Highlights from a Decade of Humpback Whale Research in the Gulf of Chiriquí, Western Panama, 2002-2012

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ABSTRACT

Research in the last decade in the Gulf of Chiriquí (82°W, 8°N) in western Panama has revealed this as an important area for southern hemisphere humpback whales belonging to Breeding Stock G. Small-boat surveys were conducted during the austral winter season (July-October) between the years 2002-2012 to assess their distribution, relative abundance and linkages to other breeding and feeding areas. Over 11,000 km were surveyed during 105 effective sea-days. A total of 502 sightings were made of 999 individual whales, including 262 calves. Over half (52%) of all sightings have included calves, which is a notably high percentage compared to other breeding areas. Photographic identifications have been obtained for 246 individual whales. Of these, 19 have been seen in multiple years. Initial comparisons of our catalog to other regions have established links to southern Costa Rica, and to feeding areas off Chile and Antarctica. This breeding area off Panama is notable because whales arriving here undertake an unusually long-distance, cross-equatorial migration from Antarctica and Chile, likely prompted by warmer water temperatures. Panama is also a breeding area for humpback whales from the Northeast Pacific, migrating from the California-Oregon-Washington feeding area during the boreal winter (December-March). In the next few years we plan to expand our research in the following areas: genetic analysis to further elucidate the relationship to other South Pacific breeding and feeding areas; comparison of mother-calf habitat use to other breeding areas used by Breeding Stock G to determine the role this area plays for calving; and long term acoustic monitoring to examine the temporal dynamics of area occupancy between the two distinct populations that migrate to Panama from the northern and southern hemispheres. Considering the tourism boom currently experienced by Panama and the proposed mega-developments for the Gulf of Chiriquí, fully describing the importance of this area will be crucial in ensuring that the proper conservation measures are taken.

KEYWORDS: HUMPBACK WHALE, BREEDING STOCK G, BREEDING GROUND, PHOTO-ID, DISTRIBUTION, MIGRATION

INTRODUCTION

Humpback whales have been previously described off the Pacific coast of Central America during the austral breeding season (Townsend 1935; Acevedo and Smultea 1995; Florez-González et al. 1998; Rasmussen et al. 2007; Best 2008). These whales have been linked to feeding areas off Chile and Antarctica (Acevedo et al. 2007; Rasmussen et al. 2007) as well as to adjacent breeding areas off Colombia (Florez-González et al. 1998). Central America is unique because it harbors the northernmost breeding area of any southern hemisphere humpback whale population, with whales migrating approximately 8300 km from the feeding areas (Acevedo et al. 2007; Rasmussen et al. 2007). Whales migrating from feeding areas off California-Oregon-Washington also use Central America as a breeding area between December and April (Steiger et al. 1991, Calambokidis et al. 2000, Rasmussen et al. 2012). This is the only known breeding area in the world that hosts two populations from distinct hemispheres.

Here we describe the results of small-boat surveys in the Gulf of Chiriquí, western Panama, conducted during the austral winter season (July-October) between the years 2002-2012. Our objectives were to assess whale distribution, relative abundance, and group composition and to determine linkages to other breeding and feeding areas through photo-identification.

METHODS

The Gulf of Chiriquí lies in the western part of Panama, and is bordered by the Azuero Peninsula to the east, and Punta Burica to the west. (7°18'-8°18'N, 82°54'-81°36'W; Fig. 1) This gulf is characterized by generally shallow waters (<300m) and many island groups. Surveys were opportunistic in design, aiming at maximizing the number of whales to be sampled. The breeding season for the southern hemisphere is considered to be between June and October (Chittleborough 1958) and most surveys were conducted in August and September of

every year, except for 2005, when there was no fieldwork. Daily surveys were conducted from open-hulled small boats (between 22-28 feet in length), with outboard engines. Surveys were conducted at an average speed of 15 knots, with 2-3 observers on board. Data collected for every whale sighting included GPS location, behaviors, group composition, bottom depth, and sea surface temperature. Photo-identification techniques were used (Katona and Whitehead 1981) in which whales were approached slowly from behind, and the undersides of the tail flukes were photographed with a *Nikon* digital SLR camera in order to identify individuals.

