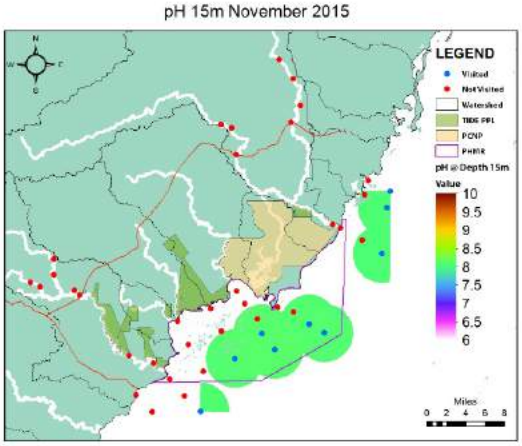


pH 10m December 2015

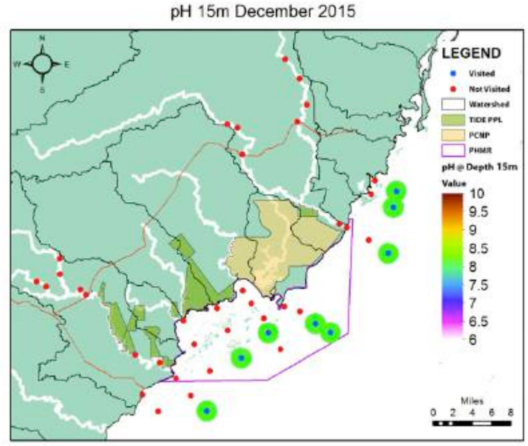


15m

pH 15m November 2015



pH 15m December 2015



4.4 pH - General conclusions:

- 2015 PHMR pH data demonstrated very different trends compared to 2014. January to May revealed stable values in 2015, while the same period exhibited the most variability for 2014.

- The greatest spatial variability was seen at the 1m depth for all months.

- Increasing pH from April to August coincides with a general trend of ocean warming during this time.

- pH was generally lower at the surface compared with other depths.

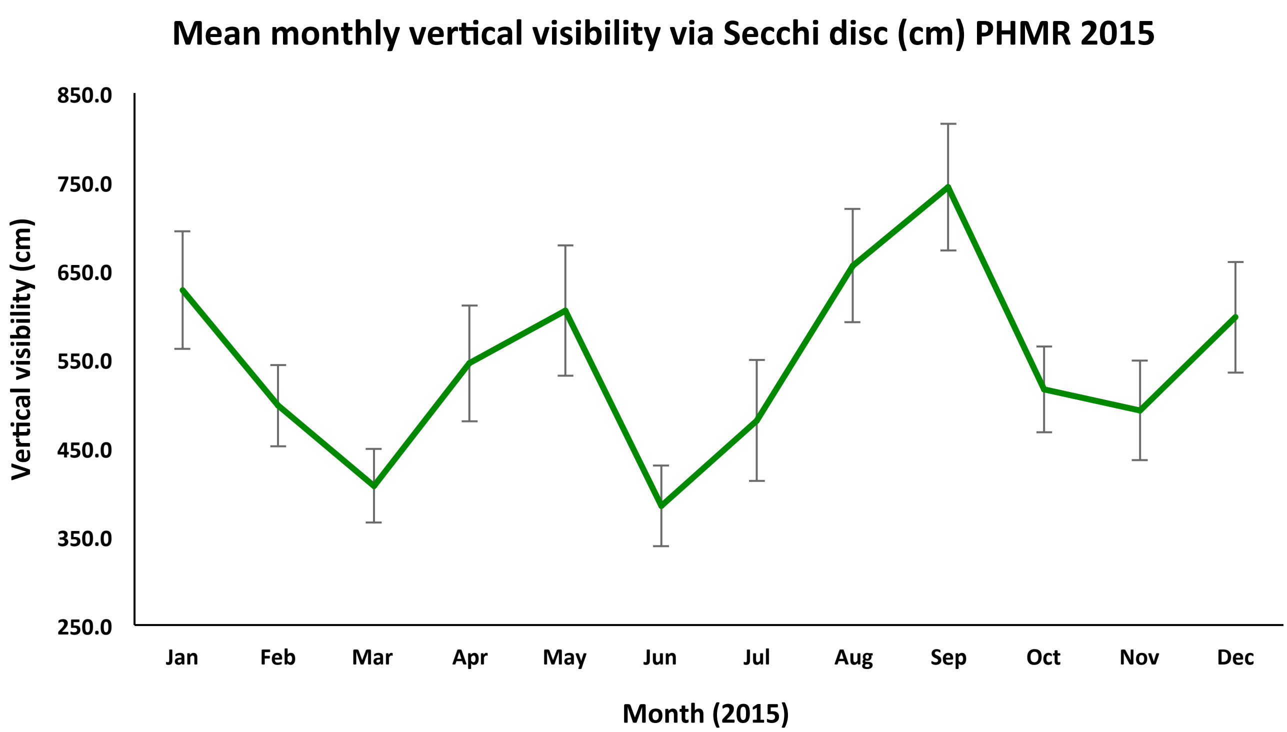
- In general, pH is considerably more neutral in the upper streams of the rivers than lower streams and in the sea.

- In 2015, PHMR mean surface pH stayed relatively stable throughout the year and was generally more alkaline than rivers. Mean pH in both rivers tended to increase throughout the year.

5. Visibility

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

5.1 Mean monthly visibility, PHMR, 2015 (Fig. 5.1):



- Mean vertical visibility in PHMR exhibited more frequent fluctuations throughout the year than previous years, peaking at 743.8cm ± 71.3SE in September, with two more minor peaks in May and December at around 600cm for both.

- The September peak in vertical visibility corresponded with a reduction in salinity stratification (33.6ppt ± 0.44SE at 1m, 35.3ppt ± 0.1SE at 5m, 35.7ppt ± 0.06SE at 10m and 36.2ppt ± 0.12SE at 15m; see Fig. 3.1, pg. 40) and highest temperatures for the year in PHMR (30.8°C ± 0.12SE at 1m, 30.2°C ± 0.04SE at 5m, 30.2°C ± 0.05SE at 10m and 31.3°C ± 1.23SE at 15m; Fig. 1.2).

- Mean visibility has two major troughs in March (407.0cm ± 41.6SE) and June (384.3cm ± 45.4SE).

- This 2015 trend was different from 2014, which peaked in December and January.

5.2 Visibility maps, 2015 – PHMR, Rio Grande, Monkey River (Fig. 5.2: Maps a-l):

- **January (Fig. 5.2 a):** In general, visibility increased with increasing distance from shore, the only exception being site 5E, near Moho Caye and the Snake Cayes, which had an irregularly lower visibility (100cm) than surrounding areas. Sedimentation rate was also high at the same spot in January (see Fig. 7.2 a). Southern PHMR had much poorer visibility than elsewhere, particularly at the mouths of Middle River/Golden Stream (125cm) and near Punta Ycacos (100cm).

- **February (Fig. 5.2 b):** Visibility was lowest near Rio Grande (125cm) and site 4A (190cm). Visibility increased with increasing distance from shore, except near Joe Taylor Creek and Middle River/Golden Stream where it was higher than surrounding areas (1327cm and 1247cm, respectively). Overall, visibility was poorer in offshore areas than in January.

- **March (Fig. 5.2 c):** Visibility was poorest near shore and increased with increasing distance from shore. Offshore visibility was lower than previous months in 2015.

- **April (Fig. 5.2 d):** Offshore visibility improved substantially from the previous month and showed the same general trend of increasing visibility with increasing distance from shore.

- **May (Fig. 5.2 e):** Visibility was poorer than previous months near Rio Grande and Golden Stream (220cm) and north of Monkey River (sites 8a and 8b; 200cm and 150cm, respectively). Visibility increased with increasing distance from shore as in other months.

- **June (Fig. 5.2 f):** Visibility nearshore increased but was more uniform throughout all sites, with offshore visibility lower than previous months. Visibility was between 100cm and 550cm for all sites except for those sites farthest from shore (6c, 6d, 7c and 9b), which had visibilities between 600cm and 900cm.

- **July (Fig. 5.2 g):** Visibility nearshore decreased again in July, particularly near Joe Taylor Creek (50cm), Rio Grande (300cm) and Middle River/Golden Stream (150cm). Visibility increased with increasing distance from shore, though there was lower visibility extending from the mouths of Middle River and Golden Stream even offshore (150-450cm), compared with values above 500cm at surrounding sites. No data available for northern sites.

- **August (Fig. 5.2 h):** Visibility increased overall in August and showed a similar trend to previous months, increasing with increasing distance from shore. Visibility was greatest north of PHMR, reaching 1275cm at sites farther offshore (7c, 8b). In the central coastal areas of PHMR between Middle River/Golden stream and Deep River mouths, there was relatively good visibility extending from nearshore to offshore areas (sites 4a, 4b, 4c; 500cm, 750cm, 950cm, respectively).

- **September (Fig. 5.2 i):** Visibility was higher throughout offshore regions of PHMR relative to other months, showing a similar trend of increasing visibility with increasing distance from shore. Values ranged from 200cm in Punta Ycacos Lagoon (site 5b) to 1200cm further offshore (sites 5e and 6d).

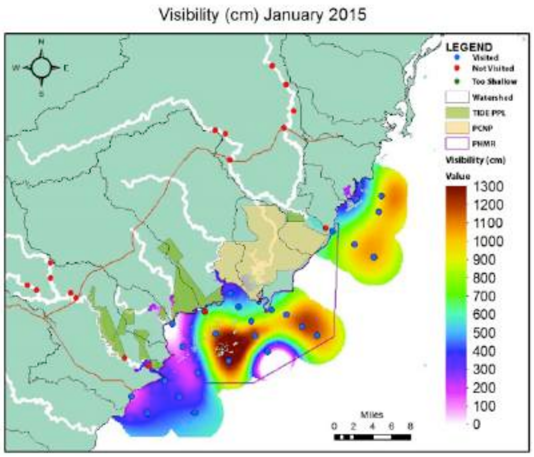
- **October (Fig. 5.2 j):** Visibility was lower on average than in the previous month, showing a similar trend in central and northern regions of PHMR and the Monkey River area of increasing with increasing distance from shore. Visibility was lowest in the waters near the Rio Grande (210cm) and Middle River/Golden Stream mouths (130cm), and poor visibility extended to adjacent southern offshore areas (site 3c; 330cm).

- **November (Fig. 5.2 k):** Visibility was lowest near Rio Grande and Middle River/Golden Stream mouths and increased with increasing distance from shore, except for one patch north of PHMR (site 7c) that had an irregularly low visibility (90 cm) despite its distance from the coast.

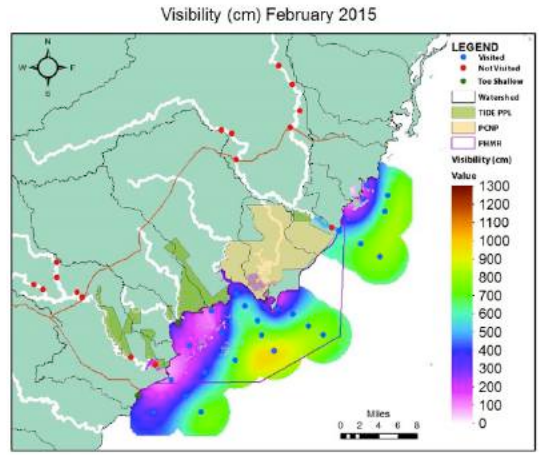
- **December (Fig. 5.2 l):** Visibility decreased from the previous month in the area extending from the Rio Grande, but increased elsewhere in offshore areas, particularly in Frenchman and Snake Cayes areas.

5.2 a-f: Visibility (cm) by month, 2015 – PHMR

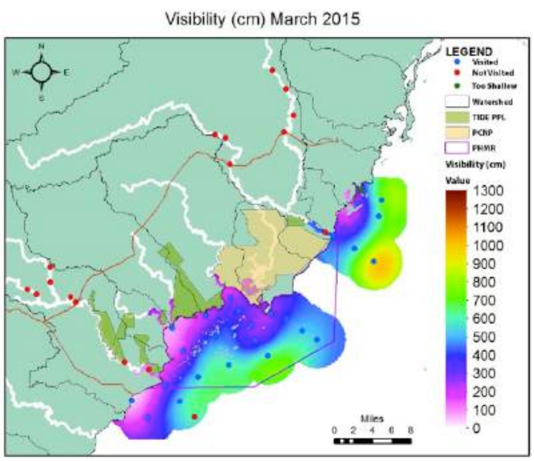
January (a):



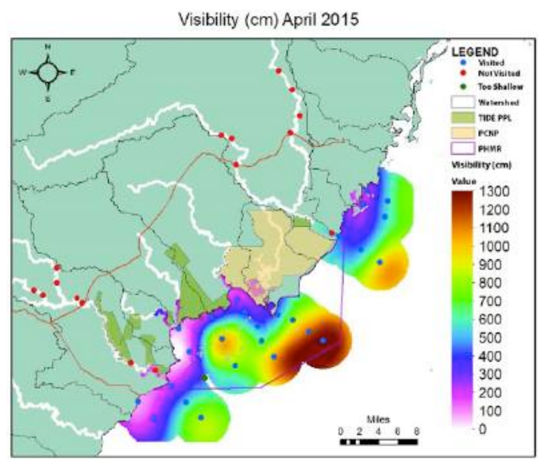
February (b):



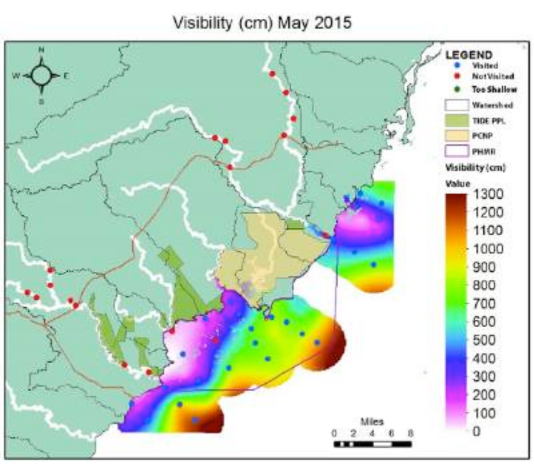
March (c):



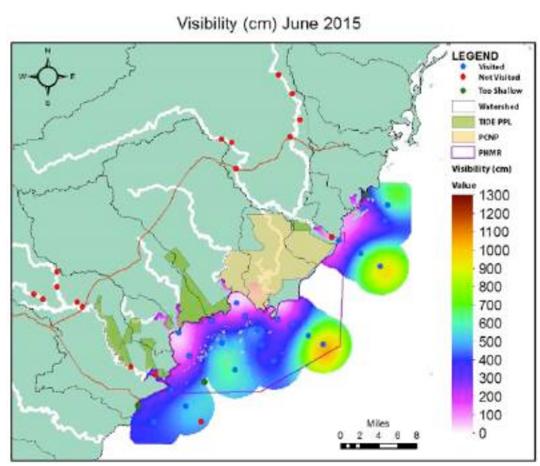
April (d):



May (e):

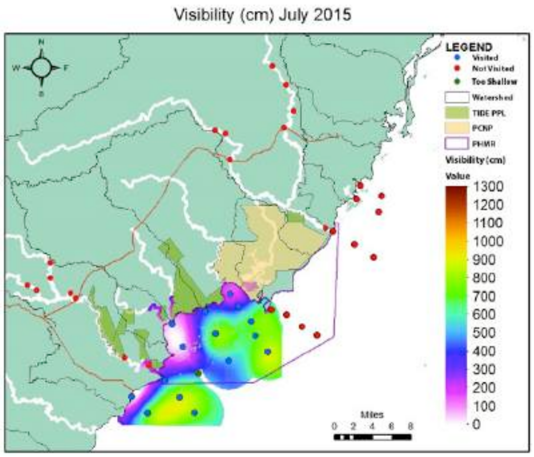


June (f):

