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Ailen Chalcobsky[1,2], Enrique A. Crespo[1,2] and Mariano A. Coscarella[1,2]

(1) Laboratorio de Mamíferos Marinos, Centro para el Estudio de Sistemas Marinos (CESIMAR), Centro Nacional Patagónico (CENPAT), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Bv. Brown 2915, CP 9120, Puerto Madryn, Chubut, Argentina.

(2) Facultad de Ciencias Naturales y Ciencias de la Salud, Universidad Nacional de la Patagonia San Juan Bosco. Bv. Brown 3051, CP 9120, Puerto Madryn, Chubut, Argentina.

Abstract

Whale watching in Argentina began in 1973, in Península Valdés, with the southern right whale (*Eubalaena australis*) as target, and it was regulated in 1984. Until now, only short-term effects of whale watching were evaluated, but the long-term effects were not. The population of whales is increasing locally and expanding to adjacent areas. Therefore, the commercial activity must adapt to this changing system, likely modifying the regulations. In the context of an integrative evaluation, the socio-biological system could be assessed using the concept of Limit of Acceptable Change. We evaluate the effect of the boats on the biological system, using a proxy of the energy expenditure of those individuals exposed to whale watching boats. The breathing rate, linearity, reorientation rate, movement speed, and total distance travelled were assessed between whales with and without whale watching boats around. Differences were not significant for every index analysed except for the breathing rate; the average number of blows decreases for all types of individuals when the boats were present. Whale watching at Península Valdés at this level of activity is carried out without significant effects on the movement indices analysed. At the light of present work and previous local research, the whales that breeding at Península Valdés may be habituated to whale watching boats.

Introduction

Whale watching is thought to be an alternative to whaling both economically and ecologically (Hoyt, 2005). As this is a non-consumptive activity it might be considered sustainable with no impact on the targeted species (Duffus and Dearden, 1990). On the contrary, it has been shown worldwide that to a certain extent, exposure to commercial boats has both short and long-term effects at individual and population levels (e.g. (Argüelles et al., 2016; Bejder et al., 1999; Bejder et al., 2006; Christiansen et al., 2010; Christiansen et al., 2013; Dans et al., 2008; Fumagalli et al., 2018; Tyne et al., 2018). Many studies have compared the behaviour of cetaceans in the presence and absence of whale watching boats. In general, the results show that when boats are present there is some change in behaviour of cetaceans (e.g. (Constantine et al., 2004; Coscarella et al., 2003; Christiansen et al., 2010; Williams and Noren, 2009). The short-term effects are more easily observed at the individual level, whereas the long-term effects are more difficult to assess and could have consequences not only on the individual fitness but also at the population level (Scheidat et al., 2004).

Globally, whale watching is a commercial activity that has increased exponentially in the last decades, providing great economic benefits to the local people, as well as at regional or national levels (Hoyt, 2001; O'Connor et al., 2009). In Argentina, it started in Puerto Pirámide in 1973 targeting the Southern Right Whale (SRW). Initially, whale watching annual demand was around 70 passengers with an increase to more than 100.000 passengers in 2010 making it the main economic activity in Puerto Pirámide (Chalcobsky et al., 2017). In the beginning, there was no regulation on whale watching practices and due to the increasing demand, the government started to regulate it in 1984 by the law of wildlife marine watching (Provincial Law N°2381). This law establishes a restricted area for whale watching (Figure 1); the number of whale watching licenses and a maximum of one boat per company at the same time at sea; a restriction on the duration of trips; the time between consecutive trips; and the number of boats watching the same whale at the same time. With these regulations, the government established safety measures for tourists and whales, and a quality standard for service for the tourist (Chalcobsky et al., 2017; Fazio et al., 2015).

Península Valdés is a Natural World Heritage where every year between April and December, the SRW arrives for breeding (Payne, 1986). As from the early 1970s, the population size of whales around Península Valdés has increased at 7% approximately, a high rate considering their life history (Cooke et al., 2001; Crespo et al., 2018), but this rate dreased to 0.06% and 2.30% for total number of whales and number of calves, respectively in 2016 (Crespo et al., 2018). The population structure and distribution have changed with time. In the beginning of the surveys, there were more juveniles and adults, either in isolation or in breeding groups, and fewer mother with calves. Almost every whale was close to the shore in shallow waters (Payne, 1986). As years went by, most of the whales found near the shore were mother-calf pairs, displacing juveniles and adults to deeper waters (Arias et al., 2018; Crespo et al., 2018; Rowntree et al., 2001; Sueyro et al., 2018).

