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# Preliminary report on the impacts of swim-with-whale tourism on humpback whale behaviour in Hervey Bay, Queensland, Australia

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INTERNATIONAL
WHALING COMMISSION

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**Abstract**
The swim-with-whales (SWW) industry is rapidly growing; however, the literature to document the impacts of swimmers on target whale populations is currently limited. The International Whaling Commission (IWC) Scientific Committee has recommended that further research into the impacts from SWW programs is required and that a precautionary approach towards management of the industry should be taken until impacts are further understood. To fulfil the recommendations of the IWC, this study assesses the impacts of a newly sanctioned SWW program with humpback whales in Hervey Bay, Queensland, Australia. Between 19 July 2018 and 15 September 2018, 19 dedicated SWW trips were run and 32 pods were encountered. The behaviour of humpback whales were evaluated in 15-minute intervals Before, During, and After swimmers were in the water. Across Before, During, and After intervals (≥15 minutes), whales showed significant changes in the proportion of time spent in each behaviour. These changes occurred in both general behavioural states as well as more specific activity states. Between the During-After intervals, whales spent significantly less time interacting with the vessel, less time resting, and more time traveling. However, changes in the probability of behavioural state transitions analysed using Markov chains found no significant differences in transitions among the Before, During, and After intervals. Nineteen individual humpback whales were photographically identified and none were re-sighted within the same season during a SWW trip. It should be noted, that the results of this study are preliminary and represent only one season (six weeks) of data collection. Further data collection is needed to increase sample size and increase confidence in the results.

## Introduction

Swimming with wild cetaceans is a rapidly growing form of whalewatching tourism. The majority of swim-with-whales (SWW) programs are based on humpback whales (*Megaptera novaeangliae*) and are located in the Dominican Republic, French Polynesia, the Kingdom of Tonga, New Zealand and Mayotte (Mozambique Channel, Africa), with smaller additional SWW operations existing for other mysticete species (Gero et al., 2016; Rose et al., 2005). In a review of SWW tourism operations worldwide (excluding smaller cetaceans such as dolphins), Rose et al. (2005) found over 50 commercial operations advertising dedicated SWW programs via the Internet in 2005, compared to 29 operators in 2003 (Rose et al., 2003). This sharp increase over a relatively brief period has occurred without sufficient research into the impacts SWW activities may have on target species.

Few studies have investigated the impacts of swim-with programs on the behaviour and ecology of large baleen whales. In some locations and for some species, behavioural responses from SWW activities have been evaluated. Changes to behavioural budgets, such as decreased resting and socializing, and increased traveling have been documented for southern right whales (Lundquist, 2007; Lundquist et al., 2013) and increased swim speeds for humpback whales (Kessler et al., 2013). Other factors such as swimmers' behaviour and animal group composition may also play a role in animals' responses to swim-with activities (Machernis et al., 2018). Overall, the current research suggests that the rate at which swim-with whale operations are expanding may not be sustainable for the targeted population on which they rely (Gero et al., 2016).

Evaluating impacts from SWW activities on whale behaviour proves challenging given the lack of reporting and documentation from existing SWW operations, difficulty interpreting and documenting short-term disturbance, and further understanding the long-term, population-level consequences from disturbances of anthropogenic activities on marine mammals. Disturbance is not always apparent and can be mistaken by a layperson as innocuous or a natural shift in the animal's behaviour. For example, swimming with spinner dolphins in Hawaii is a growing concern given the large body of scientific research documenting a decrease in animal's resting behaviour (*e.g.* Danil et al., 2005; Johnston et al., 2014; Tyne et al., 2015). Behaviour which researchers categorize as disturbance is not always overt (e.g. increased stress hormones, inadequate rest) to a layperson, who may interpret spinner dolphins coming out of their resting behaviour to investigate a swimmer as a positive, non-disruptive response by the animal.

Short-term behavioural changes, such as decreased resting behaviour, increased swim speeds, and/or reduced foraging are important to monitor. Repeated short-term changes may lead to long-term consequences. The energy expenditure from continual avoidance from a source of disturbance can have biologically significant effects on the viability and fitness of individuals and populations. In addition, the effects of increased energy expenditure are exaggerated for animals that utilize a habitat solely for resting, such as spinner dolphins in Hawaii (*e.g.* Courbis & Timmel, 2009, Johnston et al., 2014; Tyne et al., 2015), or for breeding and calving activities, such as southern right whales in Argentina (Lundquist et al., 2008). Short- and long-term habitat displacement is also a response to anthropogenic disturbance. If the environment is considered degraded by a target population, animals may choose to abandon their preferred habitat and move into areas that may not be beneficial to perform essential life functions (*e.g.* Thorne et al., 2012).

The short- and long-term effects from SWW programs on target populations are largely under-studied, especially in light of how rapidly the industry is growing. In a recent survey of global SWW operations the authors recommended detailed studies should be conducted in each location containing SWW operations to examine the impact on individuals, groups, and populations of cetacean species to evaluate management options (Gero et al., 2016). These recommendations have been further supported by the International Whaling Commission (IWC) Scientific Committee. In its reviews of SWW programs worldwide, the IWC Scientific Committee has acknowledged that (1) the effects of SWW programs will vary among targeted species and populations, (2) further research into the impacts of swim programs is required, and (3) a precautionary approach towards management of swim programs should be implemented until the impacts are better understood (IWC, 2000; 2004).

In order to fulfil the recommendations of the IWC and monitor the development of the industry, our study assesses the impacts of a newly sanctioned SWW program on humpback whales in Hervey Bay, Queensland, Australia. The goals of this study are to better understand if humpback whales change their behaviour due to the presence of humans in the water; identify factors, if any, which influence whale behaviour change in response to swimmers; and identify any management issues associated with SWW tourism. Reducing human-induced disturbance to humpback whales is particularly important in resting grounds, such as Hervey Bay. In this study we observe and document whale behaviours during commercial SWW trips to determine if this activity is having an impact on the behaviour of humpback whales. The results presented here are preliminary and represent only one season (~6 weeks) of data collection.

