Whale shark behavioural responses to tourism interactions in Ningaloo Marine Park and implications for future management

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ABSTRACT

This study examined whale shark behaviour using fixed-wing aerial surveys in Ningaloo Marine Park between 2007 and 2009. The aims of the project were to develop and trial a method to test for impacts of tourism vessels and swimmers on whale shark behaviour. Whale sharks made significantly more directional changes when vessels were present, with approximately twice as many changes in direction observed per scan when a vessel was present. Whale sharks also maintained neutral behaviours, such as surface swimming, swimming at depth, resurfacing, or no reaction during interactions and, notably, more of these were recorded when a vessel was present. This suggests that, while behaviours were maintained regardless of the presence of vessels, whale sharks may have still responded to vessels by changing direction more frequently. The aerial observations were effective in detecting an increase in directional changes but further behavioural studies are required to improve our understanding of natural diving and surfacing behaviour in whale sharks. Alternative research platforms and technologies may be necessary to investigate whale shark behaviour in more detail and to further evaluate potential impacts of tourism interactions on whale sharks.

Keywords: behaviour, ecotourism, management, whale shark.

INTRODUCTION

Whale sharks (*Rhincodon typus*) are appreciated worldwide for their size, colouration patterns and generally harmless nature. They have become a focus of tourism interactions in areas where they are known to aggregate, including the Seychelles, Philippines, Mozambique, Mexico and Ningaloo Marine Park (NMP) in Western Australia (WA) (Coleman 1997; Davis et al. 1997; Pierce et al. 2010; Gallagher & Hammerschlag 2011). Typically between March and July each year, whale sharks aggregate in NMP and the surrounding area to feed in the nutrient-rich waters created by upwelling and plankton blooms associated with coral spawning (Taylor 1996). A nature-based tourism industry has developed around the predictable presence of these animals, taking people to view and snorkel with the whale sharks. This growing industry has been carefully managed at NMP under what is considered to be a sustainable best practice management program (Coleman 1997; Mau 2008; Rowat & Brooks 2012).

The whale shark is considered at international and national levels to be a threatened species given the pressures upon it across its range. It is listed as Vulnerable on the Red List of Threatened Species by the International Union for the Conservation of Nature (IUCN) and under the Australian *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*). In WA, it is a protected species under the *Wildlife Conservation Act 1950*. The main recognised human pressures upon whale sharks are hunting and boat strike in international waters. Given that most whale sharks likely spend much of their time outside of WA state waters, the Department of Parks and Wildlife (Parks and Wildlife) can significantly contribute to an international effort for their conservation through effective local management based on understanding and reducing pressures in state waters through education, raising public awareness and community engagement. Understanding changes in population abundance or condition in state waters can be conveyed to federal authorities so that they can pursue national and international conservation initiatives.

Human disturbance, i.e. direct contact through boat strike or close proximity of boats and swimmers, is

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recognised as the most relevant anthropogenic pressure on whale sharks in WA (Department of Parks and Wildlife 2013). As there is a nature-based tourism industry reliant on interaction of tourists and whale sharks in NMP, it is important that these pressures are monitored and minimised where relevant (Department of Parks and Wildlife 2013). To address this, Parks and Wildlife developed and implemented a species management program in 1997 specific to the whale shark industry in NMP ('Management Program'; Coleman 1997). The Management Program includes a licensing system for tourism operators in NMP and a code of conduct (see https://www.dpaw.wa.gov.au/management/marine/marine-wildlife/whale-sharks?showall=&start=2) to manage interactions of vessels and people with whale sharks. In 2012 the Management Program was reviewed to evaluate its effectiveness along with the status of the tourism industry, and an updated Management Program published in 2013 ('Management Program 2013'; Department of Parks and Wildlife 2013). The Management Program 2013 identified strategies for research, including the need to assess the impact of vessels and swimmers on whale shark behaviour, and recommends the ongoing review and use of research and monitoring outcomes to inform management strategies, particularly to minimise impacts.

There has been substantial research on whale sharks in NMP (e.g. Meekan et al. 2006; Wilson et al. 2006; Bradshaw et al. 2008; Speed et al. 2008; Sleeman et al. 2010; Thums et al. 2013) and more broadly throughout the Indian Ocean (Rowat et al. 2009; Rowat & Brooks 2012) over the past 15 years. While much of this research has focussed on understanding whale shark biology and distribution patterns, there have been several studies on the whale shark tourism industry (Davis et al. 1997; Patton & Marsh 2005; Mau 2007; Anderson et al. 2014) and in particular on the impact of swimmers and vessels on whale sharks (Quiros 2007; Pierce et al. 2010; Haskell et al. 2014). However, these latter studies used an in-water observer to collect data, thus the observer could have potentially affected whale shark behaviour, thereby limiting the scientific validity of data collected. To date there has been limited research emphasis on the effectiveness of the Management Program at NMP.

A pilot research project was undertaken in NMP between 2007 and 2009 to assess the potential impacts of vessel and swimmer interactions on the behaviour of whale sharks and the consequent effectiveness of the Management Program using aerial surveys. Here we use this existing behavioural dataset compiled from 2007 to 2009 to:

1. assess the impact of interactions with tourism vessels on whale shark behaviour; and
2. assess the survey methods for their suitability in evaluating the impacts of tourist interactions on whale sharks.

This research will enable a better understanding of whale shark response to vessels, including whether the code of conduct minimises disturbance. This information will directly support the Management Program 2013 by evaluating the existing code of conduct and governance structures in place and identifying whether modifications to the code of conduct or protocols for monitoring interactions is warranted to fully meet the objectives of the Management Program 2013. Furthermore, information from this project will support improved whale shark conservation and management of whale shark tourism in NMP as well as inform conservation management options for whale sharks in other jurisdictions.

METHODS

Aerial surveys

Aerial surveys were conducted during the whale shark aggregation periods at NMP between 2007 and 2009 to assess whale shark behavioural responses to vessels and swimmers. Surveys were conducted on 11 days in 2007, seven days in 2008 and six days in 2009. All surveys were completed following a standard operating procedure (see supplementary material) with two observers and a pilot present on each survey.

Data were collected for both 'interaction' events (commercial tour vessel and/or swimmers within 250 m of whale shark) and 'control' events (no vessels or swimmers within 250 m of whale shark). When a whale shark was first sighted, a GPS location, initial directional heading, behaviour, estimated size and whether an interaction was occurring were recorded. Following the initial observation, the directional movement, behaviour and interaction details were recorded for a minimum of 15 minutes at approximate intervals of 30 seconds to one minute, unless visual contact of the whale shark was lost. Whale shark behaviours included: swam at the surface, swam at depth, increased speed, decreased speed, circled, dived deep, resurfaced, investigated and no reaction. Whale shark direction of movement was recorded in conjunction with behaviour with these headings using compass point directions (e.g. N, NW, NE, etc.; see supplementary material).

