Abundance estimates of the east Australian humpback whale population: 2010 survey and update

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ABSTRACT

An eight-week, land-based survey of humpback whales was conducted at Pt Lookout on the east coast of Australia in June and July 2010. This survey was a continuation of the long series of surveys conducted at this site, the results of which form the basis of the relative and absolute abundance estimates of Group E1 humpback whales. In a departure from previous surveys, the survey site was shifted to one with better elevation and viewing angle, and fewer sightseers. A three week calibration study with simultaneous counts at both the new and old site showed there was no significant difference in numbers of whales sighted on a daily basis, so no correction was warranted. The survey was conducted across the peak of the northward migration. The average number of whales passing per 10h over the peak four weeks of the northward migration was 84.7 ± 3.2 whales. When assessed in the context of previous surveys, the high long-term rate of population growth was maintained at 10.9% per annum (95% CI 10.5-11.3%). There is no evidence at this stage that the rate of growth is slowing. Using an updated land-based correction factor for groups available but missed in 2004 and the updated rate of population growth, 2010 absolute abundance is estimated at 14,522 whales (95% CI 12,777 – 16,504). This may, however, be an underestimate due to possible non-migration of some cohorts.

KEYWORDS: HUMPBACK WHALES, ABUNDANCE ESTIMATE, SURVEY – SHORE-BASED, TRENDS, MIGRATION

INTRODUCTION

The humpback whales (*Megaptera novaeangliae*) that migrate along the east coast of Australia were hunted to near-extinction in the 1950s and early 1960s. Since this time there has been an apparent rapid increase in the population. Surveys conducted at Pt Lookout in south-eastern Queensland over the last 30 years have demonstrated a high but steady rate of increase in the size of the population with surveys conducted by various teams every one to three years since 1981. These series of surveys now comprise one of the best records of absolute and relative abundance for any population of whales in the world.

Humpback whales undertake annual migrations between high-latitude summer feeding areas and low-latitude winter breeding areas (Chittleborough, 1965; Dawbin, 1966). Until recently, the western South Pacific has been thought of as having one population of humpbacks, the Group V population, that summered in the Southern Ocean between 130°E and 170°W, migrating to various low-latitude coastal and island areas in the region during winter. More recently, the International Whaling Commission changed the nomenclature of the region to describe breeding stocks with east Australian whales renamed E1, the New Caledonian population E2, the Tongan population E3 (IWC 2006). This group of populations extends further east into the central South Pacific including the Cook Islands and French Polynesia, previously referred to as Group VI, now termed F. While it is now considered that this area contains several populations that inter-mingle to a variable but probably small extent (Garrigue *et al.*, 2000, 2007), it is apparent that the largest stock or population of this meta-population migrates along the east coast of Australia.

Prior to the 1950s, there was little exploitation of the east Australian humpback whale population. In 1952 industrial shore-based whaling commenced at Tangalooma on Moreton Is. and a year later at Byron Bay, and together with massive illegal pelagic whaling in the Southern Ocean in the early 1960s, took whales in such abundance that the population collapsed by 1962 (more than 22,000 humpback whales were taken from Area V between 1959 and 1963 alone; Clapham *et al.*, 2009). Chittleborough

(1965) estimated the original Group V population to be ~10,000 whales but this has been upwardly revised in light of the large catches in the Southern Ocean. Jackson *et al.* (2006) estimates the original size of Group V to be 35,000 – 40,000 while Jackson *et al.* (2008) estimate the pre-exploitation east Australian population to have been 22,000 – 25,700 while the combined Oceania populations (E2, E3 and F) were 17,800 – 20,600. Estimates of the Group V population size in the early to mid-1960s include 104 (Bannister and Hedley, 2001) and 400 to 500 (Chittleborough, 1965), while Paterson *et al.* (1994) estimated there were 34 to 137 whales remaining in the east Australian stock. Although the distribution of surviving whales is not known, the rapid recovery of east Australian whales and apparent lack of recovery of whales migrating past New Zealand (Gibbs and Childerhouse, 2004) and in other parts of Oceania suggests that most of these were of the east Australian population.

