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Research Article

Beneath the lens: Exploring the impacts of underwater photographers in marine-based tourism

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ABSTRACT

As scuba diving proliferates in popularity as a nature-based recreational activity, the associated benefits and impacts are correspondingly emerging. Previous studies showed that underwater photographers are potentially the more impactful group of scuba divers. To further explore the impacts and behaviour of underwater photographers, this study attempted to predict their impacts through three photography-related variables, including species of interest, photography habit, and photography commitment through a case study in Hong Kong. A scuba diver survey was performed in summer 2021 to assess the impacts of divers, a follow-up questionnaire survey was delivered, and a total of 106 samples were collected. Findings showed that underwater photographers caused more negative impacts than ordinary scuba divers. Among underwater photographers, individuals more interested in conspicuous and actively moving species have more frequent contact with marine organisms. In contrast, those more interested in cryptic and sedentary species were more likely to cause intentional contact. Underwater photographers with greater commitment also showed more frequent and more intentional connections. Implications were drawn regarding underwater photographers' behaviors, and relevant suggestions were recommended to address the potential concerns.

Management implication: This study highlights the significant ecological impacts of underwater photographers who cause higher contact rates with the coral community, which causes more severe damage. The research suggested various policies for the protected areas managers to mitigate the advert ecological impacts from the recreational divers as follows:

- Train underwater photographers on proper techniques to reduce ecological impact.
- Regulate the use of professional photography devices in marine environments.
- Implement comprehensive pre-dive briefings to promote eco-friendly diving practices.
- Use supervised dives to ensure adherence to environmental guidelines.

By adopting the above measurements, the marine ecosystem can be protected, which can promote sustainable tourism practices.

1. Introduction

Recreational scuba diving have been suggested and often perceived to be relatively low impact in nature (Arcos-Aguilar et al., 2021; Cavallini, Marzo, Scaccia, Scipioni, & Niccolini, 2023; Chow, Cheng, & Cheung, 2019; Tapsuwan & Asafu-Adjaye, 2008). In reality, due to the

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escalating number of recreationists and nature-based tourists, recreational activities have been reported to have caused significant ecological impacts to the environment and wildlife in nature-based destinations, which also include scuba diving activities (Ferguson et al., 2022; George & Crooks, 2006; Sumanapala, Dimmock, & Wolf, 2023; Taylor & Knight, 2003).

Among various marine recreational activities, scuba diving has always been one of the most popular activities, and the scuba diving and tourism industry has been growing more rapidly than ever (Gerungan & Chia, 2020; Hasler & Ott, 2008; Musa & Dimmock, 2012, 2013; Nisa, Schofield, & Neat, 2022). The unprecedented volume of scuba divers has certainly created numerous business and employment opportunities for popular diving sites around the world (De Brauwer et al., 2017; Huveneers et al., 2017; Vianna, Meekan, Pannell, Marsh, & Meeuwig, 2012). For instance, in Australia, it was estimated that the spending of local and international divers in diving and related activities generated up to 4.2 billion Australian dollars in the year of 2013 (Beaver & Keily, 2015). However, it was suggested that scuba diving activities have caused various impacts to the marine environment and wildlife, including pollution, habitat degradation, and disturbance to and the associated damages and behavioral changes in wildlife (Abidin & Mohamed, 2014; De Brauwer et al., 2018; Sumanapala et al., 2023). Coral reefs, the main attraction in most diving destinations, are prone to damages caused by recreational and scuba diving activities. Numerous studies have recorded various levels and forms of impacts, like breakage and scaping of corals and disturbance of the benthic habitat, as well as physical and behavioral changes on other reef-associated marine organisms like reef fishes (Abidin & Mohamed, 2014; Albuquerque et al., 2014; Titus, Daly, & Exton, 2015). For example, Giglio, Luiz, and Schiavetti (2016) surveyed scuba divers in Abrolhos National Marine Park, Brazil, and found that up to 80% of divers have had contact with corals or the benthic environment and caused at least one damage each dive. In the case of Hong Kong, Chung, Au, and Qiu (2013) found that divers, on average, made contacts with marine organisms 15 times in each dive, and around 40% of all contacts caused damages to corals. Similarly, a recent study by So, Kwok, Lai, Fong, and Pang (2023) showed a more updated figure that contacts of divers with marine biota were 10 times per dive on average. It has been documented that reefs in these destinations have suffered large-scale destructions, long-term degradation, and even compositional shifts due to the volume of visitors and their associated impacts (Giglio, Luiz, & Ferreira, 2020; Hammerton & Bucher, 2015; Tratalos & Austin, 2001).