During interactions the vessel identity (although vessel anonymity was maintained in the data analysis), the vessel position relative to the whale shark, distance from the whale shark and whether the vessel was moving or stationary were recorded. An interaction was defined as the vessel and/or swimmers in the water within 250 m of the whale shark. Individual whale sharks could not be identified from the aircraft and therefore independence between observations is assumed but cumulative interactions with individual sharks may be a confounding factor.

Data Analysis

Due to the small sample size, recorded behaviours were pooled into three categories for analysis (Table 1). Change in direction of movement was rarely

Table 1

Categories of observed behaviours.

Observed behaviours	Explanation of behaviour
Dived deep Increased speed	Behaviours that reduced the likelihood of or shortened the duration of an interaction by increasing the distance between whale shark and vessel/swimmer.
Surface swam Swam at depth No reaction Resurfaced	Neutral.
Decreased speed Circled Investigated	Behaviours that maintained the likelihood of or increased the duration of an interaction by reducing the distance between whale shark and vessel/swimmer.

recorded as a behaviour as per the standard operating procedure (see supplementary material), however, could be assessed through analysis of the directional heading recorded at each sample point. Thus, change in directional heading was included in analysis as a separate variable.

Poisson regression was used to explore the relationship between response variables such as the rates of change in behaviour and directional headings of the whale shark and the presence or absence of a vessel. Poisson regression models are a type of generalised linear model commonly used to analyse count data (Zuur et al. 2013). The Poisson regression expresses the probability of a given number of events occurring in a fixed interval of time and/or space if these events occur with a known average rate. That is, it predicts the degree of spread around a known average rate of occurrence. Counts of different types of occurrences were modelled assuming a Poisson distribution and using a quasi-likelihood approach to allow for over dispersion. An offset of log (number of scans) was included to allow for the differing numbers of scans for respective counts, effectively modelling a rate of occurrence of each type (number per scan observed).

RESULTS

All three years of aerial survey data were included in the analysis (2007–2009). Due to the small sample sizes of sharks observed per year, data were pooled across years for the purpose of analysis. A total of 80 whale sharks were observed and recorded over the three years. Thirty three were 'control' events where no vessels and/or swimmers were within 250 m and 47 were 'interaction' events where a vessel and/or swimmers were within 250 m (Table 2). Whale shark behaviour was observed for a total of 28 hours with an average 40 scan samples (approximately 20 minutes) per observed shark.

Table 2

Number of control and interaction events recorded each year during the study.

Year	'Control' events	'Interaction' events
2007	18	19
2008	5	16
2009	10	12
Total	33	47

Effect of presence and number of vessels on changes in whale shark behaviour and direction of movement

There was no statistically significant effect of presence of a vessel ($p = 0.239$) nor of a linear trend in the number of changes in whale shark behaviour with the number of vessels present ($p = 0.942$). However, there were significantly more changes in whale shark directional movement in the presence of a vessel ($p = 0.038$). There was no statistically significant linear trend in the number of direction changes by whale sharks in relation to the number of vessels present ($p = 0.851$). The fitted mean number of changes in direction per scan was 0.119 when no vessel was present and 0.223 when a vessel was present. Thus, approximately twice as many changes in whale shark direction were observed per scan when a vessel was present.

Effect of presence and number of vessels on whale shark behaviour type

There was no statistically significant effect of presence of a vessel ($p = 0.782$), and no statistically significant linear trend with number of vessels present ($p = 0.424$) on behaviours that maintained an interaction; however, the infrequency of these behaviours limit our analysis power. There was a linear correlation between interaction duration and number of behavioural changes per scan ($r^2 = 0.52$, $p < 0.0001$).

There was a statistically significant effect of presence of a vessel on neutral behaviour ($p = 0.013$), with whale sharks that had a vessel present displaying more neutral behaviours. The fitted mean number of neutral behaviours per scan was 0.752 when no vessel present, and 0.873 when a vessel was present. There was also a statistically significant increasing linear trend in the number of vessels present ($p = 0.020$), i.e. neutral behaviours were recorded more per scan as the number of boats increased. Similarly, there was a statistically significant effect of presence of a vessel on behaviours that reduced an interaction ($p = 0.013$), but no statistically significant linear trend with the number of vessels present ($p = 0.075$). The fitted mean number of behaviours that reduced an interaction per scan was 0.188 when no vessel was present, and 0.085 when a vessel was present, therefore fewer behaviours

Table 3

Summary of the final behaviour observed for each whale shark observation in the absence or presence of a vessel. The total number of interactions when vessels were absent was 33, and when a vessel was present was 46.

Final Behaviour	No Vessel	Vessel present
Dived deep	21	24
Decreased speed	1	0
Resurfaced	0	1
Swam at depth	2	8
Swam at surface	9	13

that reduced an interaction were apparent with vessel presence.

In 45 of the 79 interactions where a final behaviour was recorded the observation ended with the whale shark in a deep dive (Table 3). The mean time to deep dive was 12.5 min (SE ± 1.4 min) in the absence of vessels (n = 21) and 21 min (SE ± 2.5 min) in the presence of vessels (n = 25), i.e. whale sharks remained at the surface twice as long, on average, when a vessel was present. There was no statistically significant difference between end behaviour in the presence or absence of a vessel (chi-square test 2.581 with 2 degrees of freedom; p= 0.275).

DISCUSSION

Effect of presence and number of vessels on changes in whale shark behaviour and directional movement

Whale sharks changed direction more often when vessels were present. The number of behavioural changes was also correlated to the interaction duration, with more changes observed for longer interactions. Another study investigating the impact of tourism and swimmers on whale sharks in the Philippines found directional changes increased when swimmers obstructed the whale shark's path or approached too closely (Quiros 2007). While we were unable to assess swimmer or vessel position or proximity due to the way this information was recorded, and can therefore not assess their influence on whale shark response, increase in directional changes may be a widespread response.

Understanding typical whale shark diving and surfacing behaviour is important in interpreting these results. Whale sharks have protracted surface swims following dives for the purpose of thermoregulation (Thums et al. 2013). They can also favour shallow water during food pulses e.g. fish spawning events (Graham et al. 2006). It is possible that whale sharks may tolerate the presence of a vessel, thus maintaining their behaviour, if the need to thermoregulate or feed is critical, as observed in this study with the high number of 'neutral' behaviours. However the potential ramifications of increased directional changes, vessel collisions and the associated fitness costs are unknown (Speed et al. 2008). Similarly, for NMP, the impact of vessel and/or swimmer proximity and position on this response are also unknown, but could have implications in evaluation of the existing code of conduct and its implementation.

