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Final Report

The role of social media in sharing information about the Great Barrier Reef

Susanne Becken, Ali Reza Alaei, Jinyan Chen, Rod Connolly and Bela Stantic

Griffith UNIVERSITY

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Susanne Becken[1], Ali Reza Alaei[1], Jinyan Chen[1], Rod Connolly[2] and Bela Stantic[3]
[1]Griffith Institute for Tourism Research, Griffith University
[2]Australian Rivers Institute, Griffith University
[3] School of Information Communication Technology, Griffith University

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http://www.nesptropical.edu.au

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ACRONYMS

COTS ..... Crown-of-thorns starfish
EMC ..... Environmental Management Charge
GBR ..... Great Barrier Reef
GBRMPA ..... Great Barrier Reef Marine Park Authority
NESP ..... National Environmental Science Program
TWQ ..... Tropical Water Quality

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EXECUTIVE SUMMARY

The Great Barrier Reef (GBR) is a heavily visited area, with 2.2 million international and 1.7 million domestic visitors travelling to the region every year. In addition, about one million local residents live on the nearby coast. Both visitors and residents, to some extent, use social media to share content about their surroundings, perceptions and experiences with the Reef. This data can be used for research purposes.

This present research explores whether informal information from social media can complement existing citizen science approaches and biophysical monitoring. This report provides findings from an analysis of Twitter posts and public Facebook page posts and comments that are relevant to the GBR. These social media data were analysed in terms of overall volumes, frequency of particular keywords, and sentiment.

Relevant messages from Twitter, and posts and comments from Facebook were collected for a 9 month period, between the 1st of July 2016 and the 17th of March 2017. Using several filtering systems, 13,344 relevant tweets and 6,632 posts/comments were downloaded from Twitter and 13 public Facebook pages, respectively. Some 60.6% of selected tweets had geographic coordinates that allow spatial analysis.

Tweets predominantly mentioned the physical environment of 'beaches', 'islands', and the 'Reef', in various permutations of these words. Text content varied, and included factual information, neutral statements, slang, and words expressing various emotional states. In contrast, the Facebook posts focussed more on reef-related activities, with a particular emphasis on experiential elements (e.g. "amazing"). Facebook comments contained largely positive emotional language, compared with posts (by the page owner) that focussed more on the attributes of the GBR.

Sentiment analysis was undertaken for data from both social media platforms to track whether perceptions and messages were positive or negative. The analysis showed sentiment varied over time and in relation to particular targets (i.e. defined through keywords). Despite an inherent bias towards positive text, both the Twitter and Facebook data displayed interesting variations. Some of these hint at underlying problems, but others appeared to be an artefact of the existing sentiment algorithm. Overall, Facebook posts and comments were much more positive that tweets, highlighting that the analysis of multiple platforms is useful as they fulfil different purposes and roles.

Text that mentioned environmental keywords (e.g. dead, bleaching, damaged) was likely to be negative. Surprisingly, however, the relative frequency of such text was low. Discussions of environmental problems were more detailed and richer on Facebook where there is no restriction in length of text. Facebook therefore provides an opportunity to further engage people to learn and protect the GBR; something that is largely unexploited at present. For Twitter, a dedicated hashtag system would allow relevant and useful information to be collected and at the same time empower people to contribute through citizen science.

Several recommendations on the use of social media are made at the end of the report, including their active use as a tool to share environmental values and encourage stewardship,

the need to monitor and respond, and the opportunity to use information in conjunction with other sources to enhance monitoring. The latter task will be addressed within the larger research project, where social media data will be integrated with other environmental data.

1.0 INTRODUCTION

1.1 Background

The Great Barrier Reef Marine Park and UNESCO World Heritage Area is a natural asset of global significance and one of Australia's most important tourist attractions. The Great Barrier Reef (GBR) is integral to how Australians define their identity and is a showpiece of the Australian tourism industry (Becken et al., 2014). Both Tourism Australia and Tourism Events Queensland rely heavily on imagery of the GBR to promote Australia and Queensland to visitors domestically and internationally. Research by Tourism Australia (2015) showed that 42% of international visitors ranked the GBR as the most appealing tourist attraction in Australia. Tourists were also asked to rank attractions, with the top two attractions having been named as beaches and wildlife. Both of these are highly relevant to the GBR. It is not surprising therefore that the Reef is a heavily visited destination in the Australian tourism context.

The GBR Marine Park is a multi-use protected area that is zoned into different areas to allow different types of activities such as shipping, fishing, recreation and tourism. Over 2.2 million international and 1.7 million domestic visitors travel to the region every year (Tourism Research Australia, 2015). Not surprisingly then, the largest economic benefit associated with the GBR comes from tourism. A Deloitte Access Economics (2013) study revealed that tourism generates an estimated AU$5.8 billion per year and sustains over 60,000 jobs.

In addition to regional economic benefits, tourism contributes directly to the environmental management of the GBR through an Environmental Management Charge (EMC). Collecting the EMC also provides important visitor statistics to Reef stakeholders. Accordingly, the Great Barrier Reef Marine Park Authority (GBRMPA, 2016) reported 2.62 million visitor days were spent on the GBR for the financial year ending 30 June 2016. Visitor statistics include trips to the Reef on commercial vessels of various forms, as well as scenic flights. Using EMC data, figure one shows the total number of visitor days per month, broken down into full and part day visitation. Visitor numbers fluctuate according to destination seasonality, school holidays, weather conditions and other events.

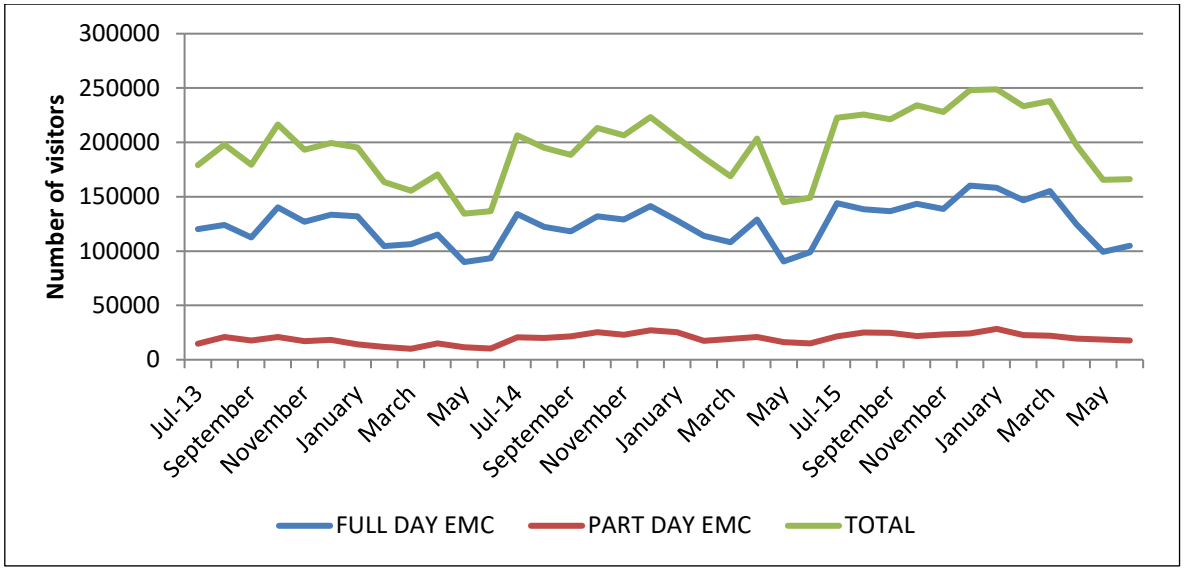

Figure 1: Visitation to the GBR based on EMC data (GBRMPA, 2016).

The relationship between tourism and conservation is complex, but there is sufficient evidence that synergies exist. In the case of the GBR, recent research has found that the tourism industry contributes significantly to Reef stewardship and protection (Liburd and Becken, 2017). It is therefore no coincidence that Tourism Australia invested into a Sir David Attenborough three-part documentary that highlighted the past, present and future of the GBR, emphasising the need to protect this natural wonder of global significance. This report examines whether visitors to the Reef talk about the marine environment in their social media interactions, and whether information contained in such posts is useful for GBR managers.

1.2 Research Aim

The GBR is under substantial pressure, and considerable investment is going into monitoring environmental changes affecting the reef and reducing environmental impacts to it from a range of activities. Recent coral bleaching events, however, indicate that current efforts are not sufficient. It is important to extend the existing portfolio of activities, by exploring innovative ways of tracking environmental conditions, and at the same time understanding people's awareness and willingness to become involved in protective actions. Engaging with visitors and others who care about the GBR through, for example, social media may create an opportunity space for larger scale support (e.g. supporting lobby groups to protect the GBR, make financial donations). The aim of this research was to assess whether people use social media to talk about the GBR, what the topic of their posts is, and whether messages reflect a positive or negative sentiment.

One of the major trends of the twenty-first century is for people to share their views, thoughts and experiences via social media. Tourists are particularly likely to post on social media about what they see and do (Travelmail Reporter, 2013), which can influence potential travellers. Consequently, the travel industry use social media to market their experiences and analyse social media as a source of information for experience improvement. Visitors use a wide range of social media to communicate with their friends, and reef tourism operators to communicate to potential visitors (e.g. commercial Facebook sites). Importantly, in addition to those visiting the GBR region, there are more than one million people living in proximity to the Reef who use

social media. The majority of local people are active users of the Reef and its adjacent beaches (Deloitte Access Economics, 2013). It therefore seems that there could be a sufficiently large number of people who live near or visit the GBR and who share information via social media that could be relevant to monitoring the state of the Reef.

This report provides findings from an analysis of Twitter posts and public Facebook page posts and comments that are relevant (i.e. with content related to the marine environment) to the GBR. These post data will be analysed in terms of overall volumes, frequency of particular keywords, and sentiment. Twitter and Facebook data were compared to provide recommendations for future research. The report provides a series of recommendations to help decision makers in using social media for GBR management.

2.0 ENVIRONMENTAL CONDITIONS OF THE GREAT BARRIER REEF

The GBR is a unique hotspot of global biodiversity. It is the world's largest coral reef system stretching over 2,600 kilometres along the coast of Queensland. It is made up of about 3,000 individual smaller reefs and 900 islands, and covers about the same area as Italy and Japan. The GBR provides habitat for 600 different types of corals, more than 100 species of jellyfish, 3,000 different molluscs, 500 worm species, 1,625 species of fish, 133 varieties of sharks and rays, and over 30 species of whales and dolphins (GBRMPA, 2014).

Over the last 30 years, the GBR has lost more than half its coral cover. The driving forces for these changes are agricultural run-off, outbreaks of crown of thorns starfish, cyclones, and a warming of water temperatures due to climate change (Fenton, Kelly, Vella & Innes, 2007). The Great Barrier Reef Water Science Taskforce, in their Final Report, noted that the GBR ecosystem has undergone significant change and decline in its ecological quality (Great Barrier Reef Water Science Taskforce & Department of Environment and Heritage Protection, 2016, p. 12). Specifically:

- *Significant, widespread losses of seagrass have occurred in areas directly affected by cyclones and river floods; seagrass abundance south of Cooktown has declined since 2009. Some recovery has been observed but appears to be patchy and site-dependent.*
- *The Reef region supports globally significant populations of dugongs. The dugong population was one of the reasons the Reef was listed on the World Heritage Register. The dugong population south of Cooktown has drastically declined from 1962 levels.*
- *From 1985 to 2012 coral cover on the mid-shelf and off shore reefs on the Reef declined by almost 50%. The main reasons for this decline have been identified as outbreaks of crown-of-thorns starfish, cyclones, and thermal stress leading to coral bleaching.*
- *From 2012 to 2015 coral cover has shown some recovery on reefs south of Cooktown, but declined further north. Coral reefs in the GBR remain under pressure.*
- *Crown-of-thorns starfish have caused widespread damage to parts of the Reef over the past five decades, due to population outbreaks which have occurred at regular intervals. Crown-of-thorns starfish (COTS) feed on corals such as staghorns and plate corals.*

In 2016 and 2017, the GBR has been affected by the worst coral bleaching event on record (GBRMPA, 2016 and 2017). The worst affected area in the 2016 event was the 600 km stretch from Cape York to Lizard Island. Popular tourist areas off the coast of Cairns were also affected; it was found later that they experienced medium to high mortality levels. Most recently, the information on coral bleaching has been updated and it is estimated that 29% of shallow water corals died from the 2016 bleaching event (GBRMPA, 2017). Bleaching is continuing in 2017 due to continuing warm water temperatures, but affected areas are further south between Cairns and Townsville. Under-water surveys are continuing to assess mortality. In addition, the Whitsunday Islands and southern parts of the reef were directly in the path of cyclone Debbie in March 2017. There is evidence of further coral deterioration as a result of cyclone Debbie, indicating that about 25% of the GBR were affected to some extent (GBRMPA, 2017). The drop in water temperatures resulting from the cyclone might assist to

mitigate further bleaching. The full extent of the damage due to the cyclone is still being assessed, yet immediate effects on tourism operations are already being felt. Cyclical climatic events, such as El Nino, also remain an ongoing concern for the GBR (Bureau of Meteorology, 2017; GBRMPA, 2017).

In the face of multiple interacting and cumulative stress factors that compromise the health of the GBR, the GBRMPA is now working towards an integrated monitoring program to help evaluate progress towards long term sustainability targets. The goal is to better integrate the many existing monitoring programs and address gaps between them by implementing new approaches, including citizen science (Addison et al., 2015). Social media channels can form one component of citizen science.

