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Abstract

The remoteness of Trindade Island, and its sister islet Martim Vaz, located 1,140 km east of Vitória, Espírito Santo State, Brazil, in the Southern Atlantic Ocean, combined with the long-term difficulties in logistics, could have contributed to the paucity of data on the presence of humpback whales in these waters. In this paper we report a set of sightings of humpback whales around Trindade Island in the winters of 2012 and 2013 based on dedicated sightings both by ship, inflatable boat and land based surveys around the main island. Altogether, twenty-five sightings of groups of humpback whales were recorded. Eight of these represented mother-calf pairs, four were represented by a mother-calf and escort group, two were groups of two whales and eleven singletons. Including both new and published data a total of fifty-four sightings of humpback whales with confirmed group composition were recorded off Trindade Is. recently. The unpublished records here presented clearly indicate a convergence of data strongly supporting Trindade Is. as a destination for humpback whales wintering off Brazil. Previous data integrated with the most recent efforts can comfortably endorse the status of the surrounding waters of Trindade Island as a migratory destination for humpbacks of the breeding stock A.

Introduction

Contrasting to the typical use of coastal shallow waters along the Brazilian coast, humpback whales are known to occur off the oceanic island of Trindade. Surrounded by deep oceanic waters, in an environment unequivocally distinct from the shallow waters of Abrolhos Banks, this island and its sister islet Martim Vaz are visited by humpback whales belonging to the breeding stock A. The remoteness of this tropical island, combined with the long-term difficulties in logistics, could have contributed to the paucity of data on the presence of humpback whales in the waters of Trindade. In this case, the lack of continuous records off Trindade and, by contrast, the practically exclusive focus on humpbacks off Abrolhos Bank, has led many researchers and conservationists to give much less attention to the use of oceanic islands as a migratory destination for humpbacks in the Southwest Atlantic Ocean (Kinas and Bethlem, 1998, Martins et al., 2001, Freitas et al., 2004, Andriolo et al., 2006, Zerbini et al., 2006).

The first genuinely reports of humpbacks off Trindade are illustrated in the Townsend's (1935) classic whaling charts. The widely used charts (*e.g.* Smith et al. 2012) where American open-boat (premodern) whalers took thousands of sperm, humpback, right and bowhead whales worldwide, evidence few catches of humpback whales off Trindade Island.

It was only recently that new information emerged as Siciliano (1997) and Siciliano et al. (1999) presented data on the presence of humpbacks waters off Trindade in the years of 1984, 1993 and 1994. It is thus suggested the use of this remote island as a migratory destination for humpback whales. These authors also discussed the probable origin of this confluence of humpback whales and their connection with other major breeding grounds off the Southwest Atlantic Ocean. Since then, others have reported additional sightings of humpbacks off Trindade (Siciliano et al. 2012, Wedekin et al. 2014, Lucena et al. 2015 and Pinheiro et al. *in press*).

New data from recent dedicated efforts have produced a considerable number of sightings around Trindade Island. The significance of these sightings and the role of this remote island as a breeding ground for humpback whales are discussed herein.

Material and Methods

Physical description of the area

The Trindade and Martim Vaz islands belong to an archipelago located 1,140 km east of Vitória, Espírito Santo State, Brazil, in the Southern Atlantic Ocean. The archipelago consists of six islands of which Trindade (20°30'S and 29°18'W), with an area of 10.1 km², is the largest and Martim Vaz, with an area of 0.3 km², the second in size. The archipelago has a total area of 10.4 km² (4.0 sq mi). Its isolation on the ocean surface makes it difficult to perceive that it is part of the Vitória-Trindade Alignment, a great E-W submarine volcanic chain. The volcano lies on the ocean floor at a depth of about 5,500 m. Other volcanic constructions belonging to this alignment between Trindade-Martim Vaz and the coast have been completely eroded by the sea, and levelled down to 100 m depth. They are the guyots, usually called banks, but the islands, probably due to prolonged volcanic activity, are still high above the ocean surface. The Trindade Is. platform has a limited area, the width varying between 800 and 3,000 m (Almeida, 2002).

