The direct impact of recreation on water quality in the Great Barrier Reef Marine Park

Report prepared for the Great Barrier Reef Marine Park Authority

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Disclaimer

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Acronyms

GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
hp	Horsepower
IMO	International Maritime Organisation
INCI	International Nomenclature for Chemical Ingredients
MTBE	Methyl-*tertiary*-butyl ether
OEDA	Outboard Engine Distributors Australia
TBT	Tributyltin

Executive Summary

The research presented in this report was funded by the Great Barrier Reef Marine Park Authority.

The research objective was to establish an empirical connection between recreational activities in the Great Barrier Reef Marine Park and water quality. It was to lay the conceptual and methodological foundation for a subsequent study that would quantify the impact by independent recreational visitors on water quality in the Marine Park.

The study adopts the definition by the Great Barrier Reef Marine Park Authority of recreation as 'a self-guided visit for fun to the Great Barrier Reef Marine Park that is non-commercial, non-research and not incurring the Environmental Management Charge—i.e. not a tourist visit'. This definition does not concern itself with the distance of people's residence to the Marine Park. Using this definition, independent recreational visitors include e.g. visiting sailors, recreational boaters and anglers, swimmers, private scuba divers, and independent travellers visiting the Marine Park.

A literature review established the key relationship between uses of the Marine Park for recreational and tourist purposes and the polluting properties of associated activities.

To scope the possible extent of impact, per person or per recreational activity, the research conducted surveys of shore-based and vessel-based independent recreational visitors. There were three survey locations, namely Cairns, Mackay and Airlie Beach. The field work was conducted on ten days during late July – mid August 2008.

A face-to-face survey was conducted of 90 shore-based independent recreational visitors, with 30 respondents for each location. The response included a total of 168 persons. The survey explored broad recreational activity patterns, observations and attitudes.

A mail-return survey was conducted of vessel-based independent recreational visitors, which yielded 85 valid responses. The response included 272 persons. The survey explored detailed activity patterns, observations and attitudes.

The research found no empirical evidence, direct or anecdotal, that shore-based recreational activities caused anything other than minor and localised water quality impacts. There is likely minimal impact on water quality from shore based recreational activities including dogs and horses on beaches, driving cars on beaches, and beach camping. Any localised issues may be addressed locally, e.g. through management by local government.

The research found empirical evidence of water quality impacts arising from vessel-based recreational activities in the Marine Park.

The research found that during boat trips, independent recreational visitors commonly discharged human excrement and urine into the marine environment. Because of the overall small recreational load and the largely diffuse character of recreational activities in the Marine Park this is unlikely to cause water quality issues.

The research found that 2-stroke carburettor engines were the most common engine type fitted to recreational vessels used by survey participants. Fuel-injected and carburettor 2-stroke engines accounted for approximately 50% of engines used. The emissions of 2-stroke engines, particularly of the carburettor type, contain many toxins, which are directly injected into the marine environment. Effectively, 2-stroke carburettor motors for boats can no longer be operated in Europe and the United States because of strict emissions limits for marine watercraft in these countries (Environment Link, 2007).

The research found widespread use of antifouling on vessels. Antifouling commonly contains copper and/or organic biocides. While TBT-based antifouling paints are now officially banned,

there are a range of other coatings available to boat owners. There is a lack of information on levels of copper and organic biocides from antifouling paints in the Marine Park.

Independent recreational visitors of the Great Barrier Reef Marine Park, shore and vessel-based, regard rubbish as the key water quality issue, possibly because of its visual prevalence. Rubbish is attributed partially to recreational activities, but mainly to urban areas in general and tourists.

On the basis of this research, a series of conclusions can be drawn.

Any management measures for the Great Barrier Reef Marine Park can draw on the high intrinsic value that independent recreational visitors, shore based and vessel-based, hold for the Marine Park, and their willingness to moderate their own actions for the good of the Marine Park.

Information campaigns about the Marine Park work best if they include television advertisements and print material that is available at tackle shops or as newspaper articles.

The water quality impact from recreation of most concern arises from the wide-spread use of outboard 2-stroke carburettor-type engines. Many countries have effectively curbed the sale of 2-stroke carburettor type engines for boats through the regulation of emissions. There are potential strategies that the Great Barrier Reef Marine Park Authority can undertake to address this pollution problem, including lobbying for effective national boat engine emission standards, working towards voluntary emission labelling or star rating of boat engines, providing information about boat engines to the general public and boat owners in particular, and initiating a buyback scheme.

More research is needed to understand both critical levels of toxicity of antifouling substances and the levels found in different regions within and adjacent to the Marine Park.

Future research into recreational use aspects of the Marine Park can build on the methodological approaches designed and tested in this study. The combination of face-to-face survey of shore-based independent recreational visitors and mail-return survey of vessel-based independent recreational visitors proved powerful. To deliver results with good statistical confidence intervals, any survey needs to be comprehensive in temporal and geographical scale and requires a large sample size to account for the diversity of values and use profiles, and the diversity and variability of uses. Importantly, the method needs to be able to capture all types of independent recreational visitors, including visitors to the region, namely inter and intra-state travellers with trailer boats and those who have sailed from other regions, including overseas.

1 Introduction

1.1 Background to the research

The Great Barrier Reef is an extensive reef system extending from the tip of Cape York in Queensland in the north almost down to Bundaberg in the south (Figure 1). The Great Barrier Reef is a declared World Heritage Area having been added to the list of World Heritage Areas in 1981. Globally, it remains the largest such area as well as being one of only a few sites to meet all four natural world heritage criteria (DEWHA, 2008) which are (UNESCO, 2008);

- To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
- To be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
- To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
- To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

The Great Barrier Reef Marine Park was established in 1975 to protect the area for the enjoyment of everyone and for its sustainable use (Great Barrier Reef Marine Park Authority, 2004). It is a multiple-use area managed to protect environmental, social and economic values (Great Barrier Reef Marine Park Authority, 2008b). Access Economics (2008) conducted a valuation of the Marine Park for the 2006/07 financial year. Using values of financial transactions only (i.e. not including non-market values such as environmental and recreational use values), it was estimated that the Marine Park contributed $4 billion to the Queensland economy (value added) in 2006/07 with tourism accounting for the majority of value and recreational activities accounting for approximately 2.6% (Access Economics, 2008). Residents of statistical local areas adjacent to the Marine Park contributed approximately 25% to the value added figure.

The Marine Park covers the entire Great Barrier Reef as well as lagoons and in-shore areas to the low-water mark (Figure 1). Management by the Great Barrier Reef Marine Park Authority provides for its long-term protection and ecologically sustainable use (Great Barrier Reef Marine Park Authority, 2008b).

Management of the Marine Park is guided by four key principles, which are (Great Barrier Reef Marine Park Authority, 2008b);

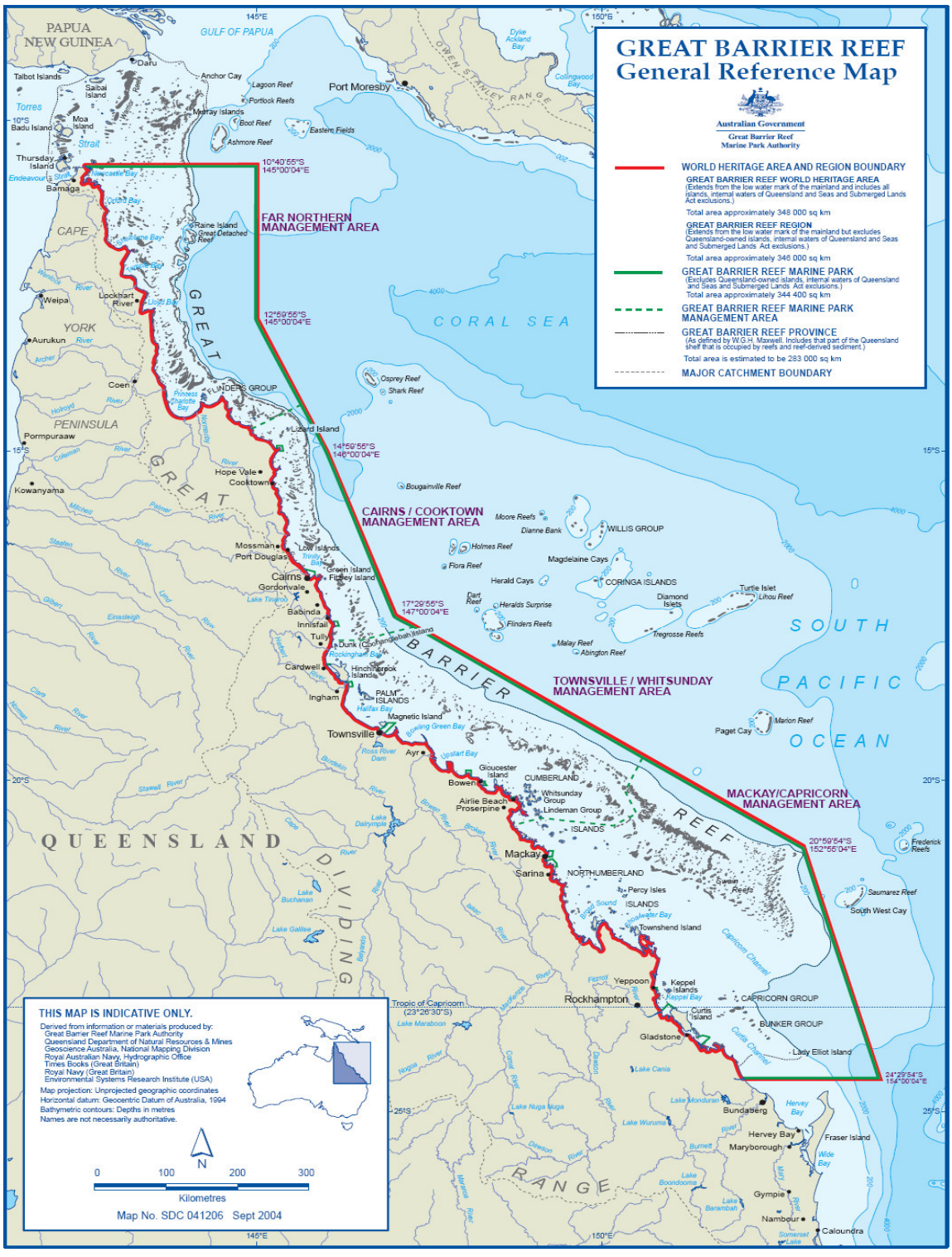
- Ecosystem level management
- Conservation and reasonable use
- Public participation and community involvement
- Monitoring and performance evaluation of management

The management principle of reasonable use covers all existing activities in the Marine Park including, but not limited to, commercial fishing, tourism, shipping, aquaculture, and recreation. These activities have been examined to varying extents from a sustainability and environmental management perspective over time with the aims of understanding and limiting their impacts (Access Economics, 2008; DAFF, 2008; Driml, 1999; Great Barrier Reef Marine Park Authority, 2008a; Harriott, 2002; Moscardo and Ormsby, 2004; Ormsby *et al*., 2004; Ormsby, 2004; Rouphael and Inligs, 2001). Recreation has received little attention so there is a paucity of information available on recreational activities, the types of actions occurring during recreational

activities that may be pertinent for the sustainable use of the Marine Park and also the extent of recreational activity being undertaken within the Marine Park.

Figure 1: Map of the Great Barrier Reef Marine Park

Source: (Great Barrier Reef Marine Park Authority, 2008b)



Water quality is a key concern for the health of the Great Barrier Reef (Australian Government, 2003; CRC Reef, 2008). Several research projects have investigated the influences of human activities on water quality in the Great Barrier Reef and the influences of different aspects of water quality on the biodiversity of the Great Barrier Reef (Australian Government, 2003; Great Barrier Reef Marine Park Authority, 2001; Harriott, 2002; Hutchings *et al.*, 2005). Major water quality variables affecting coral reef health include; water temperature, salinity, nutrient and suspended sediment concentrations, and toxicants (Great Barrier Reef Marine Park Authority, 2008d).

Recreational activities in the Marine Park and in coastal locations adjacent to it contribute nutrients, toxins and other pollutants to the waters of the Reef (Danovaro *et al.*, 2008; Environment Link, 2007; Haynes and Johnson, 2000; Leon and Warnken, 2008). A first step towards managing such activities with regards to water quality is to understand the types of impacts caused by marine and coastal recreational activities and their likely influence on the marine environment.

1.2 Terms of reference

This report documents the outcomes of a project that had the objectives of:

- Establishing an understanding of the range of recreational activities and the relative hazard they pose to water quality in the Great Barrier Reef Marine Park;
- Establishing an understanding of the sorts of behaviours associated with recreational activities and how these may impact negatively on water quality;
- Estimating the relative frequency of recreational activities; and
- Providing a scientific description of how different behaviours and activities impact on water quality in the Great Barrier Reef.

1.3 Definitions of “recreation” and “water quality”

It is important to clarify the terms “recreation” and “water quality” which are used throughout this report.

Recreation:

Recreation is generally defined as “an activity that diverts or amuses or stimulates” (Princeton wordnet, 2008). In many studies the term “recreation” is the residual of the definition for tourism, for example the National Oceans Office (2002) defines recreation as “activities that do not fit into the tourism category”.

Ormsby *et al.* (2004) define tourists as any persons travelling to a place that is not their usual environment for less than 12 months with a main purpose that is other than to work for pay. Independent recreational visitors are defined as people visiting natural environments who are not tourists, i.e. the environment being visited is close to their normal residence (Ormsby *et al.*, 2004).

The Great Barrier Reef Marine Park Authority defines tourists as being persons who use commercial operators to access the Marine Park and therefore pay the Environmental Management Charge (EMC). Fernbach (2008) argues that the purpose of defining recreation with respect to the Marine Park is to “identify groups of individuals who are not currently being accessed or communicated with via existing channels”. Recreation is thus defined as (Fernbach, 2008):

> *"A self-guided visit for fun to the Marine Park that is non-commercial, non-research and not incurring the Environmental Management Charge (EMC)—i.e. not a tourist visit".*

The Great Barrier Reef Marine Park Authority definition of recreation does not concern itself with where people reside. Using this definition, recreation activities are undertaken by independent recreational visitors, including visiting sailors, recreational boaters and anglers, swimmers, private scuba divers, and independent travellers visiting the Marine Park.

Water quality:

Water quality is defined as the physical, chemical and biological characteristics of water (Wikipedia, 2008). Water quality impacts resulting from recreational activities are changes to the physical, chemical and/or biological characteristics of water.

1.4 Structure of the report

This report contains seven sections (including the introduction).

Section 2 reviews existing information on water quality impacts of various chemicals associated with recreation and tourism. This information provides background to the development of survey methodology and context for results from the empirical research

Section 3 describes the processes employed in the empirical component of this research and the methods used for statistical analysis of the data obtained. It also explains the ethical considerations to which River Consulting subscribes for the survey process and questionnaire design.

Section 4 presents the results of a face-to-face survey of shore-based independent recreational visitors.

Section 5 presents results of a mail-return survey of vessel-based independent recreational visitors.

Section 6 provides an interpretation of results using the background information as context. It describes themes and general findings with reference to the objectives of the research.

Section 7 presents conclusions and recommendations.

2 Existing information

There is a paucity of existing information on the water quality impacts of recreational activities in marine locations. Water quality impacts of tourism are, however, well researched and there are significant similarities between recreational activities and tourist activities. These similarities aid in identifying the types of water quality impacts recreational activities may have in and adjacent to the Great Barrier Reef Marine Park. This section outlines types of recreational activities and where they occur within the Marine Park, relationships between recreational activities and pollutants or polluting behaviours and finally, the relationships between pollutants and water quality.

2.1 Recreational use of the Great Barrier Reef Marine Park

The Marine Park is an important recreational resource for people living in areas adjacent to it and for those visiting from other domestic or international locations. The definition of independent recreational visitors given in section 1.3 is broad and includes a wide cross-section of individuals and groups who may be engaged in leisure activity within the Marine Park.

An estimated 85% of tourist visitation within the Great Barrier Reef occurs primarily in two destinations, namely Cairns and the Whitsundays (Harriott, 2002). High levels of recreational activity within the Great Barrier Reef occur around regional centres adjacent to the Marine Park (Great Barrier Reef Marine Park Authority, 2008a). Fernbach (2008) also notes that Queensland coastal residents visit the Marine Park more frequently than any other group.

A survey of recreational and tourist activity in the Marine Park was conducted by Norris *et al.* (2003). Telephone interviews were used to survey 1,369 residents in the region about recreational use of the Marine Park. Norris *et al.* (2003) differentiated between residents and visitors in their survey. Residents were considered to be people living within 50 kilometres of the coast adjacent to the Marine Park and accessing the Marine Park as independent recreational visitors. Visitors were those who accessed the Marine Park using a commercial tour operator—these were surveyed either as passengers of vessels being ferried to tour operations or who were part of tour operations. Some key results from this research are presented below.

The highest level of participation in recreational activities in the Marine Park occurred amongst 31-40 year olds (Norris *et al.*, 2003). Residents aged 31-60 years accounted for 66% of non-vessel-based recreation and 72% of vessel-based recreation. Norris *et al.* (2003, p.24) estimated that 4,942,000 visits were made to the Marine Park by residents living within 50km of the coast adjacent to the Marine Park.

Resident independent recreational visitors of the Marine Park were asked to nominate the three most serious threats to the Great Barrier Reef (Norris *et al.*, 2003). Table 1 shows that over half of the respondents rated fishing as one of the most serious threats to the Reef. Other perceived threats were rubbish and pollution (29% of telephone respondents), oil spills/oil from boats (26% of telephone respondents) and boats/ships and the pollution coming from them (22% of telephone respondents).

The range and relative frequency of activities undertaken by independent recreational visitors of the Marine Park are presented in Table 2. Swimming was the most frequent non-vessel-based activity. Motorised boating and fishing were the most frequent vessel-based activities.

Fishing and snorkelling were undertaken as both vessel-based and non vessel-based activities, with their relative frequency of occurrence being higher from vessels. Fishing activities were undertaken by 72% of vessel-based and by 31% of non vessel-based independent recreational visitors. Snorkelling was undertaken by 35% of vessel-based and by 17% of non vessel-based independent recreational visitors of the Marine Park (Norris *et al.*, 2003).

Table 1: Perceived threats to the Great Barrier Reef

Percentage of telephone survey respondents, by category

Source: Adapted from Norris *et al.* (2003)

Threats	ALL RESPONDENTS	Not been in GBRMP in last 12 months	Been in GBRMP in last 12 months	
			Not vessel-based	Vessel-based
Fishing	53%	43%	54%	72%
Agricultural run off	35%	35%	33%	37%
Crown of Thorns starfish	30%	32%	28%	27%
Rubbish and pollution	29%	26%	35%	29%
Oil spills/oil from boats	26%	28%	27%	23%
Boats/ships (anchorage, presence, pollution),	22%	20%	23%	24%
Tourists/Tourism infrastructure	18%	17%	18%	18%
Coral damage – from boats & people	8%	9%	8%	6%
Human impact/general use	7%	7%	7%	7%
Coral bleaching	7%	6%	9%	8%
Global warming/climate	6%	7%	6%	4%
Coral/marine life removal/exporting	3%	4%	3%	2%
Management and government	2%	2%	1%	3%
Over development/ commercialisation	2%	1%	2%	3%
Animals – introduced species & threats from a particular animal	2%	2%	3%	<1%
Mining	2%	2%	<1%	3%
Natural disasters	1%	1%	2%	1%
Other	5%	5%	5%	6%

Table 2: Participation in recreational activities in the Marine Park

Source: Adapted from Norris *et al.* (2003)

Activity	ALL RESPONDENTS: Percentage undertaking activity	Not vessel-based Percentage undertaking activity	Vessel-based Percentage undertaking activity
Swimming	69%	77%	63%
Fishing	54%	31%	72%
Motorised boating	46%	NA	83%
Snorkelling	26%	16%	35%
Sailing	10%	NA	19%
Non-motorised boating	9%	NA	16%
Diving	4%	2%	5%
Jetsking	3%	NA	6%
Other	13%	10%	15%

Vessel-based telephone respondents to the Norris *et al.* (2003) survey stated islands as their main destination during trips to the Marine Park. The main destinations for vessel-based independent recreational visitors of the Marine Park are shown in Table 3.

