University of the Sunshine Coast
Sustainability Research Centre

Sustainability Research Centre:
Transforming Regions

The impacts of beach camping on Fraser Island water quality

A internal report to the Faculty of Science, Health and Education

April 2009

Authors
Nikita Tully | RW (Bill) Carter | Peter Brooks | Neil Tindale

This report forms part of the requirement for completion of SRP 201 Special Research Project prepared by Nikita Tully under the supervision of Associate Professor Bill Carter, Dr Peter Brooks and Dr Neil Tindale.

Sustainability Research Centre
University of the Sunshine Coast
Locked Bag 4
MaroochydoreDC, QLD 4556
Tel: (07) 5459 4891
Fax: (07) 5456 5008
Web: www.usc.edu.au

Referencing

This report may be referenced as:
Tully,N., Carter, R.W., Brooks, P. and Tindale, N. (2009) The impacts of beach camping on Fraser Island water quality. Unpublished report to the faculty of Science, health and Education. University of the Sunshine Coast, Sippy Downs.

ACKNOWLEDGEMENTS

This project was funded through the University of the Sunshine Coast's Internal Research Grant program, supported by the faculty of Science, Health and Education. The field and laboratory assistance of the Technical Services Section of the Faculty, especially Daryle Sullivan and its Manager Dr Denis Podger. Thanks also go to staff of the Research and Learning Centre, Dilli Village, Fraser Island and the Capital Programs and Operations section of the University for their support during field operations.

Contents

Acknowledgements 3
Contents 4
Literature Review 5
  Introduction 7
Materials and methods 9
  Sample collection 9
  Faecal Coliforms 11
  Faecal Sterols 11
  Nutrients 12
Results 13
  January scoping study results 13
    Ground water results 13
    Beach flow results 13
    February sampling round results (9th -11th Feb 2009) 14
    Ground water results 16
    Faecal Coliform results 16
  Nutrient results 17
    Total Nitrogen 17
    Ammonia (NH_3) 18
    Nitrates (NO_3^-) 19
    Nitrite (NO_2^-) 20
    Total Phosphorus 20
    Phosphates (PO_4) 20
  Faecal sterol results 22
  Beach Flow Results 22
  Beach flow nutrient results 23
    Total nitrogen 23
    Ammonia 24
    Nitrates 25
    Nitrites 25
    Total Phosphorus 26
    Phosphates 27
Discussion 29
Conclusion 32
References: 33
Appendix 1 35
  Ground Water Results (February 9-11, 2009) 35
Appendix 2 36
  Beach Flow Results (February 9-11, 2009) 36
Appendix 3 37
  Ground Water Statistics (February 9-11, 2009) 37
  Beach Flow Statistics (February 9-11, 2009) 38

Literature Review

Fraser Island, an island off the coast of south east Queensland, Australia, is the largest sand island in the world (Hockings, 1998). In 1992 Fraser Island was granted World Heritage Listing because it exhibits "important ongoing geological and biological processes, as well as superlative natural phenomena and exceptional natural beauty" (Hockings & Twyford, 1997). As a result, the management of Fraser Island is required to meet World Heritage obligations (EPA, 2005). The Great Sandy Region Management Plan was established in 1994 with a vision for Fraser Island to be a place where "tourists from Queensland, interstate, and overseas can enjoy Fraser Island's splendor and tranquility and return home without having marred their priceless inheritance" (EPA, 2005). The Island's stunning scenery and sandy beaches make the region a popular tourist destination; attracting in excess of 350 000 visitors per year (Burns & Howard, 2003). Recreational activities such as sightseeing, walking, four-wheel driving, picnicking, fishing, boating, bait collecting, guided tours and beach camping are among the most popular. Beach camping alone attracts approximately 90 000 visitors per annum (Thompson & Schlacher, 2008). Tourism on Fraser Island is highly seasonal with December - January (Christmas) and March - April (Easter) being the most popular times (Hadwen, 2002).

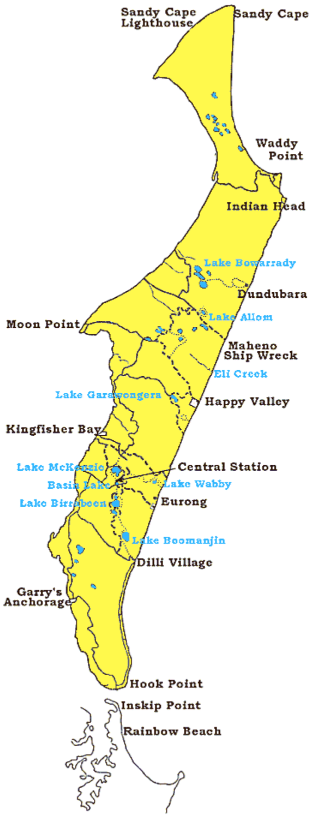

Figure 1: Map of Fraser Island

Considerable research has been conducted on Fraser Island examining the impacts of recreational four-wheel driving on foredune vegetation with regards to erosion and dune stability (Thompson & Schlacher, 2008; Hockings & Twyford, 1997). Four-wheel driving is permitted on 98% of the Fraser Islands eastern beaches. In areas where camping is permitted, there are 235 vehicle tracks which pass through the foredune, resulting in the erosion of 20% of the dune in these areas. Further more, dune vegetation that has been damaged by four-wheel driving, and can take two or more years to recover (Thompson & Schlacher, 2008). This a serious concern and calls have been made for management strategies, which aim to preserve the dunes, to be put in place. Recreational four wheel driving has also been shown to have detrimental effects on coastal fauna, in particular migrating birds, invertebrates such as crabs, and marine turtle hatchings (Moss & McPhee, 2006; Schlacher & Thompson, 2007). Beach traffic has been found to reduce the number of species and size of populations of endobenthic invertebrates (Schlacher *et al*, 2008), and as a result causes changes in community composition that could lead to further ecological consequences.

Studies carried out in the US have also shown that dune vegetation can be sensitive to the effects of beach camping (Anna *et al*, 2000). Research has shown that it is possible for campsites to loose up to 69% of vegetation due to intensive use (Marion & Farrel, 2002). As well as this, studies have shown that when campsite use increases, the concentration of the impact also tends to increase (Cole, 2006). This effect combined with the sensitivity of dune vegetation provides a serious concern for the health of the dune ecosystem.

The health of Fraser Island's freshwater dune lakes have also been monitored. The lakes are some of the Island's most popular tourist destinations, attracting 300 000 people in the year 2000. Fraser's pristine dune lakes are oligotrophic, i.e. they are low in nutrients, high in oxygen, and support a limited number of aquatic organisms and algal species (Hadwen, 2002). This means that even low levels of nutrient addition have the potential to cause a large impact on the overall health of the lakes (Arthington *et al*, 1990). Research has shown, using changes in nutrients and chlorophyll a concentrations, that Fraser Island's lakes have become slightly more biologically productive and less pristine since 1990 (Hadwen, 2002). It was suggested that the large numbers of tourists swimming in the lakes every year could cause nutrient additions, which would lead to algal blooms and eventually eutrophication, a process which would greatly diminish the lakes aesthetic appeal (Hadwen, 2002). The lakes found to be most at risk were Lake McKenzie, Lake Birrabeen, and Lake Allom. In 2003 camping at Lake Mackenzie was permanently closed due to the threat posed by increased tourist numbers, and elevated nutrient levels (EPA, 2005). Direct human waste additions were thought to be the main source of biological contaminants, however other possible sources exist. Faecal matter from birds, animals, and waste burial, associated with camping, may also have a significant effect (Hadwen, 2002).

Beach camping is one of the greatest environmental management concerns for the Fraser region (Hockings & Twyford. 1997). It causes dune disturbance due to four-wheel drives, human wastes, as well as fire rings and litter. The 124km eastern stretch of ocean exposed beaches attracts 90 000 beach campers a year (Thompson & Schlacher, 2008). Camping has been recognized as the main human use of Fraser Island's east coast (Hockings & Twyford, 2005). One study estimates that coastal zones devoted to beach camping cover approximately 23% (28.7km) of Fraser's ocean exposed foredunes (Thompson & Schlacher, 2008).

Ninety thousand people camping (and disposing of their waste) along Fraser Island's 124km of ocean exposed beaches every year is concerning. There is a possibility the sheer quantity of people camping would have the potential to introduce large amounts of human waste to the dunes. The problem with disposal of faecal matter is two fold. Human waste breaks down into compounds that contain nitrogen and phosphorus which plants and algae use as nutrients, however it also contains pathogens. Should these nutrients and pathogens pollute the water table it will be a serious environmental problem capable of causing larger ecological repercussions.

The Great Sandy Region Management Plan acknowledges the threat that beach camping may pose on the long term health of the environment on Fraser Island. By 2010 management aims to "achieve ecological sustainability by reducing the environmental impacts of camping and beach camping in particular"(EPA, 2005).

In Tasmania studies have been carried out addressing the impacts of burying human waste on the Tasmanian wilderness and the Tasmanian coast. The study investigated the effects of urine addition, soil disturbance and the combination of the two. It was found that soil disturbance caused by digging had a detrimental effect on the vegetation, however urine addition was found to increase plant growth (Bridle & Kirkpatrick, 2003). These results are consistent with the role of nitrates and phosphates in plants. However concerns have been raised that nutrient additions may alter the composition of dune vegetation by favoring exotics and weeds, over native plants (Kirkpatrick & Harris, 1999). This is one of several detrimental effects which can be caused by nutrient additions resulting from urination and human waste disposal behind the foredune. Another effect is that dangerous pathogens can be introduced into the soil. In the shore zone, faecal indicator bacteria have been found to be relatively more concentrated in sand than in water (Wheeler Alm, 2003). As well as this, human waste disposal may increase nutrient levels in the ground water table. This is highly likely especially due to the fact that human waste disposal preferentially occurs behind the foredune, an area which is close to sea level, and also the ground water table.

Along the coastline ground water levels are affected by the changing tides and generally tend to lag behind the tides (Emery and Foster, 1948). At low tide the ground water level remains high (due to the previous high tide), however the sea level is lower. It is well documented that when the surface of an unconfined aquifer is higher than sea level, ground water flows into the beach zone, in a process known as marine ground water discharge (Uchiyama *et al*, 2000), (see Figure 2).

Should the ground water contain nutrients, (due to the disposal of human biological wastes) it would result in nutrient pulses into the beach ecosystem (Connors, 2007; Boehm, *et al*, 2006). These nutrient inputs could result in changes to the composition of marine algal communities (Mosisch & Arthington, 2001), and other meiofauna which live in the sand. Such changes to algal communities have been documented in Port Elizabeth, South Africa (Campbell & Bate, 1998).

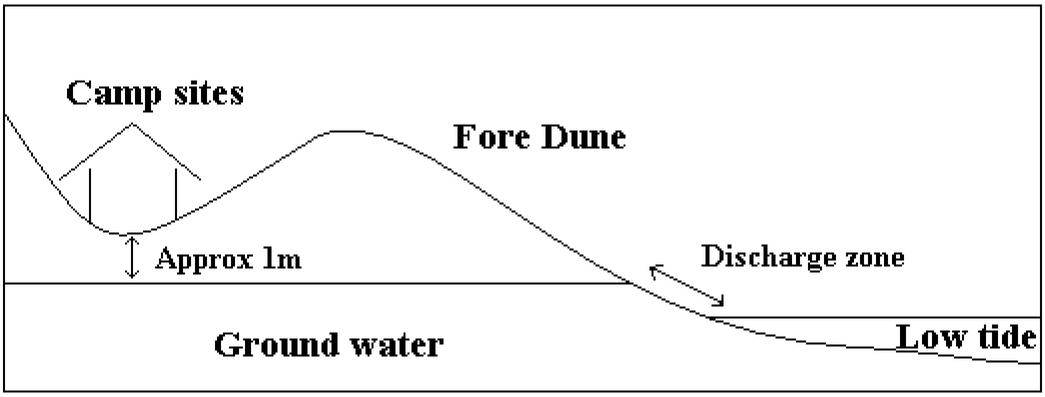

Figure 2: Marine ground water discharge in beach flows

Introduction

It has been noted that the number of visitors to Fraser Island are increasing every year. Between 1986 and 1995 alone, the number of camping permits issued per year increased from 12604 to 20054. In the year 2003 alone Fraser Island attracted 350 000 visitors. (Burns & Howard, 2003). Tourists come to the world heritage listed sand island off Queensland's east coast to enjoy the pristine environment. Visitors include backpackers, fishermen, resort visitors, tour groups and beach campers. In 2008 beach camping alone attracted approximately 90 000 visitors (Thompson & Schlacher, 2008). This is a large number of people concentrated on the islands 120 km stretch of eastern beach and has the potential to cause ecological disturbance.

Thus far the majority of scientific research carried out on Fraser Island has concentrated on the water quality of the islands pristine freshwater dune lakes (Hadwen, 2002), as well as on the impact of four-wheel driving on the beach zone (Thompson & Schlacher, 2008; Hockings & Twyford, 1997). The impacts of beach camping have been investigated in one study, though this was in relation to vegetation disturbance and trampling (Hockings & Twyford, 1997).

