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Understanding Diver Behavior on Underwater Cultural Heritage: Enriching the Observation Record Using Video Methods

Joanne Edney [1,*], Kay Dimmock [2] and William E. Boyd [3]

[1] Office of the Deputy Vice Chancellor (Research), Southern Cross University, East Lismore, NSW 2480, Australia
[2] Faculty of Business, Law and Arts, Southern Cross University, East Lismore, NSW 2480, Australia; kay.dimmock@scu.edu.au
[3] Emeritus Faculty, Southern Cross University, East Lismore, NSW 2480, Australia; william.boyd@scu.edu.au
* Correspondence: joanne.edney@scu.edu.au

Abstract: Successful underwater heritage management requires a sound understanding of visitor behavior. Primary visitors to underwater heritage sites are divers whose behavior can pose risks to the integrity of site cultural heritage and tourism values. This study seeks to understand wreck diver in-water behavior. Conventional observation of diver behavior is limiting. Wearable cameras are becoming popular across many recreational activities and potentially expand the scope and quality of diver observation. Video observation is rarely used in such research. This article demonstrates the potential of video observation, describing the analysis of first-person video records to explore details of diver behavior on shipwrecks. The evidence demonstrates that while most divers behaved responsibly, a few contributed to most contact behaviors. The analysis details this behavior, identifying, for example, that deliberate holding and touching comprised most contacts. Such findings on diver behavior inform heritage and tourism management decisions and provide a baseline for future studies. Methodologically, the study demonstrates the power of this method of observing divers and other recreationists. This is particularly valuable for researching recreationalists in confined spaces, such as caves or shipwrecks. The quality of results allows for further evidence-based examination of motivations, values, intentions and meanings underlying observed diver behavior.

Keywords: scuba diving; wreck diving; wearable camera; diver behavior; observational study; shipwrecks; management of underwater cultural heritage; Chuuk Lagoon; Federated States of Micronesia

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1. Introduction

Successful underwater cultural heritage management requires a sound understanding of visitor behavior to effectively manage these unique resources, including negative impacts. The main visitors to underwater cultural heritage sites, including shipwrecks and submerged aircraft, are scuba divers. The use of these sites by divers can diminish their cultural heritage values [1,2], primarily through physical contact because disturbance to sites can alter site context and integrity and accelerate natural decay processes, such as corrosion and biodeterioration [3–6].

Understanding diver in-water behavior at underwater cultural heritage sites assists heritage and tourism managers to balance the demands of protecting cultural heritage and providing quality wreck diving experiences. Behaviors involving physical contact by the diver or their equipment with underwater cultural heritage are those most likely to adversely affect the cultural heritage values of underwater sites. Underwater cultural heritage sites are fragile, non-renewable finite resources that cannot be restored to their original condition or replaced and, unlike reefs, cannot regenerate once disturbed or damaged [7–9]. Controlling diver contact behaviors, therefore, sit at the core of such balanced management. Understanding broader diver behavior at underwater cultural heritage sites is also important, i.e., what divers spend most of their time engaged in, what aspects of the site they spend the most time looking at and what behaviors are most prevalent. Edney and Boyd [10] demonstrated the value of detailed observation of divers to benefit the development of appropriate underwater heritage management strategies. A key feature was the use of video observation, a technique rarely used in diver behavior research.

The aim of this study was to examine and critique wreck diver in-water behavior as a contribution to informing underwater cultural heritage and tourism management. The two study objectives were: (1) to identify diver contact and non-contact behaviors at shipwrecks and (2) to clarify the frequency of diver contact behaviors and durations of non-contact behaviors on shipwrecks. Quality evidence of in-water behavior is difficult to obtain; hence, a key central feature of this work is to apply an emerging technology, wearable video cameras.

2. Literature Review

2.1. Recreational Scuba Divers and Underwater Cultural Heritage

Recreational scuba diving became a reality in the mid-1940s, with equipment accessible to the general public [11]. The now multi-billion-dollar industry comprises an active and mobile community, and dive tourism forms an important part of global tourism that is significant to many local economies [11–14]. Commensurate with growth and maturation in dive tourism has been the increased demand for wreck diving. Wreck diving offers more challenging and diverse experiences, which divers often seek as skill and experience levels rise [2,15].

Shipwrecks are important recreational and tourism resources. However, they are also important components of underwater cultural heritage due to their anthropological, archaeological, cultural, historic and social values. As noted above, shipwrecks are fragile, non-renewable and finite resources that cannot be replaced or restored to their original condition once disturbed or damaged [7–9,16].

Diver use of shipwreck sites can diminish heritage, recreation and tourism values. Growth in diver visitor numbers to shipwrecks has seen higher levels of impacts at sites visited by divers. These include impairment of site integrity and stability, unintentional and intentional contacts and the effects of exhaled air bubbles on wrecks (see [1,2,17] for a detailed discussion of these impacts). Informed management of shipwreck sites is essential if cultural heritage, recreation and tourism values are to be protected from adverse human impacts [2,14].

The literature specific to wreck divers is fledgling. It has primarily focused on wreck diver characteristics, motivations, preferences, attitudes and self-reported behavior. Studies include Holecek and Lothrop's [18,19] work on wreck divers in the U.S. Great Lakes. More recently, there have been studies of wreck divers in the Federated States of Micronesia [20,21], research into Australian [21–24] and international wreck divers [1]. There remains, however, a lack of empirical studies of wreck diver actual in-water behavior in the global literature. Consequently, heritage and tourism managers are left to make decisions based on the assumed diver behavior and anecdotal information [1]. Knowledge of the actual behavior will enhance the effectiveness of management strategies for underwater heritage sites [2,14].