Table 3: Main destination for vessel-based independent recreational visitors of the Marine Park

Source: Adapted from Norris *et al.* (2003)

Note: Multiple responses were allowed and totals add to more than 100%

Main Destination	Percentage of vessel-based recreational users (n=366)
Islands	41%
Reef/shoals/cays/rocks/wrecks	19%
Particular area (distance from coast)	19%
No particular destination	7%
Creek/inlet/river	6%
Bay	6%
Beach	4%

Tourist and independent recreational visitors of the Marine Park indicated that for their most recent trip, the overall environment, cleanliness of the environment and water quality were rated as the top three features with regard to the overall quality of their trip (Norris *et al.*, 2003). Water in the marine park was considered to be of very good quality by 44% of all respondents (Table 4). Mean water quality rating was above "good" for both vessel-based recreational users and tourists.

Table 4: Water quality rating by tourist and independent recreational visitors of the Marine Park

Source: Adapted from Norris *et al.* (2003)

Ratings were on a scale from 1="very poor quality" to 5="very good quality"

	Vessel-based recreational users (n=366)	Tourists (n=1729)	All respondents (n=2095)
Percentage who rated water quality as 'very good'	44%	47%	46%
Mean rating for water quality	4.14	4.23	4.21

Weather was an important consideration for independent recreational visitors of the Marine Park (Norris *et al.*, 2003). Recreational activities, particularly those based on marine environments, are reliant on appropriate weather conditions (Jennings, 1998). Boating activities often depend on low wind conditions, except for larger motor boats or craft skippered by experienced sailors. Beach activities may also be limited on gusty and/or cold days. When deciding whether to visit a location during a recreational trip in the Marine Park, 39% of respondents (Norris *et al.* 2003) considered it very important that it was sheltered from the weather. Winds, tides, wave quality and water clarity were also important considerations for vessel-based independent recreational visitors of the Marine Park when considering locations to visit (Norris *et al.*, 2003).

2.2 Recreational activities and pollutants of marine waters

Recreational activities are generally defined quite broadly, for example; “recreational fishing” or “sailing”. Subsets of actions associated with these activities may have water quality impacts. For example, users of smaller boats on day trips may deposit raw faeces or sullage into the water, large permanently moored boats may use toxic antifouling materials on their hulls and dog owners may choose to leave behind dog faeces after walking their pet on the beach.

Groves (2008) reviewed literature in relation to waste and anti-littering/pollution campaigns and lists the following common behavioural problems that impact on water quality: cigarette butt littering, failure to pick up dog faeces, failure to recycle, littering, illegal dumping and home-use fertiliser applications. Of these, only cigarette butts, dog faeces and littering are associated with recreational activities in or adjacent to the Great Barrier Reef Marine Park.

There are various reasons why people pollute, such as a lack of knowledge or awareness of issues, behavioural patterns, the state of the environment (i.e. visible presence of pollution), a belief that compliance measures such as fines are unlikely to be imposed, a lack of facilities available to encourage environmentally friendly behaviour or the high cost of using such facilities (Groves, 2008). Groves (2008) shows that improving the availability of facilities, such as rubbish bins, free green waste vouchers for rubbish tips and pet-poo bag dispensers may be effective in reducing the amount of rubbish/pollutants in the environment. Signage, clean environments and social pressure are also effective mechanisms for reducing polluting behaviours by the public (Groves, 2008).

The National Oceans Office (2002) identifies twelve disturbance categories for marine environments that result from human activity. These are summarised in Table 5 . The impacts listed include physical impacts to marine ecosystems that are not considered part of the definition of water quality. These disturbance categories are used subsequently to describe the types of impacts associated with motor emissions, antifouling compounds, faecal matter/urine and the use of sunscreens.

Harriot (2002) identifies pollutants from tourist activities that may affect marine water quality such as waste discharges, antifoulants, introduced pests, changes in light from permanent pontoon moorings and oil/chemical spills. Groves (2008) states that dog faeces may have an impact on water quality by providing an external source of nutrients. Oil spills, antifoulants and litter are significant pollutants of the waters of the Marine Park (Great Barrier Reef Marine Park Authority, 2001) and may be associated with some recreational activities.

Danovaro *et al.* (2008) show that sunscreen changes the chemical composition of marine waters and ultimately may lead to increases in coral bleaching. Overseas, some popular marine tourist destinations, such as in Mexico, have banned the use of sunscreens due to their impact on water quality (Danovaro *et al.*, 2008).

Table 5: Description of disturbance categories from human activities in marine environments

Source: adapted from National Oceans Office, (2002).

Disturbance category	Description
Chemical changes	Changing the concentration or properties of compounds naturally occurring in the ocean, such as changes to salinity, nutrients, and dissolved oxygen
Contaminants	Introducing substances that are not normally found in the marine environment, such as heavy metals, polychlorinated biphenyls and litter
Temperature change	Changing the marine environment's natural temperature range
Mechanical change	Removing or changing structural (biological or physical) components of the ecosystem
Nuclear radiation	Introducing radioactive isotopes into the marine environment
Electromagnetic radiation	Introducing radiation that consists of electromagnetic waves
Noise	Increasing the level or amount of sounds in the marine environment beyond its natural range
Biological interaction	Removing or damaging organisms
Introduced pathogens	Introducing disease-producing organisms to the marine environment, either from terrestrial or marine sources
Introduced marine species	Introducing species that do not occur outside of the naturally or historically occurring biota
Turbidity/light	Changing the extent to which light penetrates the water column
Artificial light	Introducing a source of light that would not naturally occur in the marine environment

2.3 Relationships between marine water quality and recreational pollutants

The following section describes the impact that pollutants associated with recreational activities within and adjacent to the Marine Park may have on water quality. Key impact categories are identified and linked to the disturbance categories described by the National Oceans Office (2002).

2.3.1 Motor emissions

Vessel based recreation constitutes a considerable proportion of all recreation in the Marine Park. Norris *et al.* (2003) found that 27% of respondents in a telephone survey of coastal residents had been on a vessel-based recreational trip to the Marine Park in the previous 12 months. An estimated 177,000 to 212,000 coastal residents living adjacent to the Marine Park had undertaken vessel-based recreational activities in the Marine Park in the one–year period (Norris *et al*., 2003). Of vessel-based activities reported, 83% were conducted on motorised boats whilst 16% were undertaken on non-motorised vessels (Norris *et al*., 2003).

All marine motors emit pollutants. Outboard motors exhaust directly into the water whilst inboard motors exhaust close to the surface of the water. Both of these engine types can alter the existing chemical composition of water and introduce contaminants to the water (Bender *et al*., 2005).

There are five types of spark ignition (petroleum) engine types used in outboard marine engines and personal watercraft in Australia (Environment Link, 2007). These are:

- 2-stroke with carburettor
- 2-stroke with pre-chamber fuel injection
- 2-stroke with direct fuel injection
- 4-stroke with carburettor
- 4-stroke with fuel injection

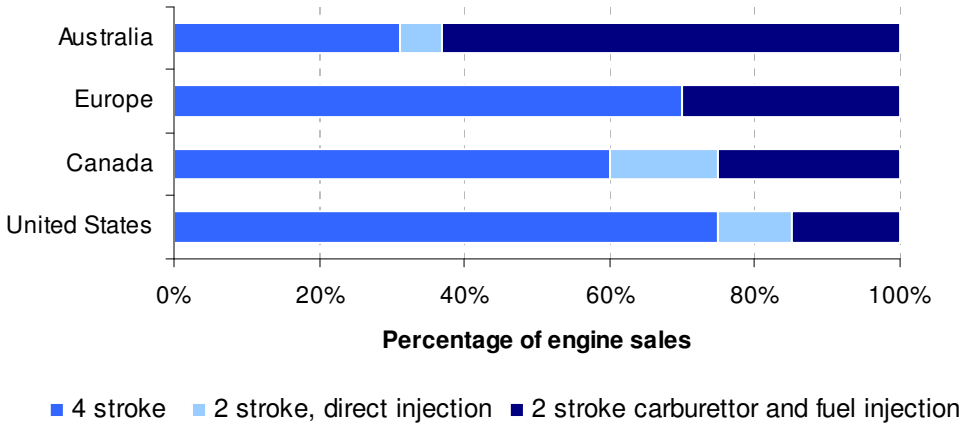
Both 2-stroke carburettor and 2-stroke pre-chamber fuel injection engines are more polluting than the other three types with up to 30% of fuel remaining un-burnt during combustion and the need to add oil to fuel to lubricate the engines (Environment Link, 2007). The majority of outboard motors in Australia are the 2-stroke with carburettor type which is the most polluting marine engine type available (Environment Link, 2007).

There are no Australian regulations or standards to limit air polluting emissions from marine outboard engines (Environment Link, 2007). Using overseas regulations as a guide, approximately 40% of all marine outboard engines available in Australia in 2005 did not comply with any emissions standard set by the Californian Air Resources Board (CARB) and no 2-stoke carburettor engines complied with any international marine outboard emissions regulations in that year (Environment Link, 2007).

Sales of 'high emission' engines in Australia are higher than in other developed countries. Of engine sales, 63% are 2-stroke carburettor and fuel injection motors (Figure 2 – Environment Link, 2007).

Figure 2: Percentage of outboard engine sales by country and engine type

Source: adapted from Environment Link (2007)



Marine outboard motors exhaust directly into the water which affects the chemical balance of the water due to the solubility of fume components (Bender *et al.*, 2005). Pollutants emitted from recreational marine engines include: benzene, toluene, ethyl benzene, xylene, methyl *tertiary*-butyl ether (MTBE), polycyclic aromatic hydrocarbons, carbon monoxide, nitrogen oxides, particulate matter and saturated hydrocarbons. These chemicals are contaminants that are not normally found in the water of the Marine Park (Environment Link, 2007; Haynes and Johnson, 2000). Major inputs of petroleum into the marine environment are associated with industrial discharge and urban runoff (37%), vessel operations (33%), tanker accidents (12%), atmospheric deposition (9%), natural resources (8%) and exploration production (2%) (Haynes and Johnson, 2000).

Polycyclic aromatic hydrocarbons are considered to be the most biologically harmful of all petroleum compounds (Neff, 1990 in; Haynes and Johnson, 2000). Polycyclic aromatic hydrocarbons eventually settle into the bottom sediment of the ocean affecting filter-feeders and bottom-dwelling organisms causing bio-accumulation of toxins in their tissues, genetic mutations and cell atrophy (Haynes and Johnson, 2000).

MTBE is used as an additive to reduce emissions, and therefore air pollution, by promoting more complete combustion of petrol (US EPA, 2008). Australian standards have set maximum levels for components recognised as being detrimental to air (and by inference, water) quality so petrol may contain an MTBE maximum of 1% (EWH, 2007).

MTBE is introduced into marine waters predominantly through the emission of unburnt petrol from boat engines. A study of MTBE levels in a recreational harbour in the US (Zuccarello *et al.*, 2003) has shown that the highest concentration occurred at the harbour's boat launching ramp and that variation in the levels of MTBE were consistent with the pattern of use by recreational boats.

Although Bender *et al.* (2005) reported that levels of MTBE tend to diminish within weeks or months after their introduction so that aquatic ecosystems do not appear to significantly degrade overall, they were careful to also note that MTBE and polycyclic aromatic hydrocarbons have been linked to both acute and chronic toxicity in fish. They may adversely affect fish growth as well as plankton survival and reproduction.

2.3.2 Hull antifouling compounds

Antifouling coatings are used on vessels to inhibit marine growth on submerged surfaces. Marine growth reduces hull speed and may affect the operation of moving parts such as rudders and propellers (Norglass, 2006). Two major types of antifouling are used in boating applications – soft antifouling compounds wear away over time and are only suitable for slow-moving vessels; hard antifouling coatings leach biocides over time to prevent marine growth (Norglass, 2006). Antifouling compounds may include copper and organic biocides as inhibitors of marine growth (ANZECC, 2008). They work by creating a poisonous barrier at the interface of marine waters and boat components.

Tributyltin (TBT), a highly toxic substance used previously as an antifouling agent, is now banned under an International Maritime Organisation convention to which Australia is a signatory. The use of TBT on vessels less than 25 metres in length was banned in Australia in 1989 (DEH, 2004) and its use on vessels greater than this size will be banned in Australia by September, 2008 (AMSA, 2007). Haynes and Loong (2001) report low TBT concentrations across most of the Marine Park. Elevated levels of TBT were observed in some marinas suggesting that some small craft may continue to use TBT-based antifouling paints (Haynes and Loong, 2001). The Australian Pesticides and Veterinary Medicines Authority has deregistered all antifouling products containing organotins as active biocides, effectively banning the sale and application of organotin antifouling systems in Australia (Thompson Clarke Shipping Pty. Ltd *et al.,* 2004).

Boat owners now have a range of other coatings to use as antifouling agents with blends of organic antifouling compounds and copper-based products available. One freely available organic compound, dichlofluanid, is a fungicide used in agriculture. In the last few years it and other, similar fungicides have also been used as alternatives to TBT as active ingredients in antifouling products. According to Sakkas and Albanis (2003) the continued input of such pesticides has led to reports of elevated concentrations in natural waters (fresh and marine) and their sediments, posing a hazard to aquatic life.

Leon and Warken (2008) state that copper-based antifouling paints can affect photosynthesis of seagrasses, inhibit development of coral larvae and bio-accumulate in marine animals including fish and turtles. As well as its use in antifouling paints on vessels, copper also enters marine

waters through sewage discharges from urban areas and from fungicides and herbicides used in agriculture (Victor and Richmond, 2005). There is little known about the impacts of copper on corals and other marine organisms, but research on the impact of copper on coral spawning shows that relatively low concentrations of copper (5-20 µg/L) can significantly reduce coral fertilisation success rates (Saphier and Hoffman, 2005).

2.3.3 Faecal matter and urine

Faecal matter from humans and other animals including dogs and horses can impact on coral reef communities by enriching the nutrient level in water (Pastorok and Bilyard, 1985). Low levels of nutrient enrichment increase the primary production of benthic algae without changing the structure of the food chain, species composition or biomass (Pastorok and Bilyard, 1985) but higher levels of nutrient enrichment can lead to changes in the food chain and algal blooms including blooms of blue-green algae. This can affect coral communities by reducing light penetration vital to coral health and by creating more favourable conditions for other organisms that may then out-compete corals (Pastorok and Bilyard, 1985).

The level of nitrogen input from recreational boating is not considered in many studies on hazards to water quality in the Great Barrier Reef Marine Park (Hutchings *et al*., 2005; Moss *et al*., 2005; Pastorok and Bilyard, 1985). Leon and Warken (2008) estimated that an average of 250g of faecal matter and 1.15kg of urine are excreted per person each day by people using recreational vessels in the Marine Park. This correlates with 9-17.5 grams of nitrogen being excreted into sullage tanks or the ocean directly by vessel-based independent recreational visitors of marine waters (Leon and Warken, 2008). Norris *et al.* (2003) estimated that 58% of vessel-based resident independent recreational visitors of the Marine Park had a trip length of at least one day suggesting that the majority of vessel trips involve excretion of urine and faecal matter into sullage tanks or directly into the waters of the Marine Park.

The introduction of faecal matter and urine to marine waters is associated with chemical changes and introduced pathogens (National Oceans Office, 2002). Thus the input of faecal matter and urine may have implications both for the marine biodiversity of the Marine Park and for human health. High levels of faecal and urine deposition by recreational boaters in peak times and in popular locations may lead to temporarily elevated levels of human pathogens that pose a hazard to direct-contact users of the water and any aquaculture operations in close vicinity (Leon and Warnken, 2008).

Morton Bay—unlike the Great Barrier Reef Marine Park—has many marinas with vessel sewage pumping facilities. Even so, the use of these by recreational boaters in Moreton Bay in south-east Queensland is low (Leon and Warnken, 2008). There is only one operational vessel sewage pumping facility in the GBRMP, in Port Douglas, which is said to have virtually no recreational use due to charges associated with use of the facility (Yorkston, Great Barrier Reef Marine Park Authority, personal communication, 02/10/2008).

The Great Barrier Reef Marine Park Authority has implemented new vessel sewage regulations (Great Barrier Reef Marine Park Authority, 2008c). Boats that carry less than 16 people and are fitted with a toilet must now reduce the sewage to fine slurry that may be discharged anywhere in the marine park outside boat harbours, canals or marinas and more than 1 nautical mile seaward of an aquaculture operation. In addition, boats carrying 16 or more people must discharge the slurry more than one nautical mile seaward of the nearest reef or low-water mark of the nearest island or the mainland. Vessels with sewage treatment capabilities may discharge in more locations depending upon the level of treatment.

2.3.4 Sunscreen

Sunscreen has been implicated in impacts on marine bacterio-plankton and has been shown to cause coral bleaching in tropical corals (Danovaro *et al*., 2008). Ultraviolet light-blocking ingredients in sunscreens cause coral bleaching even at extremely low concentrations and can accumulate in the tissues of aquatic animals (Danovaro *et al*., 2008). Danovaro *et al.* (2008) estimated that approximately 25% of the sunscreen applied by swimmers washes off into the water. Table 6 shows four ultraviolet blocking chemicals commonly found in sunscreen that Danovaro *et al.* (2008) reported can create high levels of coral bleaching even at low concentrations.

Table 6: Chemicals commonly found in sunscreens and associated with high levels of coral bleaching

Adapted from Danovaro *et al.* (2008)

INCI – International Nomenclature for Cosmetic Ingredients

Chemical name	INCI name	Abbreviation
Butyl p-hydroxybenzoate	Butylparaben	BP
2-Ethylhexyl-4-methoxycinnamate	Ethylhexylmethoxycinnamate	OMC
2-Hydroxyl-4-methoxybenzophenone	Benzophenone-3	BZ
3-(4'-Methylbenzylidene) camphor	4-methylbenzylidene camphor	MBC

3 Methodology

3.1 Overview

The purpose of this project was to estimate the impact on water quality due to recreational activities undertaken in and adjacent to the Great Barrier Reef Marine Park (Section 1.2). To achieve the project objectives the research would:

- Establish the range of recreational activities undertaken by recreational visitors;
- Identify those behaviours that would affect water quality;
- Estimate the impact of these behaviours on water quality; and
- Develop an understanding of the estimated impact of particular activities and behaviours on water quality.

The research included desktop and empirical research components. The desktop research was developed to provide context for the empirical research.

Desktop analysis included:

- Identification, review and synthesis of relevant scientific studies into the potential impacts on water quality of recreational activities within the Great Barrier Reef; and
- Identification of the types of activities that create impacts on water quality in the Great Barrier Reef including both vessel-based and shore-based activities undertaken in and immediately adjacent to the Great Barrier Reef.

