Report of the Southern Right Whale Die-Off Workshop

15-18 March 2010, Centro Nacional Patagónico, Puerto Madryn, Argentina

1. Introduction

At its 61st annual meeting in Madeira in June 2009 the Scientific Committee of the International Whaling Commission (IWC SC) received data on exceptionally high mortality ('die-offs') of southern right whales (*Eubalaena australis*) in the region of Península Valdés, Argentina, during the period from 2005-2008 (Uhart *et al.* 2008, 2009). It recommended that a steering committee be formed (R.L. Brownell, Jr. [convener], V. Rowntree, T. Rowles, M. Uhart and H.C. Rosenbaum) to plan a workshop in 2011 to review possible causes and impacts of this mortality and to identify future research needs. By August 2009 it had become clear that another year of high mortality was underway (see the following paragraph) and the steering committee, in consultation with the IWC Head of Science (Greg Donovan), decided to hold the workshop in the first quarter of 2010.

Since 2003, when the Southern Right Whale Health Monitoring Program (SWRHMP) was established for the Península Valdés region by a consortium of local NGOs, a total of 366 right whale deaths has been recorded, with peaks in 2003 (31), 2005 (47), 2007 (83), 2008 (95) and 2009 (79). Most (91%) of the animals dying have been first-year calves. The Península Valdés population was increasing at a rate of approximately 6.8% from the early 1970s to 2000 (Cooke *et al.* 2001, 2003). The rate of increase has not been estimated since the die-offs started, but if the population has continued to increase at the same rate since Cooke's estimates, it may now number around 6,100 whales (Rowntree pers. comm.). Therefore, the average annual recorded calf mortality in the Península Valdés region from 2007-2009 (presumably not all dead calves are observed and reported) would be around 1.4% of the estimated population size. The number of live calves counted has been increasing at a rate of 6.8% annually since 1971. Over the period from 2003-2009, the count of live calves increased at 11% per year while the number of dead calves counted increased at 25% per year (Rowntree *et al.* unpublished data).

The general aim of the workshop was to obtain a better understanding of all aspects of the recent high mortality of right whales in Argentina. Towards this end, it brought together three groups of scientists: (1) local experts with direct knowledge of the ecology and marine environment of the Península Valdés region, (2) experts studying right whales in the region and (3) international experts on whales and mortality factors such as disease and biotoxins. Specifically, the workshop sought to determine the cause(s) of the recent high mortality and the implications of this mortality for the right whale population as well as to develop a future research and monitoring programme.

The workshop was hosted by the Centro Nacional Patagónico (CENPAT) in Puerto Madryn, Argentina, and local arrangements were handled by Enrique Crespo of that institute. Crespo and R.R. Reeves were added to the steering committee for the workshop in early 2010. Workshop funding was provided by the IWC, NOAA Fisheries, and the U.S. Marine Mammal Commission.

a. Opening and welcome

Dra. Mirtha Lewis, Director of the Centro Nacional Patagónico, welcomed participants to the host laboratory. Further words of welcome and introduction were given by Crespo and Brownell.

The list of participants is given as Annex A and the meeting agenda is given as Annex B.

b. Arrangements

Reeves was appointed chair. Peter Thomas agreed to serve as the lead rapporteur, with various other participants helping to draft parts of the report on an as-needed basis.

c. Documents and document control

No new documents were prepared specifically for the workshop and therefore no document numbering system was established. Most of the new material was presented in the form of slide presentations, of which summaries have been incorporated into this report.

d. Reporting

The workshop report was to be completed in time for submission as a document to the 62nd IWC SC meeting in May-June 2010. Responsibility for preparation of the draft final report was assigned to Reeves, Thomas and Brownell (editors) on the understanding that it would be circulated to participants for review and then appropriately revised by the editors.

2. Background on southern right whales around Península Valdés

a. History of the population around Península Valdés and in the South Atlantic

Brownell gave an overview of this topic, noting that most of the global population of southern right whales was historically, and remains today, centred in the South Atlantic Ocean. Early whaling in coastal Brazilian waters has been summarised by Richards (2009). Shore whaling had started near Bahia by 1603 with Basque whalers providing instruction and guidance. This hunt was directed mainly at females with calves and took place between May and November. By 1678, three whaling stations operated in Bahia, one in Rio de Janeiro and one on Ilha de Santa Catarina (a decade later several were operating on the island) in southern Brazil. Until 1770, catch levels were 20-30 per year, but after that year they jumped to more than 1,000 per year for all operations combined. The right whale population in Brazil became depleted and whaling there had all but stopped by the early 19th century. Townsend (1935) plotted catches of right whales by American ship whalers in the late 18th, 19th and early 20th centuries, centred mainly in two large areas – (1) Brazil Banks (covering a larger area from southern Brazil to central Argentina) and False Banks (east and south of the La Plata River, between Uruguay and Argentina), and (2) around the Falkland (Malvinas) Islands at about 52° S. Southern right whales were a very minor component of the worldwide commercial catch in the early part of the 20th century and by the mid 1930s they were generally protected because of their extremely depleted status.

Tormosov *et al.* (1998) reported that between 1951/52 and 1970/71 at least 3,368 right whales were taken by Soviet factory-ship operations in the Southern Hemisphere. Most of them were taken in the 1960s with over a third (1,315) caught by *Sovietskaya Ukraina* during the 1961/62 season in the western South Atlantic off Argentina.

A team led by R.M. Gilmore, aboard the U.S. National Science Foundation's research vessel, *Hero*, searched for whales along the coast of Argentina and Uruguay between 9 June and 7 August 1969 (Gilmore 1969). A concentration of 20-25 right whales was observed near shore at the entrance of Golfo Nuevo. According to Brownell, who was on the cruise, it covered waters along the Argentine coast from just south of Mar del Plata to Tierra del Fuego. The first right whale was observed in mid-July, west of the entrance of Golfo San José. There were no further sightings as the vessel passed Punta Norte and came to anchor near the mouth of Golfo Nuevo for the night. The next morning, the vessel searched the perimeter of Golfo Nuevo and it was only while preparing to depart from the gulf in the afternoon that the 20-25 right whales were encountered inside its western entrance.

b. Long-term studies by non-governmental groups (NGOs) since 1971

Rowntree summarised the long-term research programme initiated by Roger Payne in 1970 at Península Valdés (Payne 1986). This region is a calving/nursery ground for southern right whales. Calves are born and spend their first two to three months of life in waters bordering the peninsula (Whitehead & Payne 1981; Thomas & Taber 1984). The whale season in the region extends from May (possibly even April) to December, with peak numbers present in late September (Whitehead and Payne 1981). Most calves are born in August or September. The whales are primarily fasting while on the nursery ground but may feed ocasionally on early spring plankton blooms by late September (Payne 1995; Sironi 2004; Hoffmeyer *et al.* 2010). The only definite connection between the Peninsula Valdés whales and a feeding ground comes from four re-sightings of known individuals off South Georgia in the region of the western South Atlantic with the highest abundance of krill (*Euphausia superba*) (Atkinson *et al.* 2001; Bonner 1987; Moore *et al.* 1999; Rowntree *et al.* 2008). As mentioned earlier, Soviet whaling operations removed 1,312 right whales on the Patagonian Shelf (centred around 42°S) in November-December 1961 (Tormosov *et al.* 1998), suggesting that the whales forage there immediately after leaving Península Valdés. Around South Georgia, right whales appear to arrive in January and reach peak numbers in March (Bonner 1987) although they have been sighted there in every month of the year (Moore *et al.* 1999).

In discussion, Brownell pointed out that three right whales taken in either the 1927/28 or 1928/29 whaling season had been feeding on post-larvae of lobster krill (*Munida gregaria*) on the Patagonian Shelf (Matthews 1932) and a right whale taken off South Georgia in 1926 reportedly had krill (*Euphausia superba*) in its stomach (Matthews 1938). Also, a 6.5 m calf taken at South Georgia on 26 August 1926 had milk in its stomach (Matthews 1938).

Rowntree presented data on demographic parameters of the right whale population that visits Península Valdés. Every year since 1971, surveys have been flown along the perimeter of the peninsula and each whale encountered has been documented by photographing the individually distinctive pattern of callosities on its head and recording its location and the presence or absence of a calf (Payne *et al.* 1983). From these data, the population size was estimated at 2,577 whales in 1997 (IWC 2001, p. 19; Cooke *et al.* 2001), 3,346 in 2000 and, extrapolating at a growth rate of 6.8% per year, 6,100 in 2009 (Rowntree, pers. comm.).

The almost 40-year data set also illuminates the reproductive histories of known individual females. A three-stage model of the adult female population has been used to fit the observed calving histories (Cooke *et al.* 2003). The modal calving interval is considered to be 3 years with 1 year spent in each of three stages: calving, resting and receptive. Population parameters were estimated by fitting the models to the individual sighting histories. Cooke *et al.*'s (2003) most recent updated estimates of demographic parameters through the year 2000 were presented to the workshop by Rowntree and include: mean calving interval 3.42 yr (S.E. 0.11 yr); mean age of first calving 9.1yr (S.E. 0.4 yr); annual adult female mortality rate 0.020 (S.E.0.004); annual rate of population increase 6.8% (S.E. 0.5%); reproductive female population size in 2000, 697 (S.E. 48).

In discussion following Rowntree's presentation, it was noted that right whale distribution around Península Valdés had changed from the 1970s to the 1990s, with a shift of occupancy from the outer coast into the two gulfs, especially the more southerly Golfo Nuevo, but there is no obvious connection to the recent high mortality of calves. According to Moore, Lysiak (2009) found evidence of a recent decline in isotopic carbon in the baleen of North Atlantic right whales, possibly linked to climatic shifts. No similar decline has been reported for southern right whales.

In response to a question of whether right whale calves feed on anything other than milk while in the area of Península Valdés, it was noted that this had not been observed directly (Thomas and Taber 1984) nor had evidence of solid foods been found in the stomachs of necropsied calves.

c. Long-term studies by the Marine Mammal Laboratory, CENPAT

Crespo summarised the unpublished results of aerial surveys around Península Valdés during the period 1999-2008 by a team of scientists affiliated with the Marine Mammal Laboratory, Centro Nacional Patagónico (CONICET) and the University of Patagonia (Enrique A. Crespo, Susana N. Pedraza, Silvana L. Dans, Mariano A. Coscarella and Guillermo M. Svendsen).

He noted that this programme is designed to monitor trends in numbers, seasonal changes within and through years, changes in distribution and seasonal patterns of arrival and departure of whales in the area. Twelve aerial surveys were conducted between May 1999-December 2000 and 29 between October 2004-November 2008, flying parallel to the coastline at an altitude of 500 feet with a strip width of 1500 m, from the mouth of Chubut River (42°30′) to Puerto Lobos (42°) for a total coastal strip length of 620 km. Whales were classified as: a) mother-calf pairs, b) solitary individuals or c) breeding groups considered as one female and *n-1* males. Around 95% of the whales were within the strip and the number of whales in the strip can be considered a measure of relative abundance. The interval between flights ranged from 45-50 days. Crespo considered this to be beyond the average residence times of whales in the area, so ideally during each census new individuals were being counted (however other workshop participants noted that mother-calf pairs have longer residency times, e.g. a mean of 77 days in 1973; Rowntree *et al.* 2001). Every year a bell-shaped curve of whale numbers was obtained with the first whales arriving in May and the last departing in December with the peak in late September.

The maximum counts occurred in September: 556 in 1999, 543 in 2000, 724 in 2005, 786 in 2006, 777 in 2007 and 673 in 2008. The rate of increase for the period 1999-2006 was estimated from the slope of the linear regression of the log-number of newborn calves in the peak of the season through time (r= 4.4, Lower CI 95%= 0.5, Upper CI= 8.3; R^2= 0.71, n= 6) and the log-number of whales in the peak of the season through time (r= 3.7, Lower CI 95%= 0.7, Upper CI= 6.8; R^2= 0.74, n= 6). The observed rate of increase is lower and probably underestimated relative to that estimated by mark-recapture methods but with similar confidence intervals. The estimated cumulative number of calves present was 335 in 1999 and 553 in 2008, while the estimated cumulative number of whales was 1,318 in 1999 and 2,507 in 2007. It should be noted, however, that mothers and calves have longer average residence times than other whales and therefore the calf numbers are probably positively biased.

In addition to the whales observed along Península Valdés, aerial surveys of Golfo San Matías to the north encountered more than 120 whales in the peak of the season. The whales counted there, primarily single individuals and courting groups, are additional to those counted along Península Valdés.

d. Prior documentation/history of stranding events

Rowntree reported that, before 1994, records of strandings were maintained on an opportunistic basis. She stressed that in the early years of the right whale photo-identification project, when the whale population may have numbered only about 500, one would not expect many strandings to have occurred. If there had been large numbers, she is confident this would have been noticed during the multiple aerial surveys conducted along the coast at the time. Beginning in 1994, A. Carribero, M. Rivarola and A. Arias made a concerted effort (supported in part by a grant from the National Geographic Society) to record strandings, began developing a reporting network, conducted visual surveys of some beaches and took measurements and collected tissue samples and baleen from stranded whales to support studies of toxins, genetics and isotopes. A marked increase in survey effort occurred in 2003 with the initiation of the Southern Right Whale Health Monitoring Program (SRWHMP).

Harris reported counts of live and dead right whale calves in the eastern portion of Golfo San José between 1982 and 1988 (Table 1) (Harris 1990). During this 7-year period, counts of live calves ranged from 11-20 (mean of 15) and counts of dead calves ranged from 0-6 (mean of 3). The highest observed mortality rate (dead calves counted/live calves counted) in one year was 42% in 1987, followed by 30% in 1985.

However, the calf counts reported by Harris were from a limited area, made from a cliff-top observatory on the eastern edge of the gulf, and only those counts made on calm days at high tide with the best opportunities for observing whales were used. Comparisons with aerial surveys made at the same time in the same area indicated that total counts of live calves from the observatory were similar to those from the aircraft. Most of the dead calf carcasses were visited and measured. They were also observed during subsequent counts and if a carcass had moved with high tides, this was noted to avoid the possibility of double counting.

Table 1: Cliff-top counts of live and dead calves (0-3 months of age) in Golfo San José between June and December of 1982-1988 (Harris 1990).

Year	Number of live calves	Number of dead/stranded calves	Mortality rate	Survival rate
1982	14	3	21.4	0.786
1983	14	1	4.14	0.929
1984	15	0	0	1
1985	20	6	30	0.700
1986	17	3	17.6	0.824
1987	12	5	41.66	0.583
1988	11	1	9	0.910
Average	14.71	2.7	18.11	0.819

3. Background information specific to the southern right whale population and Península Valdés

a. Predation by killer whales

Sironi presented information (Sironi *et al.* 2008) on killer whale predation on southern right whales between 1972-2000. In the 1980's, right whales abandoned the area with the highest occurrence of killer whales (the Eastern Outer Coast [EOC] of Península Valdés) and moved into Golfo San José and Golfo Nuevo, where killer whales are rarely seen (Rowntree *et al.* 2001). A total of 117 killer whale/right whale encounters were reported between 1972 and 2000 off the coast of Península Valdés. Of 112 encounters, 63 (56%) were grade 1 (no behavioural changes observed), 37 (33%) were grade 2 (behavioural changes observed), and 12 (11%) were grade 3 (actual attacks by killer whales on right whales were observed). Adult right whales with or without calves were the main targets of the attacks; in fact, 80% of the attacked whales were adults. Right whale calves were seen in only two attacks (16.7%). The number of encounters per decade decreased with time, from 68 encounters in the 1970's and 26 in the 1980's to 23 in the 1990's. At the EOC the frequency decreased significantly from 11 encounters per year in the late 1970's to 2.3 per year in the late 1990's. Also, in the late 1970's, the encounters occurred over 8 months each year, from May to December, whereas in the late 1990's the 'time window' of encounters was reduced to only 4 months each year, from August to November.

Península Valdés has features that are advantageous for right whales to reduce predation risk. Mothers and calves aggregate in shallow bays, which may be an effective anti-predator strategy (Thomas and Taber 1984). In fact, calves were not the main targets during the observed attacks. It is possible that the relatively lower predation risk in the gulfs promoted the abandonment of the EOC by right whales. Although killer whale predation pressure can influence habitat choice by right whales, other causes for the observed changes in right whale distribution around Península Valdés cannot be ruled out. The predation rate decreased between 1972 and 2000, a trend that likely continues to the present. Only one dead calf in 2003 and two in 2009 had wounds that could be attributed to killer whale bites (SRWHMP;

Sironi, unpublished data). Thus, attacks by killer whales may represent a minor threat to right whales at Península Valdés compared to the yet unknown causes for the unusual mortality levels recorded in recent years.

b. Parasitism by kelp gulls

Sironi updated information on gull harassment of right whales at Península Valdés (Sironi *et al.* 2009). Kelp gulls (*Larus dominicanus)* eat the living skin and blubber of southern right whales and the whales spend less time resting and more time in high-energy behaviour to avoid gull attacks (Rowntree *et al.* 1998; Thomas 1988).

Gull attacks were first reported by Cummings *et al.* (1972) and the impacts on right whale mothers and calves were described and quantified in Golfo San José by Thomas (1988) in 1984. Sironi reported a 5-fold increase in the number of gull attacks recorded between 1984 and 1995, and he stated that the overall increase has continued to the present. Figure 1 shows the trend in gull attack frequency in Golfo San José and Golfo Nuevo between 1995 and 2009. At both sites, attack frequency was 12 % in 1995 and doubled to an average of 23.3% in Golfo San José and 24% in Golfo Nuevo for 2007, 2008, and 2009, the years with the highest observed right whale mortality.

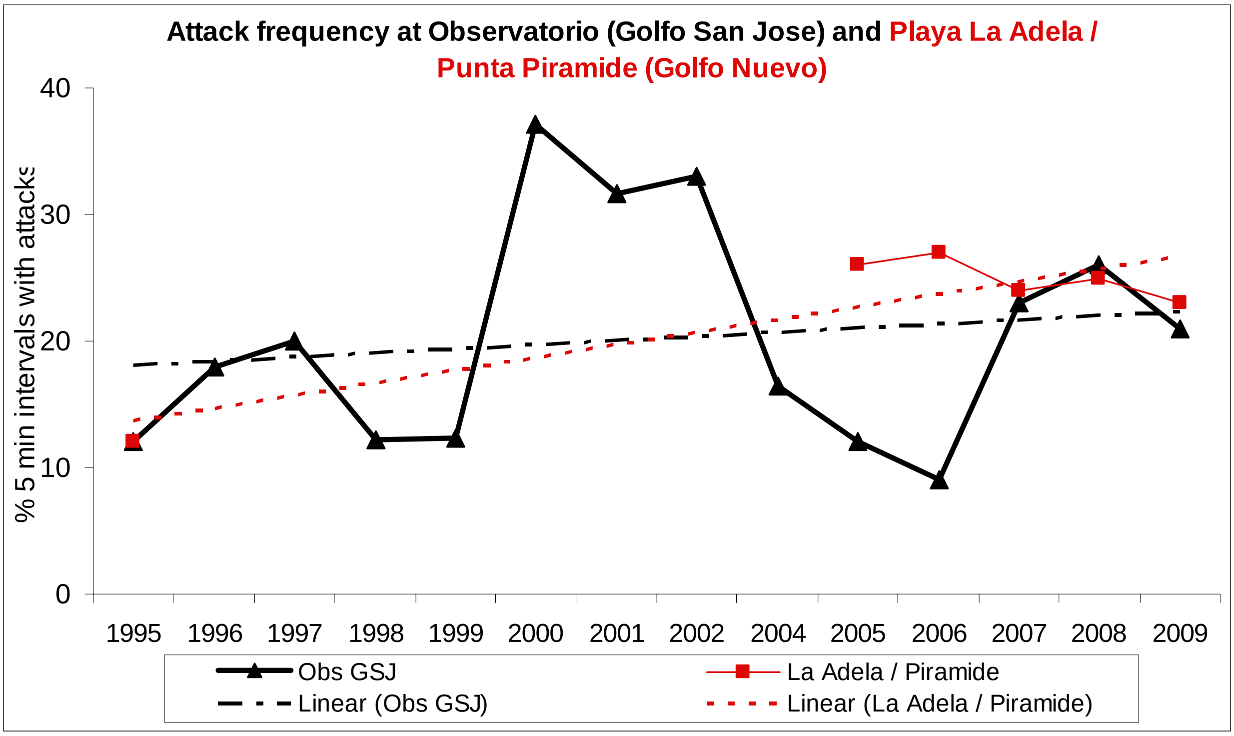


Figure 1. Frequency of gull attacks observed at Observatorio (Golfo San José) and Playa La Adela/Punta Pirámides (Golfo Nuevo) (Sironi et al., unpublished data).