## METHODS

### *Study site*

Hervey Bay is a wide, shallow bay located at 25°00’S, 152°52’E on the east coast of Queensland, Australia (Fig. 1). It is bounded by Fraser Island to the east and the Queensland coast to the west. Depths do not exceed 40 meters (m) throughout the majority of the bay, and most of the bay is 18 m deep with a sand and mud bottom (Vang 2002). This study was conducted within the Great Sandy Marine Park, an area covering approximately 6,000 square kilometres ($km^2$), including Hervey Bay itself (~ 4,000 $km^2$) (Queensland Department of Environment and Science 2018).

### *Survey effort*

All trips departed Urangan Harbour (25°17’34.5”S, 152°54’36.7”E) at 0700 and were conducted on a 12 m aluminium rigid hull vessel with four outboard engines. Trips lasted 3 hours, including the 30 – 45 minute travel time to and from the main whalewatching area. While underway, the vessel captain, crew, and a dedicated researcher used a continuous scanning methodology with the naked eye to locate whales.

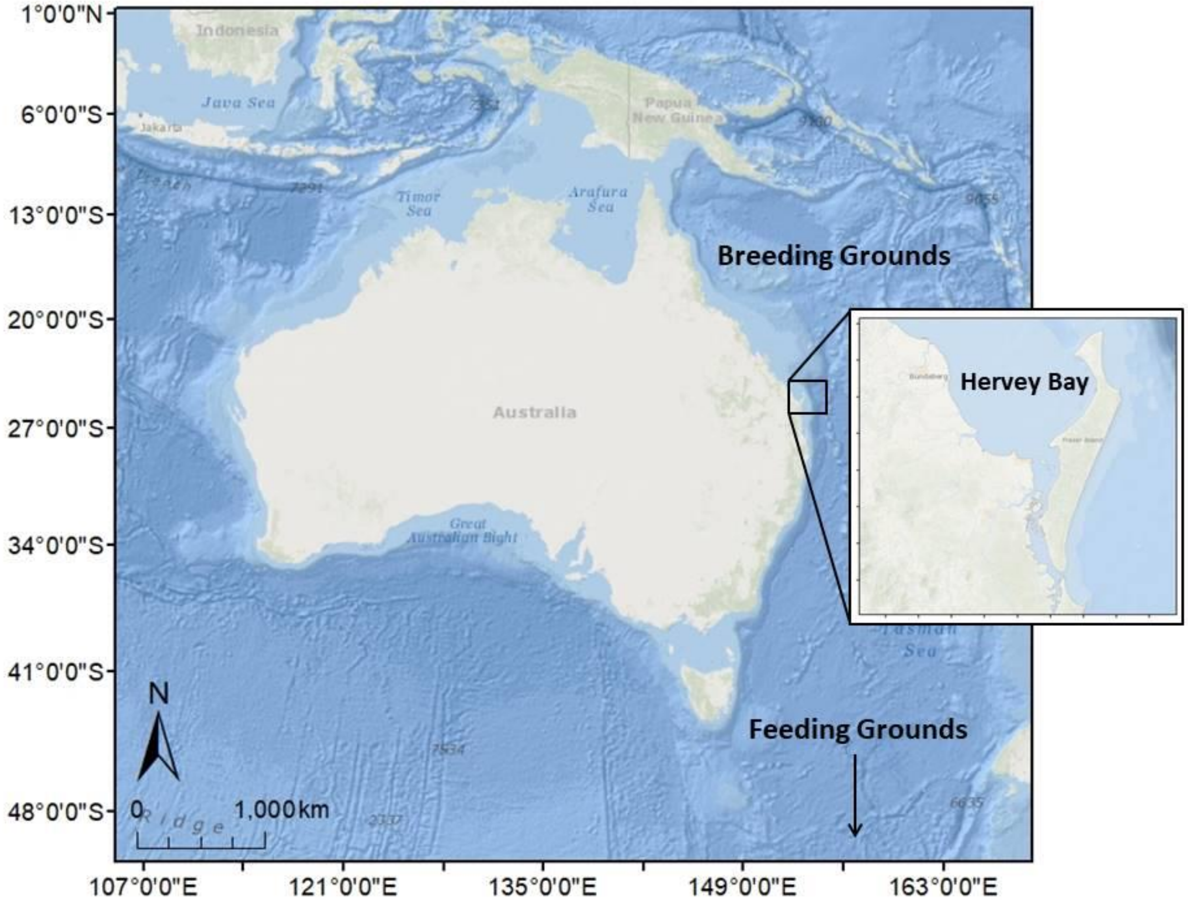



Figure 1: Map of study area showing relative position of Hervey Bay along humpback whale migration route

***Trip structure***

All SWW encounters were divided into discrete Before, During, and After intervals that lasted a minimum of 15 minutes (Fig. A1, appendix). The 15-minute minimum was selected to maximize time spent observing whales in Before, During, and After intervals within the constraints of a 3-hour SWW tour. Once whales were sighted, the vessel made its initial approach to the pod (300-500 m). The Before interval is defined as the time period beginning when the vessel initially approaches the pod within approximately 300 m. While in the Before interval, the captain maneuvered the vessel at a no-wake speed to follow the whales and did not approach the pod within 100 m. The captain used the Before interval to determine whether conditions were suitable for swimmers to enter the water. To remain in compliance with local regulations for SWW, no swim attempts were made if a calf was present (Fraser Coast Tourism & Events, 2018). For passenger safety, no swim attempts were made if there were rough sea conditions, or if the whales were exhibiting surface active behaviours or evasive behaviours (e.g., head slaps, peduncle throws, tail slaps, long dive times).