Given the current conditions of the whale watching in Península Valdés, the most sighted groups in the area are the mother and calf pairs. The regulations in place are conservative, mainly to protect the calves. The effect that the whale watching boats produce on the individuals was only partially assessed (Argüelles et al., 2016). Additionally, the biological system is changing due to the increase in the population and its expansion (Arias et al., 2018; Crespo et al., 2018; Sueyro et al., 2018), and the social system has to adapt to this new condition modifying the regulations (Chalcobsky et al., 2017). One of the proposed methods to do this is to set the Limit of Acceptable Change (LAC), where changes in the ecological and social systems have to be analysed (Stankey et al., 1985). The recommendation of future management measures has to take into account indicators from both systems. This paper assesses the effect of the boats on the biological system, as a proxy of the energy expenditure of those individuals exposed to whale watching boats. Therefore, the present work evaluates the changes in breathing rate and indices of movement like linearity, reorientation rate, movement speed, and total distance travelled in whales exposed at whale watching boats inside the restricted area of commercial activity.

Methods

Data collection

Continuous focal follow-ups of arbitrarily chosen individuals of Southern Right Whale (SRW) were recorded between August and November 2017. The study was conducted in the waters near Puerto Pirámide, departure point of whale watching boats, and within the area authorized for their sailing. The data were collected with a total station (Pentax v-227) and a tablet Samsung running Cyber Tracker application (open access), specially designed for this study. The land station was located on a cliff at 47.36 m high (-42°35´01.5´´, -64°18´33.0´´) in Punta Pirámide (Figure 1). The data were taken always by the same person to reduce observer error (Lehner, 1998). The focal follow-ups of whales and boats were carried out when the Beaufort scale was lower than 3.