Between 1999 and 2001, during continuous focal animal behaviour observations of 154 juvenile whales (approx. 1 to 4 years of age), 187 gull attacks were recorded (Sironi 2004). In addition, during hourly scans, 652 gull attacks were recorded on whales of all age classes. The majority of attacks (81%) were aimed at mother-calf pairs, 9 % were aimed at juveniles and 8.4 % were aimed at adults. The attack rate/h on mother-calf pairs (2.7) was 5x higher than for juveniles (0.5) and for juveniles the attack rate was highest (5.2) when they were interacting with mother-calf pairs and lowest (0.7) when they were in groups containing adults only. A small proportion of the gulls that were visible to the observer at any one time were involved in attacks. Gulls aimed 90.4% of their attacks at existing skin lesions and the remaining 9.6% at apparently smooth skin. Analysis of aerial photographs (Rowntree *et al.* 2008; Sironi and WCI/ICB unpublished data) showed that the percentage of whales with gull-induced lesions increased from 1% in 1974 to 37.8% in 1990, 67.6% in 2000 and 76.8% in 2008 (Figure 2).

The behavioural response of whales to gull attacks has changed as the attacks have become more widespread over the years. In 1984 about 25% of mothers attacked by gulls temporarily adopted resting postures ('crocodiling', or lying on the back or side) that put their dorsal region, from the blowholes to the caudal peduncle, under water (Thomas 1984). Since 1995 mothers spend the majority of their time, whether resting or travelling, in this 'crocodiling' or 'galleon' posture to keep their vulnerable backs submerged (Rowntree *et al.* 1998; Sironi and Rowntree, unpublished data). A significant consequence of the success of this maternal gull avoidance behaviour is that gulls now target calves much more frequently than they did in the past. In 1995, attacks on mother-calf pairs were directed at the calves almost as often as at the mothers (44% of 1,184 attacks)(Rowntree *et al.* 1998). In contrast, in 2009, 76% of the attacks on mother-calf pairs were aimed at the calves and the remaining 24% were aimed at the mothers (based on 934 attacks observed) (Sironi *et al.*, unpublished data).

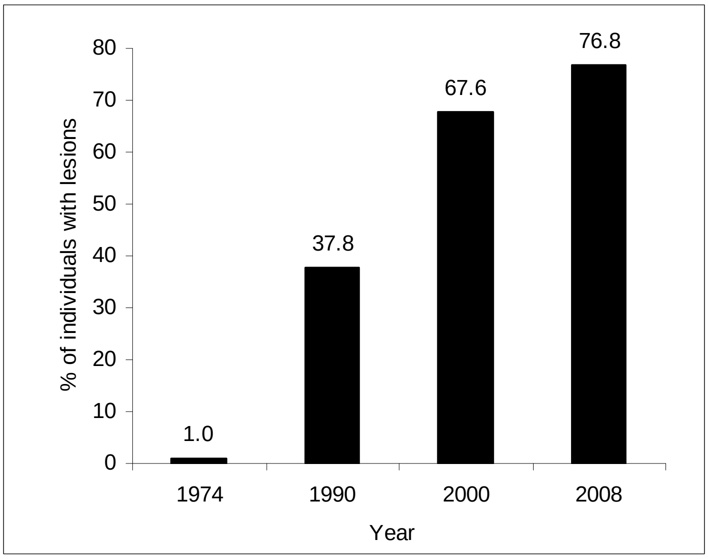


Figure 2. Percentage of individual whales with visible gull-peck lesions on their backs (1974-2008) (Sironi and WCI/ICB, unpublished data).

Gull attacks interrupt resting and nursing bouts and social interactions, and they may affect the behavioural development of calves and juveniles. Rowntree *et al.* (1998) suggested that intense gull harassment could compromise calf survivorship in this population, although a cause-effect relationship would be difficult to prove. The percentage of whales with gull marks and the attack frequency have continued to increase with time. This may be a consequence of the population growth of some gull colonies due to the increased availability of garbage and fishery refuse at landfills and offshore. Also, the fact that juvenile gulls attack whales indicates that gulls are able to imitate and quickly learn this 'new' behaviour so it is spreading within the local gull population. It is possible that all whales at Península Valdés will have gull-caused lesions in the near future.

Fazio and Bertellotti described various features of gull attacks based on their observations from whale-watch boats and cliff observatories along the edge of Golfo Nuevo (Bertellotti & Fazio in prep.). The kelp gull is a generalist and opportunistic species that feeds mainly on invertebrates and fish, but it also consumes garbage and fishery discards. Around Península Valdés, kelp gulls feed on pieces of skin and blubber ripped from the whales' backs, producing severe injuries because once a wound is opened gulls continue to enlarge it. This behaviour has increased since the first records in the early 1970s, along with the increase in the gull population.

During the whale reproductive seasons from 2005 to 2009, observers aboard whale-watch boats embarking from Puerto Pirámides (in eastern Golfo Nuevo) recorded gull attacks during 1,559 trips. The attack rate for 5,703 whale sightings was similar across years, with an overall mean of 4.50 attacks/h (SD=17.91) but the rate was consistently higher in July, August and September than in other parts of the season. Observations were made from a cliff in Punta Flecha (60 km from Puerto Pirámides) in September and October 2009. There, the mean attack rate was 8.61 attacks/h (SD=14.781, N=150). There were no significant differences in values from the previous years (ANOVA: P=0.3). Analysing the four years together, attack rates are higher within 200 m of shore (Kruskal-Wallis: X^2_3 =67.85, P<0.001; T3-Dunnet: P<0.001) and for mother-calf pairs.

Fazio and Bertellotti also provided information to the workshop on attempts by researchers at CENPAT to ascertain if gull-transmitted disease has played a role in the recent mortality events. Kelp gull attacks not only cause stress to the whales but also may transmit infections to them. Two groups of diseases might be transmitted: infections carried by and infecting the gulls themselves and whale-specific diseases transmitted by the gulls from one individual whale to another. A third potential risk category is the introduction of opportunistic pathogens into the whale via gull-damaged skin. In order to monitor disease in both gulls and whales, different sampling protocols were implemented. Whale health was assessed by taking skin and blubber biopsy samples from both healthy skin and lesions on live animals using a crossbow from a boat. Health monitoring of kelp gulls consisted of taking blood and swab samples. Analysis protocols include histopathology for the detection of viruses, bacteria and fungi. In addition, blood samples were collected intermittently between 2005 and 2009 from kelp gulls at nesting colonies. The sampling protocol included live capture and syringe blood extraction as well as swabbing from the mouth and cloaca. Analysis protocols include the detection of viruses, bacteria and fungi. From 2006 to date, 55 samples have been collected. These had been sent out for analysis but no results were made available to the workshop.

Much interest was expressed by workshop participants in the possible relationship between widespread and increasing kelp gull parasitism and the recent high mortality of right whales at Península Valdés. Discussion indicated that up to 80% of living calves have gull-peck lesions on their backs; this is not reflected in stranding data since either stranding position (often ventral side up) or extent of decomposition prevents examination of the backs of a large percentage of dead whales. It was also noted that some live calves have gull-peck lesions over their entire back. Lesions can heal with time, as the lesion fills in with epidermis around the edges and the exposed blubber is eventually covered, albeit leaving a depressed area.

The risk of disease transmission by gulls was discussed. During the time of year when they are feeding regularly on whales, the gulls often fly from breeding areas, to local dumps, to whales, in relatively short periods of time. Local dumps contain both human refuse and fish offal from the large fishing industry centred in Puerto Madryn. Moore emphasized the importance of continuing to investigate the possible role of gull parasitism in calf mortality. This should include consideration of the possibility that the gulls serve as disease vectors as well as the fact that behavioural changes by right whale mother-calf pairs during the calving/nursery period are energetically costly and possibly also stressful.

c. Whale watching

Information was provided on three subjects of study in collaboration with whale-watch operations – (1) demographic analyses from photo-identification, (2) analyses of whale responses to disturbance by the tourboats and (3) observations of wounds and scars on whales caused by vessel strikes.

Lindner, on behalf of a group of co-authors (Alejandro Carribero, Romina Espinosa, Luisina Bossio and Nadia Geremias), presented information on photo-identification and resightings of individual right whales from whale-watch boats in Golfo Nuevo. Although right whales are observed in the two large gulfs at Península Valdés every year from May to December, changes in their distribution have been observed over time. The working hypothesis of this study was that the pattern of return by individual whales subject to the influence of whale-watching would differ from that of the rest of the population. The objective of one element of the study was to determine the proportion of identified animals exposed to whale-watching that returned to the area in subsequent seasons.

Starting in 1995, a trained observer worked aboard the whale-watch boats in the waters adjacent to Puerto Pirámides. Photo-identification, based on photographs of callosity patterns organised in a digital catalogue, was used to construct encounter histories for use in mark-recapture models. The study identified a total of 931 individuals, of which 56 were seen and photo-identified on more than one occasion. Using multi-state mark-recapture models, the probability of return to the study area was estimated at one, two and three years after initial photo-capture.

The models indicated that 43% of the whales had a probability of returning to the study area every 3 years, 20% every two years and 36% every year. Furthermore, 15% of the photo-identified individuals were documented in the area off Puerto Pirámides only once during the study period. The authors concluded that some proportion of the whales that visit the area do not return in subsequent seasons, and that the population of whales present in this area each year therefore consists of both ‘new’ individuals and ‘returning’ individuals. They also surmised that the whales do not move as cohorts or seasonally stable groups but rather as individuals.

Lindner summarised her team’s findings with regard to right whale responses to whale-watch boats. Golfo Nuevo is the centre of whale-watch tourism directed at right whales, which has expanded from a total of about 4,500 tourists embarked in 1987 to 119,000 in 2006. The objective of this study was to describe the behavioural responses of right whales to the proximity of whale-watching boats. In general, the whales moved away from the boats, the interaction of whales with the boats caused short-term behavioural changes, and different approach speeds elicited different reactions from the whales.

Between 2004 and 2009, trained observers on whale-watch vessels recorded the interactions between whales and tourboats. Only a small proportion of the whales (15.25%) approached the boats. When the boats approached rapidly, the whales tended to move away (54.1% of the time), but if the boat approached at slow speeds, the whales generally appeared undisturbed (47.37%). Approximately 35% of the observations were made at the instant of first sighting, and 30%, 21% and 14% corresponded to behaviour observed 5, 10 and >10 minutes after initial sighting, respectively. The months of September and October had the greatest proportion of sightings (27.0% and 26.7% respectively), coinciding with the peak of tourist demand but not the peak abundance of whales in the area.

These results were interpreted by the authors as suggesting that only a small proportion of the whales interact with tour boats, and with no apparent adverse effects. Also, they interpreted their results as indicating that the speed of approach influences short-term whale responses. The authors presented their conclusion that whale-watch activities at the peninsula have developed and are currently governed more by efforts to meet tourist demand than by precautionary conservation measures designed to minimise disturbance effects on whales.

Lindner also presented analyses of scars and wounds observed on living right whales that she attributed to vessel strikes. In the catalogue of identified whales in the area, some have wounds or marks clearly caused by collisions with boats. An analysis of photographs of whales identified during the seasons of 2007, 2008 and 2009 found that 6% of them had evidence of vessel strikes. The workshop recommended that Lindner and colleagues prepare and publish a report on their findings on the return patterns of individual whales and responses to and impacts of whale watching activities.

d. Right whale feeding and potential food sources at Península Valdés

Although right whales generally fast at Península Valdés, feeding is occasionally observed (Payne 1995; Sironi 2004). Hoffmeyer *et al.* (2010) analysed the composition and biomass of zooplankton collected in the vicinity of foraging right whales at Península Valdés. Monthly plankton sampling and observations of whale behaviour and ocean features were conducted from whale-watch boats in Bahía Pirámides (Golfo Nuevo) between July and November 2005. During this study period, whales were seen feeding for 5 days between 19 and 23 October. Data and samples collected on 10 October provided a baseline for ocean and food conditions and whale behaviour when the whales were not feeding.

On 19 October 2005, at least 17 whales were seen feeding as the whale-watch boat approached and they continued to feed, with no observed change in behaviour, from 0800 until 1800 hours. During this feeding episode, zooplankton biomasses in the vicinity of the whales ranged between 0.09 and 0.21 g wet weight m^{-3}. These values were 2-3 times higher than those observed on 10 October when whales were not feeding. The zooplankton biomass values recorded around feeding whales at Península Valdés were lower than, or similar to, the low end of the ranges reported elsewhere on the Argentinian and Patagonian continental shelf. Nonetheless, these zooplankton densities apparently were sufficient to be used by right whales.

Menéndez *et al.* (in prep.) analysed floating faecal samples from right whales around Península Valdés. Right whales go there after a long migration from feeding areas at high latitudes and it is generally believed that they do not feed regularly in this calving/nursery area. However, feeding behaviour of whales has been observed occasionally in both Golfo Nuevo and Golfo San José, especially during the springtime (Thomas and Taber 1984; Sironi 2004). Also, faeces of whales have been detected from whale-watch boats operating in north-eastern Golfo Nuevo. Faeces collected in October 2004 were analysed qualitatively as part of a large project to evaluate plankton availability relative to right whale feeding behaviour. Some material was identified as mandibles and coxae of *Calanus australis* and/or *Calanoides carinatus,* large copepods typically found in the local area. Pieces of crustacean segments and antennae were also observed, some of which probably corresponded to euphausiids. In terms of relative abundance, copepod mandibles were the most abundant remains (>70%), non-identified tegument parts were abundant (30-70%) and copepod coxae and prosomes were scarce (<30%). These findings, the first of their kind from Argentina, provide clear evidence that right whales forage to some extent either at the calving/nursery area or on the Patagonian shelf immediately prior to arrival. The consumption of large copepods by southern right whales is consistent with the well-documented central role of *Calanus finmarchicus* in the diet of North Atlantic right whales (*Eubalaena glacialis*). Tormosov *et al.* (1998) found that whales killed north of 40°S had stomachs filled with copepods, between 40° and 50° S they ate a mix of krill and copepods and south of 50° they had stomachs filled with krill.

4. Background on southern right whales elsewhere in the western South Atlantic

a. Information related to summer foraging areas and prey

Information was presented from a number of studies on aspects of southern right whale reproductive and foraging behaviour away from the calving and nursery area at Península Valdés. These studies considered 1) linkages between reproductive success and changes in krill abundance, 2) possible maternally directed site fidelity to feeding locations and 3) identification of foraging locations from right whale baleen and blubber characteristics.

Rowntree reviewed the results of a study that linked reproduction in southern right whales with changes in sea surface temperatures (SST) and therefore krill abundance. In that study, Leaper *et al.* (2006) found that the reproductive success of the Península Valdés right whales, as measured from photo-identification data, was significantly correlated with SST off South Georgia in the sub-Antarctic, a likely feeding area. The authors reported that while southern right whales generally display a 3-year calving interval, when they deviate from this it is more often to a 5- rather than 4-year interval. This suggests that reproductive failure comes late in pregnancy or early in lactation (Leaper *et al.* 2006, and see Knowlton *et al.* 1994). The whales had fewer calves than expected when the SSTs off South Georgia were higher than normal with a 6 year lag between the El Niño events in the Pacific and the observed impact on right whale reproductive output. The chick and pup productivity at South Georgia of gentoo penguins (*Pygoscelis papua*) and Antarctic fur seals (*Arctocephalus gazella*) respectively, also showed significant negative relationships with SSTs during the same years. Time lags of 11 months between SST impacts on krill abundance and changes in chick or pup production were consistent with the life-history patterns of these populations (Trathan *et al.* 2006).

It was pointed out that the Leaper *et al.* (2006) study antedated the recent 'die-off' years at Península Valdés as it was based on a data time series from 1983-2000. The workshop **recommended** that the Leaper *et al.* paper be updated as soon as possible.

Southern right whales show strong maternally directed site fidelity to their near-shore calving/nursery grounds where they congregate in winter, but little is known about their summer feeding ranges and whether choices of feeding locations are also maternally directed. Valenzuela *et al.* (2009) described maternally directed site fidelity to feeding grounds by combining genetic and stable-isotope analyses of skin samples collected from live whales at Península Valdés. They found that isotopic values were more similar than expected among individuals sharing the same mitochondrial haplotype, indicating that calves learn their feeding locations (represented by an extremely broad isotopic range: -23.1 to -17.2‰ $\delta^{13}C$, 6.0 to 13.8‰ $\delta^{15}N$) from their mothers and teach them to their offspring. These findings suggest that the timescale of culturally inherited site fidelity to feeding grounds is long (at least several generations). According to Valenzuela *et al.* (2009), such 'cultural conservatism' may affect the species' flexibility to find and exploit new feeding opportunities and could help explain why reproductive success declines following ENSO-driven sea-surface temperature anomalies in an important feeding ground near South Georgia.

Rowntree reported on efforts to use stable isotope analyses of baleen and fatty acid analyses of blubber to identify right whale foraging locations and prey types. Baleen from an adult right whale contains a 6- or 7-year history of the whale's foraging pattern (Rowntree *et al.* 2008). Stable carbon isotope analyses of 5 baleen plates of adult right whales that died at Península Valdés showed a range of foraging strategies. All of the plates contained annual peaks that were consistent with foraging on plankton on the Patagonian Shelf shortly after leaving Península Valdés. Stable carbon isotopic signatures consistent with feeding off South Georgia or south of the Polar Front, probably on krill, indicated that most of the whales (4 of them) travelled to higher latitudes after initially foraging on the Patagonian Shelf. One whale had fed only at lower latitudes and thus had probably remained on the shelf to feed on copepods. Future analyses of the baleen and blubber of stranded calves could indicate the presence of krill and possibly the proportions of krill and copepods in the diet of their mothers while pregnant. The workshop **recommended** that this work be completed as soon as possible.

b. Southern right whales in Brazil

Groch reported that southern right whales were historically abundant off the Brazilian coast, from the border with Uruguay to the Northeast region. This population was severely depleted by commercial whaling in the 19th and early 20th centuries and was subject to intensive coastal whaling until 1973. By that time, the whale population appeared to have been extirpated from the region (Palazzo and Carter, 1983). In the early 1980s, right whales were 'rediscovered' in southern Brazil, and they have been studied since then. Since 1986, the species has been protected by national legislation in addition to the protection afforded under the IWC. Groups of right whales are sighted from July to November, especially along the southern Brazil coast, with peak abundance in September (Groch, 2005). Groups consist mostly of females with calves, but juveniles and adults without calves have also been sighted. The main area of concentration, located in Santa Catarina State, is a Right Whale Environmental Protection Area (130 km of coastline) established in 2000.

Between 1936 and 2009, 55 right whale strandings were recorded along the Brazilian coast (Greig, *et al.,* 2001; Gomes, 2005; Groch, unpublished data). Most of these records occurred in Rio Grande do Sul State, south of the main seasonal area of concentration. Of the total, 74% (N=41) occurred between 1990 and 2009, resulting in a rate of ~2 strandings/year. About 61% (N=34) were calves. The cause of 10 strandings was determined: 4 were attributed to entanglements and 6 to ship strikes.

Right whales wintering in Brazil have also been sighted off Península Valdés. In a comparison between 335 whales identified in Brazil and 1,884 whales identified in Argentina (comparison of data until 2004), 38 matches were found, representing 11.7% of the whales identified in Brazil (Groch *et al.* 2005).

Groch further reported that of the individual right whales identified in Brazil, 10%, mostly females, have been resighted from photo-ids, with a modal calving interval of 3 yr. The number of right whales encountered off Brazil appears to be increasing at a rate of about 14%/yr (Groch *et al.* 2005). The abundance of this population has been estimated to be as high as 555 whales in 2002 (Groch, 2005). To date, there has been no comprehensive assessment of the interchange/overlap between individuals photo-identified in different areas along the east coast of South America, and no regional population assessment has been carried out. The workshop **recommended** that this work be undertaken as soon as possible and at least by the time of the southern right whale assessment meeting to be held in 2011.

