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Influence of conservation education dive briefings as a management tool on the timing and nature of recreational SCUBA diving impacts on coral reefs

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ABSTRACT

This study investigated the frequency and timing of physical impacts SCUBA divers have with the coral reefs in Key Largo, and whether these impacts are accidental or deliberate. Our study looks at the timing of diver interactions and how these can be managed. We also investigated the importance of diver conservation education and the value of conservational programmes in the Florida Keys as a user management tool.

We used a triangulated method of direct observation, questionnaires and dive briefing analysis. The study took place over a three-month period from June until August 2010 in the John Pennekamp State Park Key Largo, Florida. 97% of the divers observed ($n = 83$) physically interacted with the reef during their dive. Most contacts were accidental and were concentrated in the initial part of the dive. More in depth conservation education dive briefings significantly reduced the number of impacts divers made. Divers from the operator with conservation centred briefings impacted the reef significantly less with 0.16 ± 0.08 (mean $\pm$ SE) touches per minute compared with 0.37 ± 0.06 (mean $\pm$ SE) for the other charters. Our findings highlight the importance of conservational initiatives and improved conservational briefings on board dive charters. Gathering data on anthropogenic influences, like SCUBA divers, provides reef managers with vital information that can be used in reef management.

1. Introduction

Coral reefs have unique biodiversity and provide important ecological ecosystem services. However, concern surrounding the depletion of the world's coral reefs is mounting. An assessment by 96 countries on 372 reefs in 2008 concluded that 19% of the world's coral reefs have been lost since 1950 and that 15% is at a critical risk, with an additional 20% under serious threat of being lost within the next 10–20 years (GCRMN, 2008). Pollution, over fishing and climate change are major factors contributing to the decline in survivorship, reproduction and growth-rates of corals (Brown, 1997; Gardner et al., 2003; Hughes et al., 2003; Mumby et al., 2007). Decline in the health of coral reefs has also been linked to the recreational diving industry (Shivlani and Suman, 2000; Uyarra and Côté, 2006; Van Beukering and Caesar, 2004).

A global response to the decline in coral health and cover has been the formation of Marine Protected Areas (MPAs). The success of an MPA is dependent on several factors, including both environmental conditions and local support. Although there is much debate about the effectiveness of MPAs, one measure of some success has been an increase in marine tourism (Weaver, 2008); in particular, SCUBA diving. SCUBA diving generates significant financial gain for many coastal communities with the Florida Keys being no exception, welcoming around 800,000 SCUBA divers and snorkelers each year (Mintel, 2003). The Florida Keys is home to a large MPA known as the Florida Keys National Marine Sanctuary (FKNMS) which protects over 18,000 square miles of marine habitats (NOAA, 2010b). However, the reefs are still under threat as increases in coral bleaching and disease have been recorded over the last 20 years (NOAA, 2010b).

Initially, it was argued that SCUBA diving had little impact on coral reefs (Hawkins and Roberts, 2003; Talge, 1992). However, more recent studies by Schleyer and Tomalin (2000) and Uyarra et al. (2009) have found that SCUBA diving activities can negatively affect coral reefs. The cumulative effect of diving can leave corals more susceptible to other background pressures such as disease (Hawkins and Roberts, 1992; Medio et al., 1997; Tratalos and Austin, 2001). The effect that diving has on a reef depends on diver activity, the type of coral that is damaged and its life cycle. Such

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damage includes breakage, abrasions and sedimentation effects. Coral polyps can easily be damaged by touch; such damage is deliberate, but probably due to inability to correctly identify coral and ignorance of its fragility. Green and Hendry (1999) found that non-specialists were only able to accurately identify three out of ten coral species with 67% accuracy; demonstrating how challenging it can be to identify corals. Coral breakage is normally the result of a fin kick, with branching coral being most susceptible to this type of damage (Harriott et al., 1997; Rouphael and Inglis, 1997). Abrasion damage breaks corals' protective tissue membranes, rendering them more susceptible to disease. Sedimentation damage can occur by divers increasing the water turbidity resulting in complete or partial burial of coral polyps (Meyer and Holland, 2009). Nugues and Roberts (2003) found that sedimentation can facilitate algal growth over coral, which can contribute to phase-shift from a coral dominated to an algae dominated ecosystem.