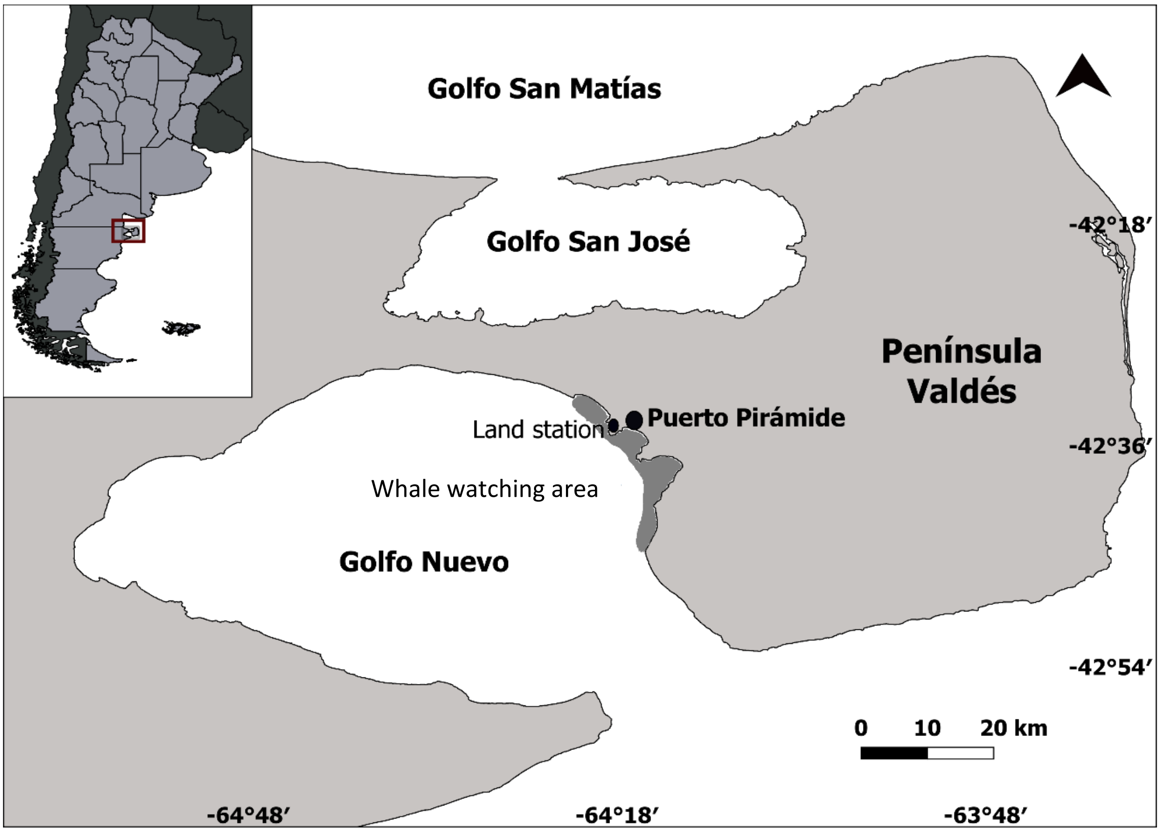


Figure 1. *Study site in Península Valdés. The shaded close to the lĩand station isthe restricted area for whale watching.*

From the land station, the vertical and horizontal angles of the position at sea of whales and boats were recorded with the total station, meanwhile, the behaviour of whales or state of boats were recorded with the Cyber Tracker© application. Data from the impact and control cases were collected. The impacted cases were those when the whale was being watched by a whale watching boat closer than 50 m, while control cases were collected when the whale was within the whale watching area but had no boats close to it. In this case, data were collected before or after the usual touristic schedule or in places at more than 500 m from the boat. For the control case, an arbitrary whale was chosen (focal individual) and followed as long as possible. For each focal individual it was recorded the type of group it was with (mother with calf, breeding group, or solitary), the type of individual (adult, mother, calf, juvenile or unidentified), its behaviour (surfacing, moving, resting), and each breathing and position at every surfacing. For the impacted case, an arbitrary boat was chosen, and it was recorded the name of the boat, the captain, the state (moving, correcting position, stationary) and its position. At the beginning of each impacted track, it was only recorded the position of the boats, but when the boat was close to a specific whale (focal individual), the position and behaviour or state of both focal objects (whale and boat) were recorded sequentially. When the boat left the focal individual, only the whale position and its behaviour were recorded due to a high probability of losing the focal whale if we continued with the alternate follow-up. Focal follow-ups were finished when the focal individual was in presence of another individual to avoid measurement errors from sampling the wrong animal (Christiansen et al., 2014), or if it was lost or when the conditions were unfavourable (distance, the reflection of the sun, wind speed, Beaufort scale). Conspicuous behavioural events, such as jumps or feeding, and environmental factors were also recorded.

The data recorded with the theodolite (angles) and with the tablet (behaviours/states or weather conditions) were manually uploaded to the Pythagoras software to obtain the latitude and longitude of all the points recorded (Gailey and Ortega-Ortiz, 2002). We used tracks with three or more records. For the breathing rate analyses, the individuals with no recorded blows (n=2) were removed from the analysis. From the tracks, linearity, reorientation rate, movement speed, total distance travelled and breathing rate were obtained for the different types of individuals in the presence and absence of whale watching boats. Linearity is the distance between the initial and end points of a trackline divided by the total distance travelled (the sum of the partial distances between consecutive points -cumulative distances- along the track); the values range from 0 (track with no constant direction) and 1 (straight trackline) (Batschelet, 1981). Reorientation rate is the sum of all course changes (degrees) along the trackline divided by the duration (minutes) of the trackline (Smultea and Würsig, 1995); it represents a magnitude of the course changes along a trackline. Movement speed (kilometres per hour) is the distance travelled between two consecutive points divided by the time between them and the breathing rate (blows/min) is the number of blows recorded divided by the entire time of the trackline.

Data were analysed with 2 ways-ANOVA to test whether the presence of boats has effects on any of the indices analysed for each type of individual. An overall significance level of 0.05 was used.

Results

Data were collected during the reproductive season of SRW between August and November 2017, on 23 days totalling 86 observation hours. A total of 153 focal SRW were recorded (113 impacted and 40 control) of which 46 were mothers, 70 calves, 23 adults without calf, 7 juveniles, and 7 unidentified whales. The adults without calf and juveniles were included in the same group due to the low number of the former ones. The observations that could be assigned to neither of the defined groups were not included in the analyses. Finally, 36 mothers (M), 50 calves (C), and 18 adults and juveniles (AJ) were considered (Table 1).