5. Global trends in disease and toxic algal blooms and other baleen whale 'die-offs'

a. Disease

Gulland noted that there are increasing reports of disease outbreaks and mortality events in marine mammals worldwide (Gulland and Hall 2007). This increase is partially explained by increased surveillance and improved technology for pathogen and toxin detection, but it also reflects the increasing frequency and distribution of factors such as harmful algal blooms that produce biotoxins that impact marine mammal health. Over the past 20 years, the majority of marine mammal unusual mortality events in the US with identified causes resulted from exposure to biotoxins such as domoic acid, brevetoxin and saxitoxin. Although increased numbers of dead marine mammals on beaches are relatively easily observed, such increases are not always a consequence of disease epidemics, but can result from changes in the prevalence of endemic disease, changes in nutritional status, direct anthropogenic impacts and changes in environmental conditions altering carcass distribution. Mortality events are typically a result of changes in multiple factors altering the animal's resistance to disease or exposure to a lethal factor, thus investigation of mortality events requires identification of potential predisposing factors as well as proximate factors causing death of an individual. For example, during the 1999-2000 mortality of eastern gray whales, examination of stranded animals revealed encephalitis, parasitism, domoic acid exposure and ship strikes as proximate causes of mortality, whereas photographic assessment of body condition of live animals revealed a severe change in nutritional status of the population as an underlying factor in causing increased mortality (Gulland *et al.* 2005). Limitations to investigations of unusual mortality events to date include difficulties in establishing nutritional status of individuals and distinguishing fatal starvation from seasonal fasting, lack of knowledge on the range of endemic pathogens in marine mammals, and paucity of data on lethal doses of biotoxins. As cumulative stressors can be fatal, it is important to not only identify proximate causes of mortality, but also to examine the entire life cycle of marine mammals impacted by unusual mortality events to understand reasons for die-offs.

b. Toxic algal blooms

Rowles reported there are numerous harmful algal blooms (HABs) in marine waters globally but only a few of them have been associated with marine mammal morbidity and mortality through toxin effects on the animals. Some biotoxins affect prey species and indirectly affect marine mammals through prey depletion or prey shifts. Similar to other toxicant exposure routes, potential exposure pathways for HAB associated biotoxicosis include: 1) absorption (dermal), 2) inhalation (respiratory), 3) ingestion through prey or lactation and 4) transplacental. For known biotoxicosis in marine mammals, ingestion is the more common route of exposure, with inhalation and transplacental exposures only occurring with a few toxins. Certain dinoflagellates, diatoms and cyanobacteria are known to produce biotoxins under certain conditions and for some of those toxins diagnostic tests are available. Those HAB associated biotoxins that have been evaluated for toxicity in marine mammals include ciguatoxins, brevetoxins, saxitoxins, okadaic acid, and domoic acid (see Table 2). Of these toxins, the three most commonly associated with morbidity or mortality in marine mammals are domoic acid, brevetoxins and saxitoxins. The reported prevalence of *Pseudonitzschia* blooms with domoic acid in marine environments as well as in prey species or marine mammal tissues is increasing in geographic extent and frequency. Of population concern for marine mammals are the frequency of exposures to this toxin in many marine ecosystems, the permanent long term effects of a single exposure, the acute reproductive and neurological effects and the documented transplacental exposures and impacts on the developing foetus. Brevetoxins are more limited in geographic scope but can be equally as significant for acute mortality events and the potential for secondary effects such as prey depletion and immune suppression. Saxitoxins also have wide geographic distribution in ecosystems and may have acute mortality at certain doses and in certain species. Data on North Atlantic right whales show that these animals annually graze on prey containing saxitoxin and periodically containing domoic acid without detection of any apparent biological effects on the animals. Given that most marine mammal exposures to biotoxins are through ingestion, many biotoxicosis cases in marine mammals may not occur coincident with the actual blooms but at a specific lag time after the bloom as the toxin moves through the food web. In some cases there is evidence of effects in marine mammals in the absence of an identified bloom in the area even when remote sensing is being used for monitoring. In most cases there are no easily identifiable lesions (except in domoic acid biotoxicosis) and in some cases exposure occurs days to weeks prior to the development of pathological lesions, therefore diagnosis in the absence of toxins in tissues, fluids, or gut contents (or prey) is extremely difficult. There are many HAB-associated biotoxins in marine waters and foodwebs for which there are no validated tests and for which the mechanisms of action and toxicity are not yet known.

Table 2. Common significant biological toxins in the marine environment (compiled for the workshop by T. Rowles).

Toxins	Organism	Exposure route	Symptoms	Gross or Histologic Lesions	Reported in	Life stage	References
Algal Toxins							
Domoic acid	*Pseudonitzschia australis*	Ingestion (prey, milk) Transplacental	Seizures Abortion Cardiac failure	Hippocampal necrosis and atrophy Cardiac necrosis	Pinnipeds Cetaceans	Feeding animals, suckling animals, foetuses, delayed effects in young animals following *in utero* exposure	Scholin *et al.* 2000; Brodie *et al.* 2006.
Saxitoxin	*Alexandrium, Gymnodinium, and Pyrodinium spp.*	Ingestion	Acute mortality incoordination, drowsiness, paralysis	None	Cetaceans Pinnipeds	Feeding animals	Geraci *et al.* 1989 Hernandez *et al.* 1998
Brevetoxin	*Karenia brevis*	Ingestion (prey and milk) Inhalation	Acute mortality, respiratory distress, neurological signs	Respiratory tract inflammation	Cetaceans Manatees	All nursing animals	Watkins *et al.* 2008
Ciguatoxin	*Gambierdiscus toxicus*	Ingestion of reef fish	Diarrhea, weight loss, itching, seizure, respiratory paralysis, temperature sensation reversal, fatigue	None	Suspected in Hawaiian monk seals	Feeding animals	Gilmartin *et al.* 1980
Okadaic Acid		Ingestion	Unknown	Unknown	Cetaceans		
Microcystins	Cyanobacteria	Ingestion, Inhalation, Dermal	Liver failure	Hepatic necrosis	Sea otters	Feeding animals	Miller pers. Comm..
Bacterial Toxins							
Botulinum	Clostridium botulinum	ingestion	paralysis	None	Beluga whale	All life stages	CDC 2003; Miller 1975
Tetanus	Clostridrium tetani	Ingestion Injection	Paralysis	None		All life stages	

c. 'Die-offs' in other baleen whale populations

Brownell summarised information on the few reported 'die-offs' of baleen whales. The first known report of such a 'multiple-death event' (other than incidents involving ice entrapment) occurred in 1987 when 14 humpback whales died in Cape Cod Bay (Massachusetts, USA) after consuming saxitoxin-contaminated mackerel (*Scomber scombrus*) (Geraci *et al.* 1989). In early 1995, at least 425 marine mammals, including individuals from three species of baleen whales, and 200 seabirds were found dead in the upper Gulf of California, Mexico (Vidal 1996). Four Bryde's whales were found dead in the Persian Gulf in 2007 (Braulik *et al.* 2010) but no details were available regarding the cause(s) of those deaths. Another 'die-off' may have occurred in the upper Gulf of California as J. Urbán-Ramírez informed Brownell that the remains of 10 dead baleen whales were found there in April 2009. Also, about 50 humpback whales were found dead along the coast of Western Australia during the latter half of 2009 (Doug Coughran, pers. comm. to Brownell).

The largest reported 'die-off' of baleen whales prior to the recent right whale mortality in Argentina involved gray whales in the eastern North Pacific. In 1999 and 2000, respectively, 283 and 368 gray whale deaths were documented. However, in 2001 the documented number of dead gray whales was only 21, which is around what is considered the background level for that population (Gulland *et al.* 2005; Brownell *et al.* 2007).

5. Southern Right Whale Health Monitoring Program
a. Stranding response protocols 2003-2009

Chirife described systematic efforts to monitor right whale mortality at Península Valdés that began in 2003, with the establishment of the Southern Right Whale Health Monitoring Program (SRWHMP). This programme is operated by a group of NGOs (Whale Conservation Institute, Wildlife Conservation Society, Instituto de Conservación de Ballenas, Fundación Patagonia Natural and Fundación Ecocentro).

Locating stranded whales.

The SRWHMP field team is active during the six months that right whales are present at Península Valdés (mid-June to mid-December). The team locates strandings through 1) bi-monthly surveys of the beaches where the whales concentrate, 2) aerial surveys of the coast and 3) reports from members of a local stranding network. The network's 70-plus members live and work along the coast of the peninsula and include wildlife officers, fishermen, local inhabitants, whale-watch captains, dive-boat operators, tour-guides, boat captains, airplane pilots, scallop fishermen, researchers, non-governmental organizations and local authorities such as the Coast Guard. The land-based survey effort has varied with vehicle availability and the number of strandings to be investigated. When the team is busy visiting multiple strandings in a given week, the survey for that week is cancelled or postponed. Aerial survey effort also varies. Strandings are recorded during at least one aerial survey a year covering the perimeter of the peninsula at the time of peak whale abundance. This survey is conducted collaboratively by the Whale Conservation Institute and Instituto de Conservación de Ballenas and is dedicated to photo-identification of individual whales. The stranding network consistently reports most of the strandings (above 70%) recorded in the area in a year. This highlights the importance of developing and maintaining such networks.

Necropsy protocol.

Stranded animals are investigated following a right whale necropsy protocol developed for the program by M. Uhart, L. La Sala and L. Pozzi. The protocol is based on protocols developed by McLellan *et al.* (2004), F. Gulland (pers. comm.), A. Carribero (pers. comm.) and Geraci *et al.* (1993). When a stranded whale is reported, SRWHMP researchers travel as soon as possible to the stranding site. Once it is confirmed that the animal is dead, the geographical location is recorded and photographs are taken. Depending on the physical conditions and the state of decomposition of each animal, body measurements are taken and an external examination is carried out in search of scars, wounds and any other evidence of the cause of death or of human interaction. Depending on the physical condition, an internal examination or necropsy is conducted (partially or completely). In all cases the animals' tails are tagged and notched to avoid recording repetitions. Detailed protocols and sample collection lists currently used for the beached whales are available upon request.

6. Review of right whale deaths around Península Valdés and findings to date from the die-offs

Uhart and Rowntree reviewed the history of strandings at Península Valdés and presented detailed information on the recent high mortality. The recent series of 'die-offs' began in 2003 and has continued until the present (see Table 3). In 2003, 31 right whales stranded at Península Valdés, 29 of them calves. This was followed by very low mortality in 2004, when only 13 dead whales were recorded. In 2005, 7 adult right whales died at Península Valdés, more than had been recorded in a single year since some level of monitoring began in the area in the early 1970s. Six of these dead whales were found in Golfo San José within a 6-week period. In the same year 36 calves and 4 juveniles died. In 2006 only 18 whales (16 calves, one juvenile and one adult) stranded and in 2007, 83 whales died, 77 of them calves. Of these, at least 61 (60 of them calves) died over a span of 72 days. Only three of these carcasses were found in Golfo San José and the rest in Golfo Nuevo. In 2008, 95 dead right whales were found at Península Valdés, 81 of them in a period of 10 weeks – 57 (52 of them calves) of these in Golfo Nuevo and 24 (all calves) in Golfo San José. Finally, in 2009, 79 dead right whales were documented at Península Valdés – 38 (of which 35 were calves) beached in a 3-week period. Again, the majority of the whales died in Golfo Nuevo.

With respect to the recent right whale die-offs, Uhart summarised the numbers, age and sex composition, and seasonal timing of strandings, including data presented previously to the IWC SC (Uhart *et al.* 2008, 2009). The number of strandings of individuals of all ages recorded from 1971 through 2001 grew at almost the same rate as the population (6.7%/yr compared to 6.8%/yr respectively)(Fig. 3). Survey effort increased from 1994-2002 (see Item 2.d., above) and again from 2003 with the initiation of the Southern Right Whale Health Monitoring Program (SRWHMP). Since 2003, the number of whales stranded has increased dramatically: 366 right whale deaths were recorded and investigated at Península Valdés through 2009, with peaks in 2005 (47 strandings), 2007 (83), 2008 (95) and 2009 (79). Of the 366 documented deaths, 333 (91%) were calves less than 4 months old.

An analysis of numbers of strandings detected and reported, in relation to search effort and reporting efficiency, was provided by Jon Seger after the workshop, and it is included as an appendix to this report (Appendix 1).

Table 3. The number and age categories of dead whales recorded at Península Valdés since 2003, when the SRWHMP began. Ninety-one percent of the dead whales have been calves. Years with higher numbers of strandings are highlighted. (Source: SRWHMP, unpubl. data).

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**	**%**
Calves	29	13	36	16	77	89	73	333	91
Juveniles	1	0	4	1	1	0	0	7	2
Adults	1	0	7	1	5	3	5	22	6
Unknown	0	0	0	0	0	3	1	4	1
Total PV	31	13	47	18	83	95	79	366	100

a. Strandings: long-term data set

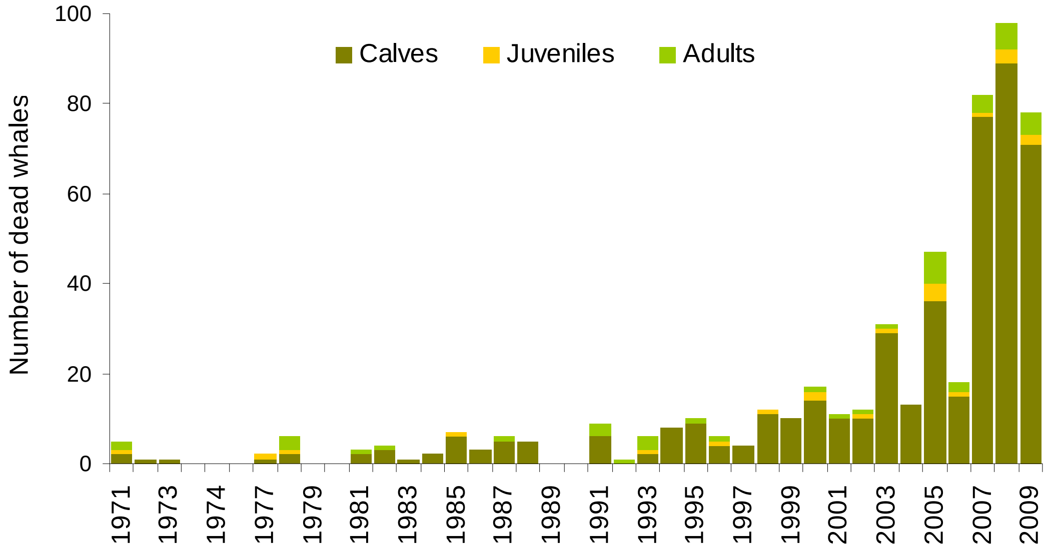


Figure 3. Number and age category of dead whales recorded at Península Valdés since 1971 (SRWHMP, unpubl. data). (note: post 2003 data are not equal in search/reporting effort to pre-2003 data, see Appendix A)

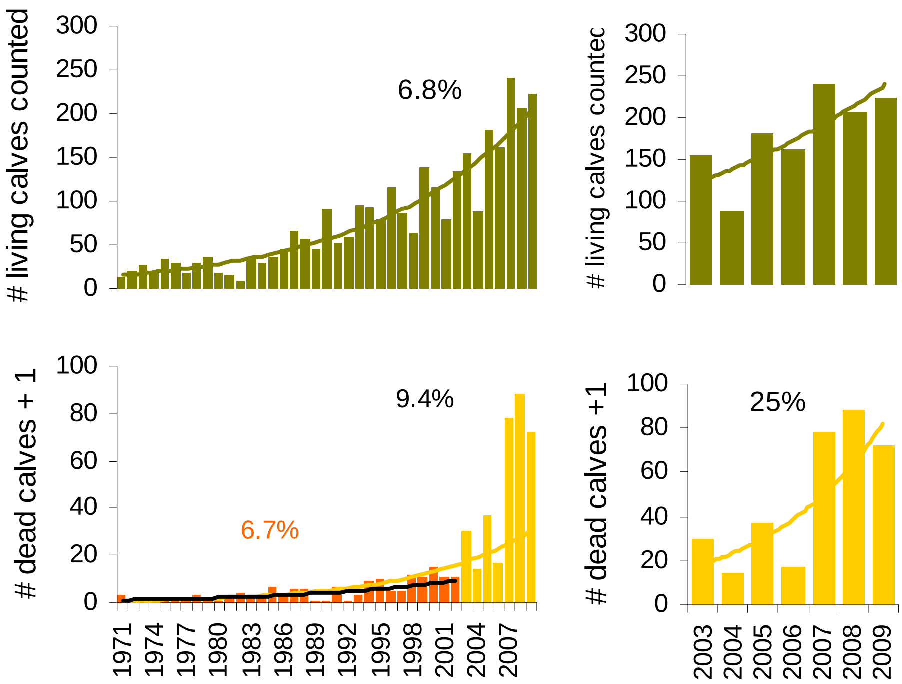


Figure 4. Rate of increase in the number of living and dead calves counted each year. The graphs on the left show the similarity in the rate of increase from 1971-2002 in the number of dead (bottom left, 6.7%) and living calves counted each year (top left, 6.8%). The graphs on the right are enlargements of the years with high mortality, 2003-2009. In these years, dead calves increased at more than twice the rate (25%) of living calves counted (11%). (Source: SRWHMP, unpubl. data).

b. Proportions of different age categories and sexes among stranded whales from 1971-2009

Uhart reported that the number of stranded calves in the period from 2003-2009 was disproportionate to the increase in number of live calves observed in surveys. From 2003-2009, the observed rate of increase in living calves from aerial counts was 0.11/yr, whereas the number of stranded calves increased at 0.25/yr (Fig. 4), indicating that the number of strandings documented was increasing at more than twice the rate of the number of living calves counted per year.

Table 4. Sex composition and sex ratio (males/total) of stranded right whales by age category (2003-2009) (SRWHMP, unpubl. data).

	Neonates	**Calves**	**Juveniles**	**Adults**	**Unknown**	**Total**
Males	0	116	1	1	0	118
Females	2	139	4	19	0	164
Unknown	0	76	2	2	4	84
Sex ratio	-	0.45	0.80	0.95	-	-
Total	2	331	7	22	4	366

Considering all age categories in all years with data, a slightly higher number of females than males have been found dead at Península Valdés (see Table 4). This sex bias applies particularly to adults and juveniles; the sex ratio of calves is not significantly different from parity.

c. Seasonal timing of strandings

Since 2003, the timing of stranding peaks and the total numbers of dead animals have changed from year to year (Fig. 5). In 2005 and 2007, strandings peaked in October and through mid-November. In contrast, the peaks in 2008 and 2009 occurred from mid-August through mid-September. Secondary peaks in strandings occurred during the first two weeks of October in 2007, 2008 and 2009. In years with low mortality, strandings were fairly consistently distributed between September and October.