Interactions were often noted to end with a 'deep dive' when the whale shark was no longer visible to the observer. However, on average it took twice as long for a whale shark to dive deep and the observation to end in the presence, rather than absence of a vessel. It should be noted that whale sharks did make multiple deep dives in some interactions before resurfacing and resuming surface swimming. However, understanding the proportions of surface versus subsurface time spent by whale sharks at NMP would be useful in determining whether whale sharks spend more overall time swimming at depth when a vessel is present. Such information could be gained from archival tags that record time and depth, thus providing an indication of the animal's movement patterns over a diurnal cycle (e.g. Wilson et al. 2006; Rowat & Gore 2007; Wilson et al. 2008; Gleiss et al. 2013).

Martin (2007) found that whale sharks sometimes appear to avoid boats by diving slowly toward the seabed, usually without noticeably changing their speed, presumably in response to the noise of the boat. Similarly, Quiros (2007) found that whale sharks that had been exposed to repeated interactions or were feeding were more likely to dive in response to the presence of a vessel. In our study we were unable to confirm whether the whale sharks had been interacted with previously and therefore the interactions were assumed to be independent. Confirming whale shark identity could be considered in future to ensure cumulative interactions with the same individual whale shark is not affecting behaviour and confounding results.

Limitations of sampling protocol and research platform

Research platforms and methods all come with particular limitations that need to be taken into account in relation to the research question and in survey design. An aerial platform was chosen for this study as it was a cost-effective option and addressed the specific research question about the impact of tour operations on whale shark behaviour by providing a neutral platform that would not have an added impact on the whale sharks. However, some limitations were identified by using this platform and the associated protocols. While methods should always be chosen appropriate to the research question(s) being asked, future studies could build on this pilot study by considering the following factors in protocol design and data collection.

The standard operating procedure did not prescribe point sampling (Martin & Bateson 1993), but rather observations were recorded as a scan sample anytime within a 30-second period, leading to inconsistencies in sampling. Further, for many scans data were missed or the whale shark was not visible to the observer. This reduced the amount of usable data on interactions and behaviours and quantitative analysis of time.

While the aerial platform offers a broad-scale and unobstructed view of the whale shark, vessels and swimmers, some fine-scale information cannot be collected with this technique. A comprehensive ethogram of whale shark behaviours, including banking, eye rolling, gulping, degree of mouth opening and gill flushing/coughing, has been described by Quiros (2007), who used boat-based or in-water observations to monitor whale shark behaviour in the Philippines. Some of these behaviours are indicative of feeding, which is an important consideration as whale shark fitness may be reduced if their feeding is repeatedly disrupted, while other behaviours were linked to avoidance. However, the aerial platform used in this study did not allow for such fine-scale detection of behaviours. Similarly, other behavioural changes that were of interest, such as increases and decreases in swimming speed, were more difficult to observe than anticipated owing to the speed at which the fixed-wing aircraft was moving. This loss of fine detail is a trade-off in having an independent platform removed from the interaction zone of the whale shark, and therefore use of this platform may be limited to examining broad-scale questions of behaviour.

Some limitations to the aerial surveys identified in this study can be overcome somewhat by a cooperative approach linking tour boat or in-water observations with simultaneous aerial observations. This would be more straightforward given the current use of an on-board electronic monitoring system (EMS) on tour boats, combined with the growing use of photo identification to identify individual animals. Novel aerial research platforms such as blimps (Hodgson 2007; Hodgson & Marsh 2007) and unmanned aerial vehicles (Hodgson et al. 2013) may have merit in assessing impacts as they record and store data that can later be reviewed and analysed. Regardless of the research platform, to be able to accurately measure behaviour, sampling must be standardised, e.g. point samples collected consistently and at set intervals (Martin & Bateson 1993) to allow quantitative analysis.

Future Research

It is apparent from this study that vessel presence is having an influence on whale shark behavioural response. This leads to additional questions of whale shark response that, if understood, could benefit the management of tourism impacts on whale sharks. For example, do the increased changes in direction by whale sharks equate to an energetic cost and subsequent reduction in fitness through impacts on critical behaviours such as thermoregulation and feeding? Long-term changes in localised behaviour of white sharks (Carcharodon carcharias) have been detected in response to cage-diving tourism interaction (Bruce & Bradford 2013; Huveneers et al. 2013). Further, an evaluation of the code of conduct and its implementation may be warranted to determine whether the position and proximity of either vessels or swimmers is having an influence on whale shark behavioural response.

The research techniques used to explore these questions need to be carefully considered. While an aerial platform used for multiple purposes may be cost-effective, and provides an independent platform to reduce responsive movement of whale sharks, it does have its limitations. Martin (2007) suggests that data collected by the whale shark tourism industry could help fill some knowledge gaps about the behavioural ecology of this species. Tour vessels can offer another cost-effective platform for data collection. A recent study at Ningaloo that used tour boats as the research platform investigated residency time and inter-season return rate of individual whale sharks that were encountered during nature-based tourism interactions. The study found no evidence that interactions with tourists affected the probability of whale shark re-encounters and that instead, physical, biological and environmental factors better explained visitation rates of whale sharks (Sanzogni 2012; Sanzogni et al. 2015)

Behavioural information could be collected directly from tour vessels, and used to develop a more comprehensive ethogram of whale shark behaviour, as well as to evaluate the impact of swimmers and vessels on critical behaviour. However, this would likely require involvement of an independent observer, particularly to address questions relating to evaluation of the tourism industry and Management Program to remove any inherent bias.

Finally, potential impacts on whale sharks from vessel interactions could be investigated through other means, such as the presence of unique scarring on some whale shark individuals, which is an indicator of previous vessel strikes (Speed et al. 2008). This could be done using data from the on-board electronic monitoring system (EMS), coupled with photo-identification data to assess the relationship between quantity and severity of scarring with the length of interaction and number of repeated interactions per individual shark, and whether this varies over time. Our study demonstrated that it is possible to detect directional and some behavioural changes in whale sharks from aerial surveys and this research could be extended through alternative research platforms.

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Supplementary material

Aerial survey standard operating procedure

NINGALOO MARINE PARK

Department of Environment and Conservation

STANDARD OPERATING PROCEDURES

GOVERNMENT OF WESTERN AUSTRALIA

Aerial Whale Shark Interaction Behavioural Response Pilot-Program

PURPOSE

To determine whether significant changes in whale shark behaviour result from commercial tourism interactions operating under the existing Code of Conduct.