2.2. Observational Research into Behavior

Underwater environments are by their nature difficult places for making systematic and detailed observations of behavior. One option is for divers to self-report their behavior. However, self-reporting can be inaccurate and reports self-perception of behavior, not actual behavior. This limitation relates to influences including social desirability, comprehension, and accuracy of recall [25–27]. While the approach is useful in studying diver perceptions [1], studying actual behavior entails participant observation, which relies on the researcher's memory and the quality of recording methods [28–30]. The method requires accuracy of observation and observer ability to immediately appreciate the significance of behavior. The presence of an observer, and participants being aware of the research, can influence behavior, a phenomenon called the 'Hawthorne effect', 'observer effect' or 'reactivity' [31,32]. It may not be possible to entirely eliminate the observer effect, yet it is desirable if observations disrupt participation as little as possible [32,33].

The use of video to record diver behavior can benefit the researcher, providing a continual and non-interpreted record of divers and their environment. Video observation improves reliability, accuracy, trustworthiness and quality of data and data analysis. From an analytical perspective, data can be viewed, coded and analyzed repeatedly. The method is discrete and less distracting than traditional observation methods. It is, therefore, effective for observing behavior with minimal effect on that behavior [34–36]. The technology is inexpensive and widely available, including wearable cameras.

2.3. Enhancing Diver Observation Using Wearable Cameras

Wearable cameras offer innovative methods for social science research, capable of observing behavior previously not accessible. They are increasingly being used in health behavioral and ethnographic studies but appear underutilized in the social sciences more broadly [37–39]. Using wearable cameras to record participant behavior is particularly relevant to leisure activities because the images capture individual and personal experiences. Furthermore, since participants are already active, the camera need not interfere in the behavior. Modern wearable cameras, such as head-mounted cameras, are small and light, offering hands-free operation [34,40]. They provide a dynamic view of the participant's visual environment, are unobtrusive, and capture data over a period of time [41,42].

In the past 15 years, a plethora of small, robust and inexpensive wearable cameras became available; many can be head-mounted [34]. Papers are emerging in the tourism and leisure literature, which demonstrates the added knowledge to be gained from wearable cameras as a research tool. Previous studies using head-mounted cameras to observe tourism and leisure behavior that signifies experience include:

- The embodied experiences of walkers and mountain bikers in Cairngorms National Park (Scotland) [37].
- The bodily experience of walkers visiting Bowling Green National Park and Townsville Town Common (Australia) [43].
- The nature experience of hikers on the Appalachian Trail (USA) [41].
- The effect of human behavior on dolphins while snorkeling with wild Hawaiian spinner dolphins [44].

Wearable action cameras, in particular GoPro®, have become commonplace amongst recreational scuba divers due to their small size, ability to be taken to 60 m depth, high video quality and ease of operation. They are used in various ways, including head-mounted. From a non-intrusive research perspective, divers are accustomed to GoPro® cameras and pay little, if any, attention to them. Participants get used to the camera presence and quickly forget them [37]. Pringle and Stewart-Evans [45], in a non-diving context, demonstrated no changed participant behavior from the camera's presence, and other studies contend the observer effect is overestimated [31,46].

There are some broad similarities between the methods used in Wiener's [44] study of the effects of human behavior on dolphins and this current study. Both studies are in a marine-based context, and both used head-mounted GoPro® cameras to gain a first-person perspective of human in-water behavior. Wiener's study used GoPro® cameras to record human movements (e.g., arm movements, use of camera, chasing) and resultant dolphin behavior. The study also employed third-person video and traditional observations of the participants to compare the behavior of participants and non-participants. Notably, no significant difference was found in the behavior of those wearing head-mounted cameras and those who did not.

The ubiquity of GoPro cameras in recreational diving facilitates acceptance of this method of data collection because divers are accustomed to their presence. It allows video data to be collected by participants providing a first-person perspective and understanding of participants' visual environment, generating additional context (e.g., the behavior of guides and other divers) [47]. Such information may be difficult to extract from traditional researcher observations of participants, providing a substantial advantage of wearable cameras in research [27,34,40].

2.4. An Application of Wearable Cameras in Diver Behaviour Research

Brown et al. [37] consider head-mounted video cameras suited to spatially constrictive, mobile and equipment-intensive activities—wreck diving meets these criteria, being situations where it is difficult to conduct observational research. Participants in the current study were scuba diving at sites where they could swim inside shipwrecks. This environment has low or no ambient light and confined spaces. In these situations, traditional observation methods would be difficult.

Diver safety was an important consideration in the methods used in this study. Scuba diving is equipment intensive, and divers need their hands free to operate the equipment. Using head-mounted cameras meant participants were not required to hold the camera, leaving them free to focus on diving, enhancing diver safety. Holding a camera can impact diver safety by impeding participants' ability to operate dive equipment and contribute to task loading. Task loading refers to competing for multiple tasks, for example, maintaining buoyancy control while navigating, managing air supply and time limits and taking photographs. Task loading can lead to diver stress, resulting in errors and accidents [48]. Reducing task loading is important, especially at deep sites and inside shipwrecks.

Another benefit of wearable cameras is that they do not constrain participants' experience. Further, a hand-held camera may have resulted in divers capturing particular images, or perspectives, because divers were aware of the camera. Instead, it was essential the video recorded natural behaviors, including how time was spent during the dive rather than highlights. A head-mounted camera meant the video data was an accurate reflection of the participants' visual environment. Therefore, using head-mounted video was appropriate for the study.

3. Study Site

This article explores video camera observation in diving research, by illustrating the research conducted at Chuuk Lagoon, in Chuuk State, Federated States of Micronesia. Chuuk is north of the equator, approximately 2000 kilometers (km) northeast of Papua New Guinea, 4000 km southeast of the Philippines and 5000 km southwest of Hawai'i. Chuuk Lagoon is around 64 km in diameter, covering 2125 km^2 and surrounded by a 225 km long barrier reef. It contains 19 high volcanic islands, 87 small islands and low coral atolls [49–51].

Chuuk was a key strategic advance military base during World War II for Japanese navy vessels, merchant vessels and aircraft, pivotal to Japan's push into the Pacific. Today, in warm, clear tropical waters, lie up to 60 shipwrecks and 13 submerged aircraft (aircraft wrecks), largely intact and with much of the cargo that was in place at the time of the sinking. See Edney [1] (pp. 426–431) for detailed information about the wreck sites. The wrecks are a legacy of World War II aerial bombing raids, primarily 'Operation Hailstone' that occurred on 17 and 18 February 1944 [52–54].