Previous studies have identified different factors that can influence the impact SCUBA divers have on a reef. Gender bias was identified by Rouphael and Inglis (2001), who found that male divers were more likely to interact with the reef. However, Uyarra and Côté (2006) found that women made more contact with the reef. The use of photographic equipment by divers was found by Rouphael and Inglis (2001) and Uyarra and Côté (2006) to increase the chance of divers' touching with the reef. Additionally, the level of diving experience may or may not affect the number of contacts divers have with the reef with Di Franco et al. (2009), Hawkins and Roberts (1992) and Rouphael and Inglis (2001) finding conflicting correlations. The topography and conditions can also affect how often a diver interacts with the reef (Hawkins and Roberts, 1992; Hawkins et al., 1999).

Education has been identified as a means of reducing diver impacts on the reef (Barker and Roberts, 2004; Davis and Tisdell, 1996; Hawkins and Roberts, 1992; Thapa et al., 2005). Improving divers understanding of actual and potential threats can install environmentally responsible behaviour (Rouphael and Inglis, 2001). Hannak et al. (2011) found that 95.6% of divers in the Northern Red Sea believed that an informative dive briefing on proper dive behaviour would be a beneficial management tool. Also, Medio et al. (1997) found that an environmental briefing reduced the number of contacts over a seven minute period from 1.4 to 0.4 touches. Projects like PADI AWARE, and REEF identification courses are all educational programmes for divers that can potentially increase diver education. Also, initiatives like the Blue Star programme that encourage dive masters to incorporate conservation education into their dive briefings are potential tools for reducing diver impacts on the reefs. Understanding when and how divers interact with the reef is important in presenting management options to minimise diver-caused damage.

In an attempt to protect the coral reefs and their biodiversity the FKNMS has limited certain activities and has considered the reefs' carrying capacity (Mumby et al., 2007). The FKNMS has a detailed mooring buoy management plan that aims to limit resource damage. Feedback from local dive shops is important in determining user needs which are a primary factor in determining the placement of the mooring buoys (NOAA, 2010b). Also, NOAA has an education and outreach action plan with the goal to increase public awareness of the marine resources and what is impacting them (NOAA, 2010b). NOAA has identified that educating users of the FKNMS is important, as the economy relies on tourism with 1.2 billion US dollars spent annually by visitors. Many of these visitors come to experience the beauty of the coral reefs by SCUBA diving or snorkelling (NOAA, 2010b). Also, the use of artificial reefs to relieve the pressure on natural reefs has been tested in the Florida Keys with the sinking of the *USS Spiegel Grove*. Leeworthy et al. (2006) found that the sinking of *USS Spiegel Grove* decreased the pressure on local, natural reefs while increasing diving business. Despite all of these efforts, little information still exists on the impact of SCUBA divers on the reefs and ways these impacts can be effectively managed.

In this study, we observed 83 divers from four dive charters in Key Largo, Florida, to determine the frequency and timing of their impacts with the coral reef. We tested the impact of depth of conservation education presented in dive briefings on diver behaviour.

2. Material and method

2.1. Test site

All dives were completed inside the Florida Keys National Marine Sanctuary. The FKNMS is 2900 square nautical miles and supports over 6000 species of fish, invertebrates and plants (NOAA, 2010b). All dives were carried out on Molasses reef, French reef and Dry Rocks reef which exhibit a spur-and-groove reef formation. The sanctuary is organised and controlled by management plans established by NOAA under US Federal Law and in association with the Florida Fish and Wildlife Conservation Commission that oversee sanctuary regulations. Due to the dependence of the local community on the fishing and diving industries there is an incentive for local residents to comply with and promote sanctuary regulations. Since 1990, the National Marine Sanctuary Programme has ensured protective measures to assist reef preservation including a ban on anchoring on coral and a ban on collecting, and even touching coral (NOAA, 2010a). A GIS study (Shivlani and Suman, 2000) found that the Key Largo National Marine Sanctuary was used for nearly 70% of all diving provided by regional, recreational dive charters, in 1995. Due to the high diving pressure on the Marine Park our study was focused on this location.