Boat surveys around Trindade Island

Sightings of humpback whales were recorded during cetacean surveys conducted in adjacent waters and over the VTC under the ProTrindade Program between 2009 and 2015 (see acknowledgements). These records were obtained by marine mammal's observers in different platforms and vessels. Data were collected following standard line transect methodology (Buckland et al., 1993). When a group of whales was sighted information of date, time, position (latitude and longitude), weather, sea state condition (Beaufort), estimated number of individuals, and the presence of calves were collected and behavioural information were taken.

Around Trindade Island sightings were made on board an inflatable boat (model MKS Zodiac equipped with Mercury outboard motor 2T - 40 HP) in July and August 2013. Monitoring of cetaceans was done with the naked eye and with the aid of binoculars equipped with reticles (Fujinon Mariner XL). When possible, photographs were taken of all the whales sighted using reflex cameras (*e.g.* Nikon D7000 with 80-400mm f4.5-5.6 lens). We used only data considered 100% reliable as the identification of species (*e.g.*

performed by experienced observers) or preferably those recorded with photographs and confirmed later by whale experts.

The inflatable boat surveys were operated whenever the weather allowed. In this case, the team consisted of two divers of the Brazilian Navy, and one or two expert researchers in cetaceans (with additional researchers from other fields on board), all equipped with GPS, camera and crossbow. Information collected included: time (hours) on the sea, sea condition (Beaufort scale), distance travelled, species sighted, number of groups, number of individuals per group and the presence of other species associated.

Occasionally, researchers conducted opportunistic sightings from advantage points in the mainland of Trindade Is. On these occasions, researchers recorded data as: species, number of individuals, group composition and location of the sighting. Whenever possible, a description of the general behavior of the whales was recorded *ad libitum*.

Statistical analysis

To compare frequency of groups composition per month and the quantity of sightings per month we use the G *test* with Williams correction. For this analysis we use the new data present here and the previously published data in Siciliano et al. (2012), Wedekin et al. (2014), Lucena et al. (2015) and Pinheiro et al. *in press.*, resulting in 54 sightings. The analysis was performed in Bioestat 5.0.

Results

In this paper we report a set of sightings of humpback whales around Trindade Island in the winters of 2012 and 2013 based on dedicated sightings both by ship, inflatable boat and land based surveys around Trindade Is. (Figure 1).

In 2013, a team of researchers spent 29 days on the Trindade Is., during July and August. In this period, ten surveys were performed using an inflatable boat, totalling more than 50 hours on effort and more than 80 nautical miles travelled around the island. Each boat survey completed a turn around the island. Altogether, twenty-five sightings of groups of humpback whales were recorded. Eight of these represented mother-calf pairs (32%), four were represented by a mother-calf and escort group (16%), two groups

of two whales (8%) and eleven singletons (44%) (Figure 2). When a single blow was located, or an aerial behavior, a dorsal fin, a tail or flipper on the surface, but was not possible to follow the sighted whale, it was considered a "singleton" group. At least eleven singletons sightings (44%) were classified thereby. In this case, the amount of singletons can be overestimated. The largest group sighted was composed of three whales, being mother calf and escort composition.

Indeed, the logistics in oceanic islands can be truly difficult, especially in the winter. For this reason, days with wind speed over 20 knots and rough seas were not used for boat surveys. In turn, whales were tentatively located in advantage points from land (Calheta beach or in front of the ECIT). The presence of singletons and mother-calf pairs has been frequent in the east side of the island.

Including both new and published data a total of fifty-four sightings of humpback whales with confirmed group composition were recorded off Trindade Is. (Figure 3). Over this period, 14 sightings were mother-calf pairs (26%), five mother-calf and escort trios (9%), 15 groups of two (no calf) (28%) and 17 singletons (32%) and three undefined groups (more than three individual) (5%). Was considered like "undefined" groups composed by three or more whales with no calves.

The largest number of sightings appeared in August ($n=27$, 52%), followed by July ($n=17$, 32%), September ($n=3$, 6%), October and May ($n=2$, 4%) and June ($n=1$, 2%). Two of the sightings previously reported (Lucena et al. 2015) did not consider specific information about the month, and for this reason were not included here (Table 2). July and August together represented almost 85% of total sightings. Despite the largest efforts were conducted in July and August 2013, the published sightings randomly obtained also presented a major concentration of sightings for these two months (Figure 3).