If conditions were suitable for swimmers to enter the water, the captain positioned the vessel near the pod while maintaining a minimum distance of 100 m from the animals and put the vessel engines in neutral. A "mermaid line" was attached to the bow of the vessel and placed in the water by a crew member (Fig. A2, appendix). The mermaid line consisted of a single line 20 m in length and 12 millimetres in diameter threaded through foam pool noodles along the entire length for flotation and stability. The During interval began at the time the line entered the water and continued until the mermaid line was removed from the water following a swim attempt. Swimmers were instructed to enter the water using a ladder to avoid excessive splashing and to keep at least one hand on the line at all times to remain in compliance with local regulations (Fraser Coast Tourism & Events, 2018). Up to 10 swimmers, including one crew member, remained in the water for a minimum of 15 minutes. Following a swim, when the mermaid line was retrieved, the After interval began and behavioural observations continued as the vessel followed the pod at a no-wake speed for an additional 15 minutes before leaving the whales and returning to the harbour (Fig. A1, appendix).

### *Data collection*

Beginning at the vessel's initial approach to a group, a dedicated researcher collected data on the composition of the focal pod and continuous behavioural data throughout the Before, During and After intervals. At the beginning of each interval, a GPS waypoint was taken using a handheld GPS (Garmin GPSMap78), and distance from the vessel to the group was determined using a Bushnell Legend 1200 laser range finder. Specific activity states were categorized into a set of five behavioural states which were mutually exclusive and wholly inclusive (i.e., a group could not simultaneously be in multiple behavioural states, and behavioural states encompassed all possible activity states) (Table 1). Whenever a change in activity state occurred, the researcher recorded the new activity state, the associated behavioural state, and the time of the observation (hh:mm).

### *Data preparation and filtering*

For analysis, we only included observations from Before, During, or After intervals lasting at least 15 minutes. We further excluded observations from an interval if there were any changes in group composition (i.e., animals joining or leaving the focal group) or if another vessel was present within 500 m, as we could not control for their effects on whale behaviour.

### *Data analysis*

#### *Proportion of time in each behavioural state and activity state*

To determine whether the presence of the vessel affected whales' activity budget, we tested for significant differences in the pooled proportion of time spent in each behavioural state and activity state in Before, During, and After intervals using a Z-test for proportions. The proportion of time spent in each behavioural state or activity state was calculated as the pooled number of minutes spent in each behavioural state or activity state per Before, During, or After interval divided by the pooled total number of minutes represented by that interval.

Table 1: Detailed descriptions of behavioural states with representative activity states

| Behavioural state | Description | Representative Activity States |
|---|---|---|
| **Diving (DV)** | Whales take visible dives and remain submerged for an extended period of time; includes fluke-up dives, fluke-down dives, and round-out dives | Fluke up dive<br>Fluke down dive<br>Round out dive |
| **Interacting with Vessel (IV)** | Whales approach vessel closer than 100 meters or display investigative behaviours such as spy hops | Mugging<br>Spy hop |
| **Resting (RT)** | Individuals remain stationary at the surface or mill at the surface without a clear direction of travel | Logging<br>Milling-Resting |
| **Socializing (SL)** | Whales visibly interact with one another; includes surface active behaviours with or without a clear direction of travel | Surface Activity (e.g. breach, pectoral slap, tail slap, peduncle throw)<br>Milling-Active |
| **Traveling (TR)** | All animals in the group travel in a consistent direction | Slow swim<br>Medium swim<br>Change direction |

*Rate of change in behaviour and activity states*

We assessed the rate of change in both behavioural and activity states by testing for differences in the amount of time between each state across Before, During, and After intervals. Time between changes in behavioural state was calculated as the number of minutes between each change in behavioural state. Time between changes in activity state was calculated as the number of minutes between each activity state. Time between behavioural and activity states was not normally distributed (Shapiro-Wilk test of normality: $W_{behavioural\ state} = 0.667$, $W_{activity\ state} = 0.704$, $p < 0.05$ both tests), so the nonparametric one-way Kruskal-Wallis was used to test for any differences.

*Duration of swim-with-whales activity*

We assessed whether either the group composition or the whales' overall behaviour before swimmers entered the water affected the amount of time whales spent with swimmers. Overall behaviour before a swim was defined as the behavioural state that the whale spent the majority of time in throughout the Before interval. The length of the During interval served as a proxy for the amount of time whales spent with swimmers. It is important to note that participants were asked to remain in the water for a minimum of 15 minutes regardless of distance to the group of whales (range of initial distance: During interval 105 – 300m; After interval 120 – 500m). However, if the whales remained nearby, swimmers had the option to stay in the water longer than 15 minutes with no set maximum time. Length of the During interval was not normally distributed (Shapiro-Wilk test of normality: $W = 0.652$, $p < 0.05$), so the nonparametric one-way Kruskal-Wallis was used to test any differences.

*Behavioural transitions*

When analysing sequences of events such as behavioural states, the dependence of each behaviour on its respective preceding behaviour can be quantified using Markov chains. Sequences of behaviours can be approximated as first-order Markov chains, where each event depends on the event immediately preceding it (e.g., Lusseau 2003). From the continuous behavioural observations, we determined the behavioural state occurring at regular 3-minute intervals over the entire observation time per Before, During, or After interval.

We constructed three 2-way contingency tables (preceding behaviour vs. succeeding behaviour) to tally instances of each transition between behavioural states for before, during, and after conditions. Transition probabilities ($p_{ij}$) were calculated as

$$p_{ij} = \frac{a_{ij}}{\sum_{j=1}^{5} a_{ij}} , \qquad \sum_{j=1}^{5} p_{ij} = 1$$

where $i$ is preceding behaviour, $j$ is the behavioural state immediately following $i$, and $a_{ij}$ is the number of instances of a transition between behaviour $i$ and behaviour $j$. Since transitions are possible among all behavioural states, the transition probabilities for each behaviour $i$ across all succeeding behaviours $j$ sum to one.

Due to small sample sizes for several transitions ($n < 5$), the Fisher's Exact Test (Fisher 1938) was used to test whether the probability of each individual transition differed across Before, During, and After periods. After the initial Fisher's Exact Test, we conducted further analysis, again using Fisher's Exact Test, to determine whether transition probabilities differed in pairwise comparisons of Before vs. During, Before vs. After, and During vs. After. The proportion of time spent in each behaviour was also tested among Before, During, and After intervals using a Z-test for two proportions to compare Before vs. During, Before vs. After, and During vs. After.

