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Population trend in right whales off southern Australia 1993-2007

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ABSTRACT

Aerial surveys for southern right whales have been undertaken annually close inshore off the southern Australia coast since 1976, at first along the southern coast of Western Australia, from Cape Leeuwin (34° 23'S, 115° 08'E) to as far east as Twilight Cove (32° 17'S, 126° 05'E). A significant increase in numbers was recorded for 1983-1992, but at a rather higher rate (*ca* 10%) than observed in recovering populations (at *ca* 7%) elsewhere eg off eastern South America and South Africa. Evidence of coastwise movement between South Australia and Western Australia led to an extension of the annual surveys to Ceduna, South Australia (32° 07'S, 133° 46'E) from 1993. They have continued annually since then, covering the area where the majority of the 'Australian' population seems to approach the coast in winter/spring: cows about to give birth appearing at an average of three years, others less predictably. The number recorded in 2007 (286 animals including 57 cow/calf pairs) was considerably fewer than in earlier years, although the 'unaccompanied' animals count was not unexpectedly low. Regression analysis, including inspection of residuals, of the data from 1993 (excluding numbers for 1996 and 1997 where there seems to have been some undercounting) gives, for 'all animals', no evidence of anything other than an exponential increase. But for cow/calf pairs, the 2007 data point is clearly an outlier. For the present the 1993-2006 cow/calf increase rate of 8.10% (95% CI 4.48, 11.83) has been taken as the current 'best estimate' of annual increase rate for that part of the Australian population that visits the southern Australian coast between C Leeuwin WA and Ceduna, SA. Current population size for animals visiting the area surveyed is estimated to be *ca* 2100, with a total Australian population of *ca* 2400.

INTRODUCTION

Following increasing reports of southern right whales off the south coast of Western Australia in the early 1970s an annual programme of aerial surveys was undertaken there from 1976 (see Bannister 1990). At first, flights covered an area east of Cape Leeuwin (34° 23'S, 115° 08'E) mainly to a point east of Israelite Bay, 25nm west of Pt Culver, at *ca* 124° 12'E, over a coastline length of *ca* 400 nmiles (*ca* 750 km) (Fig 1, area A). In some years they were extended as far as Twilight Cove (32° 17'S, 126° 05'E), covering some 500 nmiles (*ca* 900km) (Fig 1, area B).

The results from areas A and B for the period 1983-1992 (see Bannister, 2001) showed significant increases in the three classes of whale recorded ('all animals', 'unaccompanied' animals - i.e. juveniles or adults unaccompanied by calves of the year, and cow/calf pairs). The annual increase rates (range 7.1-13.5%) were somewhat high compared with estimates elsewhere, eg off South Africa and eastern South America, at around seven per cent per year. Given accruing information on movement of individuals between the Western Australian coast and South Australia, both within and between years, the surveys from 1993 were extended into South Australian waters to include the localities where, up to then, the majority of Australian sightings had been recorded, i.e. to Ceduna, SA (area C in Fig 1), taking in the major calving area at Head of Bight, SA (31°30'S, 131°10E) and the historically significant right whaling area at Fowler Bay, SA (31°59'S, 132°34'E). The total area covered then extended over some 900 nmiles (*ca* 1700 km) (see Bannister 2001).

In each year 1993-2007 there have been three flights – one 'long', over area C, between Cape Leeuwin WA and Ceduna, SA, undertaken when animal numbers were likely to be at a maximum (mid August-mid September) and two 'short', over area B between Cape Leeuwin and Twilight Cove. The latter have been timed for late July/early August and late September/early October, bracketing the long flight. The 'long' flight has concentrated on obtaining a maximum count of animals present, while also obtaining

identification photographs; each 'short' flight has concentrated on obtaining as many as possible of the latter.

Right whales are observed close to the coast each year mainly between July and October (Bannister 1990, 2001), with some localities more favoured than others. Cows accompanied by calves are found particularly in the Doubtful I Bay, WA, region, in and north east of Israelite Bay, WA and at Head of Bight, SA. 'Unaccompanied' animals are less predictable, but are often found west of Israelite Bay, WA and west of Twilight Cove, WA. As an example, the distribution of right whales recorded on the three flights of the most recent survey, in 2007, is shown in Fig 2.

A power analysis undertaken by P Corkeron in 1992 (in Bannister, 1993) showed that a series of 'long' flights over five years, ie 1993-97, would be necessary to detect a trend in those data. But further power analysis by Corkeron in 1997 (in Bannister, 1997) showed that for animals appearing close to the coast on a three-year cycle, ie cow/calf pairs, a significant detectable trend would become apparent over a period encompassing five adult female reproductive, i.e. three-year, cycles, involving fifteen years from 1993, i.e. to 2007 inclusive.

This paper reports the results obtained from the 'long' flight series, 1993-2007.

