The use of underwater viewing deck of the semi-submersible whale-watching vessel *Yellow Submarine* at Península Valdés, Argentina as a platform of opportunity for scientific research with the southern right whale, *Eubalaena australis*

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Whale-watching vessels have been used as platforms of opportunity to conduct a variety of scientific studies on cetaceans in different locations around the world (*e.g.* Robbins, 2000; Robbins and Mattila, 2000; Williams, 2003; Bejder, 2005; Peters *et al.* 2013; Christiansen *et al.*, 2014). In Península Valdés, Argentina, such studies include those by Rivarola *et al.* (2001), Coscarella *et al.* (2003), Tagliorette *et al.* (2008)[1], Argüelles *et al.* (2016), Fazio *et al.* (2016) and Arias *et al.* (2018) and the vast majority of the studies rely on observations from the top deck of vessels while cetaceans are at the surface, whereas underwater visual data can only be collected by using underwater cameras. Whale-watching vessels that offer direct underwater viewing of large whales are exceptional (*e.g.* in the southern hemisphere: Whale Watching Hervey Bay, <http://whalewatchingherveybay. com>).

The company Yellow Submarine (YS) from Argentina developed a semi-submersible vessel especially designed to watch whales underwater. The vessel operates during the southern right whale (*Eubalaena australis*) calving season (June through December) from Puerto Pirámides, Península Valdés, Argentina (42°33'S, 64°16'W), between Punta Piaggio (42°19'S, 64°16'W) and Punta Alt (42°24'S, 64°9'W), the only licensed area for whale watching operations (Fig. 1). The
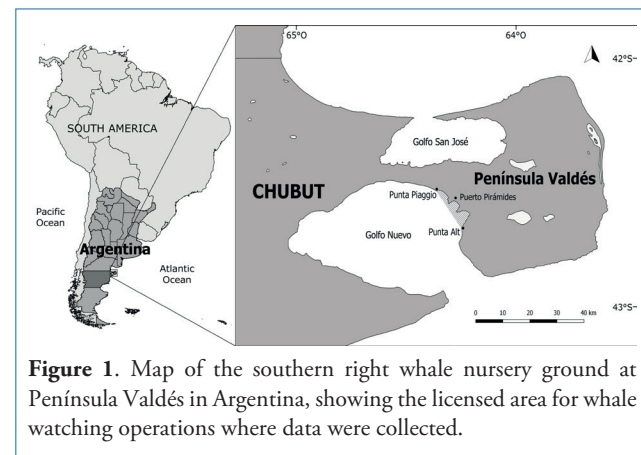

Figure 1. Map of the southern right whale nursery ground at Península Valdés in Argentina, showing the licensed area for whale watching operations where data were collected.

vessel has an overall length of 17.2 m, a 4-m beam and 2.1-m draft. Passengers can watch whales from the outdoor upper deck as a conventional tour and from the lower deck with underwater viewing. This lower deck has 40 viewing windows and seats (Fig. 2). As part of a cooperation agreement between the Instituto de Conservación de Ballenas (ICB, Whale Conservation Institute), a nonprofit organization dedicated to whale research and conservation, and YS, volunteer naturalists went on whale watch trips to collect basic scientific data to evaluate the *YS* underwater deck as a platform of opportunity for southern right whale research applied to behavior, health and population dynamics.

Specifically, we determined the percentage of whale watch trips during which the whales were observed underwater; the age class composition of the animals observed; the behavioral repertoire of different age and sex classes that can be observed; and the percentage of animals that could be sexed, particularly

[1]Tagliorette, A., Janeiro, C., Fernández Ajó, A., Harris, G., Bandieri, L. and Giese, C. (2008) *Monitoreo de avistaje de ballenas embarcado y costero en Puerto Pirámides, Chubut*. Proyecto "Consolidación e Implementación del Plan de Manejo de la Zona Costera Patagónica para la Conservación de la Biodiversidad", Fundación Patagonia Natural. ARG/02/ G31 GEF– PNUD, Chubut, Argentina. 60 p. Available in: http://www. patagonianatural.org/publicaciones/proyectos-tecnicos/informes-tecnicos/item/pmicp-2-informe-tecnico-n-16

Figure 2. The *Yellow Submarine* in Puerto Pirámides and its underwater viewing deck (left photo credit: Yellow Submarine S.A.).

for calves. Also, we assessed whether it was possible to photo-identify the whales observed from the underwater viewing deck; the average distance to the whales and the time frame of the observations; and the frequency of observations made from the port and starboard sides of the vessel. Additionally, we recorded whether unusual observations were made from the underwater platform, whether plankton was or was not visible and the average weather conditions (visibility, cloud cover, sea state, water temperature) during the trips.