3.0 SOCIAL MEDIA AND ENVIRONMENTAL MONITORING

3.1 The social media landscape

In 2014, there were over 2 billion social media users globally (We are Social, 2015). The social media landscape is continuously growing (Figure 2), indicating that information generated and shared on these platforms could be of increasing use to researchers. The rapid increase of mobile social media users (an increase by 30% in the last year) holds particular potential for mining such data in real time and relevant to particular locations (so-called spatio-temporal data). Uptake differs between countries: North America, East Asia and South East Asia are particularly engaged in social media use and make up the majority of users globally (Chaffey, 2017; We are Social, 2015).

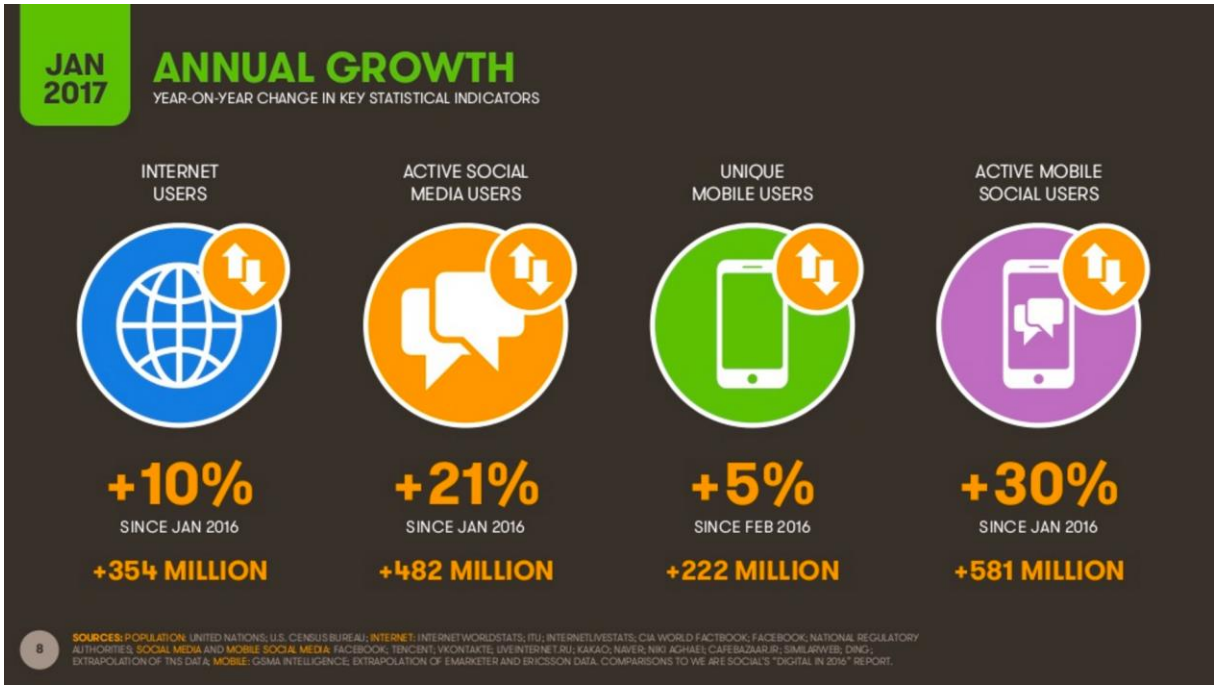

Figure 2: Social media growth statistics (Source: We are Social, 2017).

The types of platforms also differ by country, although some social media types are popular worldwide. Global statistics show that Facebook, for example, holds the largest market share of users worldwide (18%) (Chaffey, 2017). However, an individual user's Facebook data are not publicly accessible for analysis. Similarly, other leading social media platforms, such as Snapchat and WhatsApp, also have restricted public access to user content. Different to personal Facebook pages, companies specifically design their commercial webpages to be accessible to customers and the public. Facebook therefore makes content of such businesses pages available. Company webpages create content (i.e. posts) for advertisement, sales, customer service, and other business communication. Whilst many companies and organisations maintain Facebook pages as part of their strategies for digital audience penetration (Chaffey, 2017), Elliott (2015) claims that commercial Facebook pages receive only 0.2% interaction from audiences (e.g. 'likes' or 'shares').

There are a few social media platforms, such as Twitter and Weibo, where user content is accessible to the public, and therefore available for analysis. A sample of at least 1% of the 500,000,000 tweets posted daily (Twitter, 2016) is freely available for analysis. The length limit of 140 characters per tweet text means that processing is simplified in terms of data volume, but analysis (for example natural language processing) might be challenging because of limited information contained in the text. Although Twitter has lower audience penetration and interaction as a business network compared with other social media channels, the availability and accessibility of the content makes it an up-to-date, rich information source with significant audience reach. Twitter data has been used in research to explore social and economic issues at a local, national and global scale.

Instagram is another leading social media platform for organisations to connect with audiences. Forrester Research showed that Instagram users interacted with 2.3% of business postings. This was the largest audience engagement compared to other social media platforms (Elliott, 2015). Data from Instagram is used in academia research as a forecasting and monitoring tool. For example, Indiana University used Instagram data to forecast top models at New York Fashion Week, with the method resulting in 80% accuracy. However, there are a number of challenges for analysts who seek to use Instagram data, particularly pertaining to the analytical tools available for analysis of large quantities of imagery data.

The travel and tourism sector has been at the forefront of using 'online generated content' and creating new platforms for marketing and 'electronic word-of-mouth' (e-WOM), for example review platforms (Leung, Law, Hoof van & Buhalis, 2013). Businesses and destinations analyse online data to better understand visitor expectations, perceptions, and behaviours. The benefits of new approaches in relation to online data, particularly social media data, for data collection and mining are that they present inexpensive means for gathering potentially rich, authentic, and unsolicited data on travellers' perceptions and experiences (O'Leary, 2011). Social media data provides a new way of conducting consumer research (Alaei, Becken & Stantic, 2017).

3.2 Using social media for environmental monitoring

Social media data is also used in disaster and crisis management (Vivacqua & Borges, 2012; Steiger, de Albuquerque & Zipf, 2015). The analysis of 10 million tweets posted in the aftermath of Hurricane Sandy in New York in 2012 demonstrated that tweets could be used to "report" damage faster and more accurately than formal reporting systems as part of the National Federal Emergency Management Agency response processes (Bohannon, 2016). Capitalising on the real-time spread of online information via such channels, the U.S. Geological Service now monitors seismological activity by data mining of Twitter feeds in addition to its network of sensors (Meyer, 2015).

The advantages of accessing large numbers of evidenced in social media observations or 'measurements' on specific phenomena have also been recognised in the environmental domain, even though research in this area is still in its infancy. Recent research in the United States, for example, used photo imagery uploaded on Flickr, a photo-sharing website, to replace costly visitor surveys for monitoring the number of recreational visitors to lakes. The photos were used as an indicator to deduct a new metric of 'photo-user-days'. This variable was then used in the development of a visitation model, which ultimately helped to determine

that superior water clarity was associated with higher visitor numbers to lakes (Keeler et al., 2015). The research provided robust evidence that social media data can be used in human-environment research.

Building on Keeler et al.'s (2015) research, a team of scientist working for The Nature Conservancy used Flickr photos to determine tourist visitation to coral reefs, and to estimate the economic value of reefs globally (The Nature Conservancy, 2017). The resulting interactive website, Mapping Ocean Wealth, has recently won the prestigious tourism World Travel and Tourism Council "Tourism 4 Tomorrow" award.

Another recent example of researchers using Twitter data for conservation purposes is noteworthy. Daume (2016) analysed close to 3,000 tweets that made references to invasive alien species of interest. The findings showed that Twitter can provide useful information on species occurrence, as well as on human perceptions of species and their distribution. Other approaches to utilising citizens for recording environmental changes have followed a more structured approach, for example through a bespoke mobile phone app. A wide range of citizen science platforms encourage people to engage in a process of voluntary information provision on specifically designed web sites. One example is OakMapper.org, a web site created to collect and share information on the spread of a forest disease in America (Connors, Lei & Kelly, 2012).

GBRMPA has developed a platform to collect data and 'sightings' from visitors to the Reef. The Eye on the Reef program enables both visitors and operators to contribute information about reef health, marine animals and incidents. Several platforms form part of this program. At the least formal level, visitors to the Reef can provide information through a mobile app or online system. The app is used to report observations of particular species. It also facilitates the upload of photos. As with other programs involving people from the general population as "sensors", the information provided describes the particular subject of interest, the time and the particular location it relates to. In addition to the mobile app, Reef tourism operators contribute to monitoring through the Rapid Monitoring Survey or the Tourism Operators Weekly Monitoring Survey. The latter survey demands ongoing commitment to the monitoring of environmental indicators in the same location (i.e. where dive operators have a license to operate).

This present research explores whether more generic and informal information from social media can complement the targeted approach of citizen science, as evidenced in the Eye on the Reef program.

4.0 METHOD

4.1 Data

In this study, data from two social media networks, namely Twitter and Facebook, were obtained. Relevant tweets from Twitter, and posts and comments from Facebook were collected for the same period of 9 months between the 1st of July 2016 and the 17th of March 2017. As a result, 13,344 tweets and 6,632 posts/comments were downloaded from Twitter and public Facebook pages, respectively.

4.1.1 Accessing Twitter data

We employed an online streaming approach to access tweets in real time. Specifically we used a public Twitter API with restrictions to capture only geo-tagged tweets posted from the GBR region (for more details see Becken et al., 2017 submitted). It was important to capture those tweets that originate from the region, as the purpose of this research was to identify what people talk about the Reef that they see, perceive or have just experienced, for the longer term aim of enhancing monitoring systems. The research did not include global tweets that mentioned the GBR, but were posted outside the region.

Thus, to determine an approximate region of the GBR for data collection a rectangular bounding box was considered (Southwest coordinates: 141.459961, -15.582085 and Northeast coordinates: 153.544922, -10.69867) (Figure 3). The bounding box does not perfectly overlay with what is normally considered as the 'Great Barrier Reef region', either geographically or administratively. However, most data come from the coastal areas of the GBR region, with only a few originating from inland areas.

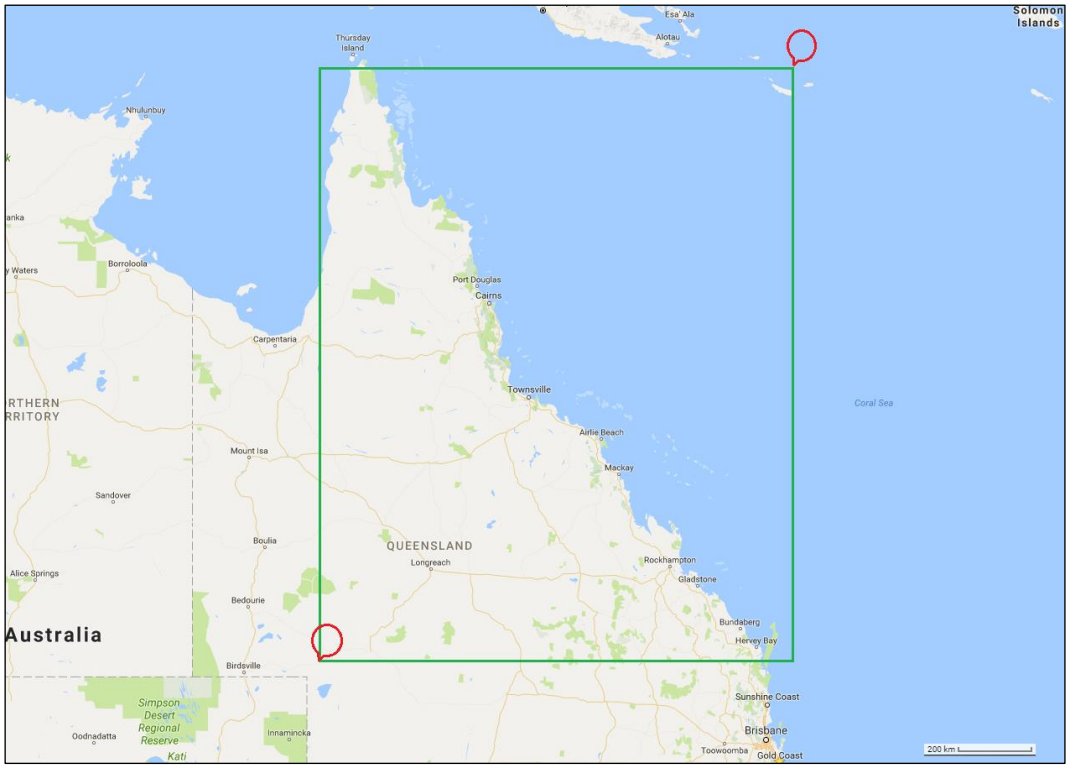

Figure 3: Map of the GBR region bounding box used to retrieve tweets from Twitter.

This above process of geographic filtering resulted in the download of about 1,000 to 1,500 tweets per day. Importantly, for this particular analysis, those tweets that were deemed relevant to the Great Barrier Reef were extracted and included in this study. Out of a total of 282,637 tweets that were posted in the GBR region, 4.7% were filtered as relevant (Figure 4). A list of keywords is provided in Appendix A.