METHODS

All surveys have been undertaken with a high wing, single engine aircraft (Cessna 172) based on Albany WA, (35° 01'S, 117° 58'E) crewed by a pilot/observer and photographer/observer. Each flight occurs close to the coast, searching an area *ca* 1 nmile wide within which right whales, particularly cows about to give birth or with newborn calves, can be found.

The survey methodology involves direct counts of animals observed within the search area (C in Fig 1). The latter includes virtually all the area to which right whales resort in winter/spring, close to the coast, in particular for the females to give birth. Most animals, particularly cows accompanied by their calves of the year, are easily observed in the relatively clear waters on the south coast, and the probability of sighting (g(0)) is assumed to be 1. This makes for a relatively simple sighting protocol, repeatable over the years. The most important factor has been to ensure little or no change in pilot- or observer-efficiency, achieved in this case by employing, over as protracted a period as possible, the same charter company (since 1995), observer/photographer (1993-1995, 1996-2007) and pilot/observer (1993-95, 1999-2003, 2004 and 2006). Flying is only undertaken on 'good' days, with wind speeds of <15 knots.

The area searched on the 'long' flight is broken up into flight 'legs' between salient points on the coast (Cape Leeuwin-Albany, Albany-Esperance, Esperance-Twilight Cove (all within Western Australia), Twilight Cove-Head of Bight (South Australia), Head of Bight-Ceduna (South Australia) (see Fig 1). An additional leg is flown each year on the west coast between Perth and Cape Leeuwin. Apart from the Perth-Cape Leeuwin leg, each is generally covered twice, once 'outwards' and once 'inwards'. Although the observer has a general instruction to count on the outward leg and photograph on the return, counts tend to be obtained both ways. For comparison between years, the numbers used are for those legs where the cow/calf count is a maximum. Even though there may be up to two days between 'outward' and 'inward' counts (though usually not more than a day) the relatively sedentary cow/calf pairs are most unlikely to have moved between legs and thus confounded the results. The same cannot be said for 'unaccompanied' animals, which come and go much more rapidly and unpredictably.

RESULTS

Counts

The results for the years 1993-2007 are given in Table 1. As indicated above the figures were obtained by combining, for each 'long' flight each year, the numbers of 'all animals', 'unaccompanied' animals and cow/calf pairs recorded for each leg where the cow/calf count was a maximum.

As a check on counts from the aircraft, comparisons are made each year with those for comparable dates from shore-based operations at Head of Bight, South Australia. No major discrepancies have been found. For example, in 2006 the aerial survey counts there of 59 adults, 43 calves on 27 August and 57 adults, 45 calves on 28 August gave the same result, for calves, as the highest count, on 19 August in perfect conditions, of 55 adults and 43 calves from the land-based operation (R Pirzl, pers. commn). In 2007 the aerial counts of 23 adults and 12 calves at Head of Bight on 1 September and 31 adults, 12 calves and 2 'yearlings' on 2 September compare favourably, though at the bottom end of the range, with daily counts of 12-20 calving pairs recorded at Head of Bight between 15 and 31 August (S Burnell, pers. comm.).

The 2007 total count ('all animals', Table 1) at 286 was lower than any since 2003 (273), largely as a result of the very low number of cow/calf pairs recorded. That contrasts with the very high count in 2005 (591) and the relatively high count in 2006 (427). The 2007 cow/calf pair count (57) was the second lowest in the series – only that for 1994 (48) (excluding counts for 1996 and 1997 where there may have been some undercounting, see Bannister 1998, 2002) was lower. On the other hand the 2007 count of 'unaccompanied' animals (172) was the second highest in the series.

Trend

A simple exponential regression (i.e. a linear regression of the natural log of the count on year) of the data in Table 1 for 'all animals', including the 2007 data point, gives an exponential rate of increase of 0.0524. Without the low 2007 data point, the rate is 0.0671. Whether or not the low 2007 data point is indicative of a slowing of the population growth rate was investigated by examining the residuals of the simple exponential regression, but there is no evidence of anything other than an exponential increase: the residual plot shows a fairly even scatter of points above and below the fitted regression line. Indeed, the variability in the counts from year to year is so high that evidence of anything other than exponential growth would take a long time to be supported statistically.

For cow/calf pairs, the 2007 data point is clearly an outlier. Including that point, the estimated rate of increase (0.0508) is lower and less precise than for 'all animals'. The opposite is true if the 2007 data point is excluded, in which case the rate of increase is 0.0778. Table 2 summarises the results, including conversion of the exponential rate to an annual percentage increase. The relevant plots, including plots of the residuals, are shown in Figures 3 and 4.

Population size

Pending mark-recapture analysis using photographically identified animals, population size for that part of the 'Australian' population found on the southern coast between C Leeuwin, WA and Ceduna, SA has been estimated using a simple model based on the numbers of cow/calf pairs sighted on the 'long' flights. Given the relative paucity of animals that visit the remainder of the southern Australian coast, the population recorded between C Leeuwin and Ceduna is likely to represent the majority of the 'Australian' population.