Previous land-based surveys at Pt Lookout. Post-whaling surveys of the east Australian population were initiated at Pt Lookout, North Stradbroke Is., in 1978, and have continued every one to three years since then. At the latitude of Pt Lookout (27°30'S) the northward (autumnal) migration peaks between mid-June and mid-July (Chittleborough, 1965; Bryden *et al.,* 1990; Paterson *et al.,* 1994). Between the late 1970s and early 2000s, two independent teams conducted surveys from this location. The first series was initiated by Michael Bryden and continued by his student Miranda Brown until 2000 (Bryden, 1985; Bryden and Slade, 1988; Bryden *et al.,* 1990, 1996; Brown, 1996; Brown *et al.,* 2003). The other series of surveys, from the early 1980s to 2002, were conducted by Robert and Patricia Paterson with help in the analysis of later surveys by Douglas Cato (Paterson and Paterson, 1984, 1989; Paterson, 1991; Paterson *et al.,* 1994, 2001, 2004). The surveys were taken over by us in 2004 (Noad *et al.,* 2006a,b, 2008).

Despite some minor differences in survey site and substantial differences in survey design and data analysis, both the original Bryden-Brown and Paterson-Cato series of surveys were in broad agreement concerning the number of migratory whales and their rate of increase. In 2004, we conducted a 14 week survey from the Bryden-Brown 32m high site, 'Norms's Seat', as this had public access while the Paterson-Cato site did not. In the analysis of data we demonstrated that the analytical techniques used by both groups lead to very similar results and that the two original series of surveys were comparable (Noad *et al.,* 2006a,b)

Prior to 2004 the most recent estimates of annual rates of population increase (with 95% CI) were 12.3% (10.1-14.4%) (Bryden *et al.,* 1996) and 10.5% (10.0-11.1%) (Paterson *et al.,* 2004). We conducted surveys in 2004 and 2007 after which the long term rates of growth was estimated as 10.9% per annum (95% CI 10.5 – 11.4%) (Noad *et al*., 2006a,b, 2008). These growth rates are among the highest recorded for any humpback whale population in the world (but similar to those of the Australian west coast population) and are close to the theoretical reproductive limit of the species (Best, 1993; Brandao *et al.,* 2000; Bannister and Hedley, 2001). The rates of increase are also remarkably consistent over time with a very tight correlation between log-transformed, normalised whale counts and year.

In terms of absolute abundance, Noad *et al.* (2006a,b) calculated the population size in 2004 to be 7,090 ± 660 (95% CI) whales. This was consistent with previous Bryden-Brown and Paterson-Cato estimates when corrected for rate of increase. Estimates of absolute abundance for 2007 were made by extrapolating from the 2004 absolute abundance estimate using the 2007-derived rate of increase. Using the land-based correction factor for groups available but missed f_m estimated from the double land counts in 2004, the 2007 absolute abundance was estimated at 9,683 whales (95% CI 8,740 – 10,729) (Noad *et al*., 2008). In 2007 we also performed aerial surveys, however, and comparing these with the land-based survey sightings suggested that the correction factor f_m should be larger than previously calculated. Using the higher correction factor produced an estimate of 12,599 whales (95% CI 9,874 – 16,076). (Noad *et al.,* 2008)

Dunlop *et al.* (2010) undertook a re-analysis of the 2004 double count data and 2007 aerial and land-based data in an attempt to resolve the discrepancies estimates of f_m. They showed that (i) some matches had been missed in the original analysis, (ii) significant heterogeneity in sighting probabilities had not been included in the original analysis, and also (iii) by relaxing the strict matching criteria we used for matching the land and aerial sightings, almost all groups sighted from the air were in fact accounted for by the land-based observers. This effectively increased the value of f_m for the land-based double count experiments of 2004 and reduced it for the aerial to land-based experiments of 2007, largely resolving the discrepancy between the two.