Survey effort was stopped at regular intervals (every 30-60min) and a hydrophone on a 10m cable designed by Cetacean Research Technology with a sensitivity of −180dBV/uPa ± 4dB, and a frequency response from 0.02kHz to 60kHz, and from 100kHz to 250kHz was deployed to determine acoustically if any humpback whales were present. A minimum of one minute was recorded for each station, and if humpback whale vocalizations were heard, longer recordings were made.

Yearly encounter rates (whales seen per kilometer surveyed per year) were calculated to give an index of relative abundance while adjusting for bias of areas of greater effort.

Identification photographs from all years were entered into a catalog for Panama. From this catalog, resighting rates were calculated as the number of sighting events in the sample/the number of unique individuals identified in that sample, both for each year and overall. The catalog was compared with identifications previously obtained off Costa Rica (2000-2004) during the austral winter, and Fundación Cequa in Chile is currently conducting a comprehensive comparison of our identification photographs against catalogs from other breeding areas in Colombia, Ecuador, and Peru, and from feeding areas in Chile and Antarctica.

Figure 1. Study area of humpback whale surveys in Gulf of Chiriquí, western Panama.

RESULTS

Over 11,000km were surveyed on 105 separate days between 2002 and 2012 (no sampling was conducted in 2005). Survey effort was variable between years due to logistical and financial constraints, with five years having less than 10 survey days, and only one year having more than 20 survey days. 2007 and 2012 had the highest number of survey days (18 and 22 respectively) as well as the most distance covered, with both years covering over 2,000km (Table 1; Appendix 1).

Table1. Survey effort and whale sightings including dates, number of survey days, km surveyed, total number of humpback whale sightings, total number of individual humpback whales, total number of calves, percent of sightings that include a calf, and number of whales seen per km surveyed.

		Survey effort				Whale sightings				
Location	Year	Start date	End date	Survey days	Km	Sightings	Whales	calves	% groups w/calves	Whales/ km
Panama	2002	5-Sep	14-Sep	6	872	19	32	7	37%	0.037
	2003	2-Sep	6-Sep	5	441	21	45	13	62%	0.102
	2004	6-Sep	9-Sep	4	402	18	33	12	67%	0.082
	2006	29-Aug	1-Sep	4	536	17	34	13	76%	0.063
	2007	28-Jul	2-Oct	18	2,104	62	125	29	47%	0.059
	2008	13-Jul	14-Sep	16	1,631	54	118	29	54%	0.072
	2009	16-Jul	9-Sep	15	1,567	86	174	51	59%	0.111
	2010	27-Aug	30-Aug	4	205	18	38	10	56%	0.185
	2011	5-Aug	26-Aug	11	1,336	66	133	32	48%	0.100
	2012	5-Aug	11-Sep	22	2,245	141	267	66	47%	0.119
All Years				105	11,339	502	999	262	52%	0.088

Most surveys were conducted either from the Islas Paridas or the Islas Secas (Fig. 1) and were focused on those areas, but extending into the adjacent Islas Ladrones and Islas Contreras. Further to the east, Isla Coiba was also surveyed, although not as frequently as the other areas. Humpback whales were sighted throughout the survey area, with most sightings occurring where the majority of the effort took place. No humpback whales were sighted during the one survey towards Punta Burica, to the west, or on the oceanic side of Isla Coiba, on the eastern side of the study area (Fig. 2).