OBJECTIVE

Primary Objectives of Behavioural Flights

- To compare the interaction data collected with the data collected from the Whale Shark Interaction Log Book.
- To obtain adequate behavioural data on a whale shark before and during interaction with commercial tour operators (CTOs) (preferred).
- To obtain behavioural data on whale sharks without interaction from CTOs (control sharks).

- To obtain behavioural data on whale sharks during interaction from CTOs (‘interaction sharks’) when data before interaction is unavailable.
- To obtain data on non-compliance with whale shark interaction Code of Conduct.

Secondary Objectives of Behavioural Flights

- To survey the area not covered by industry spotter planes from Turquoise Bay to Black Rock to obtain a more accurate portrayal of the whale shark distribution along the Ningaloo reef front throughout the season.

METHODS

Organising Flights

- To organise the flights call Norwest Air Works on (08) 9949 2888 and clearly state that you would like to conduct a whale shark behavioural flight and that you are from the Parks and Wildlife. Book the flights as early as possible, the previous week is preferred.
- Flights should be booked to depart the light air strip by 09:30 am located approximately 10 minutes south of Exmouth. Aim to be there by 09:20 am.
- Two Parks and Wildlife staff members are required to conduct the behavioural study. One person will call out the whale shark behaviour and interaction while the other will record the observations. Try to keep the staff members conducting the behavioural observations consistent to reduce error as a result of unfamiliarity with the methods. A third seat will most likely be available and should be made accessible to other staff members/volunteers that have a work related purpose for the flight. Notify supervisors of the vacancy so they can discuss staff participation opportunities. If no one can be found then it should still be offered to everyone.

- **Note:** If a volunteer goes on a flight make sure they have filled out a volunteer agreement form.

Equipment Checklist

The following items are located in the 'Aerial Survey Equipment' case and must be maintained and taken on each of the flights:

- Lowrance iFinder H2O GPS system with SD memory card
- spare AA batteries for GPS
- Flight Com IIsx voice-activated intercom
- spare 9v battery for intercom
- audio recording device
- spare blank tapes/disks
- connection cable for Audio recording device and Intercom System
- stop watch
- 2 x folders each containing:
  1) whale shark behaviour logs x 20
  2) whale shark behaviour codes x 1
  3) scales for environmental data x 1
  4) pens attached x 1
- spare pens
- watch (personal)

It is recommended that personal items such as water, snacks and air sickness bags be taken on flights.

Pre-Flight Procedures

- Check the contents of 'Aerial Survey Equipment' case and replace any items if necessary. Check the batteries of the GPS.
- Set up the GPS system to record a trail of your movements before you leave the office. Please see 'Operating procedures for collecting, transferring and exporting whale shark spotter plane data' for setting up a trail on the Lowrance iFinder GPS. Name the trail in the format DDMMYY-WSBS (Whale Shark Behavioural Study). Once the trail is set up on the GPS turn the system off until boarding the aircraft.
- Arrive at the Light Air Strip at least 10 min before scheduled flight time. Allow 10 min travel time.
- Once arriving at the airport and prior to takeoff the following needs to be explained clearly to the pilot that will be taking your flight:
  1. As a preference to fly at 1000 ft.
  2. Initially to go where the industry and whale sharks have been interacting more frequently.
  3. Preferably like to locate and circle a shark prior to C.T.O.'s interacting with it (as much time before as possible). If not then,
  4. locate and circle either a control shark with no interaction or a shark already currently being interacted with
  5. Keep you informed of what the other spotter planes are currently observing.
  6. At some time during the flight you will advise them to fly down to Black Rock and return.
  7. Once you, other Parks and Wildlife member or the pilot locate a whale shark to circle it so you do not lose visual. State that you will let them know when you are finished

collecting data on the shark and will give them further instructions on where to go next, e.g. find another whale shark or fly down to Black Rock.

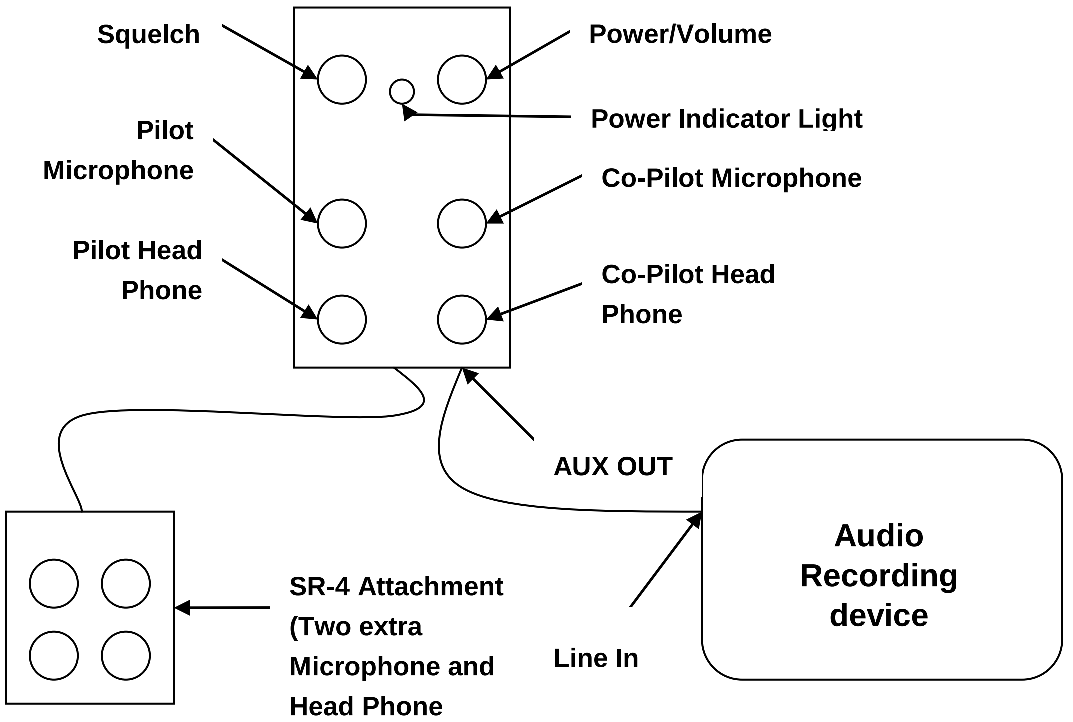
8. You will let them know when to head back to the Light Air Strip.

- The pilot will run through the pre-flight safety check

Organise Personnel and Equipment in Aircraft

IIsx Voice-Activated Intercom and Audio Recording Device

- Set up the voice-activated intercom and audio recording device as follows:



- This set up will allow you to talk uninterrupted without hindering the pilot's communication as well as allowing you to record observations made.
- Norwest Air Works will supply headsets for each passenger.
- Only attach the SR-4 attachment when there are more than 2 passengers.
- To activate turn the volume dial to the desired volume level.