Chuuk Lagoon is a world-renowned wreck diving destination, and since the 1970s, has attracted divers from around the globe. Tourism is important to Chuuk's economy, and the wrecks are Chuuk's major attraction [49,55]. Sustainable diving practices are important for the longevity of this tourism resource and to protect the significant cultural heritage values.

Chuuk was chosen as the study site for several reasons. Divers are attracted to Chuuk for the wreck diving, which offers opportunities, including diving on the outside of wrecks or inside the wrecks (wreck penetration) and the opportunity to view artifacts. The environmental quality of the site, including clearwater, is another advantage that enables observation from a distance, enhancing the experience for divers and researchers.

4. Materials and Methods

The information reported here formed part of the corresponding author's Ph.D. (referred to here on in as the researcher), seeking to understand wreck diver in-water behavior. The study collected quantitative and qualitative data from the video observations. This article reports on quantitative analysis of the video data gathered by wreck divers using wearable cameras at Chuuk from 8 November to 4 December 2014. The qualitative analysis will be reported elsewhere.

This research was conducted in accordance with the Charles Sturt University Human Research Ethics approval (2012/202), where the study commenced, then under Southern Cross University Human Research Ethics approval (ECN-15-005 and ECN-16-008), where the study was completed. Participation was voluntary, and participants were required to be 18 years of age or older and sign an informed consent form prior to participation. The consent included assigning the copyright of the images to the researcher.

4.1. Recruitment of Participants

Participants were recruited using non-probability sampling: convenience, purposive and snowball [56]. Divers staying at Blue Lagoon Dive Resort or visiting Blue Lagoon Dive Shop (on Weno) were approached by the researcher, given an outline of the study and invited to participate. Some people requested involvement in the study after seeing other divers participating. Interested divers were advised the study focus was to determine what wreck divers spent their time doing and looking at while wreck diving. All participants were offered a copy of the video data they collected [10]. More than one video recording per participant was included, consistent with Wiener's [44] method.

4.2. Cameras

GoPro® HERO 3+ Silver Edition cameras were used to collect the data. The video resolution setting was 960 p (1280 × 960 px), with a 4:3 aspect ratio. Frame speed was 60 frames per second, the recommended setting for body-mounted video, and providing the widest field of view (ultra-wide field of view) (GoPro, n.d.). The cameras were mounted on participant's heads using the GoPro® head-mount strap. A thin, soft and flexible neoprene hood with a chin strap was placed over the head-mount straps to prevent the camera from dislodging during entry into the water and throughout the dive (Figure 1).

The researcher gave participants a verbal pre-dive briefing and asked them to conduct their dive as normal. The cameras were switched on prior to entering the water and remained on for the dive duration. The cameras were switched off once the diver returned to the boat on completion of the dive.

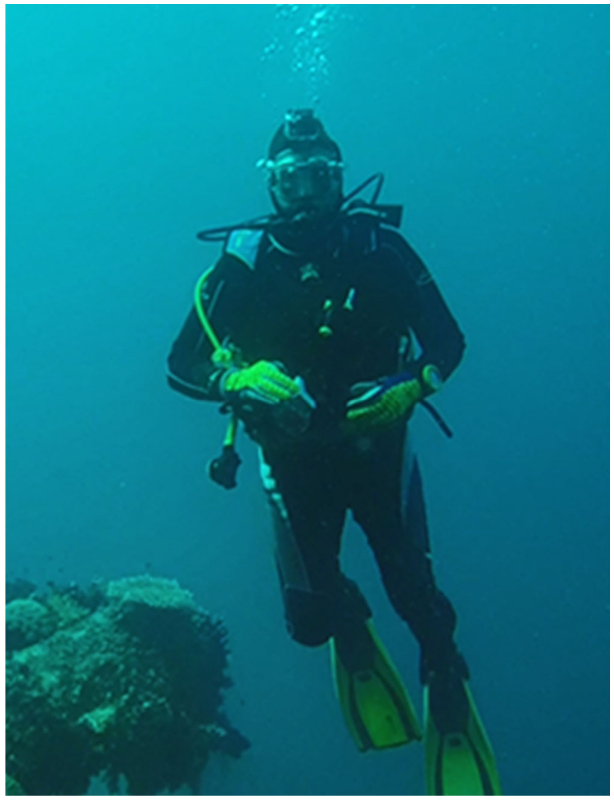

Figure 1. A study participant wearing a head-mounted GoPro® HERO 3+ Silver Edition camera. Image © Joanne Edney. Screen shot from the researcher's head-mounted camera.

4.3. Data Analysis

On completion of the dive, participants returned cameras to the researcher. The video data for each dive would typically comprise between three and five files. The files were stitched together using Pinnacle Studio 15 video editing software prior to analysis so that each dive observation was contained in a single video file. The video data was recorded as MPEG4 (.mp4) files and retained in this format for analysis. The files were exported to The Observer® XT 12.5, a software package designed for human and animal behavior studies [57] for coding and data analysis.

The behaviors documented and analyzed are described in Table 1. They reflect diver impacts on underwater cultural heritage, such as touching artifacts, activities divers engaged in and what divers spent time looking at. Five behaviors had 'modifiers' attached to further define these behaviors by dividing the behavior into subsets. Behaviors could overlap if this was what was observed (e.g., diver looking at a wreck feature while using a camera). Data were coded for analysis. Diver behaviors were coded and documented from when a diver completed their descent and ceased when the diver commenced their ascent, with one exception (a dive was cut short—Observation 12, Table 2). Here the behavior observation ceased three-quarters of the way through this dive. Each behavior was coded and noted in real-time for the duration of time they occurred, with the exception of 'hand pulling' behavior, which was recorded as 'point' type (one-off) data in Table 1. Point type data is used for behaviors "…without measurable or relevant duration." [57], as is the case for hand pulling.