Therefore, the management of divers is crucial to the conservation of coral reefs and the associated ecosystem and marine life at popular diving destinations, particularly in protected areas (Lucrezi, Ferretti, Milanese, Sarà, & Palma, 2021; Shafer & Inglis, 2000; Uyarra & Côté, 2007). Various studies have explored the impacts of divers, and studies commonly sought to quantify and document the damages caused to different marine lives (Chung, Au, & Qiu, 2013; Krieger, 2012; So et al., 2023; Zhang, Cheung, Lam, Ma, & Fok, 2024; Zhang, Ma, Lam, Fang, & Cheung, 2022). Investigation on the influences of the characteristics of divers on their behaviors has been another focus for studies. Factors like recreational specialization, diving experience and certification, and demographic characteristics have been suggested to be the key variables that may help predict the behaviors of divers (Salim, Bahauddin, & Mohamed, 2013; Walters & Samways, 2001; Zhang, Lam, Ma, Fok, & Cheung, 2023). Findings in these studies clearly indicated the heterogeneity in scuba divers and, hence the associated levels of impacts that they may induce. Such heterogeneity was also observed in other forms of nature-based recreation. Among different types of recreationists, photographers have been suggested to induce particularly high level of impact on wildlife (Cheung, Lo, & Fok, 2017; Slater et al., 2019). For example, bird-watching photographers induced greater levels of disturbance in birdwatching activities than regular visitors (Slater et al., 2019). Studies have identified that photography-related attributes in diving activities, e.g., divers carrying cameras, tend to show greater levels of impact compared to regular scuba divers (Giglio et al., 2016; Hammerton, 2017; Poonian, Davis, & McNaughton, 2010). Yet, fewer studies have focused explicitly on underwater photographers and predictors associated with underwater photography. A recent study conducted in three Italian marine protected areas by Toso, Lucrezi, and Cerrano (2022) on underwater photographers and nonphotographer and found that photographers are more likely to violate rules in protected areas than their counterpart.

Notably, commonly explored predictors like levels of experience, certification of diving skill level, and demographics were shown to have limited contributions in explaining the impacts of underwater photographers (De Brauwer et al., 2018). This clearly calls for the exploration of more detailed variables associated with the behaviors of underwater photographers and their specific characteristics. Therefore, this study attempted to investigate the impacts of divers who intend to take photos and dive with photography equipment (underwater photographers) through investigating variables that are closely relevant to the behavior of underwater photographers, including their species of interest, photography habit, and photography commitment. Findings from this study may help manage the on-site behaviors of underwater photographers and provide crucial information for the education and training of future divers in diving courses and guided tours.

2. Methods

2.1. Study area

Hong Kong, situated at 22°N and 114°E, has a territorial marine area that spans over 1600 km. A more oceanic environment can be found in the eastern and southern side of Hong Kong with influence from the South China Sea, while the Pearl River delta on the western side gives rise to more estuarine waters. In addition, the marine environment in Hong Kong is also influenced by various seasonal ocean currents from the East China Sea and the Pacific. As a result of the complex and dynamic physical conditions, marine widlife in Hong Kong is highly diverse (Lai et al., 2016).

Hong Kong has a record of over 5900 marine species, accounting for approximately 26% of China's total number of marine species (Hong Kong Biodiversity Information Hub, 2013). Moreover, Hong Kong holds an exceptionally high record of coral species, where there are 84 species of stony corals, which is even richer in stone coral diversity than the Caribbeans (Agriculture, Fisheries and Conservation Department, n. d.-a). These coral reefs are also the habitat for a wide variety of coral-associated species, such as reef fishes, starfish, clams and oysters, and shrimps and crabs (Agriculture, Fisheries and Conservation Department, n. d.-b).

The ecosystems established around coral reefs are the major attractions for recreational scuba diving in Hong Kong. Major diving hotspots in Hong Kong are mostly located in the eastern waters, where influences from the discharge of the Pearl River are minimal. Local diving operators generally offer tour to over 20 diving spots, also mostly located in the eastern waters of Hong Kong. Sampling sites were chosen concerning two sources, 1) the popularity of the sites was considered based on how regular diving tours are offered by diving operators, and 2) site selection of previous local studies on scuba diving (Au, Zhang, Chung, & Qiu, 2014; Chung et al., 2013). Ultimately, 4 popular sites where regular diving tours were offered and have been studied by past studies were chosen as the sampling site of the current study, which include Pak Lap, the Ninepin Islands, Kiu Tusi, and the High Island Reservoir (Fig. 1).

2.2. Study design

This section first explains and reviews the predictor variables, dependent variables, and control variables employed in the analysis of divers' impacts, followed by the design of the diver survey and questionnaire survey.