The model assumes that each reproductive female is recorded on the coast only once in three years, that the sex ratio is unity, that there are probably some unreproductive adult females present, and that in an expanding population there are at least as many immature animals as adults. In increasing populations there is evidence that the proportion immature can be as much as 61% (in gray whales, Rice and Wolman (1971)) or certainly more than 50% (in bowhead whales, Zeh et al (1993)). Indeed, at the 1998 Cape Town assessment meeting the ratio immature:adult was estimated to be as high as 1.41:1 (IWC 2001).

Given the very low count of cow/calf pairs in 2007 it seems unrealistic to use that figure in the estimation. But as noted above, the number of 'unaccompanied' animals does not show such a corresponding reduction. In that event the actual number of animals in the population (apart from calves of the year) may not have declined markedly, in which case it seems appropriate to retain the figure calculated in 2006, as follows.

From the 'long' flight counts over the three-year period 2004-2006, the number of reproductive females (i. e. cows accompanied by calves) recorded as visiting the coast was 434 (Table 1). Assuming a three-year calving cycle, that represents the minimum number of adult females in the population. The adult population of both sexes would then be at least 868.

As the basis for its estimate of the Australian population, the Cape Town Assessment Meeting (IWC, 2001) used the 1995 sighting figure of reproductive (mature) females of 65 (i.e. 195 over three years) for the area C. Leeuwin–Ceduna. Allowing for additional animals off the remainder of the Australian coast, *ca* 1.41 as the ratio immatures:adults, and population growth rate of 7.5%, 1997 'Australian' population size was based on 254 mature females, giving an estimate of 1197; *pro-rata* the figure for that part of the population visiting the area C. Leeuwin-Ceduna in 1997, based on 225 mature females, would have been 1060. Given the number of reproductive females recorded there for the three year period 2004-2006 (434, see Table 2), *pro rata* the total visiting the area in that period would then be (434/225) x 1060, i.e. 2045.

2045 represents the number as at 2005 (the mid-point of 2004-2006). Allowing for at least some increase since then, the current number of animals visiting the survey area is therefore likely to be some 2100, with a total Australian population of *ca* 2400.

DISCUSSION

Given the three-year periodicity in calving, different three-year breeding female cohort strengths are to be expected. A three-year cycle is obvious in the counts for 1998-2003 (Table 1; Fig 4), although it breaks down thereafter. Breeding success, as exemplified by cohort strength from year to year, has recently been correlated with changes in sea surface temperature attributed to climate change (Leaper et al, 2006). Leaper et al found that conception can be affected by high sea surface temperatures (themselves the result of earlier El Niños) in the autumn months preceding conception the following winter, with a resulting effect on pregnancy rates the following year. El Niños recorded in 2002-3 and/or 2004-5 might thus have had an effect on calving rates off the southern Australian coast in 2007.

In that context, the contrasting lack of a marked decrease in unaccompanied animals in 2007 may reflect the presence on the coast then of more non-calving females than usual. Whether that is the case should be determinable once the 2007 photographic 'matching' results are available. Alternatively, or in addition, non-breeding cows may well have changed cohorts, in which case higher cow/calf pair counts might be expected in 2008 and 2009.

ACKNOWLEDGMENTS

No data would have been available over the years but for enthusiasm and persistent hard work of the pilots (the late John Bell, Jenny Schmidt and Julie Biser) and observer/photographers (Ray Smith, Alan Murdoch and Andrew Halsall). Phil Hammond undertook the statistical analyses. Chris Burton generated Figures 1 and 2. In 2007 additional assistance came from Jasmine Antonini, Stephen Burnell, Doug Coughran, Grefin Harsa, and staff of the Department of the Environment, Heritage, Water and the Arts, Canberra, particularly Robyn McCullough. Vicky Rowntree continues to provide advice on the computer-assisted matching program, as does Greg Donovan on the sightings/photographic database.

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Table 1. Right whale aerial survey, WA-SA, 1993-2007. Comparable numbers seen.

Year	a. All animals	b. 'Unaccompanied' animals	c. Cow/calf pairs
1993	167	47	60
1994	191	95	48
1995	267	139	64
1996[1]	233	123	55
1997[3]	254	148	53
1998	342	120	111
1999	325	157	84
2000	259	113	73
2001	447	163	142
2002	377	163	107
2003	273	85	94
2004	356	142	107
2005	591	237	177
2006	427	127	150
2007	286	172	57

Table 2. Best fit regressions to the data of Table 1, C. Leeuwin WA-Ceduna SA (Area C), excluding 1996, 1997