2.2. Data collection

The study was carried out during the high summer diving season from June until August 2010 in Key Largo, Florida. Over the three-month period, 83 divers were observed from four dive shops. Dive shops A, B and C were chosen at random within the Key Largo area. Dive shop D was intentionally chosen as it was the only Blue Star rated operator within the Key Largo area. The Blue Star rating indicates that the dive charter has undertaken the NOAA voluntary environmental education programme (NOAA, 2010a). The rating is awarded due to an overall commitment by the operator to adopt environmentally sound practices including the incorporation of conservation education in dive briefings.

The dive shops were aware of our study, as their assistance was necessary with the logistics of carrying out the research. However, the divers were observed covertly to avoid them altering their personal diving behaviour. To this end, the researcher and dive buddy were treated the same as any other divers aboard the dive boats and once in the water they adopted apparently normal diving behaviour. A triangulated method of direct observation, questionnaires and dive briefing analysis was used.

2.2.1. Dive briefing recordings

The dive briefings, provided on board the dive boats before each dive ($n = 34$), were recorded using a digital Dictaphone and then transcribed. The length of each briefing was noted, as was the duration of any conservation education provided. Discretion was executed to minimise attention.

2.2.2. Direct observation

A systematic observational method was used which aimed to obtain quantitative data on observable characteristics of the divers

(as Sapsford and Jupp, 2006). The researcher observed the divers for the whole duration of each dive. For each dive, 2–3 day-trip divers were selected for observation, at random (method as Rouphael and Inglis, 2001). The divers selected were taken to be a representative sample of the diving population for the period of time the study was being carried out. The divers selected were observed from a distance of around 5 m (as Di Franco et al., 2009; Medio et al., 1997 who found that this distance was enough that divers were not aware they were being observed). As with Di Franco et al. (2009), we dismissed any results where divers became aware that they were being observed. All dives were carried out in moderate to good diving conditions, with limited swell and good visibility to allow covert observation.

For each observation, the researcher and dive buddy entered the water first and descended to the reef. Each observed dive was divided into three time periods: start, middle and end (Table 1). As every diver is different, it would be incorrect to standardise these as set time periods or even as standard proportions of the total dive, so the duration each diver spent in the three stages of the dive was determined using two factors:

1) The actions of the divers
2) The duration of the dive

The length of time each diver spent in the different stages of the dive was documented. Also, any contacts with the reef were noted as well as the stage in the dive in which they occurred. Unless specified a reef contact refers to intentional and unintentional contacts. Whether the contact was with live coral, intentional (e.g. touching with hands) or unintentional (e.g. fin kick) was recorded. Finally, the diver's gender, and whether the diver was wearing gloves and/or carrying photographic equipment were logged. A pre-printed slate was used to ensure efficiency when collecting the data and a coding system was used to note the type of contact made.

2.2.3. Questionnaire

After the dive a short questionnaire was handed to the observed divers on board the boat that were aimed at determining the divers' conservation awareness and attitude towards the state of the coral reefs. The questionnaire was kept brief to allow it to be completed on board the boat before returning to the dock. A 100% response rate was achieved for the questionnaire.

2.3. Data analysis

Previous studies have investigated the presence of conservation education rather than a comparison between different types of educational briefings; thus, a method had to be produced to carry out this analysis. The factors used to rate the dive briefings were determined from best practice guidelines from major diving organisations such as PADI, NAUI and BSAC; as well as legislative requirements of the FKNMS and the Blue Star guidelines of NOAA. Also, generational equity, the concept that natural resources should be preserved for future generations, was included as a factor due to the increasing importance of the global sustainability movement (Beardshaw et al., 2001). A systematic, unweighted method of using rating indicators was used to rate the briefings to minimise subjectivity. The following rating indicators were used:

- Legislative requirements for the FKNMS
- Best practice diving technique
- Scientific facts about the coral reefs
- Explanation/support of scientific facts
- Generational equity
- Sincerity
- Duration spent on conservation education

The first five factors were each awarded one point if mentioned; whilst the last two factors were awarded points on a ranking scale (see Table 2). To minimise subjectivity, sincerity was determined based on tone, conviction and enthusiasm. Taylor (2001) notes the importance of sincerity and conviction within ecotourism.

The data collected by the direct observation (frequency, type and timing of diver interactions) were then analysed using paired *t*-tests, Pearson's correlation coefficient and multi-regression analysis via the programme SPSS (Barker and Roberts, 2004; Kinnear and Gray, 2000). Tests for normality and homogeneity were passed to allow parametric analysis. All statistical analysis was conducted at 95% confidence limits.