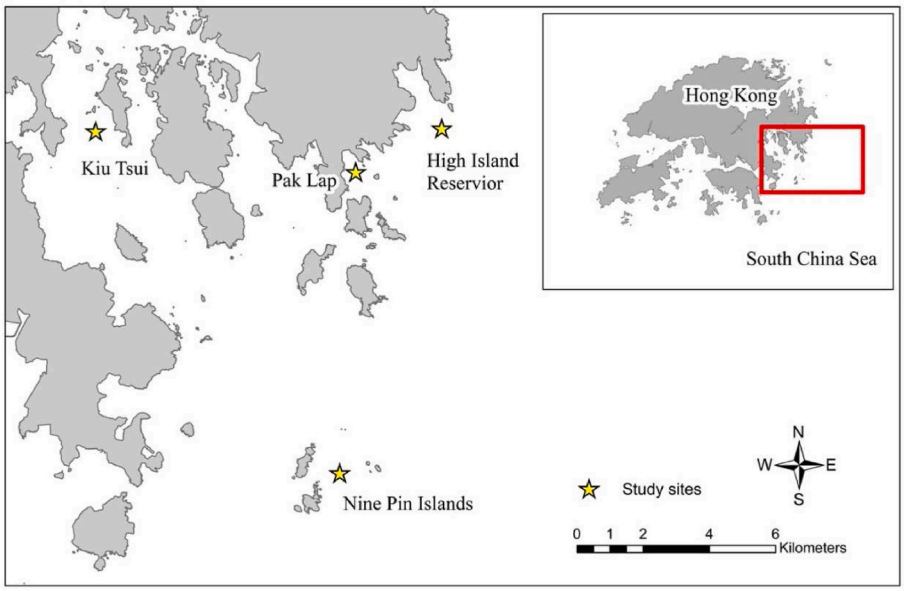

Fig. 1. Map of study sites.

2.2.1. Predictor variables

2.2.1.1. Species of interest in photography. Divers' preferences have been repeatedly shown to vary significantly as divers are commonly motivated by the opportunity to observe and interact with different types of marine wildlife, and specific efforts have been paid to explore the interest of divers in marine life (Cater, 2008; Giglio, Luiz, & Schiavetti, 2015; Ince & Bowen, 2011). Some studies have drawn linkages between diving experiences with preferences, while others associated preferences with divers' perceived impacts and attitudes (Giglio et al., 2015). Fewer studies explored how interest in marine life may influence divers' actual behavior, with a few exceptions. Uyarra and Côté (2007) indicated that divers were found to induce a greater degree of impact to corals in terms of time and frequency when observing cryptic species. More specifically, focusing on underwater photographers, the finding of De Brauwer et al. (2017) again showed that divers caused a greater level of impact when interacting with cryptobenthic species.

Taking reference from these studies, species of interest in photography in this study explored the preferences of divers in four groups of marine life, including conspicuous, cryptic, actively moving, and sedentary species. Cryptic species in this study followed the definition by Depczynski and Bellwood (2003) and Randall (2005) and mostly refer to groups, including small invertebrates like nudibranchs and mollusks and small fishes like seahorses, that generally require divers to get close to observe. On the other hand, conspicuous species refers to larger and easily spotted marine life, including cephalopods like octopuses or large fishes like groupers. The current study expanded this variable to explore a larger variety of possible interests of divers; apart from the appearances of species, divers' interests in actively moving and sedentary species were also measured as behaviors and movements of divers could potentially be influenced by the lifestyles and behaviors of the target species.

2.2.1.2. Habit in photography. Studies on the impact of wildlife photography showed that photographers generally show the tendency to approach and get close to the target species to take pictures, and hence induce a greater level of impact (Slater et al., 2019). In terms of divers, De Brauwer et al. (2018) mentioned that photographers tend to get close and cause more impact on substrates and wildlife during photography. Similarly, Giglio, Ternes, Kassuga, and Ferreira (2019) also noted that divers with cameras tend to induce greater levels of impacts on seahorses. Therefore, two typical habits in photography that likely involve getting close to the substrate and target wildlife, including the habit of taking pictures of benthic species and taking close-up and macro photographs, which may contribute to a greater chance of contact and impacts, were explored.

2.2.1.3. Commitment in photography. Experiences and recreational specialization of divers, which often include measurements on divers' commitment to activity, were reported to influence their diving behavior greatly and hence their potential impacts (Ong & Musa, 2012; Salim et al., 2013; Thapa, Graefe, & Meyer, 2006). More specialized divers were often reported to be more environmentally aware and more cautious of misbehavior, hence making a lesser chance of impact (Salim et al., 2013; Thapa et al., 2006). Yet, both studies by Chung et al. (2013) and De Brauwer et al. (2018) indicated that camera-carrying divers caused more damages to corals than those without cameras. As underwater sports and action cameras have become widely available and very much affordable when compared to more professional underwater photographer equipment like DSLR cameras, the variable on commitment in photography in this study was designed with particular focus to distinguish more professional and committed underwater photographer from less committed photographers, and hence to explore the difference between the two. Apart from cameras, the use of gloves was also included as equipment used by divers as protective gear, which may enable more frequent and intentional contact.