An additional serious threat which beach camping poses has been identified by studies from other shore areas. Research from the United States (Anna *et al*, 2000), South Africa (Campbell & Bate, 1998) and Tasmania (Bridle & Kirkpatrick, 2003) have found that human waste disposal near the beach zone has the potential to cause ecological disturbance as well as human health concerns. In light of these potential concerns, the current study set out to determine whether human faecal matter was in fact present in the ground water at beach camping zones on Fraser Island.

In this study faecal coliforms, soluble nutrients and faecal sterols were selected as indicators of human waste contamination in ground water. There are several ways to identify faecal contamination in water; however for this study three indicators were chosen. Faecal coliforms are thermal tolerant bacteria that live in the gut of warm blooded animals. They survive under the same conditions as many faecal derived pathogens and therefore high levels of faecal coliforms suggest faecal contamination and pathogens.

Nutrients were also analyzed. The breakdown of faecal matter and urine results in compounds high in phosphorus and nitrogen; therefore ground water was tested for total phosphorus, and phosphates, total nitrogen and nitrates, nitrites, and ammonia. Elevated nutrient levels in camping zones when compared to matched non-camping zones can indicate faecal input.

Faecal sterols were also tested as they are byproducts of digestion of sterols in the diet of animals. Different animals ingest various sterols according to their food source (carnivore, herbivore, and omnivore) (Leeming *et al*, 1996). These sterols are metabolized in different pathways resulting in byproducts that are organism specific. Coprostanol is the major byproduct of human digestion of cholesterol (Leeming *et al*, 1996). The native animals on Fraser Island produce very little coprostanol, thus the presence of coprostanol in wet sand is strong evidence of human faecal contamination on Fraser Island.

This study therefore used three indicators; nutrients, faecal coliforms and faecal sterols to determine whether beach camping impacted on groundwater quality, when compared to ground water in matched non-camping zones.

Materials and methods

Two sampling rounds were conducted; January 12th to 15th 2009 as a scoping study, and February 9th to 11th 2009, as an intensive study. Samples were taken along the east coast of Fraser Island from Ocean Lake to One Tree Rocks in the January scoping study, and from Guruman to Cornwell camping zones in the February study. Thirteen sites were sampled (across ten camping/non-camping zones) in the January study and 17 sites (across six camping/non-camping zones) were sampled in the February study (see Figure 3).

Sample collection

Three types of samples were collected at each camping/non-camping site sampled; foredune groundwater, beach flows, and wet sand samples. At each site, GPS data, odometer readings, vegetation and topography descriptions, number of campsites and signs of campers were recorded.

The ground water samples were taken using an Augur, in the low point behind the fore dune. Sample sites were chosen in both camping and matched non camping areas. A hole 10cm in diameter was dug into the sand until the ground water table was reached, usually a depth of approximately 1 to 2m. After reaching the ground water table, the next sand core was removed from the Auger and collected in a ziplock plastic bag to be later analyzed for faecal sterols. The sand removed after that was collected in another plastic bag and shaken to separate the water from the sand. The water which collected above the sand was poured into a labeled 250ml sterile bottle.

Beach flows were collected at low tide, between the tidal levels. A shovel was used to make a y-shaped depression in the sand, into which the ground water outflow was collected. The water was collected in a 250ml sterile bottle.

All samples were kept on ice during transport.

Each of the water samples were tested for Faecal Coliforms and Nutrient levels. The sand samples were analyzed for faecal sterols using Gas Chromatography – Mass Spectrometry.

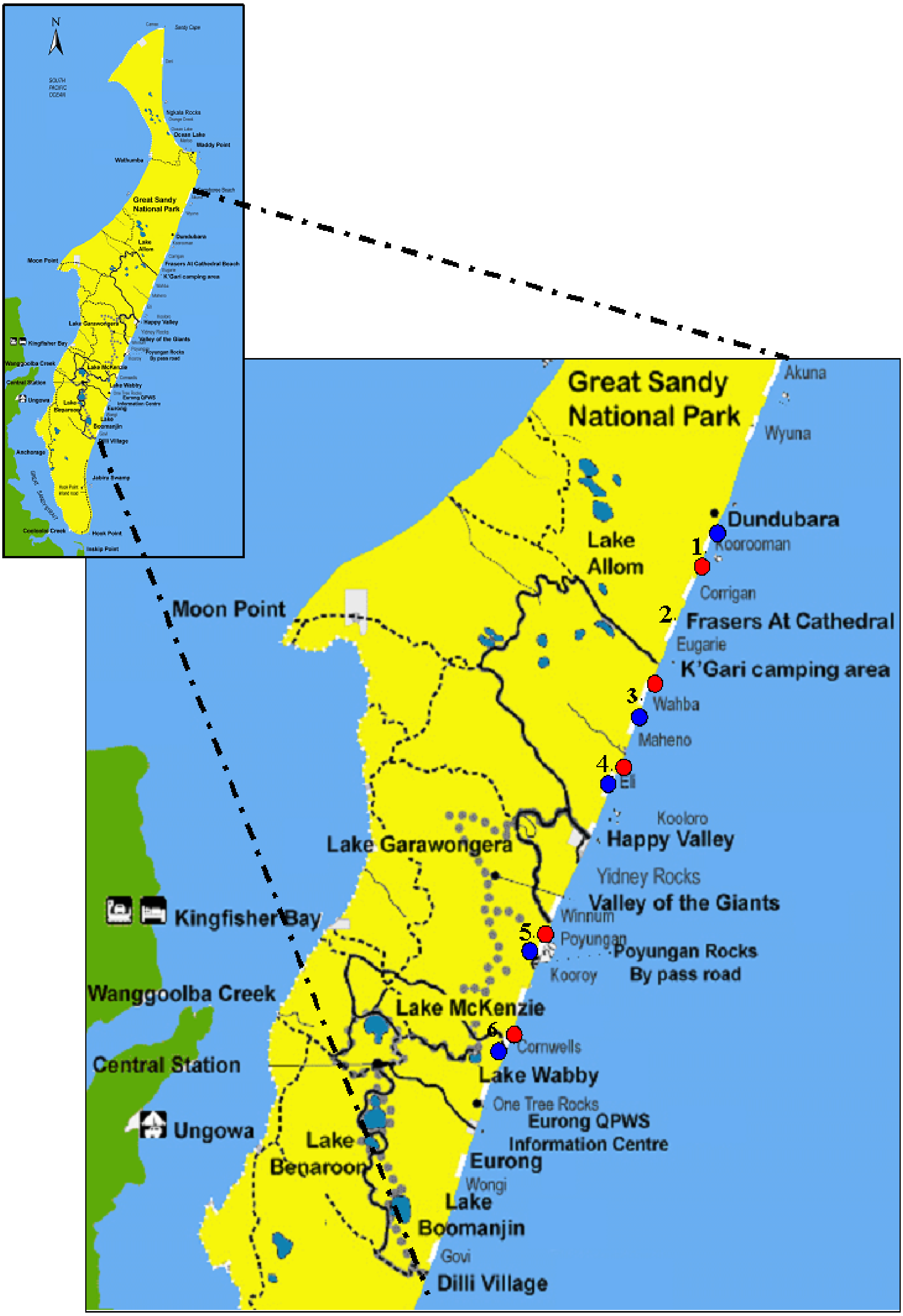

Figure 3: Camping and non-camping zones were sampled in each of the following six areas along the east coast of Fraser Island

1. Guruman 2.Yurru 3. South Eli 4. Wahba 5. Poyangan 6. Cornwell

Faecal Coliforms

The samples were collected in labeled, sterile 250ml bottles. They were kept chilled until processed within 6 hours, for faecal coliforms using the standard method prescribed by the *Standard Methods for the Examination of Water and Waste Water* , 20th Edition, (Clesceri *et al*, 1998). Briefly, using aseptic techniques, the water samples were vacuum filtered on 0.45 µm Milllipore filter membrane, then the filters were placed on coliform specific agar containing Rhizolic acid.

The plate was turned upside down, and then incubated at 45°C for 24 hours. After incubation, the plates were removed and the number of blue coloured Colony Forming Units (CFU/100ml) were counted. This process was repeated, washing the equipment thoroughly between each use.

Where the samples contained a significant amount of sediment, and smothering was a concern, 20ml or 50ml of the sample was plated as well as the 100ml. The number of CFU found was then multiplied to determine the 100ml equivalent. This method proved to be more accurate and often the low volume plate gave results higher than the 100ml plate, due to the growth of the coliforms on the 100ml plate being limited by the suspended sediment.

Faecal Sterols

Sand samples were frozen until processing. Before testing the samples were thawed.

1. Approximately 85 grams of damp sand was weighed into a pre-washed 250ml Schott bottle.
2. Methanol (30ml) and hexane (30ml) were added to the sand in the bottle, as well as 1g sodium carbonate and 10µg of cholestane internal standard.
3. The samples were then tumbled for 24 hours on a *Ratek* Tumble Mixer, at a rate of 30 cycles/min. After 24hrs the bottles were taken off and placed in the -18°C freezer.
4. The layers that formed were then separated using a liquid separation funnel. Any polar molecules were dissolved in the lower polar methanol; whereas non-polar compounds such as sterols were dissolved in the upper hexane.
5. The bottom methanol layer was drained off, and the top hexane layer was washed with 15ml milliQ water.
6. The hexane was dried with 1g of anhydrous sodium sulphate.
7. The hexane was evaporated under nitrogen gas, the residue was re-dissolved in 0.5ml of hexane, and transferred to a 1.5ml glass Gas Chromatography Mass Spectrometer (GC-MS) vial. The hexane was evaporated under nitrogen gas.
8. The samples prepared for GC-MS analysis were dried by placing them in a *ThermoSavant* ModulyoD low pressure freeze drier for 1 hour.
9. The dried samples were then derivatised for 3 hours with tritrimethylsilylimidazole, diluted with hexane, and analyzed by GC-MS.

The GC-MS used was a Varian 3900 GC coupled with a Varian Saturn 2100T MS, and a Zebron ZB5HT column which was 30m x 0.25mm ID x 0.25µm film.

The Injector was at 330°C, and the column at 200°C initially. It was then ramped at 20°C/min until 240°C, and then at 3°C/min until 330°C, where it was held for 5 minutes.

Helium carry gas was used at a flow rate of 1ml/min. The total program time was 33.7min per sample.

The split ratio was initially 50:1, closed immediately on injection for 30 seconds, then opened to 50:1. Fragment Mass was analyzed over the range (m/z) 200 to 650.

Nutrients

Dissolved nutrients were tested using the Flow Injection Analyzer (FIA) at USC. The 30ml of each of the samples was filtered through 0.45µm Millipore filters and then frozen until processing. Samples were tested for Total Nitrogen, Nitrates, Nitrites, Ammonia, Total phosphorus and Phosphates. The FIA used was a Lachat QuickChem 8000 FIA; a continuous flow analyzer and runs with a 10µl glass cuvette. Three chemistries were used NO_x with an inline cadmium column, phosphate and Ammonia. Each test was run with 7 standards; 0, 50, 100, 150, 200, 500 and 1000µg/L. For the total nitrogen and total phosphorus tests, 3ml of potassium persulfate was added to 7ml of sample in a glass test tube and then autoclaved at 121°C for 15 minutes.

All standard curves had a 0.999 correlation co-efficient. The 100µg/L and 500µg/L standards were used as internal quality checks; they were tested again as unknowns at the end of the sample run and analyzed values came in within +/- 5 µg/L of the standard concentration.

Results

January scoping study results

The preliminary scoping study (January 12-15) found *Faecal coliform levels* greater than 500CFU/100ml in the ground water at Yurru, South Maheno and Wihnam camping zones.

The south Eugarie non camping zone showed nutrient levels similar to those found in the camping zones. Figure 4 shows levels of nutrients and Faecal coliforms in Ground water in camping compared to non-camping zones.

Coprostanol was found at Poyangan camping zone and at Cornwell non-camping zone, (which was adjacent to Cornwell Group Camping Zone).