- Adjust the squelch dial until the system gives continuous communication while speaking. Too little squelch and communication will be broken up, too much squelch and communication will be activated constantly with increased background noise.
- To locate the battery for replacement remove the back panel.

Lowrance iFinder H2O GPS Set up

- Set up the GPS to record your flight track (please see attached SOP for GPS set up).
- Turn on prior to takeoff.
- If you find it difficult to obtain a signal place either on the dash board of the aircraft or position it beneath the rear windows so that it has a clear line of site with the satellites.

Observer Roles and Equipment

- Should sit directly behind the pilot. This will aid in keeping a visual on the shark as the pilot circles.
- Have one folder open with the whale shark behaviour codes and log sheet open to aid in calling out whale shark behaviour and interaction.
- Is in charge of the audio recording device by pressing record when observations begin and pressing stop when the observations finish.

Recorder Roles and Equipment

- Can sit next to the observer or at the front of the aircraft.
- The second folder ready for recording the observations.

- Have easy access to GPS system to record the set up trail and mark the whale sharks spotted. If there is a third person give them the task of marking the whale sharks spotted on the GPS. Mark every whale shark spotted.
- Stop watch to record the elapsed and progressive time the observation took place.
- Watch to record the initial and final time the observations took place. **Note:** Most GPS systems and aircraft contain a watch.

In Flight Procedures

- Before locating a whale shark the recorder should fill out the top section of a whale shark behaviour log, including the:
  1. date
  2. observer names
  3. pilot name
  4. start time
  5. height
  6. wind strength (use the scales for environmental data)
  7. surface conditions (use the scales for environmental data).
- At first all personnel on the aircraft should be spotting for whale sharks.
- When a whale shark is spotted:
  1. If the pilot and/or observer has not located the whale shark let them know the location so they can change the orientation of the plane so that the shark is located on the pilots/observers side allowing the pilot to circle the shark and the observer can start making observations.
  2. The observer must:
     i. Press record the audio recording device.

ii. State the whale shark number for that day, e.g. the first whale shark with behavioural data collected is whale shark 1 (helps when listening to audio recording).

iii. State the initial heading and behaviour of the whale shark (use the coastline to obtain an estimated heading).

iv. State any interaction that may be taking place.

v. Give a progressive update on the whale sharks:

   a) heading

   b) vertical water position

   c) behaviour

   d) interaction.

   Approximately every 30 sec to 1 min or when a behavioural change or something of interest is observed (please see the sections on whale shark observations and interactions).

vi. If you lose visual of the whale shark due to glare, the whale shark diving or just lost visual then state that visual has been lost so that it is recorded.

vii. State an estimated size of the whale shark during the observations. You can use vessels to approximate the length.

3. The recorder must:

i. Mark the waypoint on the GPS system and note the waypoint number on the whale shark behaviour log. This is used to obtain the position of the whale shark when entering the data.

ii. Start the stop watch.

iii. Enter the initial time of the observation.

iv. Enter the initial whale shark bearing and behaviour.

v. Progressively record the observations made by the observer noting also the elapsed time after the initial observation (stop watch). Try to capture all the information observed. If you miss any data then ask the observer to repeat it. If that is not possible then do not be alarmed as the audio recorder will catch anything you miss.

vi. If possible obtain a minimum of 15 min total observation time for each whale shark. This will depend on the individual whale shark and the interactions taking place. Once you feel that adequate behavioural data has been collected move on to the next whale shark.

vii. If the whale shark dives still continue to circle for a period of time (approximately 5–10 min) and continue to make behavioural observations as it may resurface. If you are uncertain whether or not it is the same whale shark you were previously recording that resurfaced then start a new whale shark behaviour log.

Whale Shark Observations Elaborated

Whale Shark Heading

The whale shark heading is taken in respect to the coastline and is an estimated heading. The heading is given simply as "The whale shark is heading……..":

- North (N)
- North East (NE)
- East (E)
- South East (SE)
- South (S)
- South West (SW)

- West (W)
- North West (NW)

Whale Shark Vertical Water Position

Swimming at the Surface (SS):

The whale shark is swimming at or within a few metres of the surface.

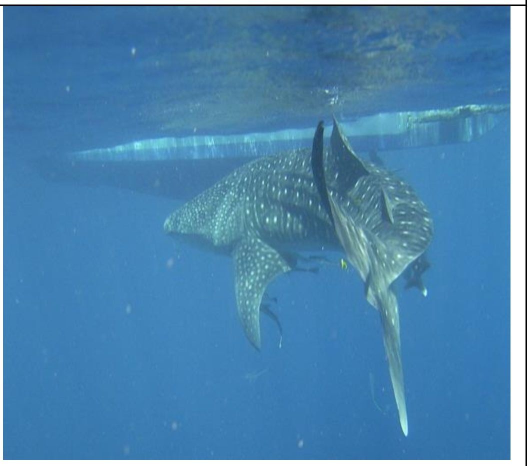
Swimming at Depth (SD):

The whale shark is swimming a few metres or more below the surface but is still visible.

Dived Deep (DD):

The whale shark has dived out of view and is no longer visible.

Whale Shark Behaviours

Behaviour	Description	Photo
Changed direction (CD)	The whale shark changed direction from its previous recorded heading. Record the new heading.	

Circled (CR)	The whale shark is swimming around in a circle.	
Dived deep (DD)	The whale shark has dived out of view and is no longer visible.	
Resurfaced (RS)	The whale shark has returned to the surface after diving.	**(no photo available)**
Investigated (IN)	The whale shark showed interest, attracted to something, inquisitive.	

No reaction (NO)	The whale shark continued as before showing no interest, taking no notice.	
Decreased speed (DS)	The whale shark slowed down.	**(no photo available)**
Increased speed (IS)	The whale shark increased speed.	**(no photo available)**
Swam at depth (SD)	The whale shark swam a few metres below the surface but is still visible.	

Note: The whale shark may show more than one behavioural reaction at a time. Note down all behavioural reactions that are observed. Also while recording use the short hand shown in the brackets.

- Example 1: As the whale shark approaches a group of swimmers it changes direction and begins to swim at depth (CD, SD).