To further assess whether the presence of swimmers affected whale behaviour, we used loglinear modelling on a 3-way contingency table of behavioural transitions (preceding behaviour (P) vs.

succeeding behaviour (S) vs. before/during/after (B)). We compared three models: a saturated model (P*S*B), a ‘null’ model (P*S, B*P), and a model including all variables and their pairwise interactions.

*Photo-identification*

Whales were photographed opportunistically throughout the Before, During, and After intervals to obtain photo-identification (photo-ID) data on the targeted individuals. To determine if the same whales were subjected to swimmers on more than one occasion, within-season matching was completed.

## RESULTS

### *Survey effort*

Between 19 July 2018 and 15 September 2018, 19 dedicated SWW trips were run, and 32 pods were recorded. Of these, 4 pods were found to have a calf after initial approach, and 11 additional pods were abandoned after the initial approach due to weather conditions or whale behaviour. The remaining pods (N = 17) all had at least 15 minutes of observation in the Before interval. Of these, 4 pods were excluded from analysis due to the presence of another vessel (n = 1) or unsuitable whale behaviour (n = 3) in the During interval. The remaining 13 pods had a complete Before and During interval. Of these, 4 pods were excluded from analysis because pods either experienced changes in pod composition (n = 2) or could not be re-sighted (n = 2) between the During and After intervals, leaving 9 pods with complete Before, During, and After intervals.

### *Proportion of time in each behavioural state and activity state*

The proportion of time spent in each behavioural state significantly differed between the Before and After intervals for the behavioural states of Interacting with Vessel and Traveling (Z-test for two proportions, Interacting with Vessel: $Z = 4.09$, $p < 0.001$, Traveling: $Z = 5.97$, $p < 0.001$) (Fig. 2, Table 3). Between the During and After intervals, whales interacted with the vessel significantly less (Z-test for two proportions, $Z = 3.01$, $p < 0.05$), rested less (Z-test for two proportions, $Z = 4.47$, $p < 0.001$), and spent more time traveling (Z-test for two proportions, $Z = 5.24$, $p < 0.001$). Resting was the only behavioural state that showed a significant difference between the Before and During intervals, with whales resting significantly more (Z-test for two proportions, $Z = 5.11$, $p < 0.001$) in the During interval.

For some activity states, the proportion of time spent in the activity state significantly differed across Before, During, and After intervals (Fig. 3, Table 4). Whales spent significantly more time performing fluke-up dives in the Before interval than in the During interval (Z-test for two proportions, $Z = 2.02$, $p < 0.05$). Mugging was significantly different across all comparisons among intervals, with the highest proportion of time spent mugging in the Before interval (Z-test for two proportions, Before vs. During: $Z = 2.28$, $p < 0.05$, Before vs. After: $Z = 4.63$, $p < 0.001$, During vs. After: $Z = 3.22$, $p < 0.01$). The activity state of Milling-Resting had a significantly higher proportion of time spent in the During interval compared to either the Before or After interval (Z-test for two proportions, Z = 5.56, $p < 0.001$). Medium swim and slow swim activity states additionally showed changes across intervals; whales spent significantly more time in these behaviours in the After interval compared to the Before interval (Z-test for two proportions, Medium swim: Z = 6.83, $p < 0.001$, Slow swim: Z = 2.04, $p < 0.05$), and for the medium swim activity state, this difference was also significant when compared to the During interval ( Z-test for two proportions, Z = 4.43, $p < 0.001$).

Table 2: Percent time spent in each behavioural state per Before, During, and After intervals and results of Z-test for two proportions comparing Before vs. During, Before vs. After, and During vs. After intervals.

| **Behavioural state** | **Before (290 mins)** | **During (208 mins)** | **After (117 mins)** | **Significant change** |
|---|---|---|---|---|
| **Diving** | 34.1% | 31.7% | 29.1% | None |
| **Interacting with vessel** | 19.3% | 13.9% | 3.4% | Before-After; During-After |
| **Resting** | 2.8% | 15.4% | 0.0% | Before-During; During-After |
| **Socializing** | 23.1% | 16.8% | 17.1% | None |
| **Traveling** | 20.7% | 22.1% | 50.4% | Before-After; During-After |

Table 3: Percent time spent in each activity state per Before, During, and After intervals and results of Z-test for two proportions comparing Before vs. During, Before vs. After, and During vs. After intervals.

| **Activity State** | **Before (290 mins)** | **During (208 mins)** | **After (117 mins)** | **Significant change** |
|---|---|---|---|---|
| **Fluke down dive** | 0.3% | 1.4% | 0.0% | None |
| **Fluke up dive** | 20.0% | 12.5% | 15.4% | Before-During |
| **Round out dive** | 13.8% | 17.8% | 13.7% | None |
| **Mugging** | 17.2% | 9.6% | 0.0% | All $p < 0.05$ |
| **Spy hop** | 2.1% | 4.3% | 3.4% | None |
| **Milling-Resting** | 1.7% | 15.4% | 0.0% | Before-During; During-After |
| **Logging** | 1.0% | 0.0% | 0.0% | None |
| **Surface Active** | 11.7% | 8.7% | 8.5% | None |
| **Milling-Active** | 11.4% | 8.2% | 8.5% | None |
| **Change direction** | 4.5% | 1.9% | 4.3% | None |
| **Medium swim** | 2.1% | 5.8% | 23.1% | Before-After; During-After |
| **Slow swim** | 14.1% | 14.4% | 23.1% | Before-After |