The empirical research component included:

- Face-to-face interviews of shore-based independent recreational visitors of the Marine Park and/or adjacent coastal areas (a target of 30 to be conducted in each of 3 locations over a 3-day field work period);
- A mail-return survey of vessel-based independent recreational visitors of the Marine Park or adjacent waters (a target of 100 to be handed out at each location during that same field work period);
- Observation of recreational activities undertaken in or adjacent to the Marine Park and recording any behaviours with potential water quality impacts; and
- Photographic evidence of recreational activities and behaviours.

The limited scope of the field work characterises the research project as a scoping study, testing conceptual and methodological aspects of recreation-relevant research in the Great Barrier Reef Marine Park and establishing new data and insights nevertheless.

Empirical research involved primary data collection in Cairns, Mackay and Airlie Beach. Expected weather conditions and tides were important considerations for choice of weekends on which to conduct field work as these are significant factors for vessel-based recreational activities in the Marine Park (Jennings, 1998; Norris *et al.*, 2003). The presence of social or cultural events that might divert people away from coastal and offshore recreation also affected the choice of dates.

Cairns was visited from Friday1st to Sunday 3rd August, Mackay was visited from Friday 8th to Sunday 10th August and Airlie Beach field work was conducted from Monday 11th to Thursday 14th August 2008. Weather conditions for the field research days were mostly fine but some days were windy, particularly during the Airlie Beach field work period. Table 7 summarises the weather conditions and tides for the time spent at the three research locations.

Table 7: Summary of weather and tide conditions for the field research days

Note: Bureau of Meteorology; * strong wind warning was issued

	Day	Temperature		Max wind gusts		Tides		
		Min	Max	Direction	Speed	High	Low	Change
		(degrees celcius)			(knots)	(metres)		
Cairns								
August 1st	Friday	14.0	26.2	NE	21	3.27	0.09	3.18
August 2nd	Saturday	12.7	25.2	NNE	13	3.15	0.19	2.96
August 3rd	Sunday	12.0	27.1	ESE	17	2.94	0.40	2.54
Mackay								
August 8th	Friday	9.5	20.0	SSE	22	4.09	1.62	2.47
August 9th	Saturday	7.3	20.4	SSE	19	4.15	1.82	2.33
August 10th	Sunday	10.0	20.5	S	13	4.43	1.78	2.65
Airlie Beach								
August 11th	Monday	16.4	21.2	SSE	16	3.18	0.88	2.30
August 12th	Tuesday	15.9	18.8	SE	35*	3.32	0.76	2.56
August 13th	Wednesday	16.0	19.4	SE	25*	3.43	0.65	2.78
August 14th	Thursday	16.8	20.0	SSE	25*	3.51	0.55	2.96

Selecting weekends as well as weekdays meant that residents who were likely to go boating mainly on weekends, and independent visitors who could go boating on any day of the week during the week could be captured by the survey. As no comparisons were intended between localities, this did not affect data analysis. However, prevailing windy conditions likely meant that boaters with smaller vessels were less inclined to go boating.

Face-to-face interviews with independent recreational visitors in areas adjacent to the Marine Park were conducted at popular coastal recreational locations in Cairns, Mackay and Airlie Beach. Mail-return surveys were placed in highly visible envelopes on the windscreens of cars with boat trailers parked at boat ramps or handed directly to boat operators at ramps and in marinas. To entice participation in the mail-back survey, prizes were raffled amongst respondents. The prizes were three $200 vouchers for use at a large outdoors/fishing goods supplier.

Details of the mail-return survey and face-to-face interviews are given in Sections 3.3 and 3.4 respectively.

3.2 Conceptual framework

Recreational activities in or adjacent to the Great Barrier Reef Marine Park can occur on/in water or on land. Most water-based activities require a vessel as an enabling platform. Different recreational activities are associated, to varying degrees, with different types of watercraft. Table 8 presents a conceptualisation of this association and hypothesises about the relative frequency of association between platforms and activities.

Table 8: Activities associated with different types of vessel

A higher number of ticks indicate a higher expected relative frequency of association

	Type of craft		
Activity in the GBRMP	Sailing boats	Power boats	Man-powered boats
Fishing	✓✓	✓✓✓	✓
Diving	✓	✓	✓
Snorkelling	✓✓	✓	✓
Shore-based camping	✓	✓	✓✓✓
Boating only	✓✓✓	✓✓	✓✓
Swimming	✓✓✓	✓✓	✓✓
Kayaking	✓	✓	✓✓✓
Resting	✓✓✓	✓✓	✓✓
Entertaining	✓✓	✓✓	✓
Beach walking	✓✓	✓✓	✓✓

Not all recreational activities are vessel-based. Recreational activities also occur along the coastline adjacent to the Marine Park. Norris *et al.* (2003) report swimming, fishing, snorkelling and diving as recreational activities undertaken in the Marine Park that do not require the use of a vessel. Walking, dog walking, camping and beach driving are some other activities that may occur on the coastline adjacent to the Marine Park.

A conceptualisation of recreational activities and polluting behaviours is shown in Table 9. These activities are linked to the disturbance categories described by the National Oceans Office (2002; Table 5).

3.3 Mail-back survey

The use of a mail-back survey to gather information from independent recreational visitors undertaking boating and related activities allowed respondents time to consider the activities they undertook during their trip and to fill out tables and respond to questions completely.

The survey package was in an A4-sized white envelope with the GRBMPA logo and the statement “To the boating enthusiast” in blue marker pen on the front. The package contents included;

- A research cover sheet describing what the survey was about, why it was being conducted and the organisations involved (Great Barrier Reef Marine Park Authority and River Consulting);
- An instruction sheet to guide respondents through the questionnaire and submission process;
- The questionnaire;
- A blue address slip and unmarked envelope for respondents who wished to participate in the draw for the prize raffle. Respondents were to write their details on the blue slip, place this inside the unmarked envelope and seal the envelope; and
- A reply-paid envelope addressed to River Consulting into which the questionnaire and prize raffle envelope were to be placed for mailing.

Survey packages were distributed at boat ramps and at marinas in Cairns, Mackay and Airlie Beach. Table 10 shows the locations where surveys were distributed.

Table 9: Recreational activities and possibly associated behaviours that may impact on water quality

Activity	Impacting behaviour	Potential impacts on marine water quality
Dog walking	Not picking up dogs' faeces	Eutrophication of inshore areas
Horse-riding	Not picking up horses' faeces	Eutrophication of inshore areas
Beach/rock fishing	Deposition of human waste in terrestrial near-shore environment	Input of human waste elements including nutrients and pathogens
	Disposal of rubbish into near-shore environment	Degradation of debris
Jetskiing/water skiing	Cleaning/washing of vessels in near shore areas	Input of soap, detergents, sunscreen
	Engine/craft emissions	Input of oils and other vehicle/mechanical pollutants
Coastal camping	Disposal of rubbish into marine environment?	Changes in chemical composition due to degradation of debris
	Cleaning of camping utensils	Input of detergents and soaps
	Deposition of human waste in terrestrial near-shore environment	Input of human waste elements including nutrients and pathogens
Vessel-based recreational fishing	Fish filleting/preparation	Concentrated input of organic matter (fish scales, carcasses, etc) at boat ramps/wash down facilities leading to isolated pollution to surrounding waters
	Disposal of rubbish into marine environment	Decomposition of debris
	Berleying water	Muddies water, adds nutrients
Snorkelling & diving	Peeing in water	Input of nutrients and pathogens
	Skin protection with sunscreen	Input of sunscreen
Recreational boating (sailing, motor-cruising)	Faeces/sullage disposal in marine or near shore areas	Input of human waste elements including nutrients and pathogens
	Disposal of rubbish into marine environment?	Changes in chemical composition due to degradation of debris
	Poor engine maintenance of vessels/vehicles	Input of oils and other vehicle/mechanical pollutants
	Cleaning/washing of vessels at sea or in near shore areas	Input of soap, detergents, sunscreen

Table 10: Boat ramps and marinas visited where surveys were distributed

	Boat ramps	Marinas
Cairns	Cairns city (x2), Holloways Beach, Machans Beach, Trinity Park, Yorkey's Knob	Bluewater Marina, Marlin Marina, Yorkey's Knob Boating Club Marina
Mackay	Shoal Point, Bucasia, Eimeo. Mackay Harbour, Hay Point	Mackay Marina
Airlie Beach	Cannonvale Beach, Abel Point, Conway Beach, Shute Harbour, Wilson Beach	Abel Point Marina

More than 100 surveys were handed out in Cairns and Mackay with slightly less than the target number handed out in Airlie Beach. A summary of the number of surveys handed out and the response rate is provided in Table 11.

Table 11: Summary of mail-return survey handouts and responses

	Target number of surveys to be handed out	Actual Number of surveys handed out	Number of responses	Response rate (%)
Cairns	100	178	26	15%
Mackay	100	180	44	24%
Airlie Beach	100	92	15	16%
TOTAL	300	450	85	19%

The response rate is good for a mail-response survey. Larson (2005) conducted a time series analysis of mail-response surveys reported in the Journal of Business Logistics. He found that the average response rate had declined from almost 40% in 1990 to 14% in 2003. He found that monetary incentives tended to increase response rates.

Respondents were expected to take between 10 and 20 minutes to complete the survey. It was designed to obtain data on who was undertaking recreational activities, how they were accessing the Great Barrier Reef Marine Park or adjacent waters, what kind of recreational activities they were undertaking and what kind of other actions occurred during these activities. A sample of the mail-return questionnaire is provided in Appendix 1.

The survey was composed of:

- Demographic questions to obtain a description of the number of people engaged in any particular boating trip and general demographic descriptors;
- Vessel questions to obtain a description of the type of craft used to access the Marine Park and/or adjacent waters, the numbers of engines the craft had, hours of usage of the engines, where the boat was normally moored or stored, and if and when the boat was last painted with an antifouling coat;
- An activity table to allow a detailing of the types of recreational activities undertaken during the boating trip and descriptions of where these were done;
- A behaviour table to allow a description of the frequency of occurrence of a range of behaviours associated with boating activities that may impact on water quality; and
- Respondent perspective questions designed to allow respondents to (i) provide a description of their perspective on water quality impacts and changes and (ii) to find out about how respondents felt about different aspects of the Great Barrier Reef and how they accessed information about the Great Barrier Reef.

Information about the vessel was gathered through direct questions about ownership and normal storage location and by using a table of engine(s) characteristics. A choice of five main engine types was listed and spaces were allowed for respondents to include and describe other types of engines used. Respondents were asked to provide the size of the engine in any of a range of measures, indicate whether the engine was an inboard or an outboard and record the hours of use during their trip.

To obtain descriptions of the locations and intensity of recreational activities carried out, respondents were asked to fill out a table of activities including where they undertook them (i.e. close in-shore, in-shore, and off-shore). Geographical locations of trip destinations were obtained by asking respondents to describe the places they visited during their trip.

Respondents were asked to provide a description of behaviours or actions that may have occurred during their boating trips. This allows a description of the behaviours that occur in association with different vessels as well as the frequency of occurrence. Some of the listed activities had negative connotations, so an introductory paragraph appealed to respondents to answer honestly.

Respondent perspective questions were asked to provide more information on water quality impacts of recreational activities in the Marine Park. Some independent recreational visitors of the Marine Park undertake recreational activities regularly and may provide insight into impacts of recreational activities and observations on changes in water quality or recreational activity.

A pre-test of the mail-return survey was conducted in Townsville in the weeks prior to the Cairns field research. Prospective respondents were informed that their responses would not be used in the report but that their time would help to guide the research in terms of survey development. Respondents were offered vouchers at a local take-away store in acknowledgment of their time contribution. The pre-test indicated that there were no major issues with the survey format although some minor changes were incorporated in the final version of the mail-return survey.

3.4 Face-to-face interviews

Face-to-face interviews were used to obtain information from coastal independent recreational visitors. At survey locations, independent recreational visitors were approached in order of appearance. If there were groups of two or more people, questions were directed at one person only. In most cases the respondent answered on behalf of the group (e.g. couple or family) but in other cases only for themselves. The questionnaire was short, being designed to be completed in less than ten minutes for the majority of respondents. A copy of the face-to-face questionnaire is provided in Appendix 2.

A total of 90 face-to-face interviews were conducted, made up of 30 from each location. Cairns interviews were mostly conducted at Holloways Beach, Kewarra Beach and Machans Beach. Mackay interviews were conducted at Shoal Point, Harbour Beach and Iluka Beach, and Airlie Beach interviews were almost all completed at Cannonvale Beach with some done at Shute Harbour. Interviews were usually conducted in the mid-mornings, mid-afternoons or early evenings.

The face-to-face interviews included:

- Demographic questions for genders and ages of other members of the group participating in the recreational activity, if relevant, as well as a post-code and gross household income category of the respondent only (i.e. not including other members of the group);
- Activity questions to both describe the activity or activities in which respondents were currently engaged as well as those recreational activities they had undertaken in the Marine Park in the last 12 months; and
- Independent recreational visitor perspective questions to obtain a description of polluting behaviours that respondents may have observed, important water quality impacts of recreational activities as they perceive them and changes in water quality and/or recreation over time. Respondents were also asked to provide a description of how they access information on the Marine Park and to respond to statements on the Great Barrier Reef using Likert-type scales.

3.5 Ethical conduct of research

The research, and therefore the survey, was governed by stringent ethical considerations. A professional code of ethics that recognises five ethical responsibilities towards survey participants was followed:

- Informed consent: People were given information about the survey, both in writing and verbally (Appendix 1).
- Voluntary participation: People were asked whether they wished to participate and were offered the opportunity to stop the survey at any stage. Respondents could also decline to answer any questions that made them feel uncomfortable.
- No harm: No physical or psychological harm would come to any person from participation in the survey.
- Confidentiality and anonymity for recreational fishing survey participants: No personal information or contact details were collected.
- Privacy: Respondents remained free from intrusion. Interviewers would request participation in the survey but were instructed to gracefully accept negative responses and avoid approaching any one person more than once.

3.6 Coding

Coding is a requirement for quantitative analysis of survey data and involves the creation of classification systems that impose a particular order on the data. These systems need to reflect matters under investigation. Much of the work in classifying responses is done as part of the questionnaire design stage, where a set of fixed responses is provided to respondents. Open-ended questions may be coded but are often used in a descriptive way after the data have been collected.

Data cleansing was conducted and inconsistencies in data removed to ensure that subsequent analysis was conducted on clean and correct data.

3.7 Data analysis

Quantitative analysis was undertaken of statistical data using Microsoft EXCEL and using STATISTICA (v7.1). STATISTICA is a comprehensive, integrated data analysis, graphics, database management system (StatSoft, 2001). Specific techniques employed included:

- Basic statistics to provide the means (average) of observations, median (for skewed distributions), minimum and maximum observed values, and a measure of variability (variance, standard deviation).
- Frequency distributions and frequency tables showing the number of observations falling into each of several categories of values.
- Statistical significance testing. A variety of statistical techniques were employed to assess the significance of observed differences between groups of respondents and relationships between variables. Where data was of ordinal scaling, or test assumptions were not met, appropriate non-parametric techniques were employed. When a difference is found to be statistically significant, there is confidence that the result is reliable and can be replicated. In other words, the finding is unlikely to have occurred as a consequence of chance factors or sampling error. When conducting analysis, a level of probability, known as the alpha level is set. The alpha level reflects the probability that the an effect has been claimed when there was none. Unless otherwise stated, tests for statistical significance in this work applied an alpha level of .05.

- Principal Component Analysis (PCA) was used to (1) explore a set of variables with a view to identifying the underlying structure and (2) to simplify a large set of variables into a smaller, simpler set of factors for further analysis (Diekhoff, 1992).
- Qualitative analysis of the textual data was undertaken, which was gathered in the form of transcripts and observational field notes. Textual data were explored using content analysis to generate categories and explanations.

3.8 Observations and photographic evidence

During the field work, the research team noted and recorded any water-quality related pollution on beaches and boat ramps.

When photos were taken of persons who were recognisable in the picture, informed consent was obtained. The digital image was then shown to the person and permission sought, in writing, for use of the photograph(s) for research purposes. If permission was declined the photograph was deleted from the disk.

4 Results: Interviews with shore-based independent recreational visitors

Face-to-face interviews with shore-based independent recreational visitors yielded 30 responses in each of the three survey locations (Cairns, Mackay and Airlie Beach) for a total of 90 responses. Each response in the face-to-face interviews is referred to as a shore-based (non vessel-based) respondent.

Regardless of how many people were in a 'group' being interviewed, the interview was still classified as one response. The 90 responses comprised 168 persons in total. Figure 3 shows the distribution of size of respondent 'groups' and Figure 4 shows the age and gender distribution of all 168 persons.

Figure 3: Group-size profile for shore-based respondents

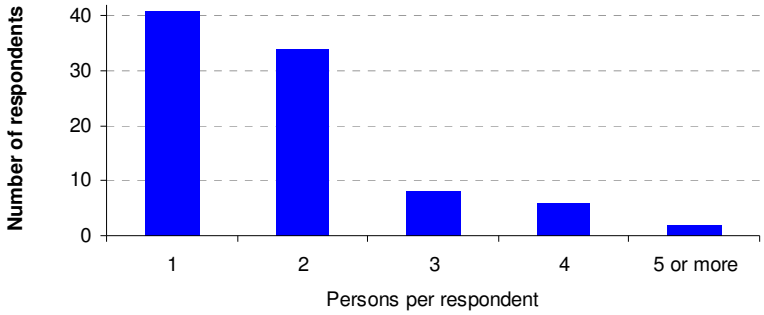
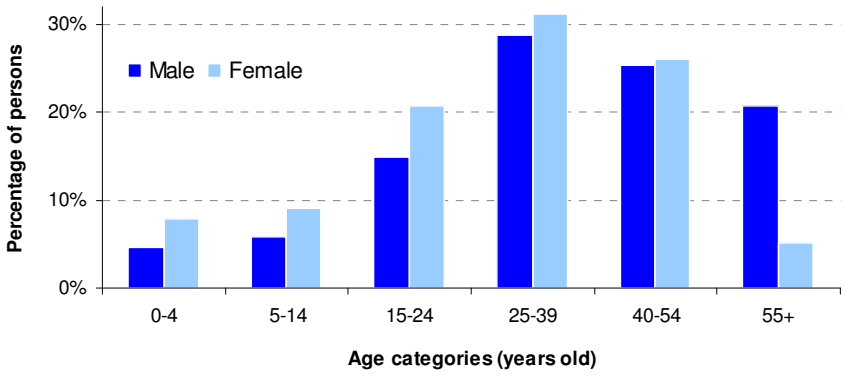
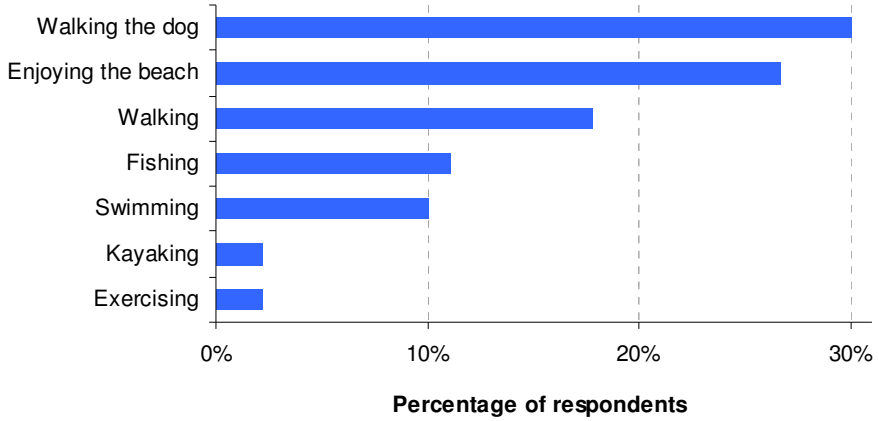


Figure 4: Gender and age distribution for all persons among shore-based respondents



Recreational activities concentrated around enjoying the beach and walking the dog(s). Figure 5 shows the profile of recreational activities that shore-based respondents were engaged in when they were approached for interview.