3. Results

3.1. Diver attitudes and characteristics

All divers observed were over 18 years of age and no trainee divers were observed. Of the observed divers, 59% were male and diving experience ranged from 4 dives to over 1000 dives. 12.4% of divers wore gloves and 14.1% carried photographic equipment. The multiple liner regression showed no significant relationship between the divers' genders, or previous experience, on the frequency of reef interactions ($p = 0.284$ and $p = 0.852$ respectively). The use of photographic equipment was also not significant ($p = 0.057$). Wearing gloves did not significantly affect the total number of interactions made with the reef ($p = 0.119$), however, the use of gloves did significantly increase the frequency of coral touches divers made ($p = 0.036$). Overall, 95.2% of divers declared a concern about the state of the world's coral reefs. Furthermore, just over half of the divers (54.2%) felt that SCUBA diving does negatively impact

Table 1
The characteristics of each time period of the dive (information adapted from BSAC, NAUI and PADI guidelines (2010) and researchers knowledge).

Time period of dive	General comments	Observable characteristic
Start	Entry into the water and descent to the reef. General acclimatisation and checking of equipment.	• Descent • Establishment of neutral buoyancy • Securing of lose equipment such as gauges • Establishment of location and underwater compass heading.
Middle	The main body of the dive. The diver appears comfortable and into the dive. Is looking at the surrounding reef and checking navigation.	• Has moved away from entry point of the dive. • Is looking at surrounding environment, possibly taking pictures or showing buddy interesting life. • Continued navigation away from entry point.
End	The diver is communicating with their buddy about surfacing and checking their location, air supply and time. The diver starts to ascend.	• Signal to ascend between dive buddies. • Looking to surface for boat • Checking air supply and time if three minute safety stop is carried out • Ascent

Table 2
The seven rating indicators for the dive briefings and their points value.

The rating indicator	The requirements	Points value
Legislative requirements for the FKNMS	Mention important legislative requirements for the FKNMS such as: • No take rules • No touching coral • No harassing or disturbing the marine life	1 point
Best practice diving technique	Mention factors like: • Securing loose equipment • Proper positioning in the water • Establishing neutral buoyancy • Control descent	1 point
Scientific facts about the coral reefs	Mention facts like: • Their regional decline • Fragility • Biological importance • The value of their ecosystem services	1 point
Explanation/support of scientific facts	Expand on scientific facts by providing statistics or explanations. For example: • 80% of coral reefs have been lost • Coral is a living organism with a thin protective membrane that can easily be damaged by a fin kick.	1 point
Generational equity	Mention the importance of preserving the quality and biodiversity of Coral Reefs for future generations.	1 point
Duration of conservation education within the briefing	The total length of time of conservation education provided in the dive briefing.	Grouping (E.g. 0 s received 0 points, 1–10 s 1 point, 11–20 s 2 points etc.
Sincerity	The conviction, tone and enthusiasm and sincerity used to convey the conservation education within the dive briefing.	Grouping: Review of Dictaphone notes grouped briefings in terms of sincerity, tone and enthusiasm.

coral reefs. Neither the level of concern for the state of the world's coral reefs nor the opinion on the impact of SCUBA diving on the coral reefs influenced the frequency of diver impacts ($p > 0.05$).

Divers' prior conservation awareness was assessed through the questionnaire supplied to the divers that were observed on the dive to see if it influenced their behaviour in the water. Of the divers surveyed, 62.5% had not undertaken any formal conservation awareness training, such as PADI Project AWARE, REEF or an academic course. We found that there was no significant difference between the numbers of touches made by divers who had prior conservation education compared with those who had not ($p = 0.544$).

3.2. Diver behaviour underwater

3.2.1. Interactions with reef

In this study, 97% of the divers made at least one direct impact with the reef at some point during their dive. Only two divers had no contacts with the reef. The average number of contacts per minute was 0.33 ± 0.06 (mean $\pm$ SE) which equates to an average of 17.89 touches over the average dive time of 54.21 min. Per minute, there was an average of 0.147 ± 0.03 (mean $\pm$ SE) accidental and 0.169 ± 0.04 (mean $\pm$ SE) deliberate touches. Many of the accidental touches were caused by fin kicks and loose equipment dragging on the reef.