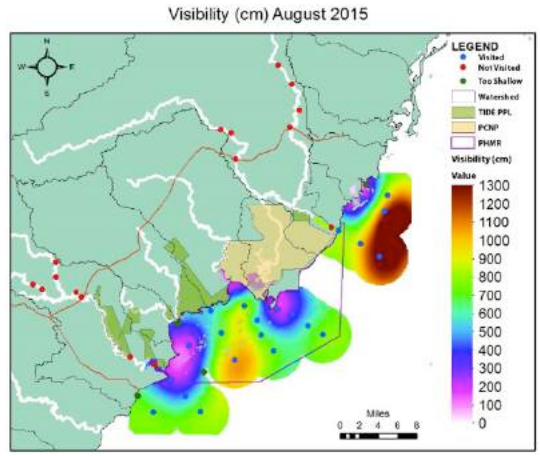


5.2 g-l: Visibility (cm) by month, 2015 – PHMR

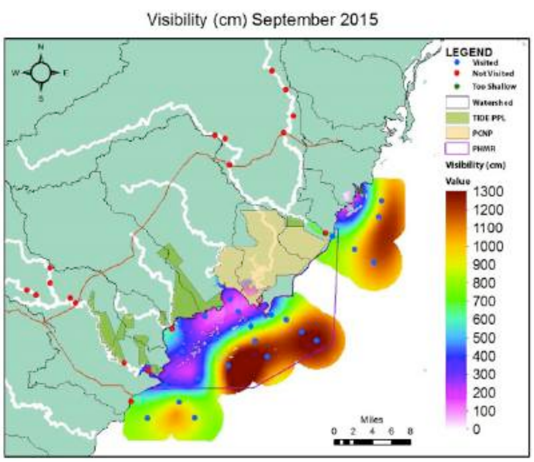
July (g):



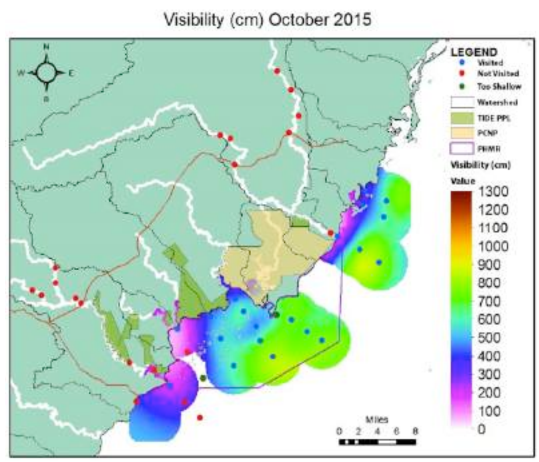
August (h):



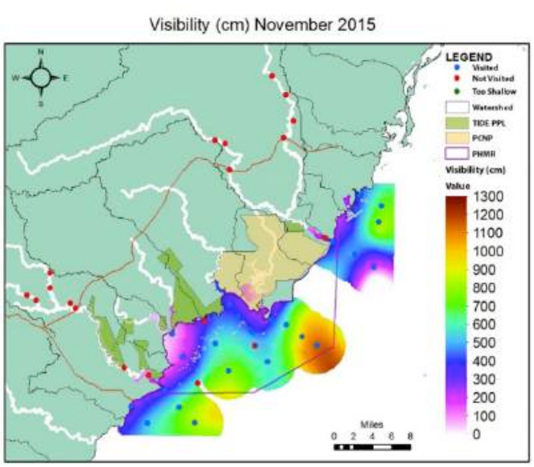
September (i):



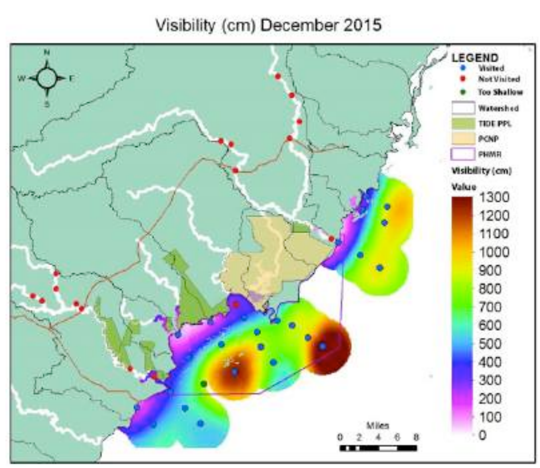
October (j):



November (k):



December (l):



5.3 Visibility – General Conclusions:

- The only clear trend in visibility is an increasing visibility gradient in general as distance from shore increases. Lowest visibility tends to be near the mouths of Rio Grande and Middle River/Golden Stream.

- Over the course of 2015, mean visibility had several peaks (February, May and September) and troughs (March, June and November), very different from the trend in 2014, which peaked in January and December and remained lower in the in-between months.

6. Nutrient Analysis: Nitrate & Phosphates:

6.1 Mean surface nutrient concentrations (nitrates and phosphates) by month, 2015 – PHMR, Rio Grande, Monkey River (Figs. 6.1 a, b):

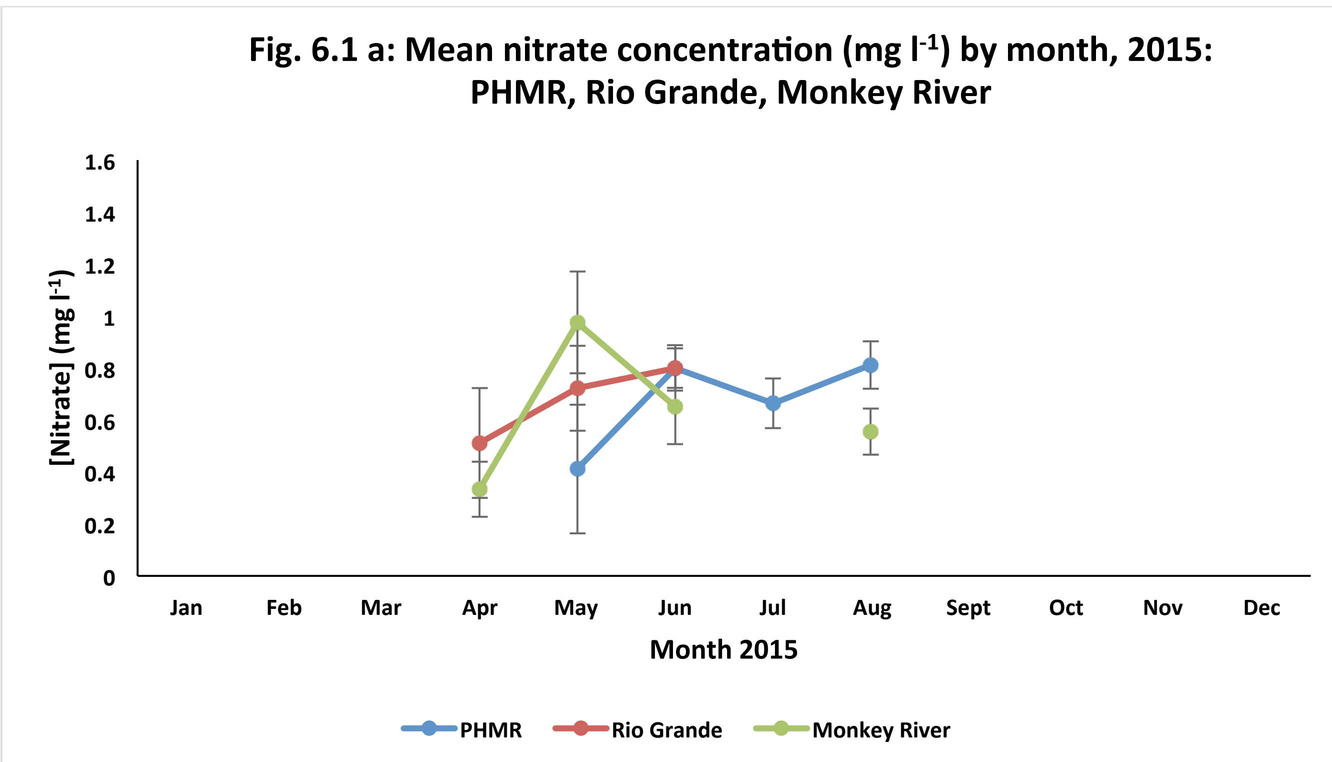
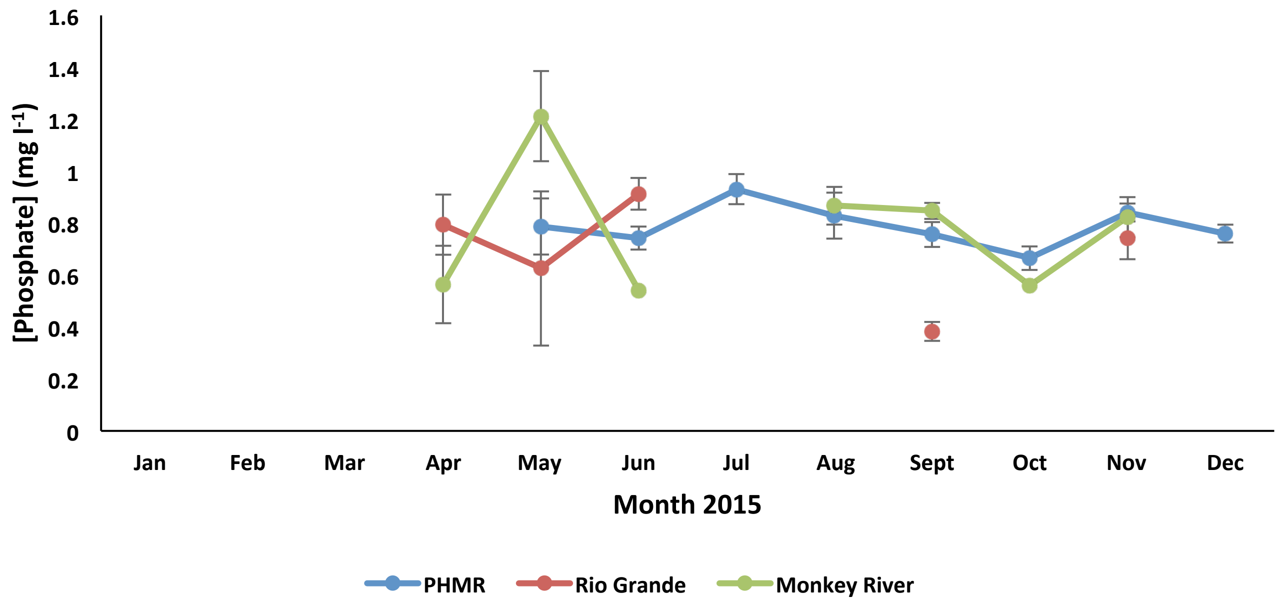


Fig. 6.1 b: Mean phosphate concentration (mg l^{-1}) by month, 2015: PHMR, Rio Grande, Monkey River



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

- ***PHMR**: January, February, March, April, September, October, November and December.*
- ***Rio Grande**: January, February, March, July, August, September, October, November and December.*
- ***Monkey River**: January, February, March, July, September, October, November and December.*

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

- ***PHMR**: January, February, March and April.*
- ***Rio Grande**: January, February, March, July, August, October and December.*
- ***Monkey River**: January, February, March, July and December.*

- **Nitrates (Fig. 6.1 a):** Mean nitrate concentrations in all areas were somewhat variable and revealed no clear trends. In PHMR, mean nitrate concentration was highest in August (0.81mg l^{-1} ± 0.09SE). In Rio Grande, mean nitrate concentrations were highest in June (0.80mg l^{-1} ± 0.09SE). In Monkey River, mean nitrate concentrations were significantly higher in May (0.98mg l^{-1} ± 0.2SE) than in April or August, and considerably higher than June. Mean nitrate concentrations were lowest in April in Rio Grande and Monkey River (0.51mg l^{-1} ± 0.21SE and 0.33mg l^{-1} ± 0.11SE, respectively) and May in PHMR (0.41mg l^{-1} ± 0.25SE).

- **Phosphates (Fig. 6.1 b):** Mean phosphate concentrations remained fairly stable in PHMR, between 0.67mg l^{-1} ± 0.05SE and 0.93mg l^{-1} ± 0.06SE. Concentrations were more variable in the rivers and revealed no clear trends. Like the mean nitrate concentration, mean phosphate concentration was highest in June in Rio Grande (0.91mg l^{-1} ± 0.06SE). In Monkey River, mean phosphate concentration was again significantly higher in May (1.21mg l^{-1} ± 0.17SE) than other months. Concentrations were lowest in October in PHMR (0.67mg l^{-1} ± 0.05SE), September in Rio Grande (0.38mg l^{-1} ± 0.04SE) and June in Monkey River (0.54mg l^{-1}). In the third quarter of the year, mean phosphate concentration showed similar declining trends in PHMR and both rivers.

6.2 Nitrate maps, 2015 – PHMR, Rio Grande, Monkey River (Fig. 6.2 a-l):

- **April (Fig. 6.2 d):** The highest nitrate concentration was observed in the Colombia branch of Rio Grande (0.93 mg l^{-1}). Concentrations decreased with increasing distance downstream in Monkey River (from 0.4 mg l^{-1} at site MR_TB_1a to 0.1 mg l^{-1} at site MR_BB_1b). No data available for PHMR.

- **May (Fig. 6.2 e):** Nitrate concentrations were higher in the rivers than at observed values in PHMR. The highest concentrations were in the upper reaches of Monkey River (site MR_TB_1a; 1.4 mg l^{-1}). Nitrate concentrations in PHMR were highest at the mouth of Monkey River (site 7a; 0.9 mg l^{-1}).

- **June (Fig. 6.2 f):** Nitrate concentrations were, on average, higher in June than May in both PHMR and Rio Grande. Nitrate concentrations in PHMR were highest offshore from Rio Grande (sites 2b, 2c; both 0.97 mg l^{-1}).
- **July (Fig. 6.2 g):** There is no river data for nitrates in July, but in PHMR nitrate concentrations were highest near the mouth of Deep River but offshore (site 5e; 0.87 mg l^{-1}).

- **August (Fig. 6.2 h):** Nitrate levels were higher than previous months in PHMR but lower than previous months in Monkey River. There is no nitrate data for Rio Grande in August.

6.2 a-f: Nitrate concentration (mg l^{-1}) by month, 2015 – PHMR, Monkey River, Rio Grande

January (a):

No data available for January 2015

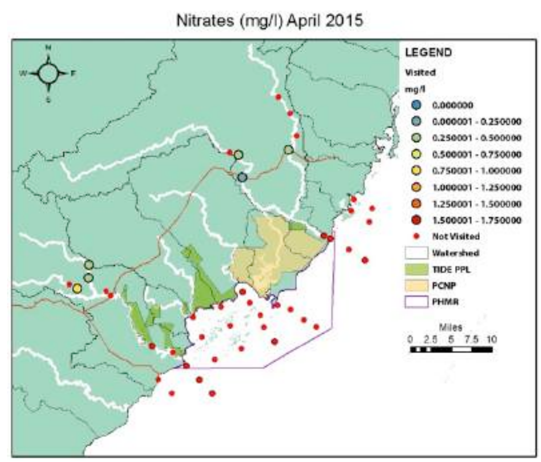
February (b):

No data available for February 2015

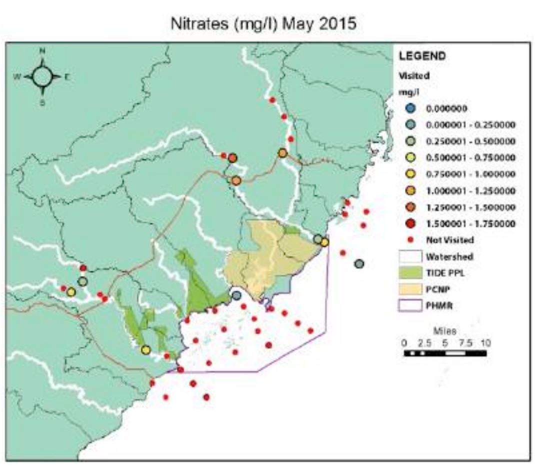
March (c):

No data available for March 2015

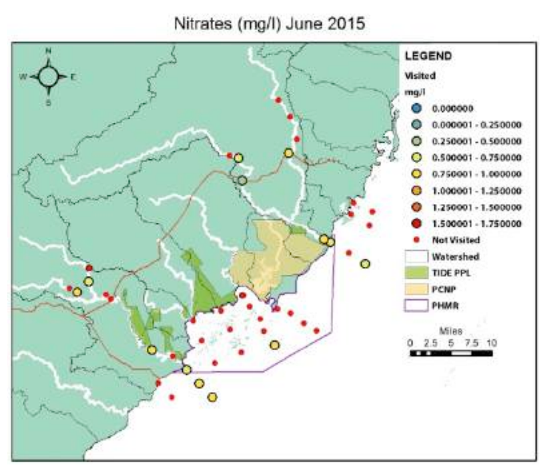
April (d):



May (e):



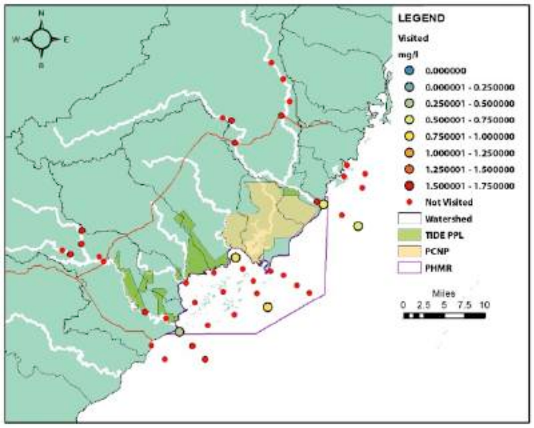
June (f):



6.2 g-l: Nitrate concentration (mg l^{-1}) by month, 2015 – PHMR, Monkey River, Rio Grande

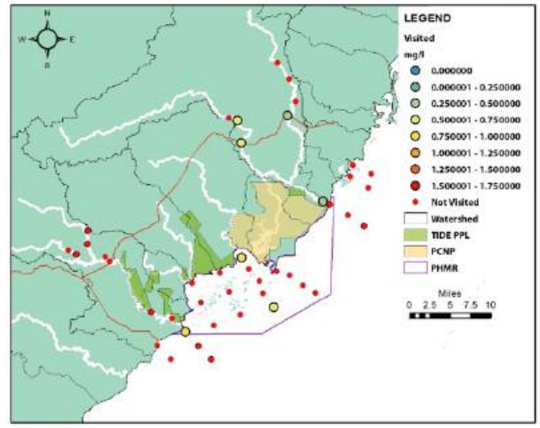
July (g):

Nitrates (mg/l) July 2015



August (h):

Nitrates (mg/l) August 2015



September (i):

No data available for September 2015

October (j):

No data available for October 2015

November (k):

No data available for November 2015

December (l):

No data available for December 2015

6.3 Phosphate maps, 2015 – PHMR, Monkey River, Rio Grande:

- **April (Fig. 6.3 d):** In Rio Grande, phosphate concentrations were highest upriver in the Columbia Branch (1.01 mg l^{-1}) and decreased with increasing distance down-river. In Monkey River the opposite trend was seen.