Figure 5: Recreational activities being undertaken by shore-based respondents



Shore-based respondents were asked what kind of recreational activities they had undertaken in the Great Barrier Reef Marine Park (or adjacent areas) over the last 12 months and how many times they had engaged in these. Approximately two thirds of respondents indicated they had been swimming or fishing at least once (Table 12). More than half of respondents had been on a motor boat in or adjacent to the Marine Park at least once.

Table 12: Activities that shore-based respondents had undertaken during the last 12 months

Activity	Percentage of respondents (%)
Swimming	68%
Fishing	66%
Motor boating	54%
Snorkelling	37%
Sailing	20%
Scuba diving	7%
Kayaking	6%
Jetskiing	4%
Kite-surfing	1%

Table 13 shows the frequency of recreational activities undertaken by respondents (only for activities with a minimum participation of 20% of respondents). Swimming and fishing were the most frequently undertaken activities.

Of shore-based respondents, five had been kayaking (min=3, max=20 times) over the past 12 months, four had been jet-skiing (min=1, max=12 times), four had been scuba diving (min=2, max=150 times) and one had been kite-surfing (20 times).

Shore-based respondents were asked to indicate how often they had seen pollutants or polluting behaviours over the last twelve months. They were presented with a list of pollutants and polluting behaviours and asked to indicate the frequency of observation of these on a scale from 1 to 5 (1=Never; 2=Rarely; 3=Sometimes; 4=Often; 5=Always). The average frequency of observation is shown below in Figure 6 for each location.

Table 13: Frequency of occurrence of recreational activities by shore-based respondents over the last 12 months

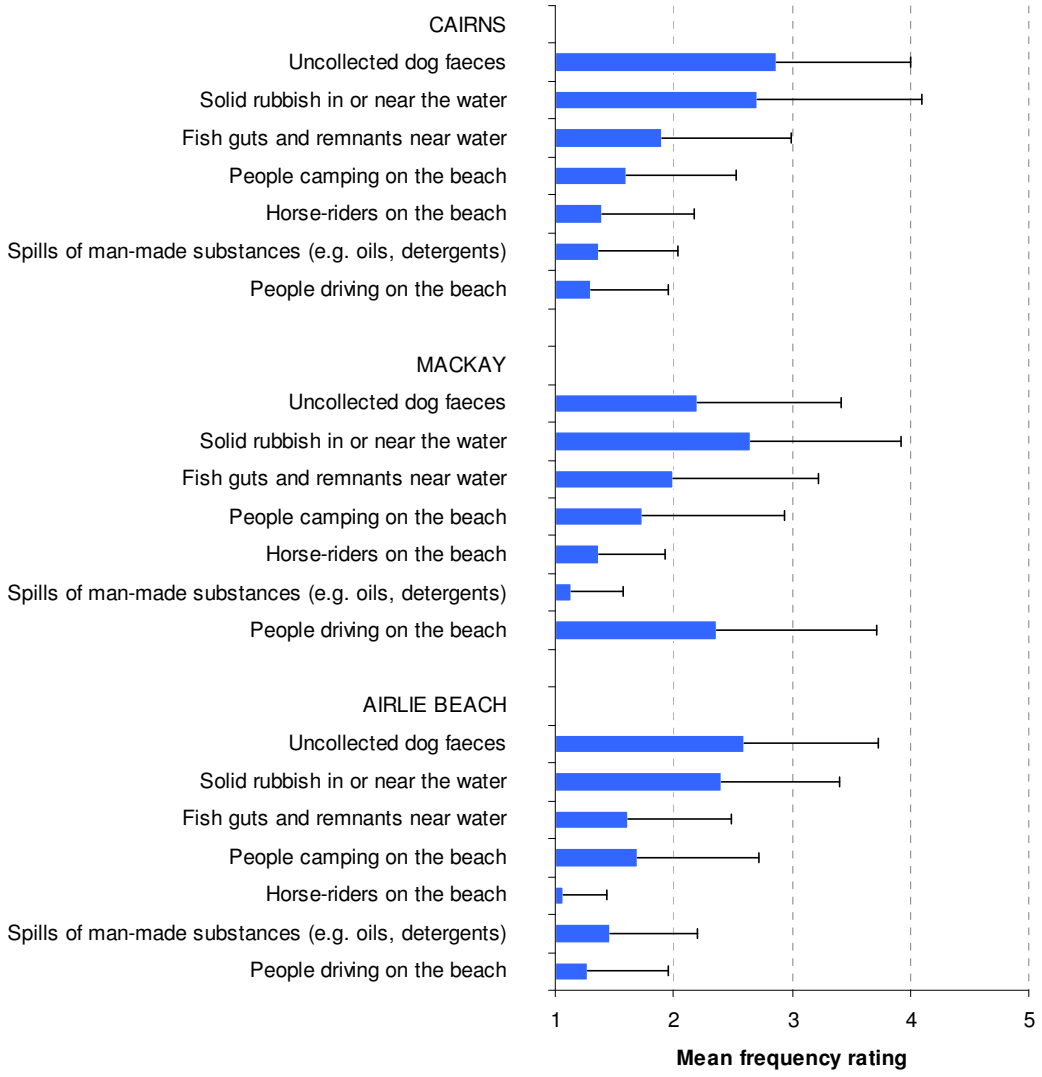
Note: Scuba diving, kayaking, Jet-skiing and Kite-surfing are reported in the text as there were insufficient observations to present summary statistics on them

	Swimming	Snorkeling	Fishing	Sailing	Motor boating
Minimum	1	1	1	1	1
1st Quartile	3	2	3	1	2
Median	10	5	10	4	7
3rd Quartile	45	10	29	7	15
Maximum	350	50	365	250	312

Figure 6: Frequency with which pollutants/polluting behaviours were observed by shore-based respondents

Data sorted by descending order of mean values for Cairns respondents; Bars show standard deviations.

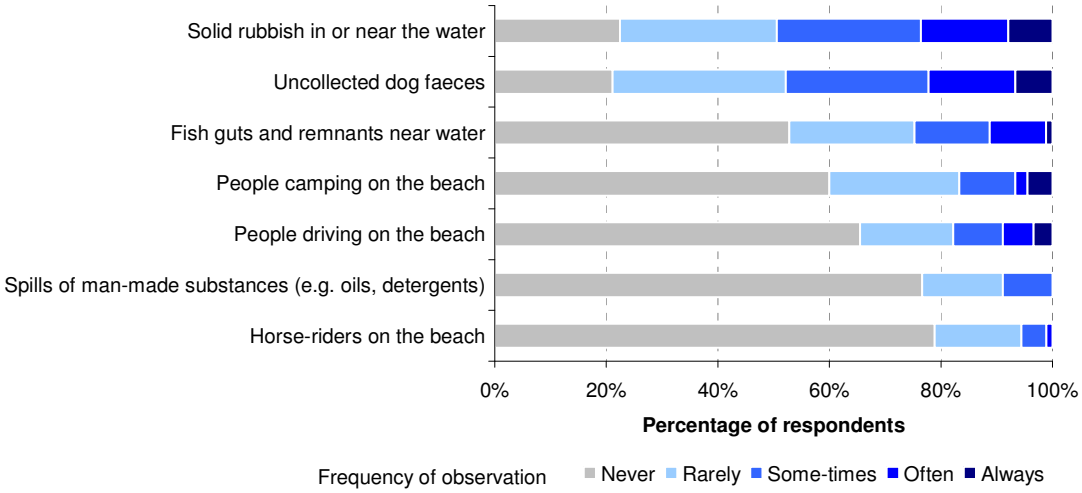
5-point rating scale: 1="Never", 5="Always"



Across the locations uncollected dog faeces and solid rubbish in or near the water were the two most frequently observed signs of polluting behaviours with means of 2.56 and 2.58 respectively. Figure 7 shows the frequency distribution of observations on pollutants/polluting behaviours for all shore-based respondents.

Figure 7: Frequency distribution for observations of pollutants/polluting behaviours by shore-based respondents across the survey locations

Note: Items sorted by mean value



A Kruskal-Wallis multiple comparisons of medians test was conducted to test for differences in observations between Cairns, Mackay and Airlie Beach shore-based respondents. Significant differences were found for observations on “Horse-riders on the beach” and “People driving on the beach”. Mackay shore-based respondents observed “People driving on the beach” significantly more regularly than either Cairns or Airlie Beach respondents.

Shore-based respondents were asked to nominate any water quality impacts they thought resulted from recreational activities. Table 14 shows the frequency of impacts/pollutants of recreational activity in the Marine Park nominated by shore-based respondents. Rubbish was the most frequently stated pollutant of water associated with recreational activities with 29% of shore-based respondents across the survey regions nominating this as a principal pollutant of recreational activity in the Marine Park. Rubbish was regarded an issue by a larger percentage of Cairns respondents than in Mackay and Airlie Beach. Approximately 18% of respondents stipulated that there was no impact while 44% of respondents could or did not answer the question.

Table 14: Water pollutants of recreational activities nominated by shore-based respondents

Note: Totals add to more than 100% as respondents could specify more than one impact/pollutant

	Frequency of nomination (percentage of respondents)			
Pollutants	Total	Cairns	Mackay	Airlie Beach
Rubbish	29%	43%	30%	13%
Fuel pollution (exhaust)	7%	3%	3%	13%
Oils from boating	4%	3%	0%	10%
Sunscreen	2%	3%	3%	0%
Dog faeces	2%	0%	3%	3%
Urine	1%	0%	3%	0%
Sullage	1%	0%	0%	3%
No impact	18%	30%	10%	13%
Did not answer	44%	27%	50%	57%

Shore-based respondents were asked to describe any changes to water quality and recreation in the Marine Park. The majority of respondents (71%) indicated that they had observed no changes (Table 15). There were some differences across the regions with Mackay respondents indicating both “no change” (77%) and that the water was “cleaner now” (10%). Airlie Beach respondents most frequently noticed “seasonal changes in water quality due to weather” and that the water was “more silty/muddy”.

Table 15: Observed changes to water quality and/or recreation in the Marine Park

	Percentage of respondents (%)			
Observed change	Total	Cairns	Mackay	Airlie Beach
No observed change	71%	77%	77%	60%
Seasonal changes due to weather	9%	7%	7%	13%
More silty/muddy	6%	3%	0%	13%
Cleaner now	4%	0%	10%	3%
Less fish	3%	7%	0%	3%
Beach has changed	2%	7%	0%	0%
More rubbish	2%	3%	3%	0%
Weed beds	1%	0%	0%	3%
Did not answer	3%	3%	3%	3%

Shore-based respondents were asked to nominate any factors that made water in the Marine Park ‘more polluted or more clean’. Table 16 shows the frequency of responses to this question across the region. Respondents providing answers observed that important factors in making water in the Marine Park more polluted were rubbish, runoff from agriculture, urban runoff and chemicals/oils from shipping. Runoff from agriculture was more frequently mentioned as a source of water pollution by Cairns respondents while a higher proportion of Airlie Beach respondents mentioned recreational boating waste and sullage as a source of water pollution, along with the marina development, dredging and beach modifications.

Table 16: Shore-based respondents' perceptions regarding sources of water pollution in the Great Barrier Reef Marine Park

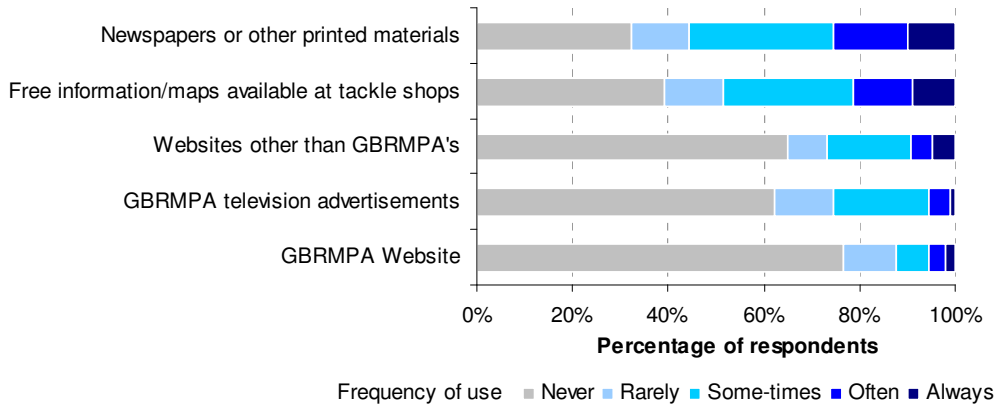
Note: Totals may not add to 100% because some respondents did not provide comments whilst others commented on more than one factor making water in the Marine Park more polluted.

	Percentage of respondents			
Impact/activity	Total	Cairns	Mackay	Airlie Beach
Rubbish	21%	13%	27%	23%
Runoff from agriculture	16%	23%	7%	17%
Urban runoff - oils/chemicals	12%	17%	13%	7%
Chemicals/oils from ships	11%	10%	13%	10%
Dredging/groynes/beach modification	8%	7%	0%	17%
Urban development	8%	3%	3%	17%
Recreational boating waste and sullage	8%	0%	0%	23%
Marina developments	7%	0%	3%	17%
Urban sewerage	6%	7%	0%	10%
Rain events	6%	3%	10%	3%
Fuels/oils from boating	3%	0%	3%	7%
Ship ballast water	3%	0%	10%	0%
Dog faeces	2%	7%	0%	0%
Two stroke motors	1%	0%	3%	0%
Sunscreen	1%	0%	0%	3%
Tourist boats - sullage	1%	3%	0%	0%
Better foreshore management	1%	3%	0%	0%
Did not anwer	24%	23%	33%	17%

Shore-based respondents were asked how frequently they used different sources of information to find out about the Marine Park. Respondents were provided with a list of information sources and were asked to respond on a five-point Likert-type scale with 1=Never and 5=Always. Figure 8 shows the frequency distribution for the use of different types of information sources.

Figure 8: Frequency of use of different sources of information to find out about the Marine Park

Items sorted by mean value

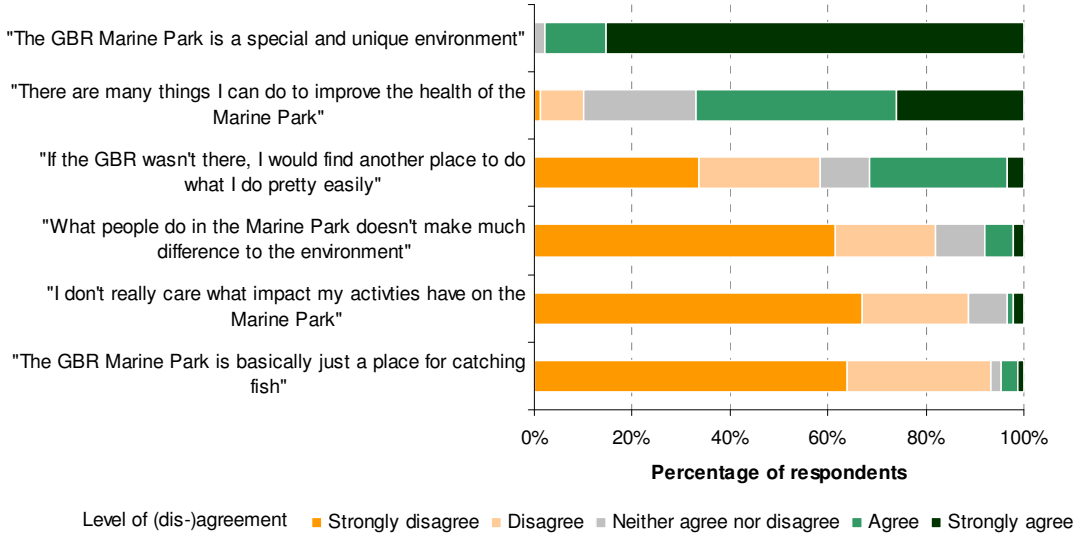


Newspapers and other printed materials were the most commonly used source of information on the Marine Park; 56% of respondents used these sources of information at least "sometimes". The Great Barrier Reef Marine Park Authority website was least frequently used by shore-based respondents; more than 75% of respondents "never" used this source to find out information on the Marine Park. Websites used other than the Great Barrier Reef Marine Park Authority's were the Bureau of Meteorology website (www.bom.gov.au) for weather and tidal information and the Queensland Environmental Protection Agency website (www.epa.qld.gov.au) for information on camping in the Marine Park.

Respondents were presented with a list of attitudinal statements on the Great Barrier Reef and the Marine Park and asked to indicate their level of agreement with these using a five-point Likert-type scale (1=Strongly disagree; 2=Disagree; 3=Neither agree nor disagree; 4=Agree; 5=Strongly agree). Figure 9 shows the distribution of responses to this question.

Figure 9: Agreement with statements on the Great Barrier Reef and the Marine Park

Items sorted by mean value



A large majority of shore-based respondents (98%) agreed with the statement "The Great Barrier Reef Marine Park is a special and unique environment" and 94 % disagreed with the statement "The Great Barrier Reef Marine Park is basically just a place for catching fish".

Respondents were asked to provide an indication of their gross household income, before tax, by category. Table 17 shows the distribution across household income categories for respondents from the three survey locations. For total responses, the household incomes were relatively evenly distributed between categories. There were fewer low-income shore-based respondents in Cairns and more respondents in the highest income category. Half of the respondents in Mackay reported having an annual household income >$100,000.

Table 17: Gross household income of shore-based respondents

Income category	Cairns (n=30)	Mackay (n=24)	Airlie Beach (n=24)	Total (n=78)
<= $35,000	13%	21%	17%	17%
$35,001 - $60,000	23%	8%	25%	19%
$60,001 - $100,000	20%	21%	29%	23%
$100,001 - $150,000	17%	29%	17%	21%
> $150,000	27%	21%	13%	21%

5 Results: Survey of vessel-based independent recreational visitors

The survey of vessel-based recreational activities in and adjacent to the Marine Park yielded 85 valid responses. Respondents to the reply-mail survey are referred to as vessel-based respondents. A respondent comprises the person who completed the survey and the other person(s) who he/she undertook the trip with ('the group'). Average group size was 3.15 persons in Cairns, 3.5 persons in Mackay, and 2.4 persons in Airlie Beach. In total, the 85 responses included 272 persons (3.2 persons per respondent).

Table 18 shows the distribution of group types for vessel-based respondents. A relative majority of responses were from persons who undertook the boat trip 'with partner or spouse' (32%). In Airlie Beach this segment encompassed two thirds of all respondents. In Cairns, a relatively larger segment went boating 'with family and friends' (32%). In Mackay the strongest categories were 'with family' and 'with friends' (30% each).

Table 18: Composition of vessel-based respondent groups

	Cairns	Mackay	Airlie Beach	Total
Untertook trip with…	(n=25)	(n=44)	(n=15)	(n=84)
…nobody else	4%	7%	13%	7%
...spouse or partner	28%	23%	67%	32%
...family	16%	30%	0%	20%
...friends	16%	30%	7%	21%
...family and friends	32%	9%	13%	17%
...other	4%	2%	0%	2%
Total	100%	100%	100%	100%

Figure 10 shows the age distributions for respondents in the three survey locations. Age distributions were different for the three locations with Cairns having the highest percentage of respondents below 40 years of age. Age distribution in Mackay was more even than the other two survey locations with a minor peak in the 5-14 years age bracket and the biggest proportion of respondents within the 40-54 years age bracket. Airlie Beach respondents tended to be older with over 50% being 40 years and older and one third of respondents being 55 years or older. No statistically significant differences in age distributions between the populations were revealed using Mann-Whitney U tests.