3.2.2. Interactions with live coral

An average of 0.096 ± 0.03 (mean $\pm$ SE) coral touches per minute was observed, which equates to an average of 4.87 touches of live coral over the average dive time of 54.21.

3.2.3. Extrapolation over the season

No data currently exists on the total number of SCUBA divers diving the reefs around Key Largo. However, if the information obtained from this study is considered, then over the three-month period that this study was conducted the dive charters involved in this study carried between 6 and 25 divers, completing two tank dives per trip. If the average dive time of 54.21 is used, then one dive boat of divers is impacting the reef between 227.7 and 948.7 times and touching coral between 62.4 times and 260.2 times per dive trip.

3.3. Timing of diver interactions

As described in the methodology the dive was divided into three sections: start, middle and end. From the direct observations it was found that divers do vary in the amount of time they spend in each period of the dive (see Fig. 1). The differences in the amount of time divers spend in each period of the dive show that divers vary significantly in their dive profiles.

There was a significant difference between the number of touches divers made in the start phase of the dive compared to the middle and end periods (independent t-test: $p = 0.000$ and $p = 0.001$ respectively). Fig. 2a illustrates these results showing that divers are two and half times more likely to interact with any part of the reef during the start of the dive compared to the other stages of the dive. This trend was also found with the number of (specifically) coral touches per minute within each period (Fig. 2b). Divers were over three and a half times more likely to touch coral within the start stage of the dive compared to the middle or end stages of the dive (independent t-test: $p = 0.011$ and $p = 0.021$ respectively).

Many interactions were unintentional within the start stage and were caused when divers were trying to determining navigation as well as establishing neutral buoyancy and securing equipment. In addition, several entry points for divers were over shallow branching corals like *Acropora palmata*. We noted that 42.1% of dive site entry points were directly over shallow coral reefs (4–8 m).

3.4. Influence of conservation education dive briefings on diver behaviour underwater

Out of the 34 analysed dive briefings, 26.5% did not mention any conservation education. The average time spent on conservation

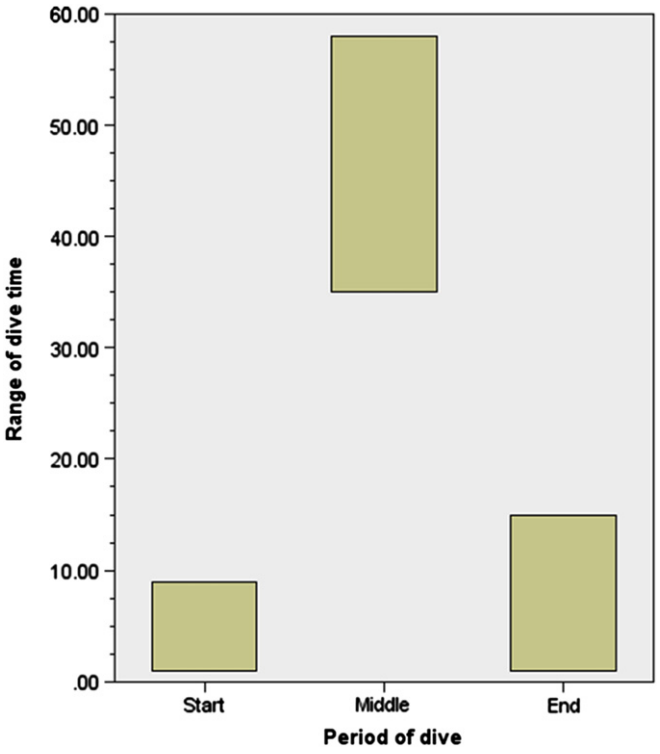

Fig. 1. The range of time divers spent in each time period of the dive.

education was 19.2 s. The maximum conservation score awarded was 16 points and the lowest score was zero (failure to provide any conservation education). No dive briefing included all of the factors in the rating system, with six out of the seven factors being the maximum included in a single briefing. The 25 briefings that provided conservation education each received a time and sincerity rating. Of the other five indicators, diving technique and the legal requirements of the FKNMS were the most commonly mentioned indicators ($n = 18$ and $n = 16$ respectively). The least covered indicators were generational equity ($n = 5$) and the support of scientific facts ($n = 4$).