- **May (Fig. 6.3 e):** Phosphate concentrations were highest in the upper reaches of Monkey River (1.7 mg l^{-1} at Trio Bridge and 1.1 mg l^{-1} in both the Bladen Branch and Swasey Branch). In PHMR they were highest offshore near Deep River and at the mouth of Monkey River (0.99 mg l^{-1} and 0.96 mg l^{-1}, respectively). In Rio Grande, phosphate concentrations were highest downstream (site RG_RG_1c; 0.96 mg l^{-1}).

- **June (Fig. 6.3 f):** Phosphate concentrations in PHMR increased with increasing distance from shore, with the exception of site 2A at the mouth of Rio Grande, which had a higher phosphate concentration more similar to the concentration in the lower reaches of Rio Grande. In Rio Grande concentrations decreased with increasing distance downstream.

- **July (Fig. 6.3 g):** Phosphate concentrations in PHMR were once again highest near the mouth of Deep River (1.1 mg l^{-1}). Near Deep River, concentrations decreased slightly with increasing distance from shore, opposite the trend seen here in other months. Near Monkey River concentrations increased with increasing distance from shore.

- **August (Fig. 6.3 h):** No clear trends in phosphate concentrations are observable in August due to insufficient data.

- **September (Fig. 6.3 i):** Phosphate concentrations were higher in Monkey River than in Rio Grande, but in PHMR the highest concentrations were observed near the mouth of Rio Grande. Concentrations decreased with increasing distance offshore from the Rio Grande mouth, but increased with distance offshore from the mouths of Deep River and Monkey River.

- **October (Fig. 6.3 j):** In PHMR a similar trend was seen as in September, with phosphate concentrations near the Rio Grande mouth decreasing with increasing distance offshore, but near Deep River and Monkey River increasing with increasing distance from the mouths.

- **November (Fig. 6.3 k):** In Rio Grande, phosphate concentrations decreased with increasing distance downstream. In Monkey River, phosphate concentrations were highest at the mouth, decreased upstream and then increased again in the upper reaches. In PHMR, concentration was highest near Deep River and increased slightly with increasing distance from shore near Deep River and Monkey River.

- **December (Fig. 6.3 l):** Phosphate concentrations in PHMR were highest near Deep River and followed the same trend of increasing with increasing distance from shore near Deep and Monkey Rivers.

6.3 a-f: Phosphate concentration (mg l^{-1}) by month, 2015 – PHMR, Monkey River, Rio Grande

January (a):

No data available for January 2015

February (b):

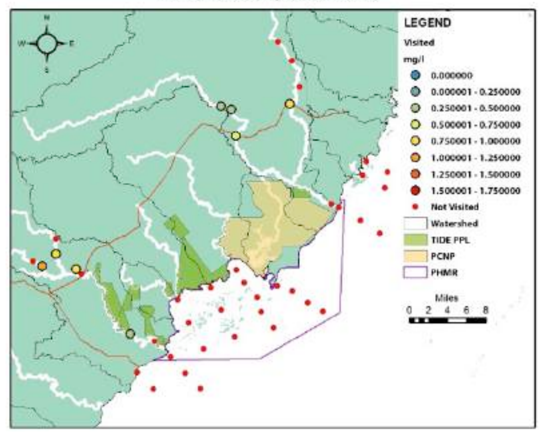
No data available for February 2015

March (c):

No data available for March 2015

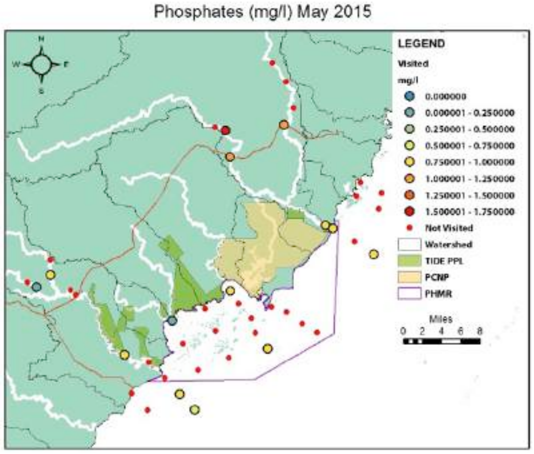
April (d):

Phosphates (mg/l) April 2015



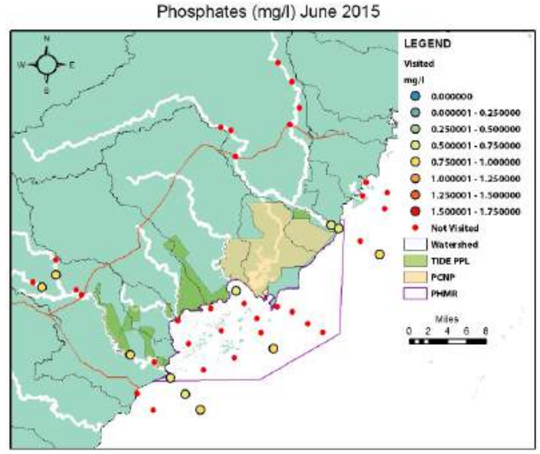
May (e):

Phosphates (mg/l) May 2015



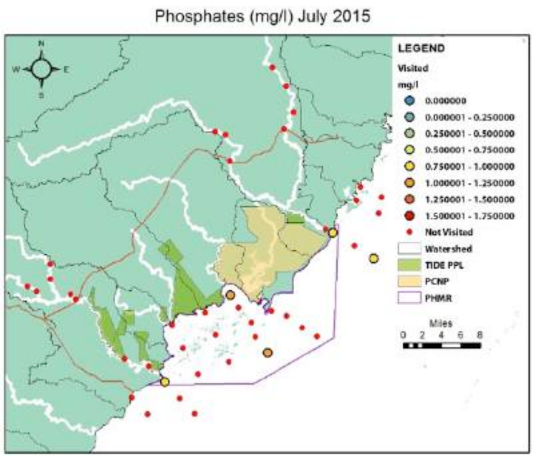
June (f):

Phosphates (mg/l) June 2015

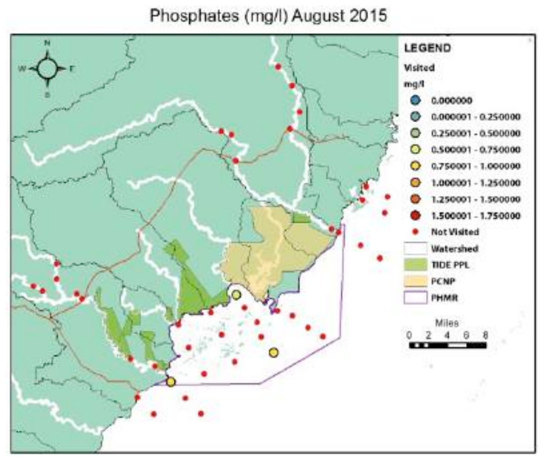


6.3 g-l: Phosphate concentration (mg l^{-1}) by month, 2015 – PHMR, Monkey River, Rio Grande

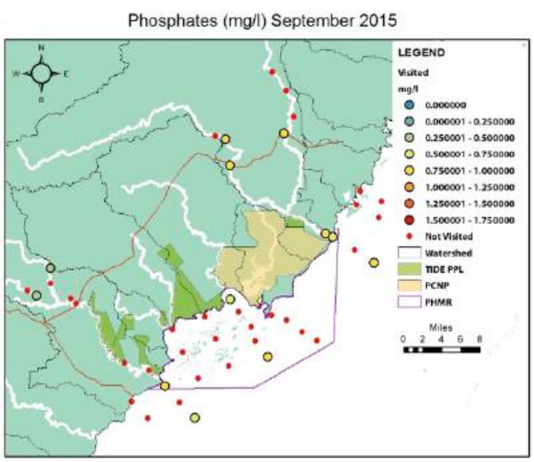
July (g):



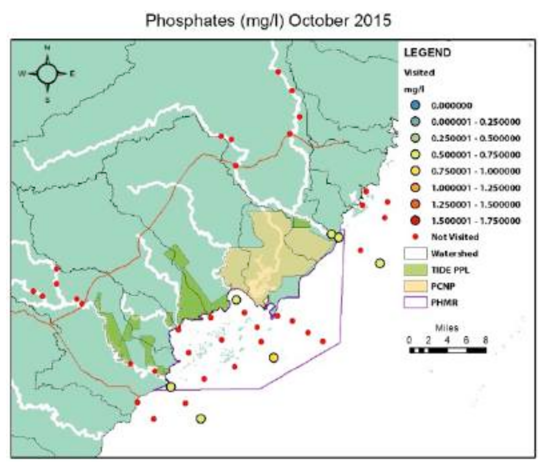
August (h):



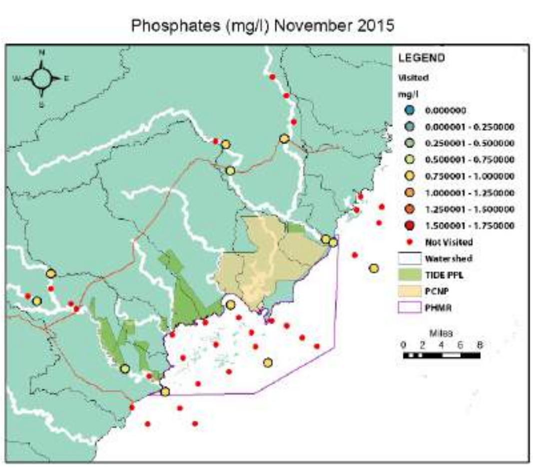
September (i):



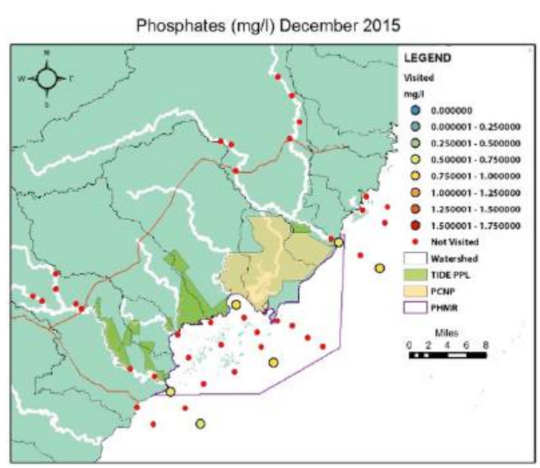
October (j):



November (k):



December (l):



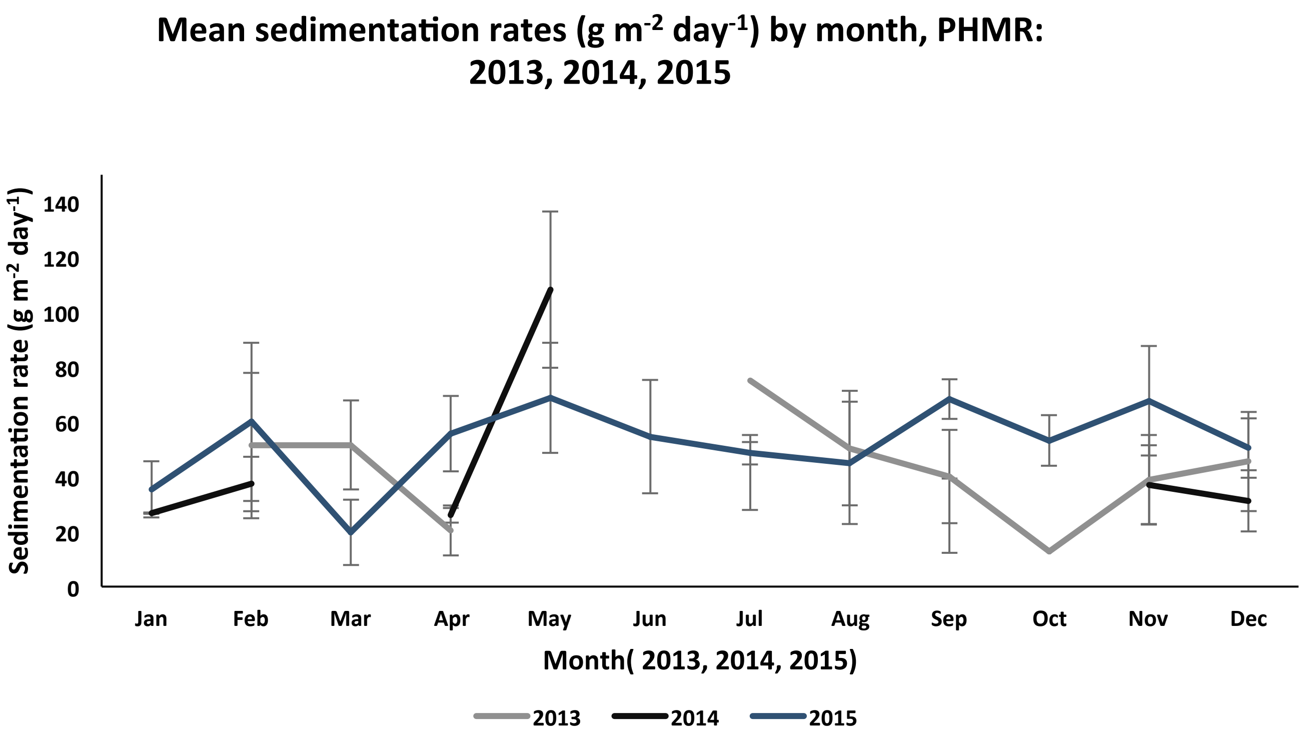
6.4 Nitrate and Phosphate: general conclusions:

- There are no clear trends in phosphate or nitrate concentrations over the course of the year, although concentrations of both nitrates and phosphates were highest in May in Monkey River and June in Rio Grande. These peaks correspond with a sudden increase in salinity stratification in PHMR beginning in May (Fig. 3.1).
- In PHMR, near the mouths of Middle River and Monkey River, nitrate and phosphate concentrations in general increased with increasing distance from shore; however, this trend was not observed near the mouth of Rio Grande and often the opposite was observed.
- Mean phosphate concentrations in PHMR were high throughout the year in 2015, whereas in 2014 they were lower in the second and third quarters and then increased to values similar to 2015 in the last quarter. Mean nitrate concentrations in the rivers were lower in 2015 than 2014.
- Declining mean phosphate concentrations across sites in the third quarter of the year correspond with a simultaneous increase in salinity and decrease in salinity stratification in PHMR (Figs. 3.1, 6.1b).