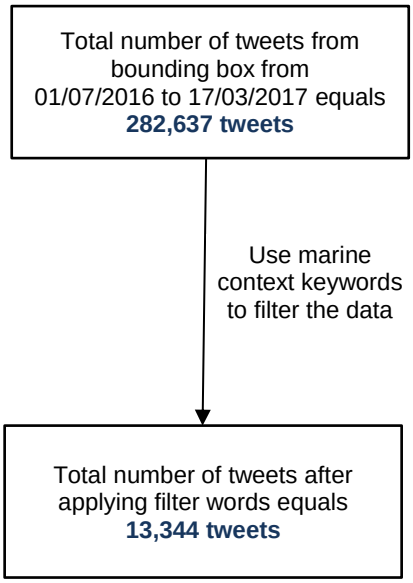

Figure 4: Number of tweets recorded in scope, and number of tweets deemed relevant for the GBR marine context.

Whilst the above two-stage filtering generally functioned well, some days are missing. The reason is that because of ongoing development of the research environment and (computing) cluster, the server had to be stopped for modifications to the hardware and software architecture, which in some instances led to server failures. For the purpose of this present research these missing days do not present a problem *per se*, because the focus here is less on the number of tweets per day (e.g. as an indicator of visitation), but on the content. However, future real-time assessments will require stable systems (including back up for power outage) to ensure that all data are being captured. Table 1 provides an overview of the missing days.

Table 1: Missing days for Twitter streaming of bound box filtered data

Time frame starting July 2016	Missing dates due to issues with the server
2016	
July	none
August	20, 26,27,28,29
September	1,2,3,4,5
October	15,16,22
November	19,20,21,25,26
December	none
2017	
January	none
February	10,11,12,15,16,29,30
March	3,4,5,16

The Twitter data represent a type of complex raw data in the JSON (JavaScript Object Notation) format. Data are stored in a NoSQL MongoDB database, which is located on a cluster computer with a Hadoop Distributed File System (HDFS).

4.1.2 Accessing Facebook data

In this study, we developed client library to support the Facebook Graph API and the Facebook JavaScript SDK. Initially, we searched to find a set of public Facebook pages in relation to the GBR marine park and the activities that are happening around it. We used “Great Barrier Reef”, “GBR”, “Dive”, “”Reef”, and “GBR Tour” as keywords to search for public Facebook pages. Approximately 20 relevant pages were found. This number was smaller than expected, and even the targeted search for known marine tour operators did not reveal many more pages of interest. After a visual inspection of the pages and based on the popularity and activities (including the volume and how recent posts were), 13 public Facebook pages of the GBR were selected for analysis.

The public Facebook pages and their properties are listed in Table 2. We collected the posts and comments from each page by developing an application programming interface (API). The Great Barrier Reef Marine Park official page attracts most people amongst the selected pages, receiving about 65,000 followers/likes (Table 2).

Table 2: Relevant public Facebook pages of the GBR Marine Park and key statistics.

Facebook Page Name	Facebook Page Description	People who like the page (N)	Followers (N)
Great Barrier Reef Marine Park	Responsible for the management of the Great Barrier Reef	64990	63870
Deep Sea Divers Den	Dive operator based in Cairns	58381	57244
Pro Dive Cairns	Dive operator based in Cairns	18679	17507
Mike Ball Dive Expeditions	Dive operator based in Cairns	13662	13312
Spirit of Freedom	Dive operator based in Cairns	7254	7037
Passions of Paradise Great Barrier Reef Day Tour - Cairns Australia	Reef tour operator based in Cairns	6552	6199
Reef Teach, Cairns, Australia	Education Centre for the Great Barrier Reef	3830	3770
Great Barrier Reef Australia	Tourist attraction, Facebook page linked to http://www.reefhq.com.au/	2198	2159
Great Barrier Reef Biology	Online community to share scientific knowledge about the Great Barrier Reef	1416	1403
Reef Safari Diving & Photography	Dive operator based in the Whitsundays	1226	1208
Grey Nurse Shark Watch	Community grey nurse shark photographic identification monitoring program	1081	1072
Reef Encounter	Great Barrier Reef tour operator based in Cairns	556	546
Lizard Island Reef Research Foundation	Non-profit organisations raising funds to support scientific research at the Lizard Island Research Station	538	528

To understand Facebook as a social media network it is important to clarify key terminology related to who is seeing and interacting with the content on a Facebook page. When individuals visit a public Facebook page of interest to them, they can choose to *like* or *follow* it. When individuals *like* a public page on Facebook, they automatically opt into following the page as well. This means that the posts written on the page will be seen in their news feed and the page will be listed in their 'liked' directory. Individuals can unfollow the page after liking the page. This means they will not see the content posted on the page in their news feed. On the other hand when Facebook users follow a page without 'liking' it, they will see the posts written on the page in their newsfeed, however they are not counted as a like on the page. This option was set up for people who do not want to befriend someone on Facebook but still want to see the posts.

There are also some differences between a post and a comment. Writing posts on a public page lets customers, visitors and fans know what the business is doing. Posts should be meaningful, attract attention, and entice visitors/clients with news or special offers. Comments are mostly (but not always) about people's personal views or perception in response to a post,

the business or the promoted activity. When people comment on a post, they provide feedback to the company about their attitudes. Companies can delete comments.

In general, Facebook's newsfeed algorithm provides more weight to comments than likes for a given post. In addition to the posts and comments, there are reviews and star rating provided by the public page visitors. It is important to note that only pages that allow reviews will show a star rating. Higher star indicates higher quality and vice versa. A Facebook page's star rating is the average of all public star ratings that the Page has received from different people. In this analysis, we are not making use of the star rating data.

Similar to tweets, raw Facebook data are stored in JSON format in a NoSQL MongoDB database. The data are located on the same cluster computer as the Twitter data; however are stored in a different database. Historic data can be downloaded in blocks and server issues at the Griffith cluster on selected days do therefore not compromise the Facebook data in terms of missing days.

4.2 Data analysis

The following describes the analytical steps applied to both tweets and Facebook text.

4.2.1 Social media volume

The volume of social media posts was analysed first to understand fluctuations over time, but also to assess the extent of data (i.e. text) available for further analysis. Missing data related to cluster problems were interpolated by replacing missing days with the average Twitter feed volume for that particular month.
In addition, two types of keyword frequency analyses were undertaken. First, an inductive approach uses simple word count by the computer to see which terms are mentioned the most often. Data was visualised in a word cloud.

The second, deductive approach specifically looked for keywords that were identified by the research team as relevant. A framework of four categories was developed, whereby each category contained a range of specific keywords:

- Locations (main places mentioned in texts)
- Activities (e.g. swim, snorkel, dive, scuba)
- Marine species (e.g. fish, turtle, shark, whale, etc.)
- Environmental impacts or risk factors (e.g. bleach, storm, oil).

All identified keywords were then extracted from the data corpus using a case insensitive search technique, and variations of the same word (e.g. 'dive', 'diving') were compiled as the same keyword. Numbers of occurrences for each keyword were counted.

4.2.2 Sentiment analysis

The deductive keyword analyses were then followed by sentiment analysis for each individual text, using the same words and categories. Assessing and scoring sentiment of text is an analytical approach that converts subjective and unconstructed text into constructed data; namely a score that ranges from minus one (-1 is the most negative) to plus one (+ 1 is the most positive). The purpose is to determine the emotional tone behind textual data in order to

gain an understanding of positive or negative attitudes and opinions, and hence deduce possible changes in the quality of the marine environment.

There are different approaches to sentiment analysis. Figure 5 visualises the general process for undertaking social media sentiment scoring. We selected a recently proposed approach for sentiment analysis (Ribeiro et al., 2016) that was specifically developed for the analysis of social media text (for a full review of sentiment analysis in tourism, see Alaei et al., (2017). Valence Aware Dictionary for Sentiment Reasoning (VADER) is a rule-based model that combines a general lexicon / dictionary and a series of intensifiers, punctuation transformation, emoticons, and many other heuristics to compute sentiment polarity of a review or text (Hutto & Gilbert, 2014). The VADER sentiment lexicon is composed of more than 7,000 items along with their associated sentiment intensity measures, as validated by humans. The VADER method only provides sentiment for English tweets, and it assigns neutral polarity to text written in other languages.

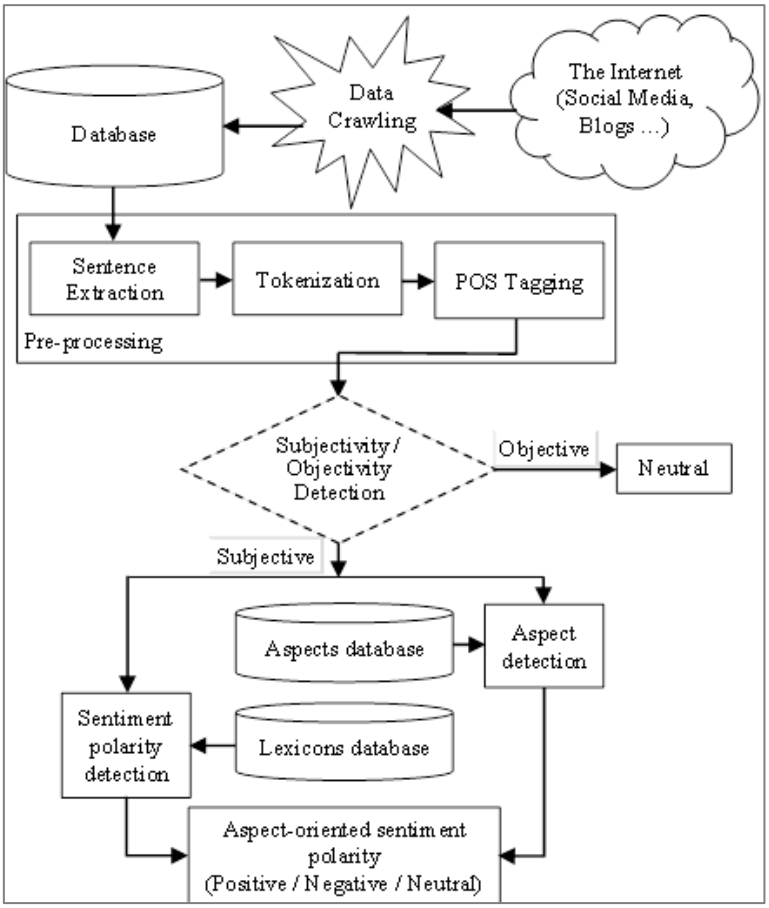

Figure 5: General framework of a sentiment analysis system (Source: Alaei et al., 2017).

A manual comparison of tweet content and the respective computed sentiment highlighted the need to adjust the method for our particular study context. Consequently, we adapted the sentiment analysis by changing the existing VADER lexicon to the context of this study. For example, we significantly improved the efficiency and made changes to the algorithm to consider domain specific sentiment. We consider the word 'great' when it is stand-alone, but ignore it when it is part of 'Great Barrier', because the word 'great' in itself is associated with

a positive sentiment. We are in the process of developing a machine learning sentiment analysis method which will be able to rely on domain specific lexicons (Hutto & Gilbert, 2014).

5.0 RESULTS

Both Twitter and Facebook data were analysed considering a monthly aggregation of data and one that focused on particular keywords. The results are presented in the following.

5.1 Volume of social media text

The number of tweets and Facebook posts varies over time. Figure 6 indicates that the Christmas period was relatively busier than other periods (except for July 2016 for Twitter) for both types of social media. Missing days have been intrapolated.

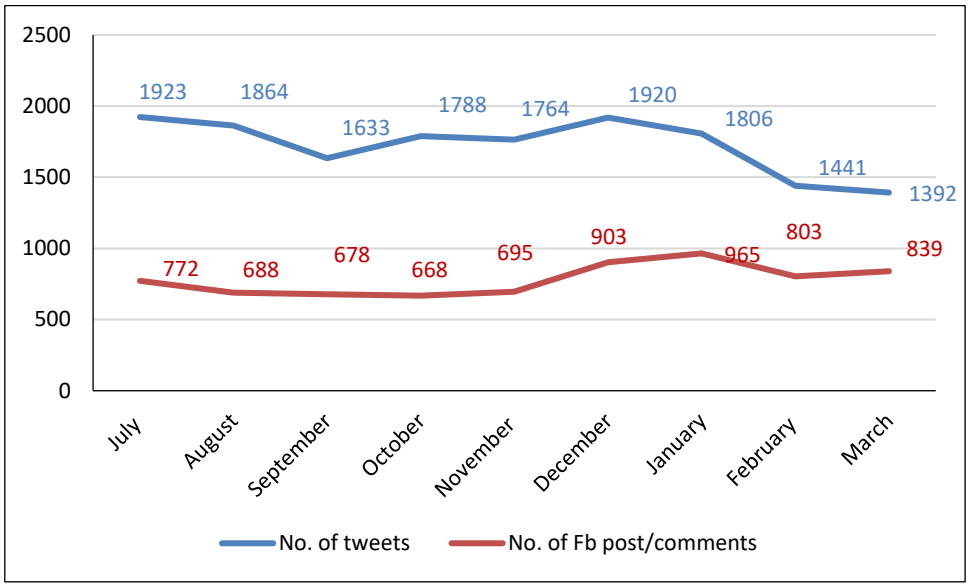

Figure 6: Number of relevant tweets and Facebook posts/comments by month.

As expected, Twitter data and Facebook posts tend to be geographically concentrated. The heat maps presented in Figure 7 visualise where the majority of tweets come from; reflecting major population centres and tourist destinations. Note that the maps only visualise those 60.6% of tweets that carried with them information on Longitude and Latitude coordinates.