Period	1993-2006		1993-2007	
Class	**All animals**	**Cow/calf pairs**	**All animals**	**Cow/calf pairs**
Exponential increase	0.0671	0.0778	0.0524	0.0508
SE	0.0152	0.0153	0.0162	0.0218
95% CI	0.0331-0.1010	0.0439-0.1118	0.0167-0.0880	0.0028-0.0988
p	0.0013	0.0005	0.0080	0.0399
R^2	0.6596	0.7225	0.4874	0.3304
Percentage annual increase	6.94	8.10	5.38	5.21
SE	1.54	1.54	1.63	2.21
95% CI	3.37 – 10.63	4.48-11.83	1.69-9.20	0.28-10.39

[1] Probable undercounts (see Bannister 1998, 2002)

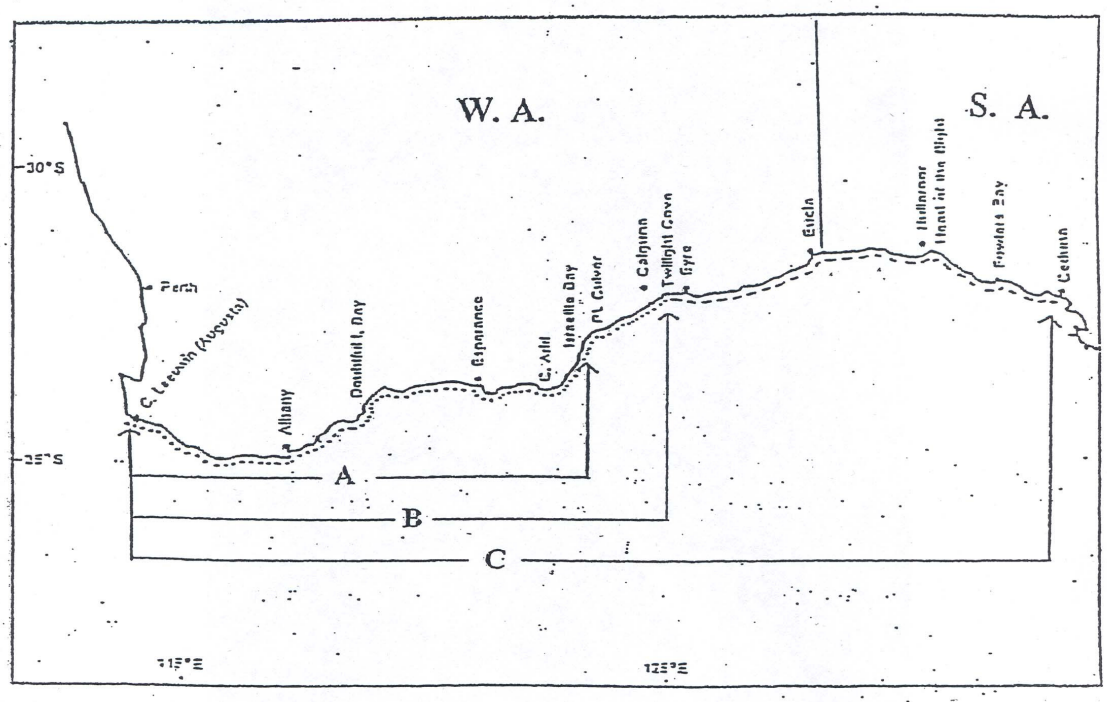


Figure 1. Aerial survey, WA-SA, 2007. Approximate position of flight path

..... traversed on 'short' flights (##1, 3)
- additional traversed on 'long' flight (#2)