A *G test* with Williams correction was performed to compare the frequencies of groups composition and per month of occurrence. We use only sightings that had of the month information of sighting ($n=52$). The number of sightings per months is different that would be expected by chance, demonstrating a significant difference ($p<0,0001$)

(Table 1). Among the frequencies of group composition, the only statistically different is referent to singleton sightings ($p = 0,0219$) (Table 1).

The groups with calves (mother-calf pair or mother-calf and escort) were recorded only in July ($n=8$), August ($n=7$) and September ($n=1$). Due to the body size, the calves' sightings seemed to be represented by new-borns (Figure 4). The sightings in July and August can indicate that females arrive earlier in the breeding season, using Trindade Island mostly as a calving ground.

Discussion

Humpback whales seasonally visit the Brazilian coast during their migration from Subantarctic waters to the tropics (Siciliano 1995, 1997). As previously described, the Abrolhos Bank ($16^{\circ}55'S$, $38^{\circ}50'W$) and nearby Brazilian continental shelf combine all necessary requirements for a calving ground. Warm ($>23^{\circ}C$) and shallow waters (0 – 50 m) covered with coral communities visited by a large number of mother-calf groups seasonally (Siciliano 1995, 1997). Abrolhos Banks as a preferred, and primary, migratory destination for humpback whales off Brazil, has attracted substantial research and conservation efforts in the last decades (Kinas and Bethlem, 1998, Martins et al., 2001, Freitas et al., 2004, Andriolo et al., 2006, Zerbini et al., 2006, Andriolo and Zerbini, 2010). In addition, shipboard and aerial surveys have demonstrated the use of a large stretch of the Brazilian continental shelf by humpbacks during their route to and from Abrolhos Bank, expanding their distribution up to the north-eastern coast (Zerbini et al., 2004). In fact, humpback whales are relatively abundant on the north-eastern Brazilian coast, far north of the Abrolhos bank, where important whaling activities occurred in the 20th century (Zerbini et al., 2004, Andriolo et al., 2010). It was thus suggested that the species is undergoing a process of reoccupation of a historical area of distribution, and the presence of new-borns indicates that calving and nursing occur in the area.

Using telemetry techniques, Zerbini et al. (2011) have pointed out a female *M. novaeangliae* tagged off Brazil (far north of the Abrolhos Banks) migrating southward over the Vitória-Trindade submarine chain (at a point 200 km from Trindade Is.) towards

the South Sandwich Archipelago. Pre-modern whaling data for South American waters (1831/32) revealed that humpback whales were observed in the same seasonal period and migratory route locations recognized at the present time in Brazil (Best, 2008). According to Best (2008) the whales observed 500 to 1,000 nautical miles off the Brazilian coast (including sightings off Trindade Is.) between latitudes 17 and 28°S in midwinter suggest that the destination of these cetaceans may not be the Abrolhos Banks, but a region further north and east.

It is common for oceanic islands to serve as habitats for humpback whales during their migrations, as is seen in the Pacific Ocean (*e.g.* Hauser et al., 2010, Robbins et al. 2011). Considering the relevance of oceanic tropical islands for humpback whales, Siciliano (1997) reported 16 sightings of humpback whales off Trindade Is. between 1984 and 1994. The group composition of the whales sighted by this author included: singletons, mother-calf, mother-calf and escort and trios. Notably, all records were concentrated in the three-month period (August (69%), September (19%) and October (12%)), a similar pattern of occurrence as of Abrolhos Banks. Further opportunistic records of humpback whales along the Vitória–Trindade chain presented in Siciliano et al. (2012) enlarge this period to July–November (4 sightings in July, 3 in August, 4 in October and 8 in November), also very much coincident with the Abrolhos ground. Wedekin et al. (2014) presented information of nine groups of humpback whales observed in the Vitória–Trindade chain in August–September 2010. Group size varied from 1 to 6 whales (average = 3; SD = 1.6). Females with new-born calves corresponded to 56% (N=5) of the sightings. Only one humpback whale was seen near Trindade, despite a search effort of 6 days and 520 km. Further reports by Lucena et al. 2015 off Trindade Is. were all concentrated in August–September.