2.2.2. Dependent variables

2.2.2.1. Rate of contact. The rate of contact has been widely adopted by studies to quantify the impact of scuba divers. The frequency of different body parts or gear of divers in contact with marine biota and the substrate were recorded in past studies (Chung et al., 2013; Giglio et al., 2016; Hammerton, 2017; Hammerton & Bucher, 2015; Toyoshima & Nadaoka, 2015), and a rate of contact was derived from the time of observation. The variable has yielded multiple significant findings previously. Therefore, it is adopted as an indicator of the impact of diver in this study, with reference taken from the abovementioned studies. In this study, an event of contact was defined as when any body parts and/or equipment that the diver was utilizing touches the substate and/or marine biota during the time of observation period of 20 min. This would account for the impacts that diver may induce both through

physical contact with marine biota, as well as the abruption of substrates that would cause sequent impacts, e.g. reduced growth rate in corals (Chung et al., 2013). The calculation of number of contact event divided by 20 min of observation yields the rate of contact which was used in the data analysis.

2.2.2.2. Intentional contact. To further distinguish the nature of the contacts made by divers, all diver contacts in this study were recorded either as "intentional" or "unintentional" contact. A similar approach has been taken by other studies in differentiating the types of contacts made by scuba diver (Barker & Roberts, 2004; De Brauwer et al., 2017, 2018; Uyarra & Côté, 2007). Measuring contacts by their intentions may help reflect how photography could have influenced the behaviors of divers. Intentional contact was defined as an action that divers are clearly aware of, and often deliberately taken either to help with their movement, observation, and photography. Divers stabilizing themselves as they hold onto substrates for an extended period would be a common example of an intentional contact. An unintentional contact refers to actions that divers are unaware of when contacts were made, an example would be contacts with substrates or corals due to a sudden loss of balance. As the interpretation of intention in contact could be subjective at times, this variable was conservatively measured. Behaviors and contacts where divers' intention was unclear were all considered unintentional to avoid the overestimation of intentional impacts, hence the potential misbehavior of divers. The classification of intentional and unintentional contact has taken reference from previous studies (Chung et al., 2013; De Brauwer et al., 2018).

2.2.3. Covariates

2.2.3.1. Demographic variables. It has been repeatedly shown that the demographic profile of divers could determine their underwater behavior and subsequent impacts (De Brauwer et al., 2018; Di Franco, Milazzo, Baiata, Tomasello, & Chemello, 2009; Giglio et al., 2016). As the current study does not aim to further explore the influence of demographic profiles, information on three demographic factors of divers, including age, level of income, and level of education were collected and included into the statistical analysis as control variables.

2.2.3.2. Certification of diving skill level. Similarly, scuba divers' skill level of qualification, experience, and specialization were acommonly found to be the determining factors of their environmentally responsible behavior (Thapa et al., 2006; Thapa, Graefe, & Meyer, 2005) and more specifically their underwater impacts on-site (De Brauwer et al., 2018; Giglio et al., 2016). To control for the influence of this factor that is not of interest in this study, the Professional Association of Diving Instructors (PADI) scuba diving certification level of divers was inquired to indicate their certification level and be employed as a covariate in the statistical model.

2.3. Data collection and procedures

Data of the current study were collected through two approaches, an underwater diver survey was taken to observe and record the behaviors and impacts of divers during SCUBA diving, and a follow up questionnaire survey was delivered upon the dive to collect information regarding divers' interests, commitment, and demographic characteristics.

The study was carried out in the period of June 2021 to October 2021, with a total of 12 sampling days. All surveys were performed only on weekends as scuba diving activities were relatively uncommon on weekdays in Hong Kong. The greater number of divers on weekends allows for easier identification of survey targets, which is particularly difficult underwater. Dates with poor weather conditions, e.g., severe rain and storms were avoided to ensure a good underwater visibility for observation. A researcher from the team would join and go on board a local diving trip organized by local diving instructors and diving vessel owners or companies on each sampling day. Each tour last from 9:00 a.m. to 3:00 p.m. Two dives were performed at each trip, one in the morning and one in the afternoon. The following sections would explain the protocols for the underwater diver survey and questionnaire survey which were developed based on previous studies (Au et al., 2014; Chung et al., 2013; De Brauwer et al., 2018).

2.3.1. Underwater diver survey

The underwater diver survey was design to collect information on variables on the photography-related attributes and contacts of divers with marine biota. Survey of divers has been an approach of sampling commonly practiced by previous studies on the collection of data with regards to the impacts of divers (Barker & Roberts, 2004; Hammerton, 2017; Krieger, 2012; Uyarra & Côté, 2007).

To identify suitable sampling dates and locations, and to ensure an adequate number of divers for survey, diving instructors and diving vessel owners were contacted and consulted to coordinate in selecting sampling dates and group of divers. This ensured that all study sites were equally visited, and divers were not repeatedly observed to avoid double counting. Consent was also obtained from the instructors and diving vessel owners in carrying the surveys during their sessions and/or on their vessels.