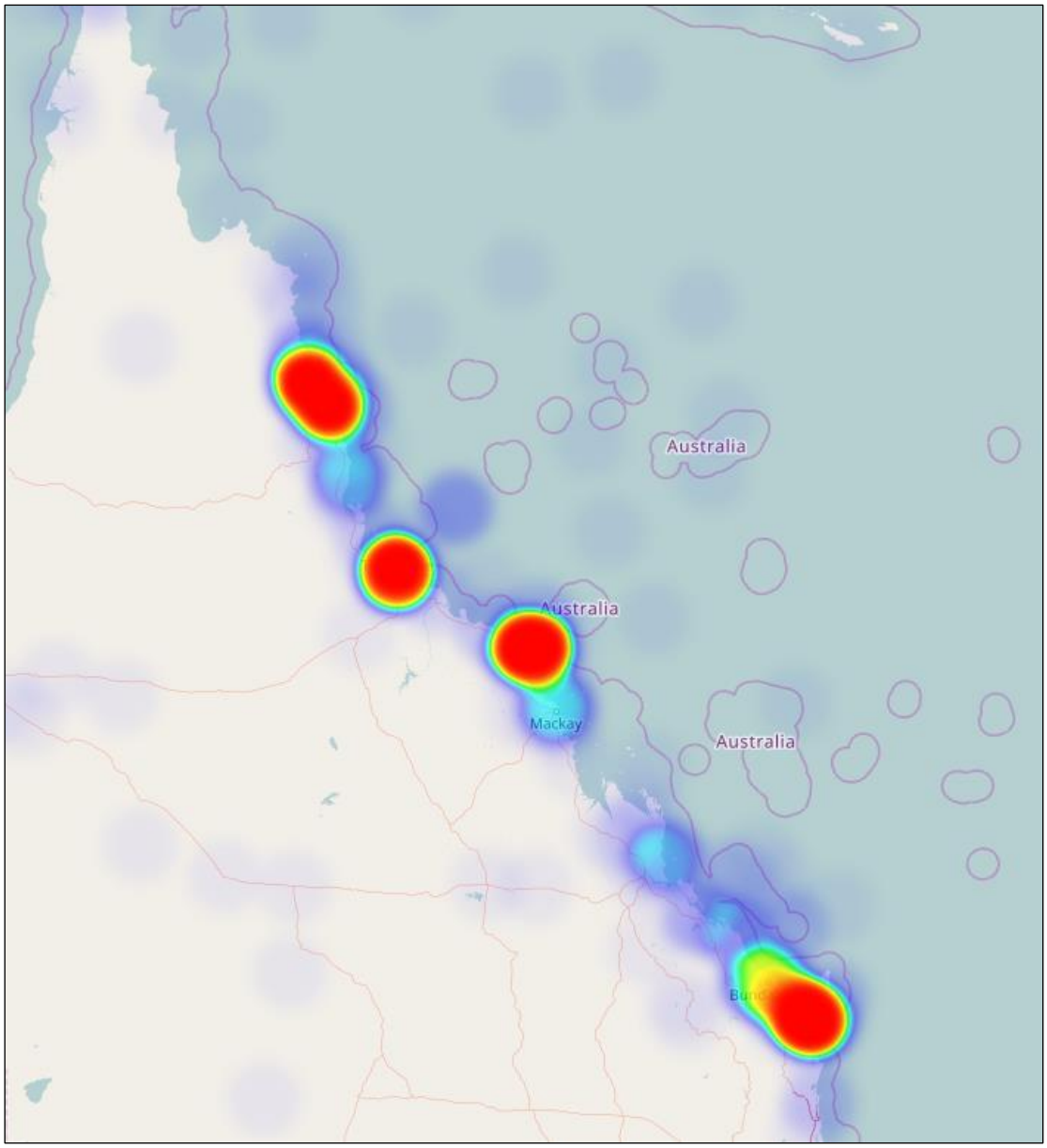

Figure 7: Twitter heat map showing where the tweets were posted (GBR region with an insert showing a zoomed map of the Cairns region). Note: red reflects higher number and purple lower number of tweets.

The majority of Facebook posts and comments come from a limited number of pages within the selected 13 pages. Table 3 provides the numbers of interactions, highlighting that the largest number of comments were received on the GBRMPA page. This is despite the fact that this page has provided fewer posts than other pages, even though the number of followers is highest amongst all pages. The largest number of posts came from the Deep Sea Divers Den. Reviews are not further analysed in this study, but could provide additional insights in future.

Table 3: Volume of text (N = Number) on Facebook pages of the GBR Marine Park.

Facebook Page Name	Posts (N)	Comments (N)	Reviews (N)
Great Barrier Reef Marine Park	272	2,210	0
Deep Sea Divers Den	476	1,598	1,601
Pro Dive Cairns	225	316	0
Mike Ball Dive Expeditions	94	151	193
Spirit of Freedom	74	162	248
Passions of Paradise Great Barrier Reef Day Tour	93	140	208
Reef Teach, Cairns, Australia	65	133	176
Great Barrier Reef Australia	17	9	63
Great Barrier Reef Biology	73	35	0
Reef Safari Diving & Photography	125	58	13
Grey Nurse Shark Watch	25	21	4
Reef Encounter	251	105	0
Lizard Island Reef Research Foundation	80	10	3

5.2 Frequency of keywords

The number of times keywords are mentioned provides some insight into what is important to social media users in the GBR region. For Facebook posts and comments, frequency analyses also highlight what Facebook owners (often tourism operators) wish to convey to their potential customers. Two approaches have been taken; one where most frequent words were counted, and another one where a framework of predefined keywords was used to extract numbers.

5.2.1 Identifying most frequently mentioned words

The corpus of text data each from Twitter and Facebook were analysed (inductively) to examine which words were most frequently mentioned. It is important to note that the tweets were already filtered to obtain 'relevant' tweets; that is tweets that were deemed to talk about the marine environment. Similarly, the Facebook pages were selected purposefully to focus as much as possible on the GBR marine environment. It is therefore expected – and hoped - that amongst the most frequently used words, there would be important cues about what matters to social media users when talking about the GBR.

The word cloud in Figure 8 (a) below shows that filtered tweets largely talked about the "beach" (N= 2,909 times), "island" (N= 2,607), "reef" (N= 1,815), and "greatbarrier" (N=1324). Note that these popular words also appeared in different formats that are not counted in the frequencies above, for example "#greatbarrierreef" (N=434), "barrier" (N=174), "#thegreatbarrierreef" (N=20), and "#barrierreef" (N=13), to name a few examples. The above example of multiple mutations illustrates one of the challenges when analysing Twitter data. The Twitter word cloud shows those words with a frequency higher than 200 (there are 44 words where word frequencies are varying between 200 and 3378).

Figure 8 (b,c) visualises Facebook posts and comments, respectively. Words with a frequency higher than 50 are shown (there are 43 words in posts with frequencies varying between 50

and 528). It is notable that Twitter posts mentioned various locations and referred to particular objects of interest. In other words, they revealed mostly information about where people were at and maybe what they saw (e.g. the beach) – possibly because this forms an important part of Twitter sharing. Instead, Facebook posts focussed more on Reef-related activities, with a particular emphasis on experiential elements (e.g. “amazing”). Facebook comments were reflective of emotional language, compared with posts that focussed more on the attributes of the GBR.

Figure 8: Word clouds of frequent words used in Twitter feeds (a), Facebook posts (b) and comments (c).

5.2.2 Frequency of pre-determined keywords

As already seen in the world clouds, tweets referred more frequently to particular locations and maybe activities than particular marine species or environmental impacts. However, amongst marine topics, postings on ‘fish’, ‘coral’, ‘white’ and ‘bleach’ still occurred, although it is surprising that the word ‘bleaching’ was relatively infrequent (Table 4).

Table 4: Frequency with which pre-selected keywords were mentioned in tweets and Facebook text

Location	Tweets N	Facebook N	Activity	Tweets N	Facebook N	Marine Species	Tweets N	Facebook N	Environment / impact	Tweets N	Facebook N
Island	**4332**	**151**	**Dive/Diving**	**876**	**1357**	**Fish**	**1023**	**475**	**White**	**709**	**73**
Bay	**1426**	29	**Swim**	**753**	**96**	**Coral**	**434**	**355**	**Bleach**	**94**	**74**
Whitsunday Islands	**1145**	**107**	**Water**	**590**	**245**	**Shark**	**404**	**281**	**Storm**	**85**	**5**
Cairns	**989**	**424**	**Boat**	**515**	**225**	**Turtle**	**378**	**334**	Oil	27	68
Hamilton Island	**966**	4	**Snorkel**	**564**	**95**	**Cod**	**303**	46	Dead	40	31
Airlie Beach	**644**	7	**Sail**	**382**	16	**Dolphin**	**230**	45	Coal	49	20
Whitehaven Beach	**527**	50	**Scuba**	**300**	**256**	**Nemo**	**177**	**123**	Mud	24	1
Townsville	**202**	21	**Marine**	**160**	**251**	**Whale**	**163**	**105**	Algae	12	14
Mission Beach	**171**	22	Paddle	61	9	**Ray**	**119**	**77**	Damage	12	8
Daintree	73	1	Goggle	8	2	Crown	73	12	Died	13	6
Heron	58	17				Dugong	32	8	Broke	15	1
Lady Musgrave	18	4				Jellyfish	42	19	Pristine	7	5
Rockhampton	15	0				Stingray	23	8	Visibility	2	15
						Starfish	21	20	Colourful	7	13
						Anemone	12	27	Dull	1	1
						Wrasse	11	31	Turbid	1	0
						Trout	13	3	Sediment	4	5
						Grouper	7	4	Dirty	4	0

5.3 Sentiment analysis

5.3.1 Monthly sentiment

Across the whole period of observation, the proportion of positive tweets was 40.1% compared with only 9.8% for negative tweets. This result supports earlier research that found that people have a tendency to share positive experiences (Brob, 2013), although it is possible that positive Reef experience indeed outweigh negative ones. Some 50.2% of all tweets are classified as neutral. This may either be an indication that the sentiment analysis algorithm is not coping, or that a considerable number of tweets do not show any polarity. Tweets in non-English language also contribute to the volume of neutral tweets, although this effect is relatively small.

There was little variation across the 9-month period, although March 2017 was characterised by a larger proportion of negative tweets, namely 12.2% (Figure 9). It is possible that this is related to both the impacts of Cyclone Debbie and the coral bleaching event which intensified in March. Separate analyses are currently being undertaken to explore the impact of these events.

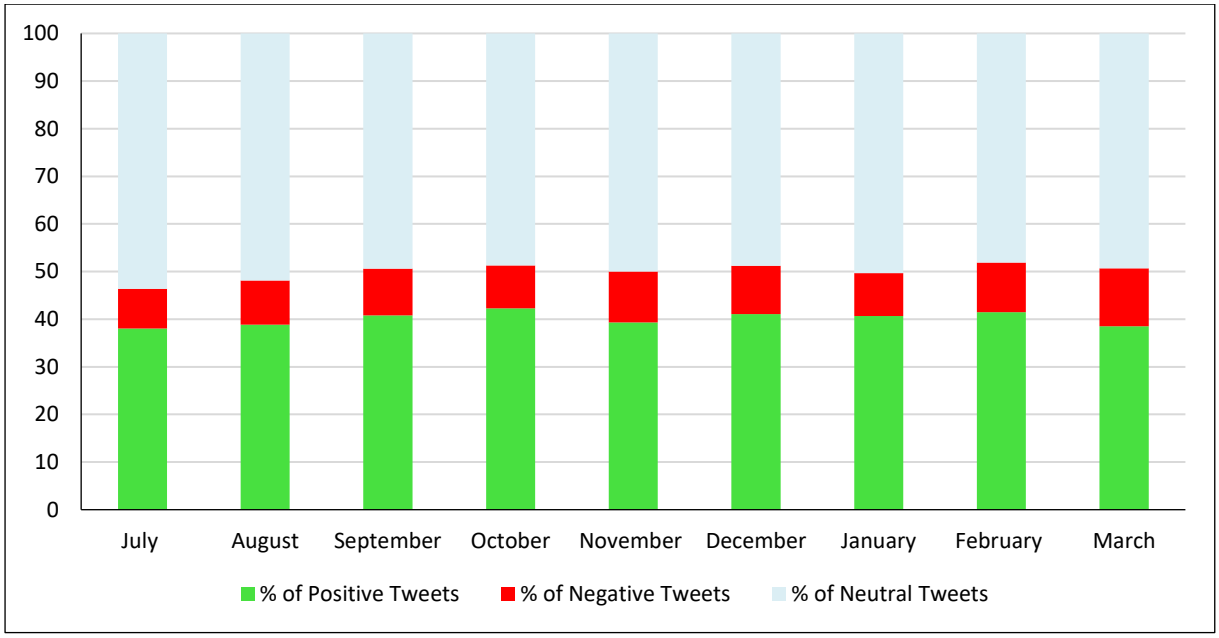

Figure 9: Percentage of tweets with positive, negative and neutral polarities collected from Twitter in different months.

The proportion of positive text is even higher for Facebook posts and comments compared with tweets (48.7% of all posts and comments). Furthermore, the share of negative posts/comments (5%) is relatively lower compared with Twitter data. Moreover, the occurrence of neutral text is smaller at 46.3%. Sentiment was lower for the months of September (42.9% of text was positive), February (44.8%) and March, (45.8%) (Figure 10).