The focus of the reporting of contact behaviors was on frequencies, as the frequency of contact is more relevant to the level of impact of the action on underwater cultural heritage than the duration. For non-contact behaviors, reporting focuses on the duration of behaviors, as duration gives an indication of the relative importance of these activities to the diver.

Table 1. Coded wreck diver behaviors.

Behaviour	Description	Type	Modifiers
Inside wreck	Diver entered an overhead environment. In the holds of upright ships, this included holds that had the hatch cover beams in place.	Duration	
Look at feature of wreck	Diver was actively engaged in looking at a feature of a wreck, either some part of the wreck fabric or an artefact *	Duration	
Look at marine life	Diver was actively engaged in looking at marine life *	Duration	
Touch artefact	Diver deliberately touched an artefact.	Duration	Pick up & inspect Pick up & move Pick up & clean Pick up and hold up Pick up and pass to other Clean
Use camera	Diver actively engaged in using some type of camera. No distinction was made between video and photographs, as most action cameras are capable of taking both videos and photographs. Likewise, most other cameras primarily used to take 'still' photographs also have the capability of taking video images. In most cases it was not possible to distinguish between the types of images being captured. Additionally, many divers with large SLR cameras have both the SLR camera and an action camera attached to the camera mounting.	Duration	Artefact Wreck fabric Marine life People People & wreck People & artefacts People & marine life Other Undetermined
Hand pulling—wreck	Diver uses their hands on a wreck to pull (or push) for propulsion. It is a wreck diving technique used by to move around wreck sites, as it minimises silting and for moving against a current because it is more effective than kicking against a current.	Point	
Sit on wreck	Diver sits on wreck or artefact (for example, the armoured battle tank on the deck of the *Nippo Maru*).	Duration	
Stand on wreck	Diver stands on fins (including fin tips) on a wreck.	Duration	
Kneel on wreck	Diver kneels on wreck.	Duration	
Hold onto wreck	Diver uses hands or other body part to hold themselves on a wreck.	Duration	
Unintentional contact with wreck Unintentional contact with artefact Unintentional contact with marine life	Unintentional contacts are those contacts made accidentally. This often occurs when divers do not have their equipment secures, due to poor buoyancy and lack of situational awareness.	Duration	Fins Knee Elbow Other body part Tank Gauges Other equipment (e.g., light, BCD #, camera, accessories)
Touch marine life	Diver deliberately touches marine life.	Duration	
Hand pulling—marine life	Diver uses their hands on marine life (typically coral) to pull (or push) themselves for propulsion.	Point	

* Determined by the main subject visible in the video recordings. # BCD is an abbreviation for buoyancy control device. Adapted from [1] (p. 117).

Table 2. Participant-generated data collection details.

Observation No.	Diver ID	Dive Site	Researcher Present	Gender	Dive Experience Level	Country of Residence	Dive Guide
1 #	AUSM5	*Rio De Janeiro Maru*	Yes	Male	Less experienced	Australia	DG1
2 #	AUSM1	*Rio De Janeiro Maru*	Yes	Male	Less experienced	Australia	DG1
3 #	AUSF2	*Rio De Janeiro Maru*	Yes	Female	Moderate ✓	Australia	DG1
4 #	AUSM4	*San Francisco Maru*	Yes	Male	Moderate ✓	Australia	DG2
5	AUSM2	*Yamagiri Maru*	Yes	Male	Moderate	Australia	DG2
6 #	AUSM2	*San Francisco Maru*	Yes	Male	Moderate ✓	Australia	DG2
7 #	UKF5	*Gosei Maru*	Yes	Female	Moderate	UK	DG1
8 #	UKM6	*Gosei Maru*	Yes	Male	Less experienced ✓	UK	DG1
9 #	UKM3	*Gosei Maru*	Yes	Male	Experienced	UK	DG1
10	UKM1	*I-169*	No	Male	Experienced *	UK	Not known
11	USF1	*Kiyosumi Maru*	No	Female	Less experienced ✓	US	Not known
12	USM2	*Shinkoku Maru*	No	Male	Less experienced	US	Not known
13	USM1	*Shinkoku Maru*	Yes	Male	Experienced *	US	DG3
14	UKF3	*Fujikawa Maru*	No	Female	Experienced ✓	UK	Not known
15	UKF2	*Gosei Maru*	No	Female	Experienced *	UK	Not known
16	UKF4	*Amagisan Maru*	No	Female	Experienced ✓*	UK	Not known
17	UKF1	*Sankisan Maru*	No	Female	Experienced *	UK	Not known
18	UKM4	*Yamagiri Maru*	No	Male	Experienced ✓^	UK	Not known
19	AUSM6	*Nippo Maru*	No	Male	Experienced ✓*	Australia	Not known
20	AUSM3	*Rio De Janeiro Maru*	Yes	Male	Experienced *	Australia	Not known
21	UKM2	*Kensho Maru*	Yes	Male	Experienced ✓	UK	DG1 + 1 Not known
22 #	AUSM1	*Kiyosumi Maru*	Yes	Male	Less experienced	Australia	DG1
23 #	AUSF2	*Kiyosumi Maru*	Yes	Female	Moderate	Australia	DG1

Key: ✓ Diver observed using a camera. ^ Diver using a rebreather. * Diver using twin tanks. # Note: Observations 1, 2 and 3; 4 and 6; 7–9; 22 and 23 occurred on the same dive. (From [1] (p. 216)).

5. Results

Participant-generated data were collected on 23 dives by 20 divers on 12 shipwrecks (Table 2). Twenty-two of these were complete dives and one partial (three-quarters) dive. One diver, who appeared to be having difficulty with buoyancy and/or dive equipment, removed the camera approximately three-quarters of the way through his dive. Analysis of the dive ended then (Observation 12, Table 2). Three participants, two males and one female, wore the camera on two occasions. The repeat dive was at a different location. A total of 14 hours of participant-generated data were analyzed. Ten participants were observed using their own hand-held cameras. The researcher was present on 14 (61%) dives where participants collected data (Table 2).