The frequency of diver interactions in relation to the rating of the dive briefing they received was analysed. The results of the Pearson's Correlation Coefficient showed a negative correlation of -0.217 ($p = 0.045$) indicating that the higher the rating of the dive briefing the lower the number of interactions divers made. The frequency of specifically coral touches was also compared to the briefing ratings, but no significant correlation was identified ($p > 0.05$).

Most respondents to the questionnaire agreed that the dive briefings were beneficial in enhancing diver caution to not contact the reef. Out of the 83 divers surveyed, 70 divers responded 'yes' and 13 responded 'no'. Interestingly, 11 of the divers that responded 'yes' listened to a dive briefing where there was no environmental conservation mentioned; suggesting that some divers may have responded 'yes' as it seemed the socially acceptable answer.

3.5. The influence of the Blue Star rated conservation initiative on diver behaviour underwater

Shop D from the study was a Blue Star rated dive operator. A significant relationship was identified between the total number of touches made by divers from shop D, compared to the other three dive operators ($t = 3.620$, $p = 0.001$). Table 3 shows that divers from operators A, B or C were over two times more likely to interact with any part of the reef on their dive than divers at shop D. The same trend was also observed with (specifically) coral touches. A multiple linear regression analysis was conducted to compare each dive shop (A, B and C) individually to dive charter D. For each dive charter (A, B and C) there was a positive significance identified when compared to dive charter D (p values ranging from 0.000 to 0.009) for both total and coral touches.

Finally, the briefing rating for the Blue Star Rated dive shop (D) was compared to the non-Blue Star rated dive charters (A, B and C). The dive briefing at dive shop D obtained an average rating score of 21.3 whilst the average for shops A, B and C was 6.92. The duration of conservation education provided at shop D averaged 50.7 ± 4.0 s (mean $\pm$ SE) compared to 8.6 ± 3.8 s (mean $\pm$ SE) for shops A, B and C. Shop D on average included six of the seven rating indicators for the dive briefings; whereas shops A, B and C averaged three of the seven rating indicators.

4. Discussion

Nearly all divers (97%) observed in Key Largo interacted with the reef during their dive. The frequency of unintentional touches was

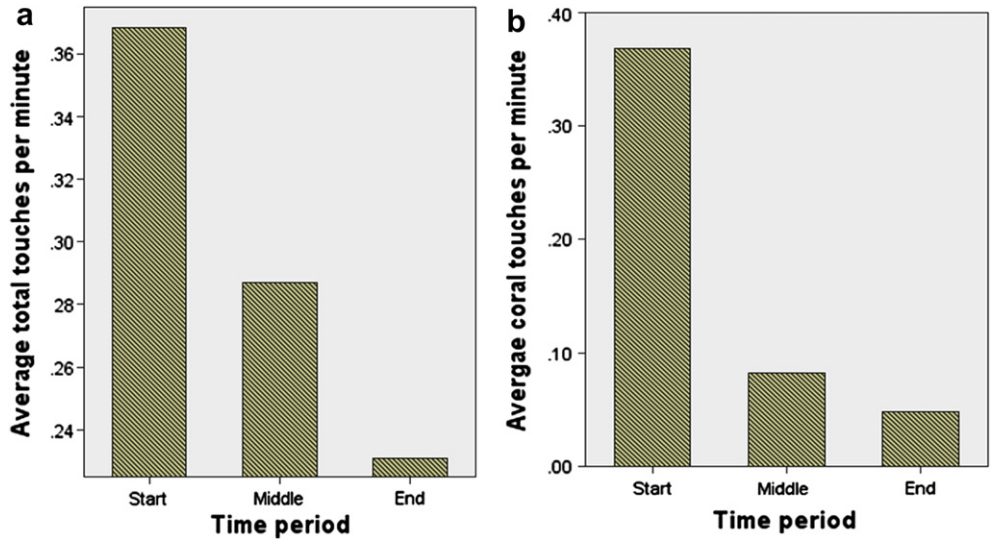

Fig. 2. The frequency of the different type of touches divers had with the reef; highlighting that most diver interactions occur during the start period of the dive.