Figure 11 shows the distribution of trip duration times for the three survey locations using box and whisker plots. The duration of boating trips ranged from just over one hour to more than 24 hours. Mackay had the largest range of trip durations with several international and interstate visitors having spent multiple days (up to 20) at sea and in the Marine Park. Airlie Beach respondents had the lowest range of trip durations from 2 to 72 hours.

The vessels used by respondents were usually stored or moored in the local area of the survey locations (59% and 29% respectively). Of boats moored elsewhere, one was from England, one from Sydney and one from Adelaide. Of boats stored elsewhere, two were from Victoria, one from Sydney, one from England and one Cairns respondent normally stored their boat in Hydeaway Bay (south of Bowen).

Figure 10: Age distribution for vessel-based respondents

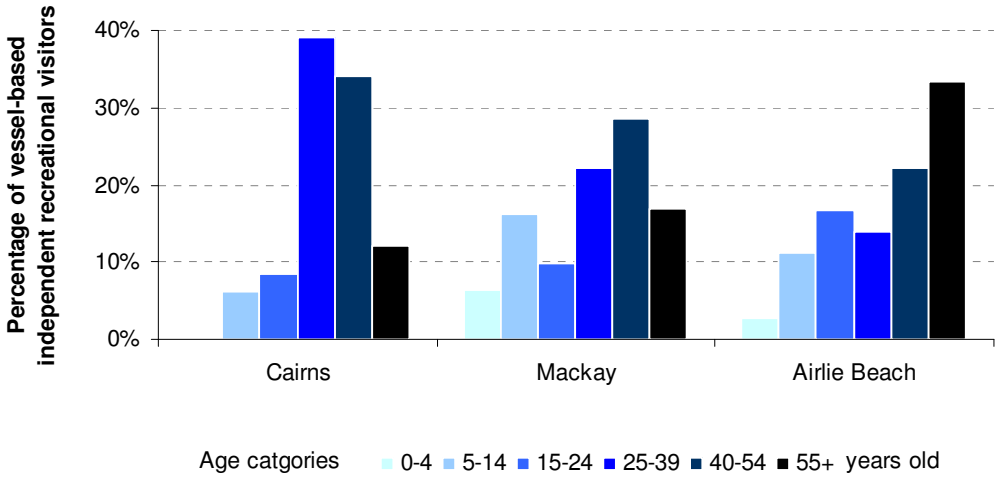
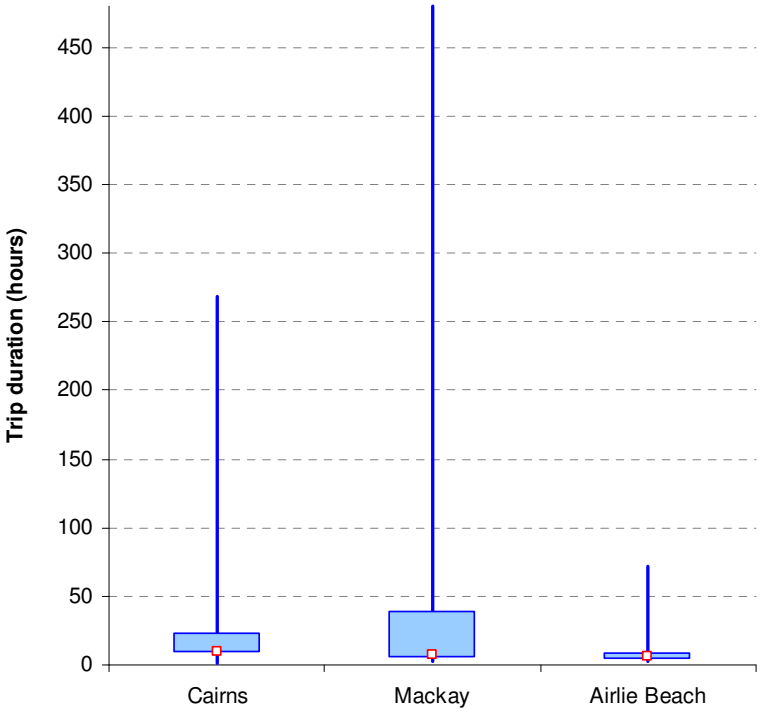


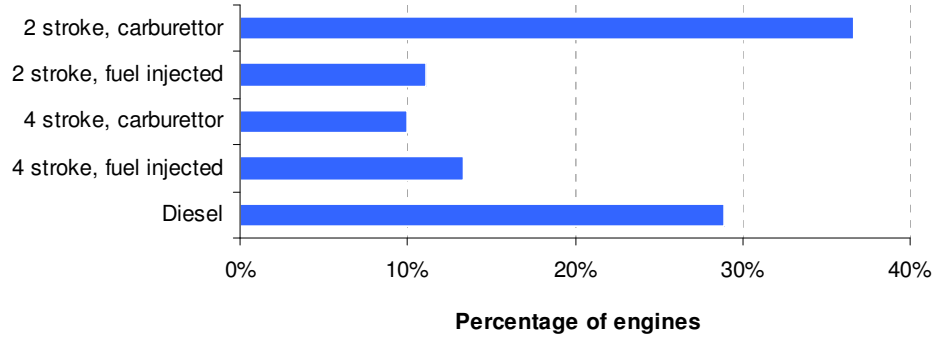
Figure 11: Recreational boating trip duration for vessel-based respondents



The majority of vessel-based respondents (94%) had a vessel with at least one engine fitted. Of vessels with engines, 8% had two engines of the same type and 7% had two different engine types. Figure 12 shows the proportion of respondents' vessels with various engine types. The most common engine was a 2-stroke carburettor (37% of engines). Diesel engines made up 29% of engines (fitted to 20% of respondents' vessels).

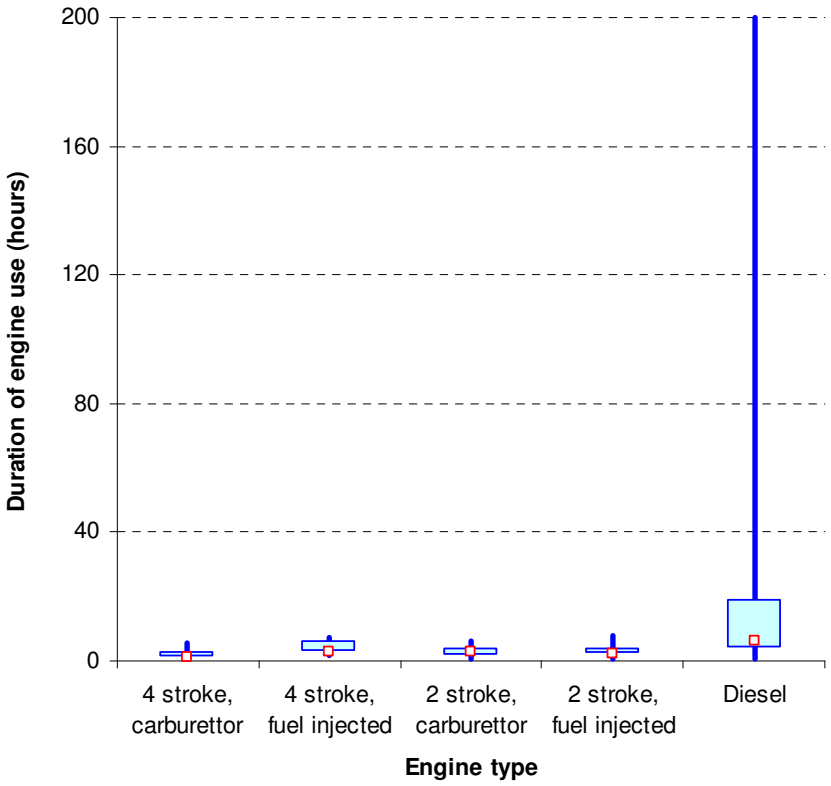
Figure 12: Engine types fitted to vessels

Note: Items add to >100% because some vessels have two different types of engine fitted



Petrol engines had a range of usage time from zero to 16 hours. Figure 13 shows the duration of use for the four different petrol engine types. The median usage time for 4-stroke fuel injected, 2-stroke fuel injected and 2-stroke carburettor engines was 3 hours. The middle 50% of usage of 4-stroke engines had the highest range of usage of all petrol engine types (3 - 6.25 hours). Amongst petrol engines, the largest range of usage time was for 2-stroke carburettor engines (0 - 16 hours). Diesel engines had a relatively high range of usage times (0 - 200 hours. The median period of usage was 6.5 hours with the middle 50% of observations falling between 2 and 30.5 hours.

Figure 13: Duration of engine use on last trip, by engine type



Vessels with diesel engines had significantly longer trip durations than vessels powered by petrol engines. Table 19 shows p-levels for tests of significant differences in trip durations based on the type of engine used by the respondent.

Table 19: Statistical differences in trip durations, by engine type

Note: Mann-Whitney tests were used to assess the differences

P-values significance: * < 0.1; **< 0.05; ***< 0.01.

	4-stroke, carburettor	4-stroke, fuel injected	2 stroke, carburettor	2 stroke, fuel injected
4-stroke, carburettor				
4-stroke, fuel injected	0.96			
2 stroke, carburettor	0.94	0.407		
2 stroke, fuel injected	0.51	0.241	0.518	
Diesel	0.008**	0.004**	0.000***	0.000***

The distribution of hours of engine use per day/per trip is shown in Table 20. Hours of engine use per day for vessels undertaking trips of more than 24 hours were calculated by dividing total engine hours by total trip hours for that vessel and multiplying by 24 hours. 4-stroke carburettor engines were used significantly less than any other engine type.

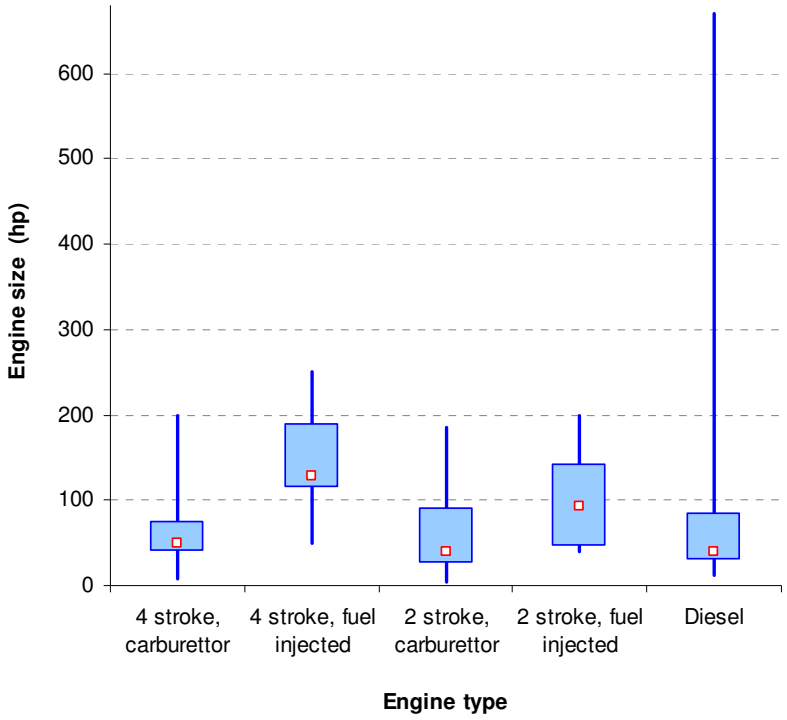
Table 20: Hours of engine usage per day/trip

Note: Engine usage per day (for trips of more than 24 hours) was derived by dividing total engine usage by total trip hours and multiplying by 24 hours.

	4 stroke, carburettor	4 stroke, fuel injected	2 stroke, carburettor	2 stroke, fuel injected	Diesel
Minimum	0.5	1.5	0.1	0.5	0.5
1st Quartile	1.0	2.7	1.5	2.0	1.8
Median	1.0	3.0	3.0	2.5	3.0
3rd Quartile	2.0	5.5	4.0	4.0	5.0
Maximum	5.5	6.5	5.0	8.0	6.1

Fuel injected engines tended to be larger than carburettor and diesel engines. Figure 14 shows the engine size distributions for the different engine types on respondents' vessels. Diesel engine sizes varied more widely than petrol engine sizes.

Figure 14: Engine size, by engine type



Mann-Whitney U tests were used to test for differences in the engine power by engine type. 4-stroke, fuel injected engines were significantly more powerful than 4-stroke carburettor, 2-stroke carburettor and diesel engines. Resulting p-values are shown in Table 21.

Table 21: Statistical differences in engine horsepower, by engine type

Note: Mann-Whitney tests were used to assess the differences

P-values significance: * < 0.1; **< 0.05; ***< 0.01

	4 stroke, carburettor	4 stroke, fuel injected	2 stroke, carburettor	2 stroke, fuel injected
4 stroke, carburettor				
4 stroke, fuel injected	0.037**			
2 stroke, carburettor	0.758	0.001***		
2 stroke, fuel injected	0.414	0.150	0.066	
Diesel	0.863	0.028**	0.849	0.215

Table 22 shows the proportion of engines mounted inboard and outboard by engine type. The majority of petrol engines were outboard motors whilst all respondent's diesel engines were inboard motors.

Table 22: Engine placement (inboard/outboard)

	Engine type				
	4 stroke, carburettor	4 stroke, fuel injected	2 stroke, carburettor	2 stroke, fuel injected	Diesel
Outboard	82%	73%	91%	100%	0%
Inboard	18%	27%	0%	0%	83%
Not specified	0%	0%	9%	0%	17%

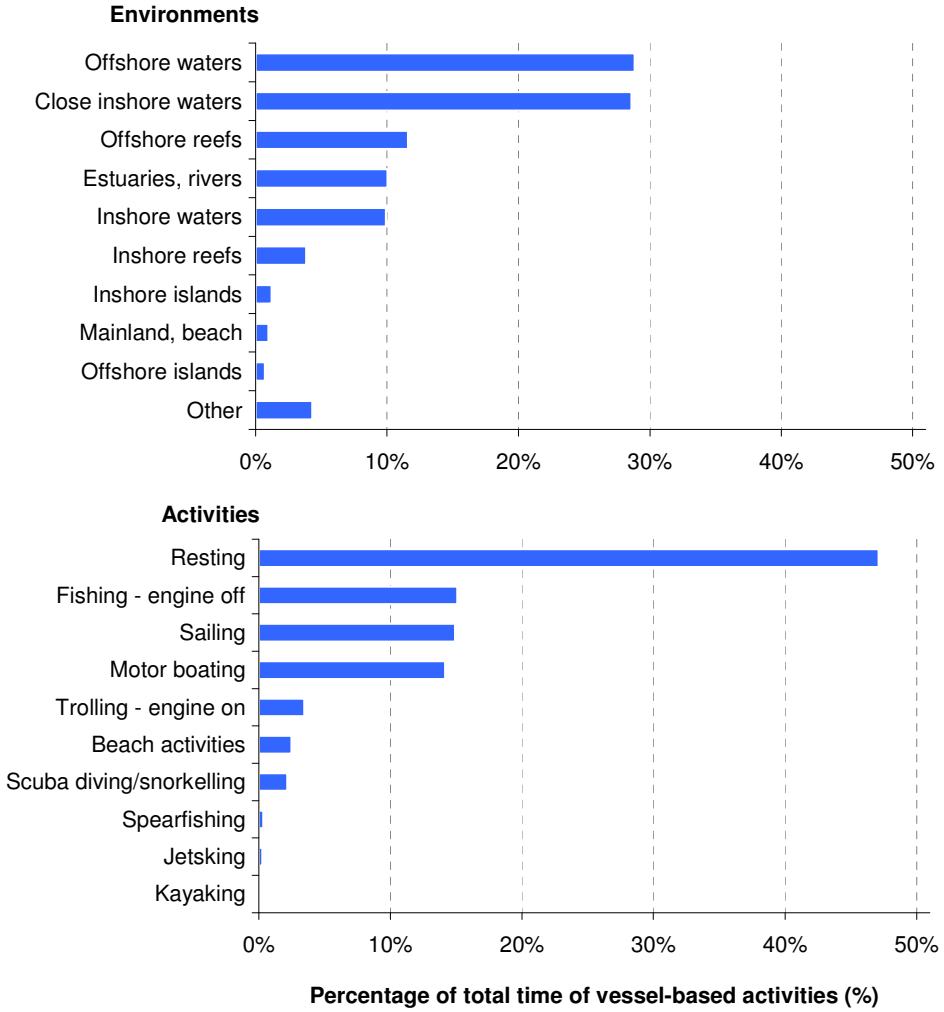
Of all vessels, 21 (25%) were treated with antifouling. No vessels using 4-stroke or 2-stroke fuel injected motors were treated. Usually larger non-trailerable vessels tend to be treated with antifouling. Of vessels treated:

- 15 had diesel engines;
- 5 had 2-stroke carburettor engines;
- 3 had both a 2-stroke carburettor and a diesel engine on board (this involved all dual engine boats; the much smaller 2-stroke engine serves as a kicker motor and is only used for trolling and/or as a safety backup); and
- 1 had a 4-stroke carburettor engine.

All vessels treated with antifouling had last been painted less than two years ago. The majority of antifouling treatments (67%) had occurred during the past 12 months.

Respondents provided estimates for the duration of recreational activities they had undertaken, and indicated where they had undertaken them. Figure 15 shows total time spent distributed across environments and activities. Equal time was spent in open offshore waters and close-inshore locations (29%). Of total time, 12% was in offshore reefs, 10% was in estuaries and/or rivers and 10 % in open inshore waters. “Other” locations included cays and shoals.

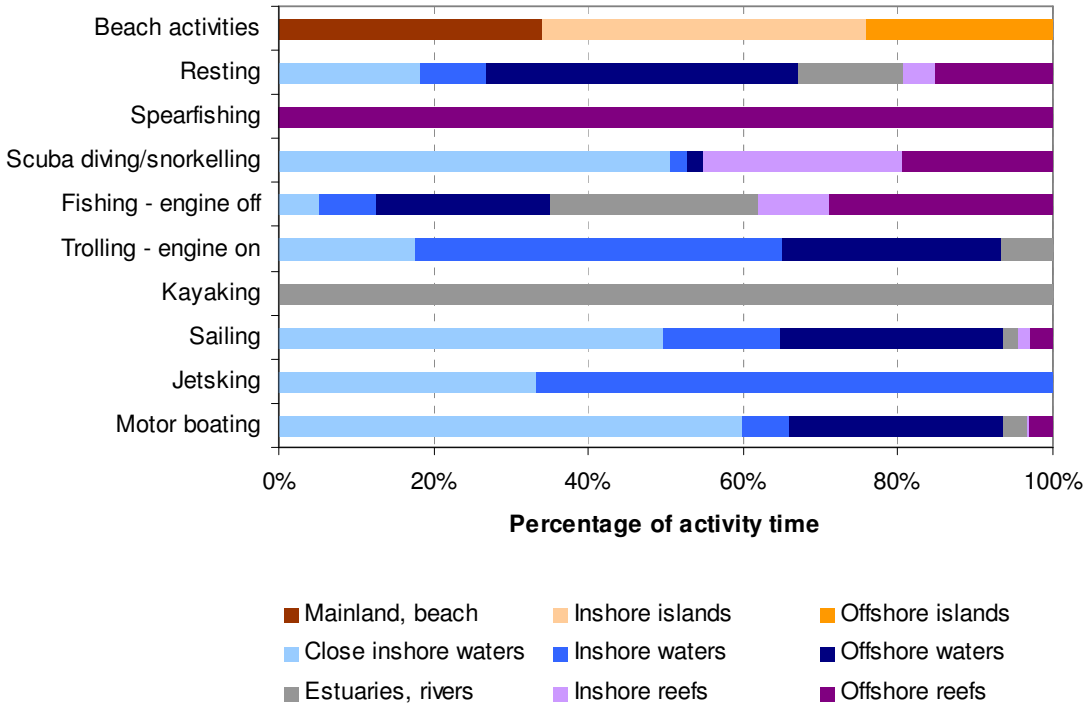
Figure 15: Distribution of total time of vessel-based activities, by environment and by activity



Almost half of total time spent (47%) involved resting, or “doing nothing in particular”. Fishing (engine off), sailing and motor boating were carried out for 14-15% of total trip time.