A: 1976-1985, 1988-91
B: 1986-1987, 1992
C: 1993-present

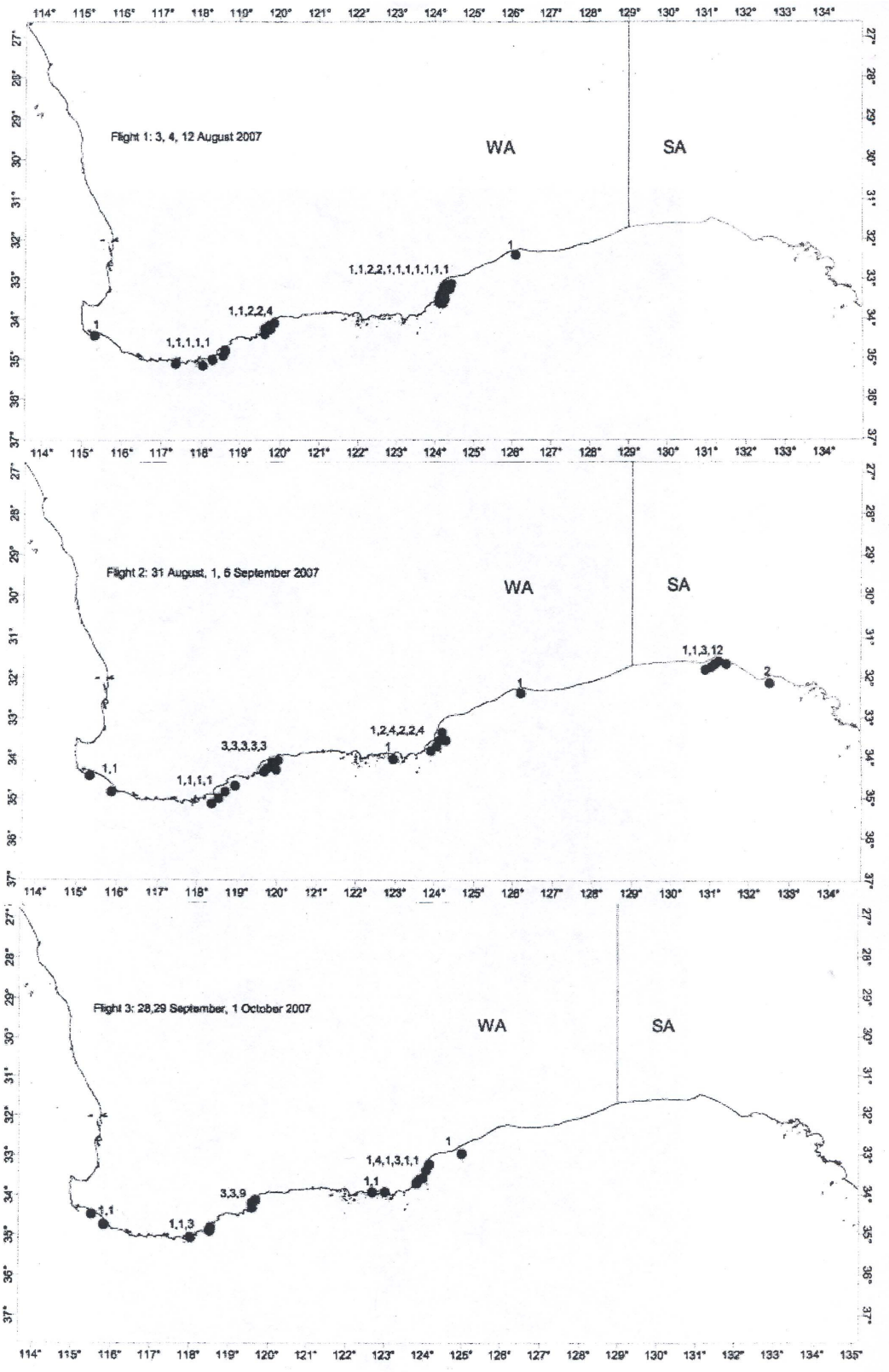


Figure 2. Aerial survey, WA-SA, 2007. Approximate positions of right whale sightings on the three flights. Localities as in Figure 1.
a. Cow calf pairs (•)