Ground water results

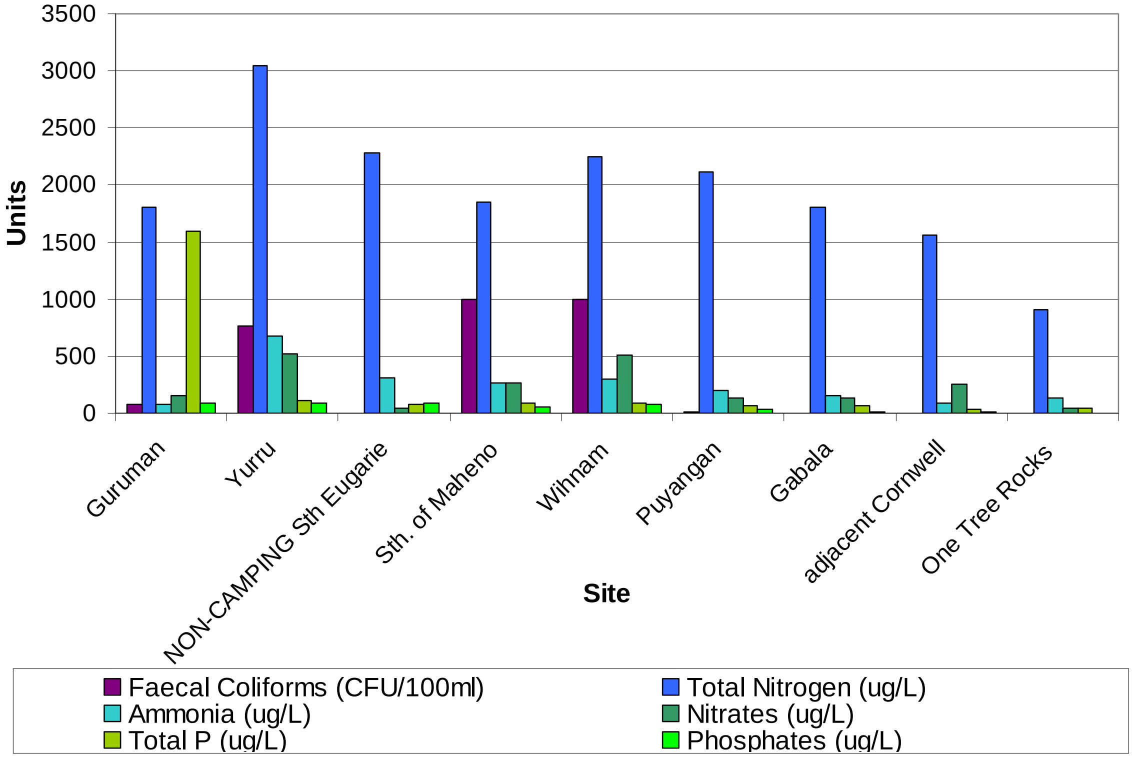

Figure 4: Levels of Nutrient and Faecal coliforms in ground water in camping areas and south Eugarie non-camping area, along the east coast of Fraser Island, Australia, in January 2009.

Four out of the eight camping zones had coliforms in the ground water, the other four had none. The non-camping site had zero CFU/100ml. Total nitrogen levels in beach flows in camping zones ranged from 900ug/L to 300ug/L. The non-camping zone had 2300ug/L total nitrogen. Ammonia levels in beach flows at both camping and non-camping sites were below 600ug/L. Nitrates were below 500ug/L in beach flows all sites. All other nutrient levels were below 100ug/L in all beach flows sampled.

Beach flow results

Levels of nutrients and Faecal coliforms in Beach flows in camping compared to non-camping zones are shown in Figure 5.

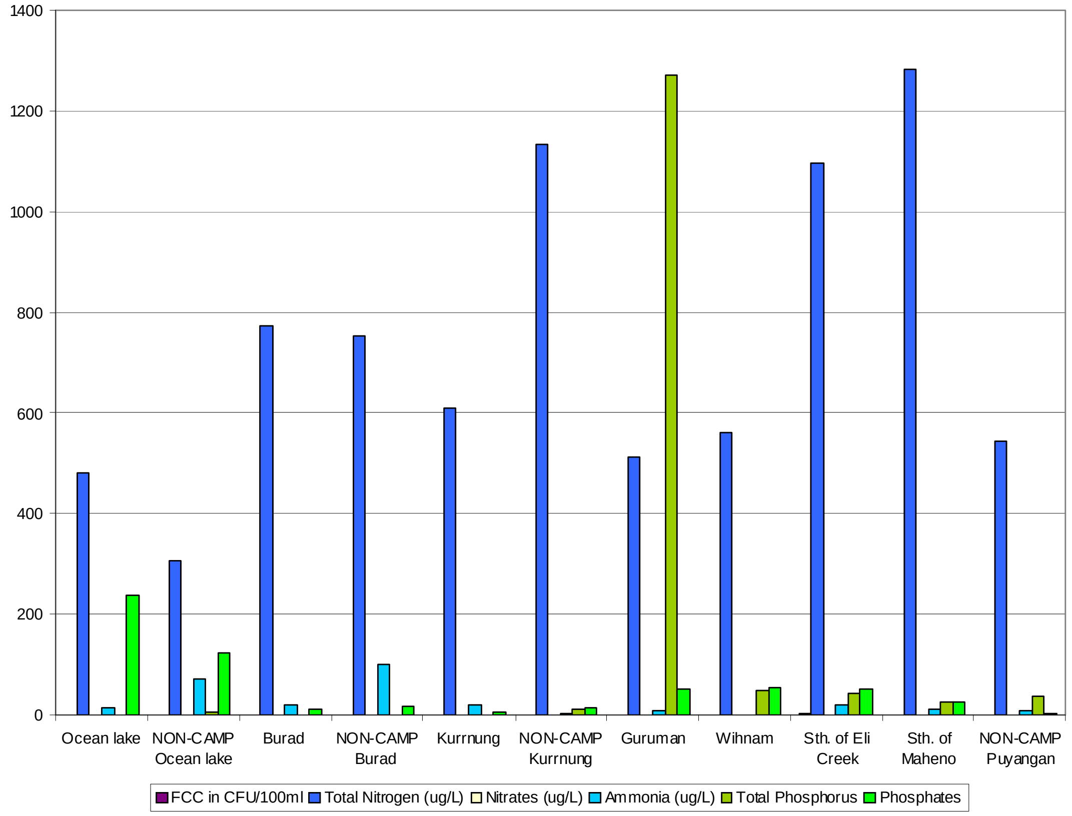

Figure 5: Levels of Nutrient and Faecal coliforms in beach flows in camping areas and south Eugarie non-camping area, along the east coast of Fraser Island, Australia, in January 2009.

February sampling round results (9th -11th Feb 2009)

When comparing indicator levels found in ground water from camping and non- camping zones (Figire 6) there is a increase in nutrient and faecal coliform levels in camping zones when compared to non-camping zones.

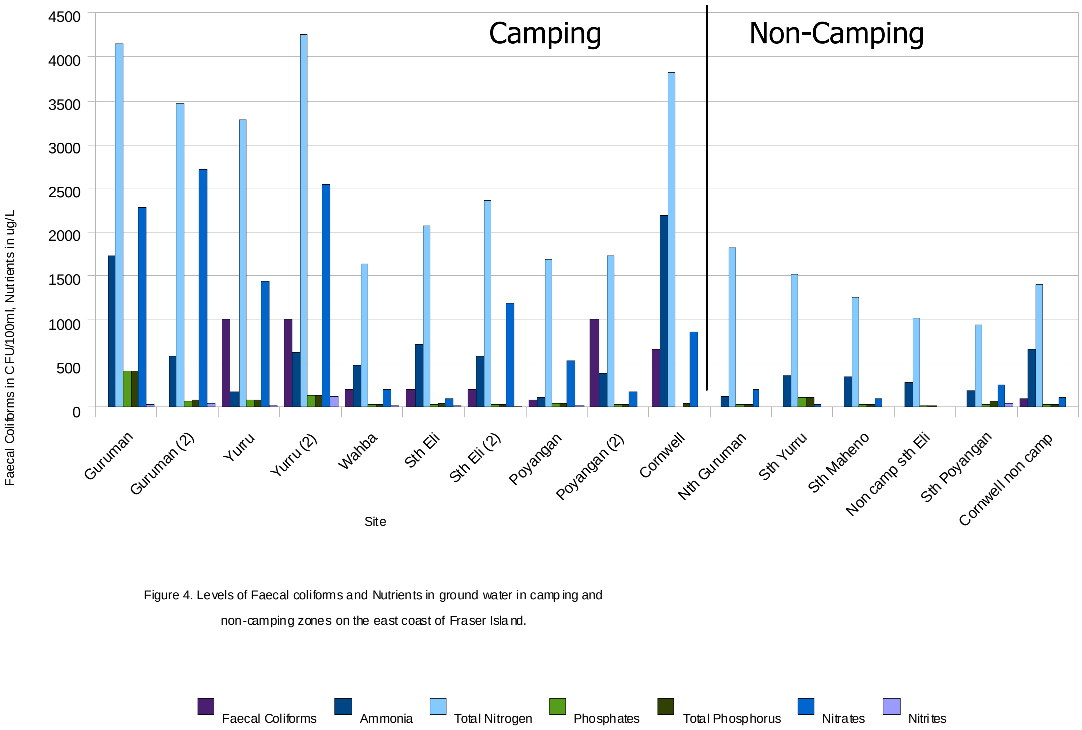

Figure 6: Levels of Nutrient and Faecal coliforms in ground water in camping and non-camping zones, along the east coast of Fraser Island.

Mean and standard deviation of indicator levels in camping and non-camping zones, as well as the ratio mean camping zones levels to mean non camping zone levels are shown in Tables 1 and 2.

Table 1: Mean Nutrient and Faecal Coliform levels (+/- Standard Deviation) found in Ground Water in camping vs. non-camping zones on the east coast of Fraser Island, Australia, and the Ratio of camp zone levels to non-camp zone levels.

Groundwater	Camping Ground water (Mean +/- SD)	Non-Camping Ground water (Mean +/- SD)	Ratio of camp zone levels to non-camp zone levels
Faecal Coliforms CFU/100ml	655 +/- 224.01	15.0 +/- 36.7	43.7 : 1
Total N (µg/L)	2843.2 +/- 1055.63	1323.8 +/- 329.8	2.1 : 1
NH_3-N (µg/L)	762.8 +/- 668.50	331.3 +/- 182.2	2.3 : 1
NO_3 (µg/L)	1200.1 +/- 1004.68	116.8 +/- 95.5	10.3 : 1
NO_2 (µg/L)	30.2 +/- 38.23	12.7 +/- 18.8	2.4 : 1
Total P (µg/L)	97.4 +/- 117.47	48.8 +/- 34.8	2.0 : 1
PO_4-P (µg/L)	87.6 +/- 121.16	42.0 +/- 33.5	2.1 : 1

Table 2: Mean Nutrient and Faecal Coliform levels (+/- Standard Deviation) found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia, and the Ratio of camp zone levels to non-camp zone levels.

Beach Flow	Camping Beach Flow (Mean +/- SD)	Non-Camping Beach Flow (Mean +/- SD)	Ratio of camp zone levels to non-camp zone levels
Faecal Coliforms CFU/100ml	15.3 +/- 27.95	6.0 +/- 11.12	2.6 : 1
Total N (µg/L)	748.4 +/- 488.65	754.8 +/- 516.40	1:1
NH_3-N (µg/L)	105.9 +/- 45.34	89.2 +/- 49.06	1.2 : 1
NO_3 (µg/L)	129.9 +/- 184.38	205.8 +/- 211.94	0.63 : 1
NO_2 (µg/L)	11.7 +/- 8.37	11.3 +/- 7.09	1 : 1
Total P (µg/L)	101.1 +/- 153.61	58.2 +/- 59.15	1.7 : 1
PO_4-P (µg/L)	40.3 +/- 16.12	38.2 +/- 12.09	1:1

Ground water results

Faecal Coliform results

The faecal coliform levels found in groundwater in camping and non-camping zones are shown in Figure 7. Faecal coliform levels in ground water in camping areas ranged from zero to 'too numerous to count' (plotted as 999CFU/100ml), with an average of 655CFU/100ml (+/- 224.01). Whereas levels in non-camping zones ranged from zero CFU/100ml to 90CFU/100ml, with an average of 15CFU/100ml (+/- 36.7).

- Coliform levels in the groundwater at both sites in Yurru camping zone were too numerous to count. South Yurru non-camping zone had Zero CFU/100ml.
- Poyangan camp zone (2) had faecal coliforms which were too numerous to count, and Poyangan (1) had 80CFU/100ml. Ground water at South Poyangan non-camping ground had Zero CFU/100ml.
- Ground water at Cornwell camping ground had 655CFU/100ml faecal coliforms. Cornwell non-camping ground had 90CFU/100ml, it was the only non-camping ground to record faecal coliforms in the water.