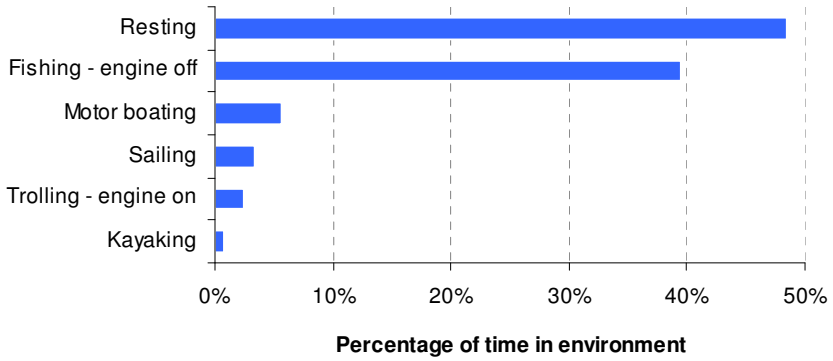
Figure 16 provides an illustration of how activities intersected with environments.

Figure 16: Proportion of time spent undertaking activities in different environments in and adjacent to the Marine Park



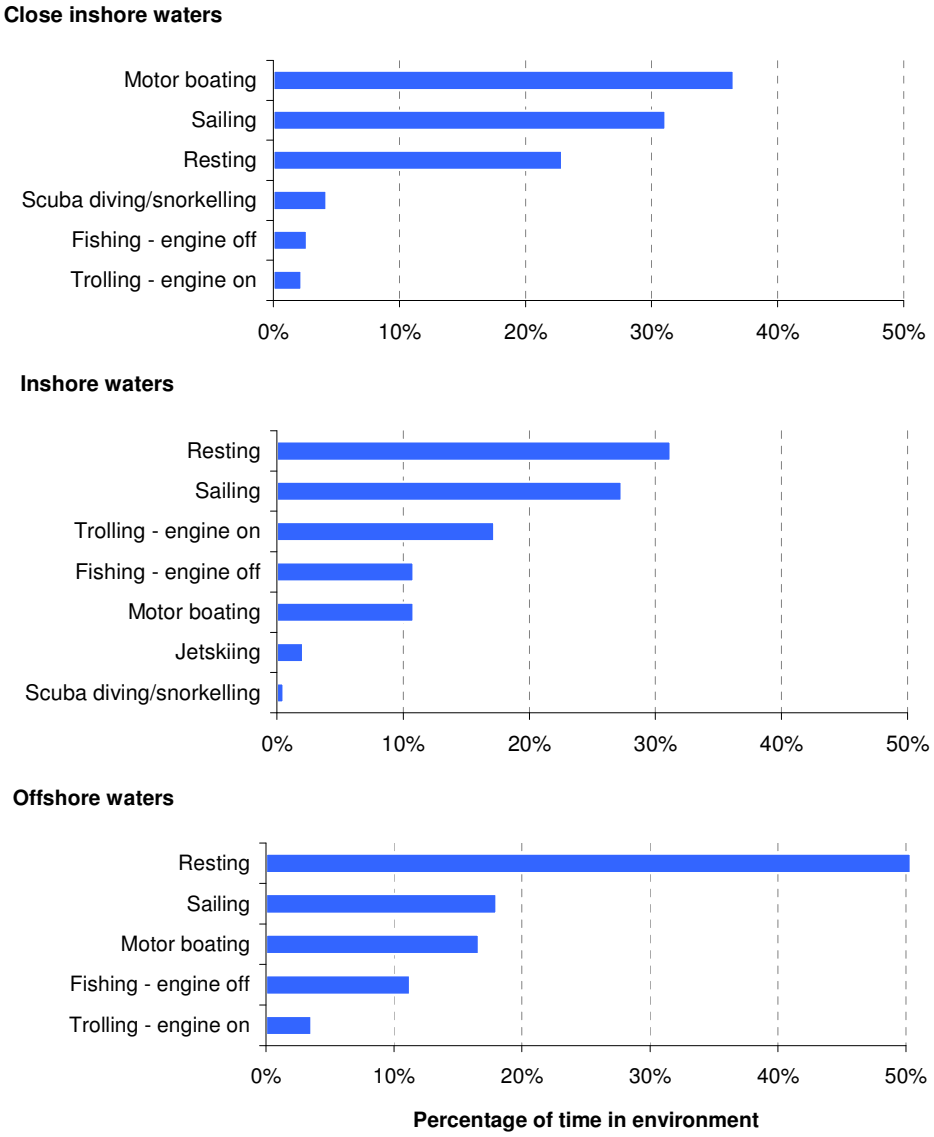
Approximately 10% of total trip time across vessel-based respondents was spent in estuaries and rivers (Figure 15). Figure 17 shows how this time is distributed across different activities. vessel-based respondents spent the majority of time in estuaries and rivers either resting (48%) or fishing (39%). Little time was spent moving.

Figure 17: Activity profile in estuaries and rivers



Of total trip time, vessel-based respondents spent about two thirds in open waters, mostly close inshore (near coast) and offshore, but also inshore (Figure 15). Motor boating was the most significant activity in close inshore waters, accounting for 37% of time. Figure 18 shows the activity profile for time spent in open water.

Figure 18: Activity profile in open waters



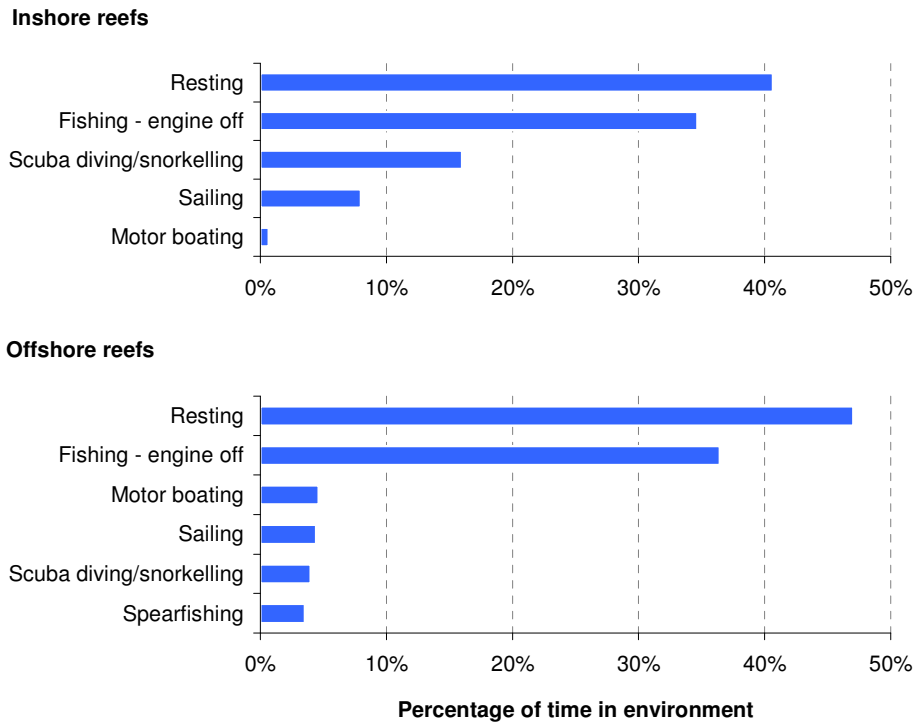
For close inshore waters, motor boating and sailing took up the majority of time with 35% and 31% of time respectively. There was some scuba diving and snorkelling, and a small proportion of time was spent fishing.

In other open inshore waters, 31% of time was spent resting and 27% sailing. Trolling (fishing from a moving boat with engine on) accounted for 17% of time with motor boating and fishing (engine off) accounting for 11% each.

In open offshore waters, resting took up 51% of time. Sailing and motor boating took up 18% and 17% respectively, and approximately 15% of time was spent fishing and trolling.

Among reefs, offshore reefs attracted more activity time than inshore reefs (Figure 15). The activity profile for inshore and offshore reefs is shown in Figure 19. On inshore reefs, vessel-based respondents devoted most time to fishing (34%) and resting (28%). Scuba diving and snorkelling was also a significant activity accounting for 12% of time. On offshore reefs, fishing and resting were the most significant activities (44% and 38% of total time, respectively).

Figure 19: Activity profile on reefs



A wide variety of locations was visited by respondents during their reported vessel-based recreational activities (Table 23). Cairns respondents most commonly visited Pixie Reef, Arlington Reef, Fitzroy Reef, and Green Island. Mackay respondents most frequently visited Round Top Island, Flat Top Island and St Bees Island. The percentage of visitation of localities was more evenly spread for Airlie Beach respondents.

Table 23: Localities visited by vessel-based respondents

Cairns		**Mackay**		**Airlie Beach**	
location	visitation	location	visitation	location	visitation
Pixie Reef	19%	Round Top Island	20%	Proserpine River	13%
Arlington Reef	15%	Flat Top Island	20%	Hook Island	13%
Fitzroy Island	15%	St Bees Island	16%	Whitsunday Island	7%
Green Island	15%	Mackay Marina	11%	Hamilton Island	7%
Sudbury Cay	12%	Brampton Island	9%	Repulse Bay	7%
Oyster Reef	8%	Scawfell Island	9%	South Molle Island	7%
Thetford Reef	8%	Pioneer River	9%	Long Island	7%
Turtle Bay	4%	Keswick Island	9%	Funnel Bay	7%
Smith's Creek	4%	Eimeo Creek	7%	Swamp Bay	7%
Vlasov Reef	4%	Slade Rock	5%	Pioneer Bay	7%
Batt Reef	4%	Dolphin Heads	5%	Langford Island	7%
Palm Cove	4%	Dangerous Reef	5%	Sid Harbour	7%
Port Douglas	4%	Shaw Island	2%	Whitehaven Beach	7%
Holloway's Beach	4%	Dunk Island	2%	Woodwark Bay	7%
Eastern Patches	4%	Palm Island	2%	Shute Harbour	7%
Double Island	4%	Cape Gloucester	2%		
Georgansons Patch	4%	Airlie Beach	2%		
Cape Grafton	4%	Cape Cleveland	2%		
Snapper Island	4%	Sunken Reef	2%		
High Island	4%	Shoal Point	2%		
		Lamberts Beach	2%		
		Torobo Rock	2%		
		Glendower Point	2%		
		Abbott Point	2%		
		Black's Beach	2%		
		Cockermouth Island	2%		
		Cebolin Reef	2%		
		Stevens Reef	2%		
		Refuge Bay	2%		
		Maryport Bay	2%		
		Dinghy Bay	2%		
		Reliance Creek	2%		
		Llewellyn Bay	2%		
		Prudoe Island	2%		
		South Molle	2%		
		Port Newey	2%		
		Weiton	2%		

From a provided list of behaviours that can affect water quality, respondents indicated whether and how often these behaviours had occurred during their reported trip. Table 24 shows the proportion of all vessel-based respondents who reported having enacted behaviours shown on the list. Table 25 shows the frequency of these actions and volumes of pollutants emitted into the water for the vessel-based respondents. Most vessel-based respondents (60%) indicated they urinated into the water or into a toilet without a sullage tank during their trip. The median volume of sullage emitted by vessel-based respondents was 20 litres per day. Vessel-based respondents who reported defecating into the water most commonly did so twice per day per trip.

Table 24: Extent of behaviours that can affect water quality

Proportion of respondents who reported this behaviour took place on their last trip

Behaviours	Proportion of respondents (%)
Urinating into water (or toilet without sullage tank)	60%
Emptying soapy liquids or detergents into water	22%
Cleaning/gutting fish	22%
Defecating into water (or toilet without sullage tank)	13%
Emptying of sullage tank	8%
Hosing off boat at the boat ramp	6%
Disposal of solid rubbish into the water	4%
Spill of any substances (e.g. oils; detergents…)	2%

Table 25: Activities contributing pollutants to waters in and adjacent to the Marine Park

Note: Numbers are reported per trip for those trips less than 24 hours in duration and are reported per day for trips of more than 24 hours in duration

	Emptying of soapy water (Litres per day/trip)	Cleaning/gutting fish (number per day/trip)	Urinating into water (number of times per day/trip)	Defecating into water (number of times per day/trip)	Emptying of sullage tank (litres per day/trip)
Minimum	0.5	0.6	1	0.75	2.9
1st Quartile	1.075	1.2	2	1	15
Median	2.3	2	3	2	20
3rd Quartile	4.95	3	6	3.7	44.8
Maximum	85.4	10	30	6	61

Of vessel-based respondents, five hosed off their vessel at the boat ramp, while three reported disposing of solid rubbish into the water. One respondent gave a description of the rubbish put into the water – *"90 beer cans torn in half, vegetable food scraps, fruit scraps".* One respondent recorded spilling 8 litres of fuel due to water contamination of the fuel tank but stated that the spill had been contained on-board using a container and that the fuel/water mix was taken back on shore.

Respondents were asked to nominate water quality impacts of recreational activities in the Marine Park. Table 26 shows the frequency of nominations. "Rubbish" topped the list with 36% of respondents mentioning it, followed by 'fuel and oil spills' (15%).

Respondents were asked to nominate any changes they had observed with respect to water quality and/or recreation. Responses were analysed and grouped in categories as shown in Table 27. There was a scattering of general observations and comments. Of respondents, 39% stipulated that they had not noticed any change, while 19% did not provide any comments and 4% stipulated they did not know.

"Less fish", "impacts around marina and foreshore developments" and "water quality worse/ more variable inshore" were most frequently nominated. Almost 40% of respondents stated that they had not observed any changes to water quality and/or recreation in the Marine Park, 4% were not sure and 19% did not provide any answers to this question or gave answers that were irrelevant.

Table 26: Water quality impacts of recreation nominated by respondents

Note: Proportions add to more than 100% as respondents could nominate more than one water quality impact of recreational activities.

Water quality impacts/ pollutants of recreational activities	Percentage of respondents
Rubbish	36%
Fuel and oil spills	15%
Exhaust fumes	8%
Sullage	7%
Anchoring	2%
Antifouling	2%
Sunscreen	2%
No impact	2%
Detergents	1%
Walking/fossicking on the reef	1%
Visibility	1%
Damage to reef coral and fish	1%
Increased turbidity	1%
No comment	38%

Table 27: General observations and comments relating to observed changes in water quality and/or recreation

Note: Totals add up to more than 100% as respondents could comment on more than one observed change.

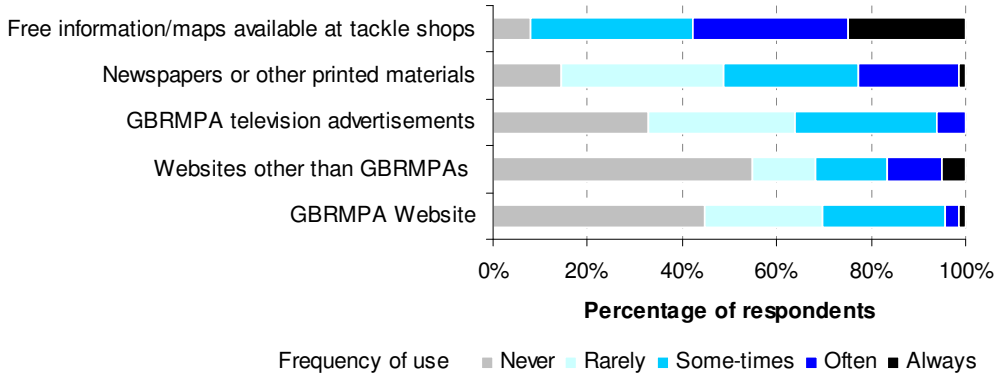
Observed change to water quality/recreation	Number of respondents commenting	Percentage of respondents commenting
Less fish	7	8%
Impacts around marina and foreshore developments	6	7%
Water quality worse/ more variable inshore	6	7%
Water cloudier	3	4%
Water quality has improved	2	2%
Water quality is better where there are less tourists	2	2%
Water pollution from coal ships (Mackay)	2	2%
Commercial fishing decreased fish stocks	1	1%
Less species of fish	1	1%
None from recreation	1	1%
Improvements in reef and water quality where prawn trawling has ceased	1	1%
Mud and silt over parts of the reef	1	1%
Rubbish/scum in the water	1	1%
Debris after floods	1	1%
Plastic bait bags in the water	1	1%
Trawlers create diesel pollution	1	1%
No observed change	33	39%
Don't know/unsure	3	4%
No comment	16	19%

Respondents were asked to indicate how frequently they accessed different sources of information to find out about the Marine Park by replying on a rating scale (Likert-type scale) from 1=Never to 5=Always. Figure 20 shows the frequency distribution of responses against each listed information source.

The most commonly accessed source of information was "free information/maps available at tackle shops" with 34% of respondents "often" and 25% of respondents "always" accessing information from this source. On average, the website of the Great Barrier Reef Marine Park Authority was accessed less frequently than any other listed information source.

Figure 20: Frequency of use of different sources of information to find out about the Marine Park by respondents

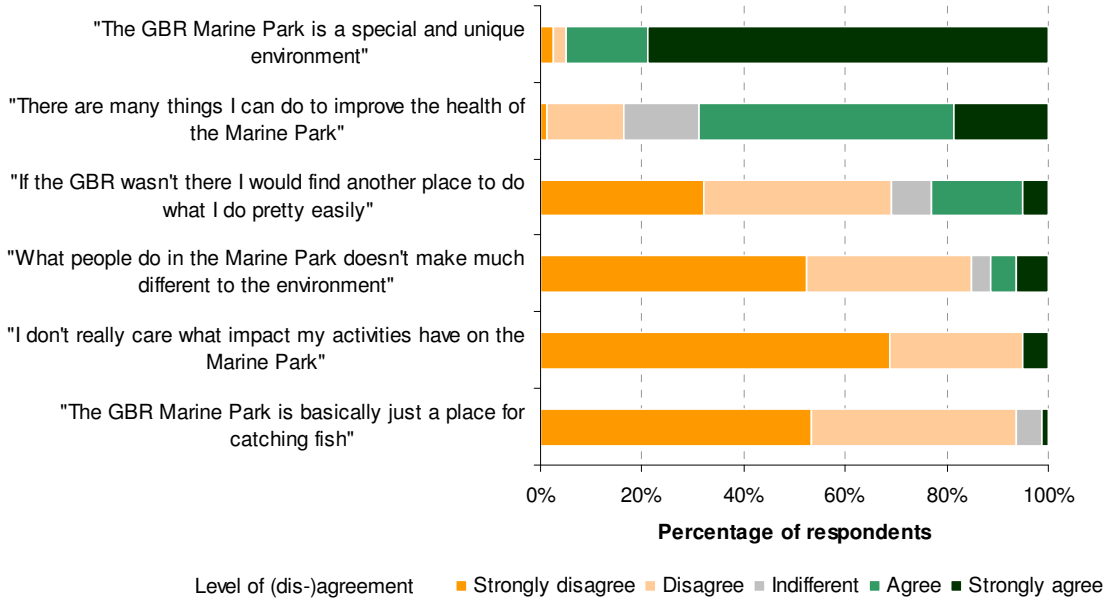
Items sorted by mean value



Respondents were presented with a set of statements on the Great Barrier Reef and Great Barrier Reef Marine Park Authority and asked to indicate their level of agreement with these. The level of agreement was assessed using responses provided on a 5-point Likert-type scale with; 1=Strongly disagree; 2=Disagree; 3=Indifferent; 4=Agree; 5=Strongly agree. Frequency distributions for each statement are presented in Figure 21.