7. Sedimentation

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

7.1 Mean sedimentation by month, PHMR – 2012, 2013, 2015 (Fig. 7.1):



- The 2015 trend in mean sedimentation rate is fairly similar to previous years. It peaked in Feb (60g $m^{-2}d^{-1}$ ± 30.1SE), May (68.7g $m^{-2}d^{-1}$ ± 20.0SE), September (68.3g $m^{-2}d^{-1}$ ± 7.2SE) and November (67.6g $m^{-2}d^{-}$

^{1} ± 19.9SE), corresponding with visibility peaks in May (604.8cm ± 73.6SE), September (726.0cm ± 70.6SE) and December (591.5cm ± 60.3SE; Fig. 4.1).

- Mean sedimentation rate was lowest in March (19.8g m^{-2} d^{-1} ± 12.0SE), similar to previous years (April in 2013 and 2014), corresponding also with a trough in visibility (Fig. 4.1).

- Mean sedimentation rate remained fairly stable during the middle of 2015, between the May and September peaks (June, 54.6g m^{-2} d^{-1} ± 21.4SE; July, 48.6g m^{-2} d^{-1} ± 16.5SE; August, 45.0g m^{-2} d^{-1} ± 9.0SE).

7.2 Sedimentation maps, 2015 – PHMR (Fig. 7.2):

- **January (Fig. 7.2 a):** Sedimentation rate increased with increasing distance from shore. The waters offshore from Deep River near the Snake Cayes had the highest sedimentation rate (72.21g m^{-2} d^{-1}). Visibility was also unusually low (100cm) in this area at the same time (see Fig. 5.2 a).

- **February (Fig. 7.2 b):** Sedimentation rate in PHMR was highest near Monkey River (119.57g m^{-2} d^{-1}). Near the mouth of Deep River, sedimentation rate again increased slightly with increasing distance from shore.

- **March (Fig. 7.2 c):** At the mouth of Deep River, sedimentation rate was higher near the mouth (31.76g m^{-2} d^{-1}) and decreased with increasing distance from shore (7.77g m^{-2} d^{-1} at site 5E).

- **April (Fig. 7.2 d):** Sedimentation rate near Deep River decreased with increasing distance from shore again, but a higher sedimentation rate was seen near Monkey River (78.57g m^{-2} d^{-1}).

- **May (Fig. 7.2 e):** Sedimentation rate was higher on average than previous months and it was highest south of PHMR (site 2C: 130.91g m^{-2} d^{-1}). Near Deep River and Monkey River, sedimentation rate decreased with increasing distance from shore.

- **June (Fig. 7.2 f):** Sedimentation rate was highest near Monkey River (105.99g m^{-2} d^{-1}). Sedimentation rate decreased with increasing distance from shore near Monkey River, but the opposite was seen near Deep River.

- **July (Fig. 7.2 g):** Sedimentation rate in PHMR was highest offshore from Rio Grande (80.45g m^{-2} d^{-1}). Near Deep River, sedimentation rate increased with increasing distance from shore.

- **August (Fig 7.2 h):** Sedimentation rate was highest near the mouth of Deep River (59.70g m^{-2} d^{-1}) and decreased slightly with increasing distance from shore.

- **September (Fig. 7.2 i):** Sedimentation rate increased relative to previous months and was highest near Monkey River (120.02g m^{-2} d^{-1}).

- **October (Fig. 7.2 j):** Sedimentation rate decreased on average from the previous month and was higher near Rio Grande (83.20g m^{-2} d^{-1}) than near Deep River (23.20g m^{-2} d^{-1}).

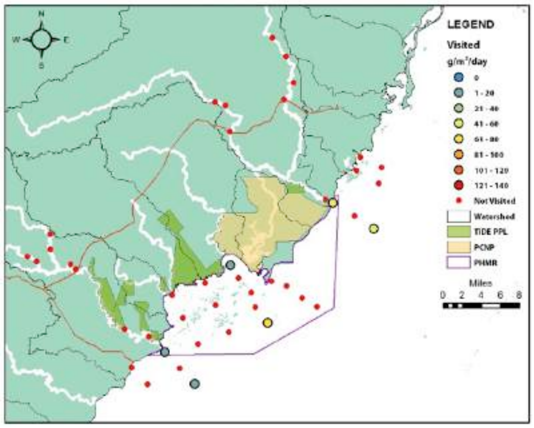
- **November (Fig. 7.2 k):** Sedimentation rate again increased on average in November and was highest near Rio Grande (126.44g m^{-2} d^{-1}). The rate decreased with increasing distance from shore across PHMR.

- **December (Fig. 7.2 l):** Sedimentation rate was highest offshore near Monkey River (site 7c; 103.20g m^{-2} d^{-1}). Near Deep River sedimentation rate increased with increasing distance from shore.

7.2 a-f: Sedimentation (g m^{-2} day^{-1}) by month, 2015 – PHMR

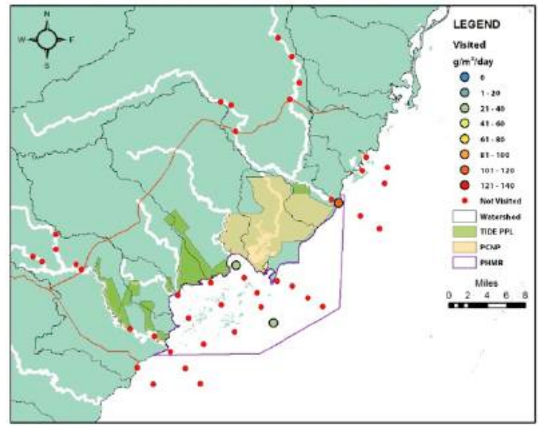
January (a):

Sedimentation (g/m²/day) January 2015



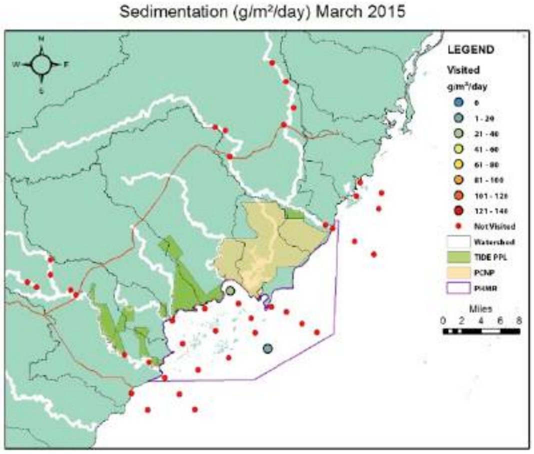
February (b):

Sedimentation (g/m²/day) February 2015



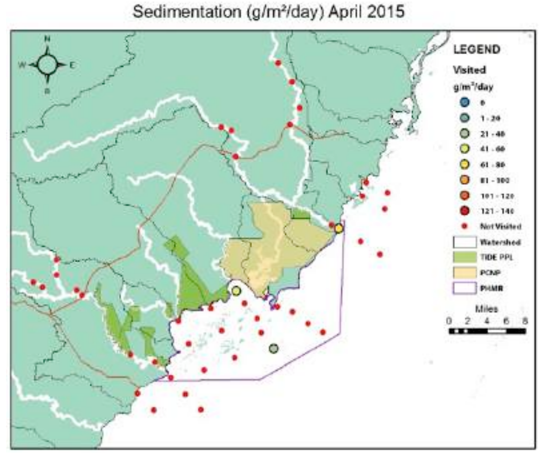
March (c):

Sedimentation (g/m²/day) March 2015



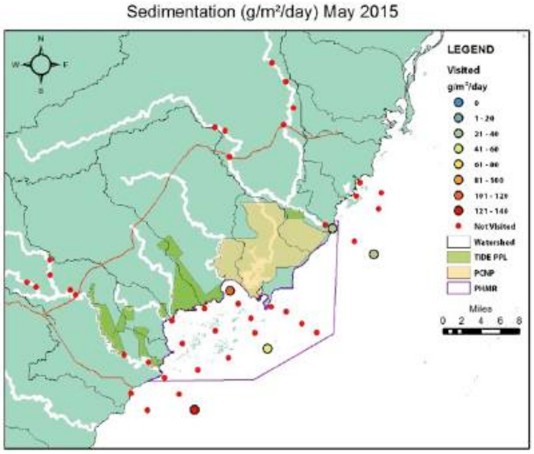
April (d):

Sedimentation (g/m²/day) April 2015



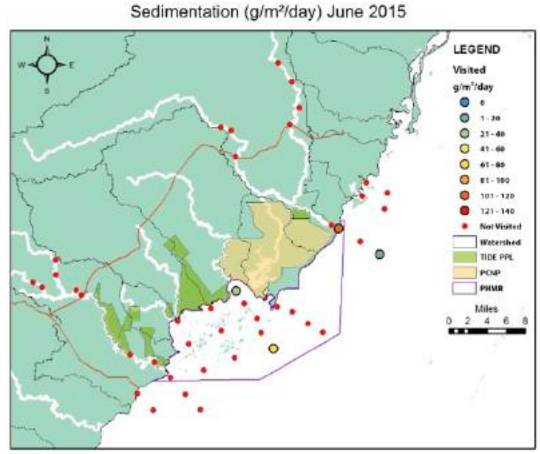
May (e):

Sedimentation (g/m²/day) May 2015



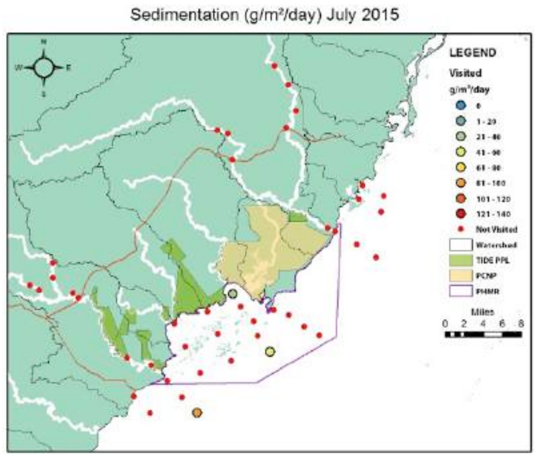
June (f):

Sedimentation (g/m²/day) June 2015

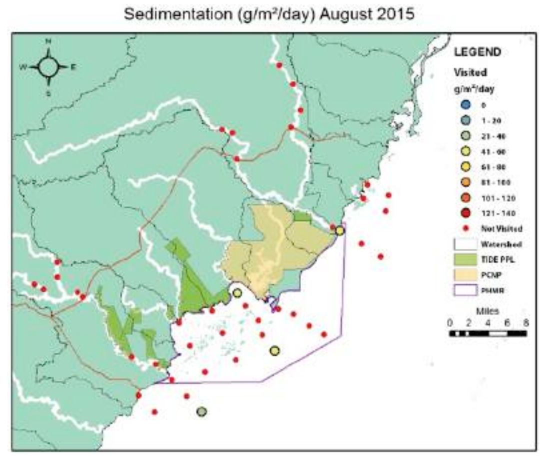


7.2 g-l: Sedimentation (g m^{-2} day^{-1}) by month, 2015 – PHMR

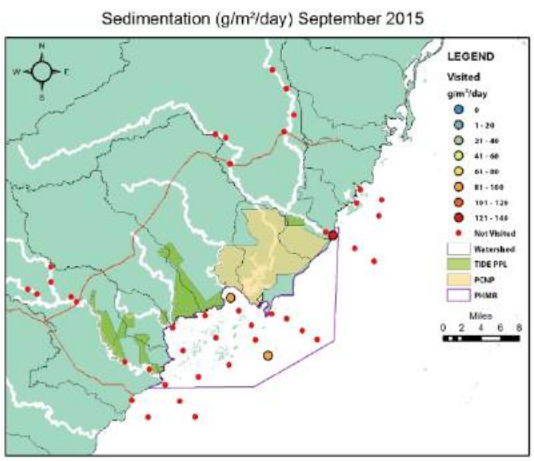
July (g):



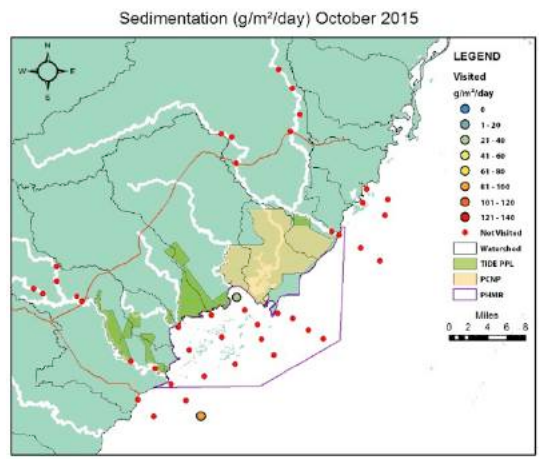
August (h):



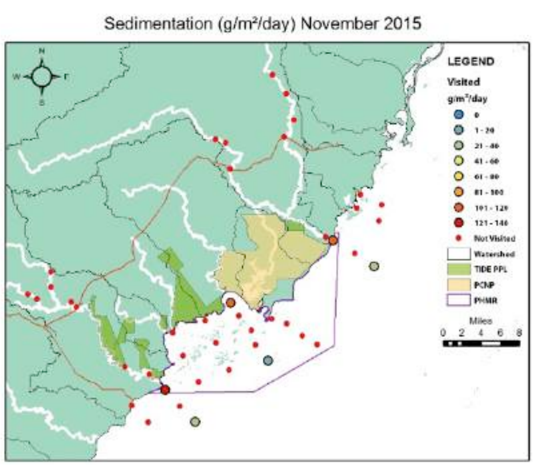
September (i):



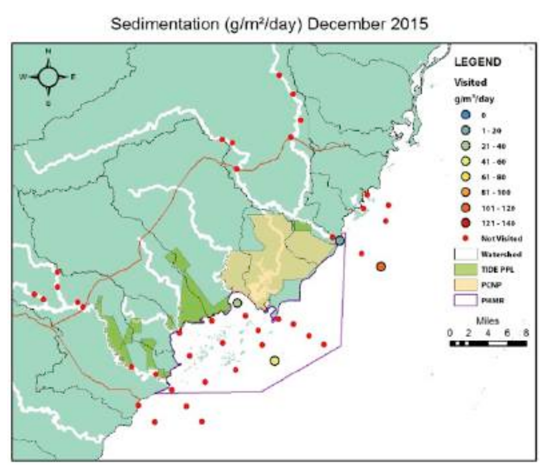
October (j):



November (k):



December (l):



7.3 Sedimentation 2015 PHMR – general conclusions:

- Mean PHMR sedimentation rate was lowest in March but remained fairly consistent through the rest of the year, with minor peaks in May, September and November.

- Sedimentation rate varied with greater frequency than in previous years at sites across PHMR. From March to May there is a trend of visibility increasing and sedimentation rate decreasing with increasing distance from shore. This trend is observed again in November, a month that had heavy rainfall and flooding. In June, July and December, higher sedimentation rate was correlated with higher visibility.

- Mean sedimentation rate was highest in May and November, corresponding with a gradient of decreasing sedimentation with increasing distance from shore, suggesting large river input. May and November were also times of decreasing mean surface salinity and increasing salinity stratification in PHMR, signs of large freshwater input from heavy rainfall.

- In some months, higher sedimentation rates were observed at offshore sites, particularly at site 2C in May, July and October and at site 5E in January, June and September.

DISCUSSION

Sea surface temperature warming in 2015

- The previously observed continuous declining trend of mean surface temperature for PHMR ended with a notable increase in 2015. The onset of an El Niño event in 2015 could be a possible cause for this warming trend. A corresponding increase in coral bleaching was also observed in PHMR in 2015, strengthening speculation that El Niño is driving this overall temperature increase.

- As in previous years, temperature dynamics showed the greatest variability near the surface. In the early part of the year, surface warming occurred, with cooler conditions remaining at depth. After September, surface cooling is seen with deeper layers retaining heat.

Monkey River temperatures less stable than Rio Grande

- Monkey River continues to be more susceptible than Rio Grande to solar warming during summer months, likely due to exposure of river to sun from riparian deforestation. Rio Grande continues to exhibit overall cooler and more stable temperatures than PHMR and Monkey River. 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.