The current study concerns a further survey conducted in 2010. The primary objective of this study was to obtain a measure of the numbers of passing whales during the peak four weeks of the northward migration at Pt Lookout and to use this, with previous survey results, to calculate the rate of population increase. Additionally we also wanted to move the primary survey site and use both the updated rate of increase and new estimate of f_m to make an estimate of absolute abundance for 2010.

METHODOLOGY

The survey was conducted from Pt Lookout (27° 26' S, 153° 33' E) on North Stradbroke Is., a large island off the coast of south-eastern Queensland near Brisbane (Fig. 1). The survey was conducted over an eight-week period from 29 May to 25 July 2010. The field methodology closely followed that of previous surveys (Bryden *et al.,* 1996; Brown, 1996; Brown *et al.,* 2003; Noad *et al.*, 2006a,b, 2008). In a departure from these previous surveys, however, we moved the main survey sight from a small headland with 32m elevation and a more northerly view ('Norm's Seat') to one with an elevation of 58m and more easterly view albeit a few hundred metres to the west ('Frenchman's Lookout'). The change in view allowed us to look across the migratory stream of whales rather than at whales receding northwards (Fig. 2). A 5m high scaffolding tower was used to gain perfect views across the study site.

Surveys were conducted from Frenchman's Lookout every good-weather day during the survey. Simultaneous, full time surveys were conducted from Norm's Seat from 24 June to 10 July to enable the new site to be calibrated against the old. Daily counts were compared with a paired T-test.

Watch structure and data collection. At both sites observations were undertaken from 0700 to 1700 each day, except during inclement weather including heavy rain or a sea state > mid-5 (open water wind speed of 20kt). Each 10h day was divided into four shifts conducted by two teams or watches. The 'early' watch observed from 0700 – 1000 and 1200 – 1400 and the 'late' watch ran from 1000 – 1200 and 1400 – 1700.

Watches consisted of five observers. Whales were spotted by the observers at each site and sightings were input directly into a notebook computer running *Cyclops Tracker* software (developed by EK). A theodolite, connected directly to a notebook computer at each site, was also used to measure the positions of passing groups of whales in *Cyclops* to prevent confusion between sightings of groups in the same area or on a similar bearing from the observation point. One observer operated the theodolite, while another operated the computer. The other three observers were 'spotters' who used bare-eyes or 7x50 binoculars with compasses and reticules to sight whales. The spotters were allocated adjacent sectors of the ocean to scan to spread sighting effort as evenly as possible.

As in previous surveys, at least one observer in each watch was 'experienced' with a minimum of one month (approximately 150h) survey time at Pt Lookout, or several seasons of prior field experience with humpback whales at other locations. All watches at both sites were balanced as evenly as possible with regard to experience and the overall level of experience was similar to that of previous surveys.

Most whales were sighted several times allowing ample opportunity for positive identification based on characteristics of the blow and roll of the back, flukes or pectoral fins. Single sightings of a blow only were noted but not included in the analysis as these were too easily confused with sea spray in windy conditions and are not sufficiently diagnostic of a humpback.

For the purpose of the census, whales were only included in the analysis if they were heading northwards and crossed a line 'abeam' extending seawards 70° from magnetic north (81° from true north) between 0700 and 1700. For whales not observed on both sides of the line (particularly at the beginning and end of the survey day) their time of crossing the line was estimated using their swim speed derived by theodolite tracking. Both numbers of groups and group size were recorded for all survey periods.

Weather conditions were recorded every hour and at the beginning and end of each day. Data recorded included sea state, swell height and direction, wind speed and direction, cloud cover (in oktas), glare (scale of 0 – 3) and any other factors affecting visibility (e.g. smoke, haze, squalls).