Table 3
Summary of diver interactions from the Blue Star rated diver charter to the non-Blue Star rated dive charters.

Type of interaction	Frequency (per minute)		Average number of touches over a dive (average dive time of 54.21 min)	
	Average for Blue Star charter (mean ± SE)	Combined average for non-Blue Star dive charters (mean ± SE)	Average for Blue Star charter	Combined average for non-Blue Star dive charters
Any reef contact	0.16 ± 0.08	0.37 ± 0.06	20.10	8.67
Coral	0.04 ± 0.03	0.11 ± 0.03	5.96	2.17
Accidental	0.09 ± 0.03	0.16 ± 0.03	8.67	4.88
Deliberate	0.06 ± 0.04	0.20 ± 0.05	10.84	3.25

55.4% which is significantly lower than the findings of Barker and Roberts (2004) and Rouphael and Inglis (2001). Although, most unintentional touches were caused by fin kicks and loose equipment supporting the findings in St Lucia (Barker and Roberts, 2004) and Australia (Harriott et al., 1997). The predominant intentional touches observed during the study were touching and holding onto the reef, either for support or out of apparent curiosity. The similarity in the average number of intentional and unintentional touches highlights that diver technique, diver knowledge and conservation education need to be improved to reduce divers' impacts on the reefs.

The divers' gender and their level of diving experiences did not influence the frequency of reef interactions supporting the findings of Di Franco et al. (2009) that diving experience does not affect the number of contacts divers make. Similarly, the use of photographic equipment by divers was not found to influence the divers frequency of reef interactions. Our results conflict with those found by Rouphael and Inglis (2001) and Uyarra and Côté (2006) who found that the use of photographic equipment increased the chance of divers' touching the reef. Rouphael and Inglis (2001) also found that the use of gloves increased the frequency of diver interactions. We found that the use of gloves by divers correlated with an increased frequency of coral touches made by divers, although the overall number or reef touches was not affected. Unlike some other MPAs, the FKNMS does not prohibit the use of gloves. From our findings and the results of Rouphael and Inglis (2001), we suggest that the wearing of gloves should not be allowed, or their use should be accompanied by information about not touching coral.

Of concern is the extrapolation of the observed impact of divers on the reefs in the FKNMS. We determined the overall impact of divers on board the dive charters involved in this study to be between 227.7 and 948.7 touches on the reef and between 62.4 times and 260.2 coral touches per dive trip. With most dive shops operating morning and afternoon charters, between four and seven days a week, and night dives offered once a week all year around (weather permitting), the pressure divers are exerting on the reefs is potentially large and continuous. Hasler and Ott (2008) predicted that coral reefs in Egypt have a carrying capacity of around 6000 divers per year. Other studies have provided more conservative estimates of 4000–6000 divers as a reef's carrying capacity, with factors like diving experience, education and background influencing carrying capacity (Hawkins and Roberts, 1997; Hawkins et al., 2005). User numbers are essential to effective reef monitoring and management (Mumby et al., 2007). Leujak and Ormond (2007) presented the concept of social carrying capacity in their study, highlighting the need to consider the number of users that avoids overcrowding or a decrease in attractiveness of the reefs.

In our study, the stage within the dive had the most significant correlation with diver interactions with the reef. The variability in diver profiles is an important consideration as we observed that divers are two and a half times more likely to touch the reef and three and a half times more likely to touch coral during the start stage of the dive. Our results are consistent with the trend found by Di Franco et al. (2009) that most contacts are concentrated to the initial part of the dive. The variability in the amount of time divers spent in the start stage of the dive depended on their ability to establish neutral buoyancy and navigation.

The shallow entry point for divers is another management consideration as divers are more likely to contact coral as they descend. The use of mooring balls in the FKNMS ensures that dive boats do not anchor on the coral; however, a more detailed consideration of the entry point of divers on the reef would be beneficial. Consideration of the size of the boat, risk and liability for specific abilities of divers, the season, current and wind direction and the length of line used to tie off on the mooring balls all need to be taken into account to ensure the most suitable entry point for divers onto the reefs.

Talge (1992) recorded an average of 4.6 coral touches over a 45 min dive compared to 4.32 coral touches in this study if a dive time of 45 min is used. These results suggest that the number of coral touches divers are making has not significantly changed over the last 20 years. Also, the average dive time has risen by 9.21 min which gives divers longer to interact with the reef. This highlights the need to remind divers about conservation issues and good practice before the start of recreational dives.