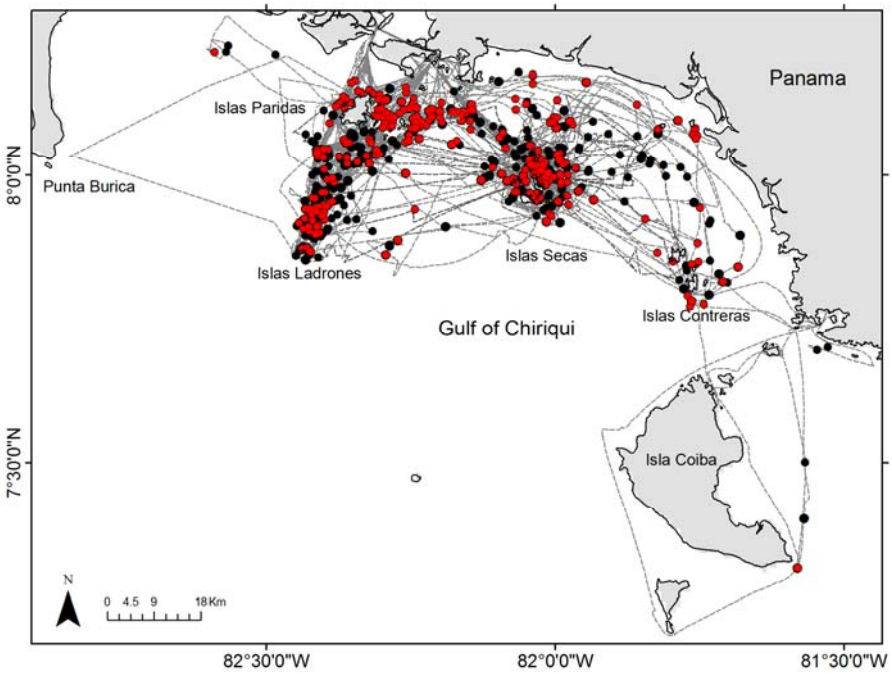

Figure 2. Survey effort and sightings of humpback whales and calves in Gulf of Chiriquí, Panama between 2002-2012. Hatched lines represent survey effort, black dots represent sightings of humpback whales, and red dots represent sightings of humpback whales that included a calf.

A total of 502 sightings were made, containing 999 individual animals. Yearly encounter rates (whales seen per km surveyed) ranged between 0.037 and 0.185 ($\bar{x}$=0.093, SD=±0.041), and the total for all years was 0.088 (Table 1).

Sightings of mothers with calves occurred throughout our survey area, but most notably around the island groups and near the mainland (Fig. 2). For all years, 52% of sightings contained a calf, while the yearly percentages ranged between from 37% to 76% ($\bar{x}$=57%, SD=±11%) (Table 1).

A total of 246 photographic identifications were obtained of unique individuals (Table 2), of which 19 (9%) were sighted more than one year; 14 were seen in two separate years, 4 were sighted in three years, and 1 was sighted over four years. By far the best year for photographic identifications was 2012, with more than twice as many (n=87) as obtained in the next highest years (n=40 in both 2009 and 2011) (Table 2). The intra-annual resight rate (whales identified on more than one day within a year) was 1.0 (no whales were seen more than one time in that year) for four years, and ranged between 1.03 and 1.22 for the other six years, with an overall rate of 1.09 for all years (Table 2). The longest duration a whale was identified was in 2008, when one whale was first identified on 14 July, and identified again 46 days later on 29 August.

The hydrophone was deployed 447 times and song was heard on 336 of these deployments (75%). Song was heard throughout much of the survey area (Fig. 3).

Table 2. Results of photographic identification of humpback whales in the Gulf of Chiriquí between 2002 and 2012. Total ID's is the number of identifications including resights, Unique whales is the total number of unique whales identified each year, new whales are whales that had not been identified in previous years, Prev seen is the number that had been sighted in previous years, % prev seen is the percentage of whales identified in previous years, Resight rate is the number of total ID's/unique whales seen.