Data analysis. Daily whale counts were compiled using the *Cyclops* files. If days had less than 5h of data, they were not included in the analysis. For days with more than 5 but less than 10h of data, a correction was made for time missed based on sighting rate for that day. A running four week average was calculated starting with each day of the survey to identify the peak four week period and the average number of whales passing per 10h over the peak four weeks of the study was calculated. The log of this was then linearly regressed with logged four-week count data from previous surveys to obtain the long-term rate of increase.

In the original analysis of the 2004 survey results, a correction for whales available but missed f_m was calculated using the results of blind double counts from Norm's Seat and an adjacent headland (Noad *et al*., 2004). This was derived using a simple reverse Lincoln-Petersen technique but subsequent aerial survey data collected in 2007 showed this was likely to be an underestimate. The 2004 data were reanalysed by Dunlop *et al*. (2010) in order to account for sighting heterogeneity through (i) a review of the matches obtained in the initial analysis of double count data, (ii) the implementation of a logistic regression approach (binomial GLM) as outlined by Buckland *et al.* (1993), (iii) the identification and removal of collinear variables, (iv) model selection using a backward step-wise approach with Akaike's Information Criterion (AIC), and (v) using the conditional probability estimates from the final iteration to calculate the correction factor and corresponding standard errors (Dunlop *et al.*, 2010; Dudgeon *et al.*, in prep.). The revised f_m allowed an updated estimate of 2004 absolute abundance. The long-term rate of increase was applied to this to give an abundance estimate for 2010 with CVs combined using the delta method to provide a SE for the resultant population estimate. This was then used to calculate asymmetrical 95% confidence intervals.

RESULTS

Relative abundance estimate. Land-based surveys were conducted from 1 June to 24 July 2010. Over the eight weeks of the survey, full 10h surveys were completed at from the lookout above Frenchman's Beach on 33 days, surveys with less than 10 but at least 5 hours were completed on 14 days, and surveys were severely curtailed or called off completely on seven days. A total of 1,169 confirmed northbound groups were observed from Frenchman's consisting of 2,458 whales including five calves. Mean group size was 2.12 ± 0.031 whales (Fig. 3).

The numbers of whales seen rose gradually until about 27 June then plateaued more or less until the end of the survey on 24 July (Fig. 4). The peak four weeks was calculated to be from 26 June to 23 July with an average of 84.7 ± 3.2 whales per 10h over that period.

Between 24 June and 10 July, full time (weather permitting), simultaneous surveys were carried out at Frenchman's and Norm's Seat. Over the 17 day period, full 10h counts were conducted at both sites on 11 days and matching 5h counts were conducted on two other days. For these matched periods, daily counts were in close agreement with totals of 956 and 944 whales at Frenchman's and Norm's Seat, respectively, a difference of 1.3% (Fig. 5). A paired T-test on the matched data shows no significant difference (P=0.61). Group composition estimation was also similar at both sites (Fig. 6). No correction was deemed necessary for data from Frenchman's for comparison with data collected previously from Norm's Seat.

The long-term annual rate of increase for the 24 years from 1984 to 2010 was 10.9% (95% CI 10.5 - 11.3%), up slightly from the 2004 estimate (10.6%) but almost unchanged since the 2007 estimate (Figs 7 and 8).

Absolute abundance of the east Australian population. The 2004 correction factor for whales available but missed by Norm's Seat observes f_m was revised to 1.212 ± 0.049 (Dunlop *et al.*, 2010; Dudgeon *et al.*, in prep.). Applying this to the 2004 data and then updating using the new rate of population growth produced an updated estimate for 2010 of 14,522 (95% CI 12,777 – 16,504).