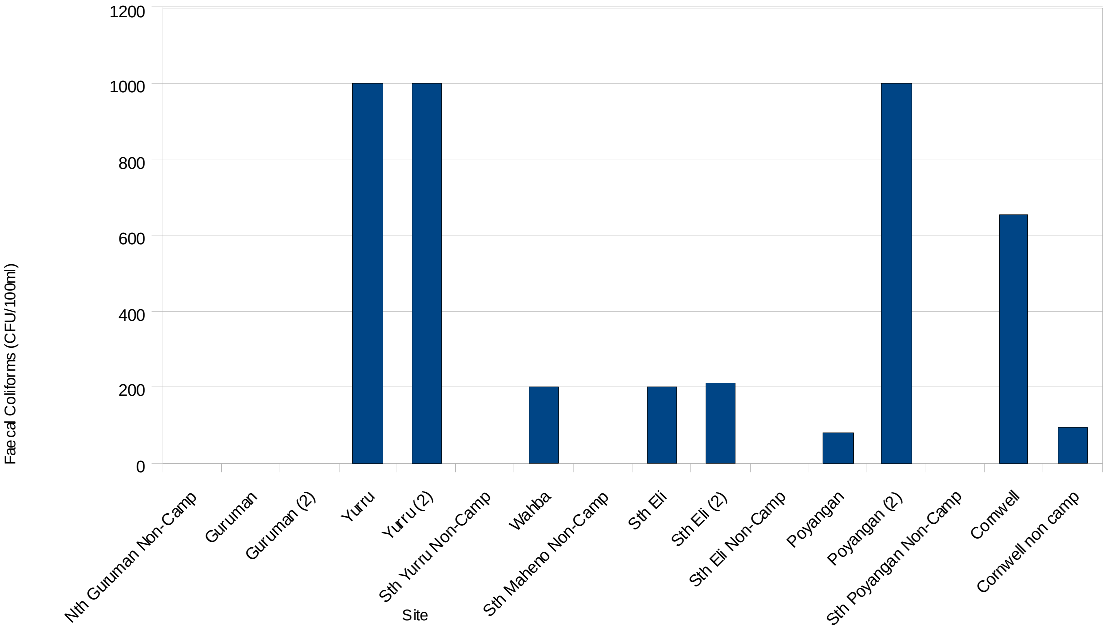

Figure 7: Faecal Coliforms levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Nutrient results

Total Nitrogen

Total nitrogen levels found in ground water in camping and non-camping sites on Fraser Island are shown in Figure 8. All ground water Total Nitrogen levels in camping zones ranged from 1633µg/L to 4252µg/L, with an average of 2843.2µg/L (+/- 1055.63). Levels in non-camping areas were less than 1830µg/L, with an average of 1323.8µg/L (+/- 329.80).

- Groundwater at Yurru (1) and Yurru (2) camp zones had 3273µg/L and 4252µg/L of total nitrogen respectively. South Yurru had 1507µg/L of total nitrogen.
- Poyangan (1) camp zone had 1692µg/L total nitrogen and Poyangan (2) camp zone had 1739µg/L. South Poyangan non-camping ground had only 944µg/L total nitrogen.
- Cornwell camping ground had 3818µg/L total nitrogen, and Cornwell non-camping ground 1401µg/L total nitrogen.

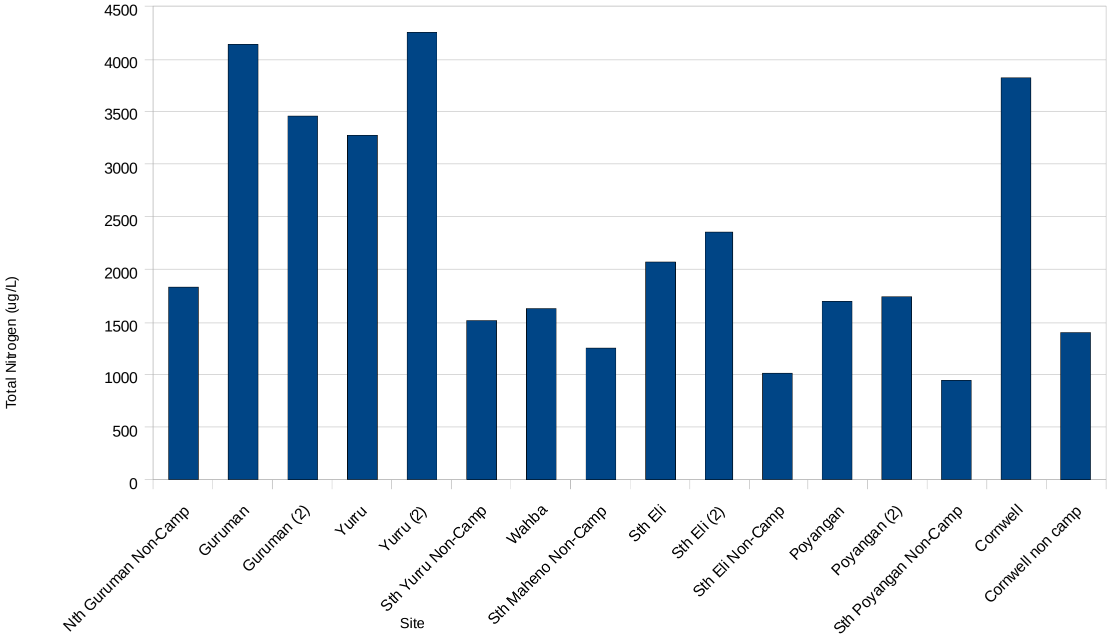

Figure 8: Total Nitrogen levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Ammonia (NH_3)

Ground water Ammonia levels in camping zones and non-camping zones are shown in Figure 9. Ammonia levels in camping zones ranged from 112µg/L to 2191µg/L, and had an average of 762.8µg/L (+/- 668.50). Levels of ammonia in non-camping zones were all less than 658µg/L with an average of 331.3µg/L (+/- 182.2).

- Cornwell had the highest ammonia level (2191µg/L) out of all the sites, whereas Cornwell non-camping ground had 658µg/L ammonia.
- Guruman (1) camp zone had 1729µg/L of ammonia, whereas North Guruman non-camping area had 135µg/L.
- Ground water at Yurru (2) camp zone had 634µg/L and South Yurru non-camping zone had 359µg/L.

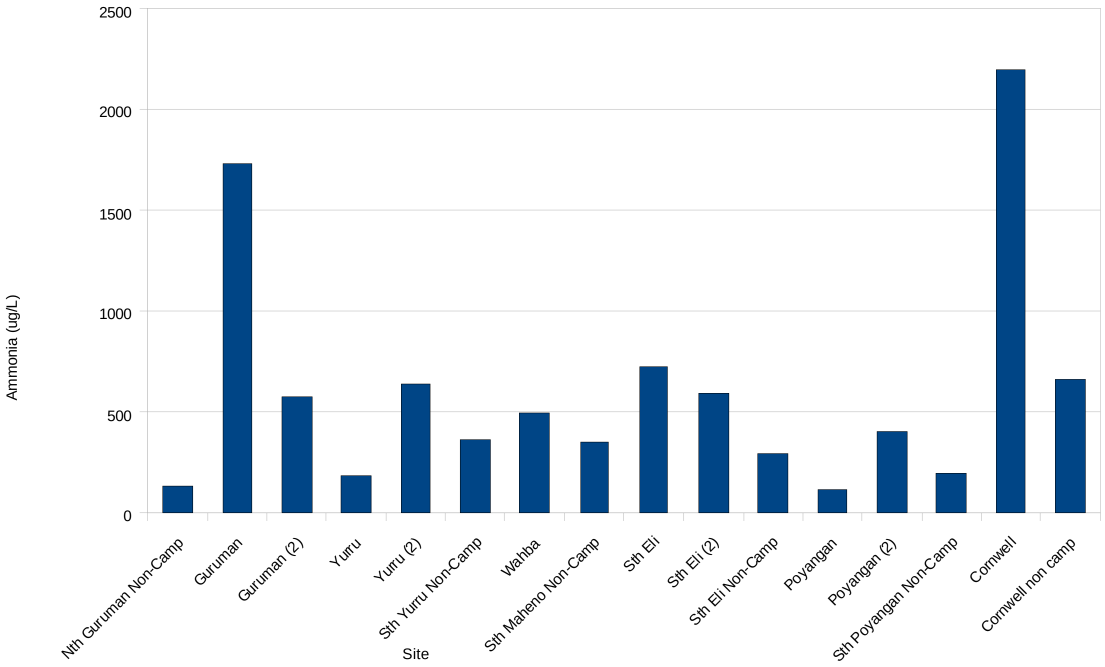

Figure 9: Ammonia levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Nitrates (NO_3^-)

Figure 10 shows nitrate levels found in groundwater in camping and non-camping zones. Nitrates in groundwater in camping zones ranged from 169µg/L to 2706µg/L, and the average was 1200µg/L (+/- 1004.68). Nitrate levels in non-camping zones were all less than 248µg/L, with an average of 116.8µg/L (+/- 95.5).

- Yurru (1) camp zone had 1435µg/L nitrates and and Yurru (2) camp zone had 2540µg/L nitrates. South Yurru non-camp zone had 35µg/L nitrates.
- Poyangan (1) camp zone had 526µg/L nitrates and Poyangan (2) camp zone had 169µg/L nitrates. South Poyangan non-camping ground 248µg/L nitrates.

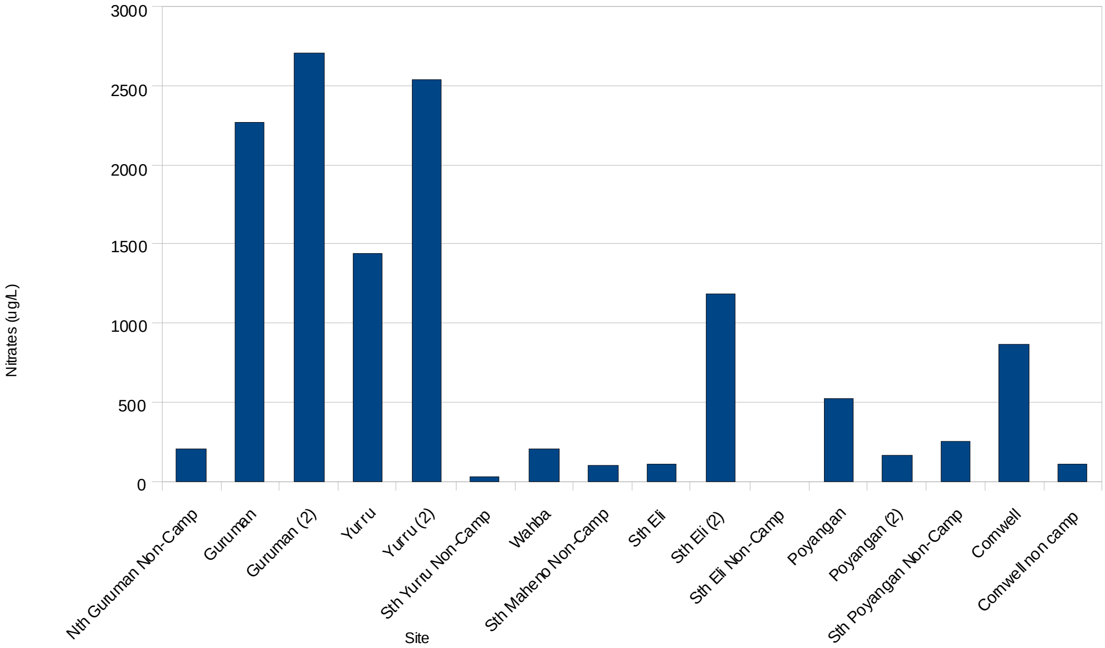

Figure 10: Nitrate levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Nitrite (NO_2^-)

Nitrite levels found in ground water in camping and non-camping zones are shown in Figure 11. Nitrite levels in groundwater in camping zones ranged from 0µg/L to 133µg/L, with an average of 30.2µg/L (+/- 38.23). The only non-camping site with measurable nitrite levels in the ground water was South Poyangan which had 51µg/L, making the average nitrate level in non-camping zones 12.7ug/L (+/- 18.8).

- Sites 1 and 2 in Yurru campground had 12µg/L and 133µg/L nitrites respectively. South Yurru non-camping zone had less than 10µg/L of nitrites.
- The two sites sampled in Guruman camp zone had 34µg/L and 45µg/L nitrites whereas North Guruman non-camping zone showed less than 10ug/L nitrites.