Regarding the protocol on the observation of divers, before the dives begin, the purpose of the research was not disclosed to any divers (except the instructors that would not be surveyed) as commonly practiced in previous studies carrying out underwater diver surveys. This is to avoid influencing the behavior of divers during their subsequent dives, as studies have indicated possible alterations of behaviors of divers when they are informed about the purpose of research ahead or be aware of being observed during their dive (Barker & Roberts, 2004; Krieger, 2012; Roche et al., 2016). Past studies suggested that during the "descending" stage, where divers first entered the ocean, they tend to cause extra impacts as they are establishing buoyancy and making other adjustments (Camp & Fraser, 2012; Krieger, 2012). Therefore, the observation of divers starts around 5 min after divers entered the water to allow time for the establishment neutral buoyancy for both the diver and the researcher. Similarly, no observations were performed when divers ascend. During the observation stage, the researcher maintains a distance of around 5 m from the surveyed divers to avoid any interruption on the divers' activities. A record form would be carried by the researcher to note down each contact events and the associated information on the relevant variables to be observed. Each survey session last for 20 min, and the researcher would observe two divers in a group at the same time and the groups were randomly identified. The researcher would not intervene any behaviors of the divers and would not disclose their purpose of diving during this stage. Any signs showing that the divers may potentially be aware of the researcher's purpose were also noted down. As each survey ends, the researcher would switch to observe another group of divers and no groups would be observed twice. If the observed group of divers left before the 20-min period ends, the research would record the total observed time.

All observations were carried out by only one member of the research team, with dive master level of scuba diving certification. This is to ensure the consistency of the observation, and to avoid any variations in observation and judgment with regards to individual differences.

The approach to not inform and interrupt divers' behaviors helped avoid the alteration in their behaviors, however, we were aware that it may constitute an issue of ethics in not helping to prevent damages on wildlife and the marine environment. Therefore, upon obtaining consent and completing the data collection process, our researcher briefly mentioned to divers individually about our observations of their behaviors, which we believe may help them understand their potential damages and be more aware in future dives.

2.3.2. Questionnaire survey

A questionnaire survey was developed to measure the interest of divers in photographing marine species with different characteristics, and to collect their demographic and diving-related information.

The questionnaire survey was divided into two parts. The first part collected information on the species of interest of divers in photography during their dives. Four questions were designed to measures divers' interests on conspicuous, cryptic, actively moving, and sedentary species respectively. A Likert scale of 1–5 were employed for all four questions, where score 1 refers lowest level of interest (Not interested at all), and score 5 refers to the highest level of interest (Very interested). In the second part of the survey, demographic information and information concerning the diving and photography activity were inquired. Divers' demographic information includes divers' age, level of education, income, level of scuba diving certification level. Two questions were included to collect information on their purpose of diving and the use of professional photography equipment by divers. The question on purpose of diving allows divers to indicate whether they are primarily aiming to take photographs during their dive or not, hence will be used as a question to distinguish photographers and non-photographers.

Questionnaire surveys were carried out on the diving vessels after the observation of divers. All observed divers were identified and they were informed the background and purpose of this research and their consent on their participation in the overall study, including the use of the underwater survey information, and their participation in the subsequent questionnaire survey were obtained. Participation in the research was completely voluntary and no compensation of any forms were given to divers. Upon obtaining consent from the divers, printed questionnaire surveys were given to divers to be completed in a face-to-face format, and the researcher went through the survey with all divers and helped them with any possible misunderstanding. The interviewed divers were kindly asked not to reveal the information about the research to other divers before the diving trip ends in case when there were two diving sessions where there may be other divers to be observed after the first dive. All collected questionnaire surveys were matched to the observed divers to ensure that the observation results can match with questionnaire results.

2.4. Data analysis

Data analysis of this study was carried out in two parts. The differences in impacts induced by non-underwater photographer divers and underwater photographer divers were explored through one-way ANOVA analysis, to first indicate whether underwater photographer divers would induce greater level of impacts as previous studies shown. In the second part of the analysis, predictor variables relevant to the behaviors of underwater photographer divers were tested with their level of impacts through multiple regression analysis, to draw associations between the variables. The two indicator variables, number contacts and percentage of intentional contact were employed to reflect the level of impact that divers induced. Number of contacts was expressed in terms of contacts within the 20-min observation period, and percentage of intentional contacts represented the proportion of intentional contacts within all contacts.