DISCUSSION

Relative abundance estimate. The eight week land-based survey estimated that, on average, 84.7 whales passed every 10h during the peak four weeks of the northward migration. This fits the pattern of the long-term trend established over the last 27 years and updates the long-term rate of growth for the population to 10.9% (95% CI 10.5 - 11.3%). Indeed this has barely changed since the 2007 survey

(10.9% with 95% CI 10.5-11.4%). While this is remarkably consistent, we have to bear in mind that the 2010 survey is just one data point on the end of a 27 year period containing 18 survey results and it would take a result a long way from the trend-line to shift the curve significantly. Even so, if we shorten the period to make the rate of increase more contemporary, we can see that 1996 – 2010 gives a rate of increase of 10.7% (95% CI 9.4 – 12.1; n = 8 surveys) while 2001 – 2010 yields 11.0% (8.2 – 14.0; n = 5). The confidence intervals increase with reduction in numbers of surveys and time, but the central trend remains highly conserved.

Compared with the last survey in 2007, however, there was only a 6.2% per annum increase to 2010. This could be explained either by 2007 having an abnormally high peak four week rate of passage, or by a reduction in the real rate of increase. The former seems more likely as (i) 2007 was above the long-term average and (ii) it is likely that in 2007 the migratory pattern was abnormally skewed to earlier in the season and much higher, particularly earlier in the season, than expected (Noad *et al.*, 2008). There is no evidence at this stage of any slowing in the high rate of growth of the east Australian population.

Absolute abundance estimate. Our absolute abundance estimate combined our original 2004 absolute abundance estimate but with a recalculated correction factor for whales available but missed f_m and our new long-term rate of population increase (together with their various SEs). The original 2004 abundance estimate was sound although we knew at the time that f_m may have been underestimated. The resultant absolute abundance estimate for 2010 of around 14,500 whales is the most robust possible until we undertake the next dedicated absolute abundance survey at Pt Lookout.

Jackson *et al.* (2008) calculated median posterior estimates of pre-exploitation carrying capacity for east Australia at 22,000-25,700 humpback whales. Using this and our revised absolute abundance range estimate of 12,777 – 16,504 (95% CI) suggests that the population may be 50 – 75% recovered. If this were the case we might expect to see some evidence of a slowing rate of increase at this point. The pre-exploitation value of *K*, however, may be not necessarily be the new post-exploitation *K*.

Unfortunately none of this takes in to account the fact that if the east Australian migratory population is heavy biased towards males and some cohorts of females are not migrating (Brown *et al.* 1995) then our absolute abundance estimates will be an underestimate of the total population abundance. In turn we would be even closer to Jackson *et al*.'s (2008) estimated *K*. However, it would seem unlikely that the bias is as large as 2.4:1 (Brown *et al*., 1995) as, at least theoretically, all mature females would need to breed every second year to maintain the high rate of population growth observed and this would required them to migrate every year for alternate mating and calving. Further studies are required to reassess the magnitude of the sex bias.

Change in survey site and future surveys. The change in primary survey position from Norm's Seat to the ridge above Frenchman's Beach was successful and useful. The additional height and more easterly and southerly views provided much better survey conditions than Norm's Seat particularly with the scaffolding tower erected for the survey. The calibration study showed that there was no significant difference in the numbers of whales seen from both platforms during simultaneous surveys. We have not performed a group-by-group analysis of these data, however, and it is possible that there may have been differences between the sites in terms of double-counting or missing groups. We feel that both of these are innately more likely from Norm's Seat (hence our desire to change to the Frenchman's site) but, if both occurred, they appear to have corrected for each other. In any case, with regards to the relative abundance survey, the important metric of whales passing per 10h day required no correction between the sites.

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REFERENCES

Bannister, J.L. and Hedley, S.L. 2001. Southern Hemisphere Group IV humpback whales: their status from recent aerial surveys. *Mem. Queensl. Mus.* 47(2):587-598.

Best, P.B. 1993. Increase rates in severely depleted stocks of baleen whales. *ICES J. Mar. Sci.* 50:169-186.

Brandao, A., Butterworth, D.S. and Brown, M.R. 2000. Maximum possible humpback whale increase rates as a function of biological parameter values. *J. Cetacean Res. Manage. (Suppl.)* 2:192-193.