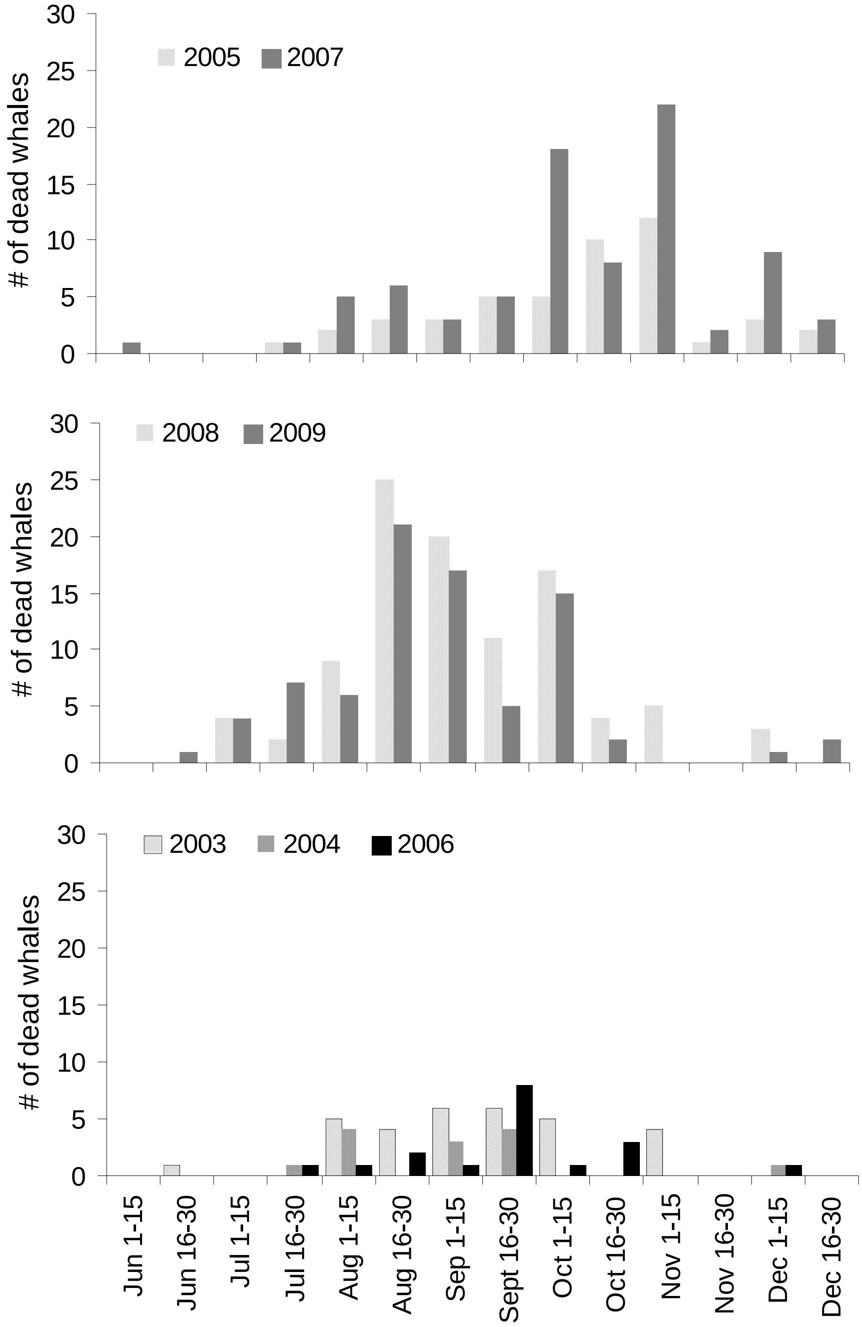


Figure 5. Annual number of dead whales documented by half-monthly blocks, 2003-2009. The top two graphs are grouped into years when peaks in mortalities occurred late (top graph) or early (middle graph) in the nursery season. Bottom graph shows the distribution of strandings in years with low mortalities. (SRWHMP, unpubl. data).

d. Locations of strandings (Golfo San José vs. Golfo Nuevo)

According to Uhart, of the 373 beached whales recorded by the program since it began in 2003, only 7 were located in areas outside of Península Valdés.

Over the years of the SRWHMP (2003 to 2009), live calves counted during the annual aerial photo-identification surveys conducted by WCI/ICB at the time of peak whale abundance were almost equally distributed between Golfo Nuevo and Golfo San José (Fig. 6). However, the percentage of dead whales has consistently been greater in Golfo Nuevo, except in 2006 (Fig. 6).

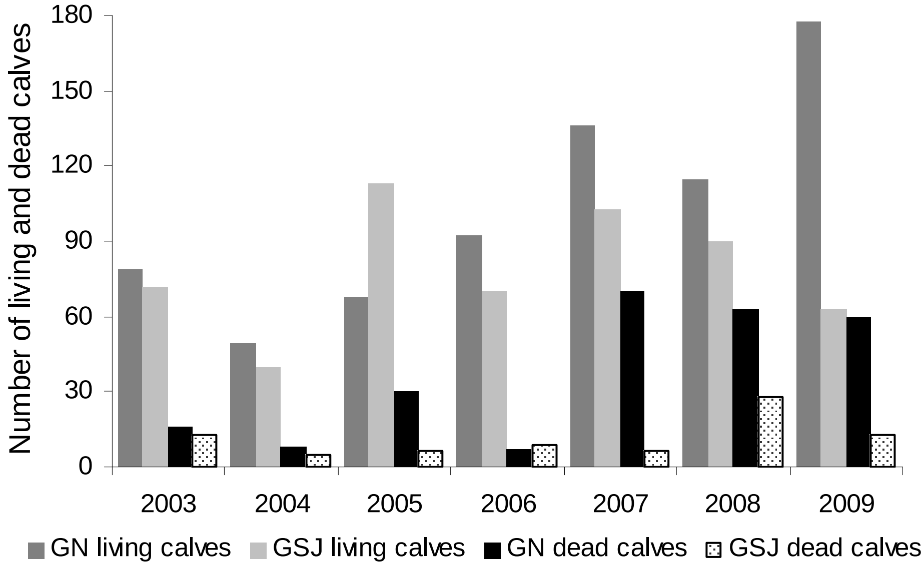


Figure 6. Numbers of living and dead calves counted in each gulf from 2003 through 2009. GN = Golfo Nuevo in darker grey and black, GSJ = Golfo San José lighter grey and stippling. Living calves (counted in aerial surveys) are in grey shades, dead calves (as tallied by the stranding network) in black and stippling. Living calves had similar distributions between gulfs. With the exception of 2006, more calves died in Golfo Nuevo, particularly in years with high calf mortality. (SRWHMP, unpubl. data)

e. Calf body length vs. stranding date

Best and Rüther (1992) conducted aerial photogrammetry on mother-calf pairs of southern right whales on the South African coast. The smallest calf measured was 4.53 m and on 1 August young calves recorded ranged from 5.41 m for primiparous mothers to 5.93 m for other females. Smaller and apparently primiparous females frequently had smaller calves, and they tended to give birth later in the season, than multiparous females. Best and Rüther measured some calves more than once within a season and found that they grew at an average rate of about 2.8 cm/day, with no significant difference between the growth rates of first calves (primiparous mothers) and later calves (multiparous mothers).

Rowntree presented data on the relation between calf length and date of stranding as a way of gauging annual differences in nutritional state. She suggested that calves growing at the expected rate up until their deaths were probably not suffering nutritional stress. According to Rowntree, differences in time of birth and calf size could explain the broad range of calf sizes observed at any one time off South Africa and among the dead calves stranded at Península Valdés (Fig. 7), particularly early in the calving/nursing season.

Stranded calves at Península Valdés are measured only once, so no direct comparison with the growth-rate estimates of Best and Rüther is possible. However, calves that strand late in the season tend to be larger than those that strand early, as expected on the assumption that the mean age will be greater. The linear regression of measured lengths of stranded calves against the day they were discovered at Península Valdés from 2003 through 2009 has a slope of 1.7 cm/day (Figure 7 upper panel). This slope would be expected to be lower than the actual growth rate because later samples include mixtures of older (early-born) and younger (later-born) calves.

An interesting and potentially informative pattern emerges when this sample of calf lengths and stranding dates is subdivided into years with high mortality late in the season (2005 and 2007) and years with high mortality early in the season (2008 and 2009). In the late-in-season years, average stranded calf length increased at a rate of 2.6 cm/day (Figure 7 lower panel), which is remarkably close to the direct growth-rate estimate of Best and Rüther (1992). The majority of the calves died after 30 September, and these were 7.3 m long on average, which is 1.2 m longer than the average of 6.1 m for mean length at birth estimated by Best (1994). Thus, it can be inferred that the calves had grown for some time, at apparently normal rates, before they died. In the early-in-season years, by contrast, the average length of stranded calves increased only slightly over the season (0.3 cm/day), and calves that died after 30 September were only 5.8 m long, on average ($n = 114$, $t = 6.3$, $p < 0.0001$ for the difference in mean lengths of late-season [post-30 September] strandings between the two sets of years).

Rowntree suggested from these data that in contrast to 2005 and 2007, when many calves grew for weeks or months before dying, most of the calves that stranded in 2008 and 2009 died fairly soon after birth, regardless of when they were born. This pattern would appear to be consistent with the hypothesis that nutritional stress (on the mothers and/or calves) or some lingering problem that made calves unviable was more of a factor in 2008 and 2009 (the early-in-season stranding years) than it was in 2005 and 2007 (the late-in-season stranding years).

Rowntree further noted that calves that died early in 2008 and 2009 tended to be longer than those that died early in 2005 and 2007 (mean of 5.8 m *versus* 5.1 m, $n = 132$, $t = 4.3$, $p < 0.0001$). This difference might be expected if relatively more of the early deaths in 2008 and 2009 were calves of older, larger, multiparous females, which tend to have larger calves and give birth earlier in the season than primiparous females (Best and Rüther 1992).

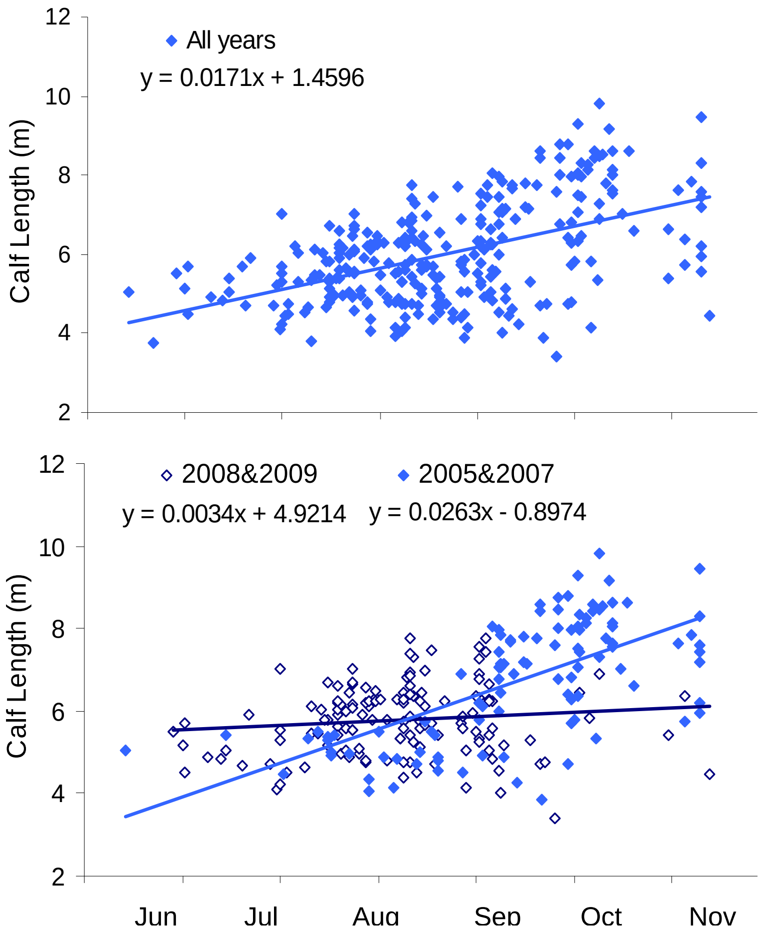


Figure 7. Body lengths of stranded calves and dates of stranding. (Source: SRWHMP, unpubl. data).

f. Pathology from gross examinations and serology

Uhart summarised the outstanding findings to date from gross pathology examinations. Rough-surf injury, boat strikes, a hard blow from another whale, and other sources of blunt-force trauma remain potential diagnoses for a calf that died in 2003 with extensive renal and spleen hemorrhages, and for a calf that died in 2009 and was found with a large skull fracture. In 2004 the skeleton of an adult male that had stranded the year before was recovered and it was found to have chronic degenerative lesions in most vertebrae of the spine, with multiple fused blocks of vertebrae consistent with ankylosing spondylitis. Polymerase chain reaction (PCR) testing for *Brucella* sp. was negative although this result was questioned due to poor carcass condition and environmental exposure. Three episodes of possible dystocia were recorded, as follows: (1) In 2005 an adult female died with a nearly full-term calf (female size 15.35m, calf size 4.46 m not including the head) in her uterus. (2) In 2007 the death of a female and her calf apparently occurred during parturition (the calf was lodged in the birth canal). This female was very small (14.60m) and her female calf was very large (5.35m). (3) In 2009 a dead male calf had an extensive bruise in the dorsal area behind the skull as well as injuries in neighbouring organs and tissues. Similar wounds have been observed in North Atlantic right whales after difficult births (W. McLellan and M. Moore, pers. comm.).

As discussed elsewhere in this report (Item 3.b.), scars and wounds from gull attacks are commonly found on the backs of right whales at Península Valdés. The gulls target existing lesions and enlarge them over the season. The percentage of whales with gull lesions has increased markedly since the early 1970s. Gull attacks were initially confined to adults, but by the year 2000, calves had become preferred targets. Currently, a significant number of calves older than a month have at least one and usually a chain of gull attack lesions on their back (WCI/ICB unpublished data).

According to Uhart, gull-inflicted lesions on dead whales' backs appeared more swollen in the first week of October 2007 than in previous years since 2003. There are also reports from those trying to obtain biopsies gull-peck wounds that lesions on the backs of living calves looked more swollen during this period than earlier in the season. Necropsies in 2007 showed that bleeding under the lesions extended through the blubber layer. In previous years, one of these lesions was found to be contaminated with bacteria, indicating that they could have led to systemic infections (see 5.j. results from histopathology). Of the 81 dead whales observed during the 2009 season, at least 24 (30%) had evidence of injuries caused by gulls prior to death. Importantly, however, not all dead whales could be examined for such evidence since many stranded with the dorsal side down or had lost their skin (Fig. 8).

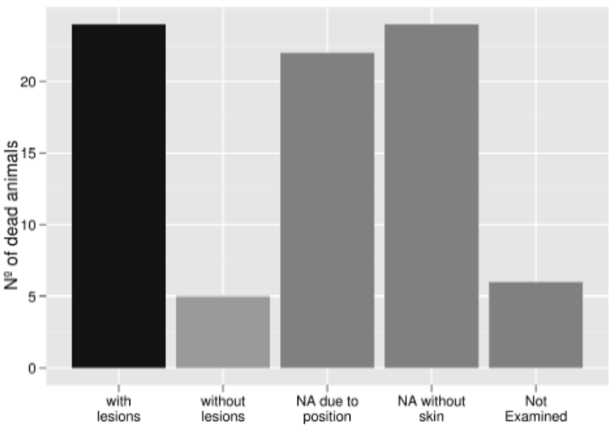


Fig. 8. Summary of information on presence or absence of gull attack lesions on dead right whales at Península Valdés in 2009 (SRWHMP, unpubl. data). NA = information not available.

Uhart further summarised the findings from infectious disease serology. Infectious disease serology was conducted on 4 calves in very fresh condition sampled between 2004-2009. Results were negative for brucellosis, leptospirosis (serovars, *L. pomona*, *L. harjo*, *L. ictero*, *L. grippo*, *L. canicola, L. australis, L. pyrogenes, L. bratislava, L. sejroe, ictero/icter, L. javanica, L. szwajizak, L. saxoebing, L. ballum, L. wolffi, L. atumnalis, L. bataviae, L. tarassovi*), influenza type A, morbillivirus panel (canine distemper, cetacean morbillivirus, phocine distemper), and seal herpesvirus (only tested on animals stranded in 2009). The two calves sampled in 2004 and 2005 were positive for canine herpesvirus. Mass tag was run on serum from 2 animals from 2009 (062909Pv-Ea01 and 072309PV-Ea07) with negative results. Pathogens included in the respiratory panel were: *Haemophilus influenzae*, *Chlamydophila pneumoniae*, *Neisseria meningitis*, *Streptococcus pneumoniae*, *Legionella pneumoniae* and *Mycoplasma pneumoniae*. Those included in the pan-viral panel were: Adenovirus Influenza A & B RSVA and B Coronavirus HPIV1 to 4 metapneumovirus enterovirus. PCR for *Brucella* sp. was run on 26 whales sampled between 2004-2009 (samples included ovary, spleen, testicle, mesenteric lymph node). Results were negative. Bacteriological culture of swabs from skin, umbilicus, uterus, genitals and lungs was conducted on macroscopically visible lesions from 6 animals between 2003-2009. Results were not significant, including *Streptococcus faecalis* (enterococcus), Gram – bacilli, *Candida* sp., *Escherichia coli* (not enterotoxigenic) and *Proteus mirabilis*.

g. Results of sampling for harmful algal blooms (HABs) and the timing of whale deaths

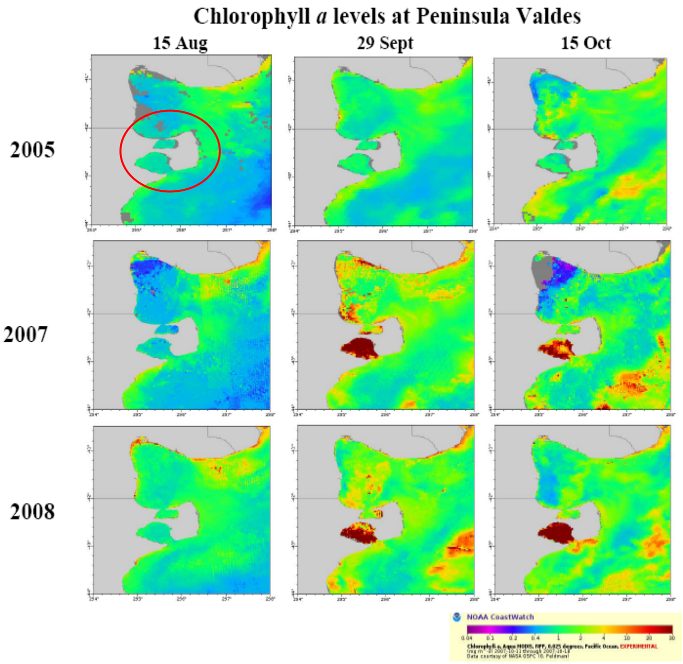


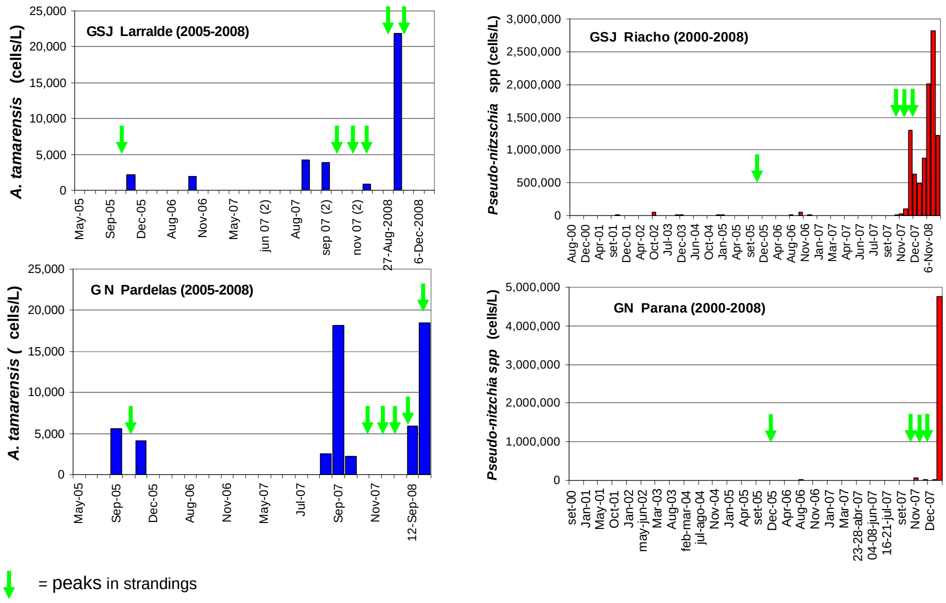
Figure 9. Satellite maps showing changes in chlorophyll a levels in the waters surrounding Península Valdés as the seasons change from winter to spring. The land is grey and the peninsula and its northern (GSJ) and southern (GN) bays are indicated by an oval in the top left map. The dark-coloured filling in GN in the bottom right map indicates extremely high levels of chlorophyll a. (Source: MODIS-Aqua, Bloomwatch 180, coastwatch.pfel.noaa.gov)

Whales are primarily fasting early in the nursing season but begin to feed occasionally at the end of September. This opens the possibility that at least some of the deaths in 2005 and 2007 were caused by or associated with the ingestion of biotoxins from algal blooms. However, in both years there were no reported die-offs of other marine mammals, marine birds or fish.

Both *Alexandrium* and *Pseudonitzschia* can produce toxins that have been linked to mass mortality of marine mammals (Scholin *et al.* 2000; Gulland *et al.* 2002). Uhart reported that Chlorophyll *a* concentrations were low at all times in 2005, but high in September and October in 2007 and 2008 in Golfo Nuevo (Fig. 9). Of the five peaks in mortality, three (1 in 2007 and 2 in 2008) occurred within a week of extremely high concentrations of Chlorophyll *a* (50-180 mg/m^3). Water samples from Golfo Nuevo in September 2007 and 2008 revealed high densities of the toxic dinoflagellate *Alexandrium tamarense*, and similar densities occurred in Golfo San José (GSJ) in 2008 (Fig. 10). However, these blooms were not temporally associated with the highest peaks in whale mortality in any year. Similarly, although high densities of the diatom *Pseudonitzschia* sp. were found in Golfo San José in December 2007 and November and December 2008, these blooms occurred well after the peaks in whale mortality. However, no signs of toxicity were observed in whales or any other marine species during those blooms, with a single reported exception: a 2-month old calf was observed dying after exhibiting respiratory distress and seemingly being unable to move (i.e. not avoiding repeated gull pecks and unable to float normally) on 29 September 2007 (A. Fazio, pers. comm.).