In the one-way ANOVA analysis, the number of contacts and percentage of intentional contact were included as the dependent variables, and the factor on type of divers, including non-underwater photographer and underwater photographer was entered as the factor to test for the differences between the two groups. To further explore the variables that influence the impacts of underwater photographers, all sub-variables within the three major variables of species of interest, photography habit and photography commitment were entered into a multiple regression analysis as predictor variables, and number of contact and percentage of contact by underwater photographers were entered as the dependent variable. In the two sub-variables in habit of photography, divers' behavior to take pictures of benthic species and to take close-up pictures were expressed as the percentage of such behaviors happening within all contacts recorded. To control for the influence of experiences and demographic factors, the age, level of education, monthly income, and scuba diving certification level of divers were included as covariates. Samples of non-underwater photographers were not included in the analysis of this part as variables explored were photography-associated.

3. Results

In the 12 sampling days from June 2021 to October 2021, a total of 106 divers were sampled which included 46 non-underwater photographers and 60 underwater photographers. No divers observed during the diver survey rejected to participate in the study and the subsequent questionnaire survey. All divers successfully completed the follow up questionnaire survey, yielding a response rate of 100%.

3.1. Demographic profile of divers

Surveyed divers in this study were mostly in the younger age groups at the age of 18–30 (51%) and 31–40 (45.1%) (Table 1). Divers were also dominantly well-educated, where around two-thirds of diver had attained an undergraduate degree and around 15% had a postgraduate degree. Majority of divers had a monthly income in the range of 20,000–39,999 HKD, those with particularly high or low income were relatively rare. In terms of the divers' SCUBA diving certification level, open water divers (39.2%) and advanced open water diver (23.5%) were the majority. Yet, a good proportion of rescue divers (15.7%), diver master (11.8%) and instructors (9.8%) were also captured. Notably, the profile of divers in terms of age, level of education, and income do not match closely with the demographic characteristics of the general population of Hong Kong. However, previous studies in nature-based recreationists in Hong Kong showed that this group of recreationists were, in fact, characterized by being younger in age, with higher levels of education and income (Cheung et al., 2017; Ma, Ng, Cheung, & Lam, 2021).

3.2. Summary of one-way ANOVA analysis on non-photographer and photographer divers

The results of one-way ANOVA analysis between underwater photographers and non-underwater photographers showed significant differences in terms of number of contacts and percentage of intention contacts.

The mean number of contacts of underwater photographers was 17.90 (20 mins^{-1}), which is significantly ($p < 0.01$) greater than the number of contacts of non-underwater photographers with a mean of 4.35 (20 mins^{-1}) (Fig. 2). In terms of the percentage of intentional contact by divers, on average, 68.2% of the contacts of underwater

Table 1
Demographic profile of divers (N = 106).

Age	%	Level of education	%
18–30	51	Primary level of below	0
31–40	45.1	Secondary level	17.6
41–50	3.9	Associate degree or undergraduate	66.7
51 or above	0	Postgraduate	15.7
Monthly income (HKD)		**SCUBA diving certification level (PADI)**	
0–9999	0	Open water diver	39.2
10,000–19,999	19.6	Advanced open water diver	23.5
20,000–29,999	31.4	Rescue diver	15.7
30,000–39,999	35.3	Dive master	11.8
40,000–49,999	7.8	Instructor or above	9.8
50,000 or above	5.9		
Total			100

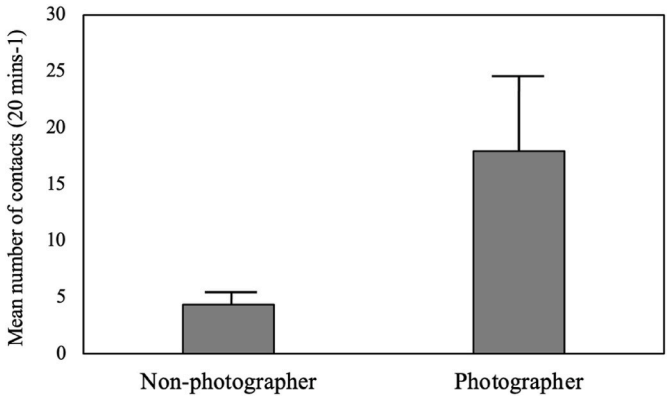

Fig. 2. Mean number of contacts of non-underwater photographers and underwater photographers. Note: Mean sq. = 4782, df = 1, F = 11.154, $p < 0.01$; Non-underwater photographers: N = 46, mean = 4.35, S.D. = 3.78, 95% CI = 3.23, 5.47. Underwater photographers: N = 60, mean = 17.90, S.D. = 27.29, 95% CL = 10.85, 24.95.

photographers were intentional, which is almost two-folds that of the chances of non-underwater photographers in intentional contact (34.3%) ($p < 0.001$) (Fig. 3).

3.3. Summary of multiple regression analysis

Multiple regression analysis was employed to investigate the associations between underwater photographers' species of interest in photography, photography habits, photography commitment, and their number of contacts, and percentage of intentional contacts (Table 2).