Data were collected during the southern right whale calving season between 3 October and 20 November 2014 (33 trips of 110 ± 10 min) and between 30 August and 30 October 2015 (38 trips of 110 ± 10 min), totaling 71 whale watching trips on board the *YS* by one trained observer at a time in the underwater viewing deck of the *YS*. Frequently, the captain used the audio system to anticipate the side of the ship where the observations would most likely occur, allowing the observer to move to the appropriate side. Real-time images from cameras at the bow and the stern were displayed on a screen in the underwater deck. At all times it was possible to observe and detect animals in both port and starboard simultaneously, as the lower deck is considerably narrow (1.3 m wide and 12.9 m long).

At the beginning of each trip, the observer recorded the date, time, water temperature (Celsius), weather conditions including sea state (1 = flat calm; 2 = ripples with some white water; 3 = 0.6-1 m waves with white caps; 4 = 1.5-2 m waves with white caps) and percentage of cloud cover (1 = 0-25%; 2 = 26-50%; 3 = 51-75%; 4 = 76-100%), assessed water visibility on a subjective scale (1 = good; 2 = medium; 3 = bad), and noted if plankton was visible. Whale groups were classified by age class as mother-calf pair (MC), adult (A), juvenile (J) or indeterminate (I). A group was classified as mixed (MG) when individuals of two or more age classes were present.
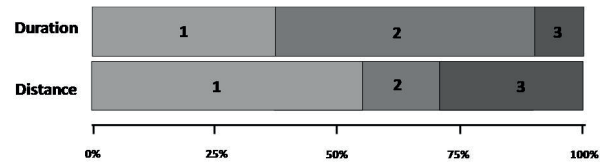

Figure 3. Estimated distance between the whales and the boat (1 = 0-5 m; 2 = 5.1-10 m; 3 = 10.1 m or more) and duration of underwater observations (1 = 1-5 sec; 2 = 6-10 sec; 3 = more than 10 sec).

During each encounter with a whale or whale group, the following mutually exclusive behavioral events were recorded for each individual whale: swimming parallel to the boat, swimming away from the boat, swimming toward the boat, nursing, whale passes under the boat, mating, surface activity (rolling at the surface, flipper/fluke slapping, breaching), resting or not determined. Each behavior change was recorded by the observer as a new behavioral event and often more than one behavioral event was recorded during a single encounter (*e.g.* swimming towards the boat may transition to passing under the boat during a single encounter).

Sex was recorded when the genital slit was observed and, if conditions allowed, photographs of the callosity pattern were taken for individual identification[2]. The closest distance between the whales and the boat was assigned to one of the following categories: 1 = 0-5 m; 2 = 5.1-10 m; 3 = >10 m; and duration of the observations in seconds was recorded in ranks: 1 = 1 to 5"; 2 = 6 to 10"; 3 = >10". The boat side of the first approach to the whales was also noted (P = port side; S = starboard side).

[2]Payne, R., Brazier, O., Dorsey, E.M., Perkins, J.S., Rowntree, V.J. and Titus, A. (1983) External features in southern right whales, *Eubalaena australis*, and their use in identifying individuals. Pages 371-445 *in* Payne, R. (Ed.) *Communication and behavior of whales*. AAAS Selected Symposium 76, Westview Press, Inc., Boulder, CO.

The observer took photographs and recorded observations, including significant lesions, physical contact between the whales and the boat and any unusual events. All photographs and observations were made during regular whale watch tourist trips, and no changes in the boat's maneuvers or the duration of the trips were requested by the observer to improve the quality or increase the volume of the data collected. Pearson's Chi-Squared tests were applied using the R statistical environment (R Development Core Team, 2011) to test for potential differences between the frequency of behavioral events among the age classes.

Visibility was considered to be medium in 45% (n = 32), bad in 41% (n = 29) and good in 14% (n = 10) of the trips. Weather conditions were predominantly good, with clear sky (1) or partly cloudy (2) in most trips (65%; n = 46). Sea state was flat calm (1) or calm (2) in most trips (94%; n = 67). The mean sea surface temperature was 11.2°C in September and 12.1°C in October 2015. We recorded presence/absence of visible plankton in 27 trips in 2015. Visible plankton was present in 19 (70%) of the trips.