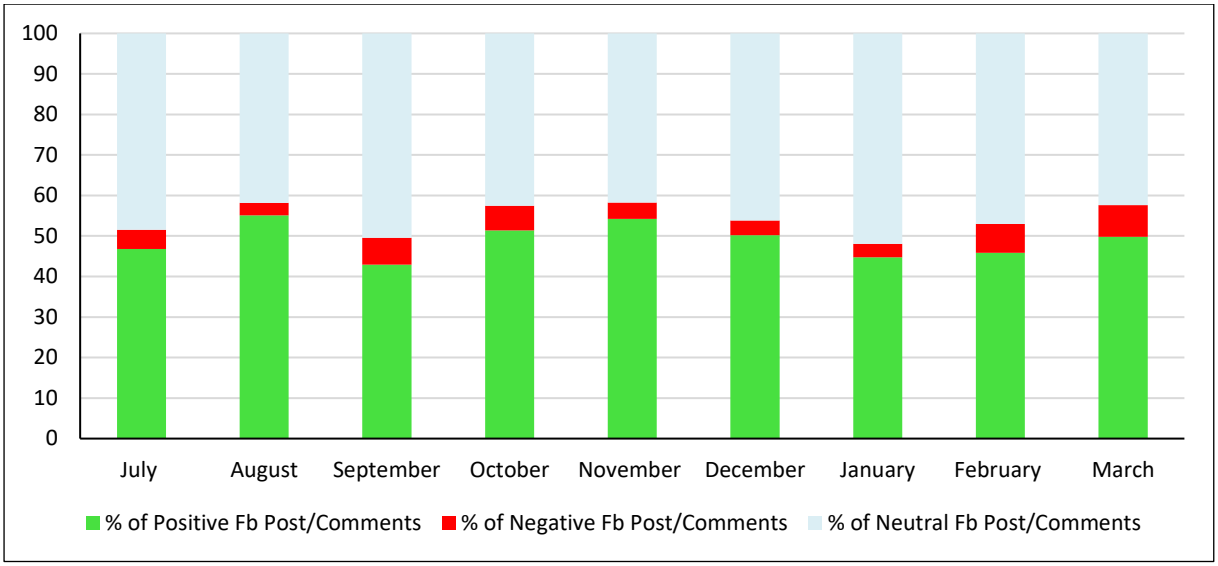

Figure 10: Percentage of posts and comments with positive, negative and neutral polarities collected from Facebook in different months.

It is useful to focus on those social media texts that where recognised by the algorithm as being either positive or negative. Figure 11 shows a comparison of the average sentiment score of both positive and negative texts for Twitter and Facebook, excluding those tweets that were classed as neutral. Across all months, Facebook text is more positive than tweets, revealing itself as a social media platform for sharing 'good news', 'happy mood' and great experiences. Twitter instead appears to have a larger share of either factual or critical (negative) content.

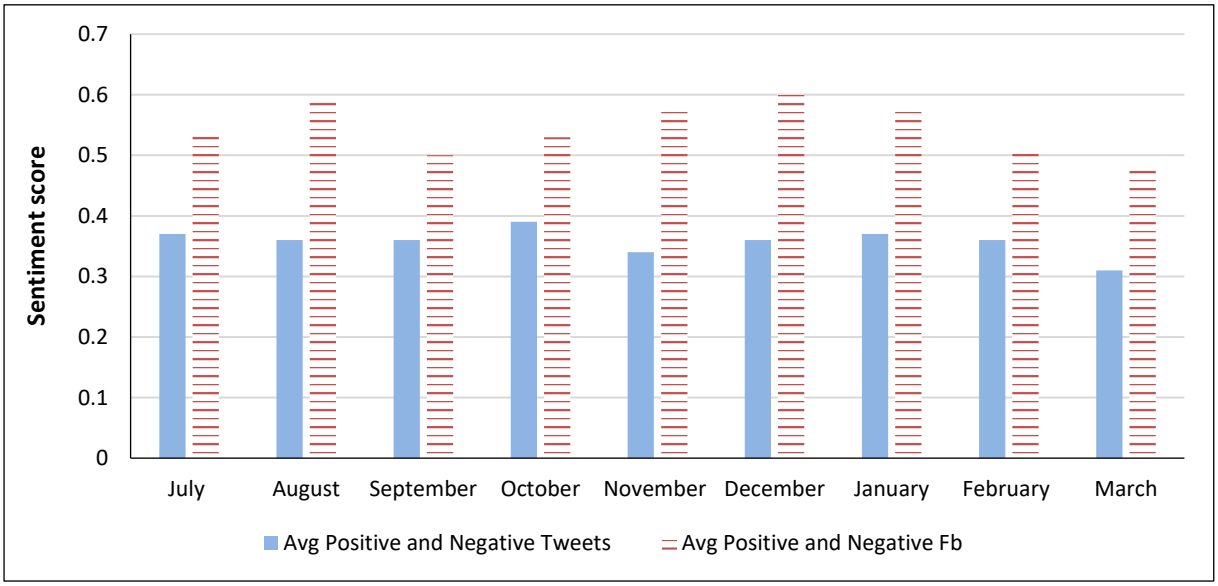

Figure 11: Comparison of average sentiment polarities of text on the GBR obtained from Twitter and Facebook data in different months.

5.3.2 Overall sentiment based on locations

Social media sentiment can also be analysed for different locations that are mentioned in the text. It is notable that for some locations that people talk about in their social media messages, the relative occurrence of negative tweets is higher than for others (Figure 12). Daintree and

Townsville are two prominent examples, where 14.3% and 8.3% of tweets were negative. A manual examination of tweets mentioning Daintree, however, reveals that the negative tweets are to some extent a result of the sentiment algorithm not correctly identifying the true meaning of the message. Example tweets highlight the need to further improve the algorithm through manual annotation and machine learning that reflects the tourism context and lexicon. Recognising irony in language is a known challenge for sentiment algorithms (Hernández Farias & Rosso, 2017).

- "Hello day we have missed you #portdouglasdaintree with wheresyoyo @ Four Mile Beach Port" (sentiment score: -0.296).
- "Hard to decide where to lay when the beach is so busy #portdouglasdaintree" (sentiment score: -0.1027)

Heron Island, in contrast, stands out as a location that is exclusively mentioned in a positive (or neutral) way. Example tweets highlight the types of messages and illustrate the associated sentiment scores.

- "I made it to #HeronIsland @CocoNell2! Those tiny baby turtles are now returning after 30yrs to mate. I was Lucky" (sentiment score: 0.4753).
- "Day 3 of #threedaysonheronisland A quiet spot to relax after scuba diving and watch the noddys" (sentiment score: 0.4939).

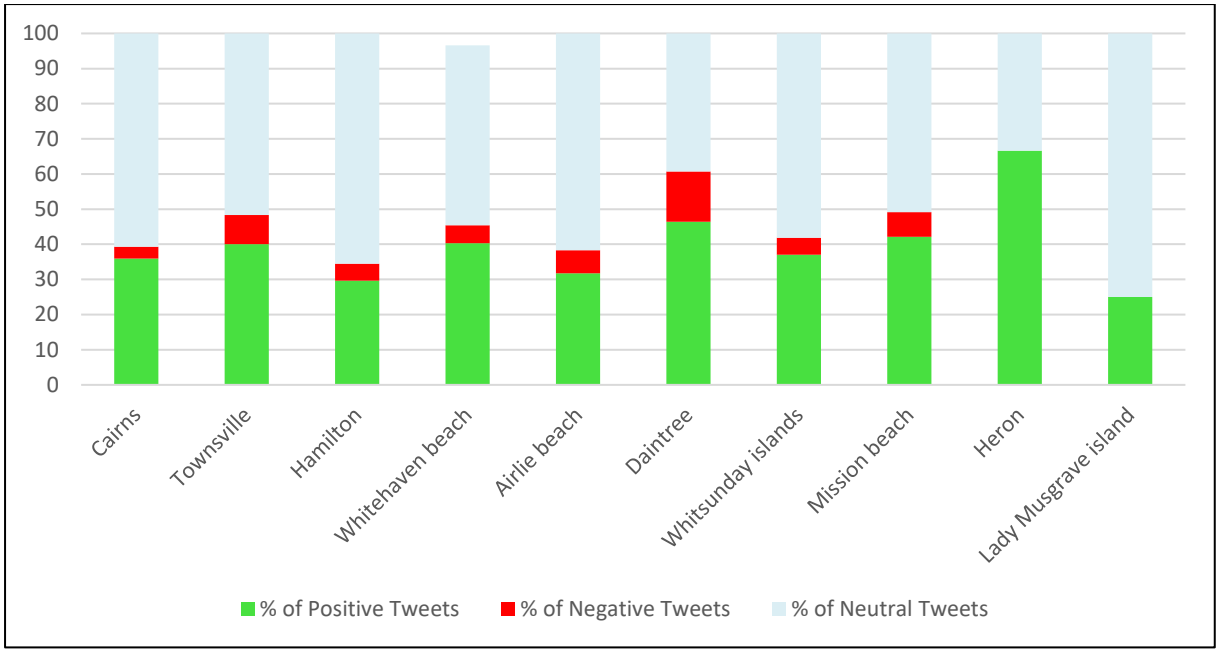

Figure 12: Percentage of tweets with positive, negative and neutral polarities collected from Twitter based on different locations around the GBR.

Facebook posts and comments were less likely to mention particular locations (see missing locations in Figure 13), and if they did so, it was usually with a positive sentiment. This is understandable since most pages referred to a particular company or site and written commentary was more likely to focus on the activity involved.

Townsville represents one exception, with 25% of related text being negative. This was influenced by some posts on coral bleaching, for example: "Currently there is a significant coral bleaching event underway through the Port Douglas to at least Townsville region".

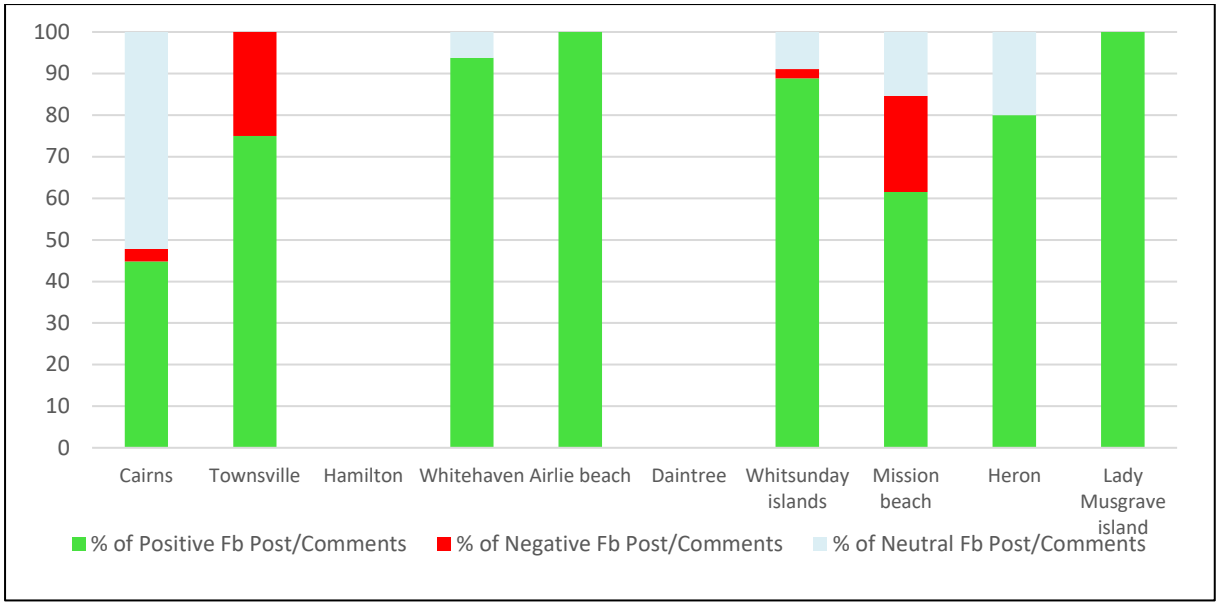

Figure 13: Percentage of posts and comments with positive, negative and neutral polarities collected from Facebook based on different locations around the GBR.

Again, as for the monthly comparison shown earlier, the location sentiment analysis shows that Facebook text is generally more positive than tweets (Figure 14), except for Townsville and (almost) Cairns.

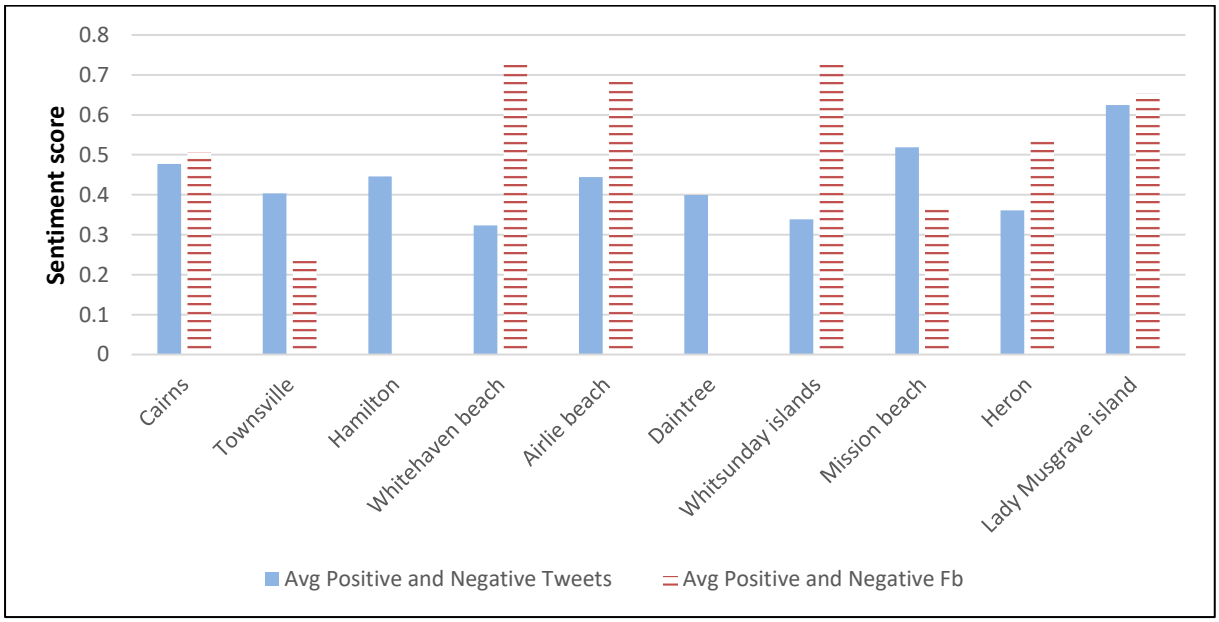

Figure 14: Comparison of average sentiment polarities of text obtained from Twitter and Facebook data based on different locations around the GBR.