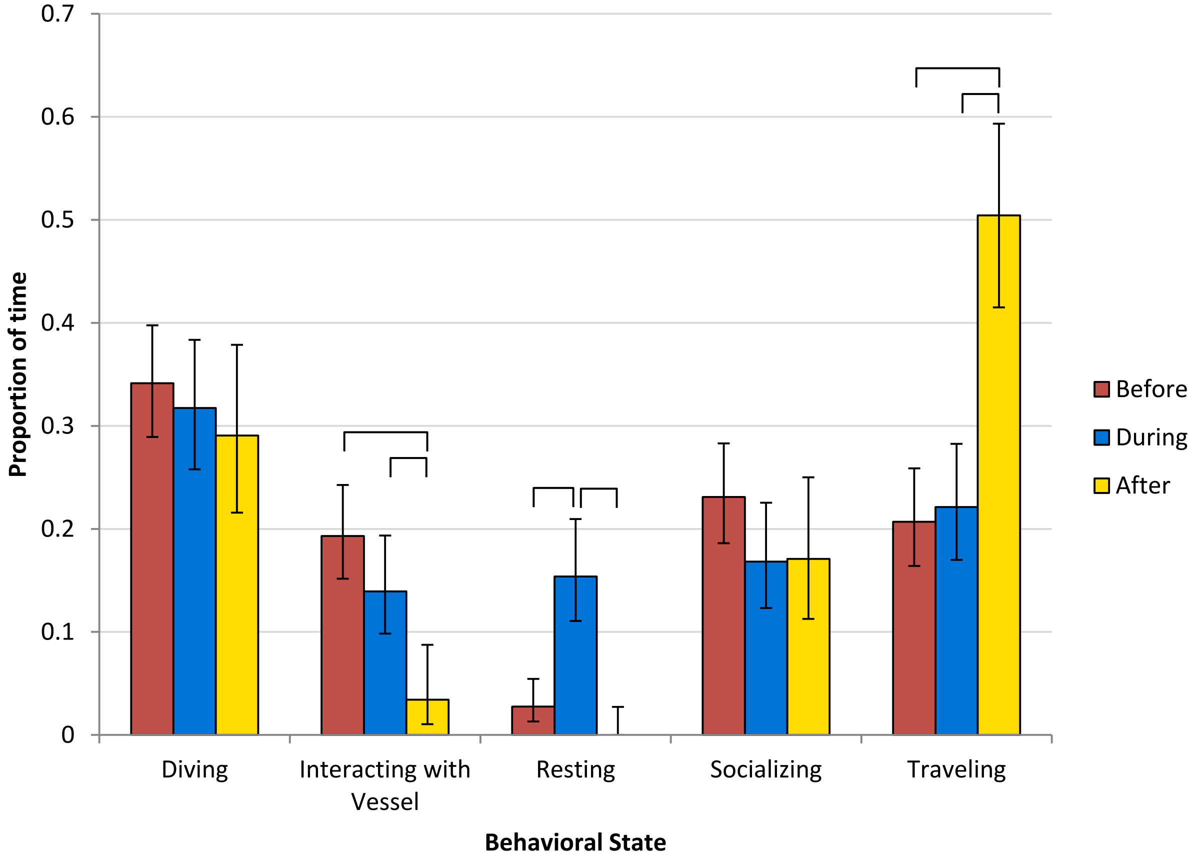



Figure 2: Proportion of time spent in each behavioural state over Before, During, and After intervals. Brackets indicate significant differences between proportions. Error bars represent 95% confidence intervals calculated using Adjusted Wald Method for proportions.

***Rate of change in behavioural and activity states***

The time between each observed change in behavioural state did not significantly differ across Before, During, and After intervals (Kruskal-Wallis test, $X^2 = 1.29$, df = 2, $p = 0.524$). However, the time between activity states did significantly differ across each of the Before (median = 2, range 1 – 19), During (median = 2, range 1 – 16), and After (median = 4, range 1 – 20) intervals (Kruskal-Wallis test, $X^2 = 8.99$, df = 2, $p < 0.05$).

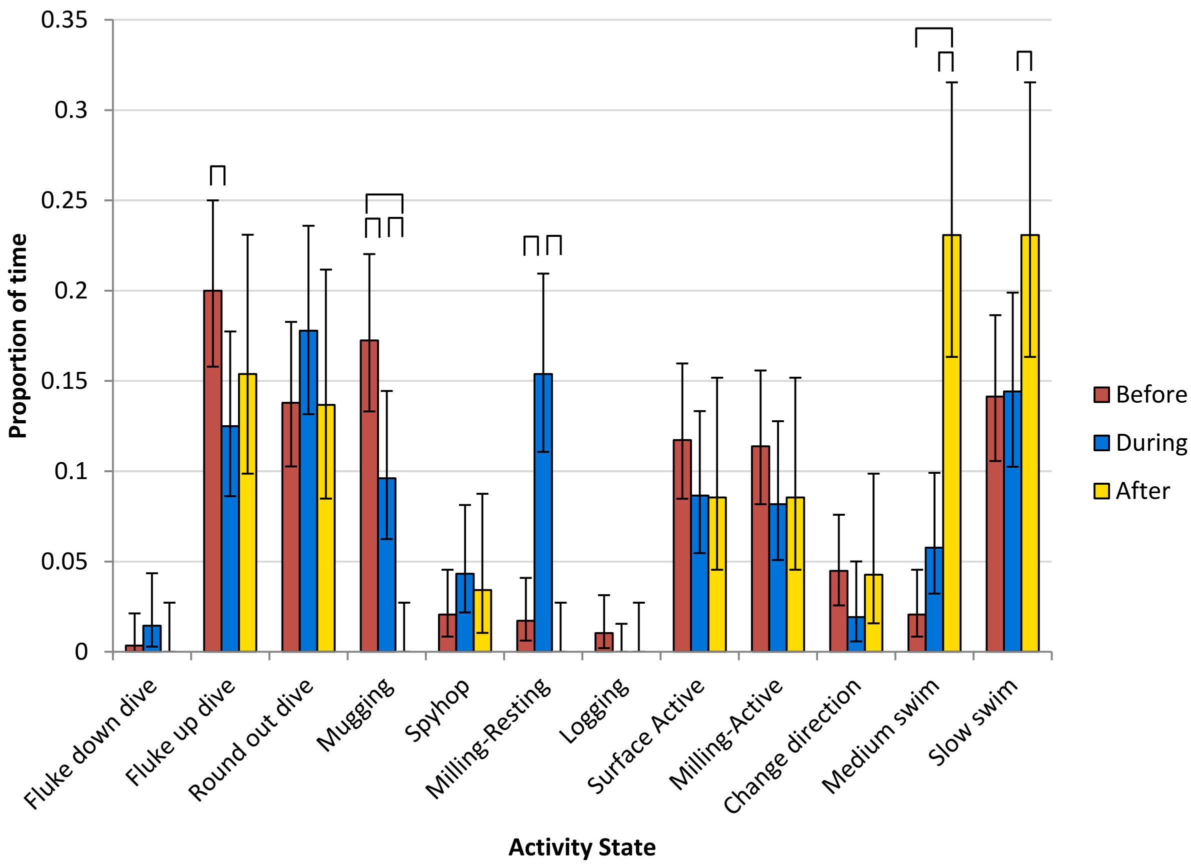



Figure 3: Proportion of time spent in each activity state over Before, During, and After intervals. Brackets indicate significant differences between proportions. Error bars represent 95% confidence intervals calculated using Adjusted Wald Method for proportions.