Year	Total IDs	Unique Whales	New Whales	Seen prev years	% prev seen	Resight rate
2002	4	4	4	0	0%	1.00
2003	11	9	9	0	0%	1.22
2004	6	6	4	2	33%	1.00
2006	4	4	4	0	0%	1.00
2007	35	34	34	0	0%	1.03
2008	35	31	28	3	10%	1.13
2009	43	40	35	5	13%	1.08
2010	12	12	12	0	0%	1.00
2011	42	40	35	5	13%	1.05
2012	98	87	79	8	9%	1.13
All Years	290	267	244	23	9%	1.09

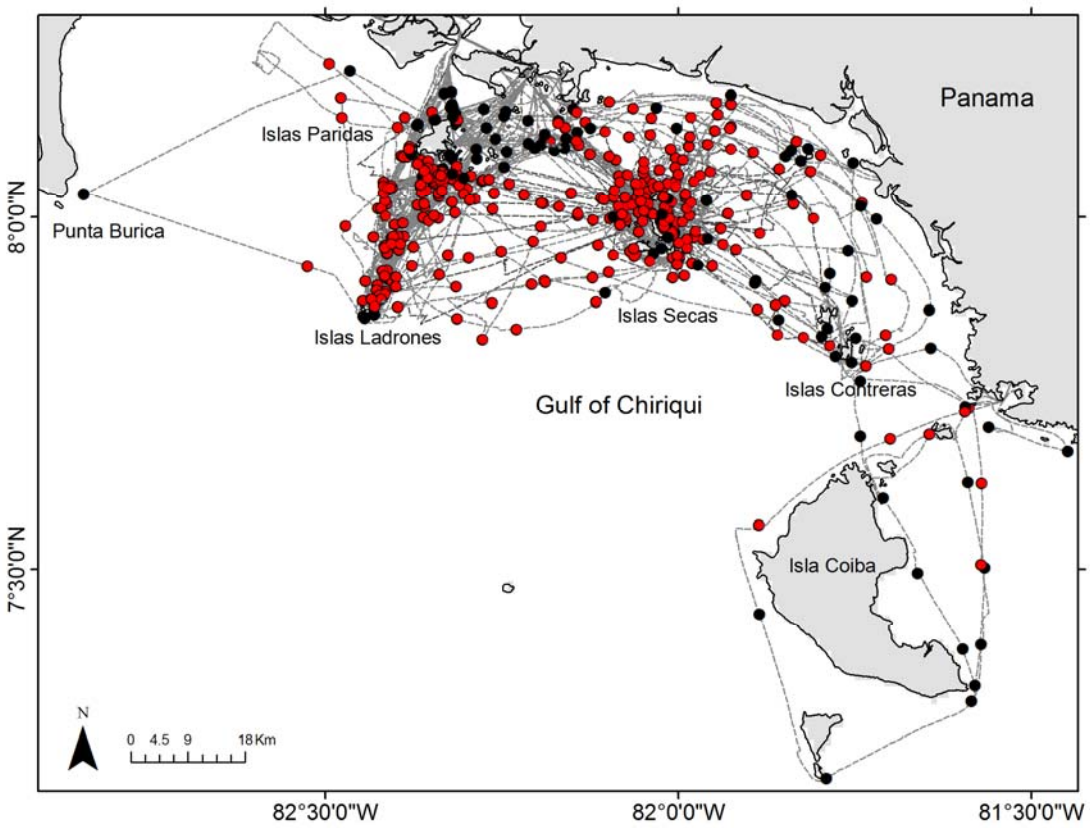

Figure 3. Survey effort and locations of hydrophone deployments and where vocalizations were heard in the Gulf of Chiriqui, 2002-2012. Black dots represent hydrophone deployments where no humpback whale vocalizations were heard, and red dots represent where vocalizations were heard.

DISCUSSION

Based on the sighting locations, the habitat used by humpback whales in the Gulf of Chiriquí appears typical of other humpback whale breeding areas: shallow waters near island groups or inshore waters near the mainland (Dawbin 1966; Whitehead and Moore 1982; Clapham and Mead 1999). Calves in particular were seen closer to the islands and near shore than non-calf sightings, as is also the case in other breeding areas (Craig 2000; Ersts and Rosenbaum 2003; Felix and Haase 1997; Martins *et al.* 2001; Smultea *et al*. 1994; Whitehead and Moore 1982).