Pinheiro et al. (*in press*) presented four opportunistic records of humpbacks around Trindade Is. from May 25 to June 17, 2009. The sightings reported by these authors on May 25th in Trindade Is. are especially relevant as they may represent the earliest migrating whales spotted in the season. In turn, this is coincident with the timing of the coastal migration route of humpbacks off Brazil. This coastal route is also evidenced by strandings records of humpbacks along Rio de Janeiro, SE Brazil, which

start increasing in the early months of the season (May to July) during the northbound migration to Abrolhos Banks, according to data presented in Moura et al. (2013).

The unpublished records here presented from the dedicated seasons of 2012 and 2013 off Trindade Is. clearly indicate a convergence of data strongly supporting Trindade Is. as a destination for humpback whales wintering off Brazil. Previous data integrated with the most recent efforts can comfortably endorse the status of the surrounding waters of Trindade Island as a migratory destination for humpbacks of the breeding stock A. Contrary to Lucena et al. (2015), groups of mother-calf around Trindade Is. are a common event in previous reports of humpback whales in Trindade Is. (Siciliano, 1997, Siciliano et al. 2012) and are endorsed with data presented here. In fact, mother-calf groups could be more frequently off Trindade as noted, as this group composition is easily non-detected by observers. Rough seas are highly expected around oceanic islands, mainly during winter months with intense wave oscillation.

As a result, Trindade Is. may represent a recognizable destination of humpback whales from the breeding stock A. It is highly probable that these whales use an independent migratory route, with an open water itinerary from cold Subantarctic waters to the warm Trindade Is. waters. During the same timing, a coastal and continental slope migration route is in use by humpbacks to reach the Abrolhos Banks and probably the northern waters of the Brazilian shelf.

Whether the use of Trindade Is. waters evolved independently by humpbacks or is a result of the expanding Abrolhos Banks population should be further investigated. The simple question but even more intriguing is how whales select such distinct environments for wintering: the turbid shallow waters of Abrolhos or the deep and clear oceanic waters of Trindade. During most of the year, the waters of Abrolhos are considerably turbid, making visibility underneath the surface harder. This is caused by the carbonatic particles originating from reefs or muddy sand from the benthonic zones, moved by the winds and currents. Matilla et al. (1994) consider the ability to see conspecifics over at least modest distances as a presumably important advantage to humpback whales seeking mates. Furthermore, mother and calves' pairs have been found to prefer shallower areas in their breeding grounds in Hawaii (Smultea, 1994), Brazil (Martins et al., 2001), Puerto Rico (Sanders et al., 2005), Ecuador (Félix and Botero-Acosta,

2011) and Peru (Santillán, 2011). Maternal females may use shallower water to avoid harassment and injury to calves by sexually active males, turbulent offshore or deep sea conditions and predators (Smultea, 1994). Curiously, mother and calves could arrive early in Trindade Is. in search of an environment free of harassment by sexually mature males and consequently, away from the primary breeding ground of Abrolhos.

The oceanic Brazilian humpback whales off Trindade Is. deserve a long-term study on habitat use, group composition, behavior pattern, genetics and acoustics even though there are difficulties in logistics and funds for research. Trindade Is. could represent the final piece of the puzzle for understanding migratory routes and destinations for humpback whales off Southwest Atlantic Ocean.