5.3.3 Activities

The sentiment associated with tweets that talk about specific marine activities varies. Both 'scuba' and 'diving', for example, show relatively high proportions of positive tweets (Figure 15). Examples of positive tweets related to scuba diving include:

- "Great barrier reefing it today. Lifelong dream to see the greatbarrier reef. First time scuba." (Sentiment score: 0.6808).

- “My first scuba diving experience today at the #GreatBarrierReef - truly unforgettable moments. #thissisqueensland” (Sentiment score: 0.4939).

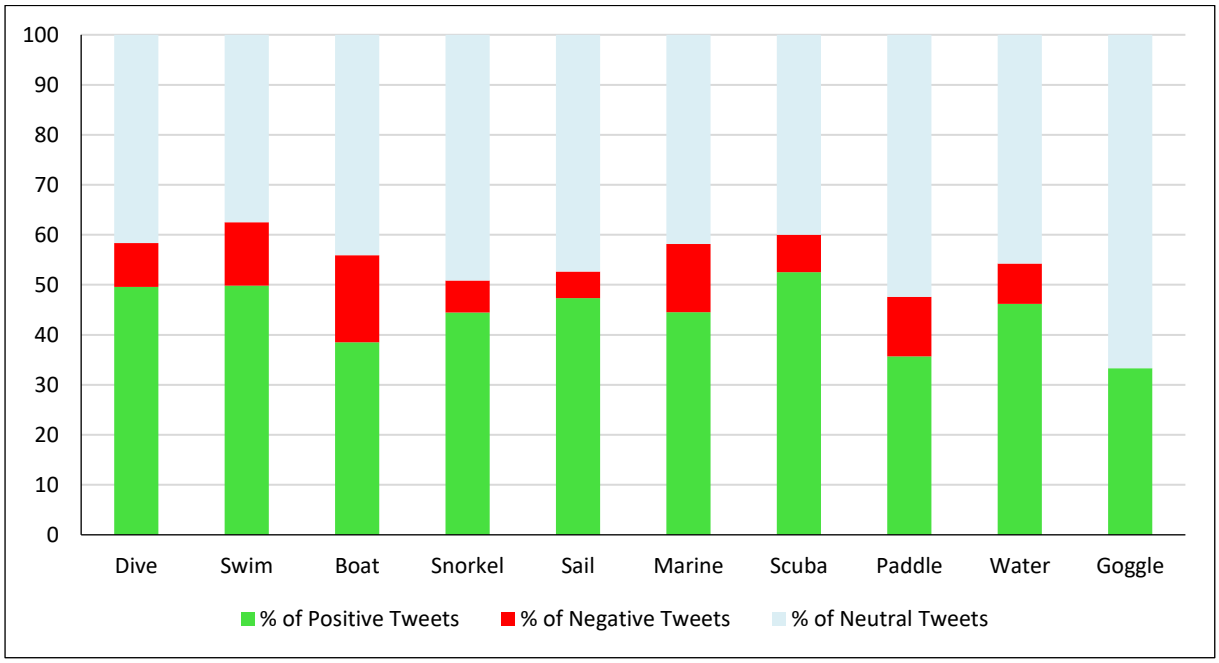

Figure 15: Percentage of tweets with positive, negative and neutral polarities collected from Twitter in relation to different GBR activities.

As seen in Figure 16, Facebook text related to activities is largely positive; which is not surprising given that several Facebook pages represent tour operators. Posts or comments that mention diving, for example, are overwhelmingly positive (75.3%). As one Facebook user commented, “*posts about scuba dive are why I love facebook*”.

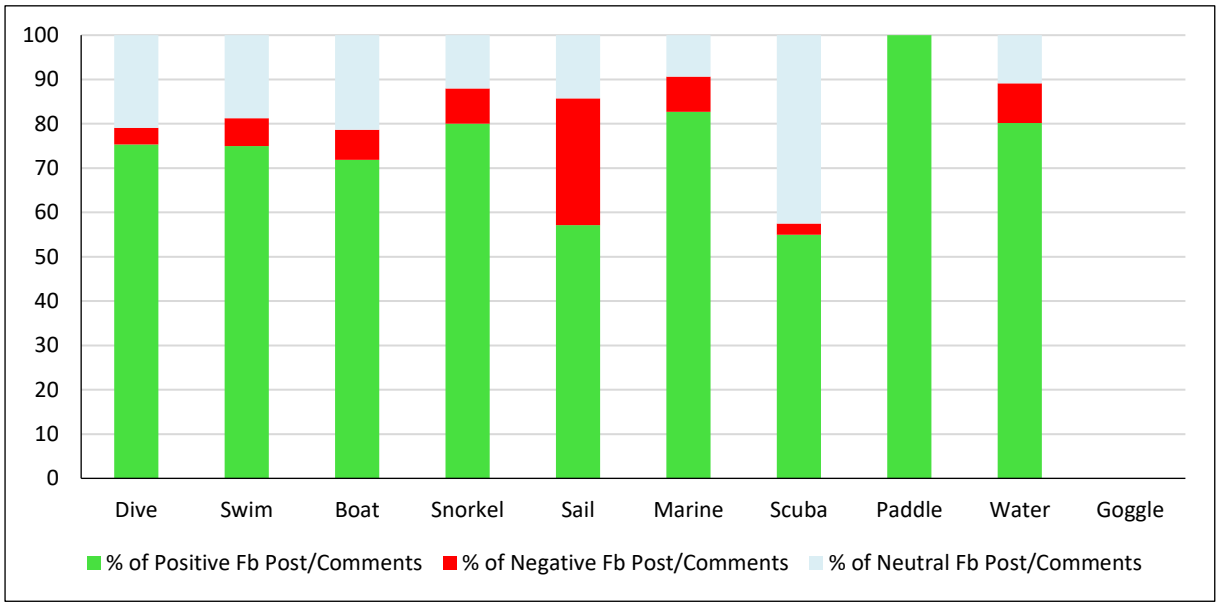

Figure 16: Percentage of posts and comments with positive, negative and neutral polarities collected from Facebook in relation to different GBR activities.

The difference in overall sentiment between Twitter and Facebook becomes particularly pertinent when examining activities (Figure 17).

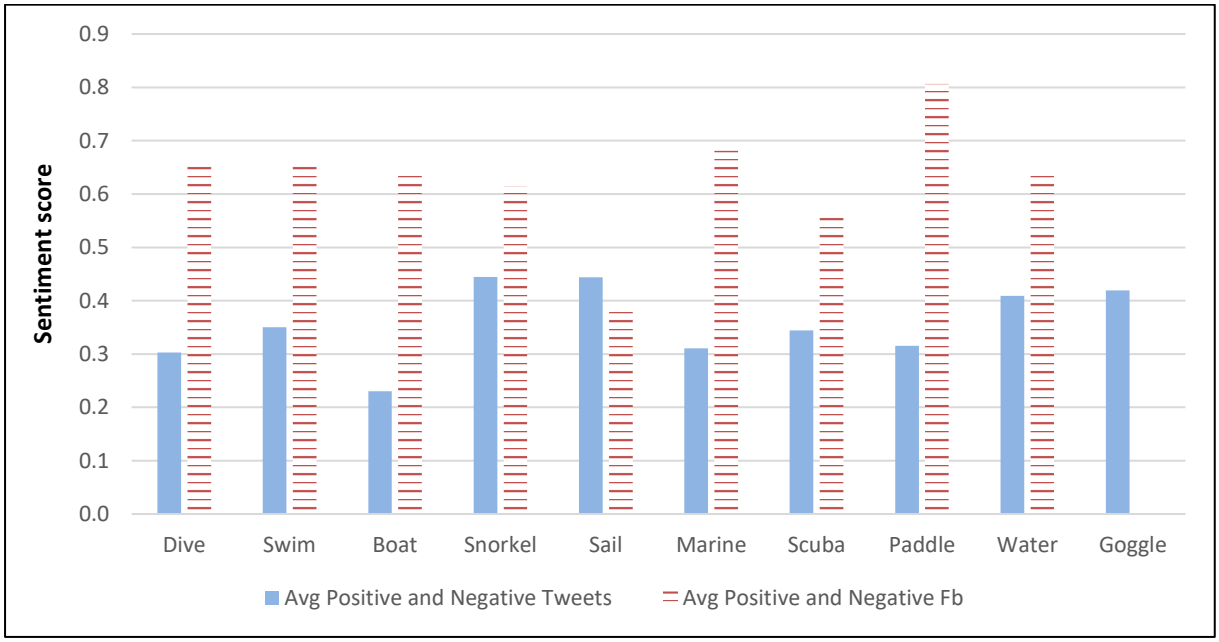

Figure 17: Comparison of average sentiment polarities of text obtained from Twitter and Facebook data in relation to different GBR activities.

5.3.4 Marine species

Social media conversations contain ample reference to different types of marine life. One tweeter specifically referred to Tourism Event Queensland's notion of the Great Eight: "*Saw 5 of the 'great 8' animals of the greatbarrier Reef on our 2 day snorkel trip: clownfish, turtles, giant clams, Maori wrasse, & sharks!*" Typically the words used were very generic (e.g. fish), but people also talk about animals more specifically. Nemo, for example, was mentioned 123 times (note: 'clownfish was only mentioned 26 times). A large proportion of tweets were neutral (Figure 18), possibly indicating that the sentiment lexicon lacks specific information on the polarity of marine sightings. Examples include:

- "Diving the GBR... Saxon Reef. Another successful day! Sharks, Sea Turtles, Nemos! And good." (Sentiment score: 0.8217).
- "#greatbarrierreef #turtles #nemo #coral #snorkel #snorkelling #dive #diving #tropics #tropicalnorthqueensland #reef" (Sentiment score: 0).

Several species attracted negative comments, for example those that related to dugongs. One tweet read:

- "It is a travesty that this cruelty to turtles and dugongs is allowed to happen. The hypocrisy of the Greens plain…" (Sentiment score: -0.8225).

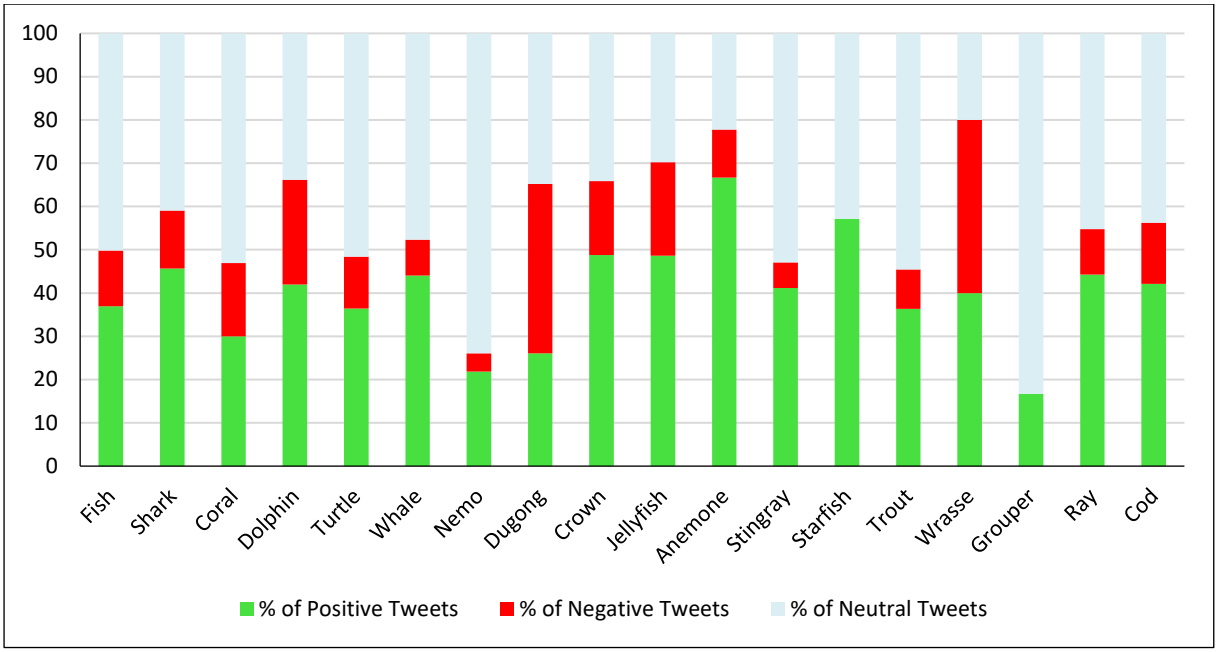

Figure 18: Percentage of tweets with positive, negative and neutral polarities collected from the Twitter in relation to different GBR marine park species.