- There are early signs, however, that conditions are changing in the Rio Grande watershed. While conditions remained more stable over the year than in Monkey River, they were more dynamic than previous years in Rio Grande. This could be due to higher impacts on the Rio Grande watershed in recent times, and this will need to be monitored closely before serious damage to aquatic ecosystems in Rio Grande occurs. Of particular concern is the Rio Grande Hicatee population.

Dissolved oxygen stratification September-December

- As in previous years, DO stratification in PHMR is strongest in the final quarter of the year, but no other clear trends are observed year to year. This stratification is likely caused by solar radiation during the warmer months of the year.

Salinity stratification during summer months

- A decrease in salinity and increase in stratification during the second and third quarters of 2015 reflect typical rainfall patterns, which were highest during this time.

- In all years from 2010-2015, where data is available, lowest salinity was observed in July, correlating with heavy rainfall this time of year.

pH trends in PHMR heavily influenced by rivers

- Deviating from expected trends, sea water became more alkaline, even during months of heavy rainfall. River pH also increased at the same time and at a higher rate, suggesting that calcium carbonate-rich river water influx may be a stronger driver of pH trends in PHMR than the neutralising effect of dilution of salt water with this freshwater input. Calcium carbonate in the rivers most likely comes from the karst limestone bedrock in surrounding watersheds.

Relationships between visibility and sedimentation

- A positive correlation between visibility and sedimentation rate (as observed in June, July and December) suggests sediments during this time are more likely a result of precipitation of oceanogenic particulate organic matter (POM). When visibility and sedimentation rates are negatively correlated (as observed from March to May) land sediments introduced by runoff are the more likely cause, in which case sedimentation rates generally decrease with increasing distance from shore.

Highest nutrient concentrations occur early in rainy season

- As observed in previous years, river nutrient concentrations tend to be highest at the start of the rainy season, when salinity decreases and stratification increases in PHMR, a sign of terrigenous nutrients accumulated and stored on land during the dry season being washed into rivers by rainfall.

- Higher river phosphate concentrations in 2015 than 2014 suggest an increase in domestic waste water inputs into the rivers.

- Nutrient concentrations in PHMR generally increase with increasing distance from shore, suggesting an oceanogenic source for higher nutrient levels offshore.

- Higher nutrient levels in the Bladen Branch of Monkey River at the start of the rainy season continues to be a concern in 2015. 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.

Natural or anthropogenic?

- One 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. This is possibly due to greater anthropogenic influences which have led to wider shallow profile compared to Rio Grande, supporting observations made in 2012, 2013 and 2014 (see 2012, 2013 and 2014 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.

2015 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:

- 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.

- 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.

Research & Monitoring recommendations:

- **Sedimentation monitoring should be broken down into organic and inorganic matter to distinguish between terrigenous and oceanic sediments, in order to inform management of sedimentation events.** Too much sediment smothers coral reefs and seagrass beds, so it is important to understand where sediments are coming from so management efforts can address this problem, where possible.

- **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 potential 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 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.

- The addition of pH to the suite of parameters measured in 2014 and 2015 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 potential oil development plans in the area.

- 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.

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 plumes 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 TPPL). 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.

ACKNOWLEDGEMENTS

- Thanks to the OAK foundation and KfW for making this work financially possible. Thanks to TIDE Marine Biologist Tanya Barona, TIDE Terrestrial Biologist Elmar Requena, TIDE Research Assistant Marty Alvarez, TIDE Science Communications Intern Danica Warns for her invaluable support in the creation of this report, TIDE GIS Specialists Ryan Moore for creating the maps in this report, and TIDE's Community Researchers for their commitment and dedication in collecting, managing, processing and analysing data to the highest quality to date. Thanks to the Belize Fisheries Department for their continuing cooperation with TIDE's research and management of PHMR.

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Appendix

Tables

Table 1a. Mean monthly temperature (°C) PHMR 1m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	22.50	28.30	29.30	32.10	29.10	30.70	30.40	31.80	32.10		28.40	28.80
1B	26.40	27.70	27.10	30.00	29.60	29.40	29.80	30.50	30.30	29.60	28.30	28.50
2A	26.40	26.80	27.70	30.70	29.60	29.90	31.00	31.20	31.10	29.50	29.20	28.20
2B	26.10	27.50	27.40	29.80	29.40	29.80	29.80	30.25	30.40		28.10	28.30
2C	26.40	27.20	27.10	29.50	29.20		29.60	30.70	30.70		28.30	28.10
3A	28.30	27.80	28.10	31.30		28.10	31.40	31.10	32.00	29.80	29.40	28.90
3B	26.50	26.80	27.60	30.70	29.20	28.00	30.80	30.80	30.70	29.50	28.50	28.30
3C	26.40	26.90	27.90	29.77	29.90	28.20	29.80	30.30	30.40	29.50	28.30	28.20
4A	27.10	27.00	27.80	30.10	29.40	28.60	30.50	30.80	30.80	29.70	28.10	28.90
4B	26.70	26.20	28.10	29.60	29.80	28.20	29.90	30.40	30.90	29.60	27.90	28.30
4C	26.40	26.20	28.10	29.90	29.70	28.10	30.00	30.30	30.40	29.60	28.70	28.40
5A	28.10	26.50	28.50	29.70	29.30	28.60	30.70	37.20	31.40	30.10	29.00	29.00
5B	27.10	26.30	29.10	29.60	29.40	28.60	30.30	30.40	31.10	29.80	28.40	29.20
5C	27.00	26.20	28.20	29.90	29.10	28.40	30.20	31.30	30.10	29.50	28.40	29.30
5D	26.60	26.20	28.20	29.60	29.20	29.00	29.40	31.80	30.10	29.60	28.80	29.40
5E	26.50	26.20	29.50	29.90	29.20	28.90	29.50	31.80	29.70	29.60	27.90	28.90
6A	27.40	26.60	28.90	30.40	29.20	28.50		31.10	30.10	30.50	27.70	28.80
6B	26.50	26.20	28.20	30.10	29.30	28.50		31.10	31.50	30.10	28.70	28.30
6C	26.70	26.20	28.50	29.60	29.30	28.60		31.30	30.10	29.60	28.30	28.60
6D	26.70	26.30	28.90	29.80	29.20	28.60		30.80	29.70	29.70	28.90	29.00
7A	27.10	26.00	28.60	30.20	29.70	28.80		31.20	30.50	29.40	28.10	24.80
7B	26.90	26.00	28.50	30.20	29.60	29.10		30.60	31.00	29.70	23.60	28.20
7C	26.60	26.30	28.10	29.80	29.20	29.10		30.60	30.60	30.00	23.70	28.20
8A	27.50	26.90	28.60	29.20	29.60	29.40		31.70	31.70	30.10	23.60	27.10
8B	26.70	26.00	28.20	29.80	29.90	29.00		30.60	30.80	29.60	23.70	28.10
9A	27.70	17.00	28.20	29.40	29.30	29.50		31.80	31.60	29.90	23.70	28.30
9B	26.80	26.00	28.20	29.70	29.40	29.40		30.80	30.90	29.80	23.70	28.00
Count	27.00	27.00	27.00	27.00	26.00	26.00	16.00	27.00	27.00	24.00	27.00	27.00
Mean	**26.71**	**26.27**	**28.24**	**30.01**	**29.42**	**28.88**	**30.19**	**31.19**	**30.77**	**29.74**	**27.39**	**28.37**
STD	1.00	1.95	0.59	0.61	0.24	0.64	0.57	1.30	0.65	0.26	2.06	0.87
SE	**0.19**	**0.38**	**0.11**	**0.12**	**0.05**	**0.13**	**0.14**	**0.25**	**0.12**	**0.05**	**0.40**	**0.17**

Table 1b. Mean monthly temperature (°C) PHMR 5m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1B	26.50	27.50	27.00	29.40	29.10	28.70	29.50	30.90	30.40	30.10	28.60	28.60
2B	26.80	26.80	27.40	29.40	29.10	28.50	29.80	30.90	30.00		28.50	28.60
2C	26.40	26.80	27.20	29.40	29.10		29.20	30.80	30.00		28.30	28.30
3C	26.80	26.90										
4A			27.90									
4B	26.80	26.20		29.40	29.30	28.20	29.80	31.30	30.20	29.80	29.20	28.40
4C	26.50	26.10	28.20	29.60	29.30	28.10	29.80	31.00	30.00	29.60	29.10	28.40
5B		26.20		29.50	29.40	28.90	30.00	31.30	30.40	30.30	28.70	28.70
5C	27.00	26.20		39.70	29.40	28.40	28.70	30.70	30.00	30.10	28.70	29.50
5D	26.80	26.00	28.20	29.50	29.20	28.70	29.40	30.70	30.30	30.00	28.70	28.50
5E	26.50	26.10		39.10	29.10	28.70	29.50	30.80	30.00	29.80	28.20	28.30
6A	27.10	26.40	28.60	29.70	29.20	28.40		30.50	30.20	30.30		28.40
6B	26.50	26.00	28.30	29.50	29.50	28.50		30.60	30.30	29.90	29.00	28.60
6C	26.60	26.00		29.10	29.30	28.60		30.40	30.30	29.60	28.70	28.30
6D	26.70	26.20	28.80	29.20	29.20	28.70		30.40	29.90	29.70	28.40	28.40
7A	26.80	25.90	28.70	29.70	29.70	28.70		30.60	30.40	30.00	28.60	28.40
7B	26.90	25.90	28.60	29.70	29.50	28.90		30.20	30.10	29.90	28.70	28.20
7C	26.60	25.90	28.10	29.40	29.20	28.80		30.20	30.20	29.70	28.30	28.20
8A			28.60									
8B	26.70	25.80	28.30	29.50		28.70		30.30	30.30	29.80	28.80	28.10
9A			28.20		29.20							
9B	26.70	25.80	28.20	29.40	29.40	28.70		30.40	30.30	29.80	28.60	28.10
Count	18.00	19.00	16.00	18.00	18.00	17.00	9.00	18.00	18.00	16.00	17.00	18.00
Mean	**26.71**	**26.25**	**28.14**	**30.57**	**29.29**	**28.60**	**29.52**	**30.67**	**30.18**	**29.90**	**28.65**	**28.44**
SD	0.19	0.45	0.53	3.22	0.17	0.22	0.40	0.33	0.17	0.22	0.27	0.31
SE	**0.04**	**0.10**	**0.13**	**0.76**	**0.04**	**0.05**	**0.13**	**0.08**	**0.04**	**0.05**	**0.07**	**0.07**

Table 1c. Mean monthly temperature (°C) PHMR 10m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B	27.10	26.60	27.00	29.20	29.20	28.70	29.60	30.40	30.10		28.90	28.60
2C	26.70	26.60	27.20	29.60	29.20		29.30	30.20	30.10		28.20	28.50
3C		26.90										
4B	27.20	26.20		29.60	29.70			30.50	30.00	30.40	29.30	28.50
4C	26.70	26.10	28.20	29.40	29.20	28.20	29.80	30.40	30.00	29.90	29.30	28.40
5C		26.10		29.70	29.40	28.70						
5D	26.70	26.00			29.10	28.70	29.50	30.40	30.30	30.30	28.60	28.40
5E	26.70	26.10		29.65	29.50	28.60	29.60	30.20	30.10	30.00	28.30	28.40
6A			28.50									
6B	26.70	25.90	28.30	29.40	29.60	28.50		30.30	30.20	29.90	29.20	28.40
6C	26.80	25.90		29.40	29.30	28.60		30.40	30.30	29.80	29.20	28.30
6D	26.90	26.00		29.10	29.20	28.60		30.40	30.20	29.80	29.10	28.30
7A	26.80	25.90	28.60	29.70	29.80	28.70		30.70	30.60	29.80	28.80	28.30
7B	26.70	25.80	28.60	29.60	29.50	28.70		30.50	30.50	29.80	28.90	28.50
7C	26.80	25.90	28.50	29.40	29.20	28.70		30.30	30.20	29.80	28.80	28.30
8B	26.60	25.70	28.60	29.40		28.70		30.40	30.30	29.80	28.70	28.10
9A			28.40		29.30							
9B	27.10	26.70	28.20	29.40	29.30	28.70		30.50	30.40	29.80	28.70	28.20
Count	14.00	16.00	11.00	14.00	15.00	13.00	5.00	14.00	14.00	12.00	14.00	14.00
Mean	**26.82**	**26.15**	**28.19**	**29.47**	**29.37**	**28.62**	**29.56**	**30.40**	**30.24**	**29.93**	**28.86**	**28.37**
SD	0.18	0.36	0.56	0.18	0.21	0.14	0.18	0.13	0.18	0.21	0.35	0.13
SE	**0.05**	**0.09**	**0.17**	**0.05**	**0.05**	**0.04**	**0.08**	**0.03**	**0.05**	**0.06**	**0.09**	**0.04**

Table 1d. Mean monthly temperature (°C) PHMR 15m: 2015												
Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2B				30.00								
2C	26.80	26.50	27.20	29.70	29.50		29.30	29.80	30.10		29.30	28.40
4C	27.40	26.50		29.40	29.70	28.90	29.80	30.10	39.90	30.10	29.20	28.50
5D	27.30	26.00			29.50	28.60	29.70	30.20	30.20	30.30	29.00	28.50
5E		26.10						30.30			29.00	
6B			28.40	29.60	29.60	28.40		30.30				
6C	27.30	25.90		29.70	29.30	28.50		30.30	29.90	29.90	29.20	28.40
6D	27.30	26.00		29.50	29.20	28.60		30.00	29.90	29.80	29.20	28.40
7B	27.10	25.80	28.40					30.60				
7C	26.90	25.90		29.40	29.20	28.70		30.40	30.00	29.70	29.10	28.30
8B	27.00	25.70	28.50	29.40		28.70		30.80	30.20	29.70	29.00	28.20
9A			28.50		29.30							
9B	26.90	25.70	28.20	29.40	29.30	28.76		30.70	30.30	29.70		28.20
Count	9.00	10.00	6.00	9.00	9.00	8.00	3.00	11.00	8.00	7.00	8.00	8.00
Mean	**27.11**	**26.01**	**28.20**	**29.57**	**29.40**	**28.65**	**29.60**	**30.32**	**31.31**	**29.89**	**29.13**	**28.36**
SD	0.22	0.29	0.50	0.21	0.18	0.16	0.26	0.30	3.47	0.23	0.12	0.12
SE	**0.07**	**0.09**	**0.20**	**0.07**	**0.06**	**0.06**	**0.15**	**0.09**	**1.23**	**0.09**	**0.04**	**0.04**

Table 1e. Mean monthly temperature (°C) Rio Grande 1m: 2015												
Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
RG_CB_1a	23.70	24.10	23.70	24.80	26.00	25.60	24.30	25.10	24.00	23.80	23.60	23.40
RG_CB_1b	23.80	24.20	23.70	25.20	25.80	25.70	24.40	25.50	24.10	23.90	23.70	23.40
RG_SM_1a	23.60	23.30	23.40	24.90	25.80	25.80	23.90	24.00	24.00	23.90	23.60	23.00
RG_SM_1b	23.70	23.30	23.70	25.10	25.90	25.90	23.70	24.40	24.10	24.50	23.70	23.10
RG_RG_1a	23.50	23.40	23.80	26.60	26.10	26.00	23.50	25.10	24.60	24.30	23.70	23.40
RG_RG_1b	23.50	23.40	23.90	26.80	26.20	26.10	23.70	25.30	24.80	24.40	23.70	23.40
RG_RG_1c	23.50	25.00	26.70	29.40	29.60	25.50	24.90	27.70	25.80	25.10	24.00	25.40
RG_RG_1d	24.60	26.70	29.50	32.30	31.20	26.60	28.60		26.10			24.80
Count	8.00	8.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00	7.00	7.00	8.00
Mean	**23.74**	**24.18**	**24.80**	**26.89**	**27.08**	**25.90**	**24.63**	**25.30**	**24.69**	**24.27**	**23.71**	**23.74**
SD	0.37	1.18	2.17	2.67	2.10	0.35	1.67	1.18	0.84	0.46	0.13	0.87
SE	**0.13**	**0.42**	**0.77**	**0.95**	**0.74**	**0.12**	**0.59**	**0.45**	**0.30**	**0.17**	**0.05**	**0.31**