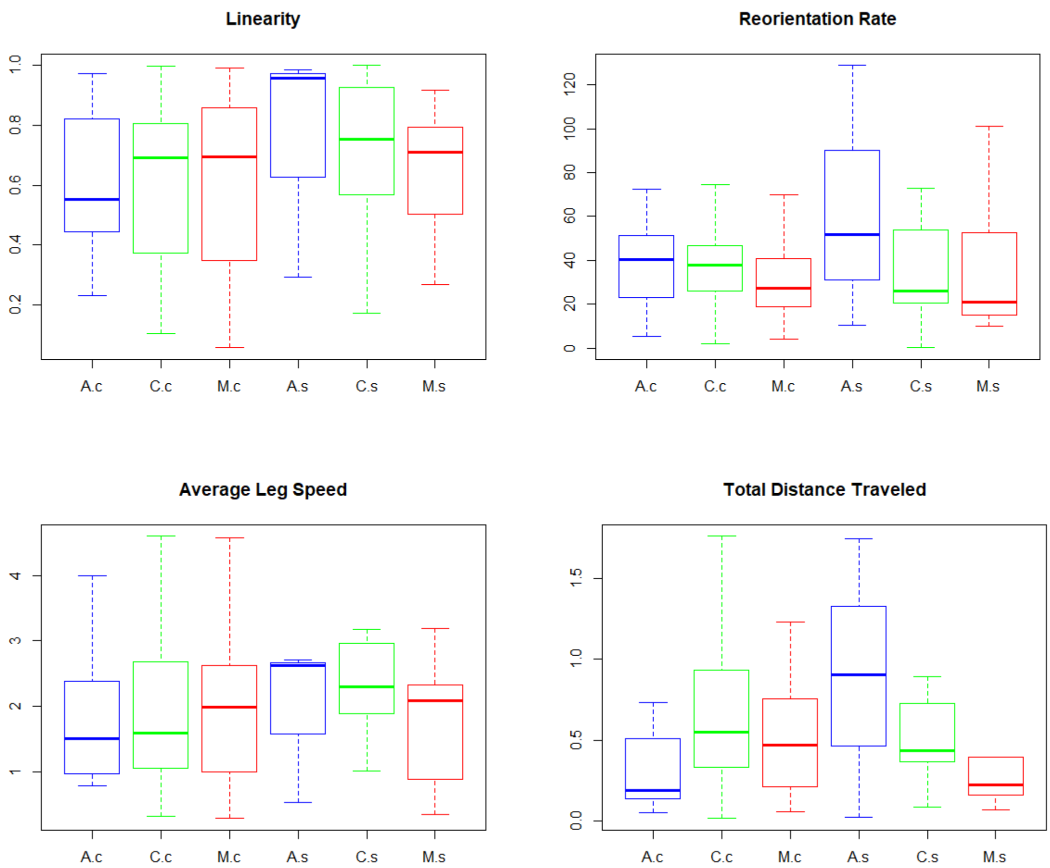
There are 6 authorized whale watching companies in Puerto Pirámide; all of them were recorded in whale-boat interactions and each was recorded whale watching all type of whales. The average time of observations of whale-boat interaction was 16.85 minutes and the observation time of whales without boats was 18.78 minutes.

The average of the indices calculated for the impacted and control cases for each type of individual are shown in Table 1.

´ *Table 1*. Average of the indices calculated for the impacted and control cases for each type of individual.

	Impacted	**Control**
Mothers	**n=27**	**n=9**
Linearity	0.62 ± 0.28	0.66 ± 0.20
Reorientation rate (°/min)	33.22 ± 21.55	34.74 ± 30.34
Speed movement (km/h)	2.04 ± 1.33	1.74 ± 1.01
Total distance travelled	0.69 ± 0.86	0.39 ± 0.35
Breathing rate (blows/min)	0.46 ± 0.34 **(N=26)**	0.60 ± 0.36
Calves	**n=36**	**n=14**
Linearity	0.61 ± 0.26	0.68 ± 0.31
Reorientation rate (°/min)	39.61 ± 20.93	32.75 ± 22.63
Speed movement (km/h)	1.93 ± 1.04	2.45 ± 1.10