***Duration of swim-with activity***

Pod composition showed a significant relationship with median length of the swim-with activity (Kruskal-Wallis test, $X^2 = 56.23$, df = 6, $p < 0.001$) with the shortest swim time (16 minutes) occurring in a pod consisting of a single adult and a single subadult (n = 1) as well as a pod with two adults and a single subadult (n = 1) (Table 2). Pods of two subadults had the longest swim times (median = 28 minutes, range = 17–52 mins, n = 5). There was no significant relationship between swim time and overall pod behaviour before a swim.

Table 4: Length of interval and initial distance to pod for each Before, During, and After interval.

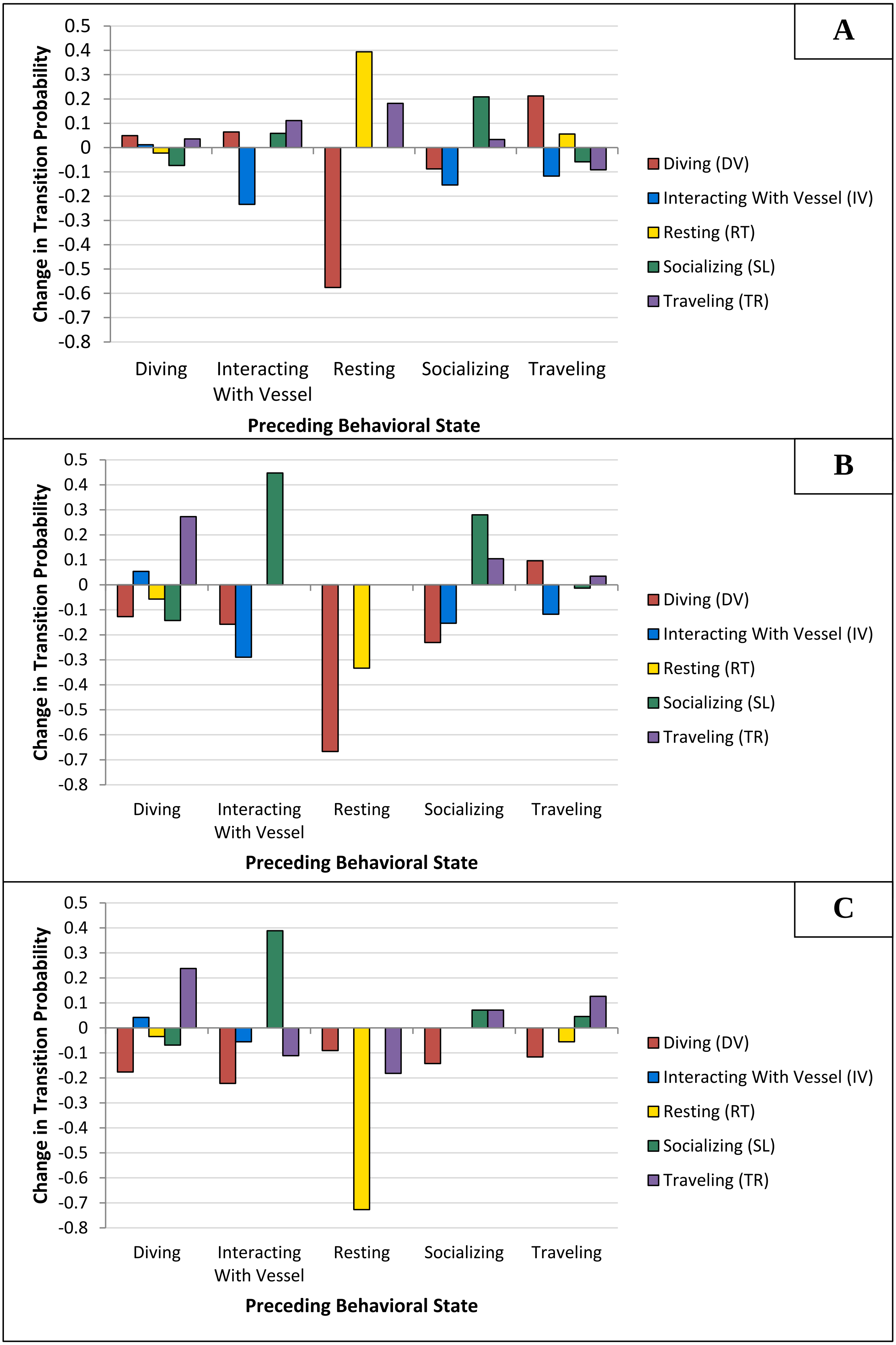
| Interval | Mean length of interval (minutes) | Mean initial distance to pod (meters) |
|---|---|---|
| **Before** | 22.41<br>(median = 20, range = 15 – 45) | 233.9<br>(median = 250, range = 80 – 300) |
| **During** | 24.35<br>(median = 19, range = 16 – 52) | 168.4<br>(median = 150, range = 105 – 300) |
| **After** | 17.0<br>(median = 17, range = 15 – 21) | 274.6<br>(median = 200, range = 120 – 500) |