Table 1f. Mean monthly temperature (°C) Monkey River 1m: 2015												
Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
MR_SB_1a	22.40	22.10	24.70	30.10	27.90	26.40	26.70	27.60	25.30	26.00	24.00	24.90
MR_SB_1b	23.80	22.90	26.90	32.50	29.70	26.40	27.50	29.10	25.80	26.30	24.60	25.80
MR_SB_1c	24.10	24.10	26.90	32.70	30.20	26.40	26.80	29.50	26.20	26.30	24.70	25.70
MR_SB_1d	25.40	25.00	26.80	32.60	31.30	26.10	26.90	29.90	26.60	26.30	24.70	25.80
MR_TB_1a	23.50	22.80	26.80	30.00	29.00	25.30	26.90	29.20	25.30	25.60	24.30	22.90
MR_BB_1a	24.90	23.90	25.90	30.40	29.60	28.40	25.90	29.80	25.90	26.60	24.70	26.10
MR_BB_1b	24.80	24.10	27.90	31.10	30.30	25.70	27.60	30.10	26.00	26.00	25.10	26.30
MR_MR_1A	25.60	27.20	30.20	30.40	32.20	26.90		30.50	28.00	26.30		25.30
Count	8.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00	8.00	8.00	7.00	8.00
Mean	**24.31**	**24.01**	**27.01**	**31.23**	**30.03**	**26.45**	**26.90**	**29.46**	**26.14**	**26.18**	**24.59**	**25.35**
SD	1.07	1.58	1.59	1.19	1.33	0.93	0.56	0.88	0.87	0.30	0.35	1.08
SE	**0.38**	**0.56**	**0.56**	**0.42**	**0.47**	**0.33**	**0.21**	**0.31**	**0.31**	**0.11**	**0.13**	**0.38**

Table 2a. Mean monthly dissolved oxygen (%) PHMR 1m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	92.70	116.80	80.60	96.80	88.90		72.00	87.10	107.10		91.30	67.10
1B	87.40	98.20	88.50	98.50	92.10		76.90	73.90	94.40	89.00	83.90	88.00
2A	93.10	98.10	91.80	94.90	93.10		82.70	73.80	92.80	91.70	84.30	92.90
2B	87.60	98.70	92.80	94.10	93.60	75.40	77.20	72.70	94.20		81.40	95.70
2C	85.40	98.60		96.00	93.60		75.70	77.30	90.70		85.50	92.10
3A	108.00	96.50	73.60	90.60			77.50	64.20	93.10	90.50	82.00	100.50
3B	85.30	103.90	89.30	93.60	86.70		81.00	72.50	88.00	89.60	84.80	91.90
3C	88.20	101.20	93.20	99.10	90.20		83.70	76.00	91.50	91.40	82.50	93.00
4A	83.10	97.60	85.70	82.90	90.50		81.10	72.80	86.60	89.70	81.20	87.60
4B	83.19	94.20	86.30	88.30	99.10		80.20	77.80	88.70	89.10	81.40	88.30
4C	88.20	94.50	89.90	91.40	93.20	80.60	73.40	74.40	94.50	90.10	81.60	93.50
5A	80.90	94.40	85.30	84.00	89.70		80.80	77.30	84.10	83.20	82.20	94.90
5B	80.70	92.20	86.20	87.30	84.70		86.80	77.50	83.30	87.70	88.00	93.30
5C	76.80	92.30	84.50	95.70	95.10	78.10	77.00	70.50	84.20	89.10	82.60	97.80
5D	85.40	95.60	88.50	87.30	95.60	91.90	74.00	69.00	89.30	91.40	93.30	95.50
5E	86.10	96.60	87.70	92.70	92.10	91.50	71.90	68.90	91.30	88.30	93.00	98.00
6A	74.20	92.30	84.40	93.50	91.90			65.60	80.50	85.20	71.30	94.40
6B	83.30	97.90	98.40	95.20	94.20	90.90		67.90	88.30	92.30	77.30	94.00
6C	92.10	94.80	91.60	94.40	95.40	92.40		72.40	90.70	86.60	88.90	91.20
6D	92.50	96.90	90.10	94.50	94.90	91.60		71.30	91.80	89.10	90.60	93.00
7A	81.30	92.80	91.80	87.50	92.40	84.30		31.80	83.10	84.90	86.70	87.60
7B	90.70	97.60	94.10	95.90	93.80	88.30		63.10	92.10	90.70	92.70	83.60
7C	90.10	97.00	98.80	94.00	95.40	85.60		61.50	92.50	91.10	91.80	83.00
8A	85.60	96.40	97.70	91.40	88.30			58.50	39.30	67.00	76.40	79.20
8B	90.70	98.30	97.60	90.10	85.00	88.10		64.50	89.70	95.40	88.60	85.10
9A	83.20	100.30	96.40	82.80	94.30			64.10	93.30	75.40	85.70	74.70
9B	89.90	96.60	97.70	93.40	95.30	87.50		62.20	92.90	94.40	91.40	86.60
Count	27.00	27.00	26.00	27.00	26.00	13.00	16.00	27.00	27.00	24.00	27.00	27.00
Mean	**86.88**	**97.42**	**90.10**	**92.07**	**92.27**	**86.63**	**78.24**	**69.21**	**88.44**	**88.04**	**85.20**	**89.72**
SD	6.39	4.76	6.02	4.48	3.46	5.59	4.33	9.83	11.06	6.01	5.52	7.42
SE	**1.23**	**0.92**	**1.18**	**0.86**	**0.68**	**1.55**	**1.08**	**1.89**	**2.13**	**1.23**	**1.06**	**1.43**

Table 2b. Mean monthly dissolved oxygen (%) PHMR 5m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1B	87.40	96.80	88.50	99.50	92.20		72.90	74.20	91.70	88.20	78.40	88.10
2B	84.10	99.40	91.90	93.80	92.70		76.70	72.80	94.60		79.40	92.40
2C	88.60	96.30		98.80	96.90		76.10	79.10	95.00		82.90	95.20
3C	109.60	93.20	95.20									
4B	85.70	100.40	89.80	90.80	97.60		77.70	73.50	82.60	89.50	63.00	88.10
4C	88.60	96.20	93.60	91.90	98.60	72.40	76.40	78.90	92.70	89.60	69.10	93.50
5B		94.80	87.40	89.20	88.40		81.40	82.90	80.80	81.30	74.70	91.90
5C	77.30	95.60	87.80	94.10	92.30		75.10	73.20	84.70	88.30	77.80	96.70
5D	86.40	93.00	89.40	89.20	92.50	89.10	72.40	73.10	91.10	86.10	92.90	95.40
5E	85.50	94.90	90.10	97.90	93.50		70.70	77.00	88.60	89.10	91.80	91.40
6A	76.50	93.10	83.80	93.20	92.50			67.70	63.30	79.50		93.70
6B	86.10	98.60	98.20	94.90	93.10	90.90		69.10	88.50	90.50	72.30	95.40
6C	91.90	96.30	92.10	95.10	95.20	91.90		74.90	89.10	89.50	77.40	93.90
6D	93.70	96.40	91.00	95.70	94.90	90.60		73.30	83.20	89.10	87.50	93.50
7A	78.80	97.50	86.40	84.50	95.10			68.70	90.20	77.40	73.70	86.60
7B	92.90	98.10	97.80	92.10	92.90			63.90	91.60	85.90	81.50	84.80
7C	91.60	96.80	98.30	95.30	94.50	87.10		64.20	91.40	91.70	87.70	84.80
8B	94.10	98.50	98.30	91.90		86.90		65.70	91.50	91.30	82.40	86.60
9A					95.70							
9B	91.20	97.60	98.30	92.30	94.50	85.10		63.40	91.00	91.30	81.10	88.40
Count	18.00	19.00	18.00	18.00	18.00	8.00	9.00	18.00	18.00	16.00	17.00	18.00
Mean	**88.33**	**96.50**	**92.11**	**93.34**	**94.06**	**86.75**	**75.49**	**71.98**	**87.87**	**87.39**	**79.62**	**91.13**
SD	7.52	2.08	4.66	3.68	2.37	6.24	3.20	5.64	7.34	4.34	7.85	3.90
SE	**1.77**	**0.48**	**1.10**	**0.87**	**0.56**	**2.21**	**1.07**	**1.33**	**1.73**	**1.09**	**1.90**	**0.92**

Table 2c. Mean monthly dissolved oxygen (%) PHMR 10m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B	73.90	92.20	92.70	93.80	91.50		75.70	66.20	90.30		59.30	84.40
2C	87.00	86.60		85.40	96.90	75.40	75.70	79.30	87.60		89.20	90.60
3C		95.30										
4B	72.20	99.40	87.30	91.70	94.00			77.40	85.40	80.30	51.00	87.40
4C	86.50	90.30	92.20	91.60	99.70	80.60	76.90	77.70	91.90	89.30	74.90	93.90
5C		93.20	84.80	95.70	93.20	78.10						
5D	86.30	95.80	89.90		94.20	92.30	71.40	73.70	87.30	84.50	84.30	95.30
5E	85.70	95.80	90.30	112.40	94.20	91.50	70.60	75.80	87.50	84.10	91.90	99.40
6B	84.20	99.00	91.00	94.10	95.50	91.30		70.10	88.10		68.20	93.80
6C	90.80	98.60	89.60	90.70	95.70	92.50		73.80	88.80	85.60	66.80	92.00
6D	89.20	95.60	92.20	93.00	94.50	86.80		74.20	84.80	87.80	74.20	93.20
7A	69.60	96.60	89.50	92.30	93.90	84.30		65.00	81.10	81.00	56.60	87.30
7B	90.10	97.00	97.50	93.30	93.60	88.30		65.60	83.70	85.50	69.30	85.60
7C	88.40	94.10	97.00	92.00	93.50	85.60		66.00	87.10	90.90	70.50	87.70
8B	91.60	99.20	98.30	93.10		88.10		66.20	88.20	84.50	71.50	88.00
9A					94.90	86.10						
9B	75.40	97.80	96.60	89.40	94.90	87.50		64.30	86.00	88.50	73.20	88.40
Count	14.00	16.00	14.00	14.00	15.00	14.00	5.00	14.00	14.00	11.00	14.00	14.00
Mean	**83.64**	**95.41**	**92.06**	**93.46**	**94.68**	**86.31**	**74.06**	**71.09**	**86.99**	**85.64**	**71.49**	**90.50**
SD	7.50	3.50	4.03	5.97	1.86	5.25	2.85	5.44	2.71	3.30	11.59	4.24
SE	**2.01**	**0.88**	**1.08**	**1.60**	**0.48**	**1.40**	**1.27**	**1.45**	**0.72**	**1.00**	**3.10**	**1.13**

Table 2d. Mean monthly dissolved oxygen (%) PHMR 15m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B				88.90								
2C	84.70	98.20		96.60	88.10		75.80	66.10	71.50		57.00	90.40
4C	67.10	94.00	92.40	89.20	97.10	72.40	76.60	76.50	87.30	81.40	79.40	91.90
5D	68.70	97.00	89.20		93.10	89.10	70.40	72.90	84.20	81.50	80.50	88.50
5E		76.10						68.10			69.60	
6B			88.40	82.70	94.40	91.00		70.60				
6C	77.90	92.10	90.50	93.50	96.20	92.00		74.80	77.50	83.70	67.90	90.50
6D	77.40	95.80	92.20	91.70	95.50	91.00		73.60	86.40	87.10	75.70	93.00
7B	88.00	84.70						66.80				
7C	85.00	94.00	96.40	92.50	94.00	87.10		67.80	82.20	82.60	58.10	87.90
8B	80.50	97.20	98.30	92.40		86.00		63.50	74.60	83.50	53.90	87.90
9A					95.00							
9B	76.20	96.50	97.60	91.40	94.10	85.10		64.30	79.70	84.40	62.10	88.00
Count	9.00	10.00	8.00	9.00	9.00	8.00	3.00	11.00	8.00	7.00	9.00	8.00
Mean	**78.39**	**92.56**	**93.13**	**90.99**	**94.17**	**86.71**	**74.27**	**69.55**	**80.43**	**83.46**	**67.13**	**89.76**
SD	7.14	6.96	3.85	3.86	2.58	6.31	3.37	4.40	5.64	1.96	9.96	1.99
SE	**2.38**	**2.20**	**1.36**	**1.29**	**0.86**	**2.23**	**1.95**	**1.33**	**2.00**	**0.74**	**3.32**	**0.70**

Table 2e. Mean monthly dissolved oxygen (%) Rio Grande												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
RG_CB_1a	96.00	95.00	99.80	88.00	122.00	84.50	95.30	95.40	92.10	89.10	94.00	85.30
RG_CB_1b	94.50	94.20	97.50	81.00	85.00	83.10	96.10	100.00	90.20	87.10	94.00	83.20
RG_SM_1a	90.00	80.00	92.90	85.00	91.00	90.00	98.10	82.80	89.10	86.40	94.00	89.20
RG_SM_1b	87.30	70.00	75.60	99.20	87.00	89.50	82.10	86.40	84.70	84.20	93.80	89.10
RG_RG_1a	85.20	89.50	79.50	55.20	84.00	78.00	89.60	72.60	78.10	86.50	83.20	95.20
RG_RG_1b	80.00	84.80	81.20	75.10	80.00	76.00	78.10	72.30	80.80	79.60	87.10	85.10
RG_RG_1c	76.50	79.37	65.30	73.00	67.40	74.20	85.50	49.40	63.40	73.20	77.90	75.20
RG_RG_1d	75.90		103.90	129.75	99.00	52.40	74.60		70.40			79.10
Count	8.00	7.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00	7.00	7.00	8.00
Mean	**85.68**	**84.70**	**86.96**	**85.78**	**89.43**	**78.46**	**87.43**	**79.84**	**81.10**	**83.73**	**89.14**	**85.18**
SD	7.73	9.00	13.55	21.89	15.96	12.05	8.78	17.01	10.13	5.53	6.56	6.24
SE	**2.73**	**3.40**	**4.79**	**7.74**	**5.64**	**4.26**	**3.10**	**6.43**	**3.58**	**2.09**	**2.48**	**2.21**

Table 2f. Mean monthly dissolved oxygen (%) Monkey River												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MR_SB_1a	99.70	108.60	112.90	105.00	86.80	88.30	96.10	68.00	97.70	89.00	73.50	93.40
MR_SB_1b	94.30	112.30	106.50	125.00	86.30	88.00	83.40	81.30	96.40	87.70	79.00	102.30
MR_SB_1c	95.30	98.30	81.00	106.90	84.30	88.90	86.40	81.30	70.10	83.90	78.00	99.60
MR_SB_1d	85.90	98.30	80.00	118.60	102.60	75.10	82.10	90.80	68.80	81.10	84.00	99.40
MR_TB_1a	80.30	74.60	82.00	52.60	29.80	81.70	70.10	77.30	73.30	83.20	73.70	85.10
MR_BB_1a	80.40	83.00	79.20	91.20	70.90	87.00	88.10	91.80	80.10	85.60	74.20	80.10
MR_BB_1b	77.50	64.00	78.60	79.00	68.90	88.50	61.30	99.40	70.40	74.60	73.50	78.20
MR_MR_1A	82.40	85.90		52.30	32.10	73.50		53.00	79.40	80.00		78.40
Count	8.00	8.00	7.00	8.00	8.00	8.00	7.00	8.00	8.00	8.00	7.00	8.00
Mean	**86.98**	**90.63**	**88.60**	**91.33**	**70.21**	**83.88**	**81.07**	**80.36**	**79.53**	**83.14**	**76.56**	**89.56**
SD	8.32	16.72	14.57	27.98	26.37	6.35	11.70	14.71	11.60	4.61	4.00	10.27
SE	**2.94**	**5.91**	**5.51**	**9.89**	**9.32**	**2.25**	**4.42**	**5.20**	**4.10**	**1.63**	**1.51**	**3.63**