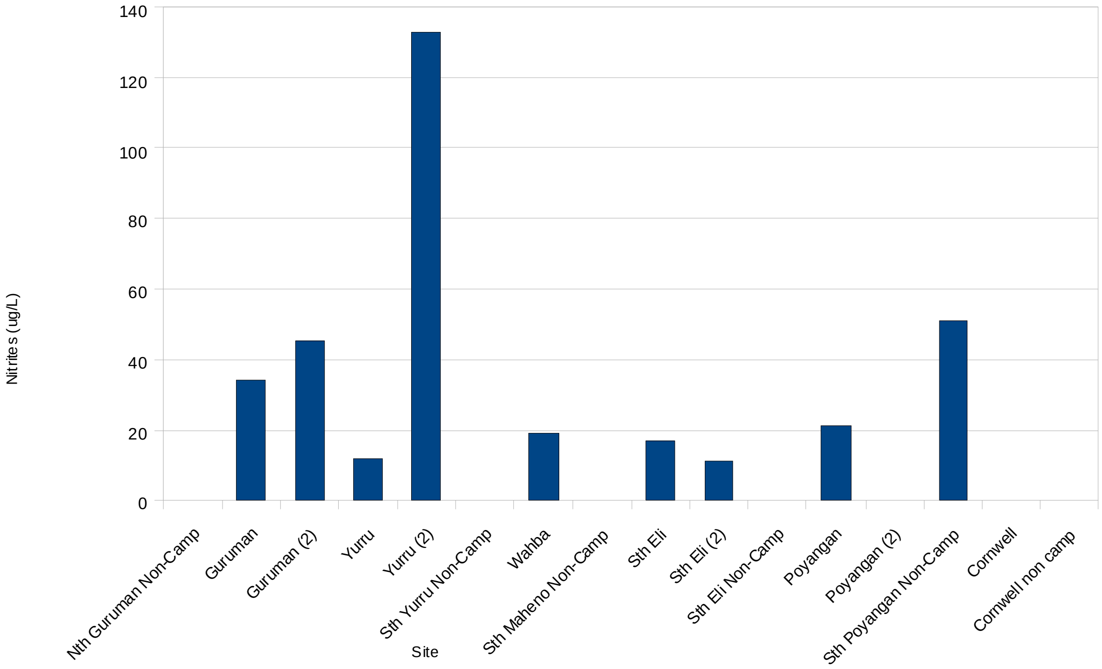

Figure 11: Nitrite levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Total Phosphorus

Ground water levels of total phosphorus found in camping and non-camping zones are shown in Figure 12. Total phosphorus levels in ground water at camping zones ranged from 28µg/L to 415µg/L, and had average of 97.4µg/L (+/-117.47). In non-camping zones total phosphorus levels were between 21µg/L and 110µg/L with an average of 48.8µg/L (+/- 34.80).

- Total Phosphorus levels at Yurru (1) and Yurru (2) camping zones were 83µg/L and 151µg/L respectively. South Yurru non-camping zone had 110µg/L of total phosphorus.
- Total phosphorus levels at Cornwell camping ground had 46µg/L of total phosphorus, whereas Cornwell non-camping area had 29µg/L of total phosphorus.

Phosphates (PO_4)

Figure 13 shows phosphate levels in ground water from camping and non-camping zones on Fraser Island. In camping zones the average Phosphate levels in ground water ranged from 0 to 415µg/L, with an average of 87.6µg/L (+/-121.16). Phosphate levels in non-camping zones were all below 110µg/L and averaged 42.0µg/L (+/-33.50).

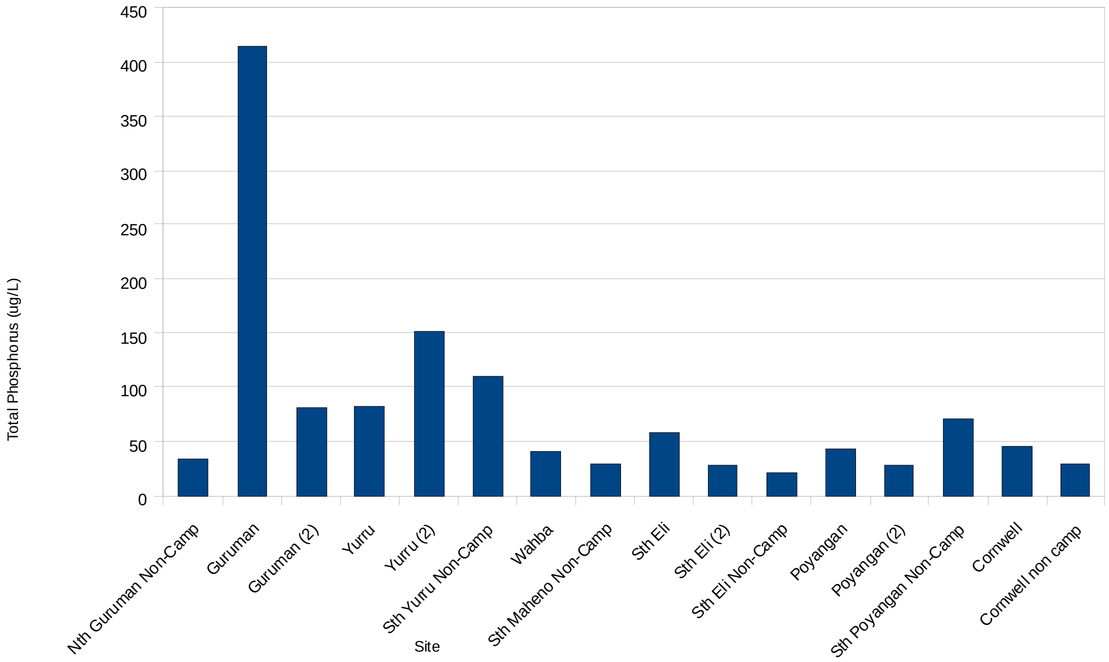

Figure 12: Total Phosphorus found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

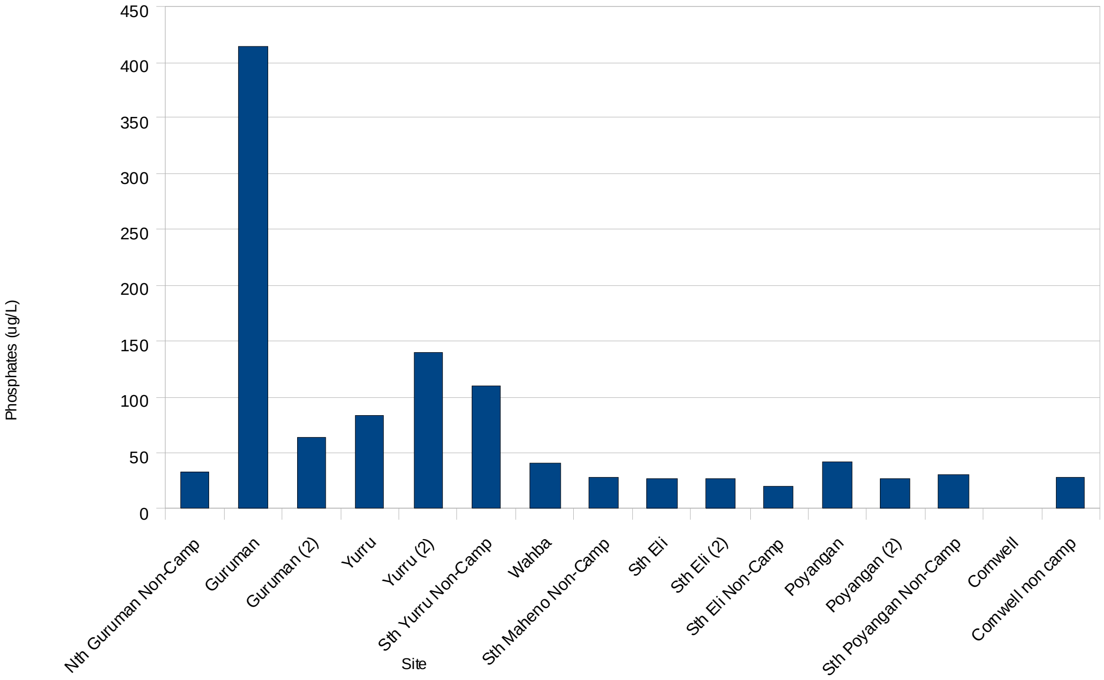

Figure 13: Phosphate levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Faecal sterol results

Coprostanol was found in the ground water of camping zones (see Table 3) at Guruman (769ng/100g sand), Wahba (204ng/L), South Eli (126ng/100g), Poyangan (4209ng/100g), and Cornwell (317ng/100g). It was also detected at South Eli non camping zone (126ng/100g), and South Yurru (493ng/100g).

Table 3: Level of coprostanol found in sand samples at camping and non-camping zones on Fraser Island.

Camping zone	**Coprostanol** (nL/100g sand)
Guruman	769
Wahba	204
Poyangan	4209
Cornwell	317
Non-camping zone	
South Eli	126
South Yurru	493

Beach Flow Results

Figure 14 shows indicators levels found in beach flows on the east coast of Fraser Island.

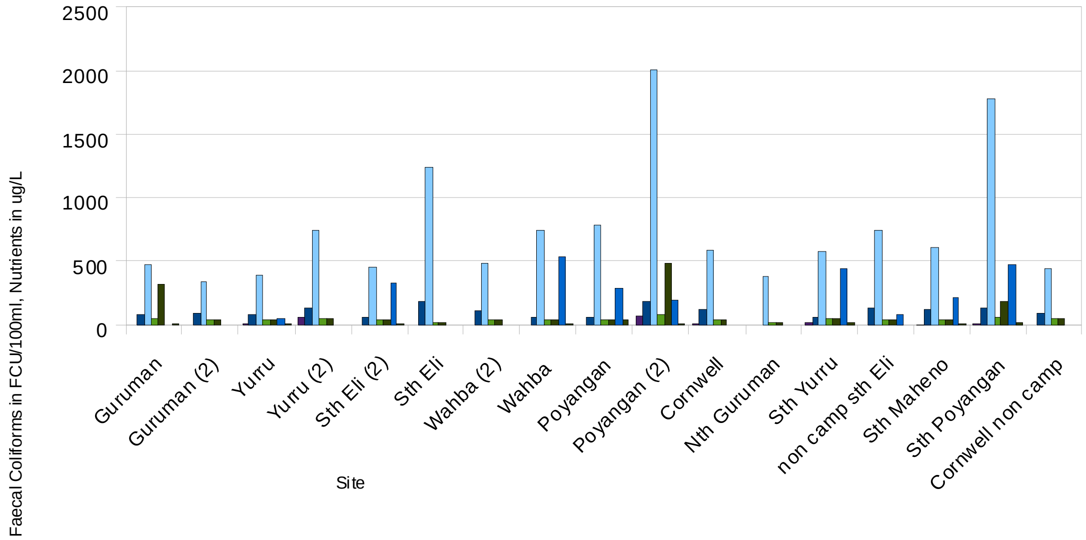

Figure 14: levels of Faecal Coliforms and nutrients found in beach flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Beach Flow Faecal Coliform Results

Levels of faecal coliforms in beach flows in camping and non-camping areas are shown in Figure 15. In camping zones faecal coliforms ranged from zero to 76CFU/100ml and had an average of 15.3CFU/100ml (+/- 27.95). Faecal coliform levels in beach flows in non-camping zones ranged from zero CFU/100ml to 28CFU/100ml, with an average of 6.0CFU/100ml (+/- 11.12).

- Faecal coliform levels were highest at South Poyangan camp zone which had 76CFU/100ml and Yurru (2) camp zone which had 65CFU/100ml.

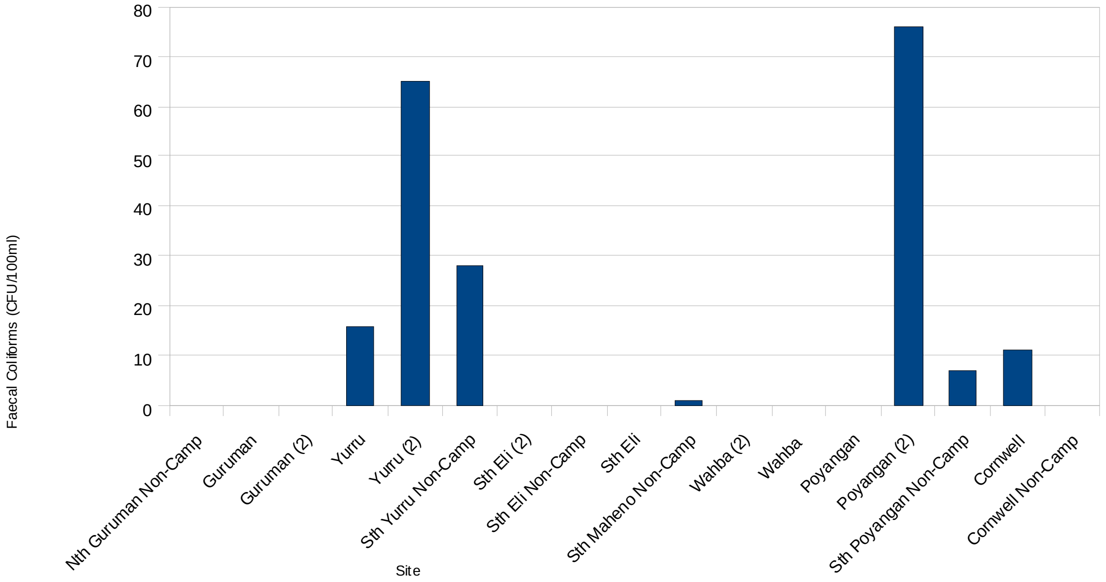

Figure 15: Faecal Coliforms levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Beach flow nutrient results

Total nitrogen

Figure 16 shows total nitrogen levels in beach flows in camping and non-camping zones on Fraser Island. Total nitrogen levels in camping zone beach flows ranged from 355µg/L to 2008µg/L with an average of 748.4µg/L (+/- 488.65). Non-camping zones had total nitrogen levels ranging from 380µg/L to 1775µg/L, with an average of 754.8µg/L (+/- 516.40).