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Figures and Tables

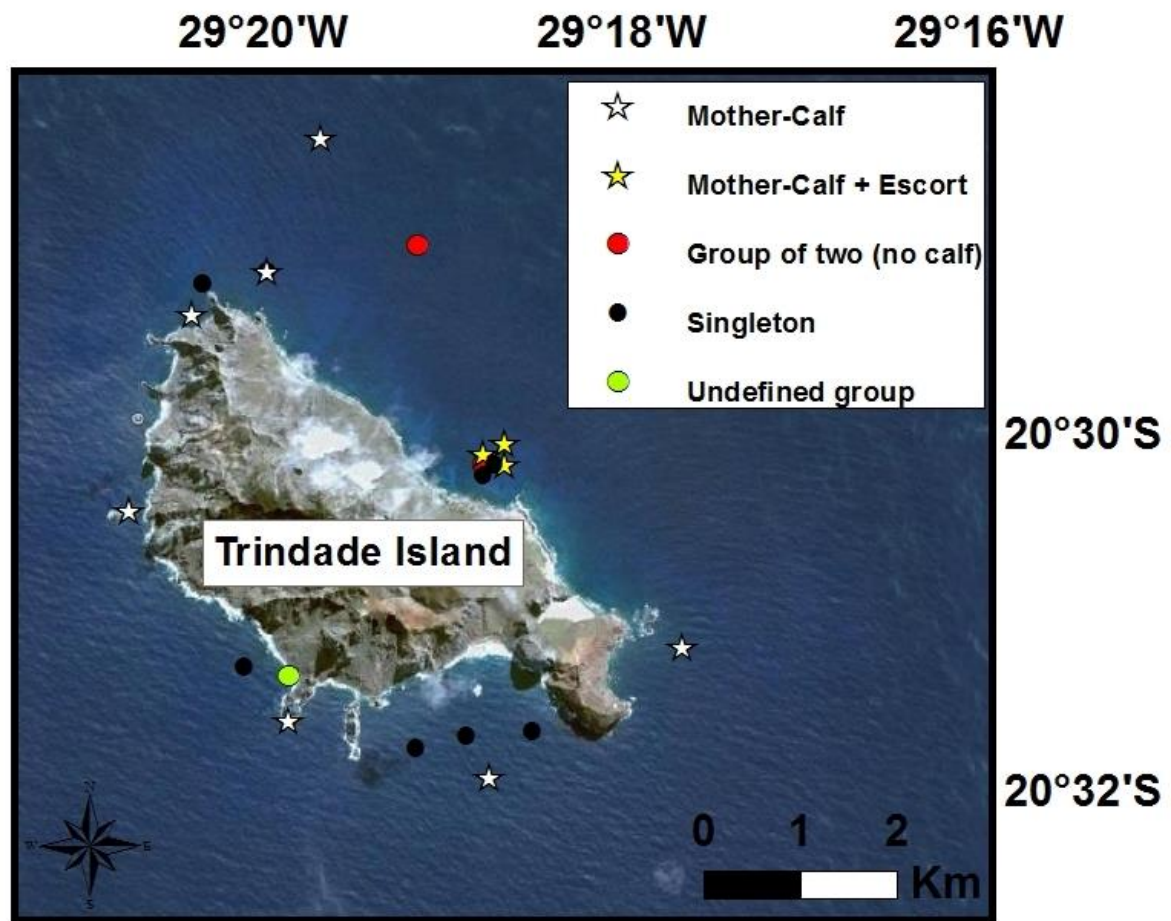


Figure 1. Sightings of humpback whales (*Megaptera novaeangliae*) off Trindade Island in 2012 and 2013.