3a. Mean monthly salinity (ppt) PHMR 1m: 2015											
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	33.37	33.66	34.0	33.38	30.97	16.71	21.99	22.49	32.26		31.80	29.76
1B	32.90	32.81	34.1	33.12	30.27	16.29	19.33	22.31	31.72	32.38	30.33	21.40
2A	31.10	33.70	33.3	33.34	31.98	17.03	22.88	22.64	29.43	29.65	31.58	29.85
2B	32.08	33.53	34.3	33.57	33.01	16.74	26.88	22.01	30.43		30.94	28.48
2C	32.76	33.43	33.4	33.41	30.31		20.40	22.26	26.05		29.40	27.37
3A	31.87	34.10	33.5	34.06		26.84	23.34	23.64	34.52	30.79	30.40	31.40
3B	31.64	34.17	35.6	34.16	33.00	25.72	22.52	27.77	34.29	29.60	28.48	30.08
3C	32.17	34.43	34.5	34.07	32.45	25.69	25.69	22.84	33.27	32.51	33.59	30.90
4A	32.02	34.19	33.9	34.24	24.12	29.18	25.75	24.40	34.77	31.09	30.40	31.69
4B	32.61	34.47	33.3	34.31	33.54	28.65	26.34	23.68	34.84	32.31	31.68	32.17
4C	32.82	34.45	34.6	34.59	33.48	28.15	31.76	24.28	33.25	33.53	32.85	32.52
5A	32.21	34.06	34.0	33.68	31.41	32.70	29.30	28.09	33.44	30.48	29.35	31.09
5B	32.65	34.31	33.9	34.56	34.24	30.33	27.32	26.05	34.48	33.07	29.54	31.46
5C	32.35	34.32	34.3	34.41	33.42	32.23	28.25	30.33	35.20	32.32	30.82	32.45
5D	32.91	34.38	34.4	34.56	34.24	27.76	32.24	28.74	34.19	32.92	29.62	32.40
5E	33.43	34.56	34.5	34.40	34.43	26.51	32.81	29.40	29.66	33.52	27.29	32.00
6A	33.93	34.21	34.6	34.82	34.26	33.57		33.44	35.23	34.89	32.59	33.10
6B	33.12	34.24	34.4	34.79	35.16	34.12		33.30	35.58	33.58	33.39	33.07
6C	32.95	34.52	34.6	34.56	35.14	34.62		33.02	34.57	33.50	30.23	33.50
6D	33.15	24.17	34.9	34.53	35.38	34.72		33.18	34.88	33.24	30.84	33.86
7A	33.96	34.24	34.8	35.10	35.66	34.07		33.76	35.08	32.84	31.36	37.70
7B	32.99	34.42	35.0	35.25	35.50	33.87		34.10	35.03	33.24	30.60	32.90
7C	33.17	34.62	35.1	35.16	35.29	34.99		34.04	34.58	34.79	30.58	33.60
8A	31.30	34.01	35.2	34.83	36.04	31.76		35.51	34.69	33.39	30.47	26.07
8B	33.17	34.43	35.1	35.23	35.93	33.58		34.30	35.28	34.11	32.24	33.46
9A	32.20	23.89	35.0	34.83	35.44	32.58		34.69	34.79	31.89	30.69	31.42
9B	32.96	34.29	35.1	35.23	35.48	33.38		34.38	35.17	34.49	31.53	33.23
Count	27.00	27.00	27.00	27.00	26.00	26.00	16.00	27.00	27.00	24.00	27.00	27.00
Mean	**32.66**	**33.39**	**34.42**	**34.38**	**33.47**	**28.92**	**26.05**	**28.69**	**33.58**	**32.67**	**30.84**	**31.37**
SD	0.71	2.73	0.62	0.63	2.58	6.08	4.15	4.99	2.28	1.47	1.43	3.01
SE	**0.14**	**0.53**	**0.12**	**0.12**	**0.51**	**1.19**	**1.04**	**0.96**	**0.44**	**0.30**	**0.27**	**0.58**

3b. Mean monthly salinity (ppt) PHMR 5m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1B	32.79	33.59	34.11	33.12	31.77	28.86	23.45	33.30	34.78	33.93	32.12	31.93
2B	33.47	34.31	34.31	33.58	33.34	30.08	27.50	33.01	35.02		32.41	32.37
2C	32.85	34.40	34.40	33.73	33.83		29.18	32.93	35.32		31.90	31.41
3C	33.17	34.44	34.54									
4B	32.78	34.46	34.61	34.33	33.71	28.66	26.75	30.99	35.88	33.47	35.06	33.19
4C	33.60	34.45	34.61	34.63	33.68	28.19	32.31	33.18	34.91	33.57	35.11	33.40
5B		34.33	34.37	34.55	34.47	32.48	29.39	30.44	35.47	34.00	32.95	32.41
5C	33.01	34.33	34.74	34.57	34.39	32.86	30.33	33.33	36.07	34.16	33.03	33.24
5D	33.17	34.37	34.65	34.55	34.54	33.69	33.18	33.46	35.36	34.55	31.52	33.30
5E	33.44	34.62	34.54	34.41	34.54	32.69	32.94	33.55	34.91	34.22	31.66	33.40
6A	33.05	34.22	34.69	34.78	34.32	33.68		33.97	35.72	35.08		33.25
6B	33.12	34.32	34.57	34.79	35.44	34.12		33.90	35.57	34.77	34.69	33.40
6C	32.97	34.52	34.64	34.54	35.17	34.62		33.82	35.43	34.37	33.90	33.65
6D	33.16	34.69	34.87	34.60	35.08	34.73		34.06	35.22	35.17	33.07	34.18
7A	33.05	34.27	34.92	35.21	32.50	34.21		34.47	35.38	34.84	33.32	33.50
7B	33.02	34.45	34.99	35.23	35.51	34.14		34.17	35.12	35.99	33.11	33.80
7C	33.18	34.64	35.10	35.14	35.29	35.18		34.05	35.00	34.95	32.89	34.24
8B	33.19	34.43	35.13	35.23		34.44		34.30	35.33	35.15	32.95	33.73
9A					35.44							
9B	33.10	34.37	35.08	35.25	35.49	34.29		34.44	35.26	35.15	33.20	33.64
Count	18.00	19.00	19.00	18.00	18.00	17.00	9.00	18.00	18.00	16.00	17.00	18.00
Mean	**33.12**	**34.38**	**34.68**	**34.57**	**34.36**	**32.76**	**29.45**	**33.41**	**35.32**	**34.59**	**33.11**	**33.22**
SD	0.22	0.23	0.28	0.60	1.07	2.32	3.21	1.09	0.34	0.68	1.08	0.74
SE	**0.05**	**0.05**	**0.06**	**0.14**	**0.25**	**0.56**	**1.07**	**0.26**	**0.08**	**0.17**	**0.26**	**0.18**

3c. Mean monthly salinity (ppt) PHMR 10m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B	34.08	34.41	34.39	33.55	33.30	33.63	30.91	34.06	35.40		34.02	33.53
2C	33.86	34.48	34.48	34.22	33.81		30.21	34.19	36.05		32.76	33.07
3C		34.40										
4B	34.05	34.46	34.93	34.86	34.35			33.81	36.11	35.05	35.50	33.60
4C	33.74	34.54	34.62	34.69	33.83	29.79	32.57	33.94	35.36	34.31	35.58	33.40
5C		34.40	35.01	34.81	34.75	34.01						
5D	33.44	34.47	35.01		34.61	34.13	33.57	33.85	35.49	35.22	32.20	33.41
5E	33.62	34.62	34.99	34.63	34.87	34.46	33.31	33.88	35.65	34.92	32.59	33.82
6B	33.34	34.45	34.98	34.87	35.55	34.13		34.10	35.68	35.00	35.39	33.65
6C	33.29	34.58	34.97	34.75	35.18	34.61		34.15	35.56	35.04	35.34	34.03
6D	33.86	34.71	34.91	34.69	35.08	34.77		34.17	35.78	35.38	34.94	34.41
7A	33.21	34.27	35.04	35.09	36.68	34.15		34.46	35.54	35.25	34.73	33.75
7B	33.26	34.44	35.03	35.23	34.54	34.85		34.44	35.83	35.26	34.73	34.70
7C	34.19	34.69	35.10	35.15	35.34	35.41		34.34	35.86	35.28	34.48	34.30
8B	33.47	34.44	35.12	35.23		34.89		34.41	35.45	35.35	34.63	33.99
9A					35.44							
9B	34.42	34.43	35.08	35.25	35.48	34.85		34.59	35.71	35.37	34.79	33.84
Count	14.00	16.00	15.00	14.00	15.00	13.00	5.00	14.00	14.00	12.00	14.00	14.00
Mean	**33.70**	**34.49**	**34.91**	**34.79**	**34.85**	**34.13**	**32.11**	**34.17**	**35.68**	**35.12**	**34.41**	**33.82**
SD	0.39	0.11	0.23	0.46	0.84	1.39	1.49	0.25	0.23	0.30	1.11	0.44
SE	**0.10**	**0.03**	**0.06**	**0.12**	**0.22**	**0.38**	**0.66**	**0.07**	**0.06**	**0.09**	**0.30**	**0.12**

3d. Mean monthly salinity (ppt) PHMR 15m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B				33.88								
2C	34.33	34.54	34.54	34.64	34.50		31.19	34.73	36.01		35.64	33.60
4C	35.06	34.06	34.94	34.69	34.36	31.31	33.30	34.36	36.28	35.26	35.93	33.73
5D	34.48	33.49	35.06		35.16	34.13	33.81	33.95	35.89	35.32	34.38	34.00
5E		34.60						33.93			34.46	
6B			35.03	25.18	35.56	34.20		34.15				
6C	34.94	34.62	35.05	35.22	35.19	34.66		34.25	36.21	35.22	35.01	34.06
6D	34.97	34.72	34.94	35.14	36.69	34.87		34.71	36.17	35.42	35.92	34.46
7B	34.33	34.43						34.38				
7C	34.61	34.69	35.10	35.18	35.34	35.48		34.48	36.05	35.34	35.41	34.34
8B	34.54	34.51	35.13	35.23		35.26		35.19	36.90	35.39	35.37	34.05
9A					35.45							
9B	34.72	34.43	35.08	35.25	35.47	35.33		35.25	35.84	35.46	35.44	34.05
Count	9.00	10.00	9.00	9.00	9.00	8.00	3.00	11.00	8.00	7.00	9.00	8.00
Mean	**34.66**	**34.41**	**34.99**	**33.82**	**35.30**	**34.41**	**32.77**	**34.49**	**36.17**	**35.34**	**35.28**	**34.04**
SD	0.28	0.37	0.18	3.27	0.67	1.35	1.39	0.45	0.33	0.09	0.57	0.28
SE	**0.09**	**0.12**	**0.06**	**1.09**	**0.22**	**0.48**	**0.80**	**0.13**	**0.12**	**0.03**	**0.19**	**0.10**

4a. Mean monthly pH PHMR 1m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	8.03	8.07	7.99	8.24	8.16	8.44	8.34	8.46	8.14		8.08	7.70
1B	8.00	8.03	8.06	8.08	8.17	8.24	8.33	8.39	8.17	8.07	8.10	7.90
2A	7.87	8.01	8.00	8.07	8.05	7.82	8.04	8.37	7.85	8.06	8.07	8.10
2B	8.02	8.10	8.03	8.11	8.05	8.10	8.27	8.31	8.13		8.06	8.17
2C	8.06	9.09		8.14	8.13		8.44	8.41	8.22		8.10	8.06
3A	8.02	7.98	7.97	8.05		8.05	8.14	8.23	8.07	8.00	7.77	8.05
3B	8.05	8.08	7.99	8.09	8.11	8.13	8.25	8.34	8.15	7.94	7.68	8.00
3C	7.94	8.01	8.04	8.16	8.13	8.14	8.12	8.47	8.19	7.97	8.05	7.92
4A	7.90	8.04	8.03	8.08	8.10	8.13	8.29	8.40	7.96	7.98	7.94	8.06
4B	7.99	7.95	8.08	8.04	8.11	8.16	8.20	8.40	7.89	7.98	7.90	8.13
4C	8.00	8.10	7.88	7.92	8.03	8.07	8.22	8.38	8.21	8.00	7.94	8.14
5A	8.03	8.05	8.02	8.01	7.95	8.14	8.19	8.34	7.89	7.95	8.00	8.14
5B	8.03	8.04	8.01	8.07	8.04	8.12	8.22	8.44	7.94	7.77	8.07	8.12
5C	8.01	8.03	8.10	8.08	8.07	7.92	8.33	8.37	7.91	7.96	7.76	8.09
5D	7.98	8.11	8.05	8.07	8.18	8.16	8.25	8.37	8.15	8.02	8.08	8.16
5E	8.06	8.13	8.05	8.14	8.17	8.15	8.32	8.35	8.24	7.94	8.05	8.16
6A	8.05	8.00	8.07	8.05	8.07	8.12		8.39	7.91	7.95	7.92	8.00
6B	8.06	8.08	8.04	8.09	8.16	8.13		8.32	7.96	7.99	7.90	8.14
6C	8.11	8.04	8.07	8.11	8.16	8.16		8.34	8.07	8.08	8.07	8.14
6D	8.12	8.02	8.06	8.11	8.18	8.16		8.33	8.17	8.09	8.16	8.14
7A	7.98	8.07	8.08	8.10	8.07	8.18		8.23	8.10	8.00	7.48	7.65
7B	8.06	8.09	8.00	8.02	8.14	8.14		8.33	8.13	8.12	8.08	8.03
7C	8.07	8.05	8.12	8.06	8.16	8.19		8.35	8.10	8.09	8.07	8.06
8A	7.95	7.96	8.11	7.77	8.08	7.93		8.16	7.85	7.64	8.05	7.91
8B	8.06	8.06	8.15	8.11	7.96	8.23		8.38	8.10	8.08	8.00	8.08
9A	7.97	7.98	8.09	7.84	8.09	8.07		8.23	7.99	7.83	8.05	7.90
9B	8.10	8.01	8.18	8.02	8.15	8.10		8.34	8.09	7.96	8.09	8.01
Count	27.00	27.00	26.00	27.00	26.00	26.00	16.00	27.00	27.00	24.00	27.00	27.00
Mean	**8.02**	**8.08**	**8.05**	**8.06**	**8.10**	**8.12**	**8.25**	**8.35**	**8.06**	**7.98**	**7.98**	**8.04**
SD	0.06	0.21	0.06	0.09	0.06	0.11	0.10	0.07	0.12	0.11	0.15	0.13
SE	**0.01**	**0.04**	**0.01**	**0.02**	**0.01**	**0.02**	**0.02**	**0.01**	**0.02**	**0.02**	**0.03**	**0.03**

4b. Mean monthly pH PHMR 5m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1B	8.03	8.08	8.09	8.13	8.19	8.16	8.36	8.35	8.14	8.06	8.09	7.96
2B	8.06	8.13	8.08	8.13	8.13	8.09	8.32	8.32	8.15		8.07	8.11
2C	8.08	8.11		8.16	8.15		8.39	8.36	8.18		8.09	8.05
3C	8.15	8.11	8.12									
4B	8.03	8.05	8.11	8.10	8.16	8.20	8.28	8.37	7.99	8.03	7.91	8.11
4C	8.06	8.12	8.04	8.09	8.08	8.16	8.27	8.37	8.20	8.07	7.98	8.13
5B		8.09	8.09	8.12	8.08	8.14	8.28	8.41	8.00	7.91	8.06	8.13
5C	8.05	8.07	8.15	8.13	8.09	8.07	8.33	8.41	8.00	8.00	7.86	8.12
5D	8.04	8.12	8.11	8.12	8.19	8.16	8.29	8.42	8.14	8.06	8.09	8.18
5E	8.08	8.14	8.10	8.17	8.18	8.19	8.33	8.41	8.18	8.01	8.10	8.16
6A	8.08	8.08	8.11	8.11	8.12	8.15		8.41	7.95	8.02		8.11
6B	8.08	8.07	8.11	8.13	8.18	8.18		8.37	8.06	8.07	7.96	8.13
6C	8.13	8.09	8.10	8.15	8.18	8.20		8.39	8.09	8.11	8.05	8.14
6D	8.12	8.07	8.11	8.15	8.19	8.21		8.39	8.14	8.10	8.14	8.11
7A	8.05	8.11	8.12	8.13	8.12	8.10		8.40	8.11	8.02	7.76	7.75
7B	8.09	8.11	8.12	8.10	8.16	8.22		8.40	8.17	8.12	8.05	8.05
7C	8.09	8.09	8.14	8.12	8.17	8.23		8.40	8.15	8.14	8.25	8.06
8B	8.10	8.09	8.16	8.14		8.24		8.42	8.15	8.10	8.02	8.08
9A					8.91							
9B	8.11	8.07	8.18	8.08	8.16	8.17		8.39	8.12	8.03	8.08	8.01
Count	18.00	19.00	18.00	18.00	18.00	17.00	9.00	18.00	18.00	16.00	17.00	18.00
Mean	**8.08**	**8.09**	**8.11**	**8.13**	**8.19**	**8.17**	**8.32**	**8.39**	**8.11**	**8.05**	**8.03**	**8.08**
SD	0.03	0.02	0.03	0.02	0.18	0.05	0.04	0.03	0.08	0.06	0.11	0.10
SE	**0.01**	**0.01**	**0.01**	**0.01**	**0.04**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.03**	**0.02**