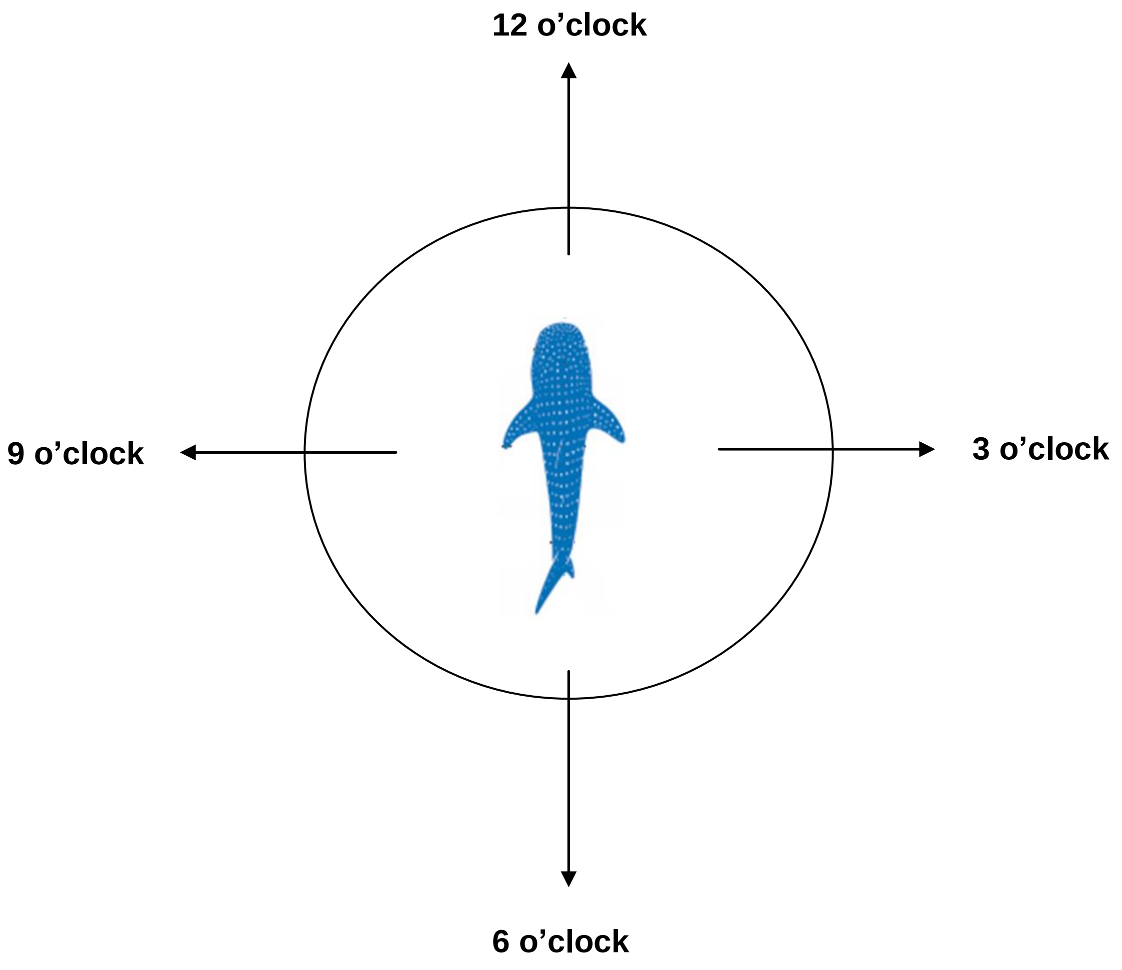
OR

- Example 2: As the whale shark approaches the group of swimmers it decreases its speed and begins to circle around them and becoming very inquisitive toward the swimmers (DS, CR, IN).

Whale Shark Interaction

Vessel

- If possible identify the vessel. If unsure ask the pilot.
- State the vessel/s position according to the whale shark. For example, if the vessel is directly in front of the whale shark the vessel will be at the shark's 12 o'clock. If the vessel is directly behind the whale shark the vessel will be at the shark's 6 o'clock.



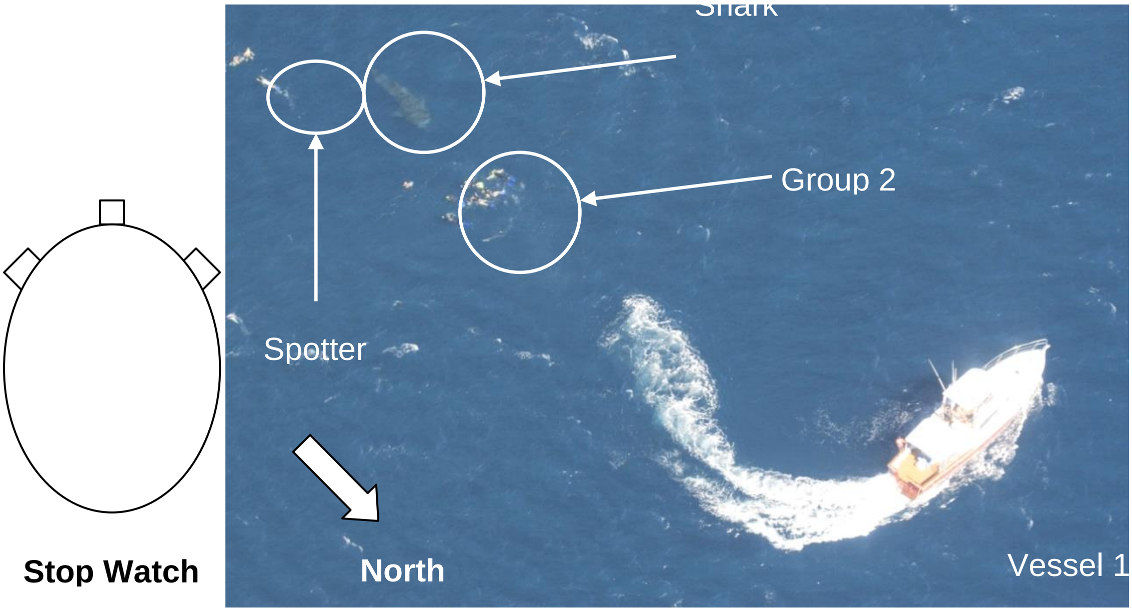
- State the vessel/s approximate distance from the whale shark in boat lengths. Only state a vessel as interacting if it is within 250 m (approximately 15 boat lengths).
- State the vessel/s status, i.e. whether it is
    a) making way (MW) – vessel is moving through the water (in gear) or,
    b) under way (UW) vessel is stationary (not in gear).

Swimmers

- When observing swimmers state:
    a) Initially what vessel they entered the water from (Vessel 1, Vessel 2, etc.).
    b) Initially what group number they are, each vessel should only have two groups (G1 and G2).
    c) When they have entered the water or in water and not yet in contact (IW).
    d) When they are in contact/swimming with the whale shark (C).
    e) When they are off the whale shark and no longer in contact(Off Shark or X).
    f) When the spotter is the only swimmer interacting with the whale shark. Usually swimming with one arm in the air (SPOTTER).