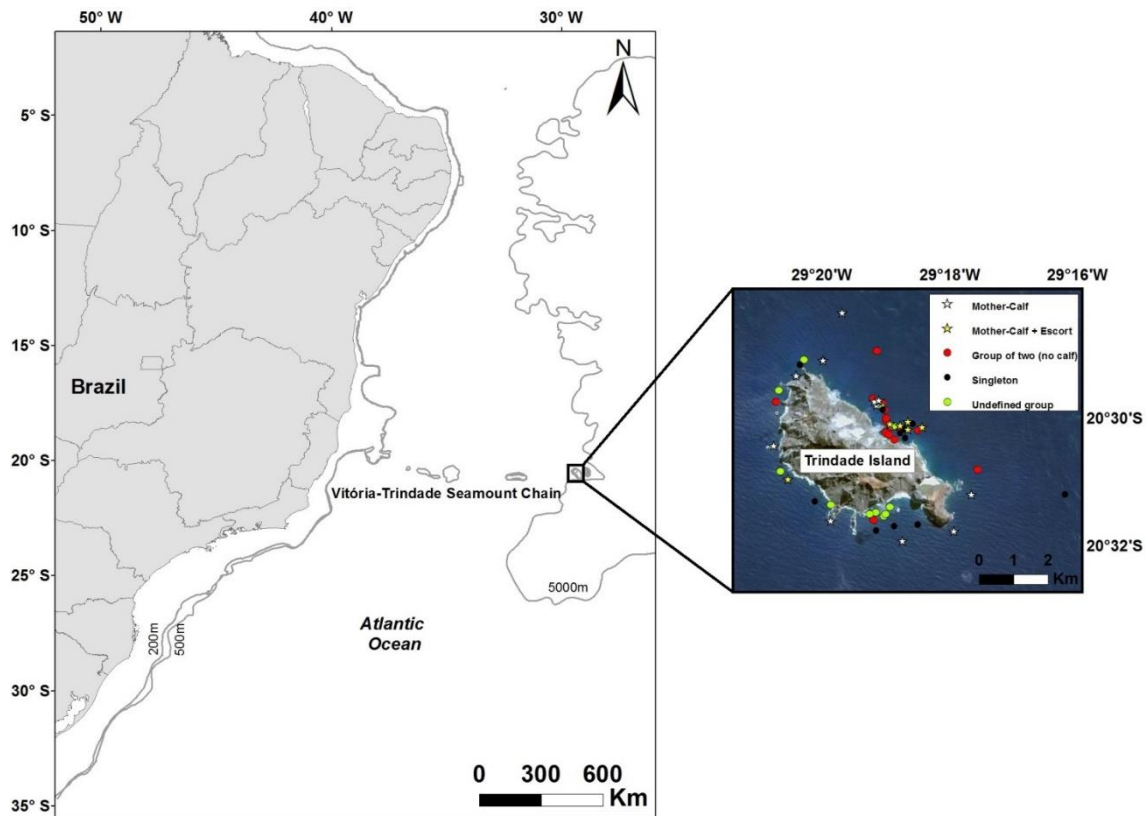


Figure 2. Group composition of humpback whales (*Megaptera novaeangliae*) recorded in 2012 and 2013 (n=25).

Table 1. Number of sightings and group composition of humpback whales (*Megaptera novaeangliae*) recorded per month with G *test* with Williams correction (n=52). *indicate significant differences (performed in BioEstat 5.0). Previously data published by: Siciliano et al. (2012), Wedekin et al. (2014) and Pinheiro et al. *in press*.

	May	June	July	August	September	October	G test	P value
Number of sightings	2	1	17	27	3	2	30.1519	<0.0001*
Singletons	1	1	4	11	0	0	13.1595	0.0219*
Group of two (no calf)	1	0	5	5	2	2	5.2275	0.3888
Mother-calf	0	0	5	6	1	0	10.0160	0.0748
Mother-calf & escort	0	0	3	2	0	0	4.1885	0.5226
Undefined groups	0	0	0	3	0	0	2.7074	0.745