Uhart also reported that traces of domoic acid had been found in the blood of one adult female right whale from Golfo San José and one calf in Golfo Nuevo, which died in October and November 2005, respectively. An additional 90 samples collected from 28 dead whales since 2007 tested negative for domoic acid and paralytic shellfish poison (G. Doucette, S. Fire and N. Montoya, pers. comm. to Uhart). Samples analysed have included stomach and intestinal contents, milk, urine, faeces, liver, brain, blood spot cards and others.

HABs have expanded in geographic range and increased in frequency in South America in recent years (Carreto *et al.* 1998; Van Dolah 2003). They are regarded as a relatively new phenomenon at Península Valdés (Gayoso 2001; V. Sastre, pers. comm. to Uhart). Nevertheless, key evidence relating the unusually high mortality of right whales in the area to HABs is lacking.



HAB data provided by V. Sastre

Figure 10. Timing of algal blooms in Golfo San José (GSJ) and Golfo Nuevo (GN) since 2005. Graphs on the left represent peaks of A. tamarensis. *Graphs on the right represent presence of* Pseudonitzchia *sp. Arrows mark times of peaks in whale mortality. (Source: Viviana Sastre and SRWHMP, unpubl. data).*

g. Changes in body condition of females with calves within season and between seasons – blow intervals

Rowntree presented preliminary results of a study using respiration characteristics (specifically blow intervals) as an index of maternal condition. Cliff-top observers recorded the time of each blow for mothers and their calves during focal animal follows lasting 30 minutes or longer. Data were collected over 6 years between 1997-2009. The initial objective of the study had been to see whether the mean time between blows (or blow interval) could be used as an indicator of a whale's breath-holding ability and thus its 'condition'. This objective was extended to include the obvious question of whether calf mortality rates correlated with this 'condition index'.

High calf mortality occurred late in the season in 2005 and 2007 and early in the season in 2008 and 2009. Length measurements of calves that died late in the season in 2005 and 2007 indicate that the calves were growing before they died while calves that died in the years with high mortality early in the season (2008 and 2009) were small throughout the season (see Item 5.e.). One interpretation might be that mothers in 2005 and 2007 were in better body condition than mothers in 2008 and 2009.

All blow interval data presented here were for mothers and calves that were resting or travelling slowly. The mean blow intervals of mothers varied greatly within each year (Fig. 11) but the mean of the mean blow intervals of all mothers in 2008 and 2009 was significantly lower than that of mothers in 2005 (68 s compared to 101 s respectively, $t = 4.2$, $df = 74$, $p = 6.9 \times 10^{-5}$), suggesting that poor body condition of mothers could have led to early-season deaths of calves in 2008 and 2009.

The respiratory pattern for adult right whales that are resting or travelling slowly on the calving/nursery ground usually includes 1 large blow, as the whale first surfaces, followed by a series of 3-5 smaller blows before the whale submerges for a minute or longer. Figure 12 is a graphic representation of the respiratory patterns observed in surfacing bouts. The cumulative frequencies of all blow intervals of mothers are grouped by years. The first third of the blow intervals are short and probably represent the short intervals after the initial surfacing blow. The divergence between years in lengths of blow intervals is largest at blow intervals lasting 1 to 2.5 minutes and probably corresponds to the submergence times between blowing bouts. The graph shows that 75% of the blow intervals of mothers in 2008 and 2009 were less than 75 sec compared to 260 sec for mothers in 2005, indicating that mothers held their breath for much shorter periods of time in 2008 and 2009 than in 2005.

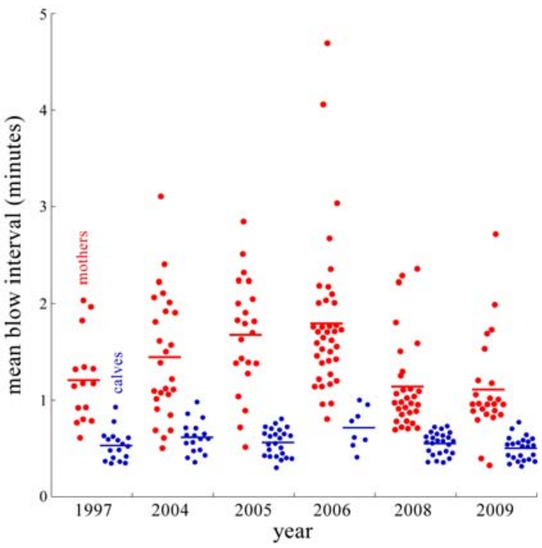


Figure 11. Mean blow intervals of mothers (red) and their calves (blue) over 6 years of observations. Bars indicate the mean of the mean blow intervals for that year. Only data for whales that were resting or travelling slowly are presented here. (Rowntree, unpublished data)

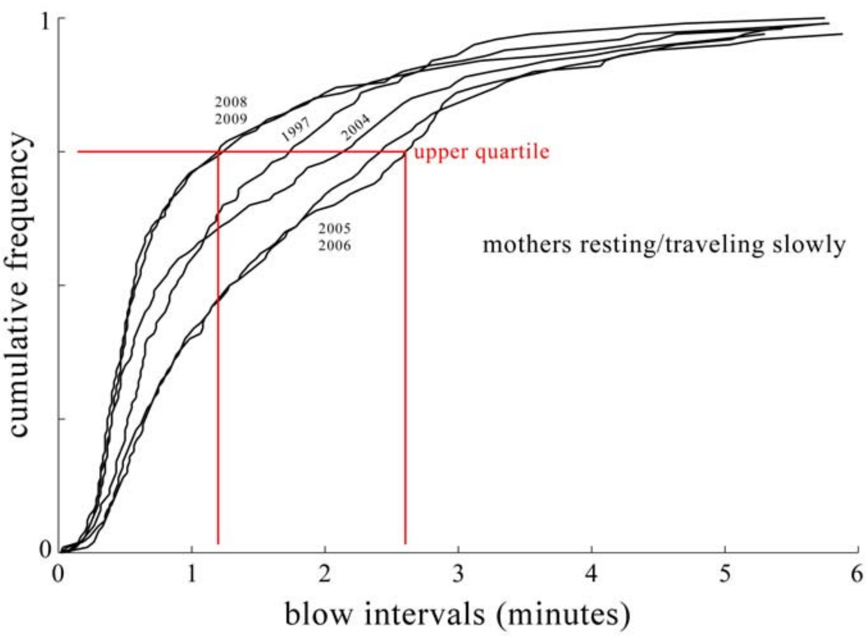


Figure 12. Cumulative frequency of blow intervals of different durations for mothers that were resting or travelling slowly in different years of a 6-year study. The blow intervals for all mothers in a year were combined. The upper quartile of the data shows a clear differentiation between years with mothers breathing more frequently in 2008 and 2009 compared to mothers in 2005. (Rowntree, unpublished data)

h. Distribution of haplotypes and clades among stranded vs. living whales

Rowntree summarised the results of a published paper (Valenzuela *et al.* 2009) as well as an unpublished new analysis by L.O. Valenzuela and co-workers. Valenzuela *et al.* (2009) showed that southern right whales from similar mitochondrial lineages (haplotypes) consume isotopically similar food (based on carbon and nitrogen stable-isotope ratios for 131 adult females sampled between 2003-2006) and concluded that different groups of potentially related whales from the Península Valdés region tend to feed in distinct areas of the southern South Atlantic and Southern Oceans. The new analysis used the previous data on population structure from Valenzuela *et al.* (2009) together with new mtDNA data on 88 additional live mothers and 43 dead stranded whales. The 37 haplotypes that appear in the combined sample of 219 live mothers from 2003-2006 (Valenzuela *et al.* 2009) and the available sample of stranded calves show similar overall frequencies (Fst = 0.001, P > 0.1 by AMOVA on the haplotype frequencies). However, while the stranded calves showed significant genetic differentiation among years (Fst = 0.008, P = 0.03), the live mothers showed none (Fst = -0.001, P > 0.1). The among-year differentiation of the calves is not merely an artefact of just one year's being distinct from all others. Given the previous findings, this pattern of mitochondrial genetic differentiation among calves stranded in different years is intriguing and raises the question of whether it is related in some way to the modest levels of differentiation among females presumed to use different feeding grounds as maternal lineage may be linked to feeding ground site fidelity (see section 4a).

i. Trace metals in whale tissues

Rosas reported initial findings from trace metal analyses of tissues from whales sampled by the SWRHMP at Península Valdés during 2003-2009. Non-essential metals, Cd and Pb, were not detected in the liver and kidney samples from 51 calves. Cu and Zn were detected and levels were significantly higher in liver than in kidney. A positive correlation was found between Cu and Zn for both organs, which suggests a common origin and/or that these metals 'behave' similarly in liver and kidney. Differences between sexes were not significant. Metal levels were higher in whales from Golfo Nuevo than in whales from Golfo San José, though the difference was not significant.

j. Results from histopathology

McAloose provided a summary of histopathology work carried out on tissue samples from 53 of the 366 (14%) right whales known to have died at Península Valdés between June 2003 and July 2009. The histological examinations were carried out in order to establish causes of death. All of this work was conducted by certified veterinary pathologists (American College of Veterinary Pathologists). All of the animals were reported in the gross necropsy records as being calves of the year, i.e. born in the year sampled.

Tissues were received from animals grossly categorised as being in condition code 2 (n=10), 3 (n=19) or 4 (n=14); condition code was not listed in the gross necropsy reports for 10 animals. Twenty-two of the animals were male, 27 were female and the sex was undetermined on gross or histologic examination in 4 animals. One or more of the following tissues were received for examination for each animal: skin, skeletal muscle and/or diaphragm, lung, kidney, gastrointestinal tract, heart, connective tissue, liver, artery, baleen, spleen, ovary, adipose tissue, cartilage, bone, lymph node, testis, tongue, nerve, thymus, trachea, oesophagus, mucosa, penis, urinary bladder, uterus, brain, pancreas, urethra, bone marrow, eye, smooth muscle, tendon, adrenal gland, epididymis, spinal cord and thyroid gland. Post-mortem autolysis was present in all cases and varied from mild to severe. Histologic assessment and interpretation depended on the ability to identify recognizable tissue and cellular architecture; establishing a cause of death was variably limited by tissue preservation and availability.

A variety of histologic lesions were identified in examined tissues. However, common significant lesions or pathologic processes (e.g. infectious disease) to explain the yearly or recurrent strandings were not identified in tissues examined histologically in these animals. Vessel strike was grossly established as the cause of death in one case. Bacterial sepsis, with hepatitis and concurrent inflamed gull-peck wounds, was present and considered the cause of death in one animal. Additional notable histologic lesions included the presence of squames (11/28), binucleated or multinucleated cells (5/28) or mild pneumonia (2/28) in the lungs, gull-peck wounds (n=6) in the skin, poor body condition (n=2) based on fat atrophy or hepatic lipidosis, colitis (n=1) and renal tubular necrosis (n=1). In vertebrate species, interpretation of the significance of intra-alveolar squames varies from incidental to a reflection of foetal distress and is dependent on additional factors including the number of squames, presence/absence of inflammation and/or other evidence of foetal distress such as intra-alveolar meconium. In examined lungs, the small number of squames and lack of additional findings was considered more likely to be an incidental finding than a reflection of foetal distress. Bi- and multinucleated cells in the lungs were rare to few in all animals in which they were seen. They were morphologically consistent with having a histiocytic origin, thought to be of pulmonary or tracheal origin, and this was considered an incidental finding; viral inclusions were not seen in any of these cells. A cause for the mild pneumonia in the two animals in which it was identified was not histologically apparent. Gull-peck lesions were found concurrently in one animal with systemic disease (sepsis, mentioned above); local inflammation (characterised by one or more of the following: dermatitis, thrombosis, vasculitis or cellulitis) in the absence of a systemic process was seen in 2 of 5 additional animals. Terminal aspiration or passive inflow of water after death (based on intra-alveolar bacteria, protozoa or foreign material in the absence of inflammation or other tissue pathology) was seen in 11 of 28 animals in which lung tissue was submitted and examined. Incidental age-related findings included extramedullary hematopoiesis (n=2) and lymph node germinal centre formation (n=1).

Ongoing monitoring for independent, multifactorial/interrelated or concurrent disease processes, including infectious, toxic or nutritional disease, genetic or environmental factors including food availability, and maternal and calf fitness are critical for establishing the cause(s) of the recent recurrent, significant mortality of young right whales at Península Valdés.

The workshop participants asked a number of questions on the material presented and presenters clarified a number of points. Most of the animals reported through the SRWHMN were dead when reported, there was only one case, referred to in Section g above of a calf reported live which subsequently died. Other than that incident there is very little observational data of the behaviour of calves or other stranding animals prior to stranding. For this reason the workshop recommends below that an alert network to detect and report such behaviour be established. Participants asked what percentage of stranded calves were neonates, with evidence of recent birth. The response was that only a small percentage of the strandings have been neonates. It was noted that while 80% of calves are gull pecked, samples of gull peck lesions have only been available for 6 stranded calves. Of those 6 samples, 3 showed inflammation and sepsis was noted in one of these. The point was made that this is a small sample of what appears to be a broad condition.

7. Health (status) of South Atlantic Ocean ecosystem

a. Offshore feeding areas (including shifts in quantity and distribution of primary and secondary production, species interactions etc.; relations to natural variability, regime shifts, climate change etc.)

Forcada described recent trends in certain characteristics of the South Atlantic Ocean ecosystem and discussed the possible consequences of changing ocean conditions in the region. The offshore waters of the northern Scotia Sea in the south-western Atlantic, and particularly north of South Georgia, are likely an important feeding area for southern right whales (Hedley *et al.* 2001; British Antarctic Survey, unpublished data courtesy of Forcada). The Scotia Sea is one of the most productive regions of the Southern Ocean and has the highest estimated density of Antarctic krill (Atkinson *et al.* 2004). Krill is the major link between primary production and millions of vertebrate predators (Croxall *et al.* 1988) and thus is a keystone species that provides structure and function to the marine ecosystem (Murphy *et al.* 2007). However, the krill in the Scotia Sea is not self-sustained. Predation on larvae and advective export of various age classes during winter are likely the main causes of local recruitment failure in krill (Tarling *et al.* 2007). Because of this, successful krill reproduction and recruitment in the West Antarctic Peninsula (WAP) are essential to support a high krill biomass in the Scotia Sea, to which krill is transported by the Antarctic Circumpolar Current, the main eastward ocean circulation that occurs within a restricted latitudinal range and is topographically constrained through the Drake Passage, between South America and the Antarctic Peninsula.

The lack of either retentive oceanic structures or the formation of new ones can affect the advection and dispersal of young krill from the Antarctic Peninsula to the Scotia Sea. Sea-ice cycles and climate–ocean variability are essential for the successful reproduction, recruitment and advection of krill. Successful recruitment is episodic and cycles tend to vary between 4 and 6 years in the Antarctic Peninsula (Quetin & Ross, 2003); recruitment indices are correlated with krill density indices across the Scotia Sea. Krill cycles are associated with ENSO (El Niño Southern Oscillation) and the Southern Annular Mode (SAM) variability (Quetin & Ross, 2003; Ducklow *et al.*, 2007; Murphy *et al.*, 2007). These are the dominant modes of large-scale climate variability in the Southern Hemisphere and induce much of the physical forcing in the Southern Ocean. The SAM is the most important mode in high latitudes and results from internal atmospheric dynamics in middle latitudes; it is associated with a meridional shift in the position and intensity of the westerly winds. Both of the climate variability modes are linked to variations in temperatures over Antarctica, sea surface temperature throughout the Southern Ocean, and the distribution of sea-ice around the Antarctic continent. Shifts in the periodicity of sea-ice cycles and derived recurring processes cause mismatches between earlier phytoplankton blooms, krill development and recruitment, and krill availability for predators. During the breeding seasons of seals and penguins, the cascading consequences for their populations are increases in distance and time of foraging trips, reduced breeding performance, lowered return of breeders and higher adult mortality (Fraser & Hofmann 2003; Forcada *et al.* 2005; Forcada *et al.* 2006; Hinke *et al.* 2007; Forcada *et al.* 2008, Forcada and Trathan 2009).

The rapid increase in ecosystem fluctuation associated with increasing climate variability observed since 1990 at South Georgia (Forcada *et al.* 2008) has limited, and rendered less predictable, the main food supply for Antarctic fur seals and several penguin species and albatrosses. This food supply is predominantly Antarctic krill, and alternative prey species are unlikely to satisfy predator demands. This has increased the fitness costs of breeding for females, notably in Antarctic fur seals, causing significant short-term changes in demographic structure through mortality and low pup production. These changes now occur with a frequency higher than the mean female fur seal generation time, thereby increasing population fluctuation. This loss of life history buffering against increasing climate variation is indicative of an unprecedented ecosystem change, which is likely to also have repercussions for southern right whales and other major krill predators.

Werner gave a brief presentation on key aspects of Antarctic krill biology and the Convention for the Conservation of Antarctic Marine Living Organisms (CCAMLR), the body responsible for the management of krill fishing operations in the Southern Ocean. For many marine animals in Antarctica, krill is the most abundant food source. These species depend on krill's being within reach of their colonies in order to feed and rear their offspring during the summer. The recent and ongoing temperature increases in the Antarctic Peninsula area are resulting in a massive reduction of sea ice, followed by a reduction of ice algae, with a consequent local reduction of krill abundance. Concentrated krill fishing also contributes to local reductions in the availability of krill. Krill fishing operations occur in the Scotia Sea region, mostly in coastal areas, in total overlap with the foraging ranges of predators tied to land sites for colonial breeding or resting. Interest in krill fishing is growing and expansion of the fishery seems imminent. Werner stated that in spite of existing conservation measures established by CCAMLR, there is a pressing need to take further action to protect krill, and in turn the land-based predators that depend on this food source, from the effects of climate change and concentrated krill fishing in Antarctica.

b. Coastal areas in the Península Valdés region

Dans (on behalf of co-authors G.V. Garaffo, M. Degrati, G. Svendsen, A. Gagliardini and E. Crespo) provided a description of physical and trophic conditions in the gulfs bordering Península Valdés based on published and unpublished data. Golfo San José is a small (814 km^2), semi-enclosed bay connected to Golfo San Matías by a 9 km-wide mouth. It is approximately elliptical (minor and major axes *ca.* 38 and 56 km long). The mean and maximum depths are 30 m and 120 m and there is a narrow depression in the middle of the gulf's mouth. The coastline is irregular, with several prominent points. The tidal regime is semidiurnal and average amplitude varies between 8.7 and 2.96 m. Winds blow predominantly from the SW quadrant at a mean velocity of 15 km h^{-1}. No permanent watercourses flow into Golfo San José. Oceanographic data suggest the existence of two distinct, broad regimes (the western and eastern portions of the gulf) based on the analysis of chemical and physical variables. At flood tide, a water jet funnels out through the western side of the mouth of Golfo San José into Golfo San Matías, while water flows in from the eastern side. Turbulence and eddies are only present in the western side of Golfo San José. A thermal front extends from south to north. The east/west zone is warmer/colder in summer but colder/warmer in winter.

Golfo Nuevo is 2,500 km^2 and its maximum depth is 184 m (Mouzo *et al.* 1978). It is a semi-enclosed basin approximately 70 km long and 60 km wide, connected to the Atlantic Ocean by a shallow (mean depth 44 m), 16 km-wide entrance (Mouzo *et al.* 1978). The temperature of the superficial layer of Golfo Nuevo is homogeneous from May to November, the cold season. However, it is spatially variable between December and April (warm season), with lower temperatures along the southern coast. Low temperatures also can occur along the northern coast. The highest temperatures occur in the central part of the gulf. In the summer a cyclonal movement of the water can be observed in satellite images.

Golfo San Matías also has a NE-SW front, mainly during the summer, with two distinct water masses, the northern one having warmer, more saline conditions than the southern one. Adult right whales and mother-calf pairs were observed in the northern area of this gulf during aerial surveys.

There have been several recent mid-summer sightings of right whales apparently engaged in feeding behaviour to the east of Peninsula Valdes, far from the coast and near the shelf break (Dans, unpublished data).