The researcher grouped participants into categories based on information provided on the consent form, observations and discussion with participants. The majority (65%) were male, and around one-third (35%) female. Most were residents of the United Kingdom and Australia, each accounting for 43.5 percent of participants, and 13 percent were from the USA. Almost half (48%) were experienced divers, with the remainder having moderate or lower experience levels (no novice divers) (26% each).

Contact behaviors accounted for almost 15% of behavior frequencies (Table 3). The most frequent contact behavior was hand pulling on wrecks, followed by touching artifacts and holding onto wrecks. Touching marine life and hand pulling on marine life ranked fourth and fifth highest in frequency. The frequencies of sitting and standing on wrecks and unintentional contacts were low. Section 5.1 provides more detail about the breakdown of these behaviors.

Table 3. Summary of scored behaviors.

Behaviour	Frequency (n)	Mean Frequency (n)	Proportion of Observed Behaviour Frequency (%)	Duratio n (s)	Mean Duration (s)	Proportion of Observed Behaviour Duration (%)
Non-contact behaviours						
Look at feature of wreck	438	19.04	28.13	34,197.77	1486.86	57.68
Inside a wreck	64	3.05	4.11	9231.18	439.58	15.57
Look at marine life	535	24.32	34.36	12,038.31	547.20	20.31
Use camera	287	28.70	18.43	2762.85	276.29	4.66
Total non-contact	**1324**		**85.03**	**58,230.11**		**98.22**
Contact behaviours						
Hand pulling—wreck	82	6.31	5.27			-
Sit on wreck	1	1.00	0.07	34.50	34.50	0.06
Stand on wreck	3	1.50	0.19	16.91	8.46	0.03
Hold wreck	46	2.88	2.96	310.59	19.41	0.52
Touch artefact	48	9.60	3.08	587.62	117.52	0.99
Unintentional contact—wreck	2	2.00	0.13	3.64	3.64	0.01
Hand pulling—marine life	24	12.00	1.54			
Touch marine life	27	4.50	1.73	100.17	20.03	0.17
Total contact	**233**		**14.97**	**1053.43**		**1.78**
Total—All behaviours	**1557**		**100**	**59,283.54**		**100**

(From [1] (p. 219)).

Non-contact behaviors represented the majority (>98%) of behavior durations (Table 3). Participants spent the highest proportion of their time looking at features of wrecks. This behavior was almost three times higher than looking at marine life, which had the second-highest duration. Being inside wrecks was another popular activity, and photography had the lowest duration. A more detailed breakdown of these results is presented in Section 5.2.

5.1. Analysis of Contact Behavior Frequencies

The most frequent contact behavior was hand pulling on wrecks. It represented 35.2% of total contact behaviors and occurred during 13 observations (Table 3). Two participants were primarily responsible for the majority of hand-pulling instances. Frequencies ranged from 1 to 24 per participant per dive, with a mean of 6.31. For more detailed frequency results, see Appendix A, Table A1.

The second most frequent contact behavior was touching artifacts (Figure 2). This behavior represented 20.6% of contact behaviors, notably recorded during five observations. Frequencies ranged from 5 to 22, with a mean of 9.6. One participant was responsible for the majority of instances of touching artifacts.

Figure 2. Diver picking up and inspecting a bottle from an artifact cluster on the *Kiyosumi Maru*. Image © Joanne Edney. Screen shot from the participant's head-mounted camera.

Touching artifacts is a critical contact behavior that has the potential for consequential impacts on underwater cultural heritage. It was examined in detail using modifiers to refine the behavior (Table 4). Picking up and inspecting artifacts was the most frequent behavior, markedly more frequent than other touching artifact behaviors. Cleaning, picking up and cleaning, and picking up and passing artifacts to other divers were the next most frequent ways divers touched artifacts.

Table 4. Touch artifacts modifier frequencies.

Touch Artefact	**Frequency (n)**					**Total n**	**Total %**	
	Observation Number							
	2	**9**	**19**	**22**	**23**			
Clean	1	4	0	2	0	**7**	**14.6**	**27.1**
Pick up & clean	1	2	1	2	0	**6**	**12.5**	
Pick up & hold up	0	0	1	0	0	**1**		**2.1**
Pick up & inspect	2	3	3	13	6	**27**		**56.2**
Pick up & move	1	0	0	5	0	**6**		**12.5**
Pick up & pass to other diver	0	0	1	0	0	**1**		**2.1**
Total	**5**	**9**	**6**	**22**	**6**	**48**		**100**

(From Edney [1] (p. 223)).

Holding onto wrecks (Figure 3) was the next most frequent contact behavior (19.7%) and occurred during 16 observations. Two participants were responsible for the majority of cases of this behavior. Contact with marine life, which included hand pulling on marine life and touching marine life, had frequencies of 24 and 27 and means of 4.5 and 12, respectively. Only two participants hand pulled on marine life, and five touched marine life. One participant was responsible for the majority of contacts with marine life and the majority of remaining contact behaviors, i.e., unintentional contact with wrecks and standing and sitting on wrecks. Two participants were responsible for all instances of these behaviors. Except for one participant, those using cameras had few contacts, four (40%) had no contact behaviors. Comparing contact frequencies and participant profile variables revealed males (88%), Australians (84%) and less experienced divers (56%) were responsible for most contact behaviors and the majority of touching artifacts instances. For more detailed information results on contacts and diver variables, see Appendix A, Tables A2 and A3.

Figure 3. Diver holding onto part of the *Kiyosumi Maru* to stay steady while looking into a small opening. Image © Joanne Edney. Screen shot from a participant's head-mounted camera.

5.2. Analysis of Non-Contact Behaviour Durations

Participants spent greater than half (57.7%) of dive time looking at features of wrecks, including artifacts, masts and kingposts, propellers and machinery (Table 3). Viewing marine life was popular (20.3%), and considerable dive time (15.6%) was spent inside wrecks (Table 3). Cargo holds were the most commonly visited parts of wrecks, and divers viewed features such as munitions, gas masks, aircraft, vehicles, bicycles, machinery, crockery, glassware, cooking utensils, tableware, shoes and clothing, beer and sake bottles. For more detailed behavior durations, see Appendix A, Table A4.