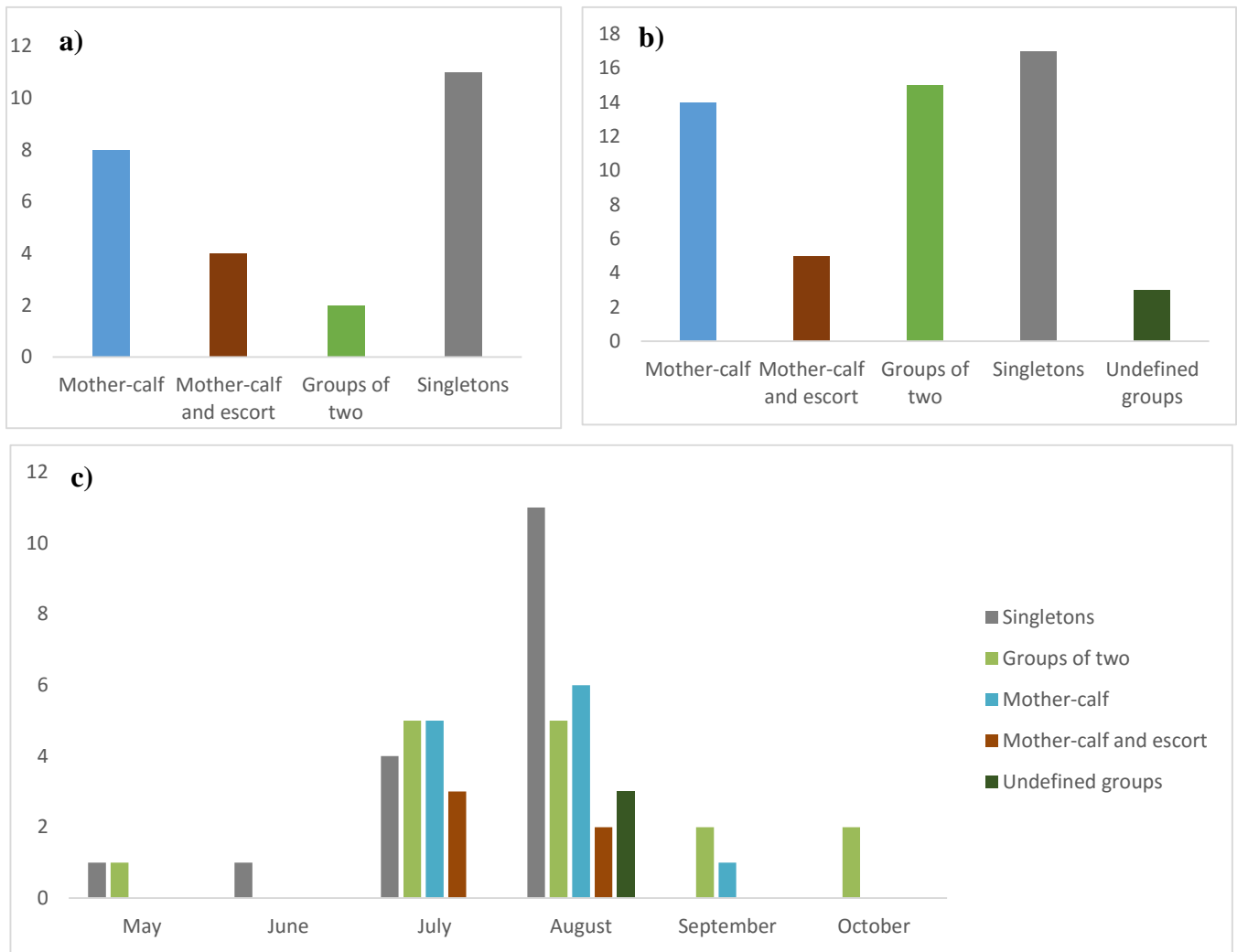


Figure 3. a) Group composition of humpback whales (*Megaptera novaeangliae*) recorded around Trindade Island in 2012 and 2013 (n=25); **b)** Group composition including published and recent sighting data off Trindade Island (n=52); **c)** Monthly variation of the composition groups of humpback whales off Trindade Island including published and new data (n=52). Previously data published by: Siciliano *et al.* (2012), Wedekin *et al.* (2014) and Pinheiro *et al.* in press.



Figure 4. Humpback whales (*Megaptera novaeangliae*) sighted around Trindade Island in July and August 2013. Note the small size of the calves, probably new-born. Photos by Elisa Ilha.

Table 2. Humpback whales (*Megaptera novaeangliae*) recorded records off Trindade Island including historical catches, published and new sighting data for 2012 and 2103.