Example Observation Photographs

EXAMPLE 1



Observer:

"The whale shark is swimming at the surface heading north. Vessel 1 is making way to the shark's 11 o'clock at approximately three boat lengths. Group 1 is off the shark but the spotter is still in contact. Group 2 is currently in water not yet in contact."

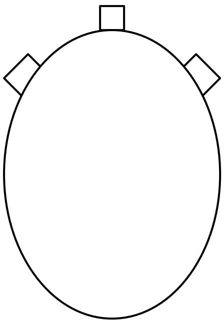
Recorder:

Time	Heading	Behaviour	Vessel 1 Distance	Position	Vessel Status	Swimmer Group
1:45	N	SS, NO	3	11	MW	SPOTTER, G1 X, G2 IW

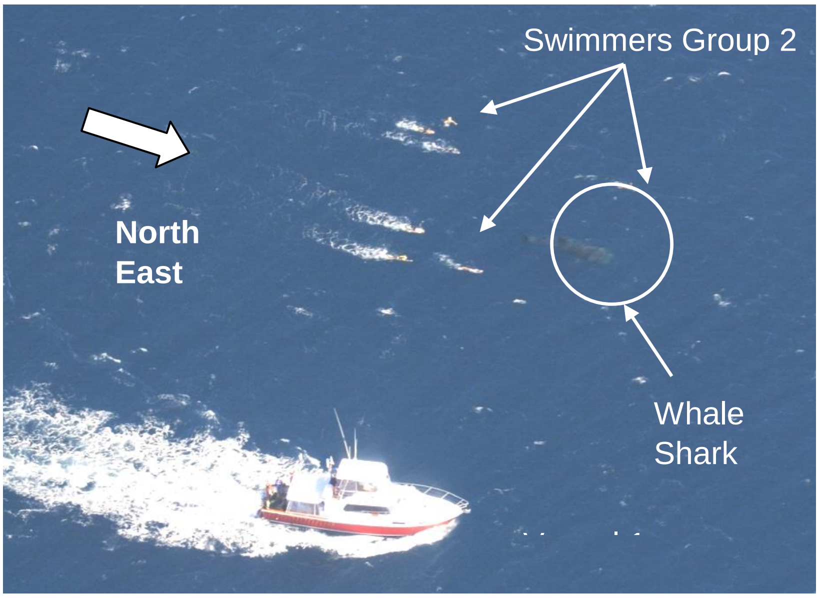
Comments:

The whale shark is currently not showing any kind of behavioural change and is about to come into contact with the second group of swimmers. Due to the position of the swimmers to the whale shark and its current heading the whale shark will more than likely show a behavioural reaction to the swimmers when it comes into contact.

EXAMPLE 2



Stop Watch



Observer:

"The shark is swimming at the surface heading north east. It looks like it has increased its speed. Vessel 1 is making way to the shark's 3 o'clock at one and a half boat lengths. Swimmers are starting to drop off the shark but some are still in contact."

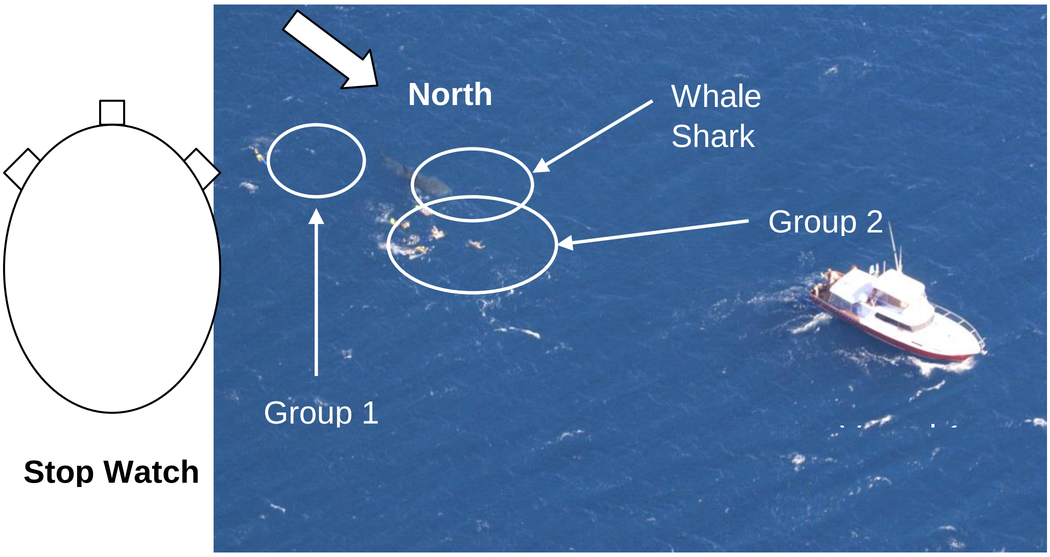
Recorder:

Time	Heading	Behaviour	Vessel 1 Distance	Position	Vessel Status	Swimmer Group
9:25	NE	SS, IS	1.5	3	MW	C

Comments:

It is hard to judge when a shark increases its speed, it is easier when there is a group swimming with it. Although swimmers have started to drop off there are still swimmers in contact with the shark, therefore the group is still in contact.

EXAMPLE 3



Observer:

"The shark has changed direction toward the swimmers heading north and swimming at the surface. The vessel is under way to the shark's 12 o'clock at two and a half boat lengths. Group 1 is off the shark and group 2 has just come into contact with the shark. It really looked like it was interested in the swimmers"

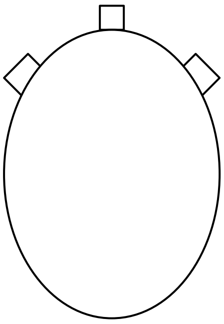
Recorder:

Time	Heading	Behaviour	Vessel 1 Distance	Position	Vessel Status	Swimmer Group
22:57	NE	SS, CD, IN	2.5	12	UW	G1 X, G2 C