Brown, M.R. 1996. Population biology and migratory characteristics of east Australian humpback whales *Megaptera novaeangliae*. *Ph.D. thesis*, University of Sydney. 322pp.

Brown, M.R., Field, M.S., Brown, C.E. and Bryden, M.M. 2003. Rates of increase for east Australian humpback whales, *Megaptera novaeangliae*, form 1991 -2000. *Paper SC/55/SH21 presented to the IWC Scientific Committee,* May 2003 (unpublished). 7pp.

Brown, M.R., Corkeron, P.J., Hale, P.T., Schultz, K.W. and Bryden, M.M. 1995. Evidence for a sex-segregated migration in the humpback whale (*Megaptera novaeangliae*). *Proc. R. Soc. Lond., Ser. B* 259:229-234.

Bryden, M.M. 1985. Studies of humpback whales (*Megaptera novaeangliae*), Area V. pp.115-123. *In*: J.K. Ling and M.M. Bryden (eds.) *Studies of Sea Mammals in South Latitudes*, South Australian Museum: Adelaide.

Bryden, M.M. and Slade, R.W. 1988. Survey of humpback whales (*Megaptera novaeangliae*) off eastern Australia, 1987. *Report for the Australian National Parks and Wildlife Service*, Canberra. 27pp.

Bryden, M.M., Kirkwood, G.P. and Slade, R.W. 1990. Humpback whales, Area V. An increase in numbers off Australia's east coast. pp.271-277. *In*: K.R. Kelly and G. Hempel (eds.) *Antarctic Ecosystems. Ecological Change and Conservation.* Springer-Verlag: Berlin and Heidelberg.

Bryden, M.M., Brown, M.R., Field, M.S., Clarke, E.D. and Butterworth, D.S. 1996. Survey of humpback whales (*Megaptera novaeangliae*) off eastern Australia, 1996. *Report to the Australian Nature Conservation Agency*, Canberra. 77pp.

Buckland, S.T., Breiwick, J.M., Cattanach, K.L. and Laake, J.L. 1993. Estimated population size of the California gray whale. *Mar. Mamm. Sci.* 9(3):235-49.

Chittleborough, R.G. 1965. Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). *Aust. J. Mar. Freshwat. Res.* 16:33-128.

Clapham, P., Mihalev. Y., Franklin, W., Paton, D., Baker, C.S., Ivashchenko, Y.V. and Brownell, R.L., Jn. 2009. Catches of Humpback Whales, *Megaptera novaeangliae*, by the Soviet Union and Other Nations in the Southern Ocean, 1947–1973. *Mar. Fish. Rev.* 71(1):39-43.

Dawbin, W.H. 1966. The seasonal migratory cycle of humpback whales. pp.145-170. *In*: K.S. Norris (ed.) *Whales, Dolphins and Porpoises*. University of California Press: Berkeley and Los Angeles.

Dunlop, R. A., Dudgeon, C. and Noad, M. J. 2010. Further investigation into abundance estimates of migrating humpback whales in Australia: Resolving unmodelled heterogeneity, estimating g(0) and producing new abundance estimates for both populations. Report to the Australian Marine Mammal Centre, Australian Antarctic Division, Kingston, Tas. July 2010.

Garrigue, C., Forestell, P., Greaves, J., Gill, P., Naessig, P., Patenaude, N.M., and Baker, C.S. 2000. Migratory movements of humpback whales (*Megaptera novaeangliae*) between New Caledonia, East Australia and New Zealand. *J. Cetacean Res. Manage.* 2(2):111-115.

Garrigue, C., Franklin, T., Russell, K., Burns, D., Poole, M., Paton, D., Hauser, N., Oremus, M., Constantine, R., Childerhouse, S., Mattila, D., GiBryden-Browns, N., Franklin, W., RoBryden-Brownins, J., Clapham, P. and Baker, C.S. 2007. First assessment of interchange of humpback whales between Oceania and the east coast of Australia. Paper SC/59/SH15 presented to the IWC Scientific Committee, June 2007 (unpublished).