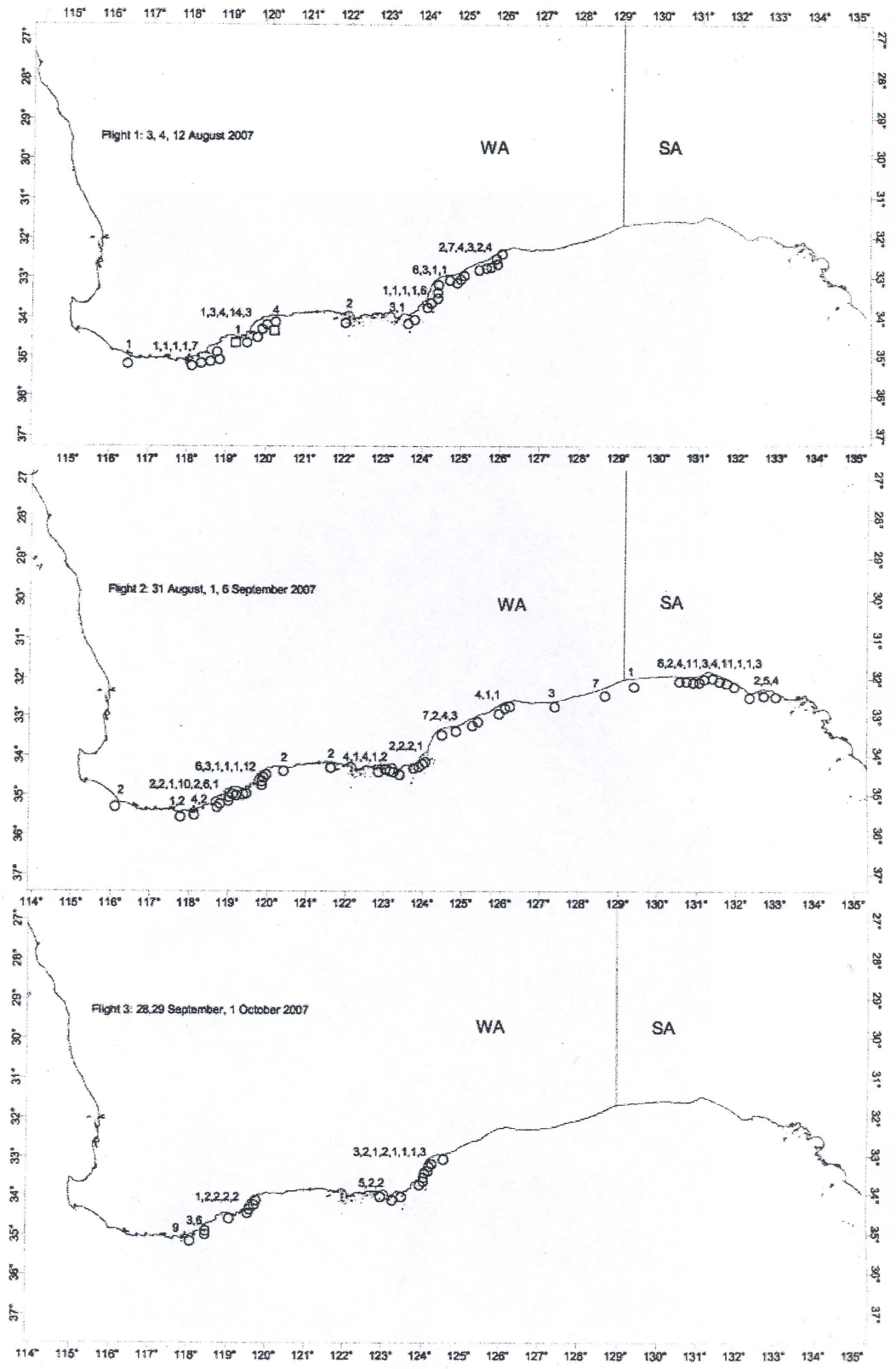
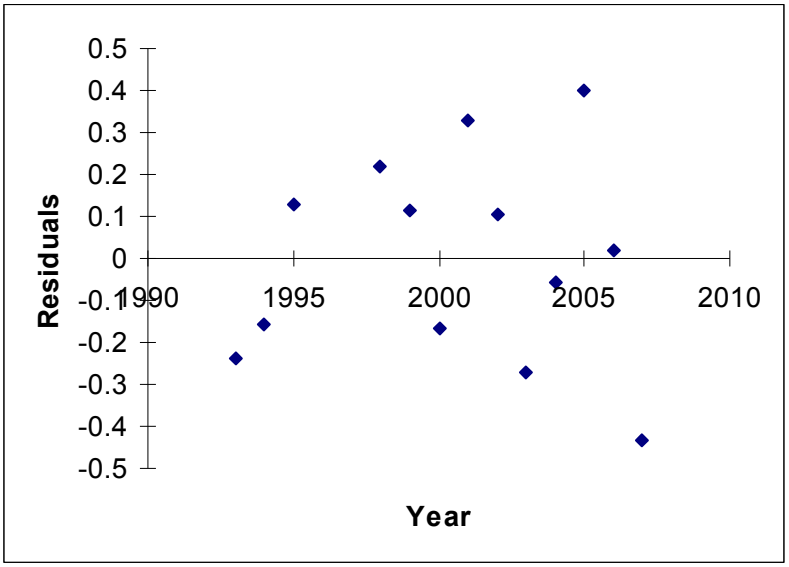


Figure 2. Aerial survey, WA-SA, 2007. Approximate positions of right whale sightings on the three flights. Localities as in Figure 1.
b. 'Unaccompanied' adults (○), and yearlings (□)