The Facebook text examined in relation to marine species keywords shows a notable negative sentiment for 'crown' – standing for crown-of-thorn (Figure 19). Some text was specifically designed to raise awareness or to educate people. For example, GBRMPA sent a post on a Facebook page:

We'd like to give a shout out to the Great Barrier Reef Foundation for their funding support to help with these coral surveys across the Reef. […]. Our work with tourism and research partners to control the coral-eating crown-of-thorns, our regulatory work and scientific-based adaptive management approach, and our focus on working with government, community and industry partners all build capacity and deliver benefits for Reef health. The Australian and Queensland governments have committed $2 billion over 10 years to protect the Reef and we are working with them to implement the national Reef 2050 Plan to improve the health and resilience of the Reef. http://environment.gov.au/marine/gbr We urge you to take up Dr Dave's challenge and do your bit to protect the Reef by following our #LovetheReef principles: http://bit.ly/20b5IOx

Another Facebook page (Great Barrier Reef Biology) posted the following text, indicating that social media platforms may well contribute to the spread of ideas and innovations that help protect the marine environment.

Whilst our own Reef has an extensive network of volunteer citizen scientists in Eye on the Reef providing data, the US Virgin Islands have gone a step further. By interviewing the local industry to reveal and map remaining hot-spots of crucial healthy coral populations that can be targeted for extra care. Would our reef tourism operators be willing to pinpoint such ecologically important locations for protection from Crown-of-thorns starfish for example?

Stingray and Grouper were associated with Facebook text that was classed as positive.

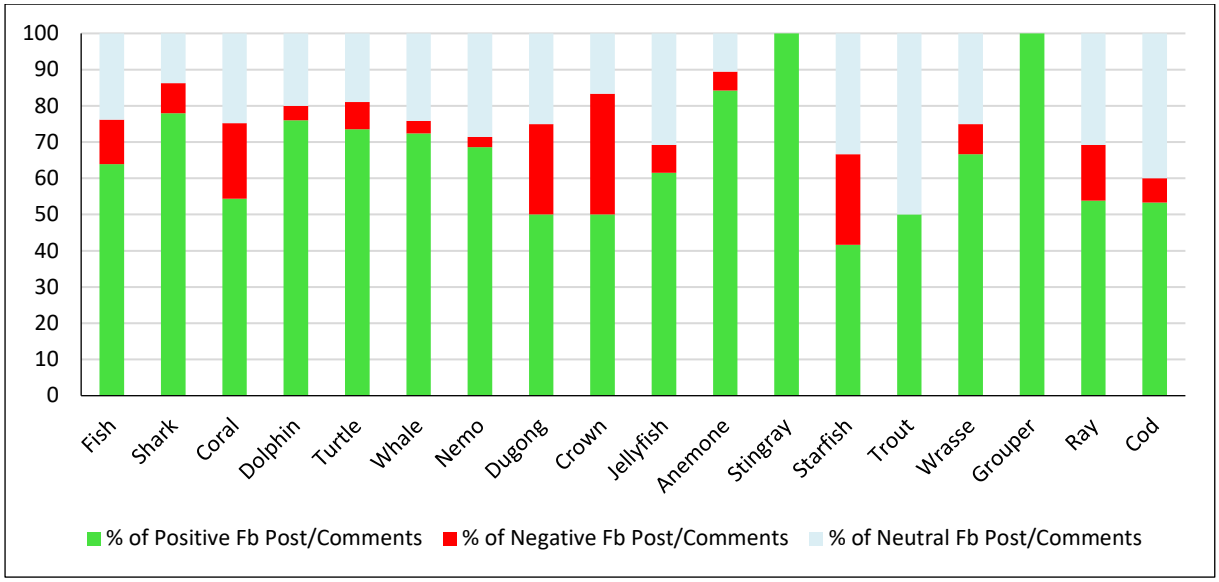

Figure 19: Percentage of posts and comments with positive, negative and neutral polarities collected from the Facebook in relation to different GBR marine park species.

Figure 20 compares the polarity scores of Twitter and Facebook text for marine species; displaying negative overall sentiment for dugong and wrasse. A manual examination of tweets related to 'wrasse' shows that most of them also contain the word 'wreck' (standing for ship wreck), which negatively influenced the sentiment. Once again, this demands future refinements of the algorithm.

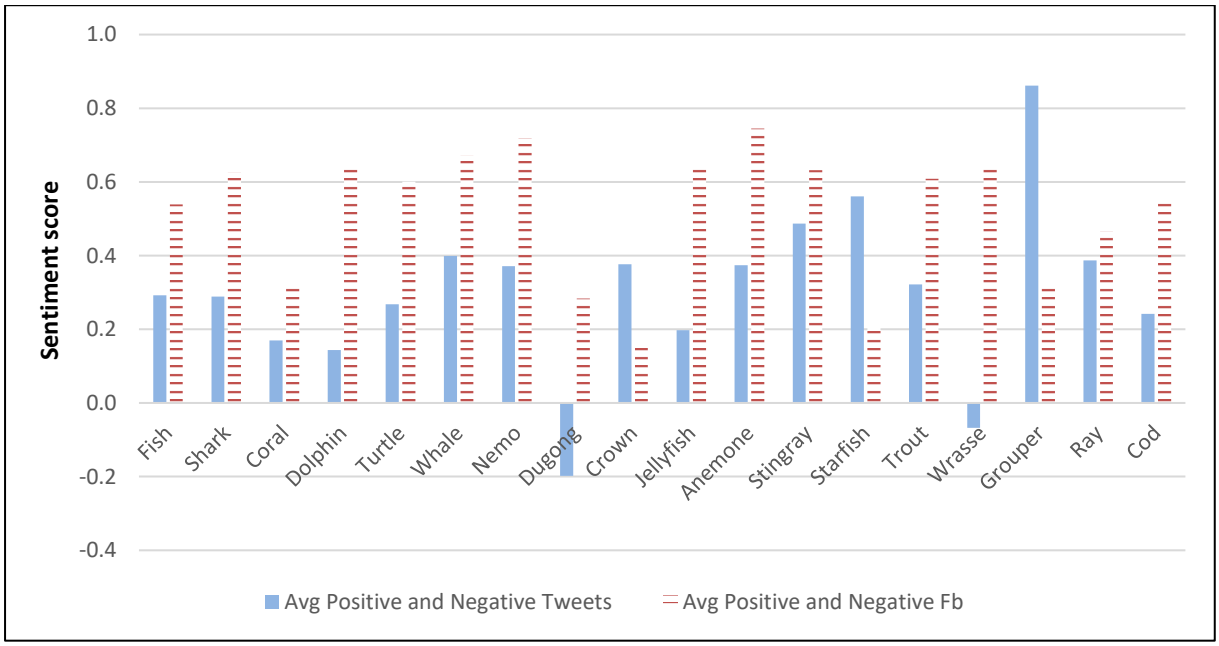

Figure 20: Comparison of average sentiment polarities of text obtained from Twitter and Facebook data in relation to different GBR marine park species.

5.3.5 Environmental impacts

Social media users are less likely to discuss environmental problems or impacts. However, keywords such as bleaching, storm or dead still indicate some level of engagement in the issues that are affecting the GBR. Figure 21 presents the proportion of positive, negative and

neutral tweets for a range of environmental keywords. Not surprisingly, the sentiment is typically negative, for example when discussing coral bleaching:

- "'It's happening now': Indigenous rangers on frontline of coral bleaching @abcnews" (Sentiment score: -0.6808).
- "Coral bleaching due to global warming has continued to worsen in the greatbarrier Reef...I think it's a pity..." (Sentiment score: -0.6808).
- "I'm going snorkelling at the Outer Reef tomorrow and am curious to see how badly the bleaching is" (Sentiment score: -0.5719).

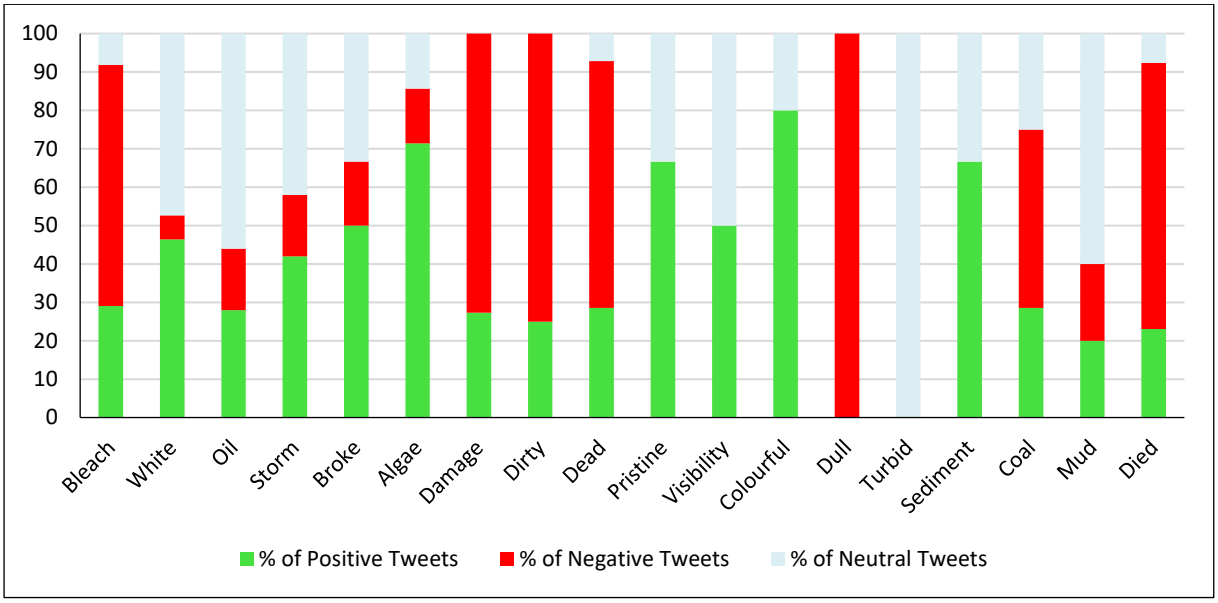

Figure 21: Percentage of tweets with positive, negative and neutral polarities collected from the Twitter in relation to different environmental impacts at the GBR marine park.

There were some interesting differences between the (short) tweets and often more detailed Facebook posts and comments (Figure 22). A number of posts indicated an engaged discussion in some of the key challenges facing the Reef – representing a mix of factual information and personal opinions. Notable examples include:

"The Cape York Peninsula Development Road isn't helping the reef by reducing sediment runoff to the Great Barrier Reef - it is actually going to make it worse. The key word is "Development". Much like the trans-amazonian highway opened up the last true wilderness areas of that landscape, so this road will to, for the same purpose - mass scale attempts at agriculture, particularly grazing. Landscape-scale bulldozing of forest for cattle grazing delivers 1000 times more pollution to the reef than this one dirt road ever could have." (Facebook post on the Great Barrier Reef Biology Page).

Several social media users engaged with Facebook pages to express political views. For example, one Facebook user commented:

"I am glad you mentioned the insanity of building the Gladstone clean coal power plant. You also need to mention the insane Adani Carmichael coal mine proposal in Queensland which would be one of the largest coalmines in the world. And you also need to mention that fugitive methane emissions from fracking make coal seam gas extraction no cleaner than coal. Australia must take a leading role on the world stage to reverse global warming. This means not only achieving zero emissions, but actually negative emissions and extracting half of the

500 Gigatonnes of Carbon (500GtC) net we have deposited long term in the atmosphere (persisting for hundreds of years). We need to get back to 350ppm CO2.Because if we don't, global warming will continue, ocean temperatures will continue to rise, and the Great Barrier Reef will be so degraded and permanently damaged, it will for all intents and purposes be dead, and you can say goodbye to the whole reef tour industry. Speak up! Speak out!"

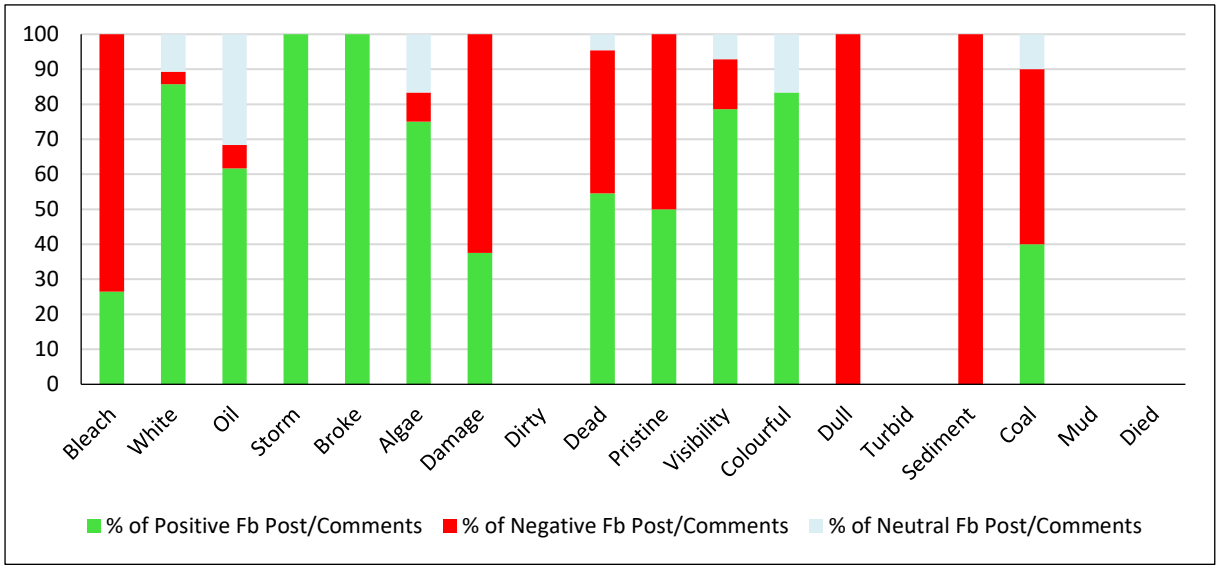

Figure 22: Percentage of Facebook posts and comments with positive, negative and neutral polarities in relation to different environmental impacts at the GBR marine park.