8. Possible explanations for recent southern right whale die-offs

Before identifying and ranking possible explanations (hypotheses) for the die-offs, a series of predisposing factors/pertinent observations/propositions were identified. The factor numbers are listed after each hypothesis (below) to show possible relevance.

a. Predisposing factors/pertinent observations/propositions

1. Valenzuela *et al.* (2009) showed through isotopic and genetic studies that different groups (as defined by genetic maternal lineage) of southern right whales biopsied at Península Valdés fed in different regions.

2. There is some evidence for differential mortality of calves among maternal lineages in the population.

3. There is evidence of a long-term decline of right whale food availability in the feeding grounds (e.g. a documented decline in krill availability in the Scotia Sea and prey-related reduction in reproductive success of Antarctic fur seals and gentoo penguins breeding at South Georgia) and that the Península Valdés right whales have fewer calves than expected in years of low krill abundance (Leaper *et al.* 2006).

4. There have been both local and global increases in harmful algal blooms (including at Península Valdés and the Falkland Islands/Islas Malvinas).

5. Some biotoxins can cross the placenta, resulting in delayed effects on neonatal survival (e.g. in pinnipeds, harbour porpoises, bottlenose dolphins).

6. There is a high prevalence of gull-peck lesions on southern right whales at Península Valdés.

a. The incidence of gull attacks has increased dramatically since first quantified in 1984 and now almost all mothers and calves are affected.

b. Mothers have changed their behaviour to prevent gulls from landing on their backs, and, as a consequence, the direct impacts of gull pecking have increasingly shifted to the calves.

c. Gulls can transmit bacterial toxins (e.g. tetanus).

d. Gull-peck lesions provide a potential portal for infection (e.g. directly from water or from avian agents).

e. Gulls are one possible vector for transmission of infectious diseases from terrestrial or other sources.

f. Gull evasion may increase right whale stress (e.g. possibly leading to immunosuppression) and energy costs.

7. Infectious diseases cause mortality in cetaceans and there is potential for these to cause differential mortality of neonates ('vertical transmission' from the mother) or other age classes (acquired).

8. A whale's energy budget may be significantly affected by whether it is feeding on krill or copepods, which differ in nutritional value.

9. Primiparous mothers in mammals are less successful than experienced mothers in raising calves to weaning.

10. Exposure to certain environmental contaminants may lead to immunosuppression, reproductive alterations or endocrine disruption, thus decreasing survival or reducing productivity. This has been observed in a number of marine mammal species, but not baleen whales.

b. Possible explanations or causation hypotheses for the southern right whale die-offs

The workshop considered a number of possible explanations for the right whale die-offs at Península Valdés and generated a series of hypotheses. These were ranked according to their probability of being the most likely. Analyses of the four most likely hypotheses are presented first. Five other possible explanations, namely demographic factors, killer whale predation, whale watching, fishery interactions and ship strikes, were also considered but ruled out. Discussion of these other possible explanations follows in a subsequent section.

<u>Relatively high (but near equal) probability of being true (with alphanumeric codes of predisposing factors (Item 8.a., above) indicated)</u>

A. The mortality of calves is a consequence of poor nutritional state of mothers. 1,2,3,6a,6d,6f,8

B. The mortality of calves is a consequence of exposure to HAB- and/or bacteria-associated biotoxins in (a) the feeding ground resulting in *in utero* exposure of the calf, or (b) the calving/nursery ground. 1,2,4,5,6a,6c,6d,6e

C. The mortality of calves is a consequence of infectious disease (viral, bacterial, protozoal etc.). 1,2,6b,6c,6d,6e,7

<u>Relatively low probability of being true</u>

D. The mortality of calves is a consequence of exposure to chemical pollutants (unlikely but cannot be ruled out; abandoned whaling stations at South Georgia, industries at Golfo Nuevo). 3,6d,10

c. Elaboration of leading hypotheses

The increased mortality of southern right whale calves observed in the past few years constitutes an unusual event which may have one, or several, potentially interacting, causes. Based on the data and background information presented by local research groups and international experts, a series of hypotheses were proposed, evaluated and ranked according to their feasibility and likelihood as drivers of this particular mortality scenario. For each plausible hypothesis, key research questions were identified and a series of recommended actions were proposed. Ongoing routine population monitoring activities, which may include actions related to low-priority or discarded hypotheses, should not be stopped as they provide baseline information for understanding future population trends or diagnosing causes of future mortality events.

For each of the three leading hypotheses (A-C, above), a Working Group met to develop an outline and proposed approach to testing.

Hypothesis A: Food

Nutritional stress is a potential cause of breeding failure and high offspring mortality in mammals, when females cannot meet the appropriate energy requirements for gestation and lactation. Among pinnipeds, there is evidence of abortion or pup abandonment when food availability is very low, but the potential consequences for large whales are not so well understood. According to Brownell, female gray whales in poor body condition (judging by their 'thinness' when observed in the feeding area near Sakhalin Island, Russia) are likely to either wean their calves early or fail to become pregnant and thus extend their calving interval by a year (or more). North Atlantic right whales had calving intervals of close to 6 years when food resources were low in the late 1990s (Greene and Pershing 2004), while in more recent years they have had a higher calving rate with a shorter calving interval of close to 3 years (Baumgartner *et al.* 2007; Kraus *et al.* 2007; Pettis 2009). It is possible that under conditions of reduced food availability, the nutritive condition of pregnant females becomes insufficient to produce a viable calf or adequate lactation.

In the Southwest Atlantic, right whales have several potential feeding grounds, based on historical catch records, with different prey species consumed at different latitudes and regions. Temperate-water prey such as copepods may be consumed on the Patagonian shelf and cold-water prey, mostly Antarctic krill, eaten south of the Polar Front (Tormosov *et al.* 1998). Precise information on the location(s) of the main feeding grounds for this whale population is still unavailable but there is isotopic evidence suggesting that the krill and other pelagic crustaceans of the northern Scotia Sea and around South Georgia are among the major food sources of the adult female right whales that calve at Península Valdés (Leaper *et al.* 2006).

Long-term population and breeding performance records of several krill predators (fur seals and penguins) that feed and breed at South Georgia, in the same general areas where right whales feed, indicate a long-term ecosystem change in association with increasing climate variability (Forcada *et al.* 2005; Trathan *et al.* 2006; Forcada *et al.* 2008). This has limited, and rendered less predictable, the main food supply of those other species and it may also have repercussions for the nutritive state of the right whales that breed at Península Valdés. This leads to the following hypothesis: The high mortality of calves at Península Valdés is a consequence of the poor nutritional state of their mothers.

<u>Outstanding questions related to this hypothesis</u>

1. Valenzuela *et al.* (2009) showed through isotopic and genetic studies that different groups (as defined by genetic lineage) of right whales biopsied at Península Valdés fed in different regions.

-Where are the feeding grounds of right whales that calve at Península Valdés?

-What is the nature and degree of movement of individual right whales between feeding grounds?

2. Evidence for differential mortality among maternal lineages in the population.

-Are there differences in haplotype frequencies between living whales and those found dead in the die-off events?

-If there are, does this correlate with isotopic signatures (i.e. particular feeding areas)?

-Are all the dead whales (represented by their haplotypes) showing similar isotopic signatures, indicating that they (or their mothers in the case of stranded calves) have fed in the same area(s)?

3. Long-term decline of food supply in the feeding grounds (e.g. as documented for krill availability in the vicinity of South Georgia). Leaper *et al.* (2006) showed that declines in krill do affect right whales.

-Have there been significant changes in the distribution and abundance of the predominant copepod species on the Patagonian shelf?

4. A whale's energy budget may be significantly affected by whether it is feeding on krill or copepods, which differ in nutritional value.

-Can diet signatures, measured either through fatty acid or stable isotope analysis, be indicative of whales' use of different feeding grounds and therefore of different prey availability and/or composition?

Recommended research actions

1. Complete the stable isotope signature analyses of available baleen from calves and adult females.

2. Undertake analyses of a sub-sample (5 exploratory, more if indicated) of the available blubber and milk samples, and of prey samples collected from feeding locations, for fatty acid distribution.

3. Complete mtDNA sequencing for existing genetic samples, match these with photo-ID data, and analyse for associations among maternal lineages, isotopes, years and deaths.

4. Obtain and analyse repeat biopsies of the same individuals, recognizing that individuals do not visit the study area every year, and conduct analyses to relate isotopic signature indicative of prey switching to aspects of female life history (e.g. calving intervals, and implied loss of calves), and also to haplotypes.

5. Develop a biopsy programme selectively targeting adult females (as many individuals as can be sampled per season) and their calves in order to assign maternities to dead calves.

6. Develop a satellite tagging programme to determine linkages between the calving/nursery areas around Península Valdés and this population's feeding areas (target n ≈ 20).

7. Conduct photogrammetric surveys of mothers and calves to assess body condition.

8. Determine whether the correlation between calf output at Península Valdés and sea surface temperature (SST) anomalies at South Georgia (Leaper *et al.* 2006) has continued since 2000.

9. Update Cooke's southern right whale population model with detailed parameterisation on adult female mortality, calf mortality and calving interval to assess whether there has been an increase in female or calf mortality.

Hypothesis B: Biotoxins

Biotoxins are naturally occurring compounds produced by bacteria, algae or other organisms that can cause a variety of diseases and/or death, depending on the toxin. In the marine environment, harmful algal bloom (HAB)-associated biotoxins have been responsible for disease and death in humans and marine mammals (for example saxitoxin causing paralytic shellfish poisoning or domoic acid causing amnesic shellfish poisoning). Some HAB-associated toxins can cross the placenta, resulting in foetal death, abortion, poor neonatal survival, expression of post-natal developmental abnormalities and abnormal behaviour. Bacteria such as *Clostridium tetani* or *C. botulinum*, which can be transmitted by animals or are present in the environment, also produce toxins that can cause disease and be fatal to marine mammals. HABs and bacterial biotoxin epizootics have been documented around Península Valdés and the Falkland Islands/Islas Malvinas where right whales calve and feed, respectively. Either of these mechanisms could have caused the seasonal deaths of right whale calves observed at Península Valdés in 2007-2009. This leads to the following hypothesis: The high mortality of calves at Península Valdés is a consequence of exposure to HAB- and/or bacteria-associated biotoxins in (a) the feeding ground resulting in *in utero* exposure of the calf, or (b) the calving/nursery ground.

General comments

Mouse bioassays of routine samples are valuable even if a specific toxin is not suspected, thus they should be conducted.

Toxins (paralytic shelfish syndrome) have been implicated in mortality events affecting gentoo , rockhopper (*Eudyptes chrysocome*) and magellanic (*Speniscus magellanicus*) penguins as well as albatrosses, petrels and prions (*Procellaridae*) in the Malvinas/Falkland Islands (Uhart *et al.* 2004).

Assessment of biotoxin exposure on the feeding grounds will always involve risk assessment (rather than direct measurement) because of the inaccessibility of these areas.

Outstanding questions related to this hypothesis

Feeding Ground:

a. Where do these whales feed?

b. Are there HABs on the feeding ground(s)?

c. Is exposure occurring?

d. If so, what biotoxins are involved?

e. Are biotoxins present in the prey, especially krill? (Note: Such a finding for krill would be pertinent to the aquaculture industry using krill as feedstock.)

f. Is there evidence of biotoxin impacts on neonatal survival of other mammalian predators feeding on krill and/or copepods on the same feeding grounds?

g. Is there any new evidence that HABs are causing mortality events for penguins or pinnipeds at either South Georgia or the Falkland Islands/Islas Malvinas?

Nursery/calving Ground:

h. Given that toxins such as domoic acid are known to have affected other marine mammal populations (Scholin *et al.* 2000; Gulland *et al.* 2002), is there post-partum exposure in right whales around Península Valdés?

i. Are toxins present at stranding locations, areas of high whale concentration, or where whales are feeding, and how do levels relate to those documented in other right whale (and other marine mammal) habitat?

j. Is a novel biotoxin present in the tissues or fluids of dead whales and is it pathogenic? Are bacterial toxins present?

k. Are gulls acting as mechanical vectors of bacteria that form toxins such as tetanus?

l. Are the suckling calves consuming water contaminated by bacteria such as *Clostridium botulinum*?

Research recommendations for this hypothesis overlap those for hypothesis C and are given in the next section.

Hypothesis C: Infectious Disease

Infectious diseases are known to contribute to morbidity and mortality in marine mammals. Recent epizootics caused by morbillivirus have been reported in pinnipeds and cetaceans in the North Pacific and in the Mediterranean, Caspian and Baikal seas and by leptospira have been reported in eastern North Pacific pinnipeds. Endemic infectious diseases, such as *Brucella* spp., *Toxoplasma gondii* and *Chlamydia* spp., have caused abortions and weak and/or dead neonates and calves and all three of these have been reported from cetaceans. Infectious disease can be concurrent with or exacerbated by other factors including immunosuppression, poor nutritional state and other debilitators such as parasites and physical trauma. Differential expression of disease can manifest in different outcomes in various age classes, such as calf mortality in the absence of apparent disease in reproductive females. This leads to the following hypothesis: The high mortality of calves at Península Valdés is a consequence of infectious disease (viral, bacterial, protozoal etc.)(see Table 5).

<u>Outstanding questions related to this hypothesis</u>

m. Is transplacental transfer of disease significant in right whale calf survival?

n. Is postnatal exposure to disease contributing to calf mortality?

o. Is infectious disease the final cause of death following prior stressors (e.g. nutrition, gull pecks and disturbance, sewage, etc?

p. Are gulls acting as mechanical vectors in the transmission of infectious disease (viral, bacterial, protozoal etc.) to right whale calves?

q. What infectious diseases and toxins are evident in gulls?

Table 5: Pathogens with potential to cause death of southern right whale calves.

Agent	Lesions observed	Species affected	References
Herpesvirus	Inclusions, necrosis,	Cetaceans, Pinnipeds, Carnivora	Blanchard *et al.* 2001 Kennedy-Stoskopf 2001 Goldstein *et al.* 2005
Morbillivirus	Inclusions, syncitia	Pinnipeds, cetaceans	Van Bressem *et al.* 1999, 2009
Calicivirus	Vesicles, placentitis, pneumonia	Cetaceans, pinnipeds	Kennedy-Stoskopf 2001
Parvovirus	Enteritis, myocarditis, cerebellar atrophy, abortion	Carnivora	Barker & Parrish 2001
Chlamydia sp.	Placentitis	Pinnipeds	T. Spraker, Colorado State University, pers. comm.
Leptospira	Nephritis, hepatitis, placentitis	Pinnipeds, ungulates	Gulland 1998
Brucella spp.	Placentitis, orchitis, meningoencephalitis	Cetaceans, pinnipeds	Bourg *et al.* 2007, Foster *et al.* 2007
Coxiella burnetti		Pinnipeds	LaPointe *et al.* 1999
Nonspecific (*Vibrio, Aeromonas, Pseudomonas* spp.)	Placentitis	All	Van Bressem *et al.* 2009
Toxoplasma gondii	Placentitis, encephalitis, myocarditis, lymphadenitis, necrosis	Cetaceans, pinnipeds, otters	Dubey *et al.* 2003
Neospora spp.		Pinnipeds	Dubey *et al.* 2003
Candida albicans	Enteritis	Bovidae	

Recommended research and management actions related to Hypotheses B and C

Note: As stated later in the report, the workshop concluded that the necropsy program (SRWHMP) was working efficiently and that appropriate samples were being taken.

1. Continue the Southern Right Whale Health Monitoring Program at Península Valdés and improve response time to examine dead whales.

2. Continue to collect and analyse a broad suite of samples and collect more data on the presence of old and new gull-peck lesions.

3. Link the stranding programme to broader environmental monitoring programmes designed to detect HABs.

4. Establish a disease sampling programme for gulls that are observed to parasitise whales and for the broader gull population.

5. Increase sustained capacity and long-term funding for the beach necropsy programme, sample archiving, database management, data analysis and publication.

6. Regardless of whether gull-peck lesions are a contributing factor in whale mortality, they cannot be considered as anything other than harmful to the animals. Therefore, closure and/or improved management of dumps, better control of fish offal (on land and at sea) and direct gull control measures would be expected to lead to improved whale health. However, the details of any such program must be formulated at the local level with the input from all stakeholders.

Additional specific recommendations or research topics related to Hypotheses B and C (letters after each recommendation/topic refer to questions above)

1. Tagging and satellite tracking to elucidate whale movements and locate feeding areas: a, b

2. Enhanced stranding response: g, h, i, j, k, l, m, n, o

3. Biotoxin analysis of prey and necropsy samples: a, b, c, d, e, h, i, j, k,l

4. Literature review and further analyses of biotoxins, infectious diseases and pathobiology of other affected species such as seals or penguins: a, b, c, d, e, f, h, i, j, k

5. Unified analysis of related die-off events in the context of environmental change: a, b, c, d, h, m, n, o

6. Analyse archived (and newly collected) samples for increased suite of toxins and/or additional infectious disease pathogens. Testing for toxins to include (but not limited to) GCMS and/or MSMS on fresh-frozen tissue, serum and/or

filter-paper dried blood or tissue (including faecal) spots for toxins. Testing for infectious diseases to include molecular diagnostic tests such as PCR, mass tag and high throughput sequencing on fresh-frozen tissue, formalin-fixed and paraffin-embedded tissue, serum and/or filter-paper dried blood or tissue (including faecal) spots: d, g, h, i, k, m, n

7. Periodical and strategically collected water samples for HAB detection in GN and GSJ in winter and feeding ground in summer: a, b, d, e, g, h, i, l

8. Establish an abnormal behaviour alert system using whalewatch vessels and survey for past anecdotes of abnormal behaviour: g, n

9. Biopsy and culture gull-peck lesions and sample whale and gull faeces and gulls for bacteria, viruses etc. (current studies to be concluded and published, and pending these results further studies to be undertaken): h, k, n, p, q

10. Perform toxin bioassays using available fresh frozen tissue or blood samples: h, i, j, k

11. Analyse blood from future strandings for HABs, infectious disease and, where practical, heavy metals: g, i, j, k, o

12. Analyse aqueous humour samples for infectious disease antibodies and toxins: g?, h, i, j, k, n

13. Collect blow samples for infectious agent culture and molecular diagnostics, metabolites such as ketones, and steroids: j, k, n

14. Continue and expand methods for body condition assessment such as bone marrow fat content and photogrammetry: o

15. Test faeces for HABs from carcasses and live animals. Test live animal faeces for cortisol. Increase efforts to collect floating faeces: a, g, h, i, k.

Additional logistical recommendations for the Southern Right Whale Health Monitoring Program

1. Provide appropriate and adequate solutions for short- and long-term sample storage and facilitate logistics for shipment of time-sensitive samples to Buenos Aires and for export.

2. Work to facilitate the permitting and export process for samples.

3. Explore and invest in temperature-independent sampling and storage protocols.

4. Explore in-country options for sample analysis. For PCR or other molecular diagnostics, consider performing DNA and RNA extractions locally in Puerto Madryn to generate room-temperature stable samples and eliminate the need for cold/frozen chain for sample storage, or transport.

5. Improve ability of the SRWHMP to get access to fresher animals by securing another truck, a second necropsy team, ATV's, and 3 Iridium satellite phones.

d. Elaboration of less likely hypothesis

Hypothesis D: : Exposure to chemical pollutants (trace elements, PCBs, PAHs, pesticides, EDCs, others)

Some persistent chemical pollutants can bio-accumulate in marine mammals and have the potential to cause toxic effects including reproductive impairment (Reijnders 1986) and immune suppression (Ross *et al.* 1996). Marine mammals can bio-accumulate very high levels of some persistent contaminants due to their life history and trophic level (Aguilar *et al.* 2002). However, most baleen whales, including right whales, feed at a relatively low trophic level and therefore tend to be less prone to bio-accumulation than are many toothed cetaceans (O'Shea and Brownell 1994). The workshop considered the possibility that chemical pollutants have had a primary or contributory role in the recent right whale die-offs. This leads to the following hypothesis: The high mortality of calves at Península Valdés is a consequence of exposure to chemical pollutants (unlikely but cannot be ruled out; abandoned whaling stations at South Georgia, new industries at Golfo Nuevo).

Very low tissue concentrations of a range of persistent organochlorine pollutants have already been documented in South American sea lions, Commerson's dolphins and dusky dolphins (Raga *et al.* 2008). Although only limited data are available on heavy metal concentrations in right whales in the Península Valdés region, levels of other pollutants like organochorines are also likely to be low given the low trophic level and predominantly offshore feeding habits of southern right whales (also see O'Shea and Brownell 1994). The workshop therefore concluded that chemical pollutants were unlikely to be a cause or significant contributory factor in the recent die-offs.