Whales were observed underwater in 96% (n = 68) of the trips. On average, 2.32 ± 0.34 different groups were observed on each trip, with a maximum of seven groups on a single trip. The average number of underwater sightings per trip (*i.e.* all groups seen during the same trip, including re-sightings of the same group or groups) was 4.41 ± 0.56. In 342 whale sightings in both years, the first approach occurred from the starboard side on 54% (n = 184) and from the port side on 46% (n = 157) of the encounters. Whales were observed from both sides at the same time only once.

From a total of 187 different groups observed, 74% (n = 138) were mother-calf pairs, 23% (n = 44) were adults, while the remaining 3% were juveniles (n = 2), mixed groups (n = 2) and one solitary individual of indeterminate age. Sex could be determined in only 2% of the encounters with calves (n = 260), in 15% of the encounters with adults (n = 102) and for only one of the five juveniles observed.

The closest distance between the whales and the boat during the observations was estimated for a total of 236 encounters and the most frequent distance range was 5.1-10 m (n = 123; 52%) followed by 0-5 m (n = 90; 38%) and more than 10.1 m (n = 23; 10%), *i.e.* 90% of observations were made at less than 10 m (Fig. 3). The duration of the underwater observations was recorded for all the encounters with whales (n = 342); most encounters (n = 188; 55%) lasted between 1 and 5 sec, followed by encounters that lasted more than 10 sec (n = 93; 27%) and those that lasted between 6 and 10 sec (n = 61; 18%).

A total of 775 behavioral events were recorded during 342 whale sightings (Fig. 4). No differences were found in the frequency of the behavioral events recorded between mothers and calves (n = 663; χ^2 = 6.60; p = 0.25; df = 5). The most frequent behavioral events were (1) swimming parallel to the boat, (2) swimming away from the boat and (3) passing