The variability in encounter rate may be explained by the variable level of effort throughout the study period (Table 1; Appendix 1). The year with the highest encounter rate (2010; 0.185 whales/km) was also the one with the least effort (4 days; 205km surveyed).

Of particular note is the high rate of calf sightings. Over half of all sightings contained a calf, which is a higher percentage than has been reported for other breeding areas (other studies ranged from 8% to 28%; Mobley and Herman 1985; Mattila and Clapham 1989; Mattila *et al.* 1989; Garrigue *et al.* 2001; Hauser *et al.* 2000; Zerbini *et al.* 2004; Felix and Botero-Acosta 2011). This could be an artifact of where the surveys take place, with an upward bias resulting from the island groups and inshore waters where calves are typically found being surveyed more than deeper offshore waters. It is clear, however, that the locations being surveyed are an important nursery area for mother and calves, regardless of whether calves are found in a broader geographical range.

The low rate of inter-annual resights (9%) for the photographically identified whales indicates that much of this population has not been sampled. Even with the doubling in sample size in 2012, the rate of resight did not notably change. The intra-annual resight rate was also relatively low (1.09) which may suggest that many of these whales are not remaining long in the area. However, mother-calf pairs are more likely to be found in shallower waters and less likely to raise their flukes and be photographically identified, which could bias our

sample. For intra-annual resight rates dorsal fin identifications of all the individuals may give a more accurate indication of residence time, although we have not attempted this approach.

The detection of humpback whale song throughout the study area is mostly consistent with where sightings have occurred. Song was also detected in areas that have relatively low density of sightings, particularly to the west of the Islas Secas. This area has not been surveyed as heavily as near the island groups, which could account for the lack of visual sightings. It is interesting to note that song has not been heard in the area to the north and east of Isla Parida, the largest island in the Islas Paridas island group (Fig. 3). This area has a large number of mother-calf sightings (Fig. 2). We do not see this same pattern, however, in other areas of our survey, where both song is heard and mother-calf pairs are sighted.

Whales identified off Panama have previously been linked to whales seen in the breeding area off Colombia (Florez-González et al. 1998), and whales seen off Colombia had been linked to feeding areas off Antarctica (Stone et al 1990). During the 10 years of this study, photographic matches were made from this catalog to the Straits of Magellan (Chile) and to the Antarctic Peninsula (Acevedo et al. 2007; Rasmussen et al. 2007). With the addition of over 200 new identifications since these comparisons have been conducted, new comparisons should further elucidate the relationship between Panama and the breeding and feeding areas of Breeding Stock G. Comparisons currently being conducted by Fundación Cequa in Chile include catalogs of whales seen off other breeding areas (Ecuador, Colombia and Peru) as well as feeding areas (Chile and Antarctica) for this stock.

Genetic sampling will also help clarify the structure of this particular stock. Three sloughed skin samples have been collected, although they have not been analyzed yet. We hope to collect biopsy samples in the next few years.

In coming years we plan to expand our research in the following areas: genetic analysis to further elucidate the relationship to other South Pacific breeding and feeding areas (three sloughed skin samples have been collected, and we hope to start collecting biopsy samples); comparison of mother-calf habitat use to other Southeast Pacific breeding areas to determine the role this area plays for calving, and long term acoustic monitoring to examine the temporal dynamics of area occupancy between the two distinct populations that migrate to Panama from the northern and southern hemispheres.

Having a long-term data set of baseline data in this location will likely be valuable to this particular population of whales. These data can be used to assess the demographic trends of this population as well as any migratory shifts that may occur. Both of these aspects could be affected by climate change, or other anthropogenic pressures such as increased boat traffic and pollution. Considering the tourism boom currently experienced by Panama and the proposed mega-developments for the Gulf of Chiriquí, fully describing the importance of this area and maintaining a long-term data set will provide crucial information toward ensuring that the proper conservation measures are taken.

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Appendix

To illustrate survey coverage and its variability over the years of the study (2002-2012), in Figure A1 we present maps of yearly survey effort and sightings.