However, the workshop strongly recommends that necropsies of stranded whales continue to be conducted as a priority along with the strategic sampling and storage of tissues for chemical pollutants and other analyses. Such research efforts are essential not just to maintain baseline data on whale health and contaminant exposure but also to facilitate investigations of any future die-offs.

Outstanding questions related to this hypothesis

1. What contaminants are southern right whales exposed to?

2. What are the biological effects of the detected contaminants (e.g. reproductive impairment due to PCBs, EDCs or trace elements (Reijnders 1986); carcinogenesis and subclinical genetic toxicity due to PAHs (Martineau *et al.* 2002); immunosuppression due to PCBs, trace elements and pesticides (Ross *et al.* 1995))?

3. Are levels of detected contaminants comparable to reported biological thresholds?

4. Are levels of detected contaminants different between live and dead right whales?

5. What evidence is there for pollutant-induced toxicity in right whales?

Recommended research actions

1. Sample tissues (blubber, kidney, brain, stomach contents, baleen, urine, blood, bile, vitreous, and liver) from dead right whales.

2. Sample skin and blubber (biopsies) from live right whales.

3. Process samples (analytical methodology) for above-mentioned contaminants according to internationally standardised methods.

4. Compare levels with proposed toxicity thresholds (e.g. Kannan *et al.* 2000; Jepson *et al.* 2005; Hall *et al.* 2006).

5. Continue current necropsy protocols and pathology analyses.

6. Explore subclinical biological effects (DNA damage, adduct formation): Comet Assays and P32 postlabelling.

7. If funding is available, screen samples for a range of chemical contaminants (trace elements, PCBs, PAHs, pesticides, EDCs, others) using internationally standardised methods.

8. If there is evidence of exposure, conduct a risk assessment to establish if any of the contaminants are at concentrations likely to induce toxic effects (based on experimental and empirical data).

9. If any individual concentrations exceed the reported thresholds for biological effects, look for correlations between these levels of exposure and pathological, physiological or subclinical effects (Sonne *et al.* 2008). For instance, if PAHs were detected in tissues, it would be necessary to correlate this information with pathological findings consistent with PAH-induced toxicity, such as tumours or proliferation of hepatocytes (Baird *et al.* 2005 *et al.*), and also subclinical damage, such as formation of adducts or strand breakage (Valavanidis *et al.* 2006).

10. Toxicological risk assessment analyses can be used to infer population-level effects of the pollutant(s) in the exposed whale population (Schwacke *et al.* 2002).

e. Further hypotheses considered but rejected

Demography

The workshop considered how demographic phenomena might have caused or contributed to the die-offs. For example, the calf die-offs could have been the result of an increased proportion of primiparous females in the population (presuming calves of such females have lower survival) or they could reflect a change in the temporal pattern of calving through time. After considerable discussion, the group concluded that the available evidence did not support a demographic explanation. Nonetheless, it was agreed that analyses to rule out plausible demographic scenarios would be valuable. Three such scenarios are outlined below.

1. The possibility that the calf die-offs are a result of an increased proportion of primiparous females in the expanding whale population can be evaluated by examining the Península Valdés aerial photo-id database to see if the proportion of primiparous females has increased from 2001 through 2009, in a manner that might account for a proportionate increase in calf mortality. Rowntree reported that Cooke's population modelling with data from 1971 through 2000 had shown no change in the rate at which new females entered the reproductive class (Cooke *et al.* 2001, 2003). Rowntree presented data on the proportion of identified females seen for the first time with a calf for each year from 1974-2008 (Fig 13), with no adjustments made for missed first calvings. The proportion of first-time calving females in this dataset showed little change over time. It was pointed out that additional effort to combine aerial- and boat-based photo-identification catalogues maintained by different research groups at Península Valdés would increase the number of individually identified calves and potentially allow comparison of the survival rates of calves born to primiparous females vs. multiparous females.

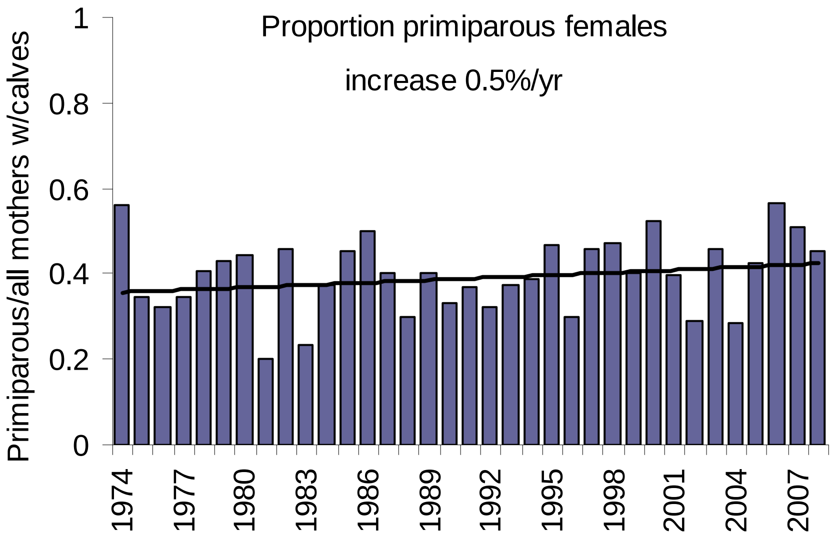


Figure 13. Proportion of first-time (primiparous) mothers in the Península Valdés right whale population, 1974-2008. Note that no consideration was given to missed first-calvings. (Source: Rowntree, unpublished data).

2. It is possible that the temporal pattern of calving has changed through time, with some unspecified impact on the survival of young animals. For example, primiparous females give birth later in the season than multiparous females but how this could relate to the annual variability in calf death rates is unclear. Temporal comparisons of calving timing in the various datasets – e.g. the Península Valdés aerial photo-identification catalogue, the Península Valdés boat-based photo-identification catalogue, the Península Valdés aerial and shore-based counts, and the southern Brazil aerial photo-identification catalogue – might provide a basis for determining whether a change in pattern has occurred.

3. A third scenario is that changes in the frequency and age structure of individual maternal lineages are linked to the die-offs. (Such linkages have been examined in the North Atlantic humpback whale population; Rosenbaum *et al.* 2002.) This possibility could be investigated by testing (possibly in the current modelling efforts) for any effects of individual haplotype, clade level, year and age of females on individual life histories.

In summary, under this hypothesis (demography) it was recommended that the following analyses be conducted on existing datasets:

a) Examine the Península Valdés aerial photo-identification database to see if the proportion of primiparous females increased from 2001 through 2009 (data from 1971 through 2000 were already analysed and no evidence of such an increase was found).

b) Combine aerial- and boat-based photo-identification catalogues to increase the number of individually identified calves to allow comparison of the survival of calves born to primiparous females to that of calves born to multiparous females.
c) Assess temporal changes in timing of calving and other parameters. This will necessitate an analysis of multiple long-term data sources, including: Argentina, Brazil and Uruguay aerial photo-identification catalogues, aerial counts and shore-based counts.

Predation by Killer Whales

Data presented by Sironi *et al.* (see Item 3.a.) showed that of 112 encounters between killer whales and right whales around Península Valdés (1972-2000), only 12 (11%) involved actual attacks, and it is likely that not all were fatal. Adult right whales were the main targets of the attacks; in fact, 80% of the attacked whales were adults, and calves were seen to be present in only two attacks (17%). The number of right whale-killer whale encounters per decade decreased with time, from 68 in the 70's, to 26 in the 80's, to 23 in the 90's. Península Valdés has features that are advantageous for right whales to reduce predation risk. Mothers and calves aggregate in very shallow bays, which may be an effective anti-predator strategy for protecting the calves (Thomas and Taber 1984). Only three dead calves out of 331 (1%) examined between 2003 and 2009 had wounds that could be attributed to killer whale bites, and these were judged to be relatively minor. Based on this evidence, the workshop concluded that killer whale predation was not a contributing factor to the recent high mortality of right whales at Península Valdés.

Whale Watching

Lindner *et al.* presented data on photo-identification of right whales from whale-watch boats based in Puerto Pirámides showing that 43% of the identified individuals returned to the area every 3 years, 20% every 2 years and 36% every year; 15% were photo-identified in the area only once (see Item 3.c.). This suggests that the vast majority of whales returned to the area at least once. Behavioural observations indicated that a few whales interacted with whale-watch boats with no apparent 'adverse effects'. A small fraction (15.3%) approached the boats, 54.1% moved away from boats approaching at high speeds and 47.4% appeared to ignore boats approaching at slow speeds. Between 2007 and 2009, 6% of the whales photo-identified from whale-watch boats had marks attributed to collisions with vessels. Whale-watching is restricted to a small stretch of coast in Golfo Nuevo, and no whale-watching occurs in Golfo San José. The workshop concluded that there was no evidence to suggest that disturbance or injury from whale-watching activity was a significant factor in the recent high mortality of right whales at Península Valdés.

Fishery Interactions and Vessel Strikes

From a total of 366 right whale deaths (including 333 calves) recorded at Península Valdés between 2003 and 2009, none of the carcasses had ropes, nets or other visible evidence of entanglement in fishing gear. Blunt-force trauma (from a boat strike or other source) remains a potential diagnosis for a calf that died in 2003 with extensive renal and spleen haemorrhages and for a calf that died in 2009 and was found with a large skull fracture. In addition, a male calf bearing 5 linear, equally spaced cuts on the peduncle in 2003 is suspected of having been the victim of a vessel strike. Finally, an adult male was struck and killed by a large ship in the port of Puerto Madryn in July 2008.

The Workshop concluded that these two factors, entanglements and vessel strikes, are not having a significant population-level effect on right whale mortality at Península Valdés.

9. Current Southern Right Whale Health Monitoring Programme

Uhart provided the following summary of the health monitoring programme.

Growing out of the long-term right whale programme of the Whale Conservation Institute/Instituto de Conservación de Ballenas, systematic efforts to monitor right whale mortality at Península Valdés began in 2003 with the establishment of the Southern Right Whale Health Monitoring Program (SRWHMP) operated jointly by the Whale Conservation Institute, Wildlife Conservation Society, Instituto de Conservación de Ballenas, Fundacion Patagonia Natural and Fundacion Ecocentro.

The programme is co-directed by Marcela Uhart (Wildlife Conservation Society) and Victoria Rowntree (Whale Conservation Institute) with assistance from Mariano Sironi (Instituto de Conservación de Ballenas). The field staff consists of one fulltime veterinarian, Andrea Chirife, a part-time seasonal veterinarian or biologist, and a variety of volunteer field assistants. The field team carries out necropsies of carcasses reported by the stranding network or found by regular land surveys. The team also conducts one aerial survey each year at the time of peak whale abundance. Necropsy completeness depends on carcass quality, accessibility and caseload. Internationally recognised standard protocols are employed. Samples for histopathology, serology, nutritional status, contaminants, infectious disease and biotoxin diagnostics, genetics, stable isotopes and fatty acid composition analysis, are collected, archived and distributed to analytical laboratories. Since 2003, nearly 3,500 samples have been collected by the SRWHMP. The sample archiving capacity includes a -20ºC freezer and liquid nitrogen dewars. Sample analysis is undertaken on an ad hoc basis, primarily pro bono by various local and international laboratories. The SRWHMP maintains a database that includes complete information on stranded individuals, such as morphometrics, photographs, samples collected, necropsy reports and laboratory results.

The professionalism, complexity and relative completeness of this program conceal the lack of a reliable financial base and hence programmatic security. For instance, without an emergency grant of US$5,000 in December 2009 from a US foundation, the one fulltime staff member, Dr. Chirife, would not be employed. The program operated with no dedicated vehicle between 2003 and 2008. During that time, it operated on borrowed vehicles despite the huge road mileage involved in operating a stranding programme at Península Valdés (i.e. almost 13,000 km were logged in 2009). Despite recent improvement in stranding network coordination by the provincial government, communication between the stranding reporters and necropsy crew is still hampered by the limited cellular phone coverage. The SRWHMP currently survives on time and resources invested by project leaders and their organisations, including salaries, equipment and supplies, office expenses, private vehicles, etc. As of June 2010 (the start of the upcoming stranding season) the SRWHMP had secured base funding from the US Marine Mammal Commission, but additional resources are needed. A minimum requirement for the programme's continuation is long-term sustained funding for a fulltime veterinarian and seasonal support staff, transportation, satellite telephone communication, better sample archiving facilities and sample and data analysis and reporting, and travel expenses to attend scientific meetings and provide community outreach.

10. Current Southern Right Whale Research Programmes (other than health and mortality monitoring)

Those involved in right whale research at Península Valdés were asked to summarise their current programmes, including both the work directed specifically at the whales and that directed at relevant ecosystem characteristics and processes. Also, they were encouraged to include immediate plans for relevant future research.

a. Non-government programmes

Rowntree provided a summary of the work conducted by researchers from the Whale Conservation Institute (WCI)/Ocean Alliance based in Massachusetts, USA, and the Instituto de Conservación de Ballenas (ICB) based in Argentina, with mostly foreign funding.

Annual aerial photographic survey of the WCI/ICB programme

An annual priority is to conduct at least one aerial photo-identification survey at the time of peak whale abundance (September) covering the 495 km perimeter of Península Valdés. The survey plane flies along the coast at an altitude of 150 m and circles over any whales encountered so researchers can photograph the callosity patterns on the whales' heads, record their locations and note the presence or absence of calves. Since 2003, the Argentine Armada has provided a Porter Pilatus prop-jet plane and crew for these surveys. Safety for those flying has been significantly improved by the use of this plane but the costs are high. Each survey, including fuel and food and housing for the survey crew, costs about 15,000 USD. Aerial photographs are analysed with a computer-assisted photo-identification system developed by Lex Hiby and Phil Lovell. Analysis and updating of the database after a single aerial survey takes about 2 months. The database spans 40 years and through 2008, the catalogue included more than 2,600 known individual whales. In recent years, the aerial surveys have been carried out by John Atkinson (photographer), Sironi (photographer, note taker, GPS recorder) and a volunteer assistant, with logistics coordinated by Diego Taboada of the ICB. Rowntree and Carina Maron, an Argentine graduate student at the University of Utah, have been responsible for the laboratory work and maintenance of the photo-identification catalogue.

Gull attack frequency

Gull attack frequency has been monitored annually since 1995 to assess the intensity of attacks and provide a baseline for interpreting the effects of management actions. Monitoring involves focal follows of mother/calf pairs from clifftops, each lasting for one hour. All gull attacks within a 5-minute interval are recorded. Between 60 and 100 focal follows are conducted each year at two sites, one in Golfo San José and one in Golfo Nuevo. This work has been directed by Sironi with the help of volunteer assistants from the Instituto de Conservacion de Ballenas. Costs are minimal (food and housing).

Biopsy sampling for genetic and isotope analyses

Biopsies are collected to link known individuals to matrilines (genetics) and to foraging locations (isotopes). On days with low wind conditions, researchers approach the whales in an inflatable 4.5 m boat, photograph their callosity patterns for later individual identification, and collect a skin sample with a crossbow. Samples are divided and one is preserved in DMSO and the other is dried. Associated data include age, sex, GPS location, time, date and weather conditions. Analyses are conducted at the University of Utah using standard PCR and equipment in the university's stable isotope facility. Participating researchers include Luciano Valenzuela, Rowntree, Jon Seger and Sironi with assistance from volunteers from the ICB. This work has been supported by general operating funds and small grants from individual donors.

Blow intervals and focal animal follows to determine body condition and behavioral budgets

Data on blow intervals of mothers and calves have been collected since 1997 to determine the effect of gull harassment on the whales' body condition (breath-holding ability). At least 40 mother/calf pairs are followed each year for periods of 30-60 minutes. The time of every blow and the animal's behavioural state are recorded for as long as the blows can be seen clearly. Focal follows of different age groups are conducted periodically to estimate the percentage of time spent in different activity modes and thus assess whether activity patterns have changed over time in response to gull harassment. This work has been carried out by Rowntree, Sironi and volunteers and requires funding for international airfares, food and housing at Península Valdés.

Documenting right whale foraging locations on the Patagonian Shelf

Efforts are underway to collect and analyse zooplankton samples from the Patagonian Shelf, the western South Atlantic and the Southern Ocean to determine the signatures and values of different tracers (stable isotopes, trace metals and fatty acids) for matching with the same tracers in the skin of living whales (biopsies) and the skin and baleen of dead calves and adults. The goal is to accumulate zooplankton samples from different latitudes and distances from shore along the Patagonian Shelf. Samples from three distinct locations are in-hand but more are needed to broaden the coverage. Because this programme has no direct access to oceanographic vessels, it will be necessary to collaborate with researchers who work on such vessels and with holders of zooplankton collections (e.g. fisheries laboratories) to obtain more samples. In addition, information is being gathered from the literature and from other researchers to assess regional, seasonal and long-term changes in the distribution and abundance of the predominant zooplankton species on the shelf. This information will help determine which species the whales are likely to be consuming in particular regions and thus the species that should be analysed for tracer signatures. Results from analyses of krill and copepod samples from the Scotia Sea are available through the British Antarctic survey and additional samples will be sought if required for additional analyses. This work is being carried out by Ph.D. student Maron, Valenzuela and Rowntree. Stable isotope analysis costs $8.50/sample ($800 per adult baleen plate) and fatty acid analysis $110/sample.

b. CENPAT Programme of Study on Southern Right Whales

Crespo and colleagues at the Centro Nacional Patagónico (CENPAT) summarised their work on right whales. Personnel include: Crespo, Susana Pedraza, Dans, María Florencia Grandi, Rocío Loizaga de Castro, Mariana Degrati, Bertellotti, Fazio, José L. Esteves, Mónica Gil. University of Patagonia: Mariano A. Coscarella, Clara Rosas. Instituto de Biología Marina y Pesquera Alte. Storni: Raúl González, Guillermo M. Svendsen. Independent Consultant: Daniel Pérez.

Surveys of the living whale population

Since 1999 the CENPAT Marine Mammal Laboratory has developed a programme to monitor the southern right whale population. Its goals are to:

- estimate and track the population rate of increase
- examine seasonal patterns of arrival and departure of different age classes
- detect and investigate any changes in distribution.

The programme was supported from 1999 to 2008 by the Fundación Vida Silvestre Argentina (a national NGO), the Global Environmental Facility and the Fundación Banco de Bilbao Vizcaya Argentaria. In 2009 it was funded by the Provincial Government but this funding was cut in the middle of the season. There is no long-term government funding, either at the national or provincial level, and each year funds are requested of private partners. This makes it difficult to ensure the continuity of the monitoring effort.

Expansion of right whales into areas such as Golfo San Matías has been investigated although with only limited effort. Three aerial surveys were conducted from Puerto Lobos to Viedma in 2007 and 2008. Boat-based surveys targeting marine mammals, including right whales, were also carried out from 2006 to 2009. Financial support for this work came from the Fundación Vida Silvestre, Agencia Nacional de Promocíon Cientifica y Técnica, the Global Environment Facility and the Secretaria Medio Ambiente Nación. There is no existing commitment for future funding.

A recent survey onboard the oceanographic vessel *Puerto Deseado/CONICET* covered a broad area from the coast to the continental slope (1500 m isobath). It is expected that this survey will be repeated in 2010.

Interactions between kelp gulls and whales

Since 2005, the behavioural effects of gull attacks on right whales have been monitored from whale-watch boats and coastal observatories. Also, samples collected from right whale lesions and from kelp gulls have been analysed in order to assess whether gulls are vectors for disease transmission. Financial support for these efforts has come from Aluar, GEF/Secretaria Medio Ambiente Nación, Dirección de Conservación and Areas Protegidas Pcia. Chubut, and CONICET.

Interactions between vessels and whales

There are two additional lines of scientific research on the interactions between vessels and whales:

- Feasibility of using DAVs (suction cup devices) and other instruments on the whales to evaluate the effects of whale-watching at Puerto Pirámides. Particular attention is being given to the potential effects of the instrumentation process on whale behaviour.
- Analysis and mapping of ship strike risks around Puerto Madryn, and considering the use of sound recorders and sonic alarms for risk mitigation.

This work began in 2007 and continues with financial support from Aluar, Fundación Vida Silvestre and the whale-watch companies.