under the boat (Fig. 4a), which totalled 83% and 85% of the patterns observed for mothers and calves, respectively. The frecuency of behavioral events for adults differed slightly from those of mothers (n = 414; χ^2 = 18.14; p <0.05; df = 5) and calves (n = 473; χ^2 = 22.30; p <0.05; df = 5). The most frequent behavioral patterns of adults were (1) swimming parallel to the boat, (2) passing under the boat and (3) swimming away from the boat, totaling 80% of the patterns observed. The remaining patterns included swimming toward the boat, resting and surface activity (Fig. 5). Conditions to take identification photographs during observations were good in 3% of observations of mothers (n = 220), 5% of
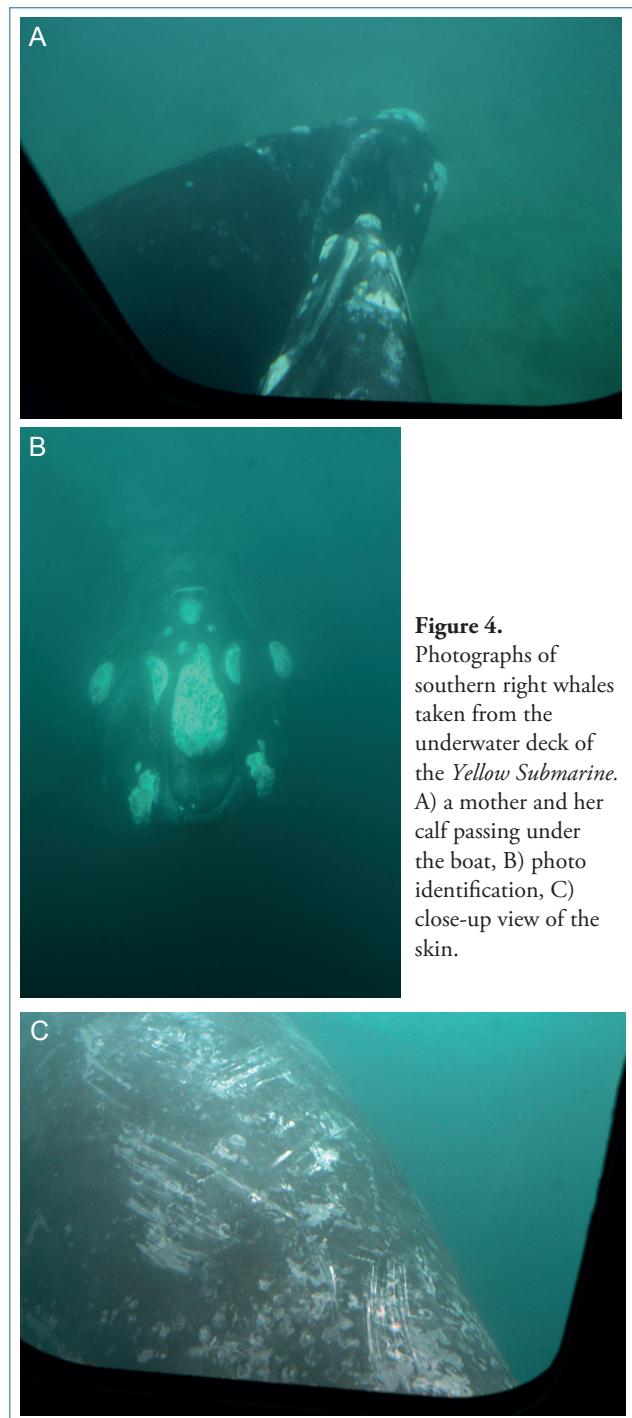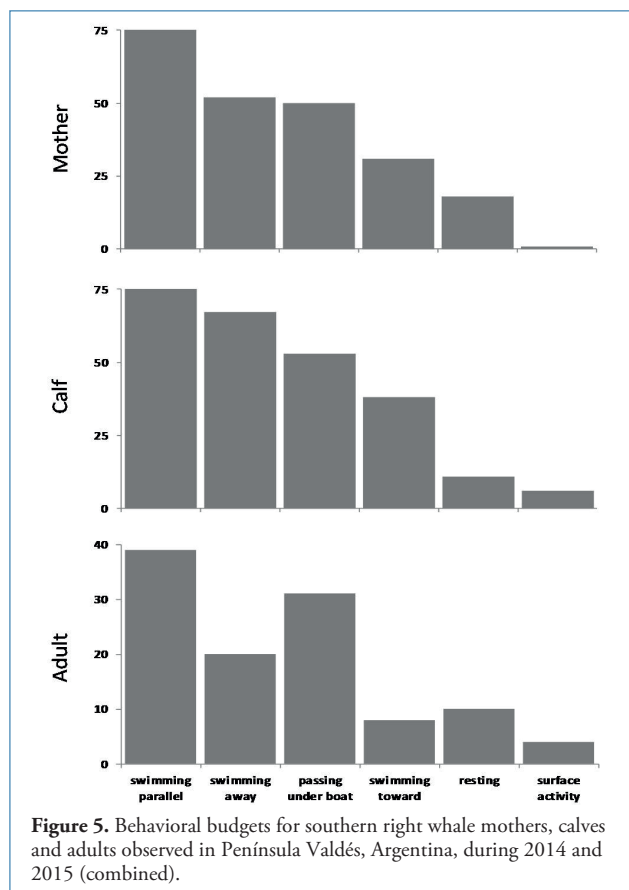
Figure 4. Photographs of southern right whales taken from the underwater deck of the *Yellow Submarine.* A) a mother and her calf passing under the boat, B) photo identification, C) close-up view of the skin.

calves (n = 260), 5% of other adults (n = 102) and 0% of juveniles (n = 5) (Fig. 4b).

During the underwater observations, we could also visualize a series of unusual behavioral events and report clear human-induced injuries in the body of some southern right whales in this calving ground, as follows: (1) a young calf was photographed carrying a small rope in its mouth on 28 October 2014; (2) an adult female with a propeller scar on her left flank was observed on 17 October 2014; (3) there was physical contact between a calf and the boat on one occasion when the calf rubbed its body against the boat (2014); (4) a male was observed copulating with an adult female accompanied by a calf on 8 September 2015; (5) a very active calf hit the boat on 14 September 2015 and continued to move toward the stern of the boat.

Whale-watching has become a major tourist industry in Península Valdés, Argentina (Rivarola et al., 2001; Sironi et al., 2005; 2009; Chalcobsky et al., 2017). This study aimed at assessing the underwater viewing deck of the whale-watching vessel *Yellow Submarine* in Puerto Pirámides, Península Valdés as a platform of opportunity to conduct scientific research with southern right whales in this nursing ground. As a general conclusion, the whale-watching vessel *Yellow Submarine* offers a unique platform to observe southern right whales at Península Valdés, Argentina from an underwater perspective, although the main limitations are the relatively short duration of the observations and the reduced visibility due to plankton blooming in spring.