Gibbs, N. and Childerhouse, S. 2004. First report of the recovery of humpback whales in New Zealand waters (unpublished). *Available from the Department of Conservation. PO Box 10 420 Wellington, New Zealand.*

International Whaling Commission. 2006. Revised Table by Breeding Stock (as at 1 May 2005). Inter-sessional Working Group on Southern Hemisphee Humpback Whales: Paper SC/57/SH11 presented to the IWC Scientific Committee, May 2006 (unpublished).

Jackson, J.A., Zerbini, A., Clapham, P., Garrigue, C., Hauser, N., Poole, M. and Baker, C.S. 2006. A Bayesian assessment of humpback whales on breeding grounds of eastern Australia and Oceania (IWC Stocks E1, E2, E3 and F). Paper SC/A06/HW52 submitted to the IWC southern hemisphere humpback workshop, Hobart, April 2006.

Jackson, J.A., Zerbini, A., Clapham, P., Constantine, R., Garrigue, C., Hauser, N., Poole, M. and Baker, C.S. 2008. Progress on a two-stock catch allocation model for reconstructing population histories of east Australia and Oceania. Paper SC/F09/SH8 presented to the International Whaling Commission, May (unpublished). 13pp.

Noad, M.J., Cato, D.H. and Stokes, M.D. 2004. Acoustic tracking of humpback whales: measuring interactions with the acoustic environment. *Proceedings of Acoustics 2004,* Australian Acoustical Society Conference, Gold Coast, 3-5 November. Pp 353-8.

Noad, M.J., Paton, D., Cato, D.H., Dunlop, R., Kniest, E. and Morris, C.W. 2006(a). Survey of east Australian humpback whales (*Megaptera novaeangliae*) at Point Lookout, 2004. Report to the Australian Department of the Environment and Heritage.

Noad, M.J., Paton, D.A. and Cato, D.H. 2006(b). Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliae*). Paper SC/A06/HW27 submitted to the International Whaling Commission sub-committee for the assessment of Southern Hemisphere humpback whales, Hobart, 4-7 April (unpublished).

Noad, M.J., Dunlop, R.A., Paton, D. and Cato, D.H. 2008. An update of the east Australian humpback whale population (E1) rate of increase. Paper SC/60/SH31 submitted to the International Whaling Commission Scientific Committee, Santiago, 1 – 13 June (unpublished).

Paterson, R.A. 1991. The migration of humpback whales *Megaptera novaeangliae* in east Australian waters. *Mem. Queensl. Mus.* 30(2):333-341.

Paterson, R. and Paterson, P. 1984. A study of the past and present status of humpback whales in east Australian waters. *Biol. Conserv.* 29:321-343.

Paterson, R. and Paterson, P. 1989. The status of the recovering stock of humpback whales *Megaptera novaeangliae* in east Australian waters. *Biol. Conserv.* 47:33-48.

Paterson, R., Paterson, P. and Cato, D.H. 1994. The status of humpback whales *Megaptera novaeangliae* in east Australia thirty years after whaling. *Biol. Conserv.* 70:135-142.

Paterson, R., Paterson, P. and Cato, D.H. 2001. Status of humpback whales, *Megaptera novaeangliae,* in east Australia at the end of the 20th Century. *Mem. Queensl. Mus.* 47(2):579-586.

Paterson, R., Paterson, P. and Cato, D.H. 2004. Continued increase in east Australian humpback whales in 2001, 2002. *Mem. Queensl. Mus.* 49(2):712.