Date	Latitude	Longitude	Group composition	Reference
XIX Century	20°30'S	029°19'W	At least two humpbacks caught by U.S. Whalers	Townsend (1939)
19 August 1984	20°30'S	029°19'W	Mother-calf & escort	Siciliano <i>et al.</i> (2012)
15 August 1993	20°30'S	029°19'W	Undefined group	Siciliano <i>et al.</i> (2012)
09 August 1994	20°30'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
09 August 1994	20°30'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
11 August 1994	20°31'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
16 August 1994	20°31'S	029°19'W	Undefined group	Siciliano <i>et al.</i> (2012)
18 August 1994	20°31'S	029°19'W	Mother-calf pair	Siciliano <i>et al.</i> (2012)
18 August 1994	20°31'S	029°19'W	Singleton	Siciliano <i>et al.</i> (2012)
19 August 1994	20°29'S	029°19'W	Singleton	Siciliano <i>et al.</i> (2012)
22 August 1994	20°30'S	029°19'W	Mother-calf pair	Siciliano <i>et al.</i> (2012)
23 August 1994	20°30'S	029°19'W	Mother-calf pair	Siciliano <i>et al.</i> (2012)
01 September 1994	20°30'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
10 September 1994	20°28'S	029°20'W	Mother-calf pair	Siciliano <i>et al.</i> (2012)
17 September 1994	20°31'S	029°20'W	Group of two	Siciliano <i>et al.</i> (2012)
08 October 1994	20°30'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
08 October 1994	20°30'S	029°20'W	Group of two	Siciliano <i>et al.</i> (2012)
July 2007	20°30'S	029°20'W	Group of two	Siciliano <i>et al.</i> (2012)
July 2007	20°30'S	029°19'W	Group of two	Siciliano <i>et al.</i> (2012)
July 2007	20°30'S	029°20'W	Group of two	Siciliano <i>et al.</i> (2012)
July 2007	20°30'S	029°18'W	Singleton	Siciliano <i>et al.</i> (2012)
August 2007	20°30'S	029°18'W	Group of two	Siciliano <i>et al.</i> (2012)
August 2007	20°30'S	029°17'W	Group of two	Siciliano <i>et al.</i> (2012)
August 2007	20°31'S	29°19'W	Undefined group	Siciliano <i>et al.</i> (2012)
25 May 2009	-	-	Group of two	Pinheiro <i>et al. in press</i>
28 May 2009	-	-	Singleton	Pinheiro <i>et al. in press</i>
17 June 2009	-	-	Singleton	Pinheiro <i>et al. in press</i>
31 August 2010	20°31'S	029°16'W	Singleton	Wedekin <i>et al.</i> (2014)
19 July 2012	20°28'S	029°19'W	Mother-calf pair	This study
19 July 2012	20°31'S	029°17'W	Mother-calf pair	This study
20 July 2012	20°29'S	029°19'W	Group of two	This study
24 July 2013	20°31'S	028°50'W	Mother-calf pair	This study
29 July 2013	-	-	Singleton	This study
29 July 2013	20°30'S	029°19'W	Group of two	This study
29 July 2013	20°30'S	029°21'W	Singleton	This study
30 July 2013	20°29'S	029°20'W	Singleton	This study
30 July 2013	20°30'S	029°19'W	Mother-calf & escort	This study
30 July 2013	20°30'S	029°19'W	Mother-calf & escort	This study
30 July 2013	20°30'S	029°19'W	Mother-calf & escort	This study

31 July 2013	20°29'S	029°20'W	Mother-calf pair	This study
31 July 2013	20°32'S	029°19'W	Mother-calf pair	This study
01 August 2013	20°31'S	029°20'W	Singleton	This study
01 August 2013	20°29'S	029°20'W	Singleton	This study
09 August 2013	20°30'S	029°21'W	Mother-calf pair	This study
09 August 2013	20°31'S	029°20'W	Mother-calf & escort	This study
12 August 2013	20°31'S	029°19'W	Singleton	This study
12 August 2013	20°31'S	029°20'W	Mother-calf pair	This study
13 August 2013	20°30'S	029°19'W	Singleton	This study
13 August 2013	20°31'S	029°18'W	Singleton	This study
13 August 2013	20°31'S	029°19'W	Singleton	This study
13 August 2013	20°31'S	029°19'W	Mother-calf pair	This study
14 August 2013	20°30'S	029°19'W	Singleton	This study
15 August 2013	-	-	Singleton	This study
August/September 2014	-	-	Mother-calf pair	Lucena <i>et al.</i> (2015)
August/September 2014	-	-	Mother-calf pair	Lucena <i>et al.</i> (2015)