Entering superstructures to see the bridge, bathrooms and galleys was popular. Human remains on the wrecks were of interest to divers. Only two participants did not penetrate the wrecks. In one case, the participant was diving the *I-169* submarine wreck, which is not possible to enter. The other participant was diving a penetrable wreck, but the guide did not lead the group inside on that occasion, and the divers, therefore, did not enter the wreck. The remaining dive time (4.7%) was spent engaged in photography/videography (Figure 4). Popular photography subjects were wrecks (features and artifacts) and marine life (Appendix A, Table A5).

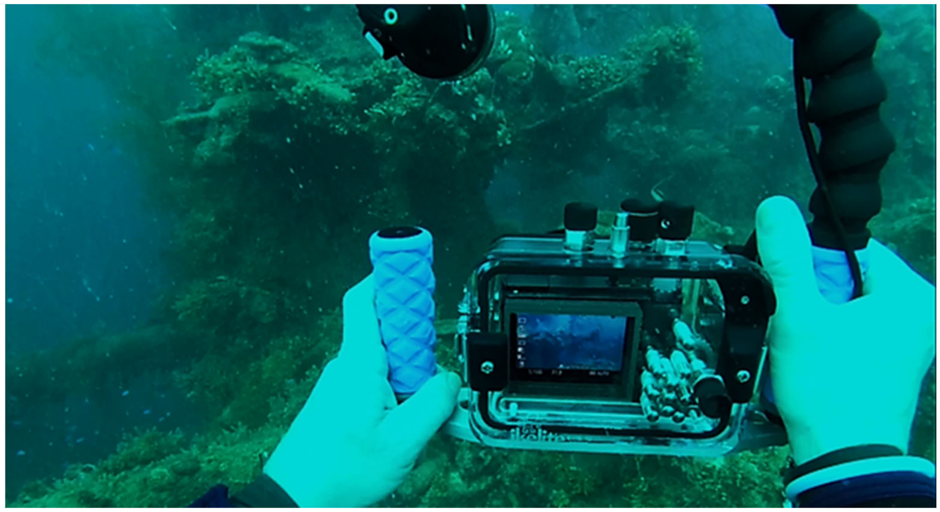

Figure 4. Participant taking a photo of the *Kensho Maru* bow gun. Image © Joanne Edney. Screen shot from participant's head-mounted camera.

6. Discussion

The study set out to examine wreck diver behavior in the context of underwater cultural heritage. In achieving its aims, the paper reports one of the first published examples of wearable video cameras to record diver in-water behavior, in addition to introducing participant-generated data and being the first to examine diver non-contact behaviors. The first-person perspective of the data offers unique insight into diver behavior, capturing the participant's environment as they saw it, a different perspective to that obtained from third-person observation. Furthermore, understanding contact and non-contact behaviors provides comprehensive knowledge of diver in-water behaviors. A study of only contact behaviors, for example, provides little insight into the proportion of time spent on other behavior types. Importantly, diver contact behaviors with heritage items affect a site's cultural heritage and tourism values through their negative impacts. Such knowledge is well understood in other fields, such as ecological impact studies of coral reef diving, which highlight how diver profile is associated with environmental damage at heavily visited sites [58].

In the current study, data analysis indicates that contact behaviors represented only a small component of total wreck diver underwater behavior. Nevertheless, understanding those behaviors is crucial, given their potential to negatively impact underwater heritage. Contact behaviors were mostly intentional, indicating they are not attributed to poor diving skills such as buoyancy control. Understanding the source of the behaviors is also beneficial, as it allows site managers better target management. This research found men, Australians, and to a lesser extent, less experienced divers were responsible for the vast majority of contact behaviors.

Hand pulling was the most common contact behavior. This is a wreck diving technique used to minimize silting and move more efficiently against currents. Touching artifacts, mostly to inspect or clean them, was the second most frequent contact behavior (approximately 20% of contact behaviors) and the one of most concern to heritage managers due to the negative impacts on cultural heritage values. It is, therefore, encouraging that this behavior accounted for such a small proportion of contact behaviors. Any contact with a wreck's fabric or artifacts can accelerate decay, and cleaning removes protective coatings, further accelerating their decay [3,6]. When divers search for artifacts and move them, the integrity and the archaeological value of sites are impaired [7]. While there is concern about the impact of these behaviors on the cultural heritage values of these sites, they, importantly, can also diminish the tourism values of the sites, since the appeal to divers is higher when artifacts can be viewed, particularly in-situ [7,59,60]. More sustainable use of shipwrecks by divers, therefore, has benefits for the protection of underwater cultural heritage, recreation and tourism values of these sites.

Understanding the source of and types of contact behaviors enables heritage managers to target management, particularly education of divers about the causes and consequences of diver contacts with wrecks and their contents. It also allows dive tourism operators who want to use sites more sustainably to target information provided to divers in pre-dive briefings, for example, discouraging the touching of artifacts. Dive tourism operators who depend on wreck sites for their livelihood, such as at Chuuk Lagoon, gain to benefit from encouraging more sustainable use of the sites their businesses depend on.

Examining non-contact behaviors reveals what divers are interested in through the first-person perspective of data. This provides information on diver preferences that should interest site managers and dive operators. Divers in this study, for example, spent much time looking at the wrecks, almost three times as much time as the next most prominent non-contact behavior, viewing marine life. The study site hosts abundant and diverse marine life, yet the wrecks held the divers' attention. The first-person perspective in this study confirms wreck divers' motivation to view shipwrecks and marine life [20,21]. The research also highlighted divers' interest in going inside wrecks, thus confirming the tourism and recreational value of both shipwrecks and marine life for dive tourism operators. This may assist dive tourism operators with the marketing and provision of experiences that appeal most to wreck divers.