Total distance travelled	0.67 ± 0.53	0.71 ± 0.73
Breathing rate (blows/min)	0.55 ± 0.24 **(n=35)**	0.86 ± 0.24
Adults and juveniles	**n=15**	**n=3**
Linearity	0.63 ± 0.24	0.75 ± 0.39
Reorientation rate (°/min)	39.82 ± 25.38	63.67 ± 60.07
Speed movement (km/h)	1.81 ± 1.05	1.95 ± 1.23
Total distance travelled	0.31 ± 0.25	0.89 ± 0.86
Breathing rate (blows/min)	0.50 ± 0.38	0.84 ± 0.09



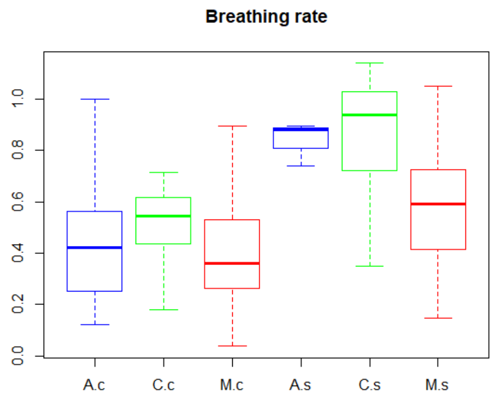


Figure 2. Comparison between different types of group individuals for each index of movement. Each box shows the mean value for each index (strong line of colour) and their standard deviations. The capital letters refer to Adults (A), Calves (C) and Mothers (M) meanwhile the low case letters are with presence (c) and without the presence (s) of whale watching boats.

Table 2. Probabilities of the ANOVAs performed for all indices analysed for control and impacted cases and for all type of individuals.

	Speed	Linearity	Reorientation rate	Total distance travelled	Breathing rate
Type of individual	0.717	0.974	0.345	0.284	0.094546
Presence of boats	0.478	0.323	0.994	0.951	**0.000294**
Type of individual: Presence of boats	0.347	0.917	0.2	0.161	0.484811

The indices analysed did not show differences (p>0.05) between the impacted and control cases for the different types of whales except for the breathing rate (Table 2). In this case, there was an effect due to the presence of the boats where the average number of blows decreases for all types of individuals when the boats are present.

Discusion

This is the first time that effects of the whale watching activity in Península Valdés are analysed using theodolite tracking to test whether there is an effect of the boat on the movement and breathing rates of the whales. Previous theodolite tracking studies for the species in the area assessed the impact of swim-with-whales experiences (Lundquist et al. 2013). Whale watching in Puerto Pirámide seems to be carried out without significant effects on the movement indices analysed for whales within the whale watching area, although there is an effect on the breathing rate. Due to the large number of whales in the area we focussed on close-up interaction at very short range. All our observations were made at distances less than 5 km from the observation point, including both impacted and control. It has beren reported that the boats have effects on whales at distances of 8-10 km (Bejder et al., 2009; Fumagalli et al., 2018; Watkins, 1986). If this is the case for the SRW, most observations considered as control could have been affected by the presence of boats. So, data in a location away from the whale watching area must be recorded to compare the same movement indices between whales inside the whale watching area with those of whales in areas without any boating activity.

The lack of significant differences on movement indices between the types of individuals with and without boats also could be related to the habituation of the individuals. As the boats have restricted navigation, the individuals may be used to a level of constant disturbance produced by the boats that sail within the area, almost constantly during daylight along the season.

In general, the term "habituation" is used when a particular disturbance is perceived as having little or no effect on the individuals, and consequently, the conclusion is that the animals are unaffected by this disturbance (Bejder et al., 2009). These conclusions could lead to making wrong decisions on wildlife management, like an increase in human activity or a decrease in conservation efforts. That is why it is important for the activities where humans are directly or indirectly in contact with wildlife to be analysed with special care (Bejder et al., 2009).

Many studies have discussed the behaviour of whales or dolphins exposure to whale watching (e.g. (Argüelles et al., 2016; Bejder and Samuels, 2003; Constantine et al., 2004; Coscarella et al., 2003; Dans et al., 2008; Di Clemente et al., 2018; Erbe, 2002; Senigaglia et al., 2016). The habituation to human activity seems to be feasible in some whale species like *Megaptera novaeangliae*, *Balaenoptera acutorostrata*, *B. physalus*, or *Physeter macrocephalus*, but this is a gradual process that occurs with constant exposure to human activity over the years (Richter et al., 2006; Watkins, 1986). The habituation is usually species, site, and context-specific, that is to say, different species could react differently at the same stimuli or the same species could react differently in different sites or context (Di Clemente et al., 2018; Watkins, 1986). This may be the case for the SRW in Península Valdés, where whale watching has been carried out for over four decades. Some individuals born in the area when the activity started returned to the area frequently and interacted with boats since their birth (Vilches et al., 2018).