Clearly, the results for both types of social media highlight that people do discuss environmental issues – with mixed sentiment, but a tendency towards more negative text, particularly for Twitter (Figure 23).

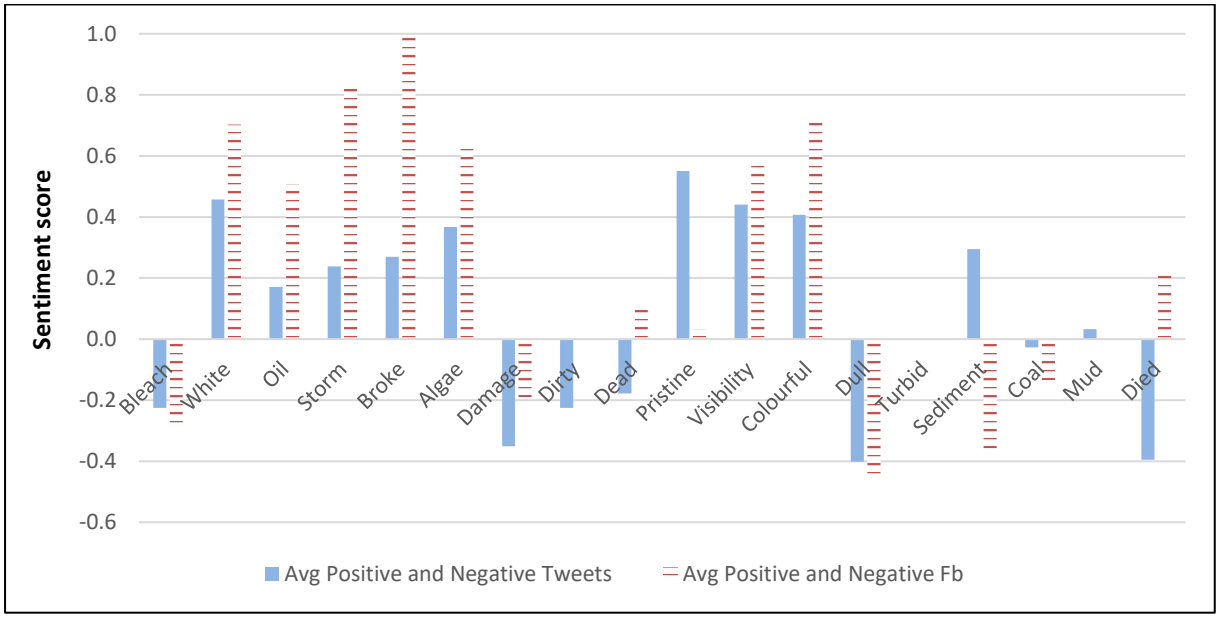

Figure 23: Comparison of average sentiment polarities of text on the GBR obtained from Twitter and Facebook data in relation to different environmental challenges.

6.0 CONCLUSION

The aim of this research was to examine whether social media contain useful information on the Great Barrier Reef. This report presented findings of a comparative analysis of Twitter feeds and Facebook posts and comments. The volume of data is considerable; however, the examination of tweets in particular has also highlighted the critical need for filtering procedures. In this research, two steps of unsupervised (i.e. computer automated) filtering were implemented; one related to the geographic location from where tweets were posted, and a second one based on a relatively large number of keywords that sought to capture those tweets that actually talked about the marine environment. This second filtering step reduced the initial volume to 13,344 tweets, or 4.7% of geo-coded tweets initially stored in the database. The number of Facebook posts and tweets from 13 identified pages amounted to a total of 6,632. Note that many Facebook messages were considerably longer than tweets, and as a result were richer in terms of information that could be retrieved.

A keyword analysis of most frequent words (through word count) and the numbers of tweets retrieved that contained a priori specified keywords gave insights into what mattered to people, but also how the two social media channels differ in terms of focus. Twitter posts often contained reference to locations or the particular object in question (e.g. the Reef or a beach), whereas Facebook was more often concerned with particular activities and experiences, and the emotions that these trigger. This was particularly evident in the Facebook comments, where visitors (or customers) commented on their trip and thanked the company or crew for a great time at the Reef.

To better understand the polarity of opinions or perceptions, sentiment analysis was carried out. An improved and extended algorithm, VADER, was used to detect and score those texts that are positive, neutral or negative. As already established in other research on social media, most posts are positive. Thus, there is an inherent bias towards positive statements and sentiment, and this was also observed in this research. Facebook was relatively more positive than Twitter, indicating that it is more an outlet to share positive emotions than negative thoughts. Comments on environmental issues and political statements formed an exception. Twitter, instead, is more likely to contain a variety of statements that could be factual, retweets of media stories, a series of hashtags, or negative observations, for example spur-of-the-moment moods and disappointing experiences that people wish to share with their friends immediately.

This research highlighted that sentiment evident in tweets and Facebook text varied for specific locations, activities and marine species. Some of these were intuitive (e.g. dugongs were associated with sad or negative feelings), others may reflect a useful indicator (e.g. diving was more positive than boating), and others are a reflection of the sentiment algorithm not recognising the true sentiment. Examples were provided in this report giving useful clues for improving the lexicon. Including domain specific words, such as ‘wreck’ (for shipwreck), in a marine lexicon seems a necessary next step.

The sentiment around some of the environmental keywords was negative, although it was surprising that the frequencies were quite low. Even coral bleaching, which has received substantial media attention, was not mentioned very often. Those people who discussed

bleaching (and other issues associated with Reef health) showed concern, and shared their views, in particular on Facebook where space is not limited. Several Facebook pages, especially GBRMPA's page, used this platform to engage and educate followers and share some useful information. Some pages tried to mobilise people to act to protect the GBR.

This research shows that neither Twitter nor Facebook are commonly used as platforms to share environmental information or to encourage citizen advocacy or a movement. Both platforms could be employed better to encourage people to learn about the Reef and support its protection. For Twitter, a hashtag system might be an option. This could be promoted by tourism operators who inform people that their tweets with GBR-related hashtags will be used in an environmental monitoring system; thus empowering visitors to contribute through sightings and observations. On Facebook, operators could share more marine information, in addition to what currently seems to be a commercial focus of promoting products and experiences. The Citizens of The Reef initiative could be an important allay in this journey of citizen engagement and science (see here http://citizensgbr.org/).

The following recommendations are made for Reef operators and managers.

- Social media provides a powerful communication channel and an opportunity not only to showcase product but also to convey corporate values, commitment and Reef stewardship.
- Tweets and posts can be used to educate residents and visitors, and to share interesting information about the Reef. They also provide a pathway to encourage support for conservation activities.
- As in other online interactions (e.g. review and recommender systems), it is important to monitor posts and tweets, especially negative ones, and respond promptly to address issues. This may reduce the spread of negative messages, and also provides an opportunity to rectify or explain particular issues.
- More generally, monitoring social media sentiment can be useful to detect areas of dissatisfaction or points of contention. This is important information for those managers who are in a position to improve conditions, or at least to address them proactively through communication. As such, sentiment analysis usefully complements traditional satisfaction surveys.
- Social media posts may also be used to track the flows of people. This is possible because the majority of tweets, for example, have coordinates attached that allow spatial tracking. This information can be useful for a wide range of planning purposes.

The next step in this research project is to integrate the Twitter and Facebook data with other citizen science data, and with biophysical information on the marine environment and other relevant geographic context (e.g. the weather). This step will then provide more insight into whether social media data can be useful beyond the notion of socio-economic monitoring, but contribute to the environmental management itself.

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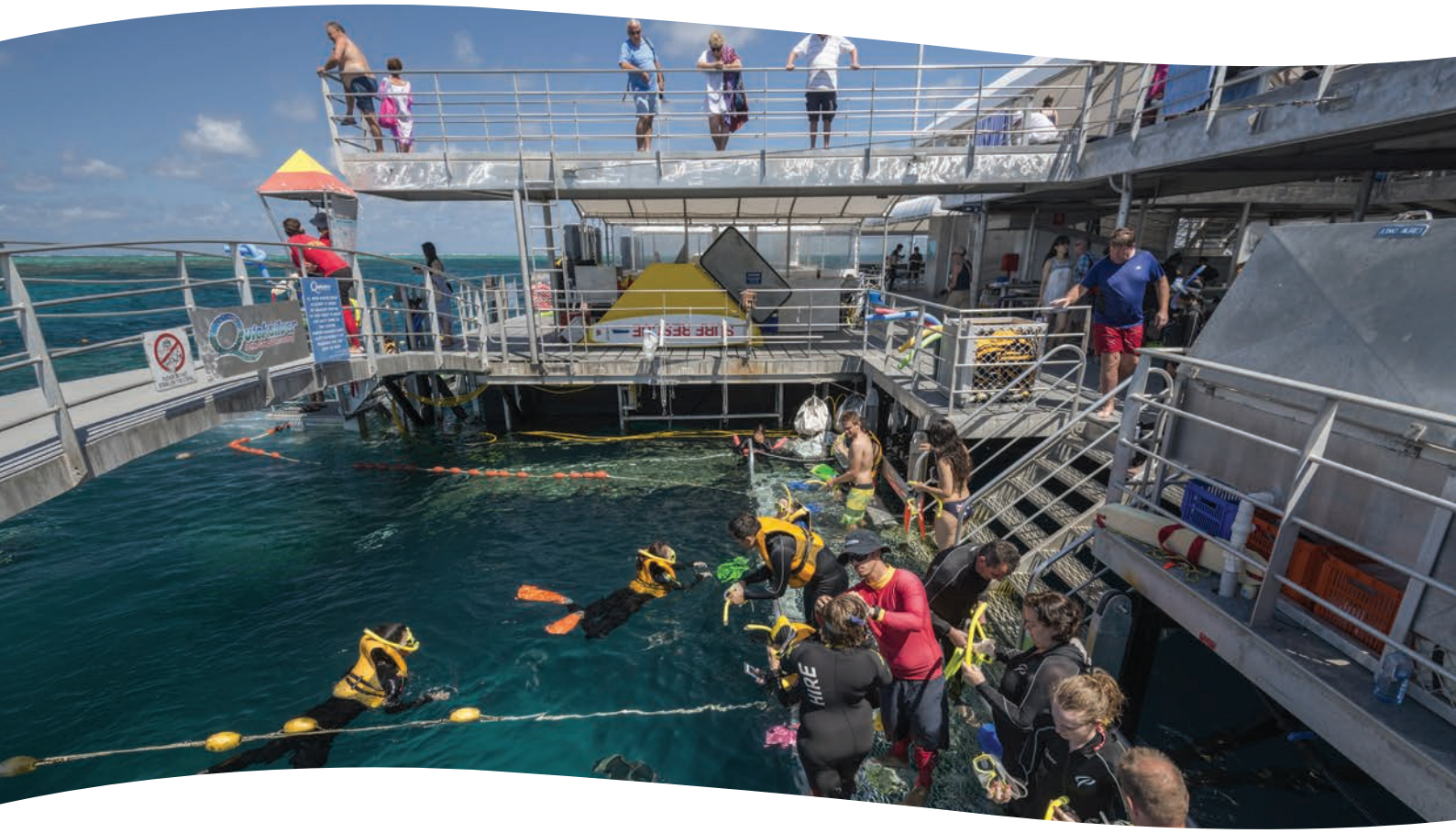
APPENDIX 1: LIST OF KEYWORDS TO FILTER RELEVANT TWEETS

Fish	Species	Togs	Swimsuit		Shells	Mussel	Died-off	
Anemone	Seahorse	Swim	Swimming	Swam	Reef	Reefs	Bleached	Bleaching	Bleach
Angelfish	Porcupinefish	Snorkel	Snorkelling	Snorkelled	Sand	Sandy	Pristine		
Barracuda	Boxfish	Fins	wetsuit	Goggles	Island	Islands	Colourful		
Clownfish	Puffer	Dive	Diving	Diver	Beach	Beaches	Murky		
Cod	Triggerfish	Scuba	Dived		Bay		Turbid	Turbidity	
Cots	Trumpetfish	Marine	Marina		Sea		Visibility		
Crown	Flutefish	Boat	Boating		Ocean				
Dolphin	Razorfish	Sail	Sailing	Sailed	Paradise				
Dory	Goatfish	Paddle	Paddling	Paddled					
Dugong	Eel	Fishing	Fished	Fishes					
Emperor	Seasnake	Fishable							
Grouper	Barramundi								
Lionfish	Damselfish								
Nemo	Rabbitfish								
Parrotfish	Batfish								
Shark	Unicornfish								
Snapper	Butterflyfish								
Starfish	Bannerfish								
Surgeonfish	Rockcod								
Tang	Stonefish								
Thorn	Crocodile								
Trevally	Marlin								
Trout	Mackerel								
Tuna	Stingray								
Turtle	Sawfish								
Whale	Hammerhead								
Wrasse	Wobbegong								

Coral	Flatworms			
Algae	Cucumber			
Plankton	Crown-of-thorns			
Jelly	Squid			
Jellyfish	Octopus			
Stinger	Cuttlefish			
Irukandji	Crabs			
Jellyfishes	Sponge			
Boxjelly				

Note: the list of species was informed by GBRMPAs Eye on the Reef app and other keywords were identified by manually analysing a subsample of tweets.



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