Figure 5. Behavioral budgets for southern right whale mothers, calves and adults observed in Península Valdés, Argentina, during 2014 and 2015 (combined).

The proportion of trips when whales could be observed from the underwater deck was very high (96%). However, this does not imply that good quality data and/or photographs could be collected on every trip (Carlson et al., 2016). The mean duration of the observations was 10 sec or less and visibility was considered to be good in only 14% of the trips. Distance estimates indicate that most observations were made at 10 m or less, limited by visibility. In 2015 plankton was visible in 70% of the trips when presence/absence were recorded, which increased turbidity and reduced visibility due to suspended particles, possibly constituted by invertebrates, fish larvae and/or phytoplankton. The combination of these factors curtailed the chances to obtain high-quality photographs of the callosity patterns for individual identification[2], e.g. only 3% of mothers and 5% of calves could potentially be photo-identified. The difficulty to obtain photographs of the callosity patterns could hinder certain research studies that are based on photo-identification of individual whales. Reduction in underwater visibility during September–November (southern spring) as recorded in this study could be expected, since plankton begins to bloom and whales are sometimes seen feeding (Sironi, 2004; Hoffmeyer et al., 2010; D'Agostino et al., 2016). Therefore, considering that the whale-watching season goes from June through December (Sironi et al., 2005; 2009), it is likely that better and longer observations could be made during the winter months (June-August) when visibility is better (Wilson et al., 2015). We also recommend to use the front part of the deck to increase underwater sighting duration.

The design of this study did not involve a systematic protocol for a visual health assessment of individuals. However, we believe that the close-up view of the skin and general body condition with a level of detail that is not possible from other platforms (e.g. shore-based or upper deck observations) is probably the most remarkable feature of the underwater viewing deck (Fig. 4c). Quantitative scoring of visual appearance has proved useful for monitoring nutritional status and general health in large whales (Hunt et al., 2013). Thus, a systematic visual examination of the whales' body condition based on the presence, severity, extent and healing condition of natural skin lesions, human-induced wounds, and presence and extent of ectoparasites, may provide useful information on their health.

The vast majority of the whales observed in both years were mothers and calves, which is consistent with the age class composition of southern right whales in their nursing grounds in spring (September-November) (Payne, 1986; Best, 1994; Crespo et al., 2015). The proportion of adults observed in 2014 (14%) was much lower than in 2015 (38%). All data in 2014 were collected in October-November whereas most data in 2015 were collected in September-October. Adults leave the area earlier than mother-calf pairs, thus the proportion of adult whales to mother-calf pairs tends to decrease throughout the season (Payne, 1986; Sironi, 2004). The small proportion

of calves that could be sexed (2%) is likely the result of the direction of sunlight coming from above, which can interfere with some underwater observations of the whales' ventral area.

The most frequent behavioral event observed was swimming parallel to the boat. This is probably a consequence of the type of approach preferred by the boat captain to give the tourists on board a better view of the whales. This perspective, when the whales' full body is visible underwater, facilitates good visual assessments of skin lesions and scars, but reduces the chances to obtain photographs of the full callosity pattern for individual identification. Conversely, the second most common pattern observed, *i.e.* the whales passing under the boat, offers a very good perspective for photo-identification. The relatively short duration and short distance of most encounters can hinder the assessment of behavioral changes or responses to different boat maneuvers (Vinding *et al.*, 2014). However, combining lower- and upper-deck observations may improve our understanding of how whales react to the approaching vessels.

Among other observations made in the course of this study, some were particularly interesting and/or relevant to assess right whale health and human impacts. The case of the young calf photographed with a small rope in its mouth on 28 October 2014 was reported to the wildlife authorities and to the Coastal Wildlife Rescue Network of Chubut Province. The calf was not seen again by whale-watching captains and guides. Other observations were useful for observers aboard to promote people's interest in whale conservation, since tourists could witness firsthand some of the threats that affect southern right whales welfare. A male was observed copulating with an adult female accompanied by a calf on 8 September 2015. Although this behavior is not rare, the case was recorded on video and photographed underwater. The images received much media attention, which helped to promote both right whale conservation, by increasing awareness in the general public, and tourism to Península Valdés.

In all cases, the behavior observed and reported here was intrinsically altered by the presence and maneuvers of the *YS*. Thus, we have created a useful database on the behavior of southern right whales in the vicinity of the boat. Our data could be used to make future comparisons with natural behavior in control areas free of vessels or with whales in the vicinity of traditional whale watching boats.

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