Figure 21: Agreement levels with statements on the Great Barrier Reef and the Marine Park by vessel-based respondents

Items in same order as shore-based respondents (Fig. 9)



Respondents were provided with space at the end of the questionnaire to give more information or add comments. Most respondents (66%) used this space, providing comments on other activities in and adjacent to the Marine Park, this research, current management of the Marine Park as well as other topics. Comments were analysed and grouped into different categories. Table 28 provides a grouping of the responses. A detailed listing is provided in Appendix 5.

Of vessel-based respondents, 14% commented on matters of management by the Great Barrier Reef Marine Park Authority. Land and urban runoff were considered to be major or the most important impacts of human activities on the waters in and adjacent to the Marine Park by 12% of respondents.

Table 28: Additional comments offered by vessel-based respondents

Comment category	Percentage of respondents commenting
GBRMP management	14%
Terrestrial runoff	12%
Urban/commercial/industrial development	11%
Recreational fishing	7%
Rubbish and littering	6%
Commercial shipping	6%
Commercial fishing	6%
General positive comments	2%

6 Other results: observations and integrated analysis of shore-based and vessel-based survey data

The observations undertaken by the research team yielded little, if any, evidence of shore-based pollution. Table 29 summarises the observations.

Table 29: Observations of water pollutants during field work

Location	Observations
Cairns - Beaches	Some empty drink bottles and cans near parking areas on Holloways Beach; one lot of dog excrement on beach
Cairns - Marinas	Small amounts of oils on water surface
Cairns - Boat ramps	None
Mackay - Beaches	Some fast-food packaging and plastic rubbish on Harbour Beach
Mackay - Marinas	None
Mackay - Boat ramps	None
Airlie Beach - Beaches	One lot of dog excrement on the beach, rubbish in drains, one fish carcass.
Airlie Beach - Marinas	None
Airlie Beach - Boat ramps	None

The two surveys contained identical questions about use of media to impart information on the Great Barrier Reef Marine Park and an attitudinal statement in relation to the Reef and the Marine Park. These data were combined and an integrated and comparative analysis undertaken.

A comparison of the use of information about the Reef from shore-based and vessel-based respondents showed several significant differences (Table 30). Vessel-based respondents used the Great Barrier Reef Marine Park Authority's web site significantly more often and took more notice of its television advertisements. In particular, they accessed the free information and maps available at tackle shops.

Table 30: Comparison of shore-based and vessel-based respondents in relation to information sources

Note: Significance levels: * <= 0.1; ** <=0.05; *** <=0.01

	Valid sample size		Vessel-based		Shore-based		p-level	
	Vessel-based	Shore-based	Mean	Standard deviation	Mean	Standard deviation		
GBRMPA Website	69	90	1.91	0.98	1.43	0.92	0.001	***
GBRMPA television advertisements	64	90	2.09	0.94	1.70	1.01	0.007	***
Free information/maps available at tackle shops	76	89	3.67	1.10	2.39	1.35	0.000	***
Newspapers or other printed materials	70	90	2.61	1.03	2.59	1.35	0.761	
Websites other than GRRMPA's	60	86	1.98	1.28	1.76	1.18	0.289	

A similar comparison was undertaken in relation to the attitudinal questions. No significant differences were found in attitudes between shore-based and vessel-based respondents.

A factor analysis was undertaken of the attitudinal items. The results are shown in Table 31. Three factors emerge, explaining 65% of variance. The resulting factor structure is quite 'clean', with only one item loading on two factors (i.e. value greater than 0.40).

Table 31: Comparison of shore-based and vessel-based respondents in relation to attitudes

Note: Principal components analysis was used for factor analysis and varimax orthogonal rotation applied to the Eigenvalues;
Loading factors >o.4 highlighted in bold

	Factor 1	Factor 2	Factor 3
"The GBR Marine Park is basically just a place for catching fish"	0.0545	**0.8367**	-0.1517
"If the GBR wasn't there I would find another place to do what I do pretty easily"	-0.1543	**0.5394**	**0.5098**
"What people do in the Marine Park doesn't make much different to the environment"	**0.6016**	0.3985	0.3195
"There are many things I can do to improve the health of the Marine Park"	0.0466	0.1617	**-0.8016**
"I don't really care what impact my activities have on the Marine Park"	0.3716	0.1257	**0.6163**
"The Marine Park is a special and unique environment"	**-0.8490**	0.1411	0.0728
Explained variance	1.2498	1.2116	1.4126
Proportion of total	21%	20%	24%

Factor 3, explaining 24% of variance, broadly encompasses awareness of one's own impacts on the Great Barrier Reef and the Marine Park. Factor 2, explaining 20% of variance, describes the use values of the Reef and the Marine Park. Factor 1, explaining 21% of variance, encapsulated people's recognition of the uniqueness of the Marine Park and people's impacts on its environment.

7 Discussion and interpretation

This research set out to establish an empirical connection between recreational activities in the Great Barrier Reef Marine Park and water quality. It was to lay the conceptual and methodological foundation for a subsequent study that would quantify the impact by independent recreational visitors on water quality in the Marine Park.

The first step in establishing the empirical connection was to conceptualise recreational activities as a set of behaviours or actions with different emission profiles. Activity-based emissions could be established from the literature. To scope the possible extent of impact, per person or per recreational activity, the research conducted surveys of shore based and vessel-based independent recreational visitors.

The three survey locations were pre-determined as were the number of face-to-face interviews to be conducted and the number of reply-mail surveys to be handed out—in line with the descriptive character of the research, resources and time lines of the research. The surveys adopted some 'standard' questions used in Great Barrier Reef Marine Park Authority surveys.

In the choice of field work times (three days per location) a number of matters were considered, including weather, tides and events that might distract large numbers of people from recreational activities in the Marine Park. Timing was paramount because of the limited number and time of field work opportunities. The choices for field work days turned out to be fortunate—the target number of face-to-face surveys was reached and more than the required number of mail-return surveys was handed out.

The response rate for the face-to-face survey was very high as very few potential respondents declined to participate and the sample size of 90 was attained, which represented 168 shore-based independent recreational visitors. The response rate for the mail-return survey was just under 20%, which was acceptable for this survey method and yielded 85 responses--representing 272 vessel-based independent recreational visitors. The response was adequate to scope the key issues and provide quantitative empirical context. If this study is seen as a scope and 'pre-test' for a more comprehensive investigation of independent recreational visitors visiting the Marine Park, the effectiveness of both methods has been confirmed.

For future research to be able to derive estimates with good statistical confidence from the vast number of independent recreational visitors across the entire Marine Park, responses from a significant proportion of independent recreational visitors must be obtained (Bennekom, 2002). Mail return sample sizes are shown to vary widely between 11% and 85% for different research projects (Hua Shih and Fan, 2008). These variations may be a result of the population being surveyed (i.e. general population vs specific populations such as 'teachers') and the relevance of the topic to the surveyed population (De Vaus, 2002). Realistically, without major financial incentives, a response rate of 20% appears to be a good outcome for this type of inquiry (Larson, 2005). There has been a tendency away from mail-return surveys to telephone surveys to overcome the issue of response rate (Larson, 2005). However, telephone surveys such as the one conducted by Norris et al. (2003) of residents in the Great Barrier Reef adjacent areas are unable to capture important groupings within non-resident independent recreational visitors, such as travelling sailors and interstate and intrastate tourists.

Respondents in the face-to-face survey were most commonly walking the beach, many with their pet dogs, or simply enjoying the beach, when they were asked to participate in the survey. During the previous 12 months, most of them had been swimming (68% of respondents, with a median frequency of 10 times), fishing (66%; median frequency 10 times) or motor boating (54%). These findings are broadly consistent with earlier research by Norris *et al.* (2003).

Vessel-based independent recreational visitors mostly lived in the vicinity of the survey location, had their boat stored or moored locally, and went on a boat trip for part of a day. However, some respondents were residents from interstate or elsewhere in Queensland who had trailer

boats. Others were vessel-based national and international travellers. They fell within the bounds of the Great Barrier Reef Marine Park Authority definition of independent recreational visitor—and therefore did not engage with the Authority through the administration of the environmental management charge.

It was interesting that a large proportion of total time spent by vessel-based respondents on their most recent boat trips (almost 50%) was spent 'resting'. Fishing made up approximately 20% of total time, of which 80% was stationary—with a large reef component—and 20% was trolling. Sailing and motor boating had almost equal time of 15% each even though fewer respondents had been sailing (16) than motor boating (69). This may suggest that sailing trips, on average, are longer and/or involve a larger proportion of time when the boat is moving.

One respondent only had undertaken activities on a man-powered vessel (kayaking). Kayakers and rowers constitute a small proportion of vessel-based users of the Marine Park and the survey distribution method possibly discriminated against this group of independent recreational visitors—they do not require boat ramps to launch their vessels.

In terms of impacts of recreation on water quality, recreation did not feature prominently in the perceptions of respondents as a polluting activity. Only in Airlie Beach, 23% of shore-based respondents nominated recreational boating waste and sullage as a water quality issue, while it was not raised in Cairns or Mackay. Respondents were more concerned about urban runoff and waste/rubbish, the down-stream impact of agriculture, and urban and coastal development. Chemicals or oils released from ships were also nominated by some respondents as being of concern. Many respondents could not conjure up how recreation would impact on water quality, and some stated that they thought there was no impact. Many respondents, particularly in Cairns, associated independent recreational visitors with rubbish, but some comments made suggest that respondents might have referred to tourists rather than independent recreational visitors.

Respondents in both surveys—29% of shore-based respondents and 36% of vessel-based respondents—nominated rubbish as the major key water quality issue. Rubbish was not necessarily attributed only to recreational activity as recreational activity may have been interpreted by some respondents to also include tourism. Some respondents commented that tourists tended to litter while locals would commonly pick up rubbish. It would appear that the visual presence of rubbish, as opposed to the invisible character of some other pollutants, influenced respondent perceptions. Litter and hard rubbish do not directly change the chemical composition of water, introduce contaminants or have any other direct water quality implications.

In Cairns and Airlie Beach, uncollected dog faeces was the most frequently observed side effect of shore-based recreation but more than 50% of respondents never or rarely saw any. Dog faeces contributes nutrients and potential pathogens to the marine environment (Pastorok and Bilyard, 1985); these are considered to be chemical changes (National Oceans Office, 2004) and in large quantities may result in changes to ecosystem structure in a localised area (Pastorok and Bilyard, 1985). Some respondents in Cairns suggested that the local council should introduce bylaws to compel all dog owners to pick up their pets' faeces whilst in public spaces. Airlie Beach respondents noted that the local council provided many pet poo bag dispensers and signage. Groves (2008) reports that improving the availability of facilities such as pet poo bag dispensers is an important step in reducing the number of dog faeces left in popular dog-walking areas.

Shore-based respondents reported only a few observations of other potential land-based recreational activities that may impact on water quality, including horse riding on beaches (leaving behind horse poo), people driving on beaches (possibly causing erosion), and people camping on beaches (possibly causing faeces, urine and detergent pollution). The research team did not observe any of these behaviours during 10 days of shore-based field work. It would appear unlikely that these activities have any discernable water quality impacts locally or more widely in the Marine Park.

Of more serious concern for water quality, though not necessarily in the mind of independent recreational visitors, are pollutants that originate from fuels and oils. Fuels and oils are contaminants of marine waters in the Great Barrier Reef Marine Park (National Oceans Office, 2004). Polycyclic aromatic hydrocarbons are considered to be the most biologically harmful of all petroleum products (Neff, 1990 in; Haynes and Johnson, 2000) and are emitted by both petrol and diesel fuelled engines. Unburnt fuel emissions also contain MTBE that may be toxic to marine organisms (Bender *et al* 2005).

Almost 40% of vessels used by vessel-based respondents were fitted with 2-stroke, carburettor engines. Recent research by Environment Link (2007) shows that these are the most polluting type of engines available, yet they make up more than 60% of engine sales in Australia. Not a single engine of this type meets current emissions standards for outboard engines set for Europe and the United States. Many of these engines are built in countries in which they can no longer legally be sold, but they continue to be built for export to countries with less stringent environmental standards, such as Australia (Environment Link, 2007). A decrease in the use of 2-stroke engines would be expected to lead to a significant reduction in levels of burned and unburned petrol products, as evident from Lake Tahoe in the USA. Legislating the use of cleaner fuel for 2-strokes may also be effective (Sterner, 2002). It appears feasible for 2-stroke engines to cause measurable water quality impacts in areas of high usage, including near boat ramps, in estuaries and rivers, and in popular near-shore and off-shore locations. It would appear prudent to limit the use of 2-stroke engines in the Marine Park, particularly in ecologically sensitive areas.

There are strategies that the Great Barrier Reef Marine Park Authority can pursue in an effort to reduce the number of 2-stroke engines, particularly carburettor-type engines, operating in the Marine Park.

- Accelerate the adoption of the voluntary emissions labelling scheme, which was adopted by the Outboard Engine Distributors Association of Australia in September 2006. It is modelled on the California Air Resources Board stars labelling scheme. Labelling is thought to influence consumer decisions and is credited, in part, for the relative decline in sales of 2-stoke carburettor engines from 84% in 1998 to 63% in 2005 of all marine outboard engine sales in Australia (Environment Link, 2007: p.29; reproduced in Appendix 6).
- Lobby for the adoption of an Australia-wide emissions based approach for new boat engines, modelled on the automotive industry of Australia, which must comply with the Australian Design Rules set for new vehicles sold, including emissions levels of Hydro Carbons, Carbon Dioxide and Nitrous Oxides (DITRDLG, 2008). The Australian Design Rules also require car dealers to display emission and fuel consumption information based on standardised tests set by the Australian Government.
- Develop an information campaign, through multiple avenues, to alert current and prospective boat owners to the emissions profiles of different types of engines, using the stars labelling scheme.
- Provide financial incentives for people residing in the Great Barrier Reef catchment to replace an existing 2-stroke carburettor or fuel-injection engine. A buyback scheme could offer a nominal purchase price, which may be a small but symbolic incentive (1) not to on-sell an old engine and (2) to upgrade to a less polluting engine type. Buyback schemes have previously been used in Australia to reduce the number of fire-arms in the community (Australian Government Attorney-General's Department, 2006) and in Sydney to buyback fridges (Fridge Buyback, 2008).

Of the engines fitted to vessels of vessel-based respondents, 29% were diesel powered, all of which were mounted as inboard engines. Inboard engines do not exhaust directly into the water, meaning they are more benign for water quality.

One quarter of vessel-based respondents had treated their boats with antifouling and all had done so in the last two years. Hull antifouling compounds are commonly used on boats that are moored and permanently in water. Antifouling materials are usually based on copper and

organic compounds in Australia. They are designed to be toxic to marine life to prevent the build-up of marine growth on the hulls of vessels and other boat parts submerged in water for long periods of time. Sakkas and Albanis (2003) discuss the hazards to aquatic life from organic antifouling agents and copper-based antifouling paints can affect the photosynthesis of seagrasses, inhibit development of coral larvae and accumulate in the tissues of marine mammals including fish, turtles and dugongs (Leon and Warken, 2008). Saphier and Hoffman (2005) show that relatively low concentrations of copper in water can impact on the spawning success of some corals. The relative importance of the contribution by recreational vessels to the levels of these substances found in marine waters is unknown. As the report by Thompson Clarke Shipping Pty. Ltd *et al.* (2004; p.22) points out, "The substantial number of recreational craft compared to commercial vessels does have implications for any survey and inspection regime that may be required to underpin any antifouling regulations for this class of craft. The limited surveying resources of the States and the Northern Territory may necessitate the development of a risk-based approach to surveying and inspecting antifouling on recreational craft."

Urine and human faecal matter contribute nutrients and pathogens to the marine environment (Pastorok and Bilyard, 1985). A majority (60%) of vessel-based respondents reported urinating into the water a median number of 3 times per day per trip. Defecation into the water occurred on fewer trips (13% of respondents) with a median frequency of twice per trip per day. Leon and Warken (2008) estimate that 250g of faecal matter and 1.15kg of urine are excreted per person per day on vessel-based recreational trips, containing 9 - 17.5 grams of nitrogen. Higher than normal levels of nutrients can result in changes to ecosystem structure in localised areas by increasing primary production (Pastorok and Bilyard, 1985). Quantification of the impacts of urine and excrement is limited by a lack of information on the total number of people undertaking recreational activities in the Marine Park.

Leon and Warken (2008) found that in Moreton Bay in south east Queensland marine recreational activity is heaviest during periods of high leisure time availability, namely around the Christmas/New Year and Easter holidays. They estimated total nitrogen emission from recreational activity in Moreton Bay, over a whole year, to be less than 2 tonnes (Leon and Warken, (2008). The amount is negligible compared with the estimated 900 tonnes of nitrogen emitted per year through sewage effluent outfalls in the region (EHMP, 2007 in; Leon and Warken, 2008). Approximately 85,000 vessels are registered to owners residing in South East Queensland (Leon and Warken, 2008) whilst approximately 70,000 are registered to residents of the Great Barrier Reef Catchment Area (Access Economics, 2007). The Great Barrier Reef extends for approximately 2300 kilometres from Bundaberg to the northern tip of Queensland. In comparison, Moreton Bay Marine Park is less than 200km long and 100km wide (EPA, 2008). This comparison implies that the recreation-generated nitrogen load across the Marine Park is low in absolute terms, highly diffuse and negligible when compared to urban and agricultural discharges.

A small proportion (8%) of vessel-based respondents reported emptying sullage into the marine environment. Details on the level of treatment and discharge areas for this waste were not obtained. The Great Barrier Reef Marine Park Authority legislates the areas in which vessels can release sullage (details at http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/vessel_sewage_regs). The provision of easily accessible and cheap facilities for waste removal can be an effective anti-pollution measure (Groves, 2008). Increasing the number of sullage transfer facilities in marinas as well as making the use of these cheaper may lead to an increase in the use of these facilities by boat owners with on-board toilets. Several people living in marinas commented that waste transfer facilities in many marinas were inadequate or prohibitively expensive.

Swimming, a seemingly harmless activity, may impact on local coral species when people apply sunscreen prior to entering the water. Danovaro *et al.* (2008) report that components of sunscreen can cause coral bleaching, even at extremely low levels. The use of sunscreen is banned in some high-use coral reef areas overseas.

The research reinforced the high intrinsic value that people attribute to the Marine Park, with 95% of shore-based respondents and 93% of vessel-based respondents agreeing that, “The Marine Park is a special and unique environment”. Respondents were concerned about the impacts that their activities might have and approximately two thirds of both vessel-based and shore-based respondents agreed that individual action mattered (“there are many things I can do to improve the health of the Marine Park”).