4c. Mean monthly pH PHMR 10m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B	8.05	8.11	8.13	8.15	8.14	8.11	8.32	8.35	8.16		8.04	8.12
2C	8.01	8.13		8.15	8.17		8.39	8.37	8.17		8.11	8.05
3C		8.10										
4B	8.04	8.06	8.14	8.11	8.16			8.41	8.03	8.03	7.94	8.11
4C	8.08	8.13	8.14	8.11	8.11	8.18	8.30	8.41	8.19	8.08	8.06	8.12
5C		8.08	8.17	8.14	8.11	8.13						
5D	8.07	8.13	8.14		8.19	8.19	8.32	8.44	8.14	8.06	8.10	8.15
5E	8.09	8.14	8.12	8.11	8.18	8.20	8.34	8.42	8.15	8.04	8.11	8.16
6B	8.09	8.09	8.13	8.15	8.19	8.21		8.35	8.07	8.09	7.98	8.13
6C	8.12	8.10	8.12	8.15	8.19	8.22		8.40	8.10	8.11	8.03	8.14
6D	8.10	8.08	8.14	8.16	8.20	8.22		8.40	8.13	8.11	8.10	8.15
7A	8.05	8.13	8.13	8.15	8.15	8.22		8.43	8.10	8.05	7.83	7.88
7B	8.09	8.11	8.15	8.13	8.18	8.23		8.42	8.12	8.13	8.04	8.05
7C	8.08	8.10	8.14	8.14	8.18	8.24		8.42	8.14	8.14	8.04	8.06
8B	8.10	8.10	8.17	8.15		8.24		8.42	8.16	8.11	8.03	8.07
9A					8.13							
9B	8.07	8.08	8.18	8.11	8.17	8.19		8.40	8.10	8.07	8.09	8.01
Count	14.00	16.00	14.00	14.00	15.00	13.00	5.00	14.00	14.00	12.00	14.00	14.00
Mean	**8.07**	**8.10**	**8.14**	**8.14**	**8.16**	**8.20**	**8.33**	**8.40**	**8.13**	**8.09**	**8.04**	**8.09**
SD	0.03	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.04	0.04	0.08	0.08
SE	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**

4d. Mean monthly pH PHMR 15m: 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2B				8.16								
2C	8.09	8.14		8.16	8.16		8.37	8.37	8.17		8.03	8.06
4C	8.04	8.13	8.16	8.12	8.12	8.15	8.31	8.41	8.18	8.08	8.09	8.11
5D	8.03	8.13	8.15		8.19	8.20	8.32	8.45	8.14	8.08	8.10	8.17
5E		8.14						8.43			8.09	
6B			8.16	8.13	8.20	8.21		8.38				
6C	8.08	8.10	8.14	8.15	8.19	8.23		8.41	8.10	8.12	8.05	8.12
6D	8.07	8.09	8.15	8.15	8.20	8.23		8.41	8.14	8.12	8.09	8.15
7B	8.09	8.12						8.44				
7C	8.08	8.10	8.15	8.15	8.18	8.24		8.42	8.12	8.14	8.03	8.06
8B	8.07	8.10	8.17	8.16		8.24		8.40	8.12	8.12	8.01	8.06
9A					8.15							
9B	8.07	8.09	8.18	8.12	8.17	8.21		8.40	8.09	8.08	8.07	8.01
Count	9.00	10.00	8.00	9.00	9.00	8.00	3.00	11.00	8.00	7.00	9.00	8.00
Mean	**8.07**	**8.11**	**8.16**	**8.14**	**8.17**	**8.21**	**8.33**	**8.41**	**8.13**	**8.11**	**8.06**	**8.09**
SD	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.05
SE	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**

Table 4e. Mean monthly pH Rio Grande												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
RG_CB_1a	7.27	7.50	7.54	7.58	7.82	7.66	7.48	7.95	7.34	7.82	8.55	7.48
RG_CB_1b	7.27	7.55	7.68	7.58	8.00	7.65	7.58	7.98	7.34	7.80	8.50	7.52
RG_SM_1a	7.75	7.55	7.41	7.56	7.60	7.56	7.59	7.75	7.35	7.81	8.30	7.78
RG_SM_1b	7.58	7.64	7.65	7.56	7.50	7.56	7.57	7.61	7.37	7.83	8.20	7.79
RG_RG_1a	7.50	7.66	7.76	7.90	7.58	7.64	7.60	8.03	7.39	7.86	8.05	7.84
RG_RG_1b	7.65	7.37	7.64	7.85	7.56	7.74	7.48	8.15	7.55	7.87	8.13	7.88
RG_RG_1c	6.44	7.70	7.84	7.98	7.87	7.74	7.76	8.11	7.55	7.51	8.20	7.52
RG_RG_1d	8.01	8.00	7.73	8.00	7.92	8.58	8.30		8.08			8.27
Count	8.00	8.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00	7.00	7.00	8.00
Mean	**7.43**	**7.62**	**7.66**	**7.75**	**7.73**	**7.77**	**7.67**	**7.94**	**7.50**	**7.79**	**8.28**	**7.76**
SD	0.47	0.18	0.13	0.20	0.19	0.34	0.27	0.19	0.25	0.12	0.19	0.26
SE	**0.17**	**0.07**	**0.05**	**0.07**	**0.07**	**0.12**	**0.10**	**0.07**	**0.09**	**0.05**	**0.07**	**0.09**

Table 4f. Mean monthly pH Monkey River												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MR_SB_1a	7.54	6.92	7.22	7.05	7.08	7.40	7.32	8.05	7.05	8.03	7.41	8.51
MR_SB_1b	7.49	6.73	7.28	7.02	7.58	7.60	7.77	7.79	7.12	8.01	7.62	8.12
MR_SB_1c	7.22	6.56	7.26	6.75	7.42	6.66	7.76	7.42	7.19	7.96	7.70	8.10
MR_SB_1d	7.23	6.91	7.28	7.24	7.04	7.43	7.52	6.74	7.22	7.67	7.75	7.84
MR_TB_1a	6.80	7.46	7.25	7.06	6.88	7.15	7.62	7.22	7.61	8.01	8.09	8.02
MR_BB_1a	7.36	7.20	7.45	7.26	7.05	7.28	7.32	7.55	7.56	7.89	7.85	7.78
MR_BB_1b	7.20	7.57	7.31	7.56	7.36	7.41	7.56	7.70	7.39	7.69	7.93	7.87
MR_MR_1A	7.29	7.77	8.02	7.65	7.75	8.16		8.68	7.80	8.40		7.93
Count	8.00	8.00	8.00	8.00	8.00	8.00	7.00	8.00	8.00	8.00	7.00	8.00
Mean	**7.27**	**7.14**	**7.38**	**7.20**	**7.27**	**7.39**	**7.55**	**7.64**	**7.37**	**7.96**	**7.76**	**8.02**
SD	0.23	0.43	0.27	0.30	0.30	0.42	0.18	0.58	0.27	0.23	0.22	0.23
SE	**0.08**	**0.15**	**0.09**	**0.10**	**0.11**	**0.15**	**0.07**	**0.20**	**0.09**	**0.08**	**0.08**	**0.08**

5a. Mean monthly visibility (cm) PHMR 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1A	195	*	100.00	130.00	130.00	*	50.00	*			150.00	200.00
1B	400	363.00	275.00	300.00	420.00	400.00	700.00	700.00	800.00	425.00	550.00	500.00
2A	315	125.00	175.00	150.00	100.00	300.00	300.00	300.00	400.00	210.00	250.00	375.00
2B	350	387.00	525.00	500.00	1000.00	500.00	800.00	500.00	900.00		675.00	600.00
2C	500	688.00		770.00	^1300.00		700.00	775.00	850.00		900.00	600.00
3A	125	*	125.00	140.00		100.00	150.00	*		130.00	150.00	150.00
3B	200	200.00	200.00	200.00	220.00	210.00	150.00	275.00	400.00		250.00	400.00
3C	400	384.00	575.00	*	400.00	*	*	*	425.00	*		*
4A		190.00	200.00	200.00	250.00	200.00	350.00	500.00	300.00	400.00		150.00
4B	1000	300.00	425.00	900.00		470.00	700.00	750.00	475.00	500.00	550.00	750.00
4C	1100	710.00	600.00	700.00	1000.00	550.00	500.00	950.00	1200.00	600.00	800.00	1100.00
5A	375	300.00	200.00	200.00	175.00	100.00	210.00	250.00	300.00	375.00	350.00	
5B	575	500.00	325.00	410.00	300.00	200.00	400.00	750.00	200.00	600.00	400.00	400.00
5C	800	600.00	300.00	500.00	700.00	400.00	700.00	550.00	600.00	480.00	500.00	775.00
5D	1200	750.00	350.00	700.00	700.00	400.00	700.00	700.00	1100.00	720.00		625.00
5E	100	900.00	675.00	1100.00	975.00	460.00	800.00	700.00	^1300.00	825.00	600.00	700.00
6A	625	264.00	275.00	400.00	800.00	100.00		250.00	450.00	*	200.00	550.00
6B	950	507.00	425.00	800.00	550.00	300.00		375.00	900.00	710.00	700.00	850.00
6C	1000	730.00	525.00	1100.00	800.00	600.00		600.00	^1300.00	700.00	950.00	900.00
6D	950	720.00	500.00	^1300.00	^1300.00	900.00		750.00	^1300.00	750.00	950.00	^1300.00
7A	600	510.00	400.00	500.00	600.00	150.00		750.00	650.00	100.00	250.00	125.00
7B	900	673.00	550.00	500.00	600.00	500.00		900.00	900.00	730.00	500.00	675.00
7C	950	746.00	900.00	950.00	1100.00	800.00		^1300.00	1100.00	720.00	90.00	850.00
8A	430	188.00	200.00	255.00	200.00	200.00		200.00	250.00	250.00	250.00	280.00
8B	950	741.00	650.00	610.00	150.00	400.00		^1300.00	1100.00	600.00	850.00	900.00
9A	350	261.00	*	240.00	700.00	*		*	*	300.00	250.00	275.00
9B	980	700.00	700.00	620.00	650.00	600.00		950.00	950.00	700.00	700.00	900.00
Count	26.00	25.00	25.00	26.00	25.00	23.00	15.00	23.00	24.00	21.00	24.00	25.00
Mean	**627.69**	**497.48**	**407.00**	**545.19**	**604.80**	**384.35**	**480.67**	**655.43**	**756.25**	**515.48**	**492.29**	**597.20**
SD	337.70	229.46	207.98	333.68	367.90	217.84	264.37	306.65	367.29	221.59	275.82	312.65
SE	**66.23**	**45.89**	**41.60**	**65.44**	**73.58**	**45.42**	**68.26**	**63.94**	**74.97**	**48.35**	**56.30**	**62.53**

***Secchi disk reached bottom before maximum visibility was reached; therefore, visibility could not be accurately measured and values have been removed from analysis**

^Visibility exceeded maximum length of sechi disk line, 1300m, so 1300m is used for analysis

Table 6a. Mean monthly nitrates (mg l^{-1}) PHMR 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2A						0.63	0.30	0.93				
2B						0.97						
2C						0.97						
5A					0.10		0.76	0.87				
5E						0.97	0.87	0.63				
7A					0.90	0.70	0.70					
7C					0.23	0.57	0.70					
Count					3.00	6.00	5.00	3.00				
Mean					**0.41**	**0.80**	**0.66**	**0.81**				
SD					0.43	0.19	0.21	0.16				
SE					**0.25**	**0.08**	**0.10**	**0.09**				

Table 6b. Mean monthly nitrates (mg l^{-1}) Rio Grande 2015

Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
RG_CB_1b				0.93	0.83	0.97						
RG_SM_1a				0.30								
RG_SM_1b				0.30	0.40	0.67						
RG_RG_1c					0.93	0.77						
Count				3.00	3.00	3.00						
Mean				**0.51**	**0.72**	**0.80**						
SD				0.37	0.28	0.15						
SE				**0.21**	**0.16**	**0.09**						

Table 6c. Mean monthly nitrates (mg l^{-1}) Monkey River 2015

Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
MR_SB_1d				0.50	1.07	0.90		0.33				
MR_TB_1a				0.37	1.37	0.60		0.66				
MR_BB_1b				0.13	1.03	0.27		0.73				
MR_MR_1A					0.43	0.83		0.50				
Count				3.00	4.00	4.00	0.00	4.00				
Mean				**0.33**	**0.98**	**0.65**		**0.56**				
SD				0.19	0.39	0.29		0.18				
SE				**0.11**	**0.20**	**0.14**		**0.09**				

Table 7a. Mean monthly phosphates (mg l^{-1}) PHMR 2015

Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2A						0.73	0.92	0.94	0.84	0.72	0.79	0.74
2B					1.00	0.65						
2C					0.56	0.78			0.73	0.67		0.70
3A					0.23							
5A					0.89	0.58	1.10	0.65	0.58	0.56	0.92	0.80
5E					0.99	0.88	1.00	0.90	0.92	0.86	0.93	0.88
7A					0.96	0.68	0.76		0.71	0.56	0.75	0.64
7C					0.87	0.89	0.86		0.76	0.62	0.82	0.80
Count					7.00	7.00	5.00	3.00	6.00	6.00	5.00	6.00
Mean					**0.79**	**0.74**	**0.93**	**0.83**	**0.76**	**0.67**	**0.84**	**0.76**
SD					0.29	0.12	0.13	0.15	0.12	0.11	0.08	0.08
SE					**0.11**	**0.04**	**0.06**	**0.09**	**0.05**	**0.05**	**0.04**	**0.03**

Table 7b. Mean monthly phosphates (mg l^{-1}) Rio Grande 2015

Site Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
RG_CB_1b				1.01	0.03	1.00			0.42		0.70	
RG_SM_1a									0.35		0.90	
RG_SM_1b				0.85	0.88	0.95						
RG_RG_1a				0.85								
RG_RG_1c				0.47	0.96	0.79					0.62	
Count				4.00	3.00	3.00	0.00	0.00	2.00	0.00	3.00	
Mean				**0.79**	**0.63**	**0.91**			**0.38**		**0.74**	
SD				0.23	0.51	0.11			0.05		0.14	
SE				**0.12**	**0.30**	**0.06**			**0.04**		**0.08**	

Table 7c. Mean monthly phosphates (mg l^{-1}) Monkey River 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MR_SB_1d				1.00	1.07			1.00	0.87		0.78	
MR_TB_1a				0.38	1.71			0.79	0.75		0.89	
MR_BB_1a				0.37								
MR_BB_1b				0.50	1.14			0.98	0.88		0.63	
MR_MR_1A					0.92	0.54		0.70	0.89	0.56	0.99	
Count				4.00	4.00	1.00	0.00	4.00	4.00	1.00	4.00	
Mean				**0.56**	**1.21**	**0.54**		**0.87**	**0.85**	**0.56**	**0.82**	
SD				0.30	0.35			0.15	0.06		0.15	
SE				**0.15**	**0.17**			**0.07**	**0.03**		**0.08**	

Table 8a. Mean monthly sedimentation (g m^{-2} day^{-1}) PHMR 2015												
Site Code	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2A	14.71										126.44	
2C	17.43				130.91		80.45	20.30		83.20	21.26	
5A	9.79	22.70	31.76	57.74	100.42	20.30	25.02	59.70	99.08	23.20	103.45	20.30
5E	72.21	37.74	7.77	30.97	48.97	73.71	40.33	43.58	97.74		16.13	59.77
7A	48.00	119.57		78.57	35.10	105.99		56.60	120.02		103.45	18.56
7C	50.53				28.31	18.34					35.10	103.20
Count	6.00	3.00	2.00	3.00	5.00	4.00	3.00	4.00	3.00	2.00	6.00	4.00
Mean	**35.44**	**60.00**	**19.77**	**55.76**	**68.74**	**54.59**	**48.60**	**45.04**	**68.30**	**53.20**	**67.64**	**50.46**
SD	25.10	52.13	16.97	23.86	44.80	42.81	28.63	17.91	12.50	42.43	48.75	39.98
SE	**10.25**	**30.10**	**12.00**	**13.78**	**20.03**	**21.40**	**16.53**	**8.96**	**7.21**	**30.00**	**19.90**	**19.99**