In terms of study limitations, the sample size of divers may constrain broad generalizations of the findings. Nevertheless, since this is the first empirical study of actual wreck diver behavior, it provides an important baseline for future wreck diver behavior research. In this sense, it is essential for the emerging field of research regarding sustainable tourism at underwater cultural heritage sites. Although the literature recognizes the observer effect has been overestimated in observation studies using cameras, and the methods used in this study were designed to minimize any observer effect, the possibility that the presence of the camera may have reduced the number of contacts made by participants is acknowledged.

7. Conclusions

Two research objectives framed this study: (1) to identify diver contact and non-contact behaviors at shipwrecks in Chuuk Lagoon and (2) to clarify the frequency of diver contact behaviors and durations of non-contact behaviors on shipwrecks in Chuuk Lagoon. Using wearable video cameras, the study achieved its objectives by collecting first-person perspective data to offer insight into what behaviors occurred. The data also advised frequency and duration of behaviors, which clarified the detail of the in-water behavior of this group of wreck divers. As a result, a baseline study is now available on which to build and clarify information for heritage and dive tourism managers at wreck diving sites. Protecting underwater cultural heritage is a key part of managing such sites, and measures taken to guide visitor management are more effective when informed by evidence.

The evidence demonstrates that while the majority of divers behaved responsibly, a few divers contributed to the majority of contacts. Deliberate touching comprised the majority of contacts. When wreck diving, divers are most interested in viewing the wrecks themselves. Other popular activities are viewing marine life and going inside wrecks.

Based on the findings of this research, the following recommendations are made:

1. Site management strategies should target the major sources and types of diver contact behaviors.
2. Education should be provided to divers and dive tourism operators about the causes and consequences of diver contact behaviors and implications to sites (i.e., cultural heritage and recreation/tourism values/economic values to businesses reliant on these sites).

3. Further research into wreck diver in-water behavior.

Further research could use larger samples at different sites to expand on the insights regarding diver behavior reported here. In addition to refining understanding of diver behavior per se, qualitative research, such as the use of photo elicitation, could investigate meanings ascribed to diver underwater behavior and wreck diving experiences to further understand the motivations, values and intentions that underlie the observed behaviors.

The findings on diver behavior contribute to informing heritage and tourism management decisions and provide a baseline for future studies. Methodologically, the study demonstrates the power of a research method of observing divers and other recreationists, namely, first-person camera-based data collections. This is particularly valuable for researching recreationalists who are operating in confined spaces, such as caves, canyons and, in this case, shipwrecks.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Charles Sturt University Human Research Ethics Committee (2012/202) and Southern Cross University Human Research Ethics Committee (ECN-15-005 and ECN-16-008).

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

Data Availability Statement: Ethics approvals do not permit sharing of the raw data. All processed data supporting the results are included in the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Frequency of participant behaviors.

Behaviour	**Frequency (n)**																							**Total**	**Mean**
	Observation Number																								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**		
Look at feature of wreck	12	19	25	9	17	5	28	36	23	16	16	10	35	20	32	12	22	11	8	32	20	14	16	**438**	**19.04**
Inside a wreck	3	3	4	1	3	1	3	2	7	0	4	1	4	3	3	2	2	6	2	4	0	3	3	**64**	**3.05**
Look at marine life	1	16	14	0	19	2	44	22	58	43	33	10	38	19	62	11	37	20	1	11	29	18	27	**535**	**24.32**
Use camera	0	0	20	25	0	11	0	49	0	0	13	0	0	33	0	74	0	1	1	0	60	0	0	**287**	**28.70**
Non-contact behaviour totals	**16**	**38**	**63**	**35**	**39**	**19**	**75**	**109**	**88**	**59**	**66**	**21**	**77**	**75**	**97**	**99**	**61**	**38**	**12**	**47**	**109**	**35**	**46**	1324	
Hand pulling—wreck	3	21	0	3	5	0	1	1	3	0	0	0	0	1	0	0	0	4	24	1	0	14	1	**82**	**6.31**
Sit on wreck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**1.00**
Stand on wreck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	**3**	**1.50**
Hold onto wreck	0	8	0	3	1	0	2	1	1	1	0	0	2	3	0	0	1	2	3	1	1	11	5	**46**	**2.88**
Touch artefact	0	5	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	6	0	0	22	6	**48**	**9.60**
Unintentional contact with wreck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**2.00**
Hand pulling—marine life	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	3	**24**	**12.00**
Touch marine life	0	4	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	15	4	**27**	**4.50**
Contact behaviour totals	**3**	**38**	**0**	**6**	**7**	**0**	**3**	**2**	**15**	**2**	**0**	**0**	**2**	**4**	**0**	**0**	**1**	**6**	**35**	**2**	**1**	**87**	**19**	233	
Total—All behaviours	**19**	**76**	**63**	**41**	**46**	**19**	**78**	**111**	**103**	**61**	**66**	**21**	**79**	**79**	**97**	**99**	**62**	**44**	**47**	**49**	**110**	**122**	**65**	1557	

Note: Observations 2 and 22, 3 and 23, and 5 and 6 were recorded by the same divers—refer to Table 2 above for more details. (From [1] (p. 221).

Table A2. Contact behavior frequencies by diver profile variables.