In terms of number of contacts, divers more interested in taking photographs of conspicuous (r = 0.258, $p < 0.01$) and actively moving (r = 0.464, $p < 0.01$) species were found to lead to significantly greater number of contacts. Divers carrying professional photography equipment were also found to be positively associated to number of contact (r = 0.340, $p < 0.05$). An adjusted R^2 of 63.1% was yielded.

On the other hand, interest in taking photographs of cryptic (r = 0.546, p < 0.001) and sedentary (r = 0.408, p < 0.01) species were found to be positively associated to the percentage of intentional contacts by divers, indicating that greater interest in such species often lead to more intentional contacts. Additionally, divers showing the habit of taking close-up pictures were also found to be significantly associated to greater proportion of intentional contacts (r = 0.363, p < 0.05). Again, divers with professional photography gear were shown to involved in a

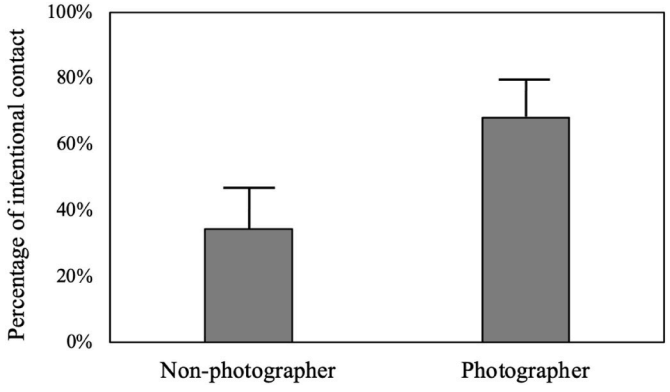

Fig. 3. Mean percentage of intentional contact by non-underwater photographers and underwater photographers. Note: Mean sq. = 2.983, *df* = 1, F = 17.959, $p < 0.001$; Non-underwater photographers: N = 46, mean = 0.343, S.D. = 0.364, 95% CI = 0.235, 0.451. Underwater photographers: N = 60, mean = 0.682, S.D. = 0.438, 95% CL = 0.450, 0.619.

Table 2
Summary of multiple regression analysis on underwater photographers (N = 60).

	Standardized coefficient (Sig.)	
	Number of contact (20 min^{-1})	Intentional contact (%)
Species of interest in photography		
Conspicuous	0.258[b]	0.081
Cryptic	0.236	0.536[c]
Actively moving	0.464[b]	−0.131
Sedentary	0.113	0.408[b]
Photography habit		
Benthic	0.004	−0.139
Close-up	0.096	0.363[a]
Photography commitment		
Diving gloves	−0.127	−0.149
Professional photography equipment	0.340[a]	0.257[a]
Demographic covariates		
Age	0.060	−0.336
Level of education	−0.396	−0.246
Income	0.602[a]	0.328[a]
SCUBA diving certification	0.146	−0.105
Adjusted R^2	63.1%	85.8%

Note.
[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

greater percentage of intentional contacts throughout their dive (r = 0.257, p < 0.05). An adjusted R^2 of 85.8% was resulted.

Among the four demographic covariates employed in the analysis, only income showed significant influence on underwater photographers' number of contact (r = 0.602, p < 0.05) and their intentional contact (r = 0.328, p < 0.05). Age, level of education, and SCUBA diving certification were not significantly associated to both dependent variables.

4. Discussion

This study again showed that, in the case of scuba diving, photographers tend to induce greater levels of impact to wildlife and the environment in recreational activities, also demonstrating the heterogeneity of divers and the need to address issues of the respective groups. This study also established the associations between species of interest of divers, photography habits, and photographer commitment, and divers' impact, showing that variation of impacts exists not only among type of divers, but among underwater photographers.

This study measured impacts of divers through two dependent variables, frequency of contact and intention of contact. While the use of professional equipment and income both significantly predicted the two dependent variables, differences were seen in terms of species of interest and photography habit in underwater photographer. This indicated not only that underwater photographers with different characteristics could induce impact differently and require specific measures to address their impacts, it also showed that future studies should employ more than one type of impact measurement to distinguish potential impacts.

One of the key differences in the results predicted using frequency of contact and intentional contact is the discrepancy on divers' species of interest in photography. On one hand, divers that were more keen to observe conspicuous and actively moving creatures were found to contact marine biota and substrate more often. Alternatively, divers more interested in cryptic and sedentary species were more likely to intentionally made contact with the marine biota and substrate. As intention was not found to be associated to observers of conspicuous and actively moving species, we suggest that contact of this group of underwater photographers were likely made when they are trying to follow and catch up with the generally fast-moving creatures, resulting in both

accidents as well as situation where they had to unintentionally made contact to stabilize themselves during the rapid movements. On the other hand, underwater photographers trying to take pictures of cryptic and sedentary creature may often find themselves closer to the reefs and substrate, which may lead them to make more intention contacts, e.g., to hold on to the substrate or surface of reef, for stabilization purpose during photography. It is likely that underwater photographers in both situations pay more attention in photography than in the control of buoyancy or being aware of the surrounding environment. The finding in photography habit that divers taking more close-up pictures tend to involve in more contacts in terms of both frequency and intention might have further hinted that the more devoted underwater photographers are in taking pictures, the more likely contacts will be made.