***Markov chain analysis***

In total, 221 behavioural transitions were recorded (Before: n = 100, During: n = 81, After: n = 40) (Table 5). Before a swim, the behavioural state transition with the highest transition probability was IV-IV ($p_{ij}$ = 0.789; $a_{ij}$ = 15), while SL-SL had the highest transition probability both in the During ($p_{ij}$ = 0.786; $a_{ij}$ = 11) and After ($p_{ij}$ = 0.857; $a_{ij}$ = 6) intervals. The probability of the RT-DV transition showed the largest change across intervals, decreasing from 0.667 before a swim ($a_{ij}$ = 2) to 0.091($a_{ij}$ = 1) during a swim (Fig. 4). There were no occurrences of resting behaviour in the After interval, and the highest instance of the RT-RT transition occurred in the During interval ($p_{ij}$ = 0.727; $a_{ij}$ = 8) (Fig. 4). None of the individual behavioural transition probabilities significantly differed across before, during, and after periods (Fisher's Exact Test, p > 0.05 for overall test and pairwise comparisons). When comparing among loglinear models, the best model was the "null" model ($AIC_{null}$=106.62, $AIC_{pairwise}$=112.06, $AIC_{saturated}$=150.00); however, it did not significantly differ from the saturated model (Likelihood Ratio Test, $X^2$ = 36.62, df = 40, p = 0.62).

Table 5: Counts of each observed transition ($a_{ij}$ values) in Before, During, and After intervals.

| | Preceding Behavioural State | Succeeding Behavioural state | | | | |
|---|---|---|---|---|---|---|
| | | Diving | Interacting With Vessel | Resting | Socializing | Traveling |
| Before | Diving (DV) | 20 | 2 | 2 | 5 | 6 |
| | Interacting With Vessel (IV) | 3 | 15 | 0 | 1 | 0 |
| | Resting (RT) | 2 | 0 | 1 | 0 | 0 |
| | Socializing (SL) | 6 | 4 | 0 | 15 | 1 |
| | Traveling (TR) | 3 | 2 | 0 | 1 | 11 |
| During | Diving | 18 | 2 | 1 | 2 | 6 |
| | Interacting With Vessel | 2 | 5 | 0 | 1 | 1 |
| | Resting | 1 | 0 | 8 | 0 | 2 |
| | Socializing | 2 | 0 | 0 | 11 | 1 |
| | Traveling | 7 | 0 | 1 | 0 | 10 |
| After | Diving | 4 | 1 | 0 | 0 | 4 |
| | Interacting With Vessel | 0 | 1 | 0 | 1 | 0 |
| | Resting | 0 | 0 | 0 | 0 | 0 |
| | Socializing | 0 | 0 | 0 | 6 | 1 |
| | Traveling | 6 | 0 | 0 | 1 | 15 |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Socializing (SL)
Traveling (TR)

Figure 4: Difference in probabilities of each behavioural state transition from (A) Before to During intervals ($p_{ij(During)} - p_{ij(Before)}$), (B) Before to After intervals ($p_{ij(After)} - p_{ij(Before)}$), and (C) During to After intervals ($p_{ij(After)} - p_{ij(During)}$). Each preceding behavioural state is shown along the x-axis with its respective succeeding behaviours represented by color. Negative values indicate a transition probability was lower in the second interval than in the first interval. Likewise, positive values indicate a higher probability of a particular transition in the second interval.

***Photo ID***

From the 13 pods that had swim attempts, 19 individual whales were photographically identified. None of these whales were re-sighted within the same season on a swim-with-whales trip.

## Discussion

The preliminary findings represent a mix of significant and non-significant results, but the low sample size must be considered when interpreting these results.

*Behavioural analysis*

The highest incidence of resting behaviour occurred in the During interval, when swimmers were present in the water. During swims, the vessel remained stationary, either with the engines in neutral or completely shut off. This may result in less disturbance to the whale(s) from the vessel, either acoustically or from vessel behaviour, allowing the whales an opportunity to rest. There was, however, no resting behaviour recorded in the After interval. This could be an artefact of the tour boat choosing when to leave the whales, i.e. only departing from the group when the whales were choosing to leave the area, or it could be indicative of a behaviour change from the whales as a result of this activity. Au and Green (2000) report effects of acoustic disturbance to humpback whales in Hawaii with whales increasing swim speed in the presence of louder vessels. Given the increase in resting behaviour in the During interval, if whales are responding to the vessel's acoustic presence, an increase in traveling and an absence of resting could be a response to the vessel starting its engines to resume the focal follow of the pod after a swim. Further analysis with a larger sample size will reveal these trends in greater detail.

If the whales are spending more time traveling after a SWW encounter, it could reflect increased energy expenditure due to SWW activities. Repeated short-term changes can result in long-term energetic consequences. Added traveling costs from avoiding disturbances, such as swimmers, can add up over time and lead to insufficient energy for vital life functions, including reduced nursing opportunities for calves. Hervey Bay is a resting ground located mid-southern migration; many of the whales rest here for a short time prior to making their southern migration to the feeding grounds. If swim-with-whale tourism causes whales to use more energy than their energy stores allow, this behaviour change could, in turn, decrease the amount of energy available to feed, breed, migrate, and reproduce, which can have population-level impacts.

Although the time between overall behavioural states did not change significantly in response to the presence or absence of a swimmer, the time between individual activity state changes did increase in the After interval. This increase reflects more consistency in activity states in the After interval, and given the significant increase in time spent traveling, this effect could result from more consistent traveling behaviour following a swim.

Markov chain analysis did not detect any changes in the probability of behavioural state transitions. This could be due to the low sample size of specific behavioural state transitions (several $a_{ij}$ values < 5) which could reduce the power of the model to detect changes. However, this could also be due to effectiveness of abiding by local regulations designed to minimize disturbance, which prohibit approaches closer than 100 m, free-swimming, and entering the water with a calf present (Fraser Coast Tourism and Events, 2018).

*Effects on individual whales*

There is a potential for SWW tourism to have cumulative effects on certain individual whales, which could in turn lead to decreased fitness of those individual whales. None of the photographically identified whales were subjected to the swimmers in our study on more than one occasion in the 2018 season. This is likely an artefact of the low sample size, and we will continue to collect identification photos of these whales to see if there is potential for certain individuals to have greater exposure than others.