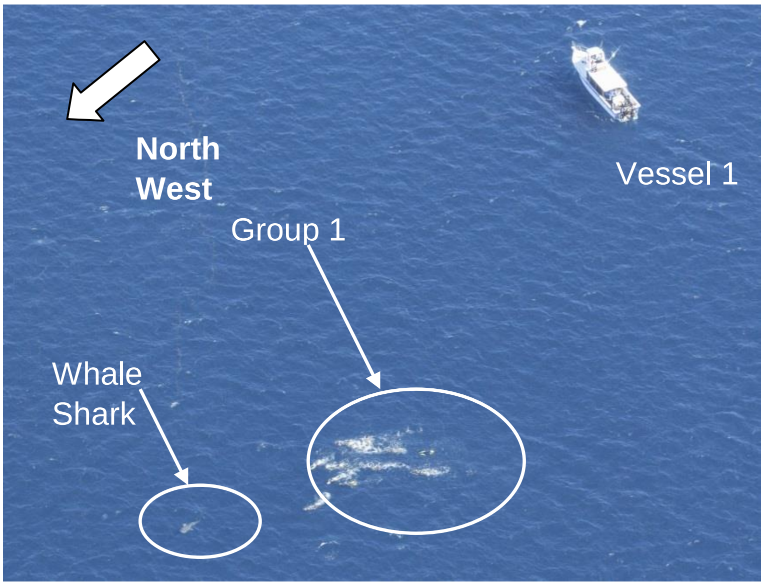
Comments:

If there is not enough room in the cells to write all observations then write in the comments section, clearly showing which observation you link that comment with. Make sure you get all behaviours recorded.

EXAMPLE 4



Stop Watch



Observer:

"The whale shark has just resurfaced now heading north west. The vessel is under way at the shark's 6 o'clock, six boat lengths. The swimmers are now off the shark but still swimming."

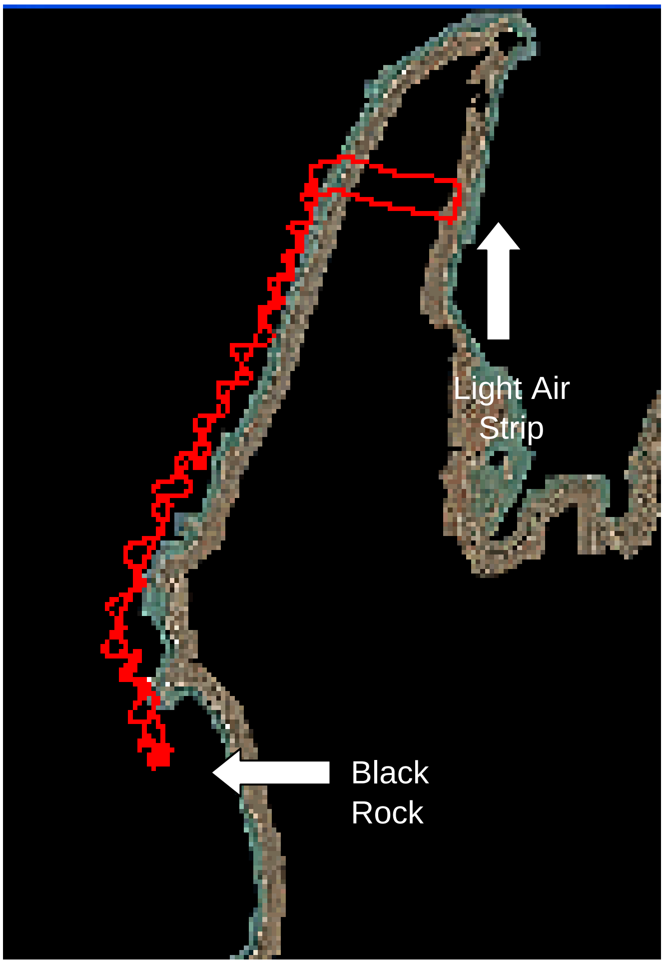
Recorder:

Time	Heading	Behaviour	Vessel 1 Distance	Position	Vessel Status	Swimmer Group
15:14	NW	SS, RS, CD	6	6	UW	G1 OFF SHARK

Comments:

Even if the shark dives keep circling as it may resurface. If the swimmers are still swimming they may still have a visual on the shark. If they stop most likely they will no longer have a visual.

Example Flight Trail



Post Flight Procedures

- After landing:

  a) Turn off the GPS.

  b) Record the finish time on the whale shark behavioural log.

  c) Disassemble equipment and return into the Aerial Survey Equipment case.

- After returning to the office:

  a) Remove the tape/disk from the audio recording device and label with the correct date.

b) Place the audio recording device on charge.

c) Remove and replace any used whale shark behaviour log sheets, place in order according to shark number, staple them together and file away in a file allocated to the whale shark behavioural flights.

d) Transfer, sort and save GPS data. Please see 'Operating procedures for collecting, transferring and exporting whale shark spotter plane data'. The folder location for saving the data is 'T:\422-Operations (District)\Shared Data\11 NATURE CONS\1114 Whale Shark Research and Monitoring\2007\Aerial Behaviour Study\Behaviour Study GPS waypoints and routes' for the behavioural study. The folder layout is the same as the SOP above.

e) The data and analysis for the 2007 season is saved at the location: T:\422-Operations (District)\Shared Data\11 NATURE CONS\1114 Whale Shark Research and Monitoring\2007\Aerial Behaviour Study\Behavioural Data 2007. Enter the data into the spreadsheet regularly as it is a time consuming process and spare blank tapes need to be made available for future flights. The entry and analysis is still currently being developed; however, it was found to be easier and more accurate to enter the data into the spreadsheet while listening to the audio recording from the flight. To obtain the progressive time of the observations the stop watch was used by starting it at the same time that the first whale shark observation was made on the audio recording and progressively entering the data into the spreadsheet and cross-referencing the data entered with the log sheets. Using both the data log sheets and the audio recording ensured that any observations made were not missed.

f) Once the data has been entered the audio recording can be deleted from the mini disc. To erase the discs:

   1. Enter into the menu.

2. Select ‘Edit’.
3. Select ‘Erase’, it will come up with the message “All track erase OK?”
4. Select ‘Yes’. ‘System file writing’ will appear on the display.
5. When completed ‘Blank disc’ will appear on the display.

As there are limited spare mini discs and none available for purchase the mini disc recordings must be entered and erased on a regular basis.

g) The data and analysis for the comparison between the observations made on the behavioural flights and the data collected from whale shark log sheets, filled out by the operators, can be found at the location T:\422-Operations (District)\Shared Data\11 NATURE CONS\1114 Whale Shark Research and Monitoring\2007\Aerial Behaviour Study\Behavioural Data 2007\Comparison Behavioural Data with Log Sheet Data. It is a simple process of finding which behavioural flight dates have vessels that have been identified and locating the corresponding whale shark log sheets for that operator. In the analysis, the whale shark position, heading, behaviours, estimated length, interaction time, contact minutes and whether or not the shark was handballed were compared and found to be a ‘match’, ‘no match’ or ‘n/a’ depending on the data available. A confidence level was also included that refers to the confidence level that it is the same shark between the behavioural flight (BF) and the whale shark log sheets (WSL).