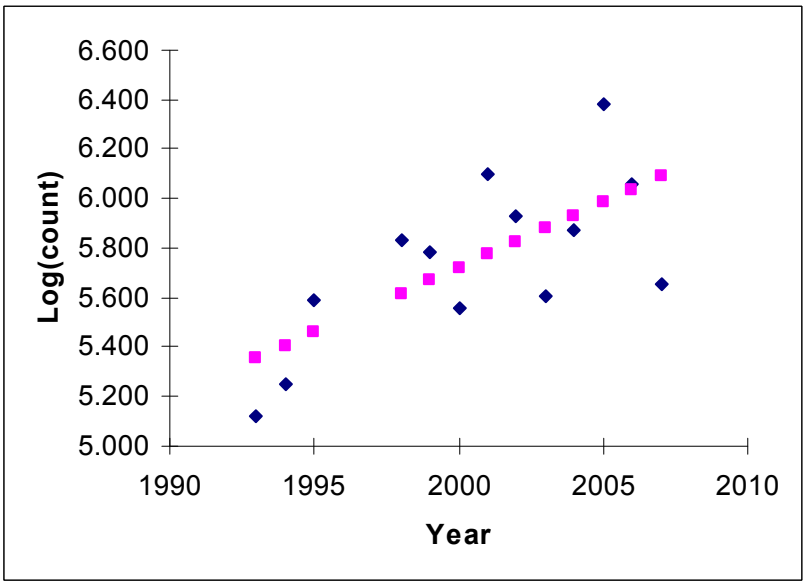
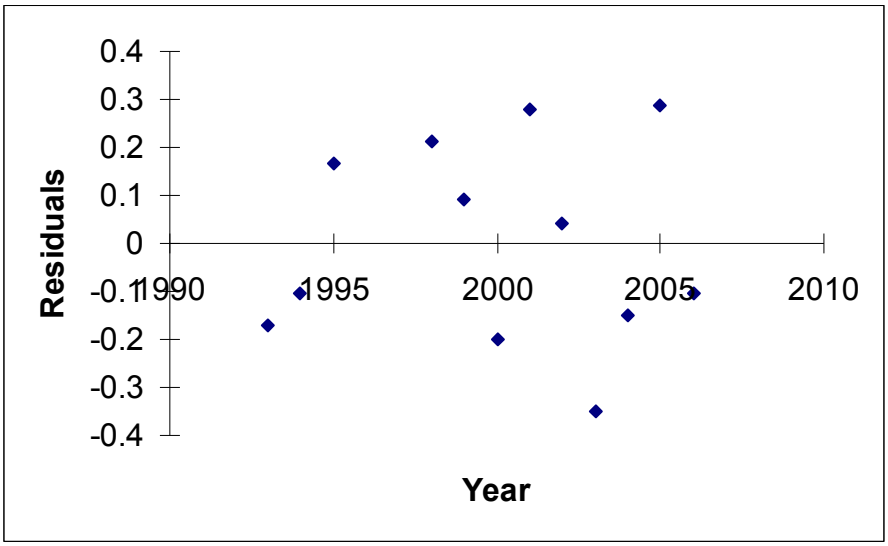


Fig. 3. Residual and regression plots for the data of Table 2 a. All animals, 1993-2007 (excluding 1996, 1997)



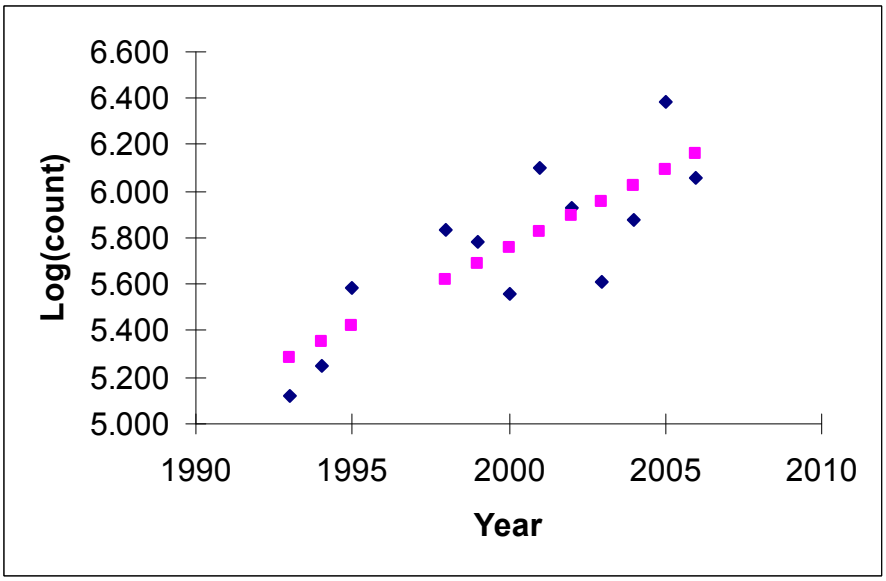
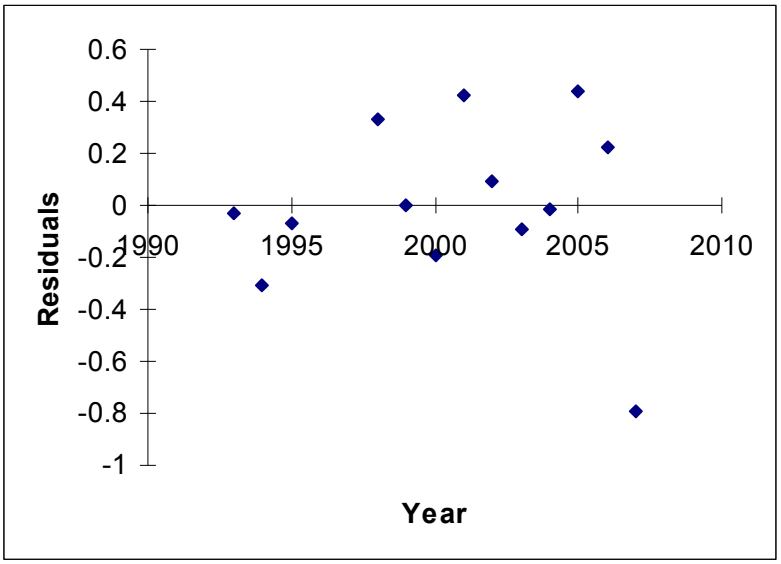