We found that the previous conservation education of divers did not influence diver behaviour in the water. Divers who had taken part in environmental conservation courses like PADI AWARE or REEF interacted with the reef as many times as those who had not. However, the level of conservation education provided in the dive briefings did influence diver behaviour by reducing the number of interactions diver made with the reef. The frequency of coral touches for the dive was also compared to the briefing ratings and no significant correlation was identified ($p > 0.05$). This result is likely due to the need for further education on coral identification because, as noted by Green and Hendry (1999), coral identification is difficult for a non-specialist. A diver's locational history will influence their knowledge and understanding of marine life; for example, a diver from England used to diving in quarries may not be aware of the biological life of the Florida Keys, hence the need for local conservation education. We show that the depth of conservation education provided is important in further reducing the number of impacts divers make with the reef.

The quality of dive briefings provided in Key Largo varied substantially, with ratings varying from 16 points to 0 points. Barker and Roberts (2004) found differences in dive briefings in St. Lucia which partly accounted to the non-significance effect of briefings on contact rates in their study. In our study, nine briefings did not provide any conservation education despite diving in the FKNMS, where there are no take rules and regulations (NOAA, 2010b). Scientific facts and their justification for preserving the reef were only mentioned in five briefings. Scott-Ireton (2008) found that explaining how and why things should be protected is more important than skills when trying to get divers to conserve their surroundings.

In our study, receiving a higher level of conservation education did influence diver behaviour in the water and reduce the frequency of diver contacts. The Blue Star rated dive charter obtained the highest briefing ratings due to the level and depth of the environmental conservation message and reef etiquette mentioned. As part of the Blue Star programme the dive shop is required to include environmental conservation information and mention reef etiquette, which, we can assert from our results, is beneficial in limiting the number of interactions divers make with the reef (NOAA, 2010b). Goodwin (1996) encourages local based ecotourism and this is essentially what the Blue Star initiative does. The local dive shops can also benefit from an eco-rating system, like the Blue Star initiative. This rating can be used as a marketing tool as society is becoming more environmentally aware. Also, it provides an avenue to educate staff and ultimately increase methods for preserving the coral reefs.

5. Conclusion and recommendations

We conclude that SCUBA divers do negatively impact coral reefs, primarily due to diver-reef and diver-coral contacts occurring in the initial, orientation stage of a dive. From our findings, the most efficacious way to reduce divers' impacts on the reef would be to reduce the time divers spend in the start phase of a dive. Based on our identified characteristics for divers in the initial phase of the dive we suggest that securing loose equipment and establishing navigation before entering the water, whilst also achieving neutral buoyancy on descent, would help to minimise damage to the reef.

The rate at which divers touch coral does not seem to have fallen significantly over the last 20 years, but dives today are longer and more numerous. Currently, there is no exact figure for the annual number of dives made on the reefs around Key Largo, which makes it difficult to put a figure on the sustainable levels of diving for the area.

Positively, our findings demonstrate that detailed conservation education during dive briefings can reduce the number of impacts divers make. A guide for environmental content in dive briefings for dive masters to use is recommended. Having an eco-rating system for dive operators is also encouraged on a larger scale as it is a tool for educating divers, increasing local based ecotourism, ensuring on-going staff conservation education and ultimately is another tool for managers to use to preserve the reefs. As consumers have an increasing choice over where they shop, eat and vacate based on the company's environmental policies and ethos, it seems logical that dive shops provide a similar option for SCUBA divers that want to limit their environmental footprint.

Unexpectedly, experienced recreational divers appeared to touch the reef no less than less experienced divers. This is where a briefing which contains local biological information and overt reminders of good practice has benefit and reef managers should consider use of this tactic.

Future work is recommended to further investigate the use of enhanced mooring line plans (more informed buoy positioning) on reducing the frequency of diver interactions. This, along with data on the number of SCUBA divers using the reefs, improved conservation education (awareness of fragility of reef organisms and example causes of diver-induced damage) and good equipment handling practice (e.g. no dragging equipment) established on board boats are the management strategies that could further reduce divers' impact on the coral reefs and are important considerations for reef managers.

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