Vessel-based respondents tended to seek more information about the Marine Park than shore-based respondents across all sources of information. For shore-based respondents, newspapers or other printed materials were the prime information source whereas for vessel-based respondents, free information and maps available at tackle shops was the single most important source of information. For both respondent groups the Great Barrier Reef Marine Park Authority website was the least used information source—lower than other websites and TV advertisements. Almost 50% of vessel-based respondents and 75% of shore-based respondents had never accessed the Great Barrier Reef Marine Park Authority website. This highlights the ongoing importance of print material, preferably free of charge, for information dissemination about the Marine Park.

8 Conclusions

This research set out to establish an empirical connection between recreational activities in the Great Barrier Reef Marine Park and water quality.

Based on literature review and results of two scoping surveys, one of shore-based independent recreational visitors and the other of vessel-based independent recreational visitors, the research demonstrates that:

- Independent recreational visitors of the Marine Park, shore and vessel-based, regard rubbish as the key water quality issue, possibly because of its visual prevalence. Rubbish is attributed partially to recreational activities, but mainly to urban areas in general and tourists.
- There is likely minimal impact on water quality from shore based recreational activities including dogs and horses on beaches, driving cars on beaches, and beach camping. Any localised issues may be addressed locally, e.g. through management by local government.
- During boat trips, independent recreational visitors commonly discharge human excrement and urine into the marine environment. Because of the overall small recreational load and the largely diffuse character of recreational activities in the Marine Park this is unlikely to cause water quality issues.
- The key impact from recreational boating in the Marine Park may be from 2-stroke carburettor outboard engines and 2-stroke fuel injection outboard engines. Sale of these engines for boats has been effectively curbed in many other countries because of their pollution characteristics. In the mail-return survey, the most common engine type was the 2-stroke carburettor type.
- There is a lack of information on levels of copper and organic biocides from antifouling paints in the Marine Park.
- Most independent recreational visitors seem to be aware of the ecological importance of the Marine Park so may respond positively to engagement by Great Barrier Reef Marine Park Authority.

On the basis of this research, the following conclusions can be drawn:

- Any management measures for the Marine Park can draw on the high intrinsic value that independent recreational visitors, shore based and vessel-based, hold for the Marine Park, and their willingness to moderate their own actions for the good of the Marine Park.
- Information campaigns about the Marine Park work best if they include television advertisements and print material that is available at tackle shops or as newspaper articles.
- The water quality impact from recreation of most concern arises from the wide-spread use of outboard 2-stroke engines. Many countries have set boat engine emission limits for spark ignition engines used by marine water craft, which effectively prohibit the sale of 2-stroke carburettor-type engines for boats. The Great Barrier Reef Marine Park Authority may want to consider lobbying the Australian Government to do likewise, support the implementation of voluntary engine labelling schemes and conduct information campaigns to influence the purchase decisions of prospective boat and engine buyers. It could also consider establishing a buyback scheme for highly polluting boat engines.
- More research is needed to understand both critical levels of toxicity of antifouling substances and the levels found in different regions within and adjacent to the Marine Park.

The research had the nature of a scoping study and laid the conceptual and methodological foundation for a subsequent study that will quantify the impact by independent recreational

visitors on water quality in the Marine Park. Future research into recreational use aspects of the Marine Park can build on the methodological approaches designed and tested in this study. To deliver good statistical confidence intervals, however, any survey needs to be comprehensive in scale and requires a large sample size to account for the diversity of values and use profiles, and the spatial variability of uses. Importantly, the method needs to be able to capture all types of independent recreational visitors, including visitors to the region, namely inter and intra-state travellers with trailer boats and those who have sailed from other regions, including overseas. A number of specific methodological conclusions can be drawn.

- The face-to-face interviews of shore-based independent recreational visitors and a mail-return survey of vessel-based independent recreational visitors provided a powerful combination of empirical methods. Both formats can capture groups within independent recreational visitors that are not accessible by telephone survey.
- Observations need to be conducted systematically if they are to provide data that can be used for triangulation.
- The survey activity needs to stretch over a sufficiently long period of time, preferably a 12-month period, and include weekends as well as week days, to account for temporal variability in shore-based and vessel-based activity of independent recreational visitors.
- Survey activity needs to cover more than three locations to account for spatial variability in shore-based and vessel-based activity of independent recreational visitors.
- Consideration needs to be given to replacing open-ended questions about water quality with a structured format for answering to improve the ability to analyse and interpret the results.
- Length of surveys was acceptable to respondents and a few additional questions may be helpful in the mail-reply survey to maximise analytical capacity, e.g. gender, residential post code, location for survey, income category and boat length.

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10 Appendices

10.1 Face-to-face survey of shore-based independent recreational visitors

Survey of residents using the Great Barrier Reef Marine Park and adjacent areas during August 2008
* © River Consulting

p1

LOCATION:_____

1. **How many people are in your group today?**
   What is their gender and what are their ages?

   Male_____ ages.....

   Female_____ ages.....

2. **What is your post code?**

   .....

3. **Could you please provide a description of the activities you are doing today?**

   .....

   .....

   .....

4. **In the last 12 months, how many times did you do any of the following activities in or adjacent to the Great Barrier Reef Marine Park?**

	Done?	Number of times?
Swimming	☐	
Scuba Diving	☐	
Snorkelling	☐	
Fishing	☐	
Been sailing on a sailing boat	☐	
Been on a motorised boat	☐	
Jetskiing	☐	
Other, *please specify*	☐	
Other, *please specify*	☐	

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5. How often have you observed any of the following over the last 12 months in or adjacent to the GBR Marine Park?

Please rate each of the following options on a scale from **1 to 5.**

	Never	Rarely	Some-times	Often	Always
	1	2	3	4	5
1. Uncollected dog faeces					
2. Horse-riders on the beach					
3. People camping on the beach					
4. Evidence that people have gutted/cleaned fish near the water					
5. Spills of man-made substances (e.g. oils, detergents)					
6. People driving on the beach					
7. Solid rubbish in or near the water					
8. Other, *please specify*					

6. What do you see as the most important impact(s) of recreational activities in the GBR Marine Park in terms of how clear and healthy the water is?

.....

.....

.....

7. Have you noticed any changes in water quality and recreation in the GBR Marine Park?

.....

.....

.....

8. How frequently do you use the following sources of information to find out about the GBR Marine Park?

Please rate each of the following options on a scale from **1 to 5.**

	Never	Rarely	Some-times	Often	Always
	1	2	3	4	5
1. Great Barrier Reef Marine Park Authority (GBRMPA) Website					
2. GBRMPA television advertisements					
3. Free Information/maps available at tackle shops					
4. Newspapers or other printed materials					
5. Websites other than GBRMPA's *please specify*					
6. Other, *please specify*					
7. Other, *please specify*					

9. How strongly do you (dis-)agree with the following statements?

Please rate each of the following options on a scale from **1 to 5.**

	Strongly disagree		Disagree		Agree	Strongly agree
	1	2	3	4	5	

1. The GBR Marine Park is basically just a place for catching fish ☐
2. It the GBR wasn't there, I would find another place to do what I do pretty easily. ☐
3. What people do in the Marine Park doesn't make much difference to the environment. ☐
4. There are many things I can do to improve the health of the Marine Park. ☐
5. I don't really care what impact my activities have on the Marine Park. ☐
6. The Marine Park is a special and unique environment. ☐

10. What is your taxable household income category?

1 ☐ <= $35,000
2 ☐ $35,001 – $60,000
3 ☐ $60,001 – $100,000
4 ☐ $100,001 – $150,000
5 ☐ >$150,000

11. Would you like to make any comments in regards to what you think makes water in the GBR Marine Park more polluted or more clean?

.....

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.....

.....

Thank you very much indeed for your time and help! ☺

10.2 Research brochure

We need your help!

Please complete the enclosed survey!

Australian Government
Great Barrier Reef Marine Park Authority

Improving information on recreational uses of the Great Barrier Reef Marine Park and adjacent waters and coastal areas

A study is currently underway on recreational uses of the Marine Park and adjacent waters coastal areas. The study explores the many ways in which people use the Marine Park and adjacent areas for recreational purposes and associated water quality impacts.

The work has been commissioned by the Great Barrier Reef Marine Park Authority to support planning and management of the Marine Park. While much research effort has been directed to understanding tourism, little has been done to date to look into recreational use of the Marine Park.

The results will help improve the GBRMPA's understanding of recreational interests in and uses of the Marine Park.

During August 2008 researchers will visit Cairns, Mackay and Airlie Beach to talk to people about their recreational activities—on the day and during the course of a year—and any aspects that relate to water quality.

Your participation in this research would be welcomed and greatly valued.

Should you have any questions, please do not hesitate to contact:

Dr Romy Greiner
Research Leader
River Consulting
Townsville QLD 4812

Ph 07 4775 2448
Mb 0418 242 156
Romy.greiner@riverconsulting.com.au

Photographs courtesy of GBRMPA image library

10.3 Survey instructions for mail-return survey

RIVER CONSULTING

Australian Government
Great Barrier Reef Marine Park Authority

SURVEY INFORMATION

How is the survey conducted?

The survey is designed as a **mail return survey**. A reply-paid self-addressed envelope is contained at the end of the survey bundle.

We expect that it will take about 10-15 minutes to complete the survey.

Who is participating?

Copies of the survey are handed out near boat ramps and marinas on one weekend only.

To get the best possible results from the research, it is important that we get as many surveys back as we can. Therefore, we would really appreciate your input.

What is the deadline?

SURVEYS MUST BE RECEIVED BY 1st SEPTEMBER 2008.

What is in it for me?

The research will be used by the GBRMPA to develop new information, which everybody can access. It will also help us to make good decisions in planning and management of the Marine Park.

As a 'thank you' for completing the survey, there are three **prizes** of $200 vouchers for BCF stores that will be drawn randomly from a raffle of respondents.

How do I participate in the prize raffle?

To go in the draw for one of the raffle prizes, please write your address on the blue slip provided, put in the small envelope, seal the envelope and include it with the completed questionnaire in the return envelope. Only the three winning entries will be opened and the winners will receive the vouchers in the mail by early September. All entries into the prize draw will be destroyed at completion of the draw.

Can I trust the research team with my information?

The research follows an **ethical code of conduct** for social research, which describes the research team's responsibilities to you and your rights in relation to the research. This includes:

- Voluntary participation: You do not have to complete the questionnaire or to complete all the questions when returning the survey.
- Confidentiality and anonymity are of utmost importance. The information you supply to us cannot be traced to you personally. The information you give to us for the prize draw will be prepared separately to the surveys. You remain unknown to the research team and the GBRMPA—unless you choose to participate in the raffle and end up winning one of the prizes.

Who do I contact if I have a question in relation to the survey?

Dr Romy Greiner (project leader), ph 4775 2448,
email romy.greiner@riverconsulting.com.au or

Dr Madeline Fernbach (project manager GBRMPA), ph 4750 0601,
email madeline.fernbach@gbrmpa.gov.au

10.4 Mail-return survey of vessel-based independent recreational visitors

Survey of residents using the Great Barrier Reef Marine Park and adjacent areas for boating activities
August 2008 * © River Consulting

p1

Thank you for taking part in this survey. Remember, your answers here are anonymous. When you are finished, please put this survey in the reply-paid envelope provided. If you want to enter the prize draw, put your name and address on the blue paper and put it in the small envelope. Put the small envelope in with the survey.

The first section has a series of questions that relate to the boat trip that you have just completed and all participants in the trip. You do not need to answer every question but if you can, that would be great. For further information, please read the information sheet.

The questions relate to your most recent boating trip.

1. Who did you undertake the boating trip with?

Please tick one option only

☐1 nobody else
☐2 with spouse or partner
☐3 with family
☐4 with friends
☐5 with family and friends
☐6 other, *please describe*……

2. Of trip participants, how many are in each of the following age groups?

Please provide a number in each row

1 ……. young children (0 – 4 years old)
2 ……. children (5 – 14 years old)
3 ……. adolescents and young adults (15 – 24 years old)
4 ……. adults 25 – 39 years old
5…….. adults 40 – 54 years old
6…….. adults 55+ years old

3. Please provide departure and arrival information for the boating trip.

1 Departure date: ……. time. …….. departure point: …….
2 Return date: ……. time. …….. return point:…….

4. Where exactly did you go?

Please name the locations/areas that you visited.

……

……

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5. Who owns the boat?

Please tick one option only

☐1 privately owned
☐2 tour operator
☐3 hire company

6. Where is the boat moored or stored?

☐1 moored locally (where you got the survey)
☐2 moored elsewhere, *location (name of city/town)*.....
☐3 stored locally (where you got the survey)
☐4 stored elsewhere, *location (name of city/town)*.....

7. If the boat has at least one motor, please provide the following details.

Please pick the type of engine (row) and then provide the associated information to the extent you are able to. This information helps us to establish total engine emissions.

Type of engine		Number of engines of this type	Size of Engine: Horse power (HP)	or Kilo watts (KW)	or Cubic centi meters (CC)	Outboard or Inboard? (O / I)	Hours of use during the boating trip?
Petrol	4-stroke with carburettor						
	4-stroke with fuel injection						
	2-stroke with carburettor						
	2-stroke with fuel injection						
Diesel	4-stroke						
	other, *please describe....*						
Other	*Please describe...*						

8. Is the boat treated with antifoul?

☐1 yes → last painted in ...../.....(month/year)
☐2 no

9. How many hours did you spend in various environments undertaking what activities?

Please provide estimates of time spent (in hours) in the appropriate cells in the table.
The table columns define different environments; the rows show different types of activities.
Impossible combinations have been blanked out. Please sum up your row entries to estimate total activity time (last column).

Close inshore = less than 200 m from mainland;
Inshore = less than 3 nautical miles or about 5 km from the mainland (but further than 200 m)
Offshore = more than 3 nautical miles or about 5km from the mainland

	close in-shore			in-shore			off-shore				
	estuary, river	close inshore water	mainland, beach	open water	reefs	islands	open water	reefs	islands	Other, *please specify*	TOTAL TIME spent for this activity hours)
For example: recreational fishing	*0,5*			*1,5*	*2*			*3*			*6,5*
motorised boating, incl. waterskiing											
jetskiing and similar											
sailing											
kayaking and similar											
recreational fishing - trawling (engine on)											
recreational fishing - engine off											
snorkelling / scuba diving											
spearfishing											
resting - spending time on board; engine off; no diving /fishing/etc											
camping											
beach walks/activities											
Other, *please specify*											

Any comments/explanations that you might like to make (e.g. different people undertaking different activities at the same time).

.....

.....

When being out in the Great Barrier Reef Marine Park, it is mostly unavoidable to do things that may impact on water quality—every engine loses some oil; people need to go to the bathroom but not every boat has a toilet and sullage (sewage) tank; sometimes there are spills on board….

We want to find out what happened on your last boating trip that might affect water quality.

Remember, we are simply trying to find out about recreational activities—please be honest in providing the facts that relate to the boating trip that you just completed.

10. Please complete the following table by indicating what occurred during your last boating trip.

	Tick if it occurred	Please explain how often? How much?
Hosing off boat at the boat ramp	☐	How often?
Emptying liquid with soap or laundry liquid into water	☐	How much?
Cleaning/gutting fish	☐	How many?
Urinating into water (or toilet without sullage tank)	☐	How many times?
Defecating into water (or toilet without sullage tank)	☐	How many times?
Spill of any substances (e.g. oils; detergents...)	☐	How much? Of what substance?
Emptying of sullage tank	☐	Approx. what volume?
Disposal of solid rubbish into water	☐	How often?
Other, *please specify* ……..	☐	How often/much?
Other, *please specify* ……..	☐	How often/much?

Any comments/explanations that you might like to make in relation to the boating activity's impact on water quality.

……

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……

11. What do you see as the most important water quality impact(s) of recreational activities in the GBR Marine Park?

.....

.....

.....

12. Have you noticed any changes in water quality and recreation?

.....

.....

.....

13. How frequently do you use the following sources to find out about the GBR Marine Park?

Please rate each of the following options on a scale from **1 to 5.**

Never	Rarely	Some-times	Often	Always
1	2	3	4	5

1. Great Barrier Reef Marine Park Authority (GBRMPA) Website ☐
2. GBRMPA television advertisements ☐
3. Free Information/maps available at tackle shops ☐
4. Newspapers or other printed materials ☐
5. Websites other than GBRMPA's *please specify*…….. ☐
6. Other, *please specify*…….. ☐
7. Other, *please specify*…….. ☐

14. How strongly do you (dis-)agree with the following statements?

Please rate each of the following options on a scale from **1 to 5.**

Strongly disagree	Disagree	Indifferent	Agree	Strongly agree
1	2	3	4	5

1. The GBR Marine Park is basically just a place for catching fish ☐
2. It the GBR wasn't there, I would find another place to do what I do pretty easily. ☐
3. What people do in the Marine Park doesn't make much difference to the environment. ☐
4. There are many things I can do to improve the health of the Marine Park. ☐
5. I don't really care what impact my activities have on the Marine Park. ☐
6. The Marine Park is a special and unique environment. ☐

15. Is there anything that you would like to add or any comments you wish to make?

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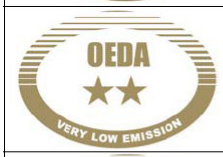
Thank you very much indeed for your time and help! ☺

10.5 Full set of additional comments offered by vessel-based respondents

Comment category	Percentage of respondents commenting
Land/urban runoff	12%
Impacts of runoff from Sugar cane farming	7%
Sewerage inputs from coastal towns	5%
Recreational fishing management - more engagement with the public by GBRMPA	5%
Rubbish in waterways	4%
Too much urban development	4%
Diesel pollution/spills from commercial shipping	4%
Inshore commercial trawling should be stopped	4%
Green zones should be shifted on a regular basis	2%
More public moorings	2%
Stop commercial netting (of creeks and rivers)	2%
Keep up the good work, incorporate the values of future generations	2%
The GBR is great - it should stay that way	2%
Oil spills from commercial shipping	1%
Risks from commercial shipping	1%
Foreshore vegetation clearance	1%
Spawning grounds for mackerel should be made off-limits	1%
Mining in Proserpine	1%
Commercial fishing impacting on fish stocks - especially coral trout	1%
Good choice of weekend for survey	1%
Surprise at the number of people littering in the GBR	1%
Heavier penalties for littering should be introduced	1%
Lead sinkers should be replaced by biodegradable sinkers	1%
Lower bag (fish possession limits)	1%
Improve education on catch and release	1%
Introduce fishing permits to Queensland	1%
Don't impose fishing licences	1%
Don't put green zones on coastal locations	1%
Tourist overcrowding	1%
Better pathways for informing the GBRMPA of issues	1%
Ban jet skis	1%
Marina water quality issues	1%

10.6 OEDA Voluntary Emissions Labelling Scheme: description of ratings

Source: Environment Link (2007: p.29)

OEDA Australian Label	OEDA Emissions Limit HC + NOx g/kW/hr	Comparison with CARB star rating HC + NOx g/kW/hr (see below)	Comparison with EPA Limits HC + NOx g/kW/hr
	> 250	None	None
	64.8 – 250*	1 star = 64.8 - 81	For P < 4.3 KW EPA 1999< 253 EPA 2006 < 81
	30 – 64.8*	2 stars = 30 – 64.8	
	5 – 30*	3 stars < 30	
	< 5*	4 stars < 5 Note: no current outboard engine can meet this limit.	