- Poyangan (2) camp zone, and south Eli camping zone had the highest total nitrogen levels, which were 2008µg/L and 1241µg/L respectively. South Poyangan non-camping zone had 1775µg/L total nitrogen.

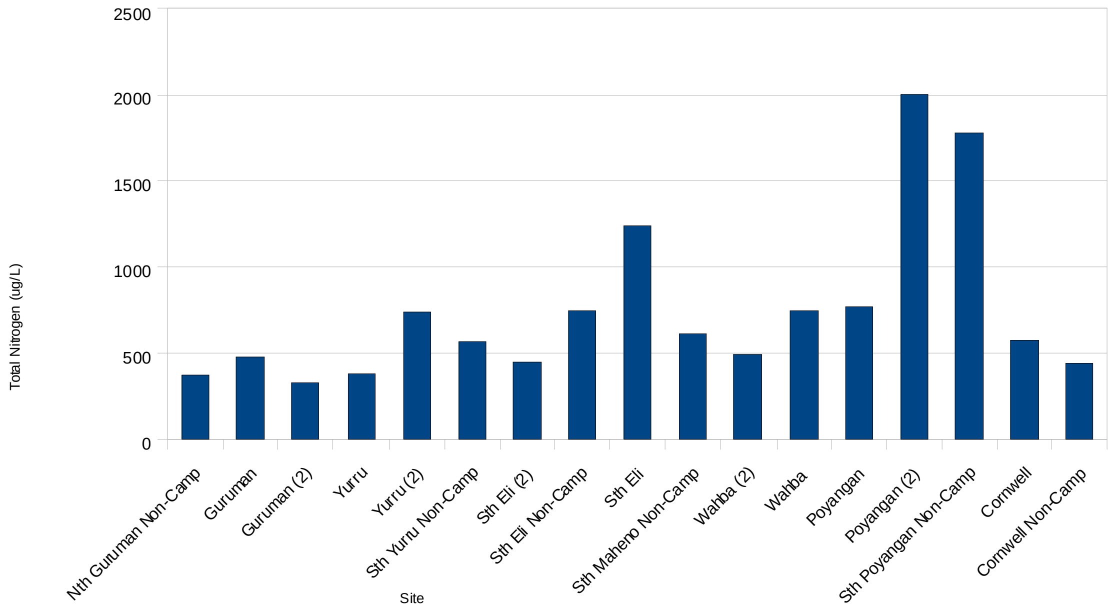

Figure 16: Total nitrogen levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Ammonia

Figure 17 shows levels of ammonia found in beach flows in camping and non-camping zones on the east coast of Fraser island. Ammonia levels in camping zones ranged from 54µg/L to 185µg/L, with an average of 105.9 (+/- 45.34). In non-camping zones ammonia levels ranged between less than 10µg/L and 130µg/L, and had a average of 89.2µg/L (+/- 49.06).

- Campgrounds at Poyangan (2), South Eli, and Yurru (2) had the highest ammonia levels; 193µg/L, 181µg/L and 130µg/L respectively.

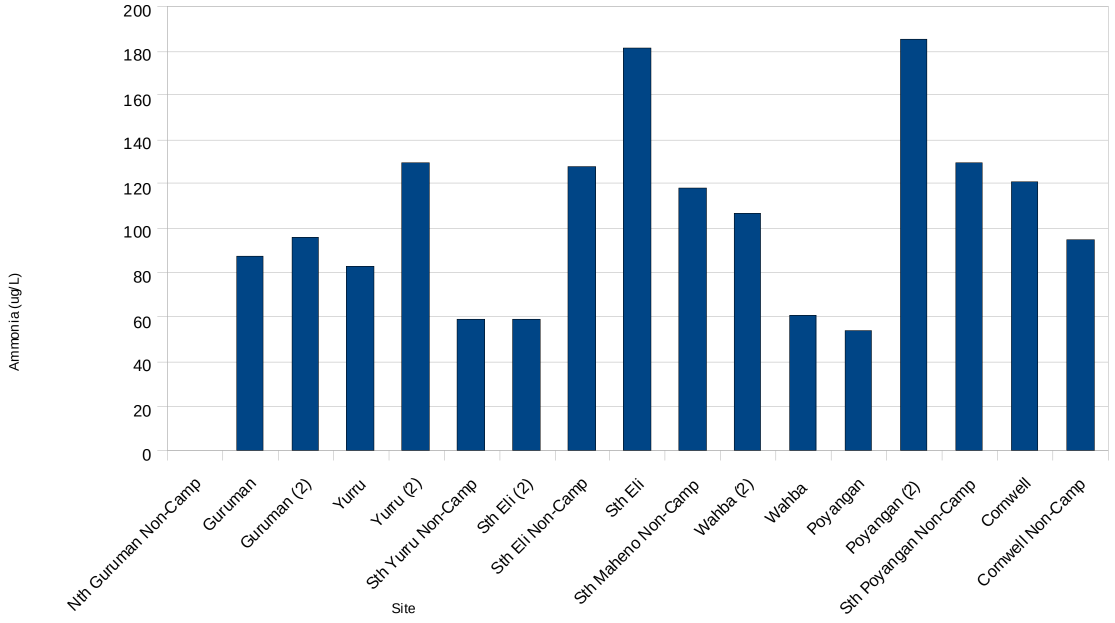

Figure 17: Ammonia levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Nitrates

Levels of Nitrates in beach flows in camping and non-camping zones on Fraser Island are shown in Figure 18. Nitrate levels in beach Flows in camping zones ranged from less than 10µg/L to 540µg/L, and had an average of 129.9µg/L (+/- 184.38). Non-camping zones ranged from less than 10µg/L to 480µg/L with an average nitrate content of 205.8µg/L (+/- 211.94).

- Nitrate levels were highest at Wahba camp zone, and South Eli (2) camp zone, which had 540µg/L and 330µg/L. South Poyangan non-camp zone 480µg/L of nitrates.

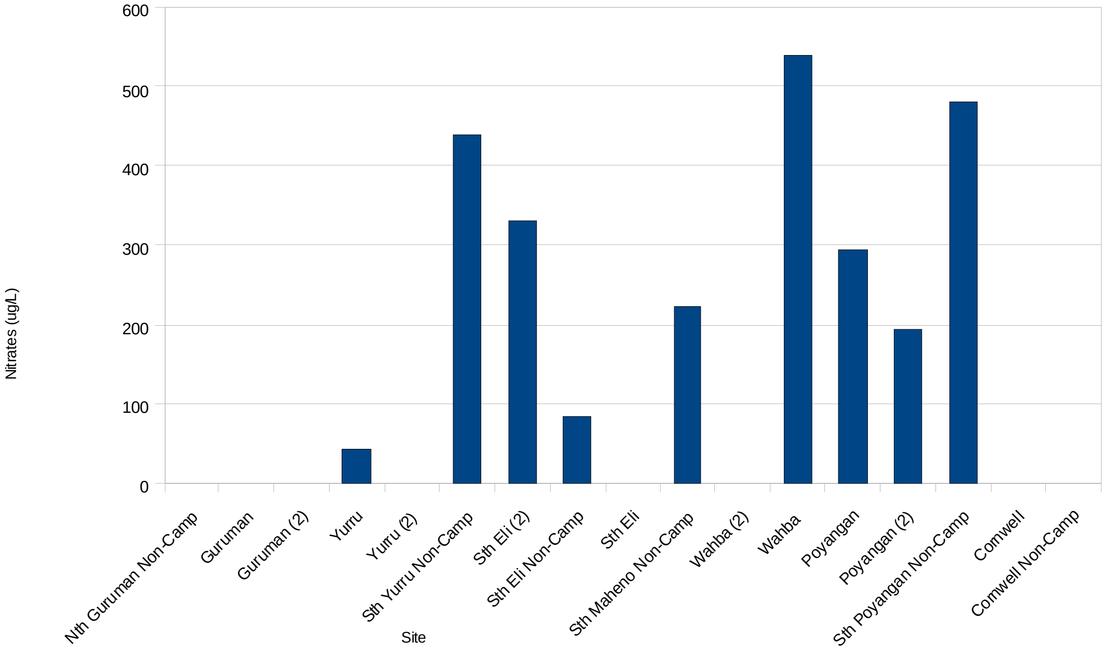

Figure 18. Nitrate levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Nitrites

Nitrite levels in beach flows in camping and non-camping zones are shown in Figure 19. In beach flows in camping zones ranged between less than 10µg/L and 32µg/L of nitrite, with an average of 11.7µg/L (+/- 8.37). In non-camping zones beach flow nitrite levels ranged from less than 10µg/L to 19µg/L, and averaged 11.3µg/L (+/- 7.09).

- Nitrite levels were highest at Poyangan campground, which had 32µg/L. All other sites had nitrite levels lower than 20µg/L.

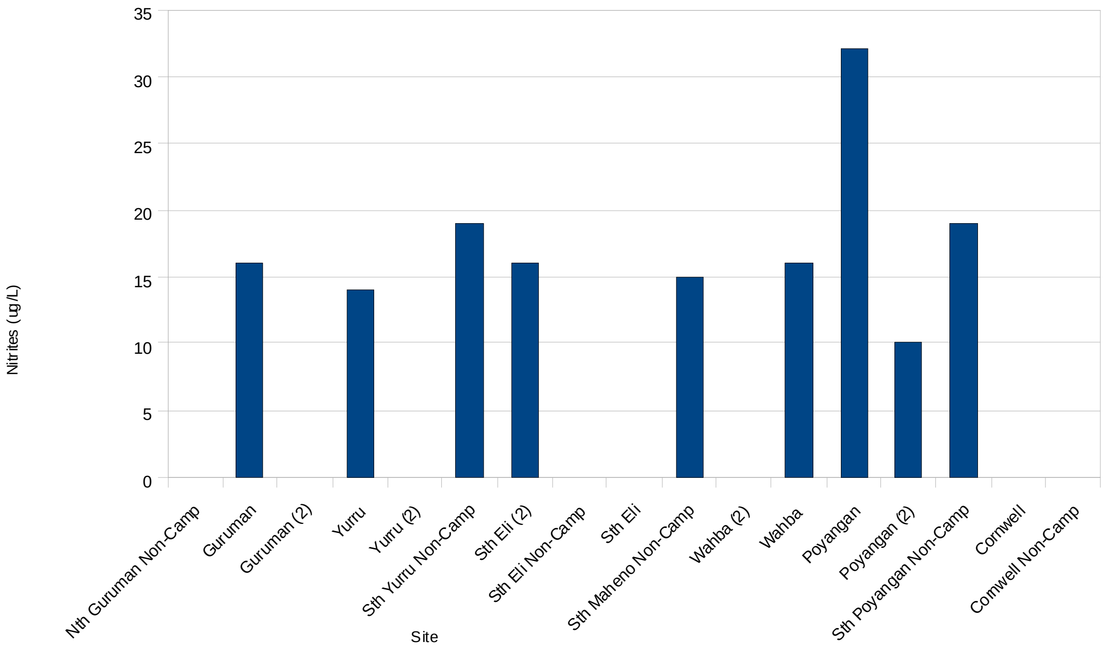

Figure 19: Nitrite levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Total Phosphorus

Figure 20 shows total phosphorus levels found in beach flows in camping and non-camping zones on Fraser Island. Beach flows in camping zones ranged from 28µg/L to 487µg/L and contained an average total phosphorus level of 101.1µg/L (+/- 153.61). In non-camping zones beach flow total phosphorus levels ranged from 23µg/L to 178µg/L with an average of 58.2µg/L (+/- 59.15).

- Total phosphorus levels were highest at camping grounds at Poyangan and Guruman, which had 487µg/L and 317µg/L respectively.
- South Poyangan non-camping zone had 178µg/L of total phosphorus.