Other

Ecosystem monitoring: Available information on levels of chemical pollutants in Golfo San José (GSJ) and Golfo Nuevo (GN) is limited in time and space. The current programme includes the sampling of hydrocarbons, heavy metals and TBT, although in a non-systematic way. There is essentially no data from GSJ, and most of the data from GN comes from the sampling of molluscs and sediments near the coast. These samples are taken as part of different projects but they do not constitute a monitoring programme.

Whale monitoring: As described in section 6.i., samples from calf carcasses from Golfo Nuevo and Golfo San José collected by the SRWHMP from 2003 to 2009 were analysed for essential and non-essential heavy metals (Cu, Pb, Zn, Cd). This work will be continued in coming years.

c. Photo-identification Project on Southern Right Whales Using Whale-watch Boats as Research Platforms (Fundación Ecocentro)

This conservation-focused research project has both scientific and educational aspects. Since 1995 trained observers onboard whale-watch boats have photographed right whales and studied aspects of the interaction between whales and tour boats. Around 1,200 different individual whales have been photo-identified to date. The intention is to continue developing re-sighting histories for known individuals, documenting return rates of the whales to the Puerto Pirámides area, and studying the reactions of whales to whale-watch boats. Also, the relationship between marine, commercial and tourist activity and the wounds observed on whales will be investigated in order to inform discussions concerning the need for traffic corridors (shipping lanes) to decrease the probability of encounters between ships and whales.

d. Future Lines of Work

Crespo and his group at CENPAT provided the following information on future work that they are considering:

- If funding can be secured, gull attacks can be recorded from aerial surveys on whales along the monitoring area in order to establish if this behaviour is spread throughout the whole area, complementing the observations performed by other research groups.
- With some additional funding, it may be possible to expand the monitoring effort to areas such as Golfo San Matías, where about a tenth of the right whale population was recorded in exploratory flights in 2007 and 2008 during the peak season.
- Taking advantage of the oceanographic research cruises, surveys of offshore areas in search of right whale feeding grounds can be undertaken at minimal cost.
- Design and implement sampling stations in Golfo Nuevo and Golfo San José for long-term pollution monitoring to assess ‘ecosystem health.’

- Considering that biotoxins can alter the behaviour of whale calves, use available human resources in the area to survey for abnormal behaviours in calves. This work can be land- or boat-based.

e. Use of Existing Datasets in Future Investigations

McAloose summarised datasets that are known or thought to be available and that might be used for further investigations of the causes of right whale mortality at Península Valdés. Local and regional datasets collected independently of research on the recent unexplained right whale mortality events exist within the scientific community and may contain valuable and relevant information once analysed in this context. These include, for example: (1) periodic (though non-systematic) collection and evaluation of sediment and mollusc samples from Golfo Nuevo and Golfo San José for hydrocarbons, heavy metals and TBT by the Environmental Chemistry Laboratory (CENPAT), (2) local and regional health and mortality information for additional species of birds and marine mammals in locations such as Península Valdés and Punto Tombo collected by the Wildlife Conservation Society or other local governmental agencies or NGOs, (3) information from ongoing population monitoring of right whales in Brazil by the Right Whale Project there (Groch) and (4) information on prey availability, e.g. the British Antarctic Survey in the UK has made acoustic estimates of Antarctic krill biomass collected information on the diet composition of land-based predators breeding at South Georgia in areas with documented right whale feeding.

Retrospective evaluation of existing datasets in the appropriate context may reveal significant direct or indirect relationships between the calf die-offs and environmental, infectious, nutritional or other factors. Towards that end, **efforts should be made** to identify and gain access to such datasets and to develop the necessary collaborations with the data holders.

11. Conclusions and recommendations

The workshop considered the evidence and concluded that there is reason for concern about the relatively high level of mortality, particularly of calves, experienced in recent years by the population of southern right whales that uses the Península Valdés region as a calving/nursery area. A total of 366 whales, including 333 calves, were found dead at Península Valdés between 2003 and 2009. For the vast majority of these, the cause of death is unknown. The workshop further took note of the statement by the IWC Scientific Committee in 2009 that the long-term databases developed by research projects in Argentina and Brazil have great value for monitoring the population dynamics and health of southern right whales in the western South Atlantic. Participants in the workshop **wished to express support** for the strong recommendation by the SC that the monitoring work on the right whale population off the east coast of South America should continue without interruption. In addition, it was noted that a programme of right whale research had started in Uruguay and participants agreed that it **should be expanded and integrated** with the programmes in Brazil and Argentina.

Three leading hypotheses to explain the spikes in mortality of first-year whales (calves) in 2005, 2007, 2008 and 2009 were identified by the workshop: a decline in food availability, biotoxin exposure and infectious disease. It was not possible to determine which of these is most likely, and it was acknowledged that some combination of factors may be involved. A fourth possible contributing factor, chemical contaminants, was considered less likely, and demographic factors, killer whale attacks, disturbance from whale-watching activities, vessel strikes and fishing gear entanglement were ruled out as significant causes of what appears to be a series of acute mortality events.

In light of the three leading hypotheses, several clear steps should be taken to build understanding of what has been killing these whales.

In addition to the specific recommendations and questions presented for each hypothesis elsewhere in this report, the following research strategy is proposed to investigate the hypotheses and to guide the allocation of research effort according to the strengths and capabilities of the different research groups.

1. The work of detecting and investigating strandings and then analysing the patterns of mortality and the samples from necropsies to evaluate body condition and presence or absence of disease, toxins or other possible causes of mortality, **should continue as a top priority**. Specifically, researchers need to:

    - Find and examine as many stranded whales as possible through a strong, well-funded stranding network.
    - Continue to implement robust necropsy protocols, with both targeted and broad-scale bio-sampling and a priority on analysis of tissue samples.
    - Document the age and sex of stranded animals and the timing and locations of deaths.

2. Continued and expanded investigations of environmental factors that may be affecting the whales in the calving/nursery area **should also remain a priority**.

    - Necropsy work (see above).
    - Conduct broad environmental monitoring or collaborate with existing monitoring programmes to detect and identify biotoxins and diseases that could be implicated in the die-offs.
    - Conduct detailed investigations of potential vectors of diseases or toxins, including detailed studies of kelp gulls as potential vectors.
    - Behaviour work (see below).

3. Besides the efforts to investigate dead whales, **it is important to continue and expand** the long-term research on live whales in the Península Valdés region to obtain demographic and behavioural information. A top priority should be the establishment of a reporting network to alert the research community whenever abnormal behaviour is observed that could be related to die-off causation.

    Demography:

    - Assess the body condition of mothers when they arrive in the area (e.g. fat rolls on neck, photogrammetry).
    - Determine which mothers are losing their calves (e.g. primiparous vs. multiparous, haplotype group).
    - Initiate a multi-year biopsy sampling programme in general, but especially targeted at assigning maternity to dead calves.

    Behaviour:

    - Seek to identify behaviour by whales on the calving/nursery ground that may indicate causes of mortality.
    - Determine if whales are exhibiting unusual behaviour attributable to poor condition, toxins or disease.
    - Using the available long-term data on behaviour as a reference, attempt to measure and assess the stress-related or energetic consequences of gull parasitism.
    - Continue to monitor the frequency of gull attacks and their effects on whale behaviour at sites where long-term data (since 1995) are available.

4. Identification of the feeding grounds of the Península Valdés right whales and investigation of environmental factors that affect these whales' survival and reproduction **should also be a priority**.

    - Assess trends, both long-term and recent, in the quantity and quality of right whale prey, and attempt to link these to trends in right whale reproduction and calf survival at Península Valdés.
    - Seek evidence of biotoxins and infectious disease on the feeding grounds and migratory routes and attempt to relate such evidence to right whale reproduction and calf survival at Península Valdés.
    - Consider a satellite-tag tracking study designed to identify the main feeding grounds of this right whale population.

5. The long-term aerial photo-identification programme (WCI/ICB) **stands out**, along with the stranding network (SRWHMP), **as a top priority**. The 40-year datasets on the population of right whales at Península Valdés **should be maintained** and data collection **should continue**. These data are critical for monitoring population trends, describing the significance of the recent die-offs and testing causation hypotheses. The recently initiated CENPAT aerial surveys to monitor trends in abundance and the boat-based photo-identification work are important complements to the long-term research and monitoring efforts.

    - Estimate current population parameters by updating Cooke's assessment (using photo-identification data through the 2009 season) and by exploring other analytical approaches.
    - Conduct an overall analysis of the population data, incorporating information on mortality (especially of adult females and calves), and search for indicators of causality.
    - Consider how to increase aerial photo-identification survey coverage of the right whales at Península Valdés. For example, increasing the number of surveys to 3/year would provide better data on (a) mother and calf condition on arrival, (b) which mothers lose their calves and (c) calf survival through the nursery season. It would also likely improve the ability to re-identify juveniles in later years.

6. Cooperation and collaboration between research groups are essential to building the knowledge needed to answer complex questions concerning die-offs such as those observed in recent years in Argentina. Therefore, efforts to improve such cooperation and collaboration **should be a high priority** for governments and NGOs.

    - Explore mechanisms for establishing a South Atlantic right whale consortium similar to the North Atlantic Right Whale Consortium (including, at a minimum, researchers in Argentina, Uruguay and Brazil).
    - Continue and strengthen the collaborations and networking that have already developed around the stranding programme and as a result of concern about the recent die-offs.
    - Broaden collaborations to encompass such things as combining datasets (e.g. aerial and boat-based photo-identification catalogues) in order to achieve greater analytical power.

7. The absence of conclusive information regarding the cause of exceptional right whale mortality should not preclude appropriate management measures. In particular, the workshop **stressed** the need for kelp gull management and policy. Regardless of whether gull lesions are a contributing factor in whale mortality, they cannot be considered as anything other than harmful to the whales.

    - Complete as soon as possible the ongoing studies to detect viruses, bacteria and fungi in the gulls already sampled.
    - Efforts towards covering, closing or consolidating dumps, better management of fish offal (on land and at sea) and direct gull control would be expected to lead to improved whale health.

The workshop **acknowledged** the considerable efforts of the researchers in Argentina (and abroad) to investigate the die-offs and commended them on their accomplishments to date in the face of fiscal and logistical constraints and in view of the sheer numbers of dead whales. The SRWHMP in the Península Valdés region has developed efficient reporting and systematic surveillance systems for dead whales, and full necropsies are conducted whenever possible, using standard protocols adopted from the US large whale stranding networks that have long experience in large whale necropsies (McLellan *et al.* 2004), particularly right whales. One of the major problems hampering identification of the cause or causes of the high southern right whale mortality is that the carcasses are considerably decomposed by the time they strand, are found by researchers or reported by network members. Nonetheless, researchers have collected a range of tissue samples that have either been analysed or are available for analysis. The investigation does not suffer from a lack of effort or expertise among scientists and volunteer right whale strandings responders in Argentina. The workshop also noted that the scientists and volunteers, as in many areas of cetacean research in Patagonia, are operating with only minimal funding and this makes their achievements all the more impressive.

The workshop further **recognised** the importance of having governmental commitment if there is to be long-term conservation of right whales in Argentina. Although there has been significant improvement over the last couple of years, an even stronger commitment by the provincial and national governments **is required**. The whale-watch industry must also continue and increase its investments in right whale research and monitoring, given that its own viability hinges on a large and healthy whale population in local waters. The workshop **stressed** the importance of establishing links and sharing information on southern right whale health and life history trends in different parts of the range, especially Argentina, Brazil, Uruguay, South Africa, Australia and New Zealand.
Researchers working on right whales around Península Valdés met in 2009 to share findings and discuss plans. Building on that experience, the workshop **recommended** that those researchers and others involved in right whale work elsewhere in the western South Atlantic (Argentina, Uruguay and Brazil) develop a consortium modelled at least in part on the North Atlantic Right Whale Consortium (NARWC, see www.rightwhaleweb.org). It should be possible to establish such a consortium with minimal funding (part-time salary for a secretary).[1]

[1] The NARWC began as a collective of field researchers combining their photo-identification catalogues to create a unified, species-wide catalogue, which is maintained by the New England Aquarium in Boston. Many US and Canadian agencies, laboratories and individuals contribute photographs on a routine basis. The consortium organises an annual scientific meeting where presentations are given on current research and management issues. Currently, about 180 people attend this 2-day event. The NARWC has a secretary who manages access to the databases according to clear rules agreed by consortium members. Under the data access application process, prospective data users describe their project and propose co-authors of planned publications to include major data providers. The databases maintained by various consortium member institutions include the photo-identification catalogue, a sightings database, a genetics database, and a necropsy database.

Among other values of a consortium are that it facilitates syntheses of data over the entire range of the population, enables rapid and targeted dissemination of new information, helps prevent duplication of effort, encourages strong collaborative research and creates synergies by submerging individual aspirations to the overall goal of species conservation and welfare. The board of the consortium produces an annual 'report card' on the state of the population. The consortium can also provide an effective voice locally, nationally and internationally in terms of policy and funding.

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Annex A

List of Workshop Participants

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Annex B

Agenda

1. Introduction
   a. Opening and welcome
   b. Arrangements – chair, rapporteurs, etc.
   c. Documents and document control
   d. Reporting – format, timing, assignments
2. Background on right whales around Peninsula Valdés
   a. History of the population
   b. Long-term studies by WCS and other NGOs
   c. Long-term studies by Argentina agencies
   d. Others
3. Review of recent mass die-offs (since 2004)]
4. Findings to date from the die-offs
   a. Numbers of dead whales recovered (including size, sex, genetics, etc.)
   b. Spatial and temporal aspects, with comparisons between the two gulfs and different years
   c. Pathology results
5. Causation hypotheses (not mutually exclusive)
   a. "Natural" mortality of calves (e.g. in relation to nutritional state ["condition"] of mothers)
   b. Toxic algal blooms
   c. Disease(s)
   d. Predation (including "harassment" by predators, gulls, adult male right whales)
   e. Disturbance by tourism, industrial activity, etc. (potentially mediated by underwater noise)
   f. Demographic adjustment (e.g. entry of first-time mothers into population)
   g. Population is near current environmental carrying capacity (mediated by "condition" adult females
6. Health (status) of South Atlantic Ocean ecosystem
   a. Offshore feeding areas (including shifts in quantity and distribution of primary and secondary production, species interactions, etc.; relations to natural variability, regime shifts, climate change, etc.)
   b. Coastal areas in Peninsula Valdés region
7. Global trends in marine mammal diseases and HABs
8. Population consequences of the die-offs
   a. Population increase after depletion by commercial whaling
   b. Future population trends
9. Possible explanation(s) for recent SRW die-offs
10. Future SRW health and mortality monitoring program
    a. Current program
    b. Future needs
11. Future SRW research program
    a. Current program (other than health and mortality monitoring)
    b. Future needs
12. Conclusions and recommendations

APPENDIX A

Testing the 'effort' hypothesis for UMEs at Península Valdés

Submitted post-workshop by Jon Seger (current at 26 March 2010)

Since 2003, the SRWHMP would be expected to have recorded a larger fraction of the calves that died than were recorded on average during the previous 32 years (1971-2002). But there is no obvious way to estimate *how much* more efficient the detection process has become, because we cannot assume that the actual calf mortality rate has remained constant. The important but difficult question is how much of the post-2003 increase in detected deaths can be attributed to increased *effort*, and how much of it represents real increases in *mortality*?

One seemingly conservative approach to this question is to assume that the first four years of the stranding project saw typical (historic) rates of calf mortality. Then we can ask whether the seemingly very high calf mortality of 2007-2009 falls significantly outside the range to be expected, given the detection efficiency implied by the data for 2003-2006, under the assumption that those years were in fact 'normal'. Of course those years may not have been 'normal', but it seems unlikely that they had abnormally *low* mortality rates, so this approach should be biased *against* the conclusion that the years 2007-2009 were truly extreme.

It seems remarkable that exponential fits to the raw data for calves detected (alive) in the aerial surveys, and calves detected (dead) on the beaches prior to 2003, both give growth rates very similar to those derived from Justin Cooke's sophisticated population model (6.7-6.8%/yr – see Fig. A1). This suggests that *on average*, strandings were detected in proportion to their actual numbers, though perhaps with low efficiency. Thus we can easily estimate the improvement in efficiency (under the assumption explained in the previous paragraph) by simply *elevating* the stranded-calves curve so that it fits the data for the first four years of the SRWHMP (2003-2006) (Fig. A1). The upper curve on the stranded-calves plot demonstrates this fit. The curve is drawn black during those four years, and gray everywhere else, to indicate that its elevation reflects a fit to those four years only (while retaining the standard 6.7% population growth rate). On these assumptions, the stranding project has roughly doubled the probability that a dead calf is detected. Alternatively, it is possible that the increase in detection is smaller than this, and that some of the high mortality years prior to 2007 were caused by smaller unusual mortality events.

But even with an assumed doubling of the detection efficiency, the three most recent years are clearly extraordinary. Table A1 shows 1- and 2-tailed Poisson probabilities of seeing as many (or as few) stranded calves as were actually seen in 2003-2009, on the assumption that the expected numbers are those implied by the upper curve.

Table A1. Poisson probabilities of seeing as many (or as few) stranded calves as were actually seen in 2003-2009.

			P	
year	predicted	observed	(1-tailed)	(2-tailed)
2003	20.52	29	0.045	0.09
2004	21.93	13	0.029	0.06
2005	23.44	36	0.0095	0.02
2006	25.05	16	0.037	0.07
2007	26.77	77	1.8e-15	3.6e-15
2008	28.61	87	0	0
2009	30.58	71	3.1e-10	6.2e-10

This is a very bad fit! A conventional contingency chi-square for stranded vs. live calves in these seven years (X^2 = 149.4, 6 d.f., $P \approx 0$) makes the same point. Clearly there has been a lot of heterogeneity in calf mortality rates among years! Even for the pre-2003 era, X^2 = 105.9, 31 d.f., $P < 1.0^{e-6}$. Some of this could be caused by variation in survey effort, of course.

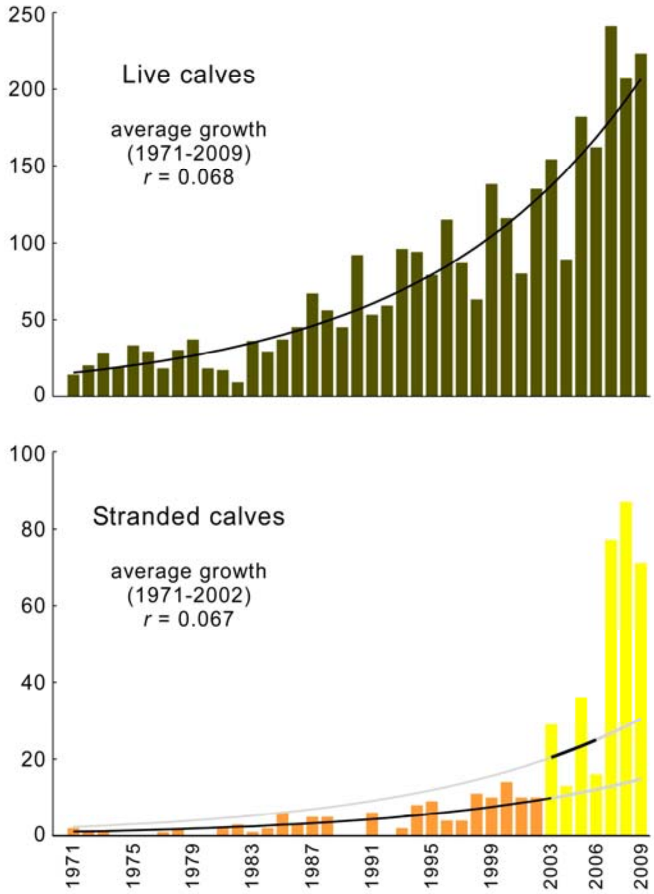

Fig. A1. Numbers of living calves counted in aerial photographic surveys (above), and numbers of stranded calves found on the shores of Golfo San Jose and Golfo Nuevo, 1971-2009. Curves are fits of the standard exponential population growth function to the raw data. In the lower panel (stranded calves), the lower curve is fit to the data for 1971-2002 only, and the upper curve is fit to the data for 2003-2006 (first four years of the SRWHMP) on the assumption that the average rate of growth is 0.067 (6.7%/yr) over all years. Each curve is colored light gray in the years that were not used in its fit. The upper curve supports the hypothesis that calf mortality was extraordinarily high in 2007-2009 (i.e., far above the exponential prediction) even on the assumption that rates of calf mortality in 2003-2006 were typical of those seen in 1971-2002.