Fig. 3. Residual and regression plots for the data of Table 2
b. All animals, 1993-2006 (excluding 1996, 1997)



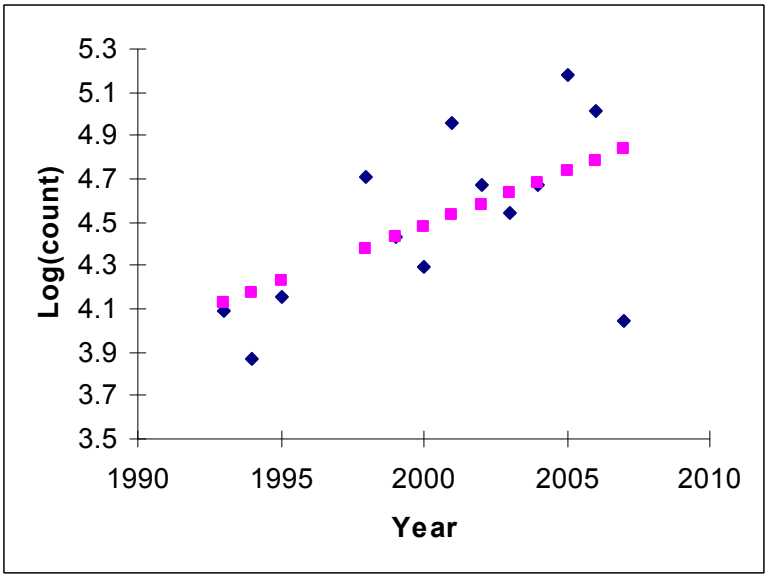
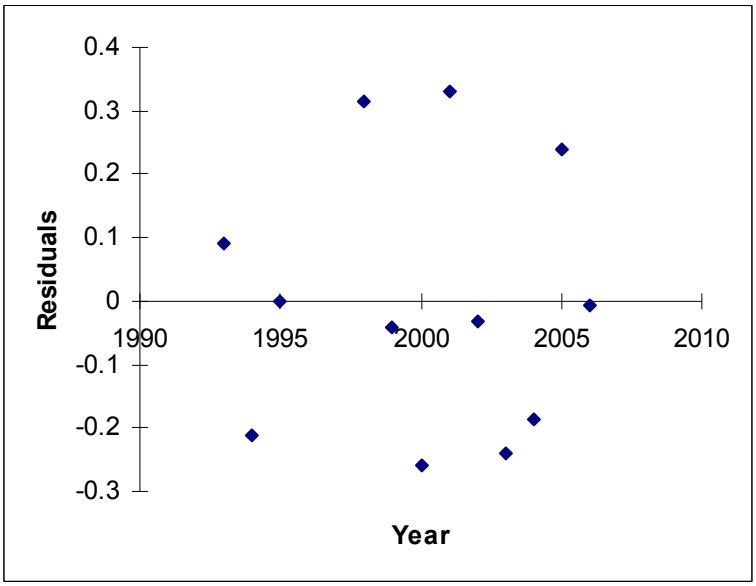


Fig. 4. Residual and regression plots for the data of Table 2
a. cow/calf pairs, 1993-2007 (excluding 1996, 1997)



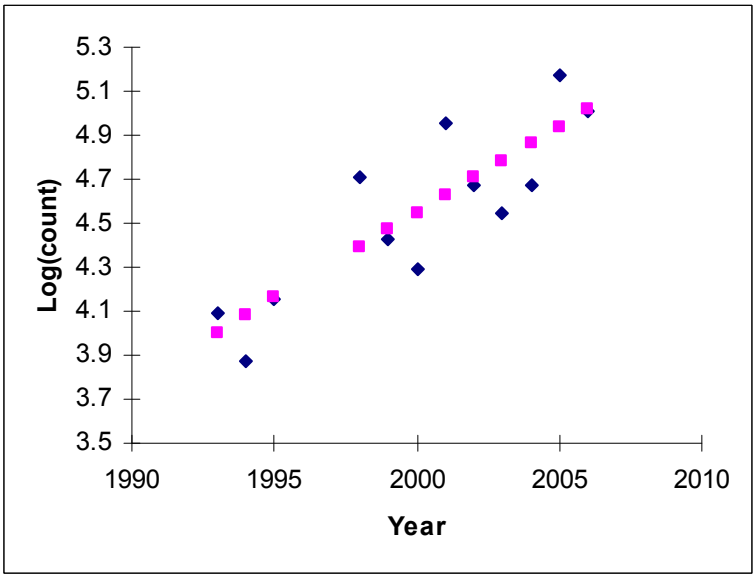


Fig. 4. Residual and regression plots for the data of Table 2
b. cow/calf pairs, 1993-2006 (excluding 1996, 1997)