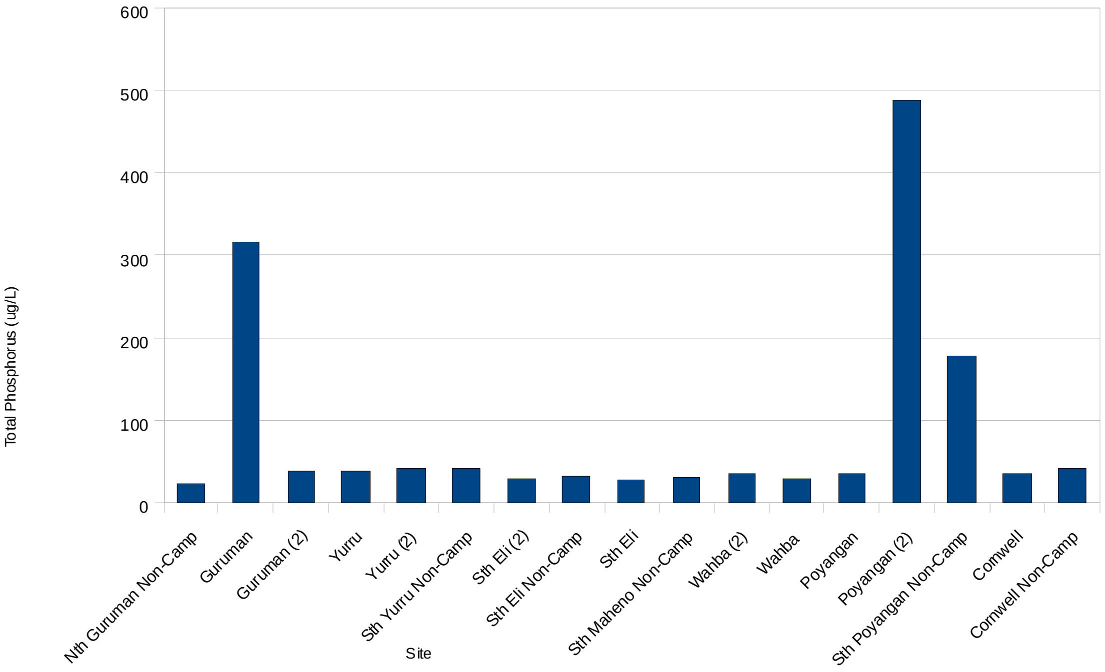

Figure 20: Total Phosphorus levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Phosphates

Phosphate levels in camping and non-camping zone beach flows on the east coast of Fraser Island are shown in Figure 21. Beach flows in camping zones had phosphate levels which ranged from 28 to 85µg/L with an average of 40.3µg/L (+/-16.12). Phosphate levels in non-camping zones ranged from 23µg/L to 58µg/L and averaged 38.2µg/L (+/-12.09).

- Poyangan (2) camp zone and Guruman camp zone had the highest phosphate levels, 85µg/L and 50µg/L respectively.
- South poyangan non-camping zone had the second highest phosphate level, 58µg/L.

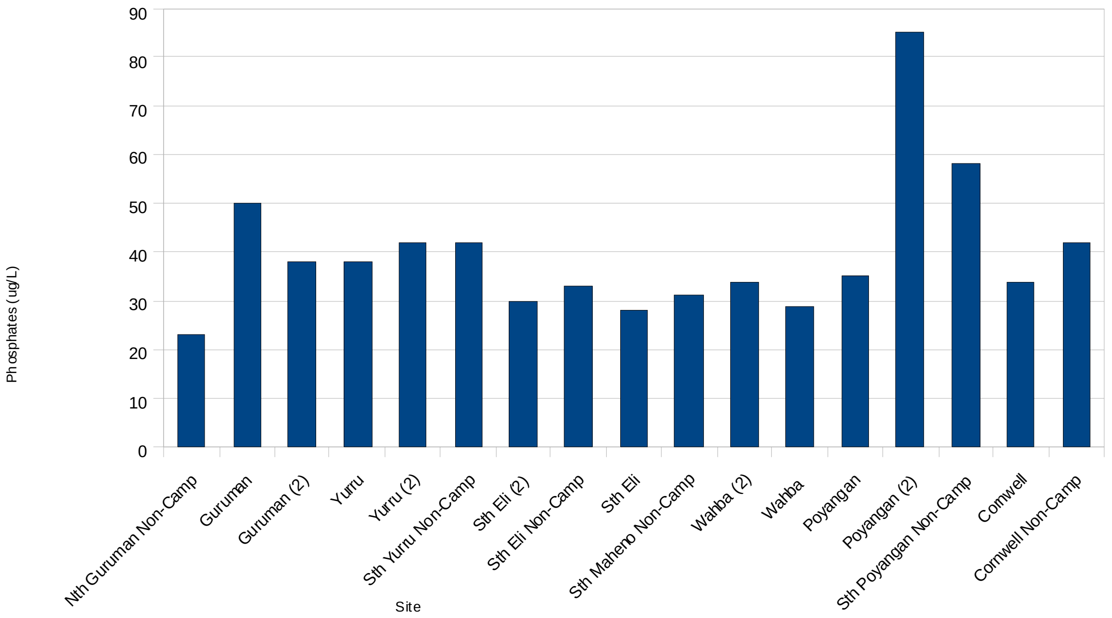

Figure 21: Phosphate levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Discussion

The results from the preliminary scoping study (January 12-15th) showed a trend towards a difference in ground water Nutrient, Faecal coliform and Sterol levels between camping and non-camping zones. Although the results of the January study were not found to be statistically significant, the study was vital in identifying camping areas which were of concern and could be tested on the second round. These areas were Guruman, Yurru, South Maheno, Poyangan and Cornwell Camping zones.

The January preliminary study also confirmed that the techniques used were appropriate and produced results. The first study also did not show a significant difference between water quality of beach flows in camping and non-camping zones. High total nitrogen levels in the control (non-camping) ground water sample were found and because of this, it was decided that more non-camping ground water samples needed to be taken on the February trip. The methods were also altered so that non-camping controls and camp sites would be paired in order to reduce potential confounding factors such as vegetation and landscape differences.

In the second trip, the study area was more focused and the number of camping zones sampled was reduced. Each camping zone was sampled twice and a paired control was sampled in the nearest non-camping zone. As well as this, on the second trip, all coliform preparation and counting was done on the island, due to the fact that coliform data taken on the last day of the January scoping study had given no results and coliform death may have been a factor. The revision of methods lead to detecting significant faecal coliforms in round two.

The results from the intensive February study show there was a difference between indicator levels in the ground water in camping and non-camping zones. The three different indicators which were used all have different ranges of effectiveness, as shown in Figure 21 below. Faecal coliforms indicate faecal contamination, however they only survive for up to two weeks in sand (Private communication, M. Katouli). Dissolved nutrients last longer than coliforms and travel further in the water table, but can also be diluted. Sterols are hotspot markers, they remain stable for a longer period than coliforms (weeks to months), however sterols bind to sand and are therefore spatially contained.

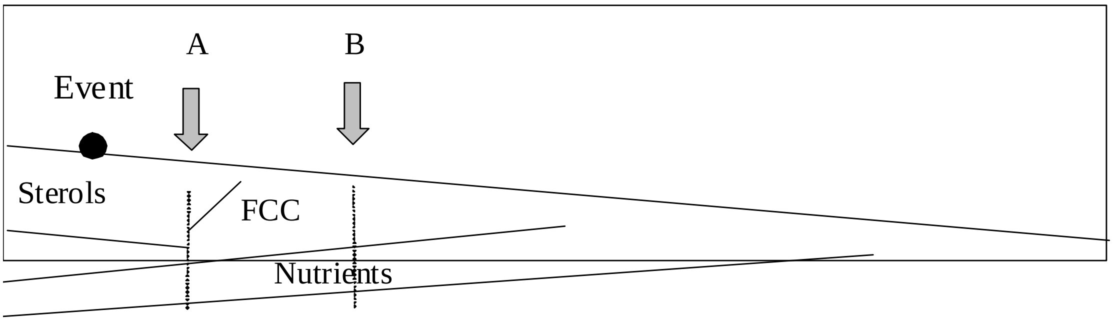

Figure 21. Possible distribution of indicators at time of sampling

If sampling occurs at point A a week after a contamination event nutrients, coliforms and sterols are likely to be detected. If sampled a few meters away, at point B one week after an event only the nutrients and coliforms that have travelled further than the sterols are likely to be detected. However if sampled at point A, a month after a contamination event only sterols and possibly slow released nutrients will be detected. Similarly if samples are taken at point B a month after an event, and a few meters away from the event location, only slow released nutrients are likely to be found. These principles fitted the results of the February study. The three indicators have the same root cause however depending on the time and location of the sampling in relation to that of the contamination event, different indicators will be found. When all three indicators are found they provide strong independent evidence for human faecal contamination in the ground water.

In the ground water, the mean faecal coliform level in camping zones was 43.7 times higher than the mean faecal coliform level in non-camping zones see Figure 5 and Table 1 . Considering the camping and non-camping sites were paired, there should be limited factors which would cause this significant coliform increase other than human waste disposal. There are only 2 camp sites, Guruman and Guruman (2), that were free of faecal coliforms, however this could be due to coliform death before sampling. All the other camping sites showed Fecal coliforms in the ground water. The elevated levels of faecal coliforms in ground water in camping zones were found to be statistically significant ($P<0.05$) at the 95% confidence interval.

Elevated nutrients were also found in the ground water in all six camping zones (see Figures 5 and 6). Average dissolved nutrient levels were 2 to 10.3 times higher in ground water camping zones than in groundwater in non-camping zones (see Table 1). Mean nitrate levels were 10.3 times higher in camping zones. The increase in total nitrogen in ground water in camping zones compared to non-camping zones was found to be statistically significant ($P<0.05$). Nitrate levels in groundwater in camping zones compared to non-camping zones were found to fall short of statistical significance ($P=0.06$).

Coprostanol was found in the ground water of 4 out of 6 of the camping zones (see Table 3). Coprostanol was found at both sites sampled within Poyangan camping ground, and levels at Poyangan (2) were particularly high (4209ng/100g). This corresponds with Poyangan campground's high coliform levels (too numerous to count), high total nitrogen levels (3818μg/L) and high ammonia levels (2191μg/L).

Coprostanol was also found in two of the six non-camping zones; South Eli had 118ng/100g of coprostanol and South Yurru had 493ng/100g of coprostanol. On both trips toilet paper was found in some of the non-camping zones. This is evidence that human waste disposal sometimes occurs in non-camping areas where there is a lower number of people in the area and increased privacy. On the second trip it was noted that South Eli had previously been used as a camping area, which may explain the coprostanol found.

Despite containing coprostanol, groundwater at both South Yurru and South Eli had no faecal coliforms, however this is possibly due to the fact that coprostanol can last longer in the sand than coliforms which die within 1-2 weeks (private communication, M. Katouli). Beach flows were not tested for coprostanol due to the fact that the sterols would not travel through the sand for such great distances.

In Beach flows, levels of Faecal coliforms ($P>0.20$), Total nitrogen ($P>0.40$), Nitrates ($P>0.40$), Total phosphorus ($P>0.40$) and Phosphates ($P>0.40$) were not found to be statistically different between camping and non-camping zones. However ammonia levels were found to be significantly increased in camping zones ($P>0.05$). The lack of a general statistical difference between indicator levels in camping and non-camping zones is likely to be due to dilution of coliforms and nutrients in the water table, as well as the sand (between the actual tent camping area and the intertidal zone) acting as a filter. North-south drifting may also occur in the water table, making differences harder to detect. The dilution also creates another obstacle for difference detection; if the difference in nutrients and faecal coliforms is diluted it is more likely to be masked by variation in other factors such as bird droppings on the beach.

The February study showed an increase in faecal coliforms, ammonia and total phosphorus in beach flows in camping zones compared to non-camping zones (see Table 2), however only ammonia levels reached statistical significance ($P=0.05$). Phosphates tend to bind to minerals and Nitrites often occur in less concentration than Ammonia. This is a concern because shallow water ecosystems are usually low in nutrients, therefore the addition of nutrient compounds, could cause changes to marine algal communities, and alter the shallow water ecosystem.

The elevated nutrients and faecal coliforms found in groundwater in camping zones have the potential to cause significant environmental effects. The fact that coprostanol was found in 4 of the 6 camping zones confirms that the nutrient and coliform input is due to human waste disposal. It is very concerning that faecal coliforms contamination exists in the groundwater on Fraser Island. Due to constant input, it is possible that faecal coliforms would pass into the ground water, causing significant health effects, especially if people on the island use bore water. As well as this, campers may set up camp on top of the previous camp group's toilet site, where unseen dangers such a pathogens may be present. Around the camp site young children playing in the sand, and digging holes can be exposing themselves to pathogens. The risks associated with human waste disposal can remain even when the visible evidence does not.

There are also problems caused by elevated nutrients, due to human waste disposal, reaching the intertidal zone. This study did not find a statistically significant difference in beach flow faecal coliform and nutrient levels between camping and non-camping zones, except for ammonia levels. However a trend to higher levels below camping zones was seen (see Table 2). For example coliform and nutrient levels were high in the ground water at Poyangan camping zone. In the Poyangan beach flow, directly opposite to where the ground water samples were taken, coliform levels were found (76CFU/100ml), that were 10 times higher than coliform levels found in South Poyangan non-camping zone (7CFU/100ml). This indicates that there may be contaminant movement in the ground water table if the level of contamination at the campsite is sufficiently high. Ground water at Poyangan campground had coliform levels that were too numerous to count.

Beach Flow contamination is a cause for concern. Increased faecal coliform levels, and therefore increased pathogen levels, pose a health risk to the children that play in the beach flows, and the fishermen that fish there. Contamination may also accumulate in filter feeding shell fish, such as Pippies, which people collect to eat. The mean faecal coliform levels in beach flows in camping zones were found to be twice as high as the mean faecal coliform levels in beach flows in non-camping zones.

Further research needs to be carried out to determine the extent of the problem. As well as investigating whether there is a relationship between intensity of camp site use and level of faecal contamination in the ground water. Further research could also include sampling during or directly after peak tourist seasons, longitudinal studies and studies investigating the effect of excess nutrients on dune vegetation.