In past studies, higher levels of recreational specialization were generally found to lead to more environmentally responsible behaviors (Cheung et al., 2017; Thapa et al., 2005, 2006; Zhang et al., 2023). In oppose to that, photography commitment measured in terms of the use of professional photography equipment, including professional cameras and camera accessories, positively predicted both frequency and intention of contact. While recreational specialization measured a more generally set of characters that covers areas like experience, knowledge, and investment, photography commitment proposed in this study focused on finding features specifically on the use of professional photography equipment that may lead underwater photographers to induce more impacts. On a positive side, this result may indicate that divers using the increasingly popular sports or action cameras, e.g., GoPro, or more casual underwater photographers are less of a concern to the environment.

Even though in the first part of the analysis, it was shown that underwater photographers tend to cause greater impacts than non-underwater photographers, the regression analysis on photography-associated variable clearly implied that more professional and more devoted underwater photographers are likely more of a concern. Measures may be taken to help reduce impacts in underwater photographers in two forms. To address the issue of frequency in contact regardless of intention, additional programmes and courses may be designed and delivered to underwater photographers to help improve their buoyancy control during photography, and also skills of photography so they may not need to rely only on physically stabilizing themselves to take good pictures. At the same time, to reduce the chance of divers intentionally making contact with marine biota and substrate, extra effort may be paid to improve the awareness of divers on their actions during photography in addition to physical skills. Delivering pre-dive briefing has been one of the ways reduce impacts by studies, so this should be made a standard practice for operators that accommodate more photographers (Hammerton, 2017; Hammerton & Bucher, 2015). It was suggested that diving with friends, family or instructors can promote responsible underwater behavior (Ong & Musa, 2011). Therefore, having a companion or instructor could be even more important for an underwater photographer in terms of improving awareness as well as providing help upon accidents.

This study adopted the approach to study divers based on the intention of their contact, i.e., intentional and unintentional contact, which yielded findings that have provided more detailed information for the management of divers. Studies in other forms of outdoor or wildlife recreational activities may also utilize the same variable to explore new management measures that can help to manage the impacts of the relevant form of recreation.

Unlike most previous studies where demographic factors, experience, and certification level were found to predict divers' impacts, the only control variable that positively predicted impacts were the income of divers. As the demographic profile of the divers surveyed in this study closely resembled that of typical recreationists in Hong Kong, where there was relatively low variation. It is possible that if a wider population with a greater variation in demographic characteristics is sampled, more significant associations may be established.

5. Limitation

The potential lack of variation in demographic profile suggested above could be a limitation for the current study. Future studies may consider stratifying their samples to capture a greater variety of divers. As the current study was carried out in Hong Kong where hard corals were relatively more dominant, it may not completely represent the scuba diver and diving activities in other more popular diving destinations and regions, e.g., the region of Southeast Asia, where there are greater diversity in their reefs. Future studies may in fact, compare the situation of scuba diving across different regions to identify any potential differences and provide relevant information.

Future studies may also carry out long term measurements on the conditional of corals or reefs to associate the contacts of photographers or non-photographers to that actual degree of impacts of their behaviors, be that intentional or unintentional. The current study was limited by time were not able to provide information of the long-term damage of the two types of divers and the type of contact that they made.

6. Conclusion

In conclusion, this study once again showed that underwater photographers were the more impactful group in scuba diving activities, hence, also demonstrating the heterogeneity of recreationists. The three photography-associated variables employed in this study all yielded significant results in predicting the impacts of divers. Divers that used professional equipment and were more interested in conspicuous and actively moving creatures tended to cause more impacts in terms of number of contacts. Divers that were interested in taking close-up pictures, interested in cryptic and sedentary species, and hold professional equipment were more associated to intentional contacts. In both cases, possible causes of the impacts in relation to divers' photography behavior were suggested, and relevant measures in education, training, and diving operations were recommended to address such situations.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Human Research Ethics Committee of The Education University of Hong Kong (protocol code 2017-2018-0122 and 01-02-2019)." for studies involving humans.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

CRediT authorship contribution statement

Anson T.H. Ma: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Lewis T.O. Cheung:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Ching Yee Lui:** Writing – review & editing, Project administration, Methodology, Investigation. **Alice S.Y. Chow:** Writing – review & editing, Supervision, Project administration, Investigation. **Ke Zhang:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Theresa W.L. Lam:** Writing – review & editing, Validation, Investigation, Formal analysis. **Lincoln Fok:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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