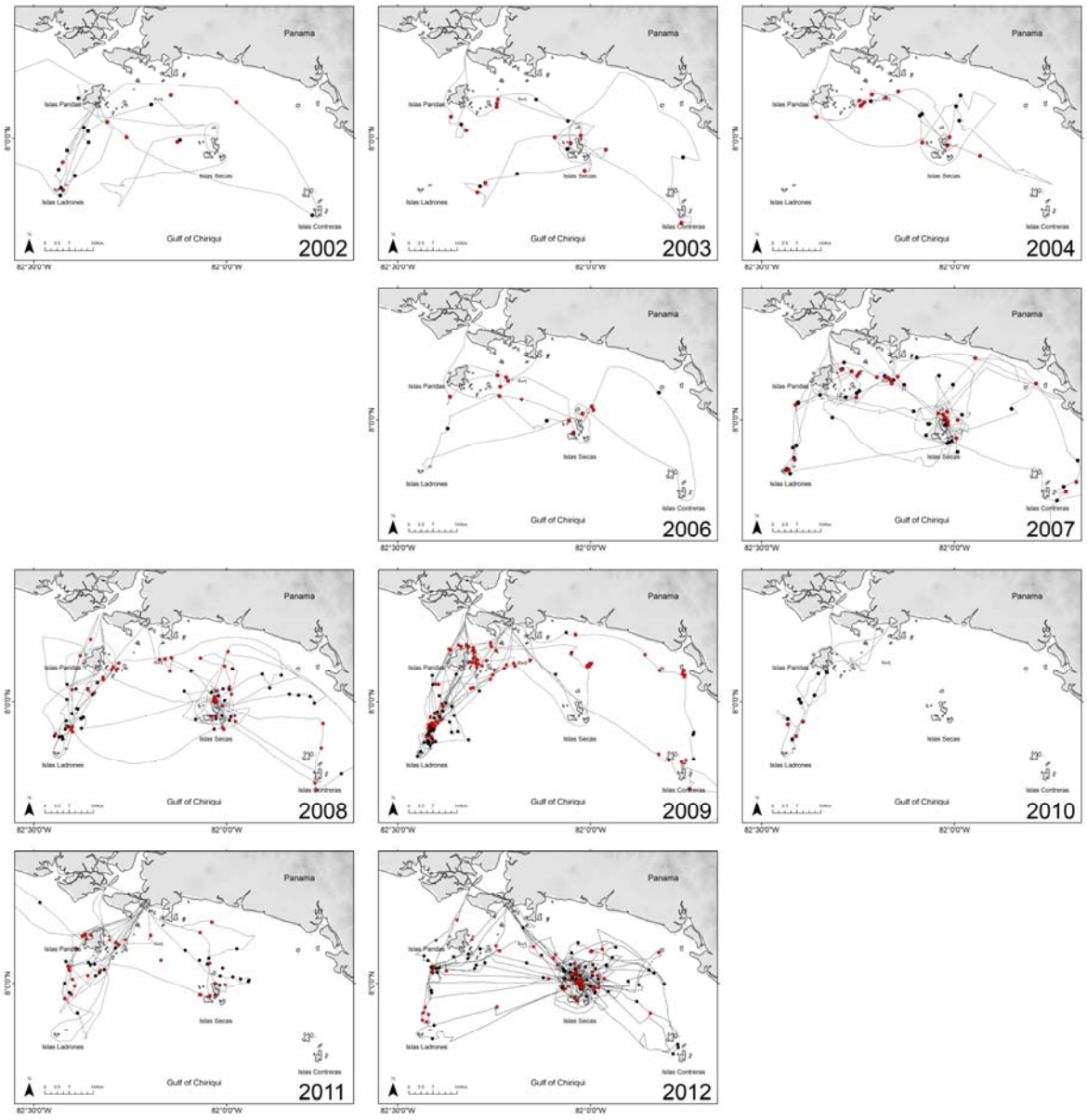

Figure A1. Maps of survey effort and humpback whale sightings by year. Hatched lines represent survey effort, black dots represent sightings of humpback whales, and red dots represent sightings of humpback whales that included a calf.