Conclusion

This study found faecal coliform levels and nutrient levels to be significantly increased in ground water in camping zones compared to non-camping zones on Fraser Island. Mean nutrient and Faecal coliform levels were 2 to 10 times higher in camping zones than in non-camping zones. Elevated levels of the sterol coprostanol were found at 4 out of the 6 Camping zones. The only significant source of coprostanol on Fraser Island is human faecal matter. This provides strong evidence of human faecal contamination in the ground water. Accumulation of faecal coliforms and nutrients in the ground water would introduce the potential for nutrient and faecal coliforms to flow out onto the beach zone at low tide. The results also showed a strong trend towards increased faecal coliform levels in beach flows from camping zones. Mean faecal coliform levels in beach flows in camping zones were twice as high as mean faecal coliforms in beach flows in non-camping zones. The contamination detected by this study is a serious concern and management action may be required to protect Fraser Island from possible detrimental consequences. Solutions may include rotating camping zones and non-camping zones, enforcing the use of portable toilets, visitor education, building amenities in heavily used camp zones or closing beach camping completely. In order for management to correctly address the problems, further research aimed at determining the scope of the problem, the effect of camper numbers as well as campsite density is needed.

References:

Anna, M. Gajda, T., Brown, J., Peregoodoff, G., Bartier, P. 2000, Managing coastal recreational impacts and visitor experience using GIS. *USDA Forest Service Proceedings*, vol 5. p15.

Arthington A.H., Miller G.J. & Outridge P. M., 1990. Water quality, phosphorus budgets and management of dune lakes used for recreation in Queensland (Australia). *Water Sciences Technology* 21: 111-118

Boehm, A., Paytan, A., Shellenbarger, G. G., Davis, K. A., 2006. Composition and flux of groundwater from a California beach aquifer: implications for nutrient supply to the surf zone. *Continental Shelf Research*, 26, 2, 269-282.

Bridle, K. and Kirkpatrick, J., 2003. Impacts of nutrient additions and digging for human waste disposal in natural environments, Tasmania, Australia., *Journal of Environmental Management.* 69, 3, 299-306.

Burns G. L. & Howard P., 2003, When wildlife tourism goes wrong: a case study of stakeholder and management issues regarding Dingoes on Fraser Island, Australia, Faculty of Environmental Sciences, Griffith University, Australia.

Campbell, E. E. and Bate, G. C. 1998, Tide induced pulsing of nutrient discharge from an unconfined aquifer into an *Anaulus australis*-dominated surf-zone., Department of Botany, University of Port Elizabeth, South Africa.

Clesceri L.S., Greenberg A.E., and Eaton A.D., *Standard methods for the examination of water and waste water*, 20th Edition, published by American Public Health Association, American Water Works Association, and the Water Environment Federation, 1998)

Cole, D. N., 2006. Modeling wilderness campsites: Factors that influence amount of impact., US Department of Agriculture. *Journal of Environmental Management.* 16, 2, 255-264.

Connors, J. J., 2007, Groundwater flow dynamics and associated inorganic nitrogen transport, Weeks Bay, Alabama. The University of South Alabama

Emery, K.O. & Foster J.F., 1948, Water tables in a marine beach, *Journal of Marine Research*. Mar. Res., 7, 644-654

EPA, 2005. Great Sandy Region Management Plan 1994-2010. Environmental Protection Agency Revised version September 2005.

Hadwen, W.L., 2002. Effects of Nutrient Additions on Dune Lakes on Fraser Island, Australia., Griffith University,

Hockings, M & Twyford, K. 1997. Assessment and Management of Beach Camping Impacts within Fraser Island World Heritage Area, South East Queensland, *Australian Journal of Environmental Management,* vol 4, 26-39.

Hockings, M. 1998. Evaluation and Management of Protected Areas: Integrated Planning and Evaluation. *Environmental Management.*, 22, 3, 337-345.

Kirkpatrick J.B. & Harris S., 1999. The disappearing heath revisited, Tasmanian Environment Center Hobart.

Leeming R., Ball A., Ashbolt N. & Nicholls P., 1996, Using faecal sterols from humans and animals to distinguish faecal pollution in receiving waters. Water Research, 30 (12): 2893-2900.

Marion J. L. and Farrel T. A., 2002. Management practices that concentrate visitor activities: camping impact management at Isle Royale National Park, USA. *US Geological Survey. Department of Forestry.*

Mosisch T. D. & Arthington A.H, 2001. Polycyclic aromatic hydrocarbon residues in the sediments of a dune lake as a result of power boating. *Lakes and Reservoirs: Research and Management* 6: 21-32.

Moss, D. and McPhee, D. P., 2006. Impacts of Recreational Four-Wheel Driving on the abundance of the Ghost Crab (*Ocypode cordimanus*) on a Subtropical Sandy Beach in SE Queensland. *Coastal Management*. 34, 133-140.

Schlacher, T. A., Richardson, D., McLean, I., 2008. Impacts of Off Road Vechiles (ORV's) on Macrobenthic Assemblages on sandy beaches., *Journal of Environmental Management.*, 41, 6, 878-892.

Schlacher, T. A. and Thompson, L. M. C., 2007. Exposure of Fauna to Off Road Vechiles (ORV) Traffic on Sandy beaches. *Coastal Management. 35, 5, 567-583*

Thompson, L. M. C. and Schlacher, T. A., 2008. Physical damage to coastal dunes and ecological impacts caused by vehicle tracks associated with beach camping on Fraser Island, Australia. *J. Coastal Conservation.*

Uchiyama, Y., Kazuo, N., Rolke, P., Adachi, K., Yagi, H., 2000. Submarine groundwater discharge into the sea and associated nutrient transport in a sandy beach, *Water Resources Research*, 36, 6, 1467-1479,

Wheeler Alm, E., 2003. Faecal indicator bacteria are abundant in wet sand at fresh water beaches,*Water Research*, 37, 16, 3978-3982.

Appendix 1

Ground Water Results (February 9-11, 2009)

Table 4: Nutrients and Faecal Coliforms levels found in ground water in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Site Name	Faecal Coliforms CFU/100ml	Total N µg/L	NH3-N µg/L	NO3 µg/L	NO2 µg/L	Total P µg/L	PO4-P µg/L
Camping Zones							
Guruman	0	4144	1729	2270	34	415	415
Guruman (2)	0	3455	576	2706	45	81	65
Yurru	999	3273	182	1435	12	83	83
Yurru (2)	999	4252	634	2540	133	151	140
Wahba	200	1633	494	207	19	41	41
South Eli	200	2072	723	103	17	58	28
South Eli (2)	210	2354	587	1182	11	28	28
Poyangan	80	1692	112	526	21	43	43
Poyangan (2)	999	1739	400	169	<10	28	28
Cornwell	655	3818	2191	863	<10	46	<10
Non-Camping Zones							
North Guruman	0	1830	135	210	<10	33	33
South Yurru	0	1507	359	35	<10	110	110
South Maheno	0	1251	348	96	<10	29	29
Non camp south Eli	0	1010	291	<10	<10	21	21
South Poyangan	0	944	197	248	51	71	30
Cornwell non camp	90	1401	658	107	<10	29	29

Appendix 2

Beach Flow Results (February 9-11, 2009)

Table 5: Nutrients and Faecal Coliforms levels found in Beach Flows in camping vs. non-camping zones on the east coast of Fraser Island, Australia

Site Name	**Faecal Coliforms**	**Total N**	**NH3-N**	**NO3**	**NO2**	**Total P**	**PO4-P**
	CFU/100ml	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Camping Zones							
Guruman	0	480	88	<10	16	317	50
Guruman (2)	0	335	96	<10	<10	38	38
Yurru	16	388	83	43	14	38	38
Yurru (2)	65	741	130	<10	<10	42	42
South Eli (2)	0	451	59	330	16	30	30
South Eli	0	1241	181	<10	<10	28	28
Wahba (2)	0	487	107	<10	<10	34	34
Wahba	0	743	61	540	16	29	29
Poyangan	0	777	54	293	32	35	35
Poyangan (2)	76	2008	185	193	10	487	85
Cornwell	11	581	121	<10	<10	34	34
Non- Camping Zones							
North Guruman	0	380	<10	<10	<10	23	23
South Yurru	28	571	59	438	19	42	42
Non camp south Eli	0	749	128	85	<10	33	33
South Maheno	1	612	118	222	15	31	31
South Poyangan	7	1775	130	480	19	178	58
Cornwell non camp	0	442	95	<10	<10	42	42

Appendix 3

Ground Water Statistics (February 9-11, 2009)

	Camp zone mean	Non Camping	Difference
Faecal Coliforms			
Guruman	0	0	0
Yurru	999	0	999
South Eli	200	0	200
Wahba	205	0	205
Poyangan	539.5	0	539.5
Cornwell	655	90	565
Mean	**433.1**	**15.0**	**418.1**
Standard Dev	**367.35**	**36.74**	**358.20**
Total Nitrogen			
Guruman	3799.5	1830	1969.5
Yurru	3762.5	1507	2255.5
South Eli	1633	1251	382
Wahba	2213	1010	1203
Poyangan	1715.5	944	771.5
Cornwell	3818	1401	2417
Mean	**2823.6**	**1323.8**	**1499.8**
Standard Dev	**1080.83**	**329.78**	**836.77**
Nitrates			
Guruman	2488	210	2278
Yurru	1987.5	35	1952.5
South Eli	207	96	111
Wahba	642.5	5	637.5
Poyangan	347.5	248	99.5
Cornwell	863	107	756
Mean	**1089.3**	**116.8**	**972.4**
Standard Dev	**931.95**	**95.52**	**930.39**
Nitrites			
Guruman	39.5	5	34.5
Yurru	72.5	5	67.5
South Eli	19	5	14
Wahba	14	5	9
Poyangan	488.25	51	437.25
Cornwell	5	5	0
Mean	**106.4**	**12.7**	**93.7**
Standard Dev	**188.62**	**18.78**	**170.01**
Ammonia			
Guruman	1152.5	135	1017.5
Yurru	408	359	49
South Eli	494	348	146

	Camp zone mean	Non Camping	Difference
Wahba	655	291	364
Poyangan	256	197	59
Cornwell	2191	658	1533
Mean	**859.4**	**331.3**	**528.1**
Standard Dev	**721.42**	**182.19**	**611.86**
Total Phosphorus			
Guruman	248	33	215
Yurru	117	110	7
South Eli	41	29	12
Wahba	43	21	22
Poyangan	35.5	71	-35.5
Cornwell	46	29	17
Mean	**88.4**	**48.8**	**39.6**
Standard Dev	**83.90**	**34.77**	**88.37**
Phosphates			
Guruman	240	33	207
Yurru	115	110	1.5
South Eli	41	29	12
Wahba	28	21	7
Poyangan	35.5	30	5.5
Cornwell	5	29	-24
Mean	**77.4**	**42.0**	**34.8**
Standard Dev	**87.88**	**33.55**	**85.29**

Beach Flow Statistics (February 9-11, 2009)

	Camp zone mean	Non Camping	Difference
Faecal Coliforms			
Guruman	0	0	0
Yurru	40.5	28	12.5
South Eli	0	0	0
Wahba	0	1	-1
Poyangan	38	7	31
Cornwell	11	0	11
Mean	**14.9**	**6.0**	**8.9**
Standard Dev	**19.34**	**11.12**	**12.35**
Total Nitrogen			
Guruman	407.5	380	27.5
Yurru	564.5	571	-6.5
South Eli	846	749	97
Wahba	615	612	3
Poyangan	1392.5	1775	-382.5
Cornwell	581	442	139
Mean	**734.4**	**754.8**	**-20.4**

	Camp zone mean	Non Camping	Difference
Standard Dev	**351.87**	**516.40**	**186.19**
Nitrates			
Guruman	5	5	0
Yurru	43	438	-395
South Eli	167.5	85	82.5
Wahba	540	222	318
Poyangan	243	480	-237
Cornwell	5	5	0
Mean	**167.3**	**205.8**	**-38.6**
Standard Dev	**206.29**	**211.94**	**249.48**
Ammonia			
Guruman	92	5	87
Yurru	106.5	59	47.5
South Eli	120	128	8
Wahba	84	118	34
Poyangan	119.5	130	-10.5
Cornwell	121	95	26
Mean	**107.2**	**89.2**	**32.0**
Standard Dev	**15.97**	**49.06**	**33.73**
Total Phosphorus			
Guruman	177.5	23	154.5
Yurru	40	42	-2
South Eli	29	33	-4
Wahba	31.5	31	0.5
Poyangan	261	178	83
Cornwell	34	42	-8
Mean	**95.5**	**58.2**	**37.3**
Standard Dev	**99.49**	**59.15**	**67.05**
Phosphates			
Guruman	44	23	21
Yurru	40	42	-2
South Eli	29	33	-4
Wahba	31.5	31	0.5
Poyangan	60	58	2
Cornwell	34	42	-8
Mean	**39.8**	**38.2**	**1.6**
Standard Dev	**11.36**	**12.09**	**10.14**