Our study precludes us to affirm that whales are "habituated to boats" but there is additional information that supports this idea for SRW around Puerto Pirámide. Argüelles et al. (2016) and Arias et al. (2018) report that the presence of whale watching boats have effects on short-term whale behaviour; nevertheless, the way the boats approach them is one of the main factors that affect their behaviour. When the manoeuvres are done according to the regulations, whales tend to remain neutral (do not change their behaviour). Is worth noticing that in most of the cases the approaching is correct (Rivarola et al., 2001). The same individuals arrive at the same area year in year out, and what is more important is that those whales born there also return to the same area to deliver their calves (Vilches et al., 2018). On the other hand, a long-term study carried out by Crespo et al. (2018) demonstrates that in the last 18 years the rate of increase of whales around Península Valdés has changed. At first, the rate of population increase was of 7% approximately and decreased to 0.06% for the total population in 2016. At the same time, the increase in population rate for calves was low but positive (2.30%), that is to say, that the population increases slowly. A relocation of the juvenile individuals and adults to deeper waters was recorded, the mother-calf pairs remaining close to the shore (Crespo et al., 2018; Sueyro et al., 2018), where the geographical conditions are more appropriate for the newborn but where whale watching is carried out (Fazio et al., 2015). Additionally, juvenile individuals and solitary adults or adults involved in breeding groups started to be recorded along the northern coast of Golfo San Matias (Figure 1) a few years ago (Arias et al., 2018). While this redistribution appears to be related to denso-dependent factors and reoccupation of old areas, the intense activity of whale watching could be influencing this redistribution. Nevertheless, the whales moved freely between zones with very little or no boat transit (like Golfo San José or El Doradillo respectively) and zones with intermediate or high boat transit (like Puerto Pirámide, Puerto San Antonio Oeste or Puerto Madryn) but returned to Puerto Pirámide where they remain for days (Zerbini et al., 2015; Zerbini et al., 2016). In addition to the scientific information, it is important to emphasize the point of view of the people who work every day on the whale watching boats and who perceive that whales have gradually become more social or curious about boats over the years. It is frequent to hear from the whaler guide (local people trained to work in whale watching trips) that the whales observe the boat for some time at close range as if examining the boat and the people (LAMAMA unpublish information).

Although the number of whales that visit Península Valdés has increased in the last years, until now, the long-term effects of whale watching on whales around Puerto Pirámide have not been explored. In the short-term, the effects of the boats may not be visible (Christiansen and Lusseau, 2014). Probably the least tolerant individuals are moving to zones with less disturbance while the most tolerant individuals or those that are vulnerable but can not leave the breeding area (e.g mothers and calves) remain there and so, we are observing the effects on these types of individuals that may be more used to the presence of boats. There is evidence that the individual level-risk change with the ontogeny, and when the parents are habituated to some type of anthropogenic stimuli, the calves are less afraid to it (Schell et al., 2018). When the individuals became more tolerant to specific stimuli could reduce their behavioural responses (Bejder and Samuels, 2003; Di Clemente et al., 2018; Richter et al., 2006). This might be the case for Península Valdés SRW. The behaviour of the juvenile whales observed today may be the reflection of the behaviour that their mothers and grandmothers have developed through the years interacting with whale watching boats.

On the other hand, the lack of significant differences in the indices analysed with and without boats could be related to a large dispersion of the data, especially in the case of adults and juveniles without boats. The fact that the only the breathing rate changed could be related to the fact that whales tend to remain underwater close (within meters) from the whale watching boats (Sironi et al., 2019). Also, whales tend to swim under the boats, and this could be the reason why the breathing rate diminished when whale watching boats are close. The breathing rate can be influenced both ways (*ie:* increasing or diminishing) in cetaceans subjected to whale watching impact; and the most consistent parameter in showing an impact is the decrease of the linearity in their paths, being species-specific (Senigaglia et al., 2016). Considering the results obtained, it is safe to say that SRW in the area is not severely affected by whale watching operations in Puerto Pirámide at this level of activity. This result is important in the view of the planning of new regulations using the Limit of Acceptable Change, and the social and economic part of the system should be given a greater consideration.

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