*Regulations*

This study did not examine tour operator adherence to the regulations, but our data collection trips followed the self-developed Code of Conduct for immersive interactions in the Fraser Coast (Fraser Coast Tourism and Events, 2018). The southern migration of this humpback whale population is age-structured, such that females with calves are the last age-class to enter Hervey Bay and the later portion of the whale season consists of mostly mother-calf pods (Stack et al. 2019). Swimming with a calf present is prohibited in this region, so the swim-with-whales activity is only offered in practicality from July-early September. There are indications in other regions that lactating females have abandoned areas in response to vessel traffic, so these precautionary measures are beneficial for protecting resting mother-calf dyads in Hervey Bay (Cartwright et al. 2012). Previous research has documented the spatial and temporal patterns in distribution of humpback whales over the 12 years just prior to the initiation of SWW tourism (Stack et al. 2019) as a baseline for comparison to examine if changes occur in how whales use this area after the initiation of this activity.

*Limitations of this study*

It is difficult to confidently assign observed changes in whale behaviour to the presence of swimmers in the water, as there are confounding effects from the presence of the vessel.

Comparing behaviours before and after the swimmers entered the water helps to understand direct impacts from swimmers; however, it does not completely remove the impact that vessel presence has on the target whale(s). There is potential that some of the observed behaviours were caused by the duration of time the vessel spent with a focal group. By the end of the observation period, the vessel spent a minimum of 45 minutes with the same focal group of whales, and there could be some compounding effects from exposure time to the vessel. Corkeron (1995) reported that whalewatching in Hervey Bay causes short-term behavioural changes in humpback whales and suggested that long-term avoidance of the area is a possibility if tourism pressure continues to increase in this region.

As this was the initial year of study, we acknowledge that a greater sample size will increase confidence in the results and allow for a more robust assessment of any effects SWW activities may have on humpback whale behaviours in Hervey Bay. Data collection is continuing in the 2019 season.

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# Appendix

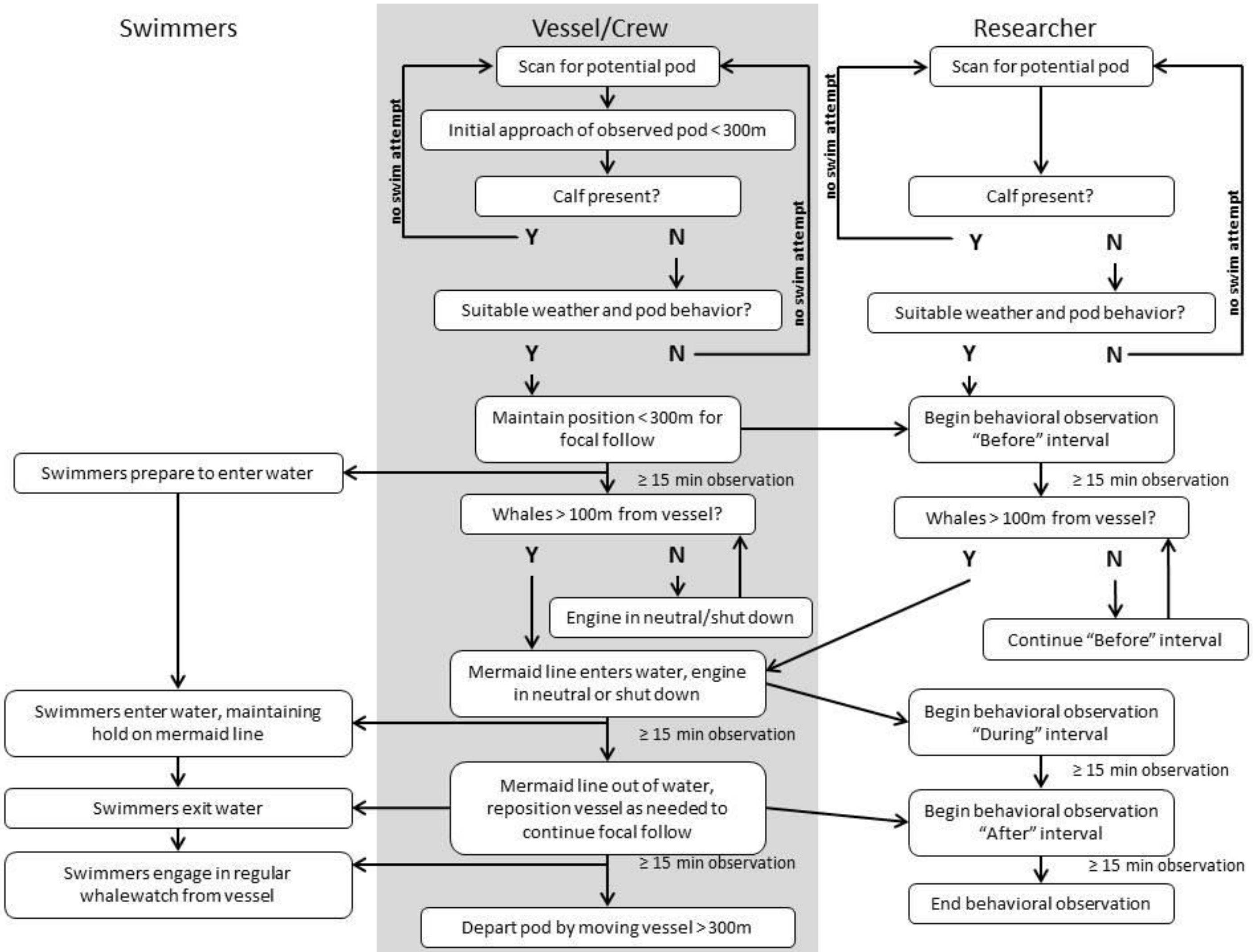


Figure A1: Flowchart diagram of SWW procedure as it relates to the swimmers (left panel), vessel and its crew (center panel, shaded), and the onboard researcher (right panel). Arrows between panels represent events occurring simultaneously in multiple roles.

Figure A2: A sub-adult humpback whale approaching the mermaid line with 8 swimmers present, including one crew member.