Diver Profile Variable	Frequencies																			
	Observations		Hand Pull—Wreck		Touch Artefacts		Hold onto Wreck		Stand on Wreck		Sit on Wreck		Unintentional Contact with wreck		Touch Marine Life		Hand Pull—Marine Life		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Gender																				
Male	15	65	79	96	42	88	35	76	3	100	1	100	2	100	23	85	21	88	206	88
Female	8	35	3	4	6	12	11	24	0	0	0	0	0	0	4	15	3	12	27	12
Total	**23**	**100**	**82**	**100**	**48**	**100**	**46**	**100**	**3**	**100**	**1**	**100**	**2**	**100**	**27**	**100**	**24**	**100**	**233**	**100**
Country of residence																				
Australia	10	44	72	88	39	81	32	70	3	100	1	100	2	100	24	89	24	100	197	84
United Kingdom	10	44	10	12	9	19	12	26	0	0	0	0	0	0	3	11	0	0	34	15
United States	3	12	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	2	1
Total	**23**	**100**	**82**	**100**	**48**	**100**	**46**	**100**	**3**	**100**	**1**	**100**	**2**	**100**	**27**	**100**	**24**	**100**	**233**	**100**
Dive experience level																				
Less experienced	6	26	39	48	27	56	20	43	2	67	0	0	2	100	19	70	21	88	130	56
Moderate	6	26	10	12	6	13	11	24	0	0	0	0	0	0	5	19	3	12	35	15
Experienced	11	48	33	40	15	31	15	33	1	33	1	100	0	0	3	11	0	0	68	29
Total	**23**	**100**	**82**	**100**	**48**	**100**	**46**	**100**	**3**	**100**	**1**	**100**	**2**	**100**	**27**	**100**	**24**	**100**	**233**	**100**

n is the number of observations (From [1] (p. 230).

Table A3. Contact behavior frequency proportions by diver profile variables.

Behaviour	Frequency Percent							
	Gender		Country of Residence			Dive Experience Level		
	Male	Female	Australia	United Kingdom	United States	Less	Moderate	Experienced
Hand pull—wreck	38.3	11.1	36.6	29.4	0	30	28.6	48.4
Touch artefacts	20.4	22.2	19.8	26.5	0	20.8	17.1	22.1
Hold onto wreck	17	40.8	16.2	35.3	100	15.4	31.4	22.1
Stand on wreck	1.5	0	1.5	0	0	1.5	0	1.5
Sit on wreck	0.5	0	0.5	0	0	0	0	1.5
Unintentional contact—wreck	1	0	1	0	0	1.5	0	0
Touch marine life	11.1	14.8	12.2	8.8	0	14.6	14.3	4.4
Hand pull—marine life	10.2	11.1	12.2	0	0	16.2	8.6	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(From [1] (p. 231).

Table A4. Durations of participant behavior.

Behaviour	**Duration (Percentage of Observation Time)**																						
	Observation Number																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Look at feature of wreck	54.23	65.88	57.21	40.81	58.39	59.18	37.49	45.36	65.14	82.32	57.49	37.81	63.02	64.00	62.20	79.51	76.96	70.46	73.86	61.61	51.86	57.72	51.25
Inside a wreck	9.70	13.74	17.81	14.76	30.51	15.28	12.11	11.54	27.18	0	20.53	7.15	18.94	22.28	18.58	18.77	13.49	18.14	28.40	22.53	0	13.29	12.83
Look at marine life	0.09	11.19	14.58	-	12.14	1.73	29.16	18.48	32.21	30.53	32.20	4.76	16.60	15.66	32.14	4.03	36.80	20.17	0.18	3.65	59.20	33.24	43.70
Use camera	0	0	10.97	32.02	0	2.67	0	21.61	0	0	3.65	0	0	17.10	0	17.53	0	0.08	0.74	0	27.28	0	0
Non-contact behaviour total	**64.02**	**90.81**	**100.57**	**87.59**	**101.04**	**78.86**	**78.76**	**96.99**	**124.53**	**112.85**	**113.87**	**49.72**	**98.56**	**119.04**	**112.92**	**119.84**	**127.25**	**108.85**	**103.18**	**87.79**	**138.34**	**104.25**	**107.78**
Sit on wreck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.79	0	0	0	0
Stand on wreck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.19	0	0	0.62	0
Hold onto wreck	0	3.43	0	4.07	0.52	0	0.60	0.11	0.11	0.07	0	0	0.63	1.40	0	0	0.02	0.32	0.54	0.05	0.21	2.53	1.55
Unintentional contact	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0
Touch artefact	0	2.80	0	0	0	0	0	0	3.50	0	0	0	0	0	0	0	0	0	3.64	0	0	13.49	2.22
Touch marine life	0	0.75	0	0	0.26	0	0	0	0.31	0.63	0	0	0	0	0	0	0	0	0	0	0	2.27	0.50
Total of contact behaviours	**0**	**6.98**	**0**	**4.07**	**0.78**	**0**	**0.60**	**0.11**	**3.92**	**0.7**	**0**	**0**	**0.63**	**1.40**	**0**	**0**	**0.02**	**0.32**	**6.16**	**0.05**	**0.21**	**19.08**	**4.27**
Total—All behaviours	**64.02**	**97.79**	**100.57**	**91.66**	**101.82**	**78.86**	**79.36**	**97.1**	**128.45**	**113.55**	**113.87**	**49.72**	**99.19**	**120.44**	**112.92**	**119.84**	**127.27**	**109.17**	**109.34**	**87.84**	**138.55**	**123.33**	**112.05**

Notes: The percentages for each observation may be higher than 100 percent because behaviors can overlap. Observations 2 and 22, 3 and 23, and 5 and 6 were recorded by the same divers—refer to Table 2 above for more details. There is no duration data for hand pulling—wreck and marine life because these behaviors are point event data. (From [1] (p. 226)).

Table A5. Use camera modifiers.

Use Camera Modifiers	Frequencies										Total n	Total %
	Observation Number											
	3	4	6	8	11	14	16	18	19	21		
Artefacts	3	11	2	7	6	10	4	0	0	1	**44**	**15.3**
People & artefacts	0	1	1	3	0	1	0	0	0	0	**6**	**2.1**
Wreck fabric	8	6	4	11	2	12	31	0	0	11	**85**	**29.6**
People & wreck	3	7	4	10	3	1	34	0	1	0	**63**	**22.0**
Marine life	4	0	0	18	2	9	5	1	0	48	**87**	**30.3**
Undetermined	2	0	0	0	0	0	0	0	0	0	**2**	**0.7**
Total—Use camera	**20**	**25**	**11**	**49**	**13**	**33**	**74**	**1**	**1**	**60**	**287**	**100**

From [1] (p. 223).

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