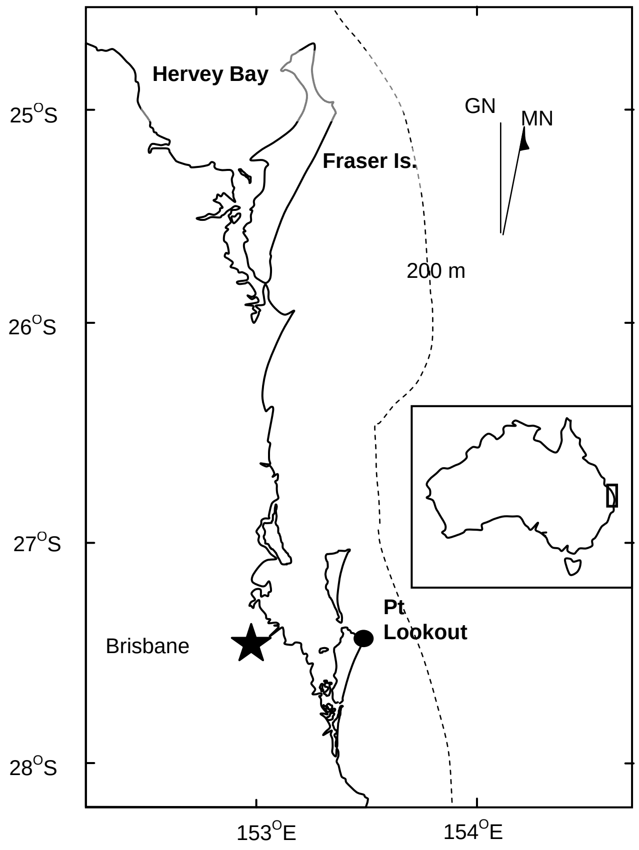

Figure 1. Southeast Queensland showing the position of Pt Lookout on North Stradbroke Is. The edge of the continental shelf is indicated by the 200m isobath (dashed line).

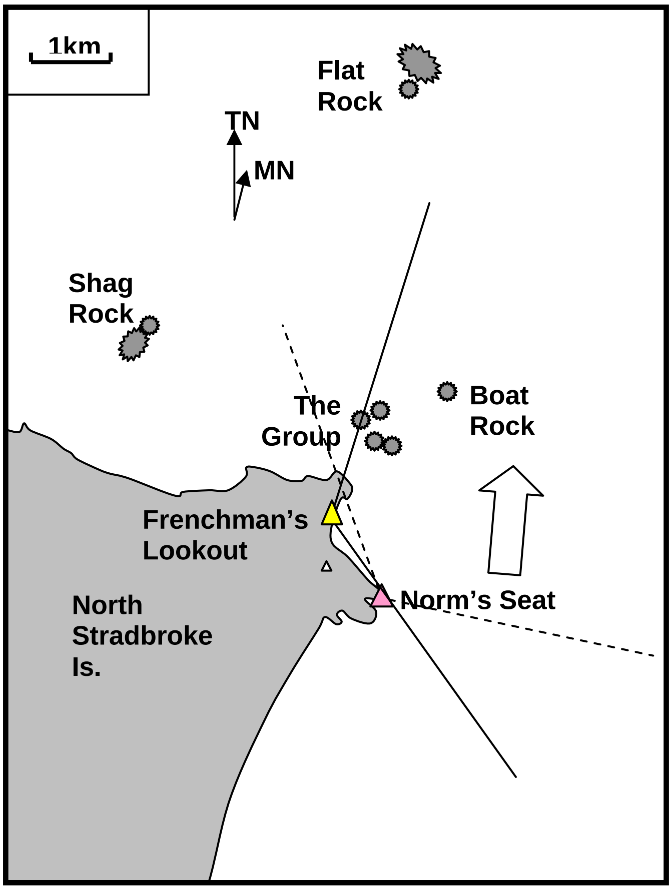

Figure 2. Pt Lookout and environs. The limits of the field of view from Frenchman’s Lookout is indicated by solid lines and from Norm’s Seat is indicated by dashed lines. The general migratory flow of whales is indicated by the large arrow. TN = true north; MN = magnetic north. The offshore islets are exposed rocks that may have seas breaking over them in heavy weather.

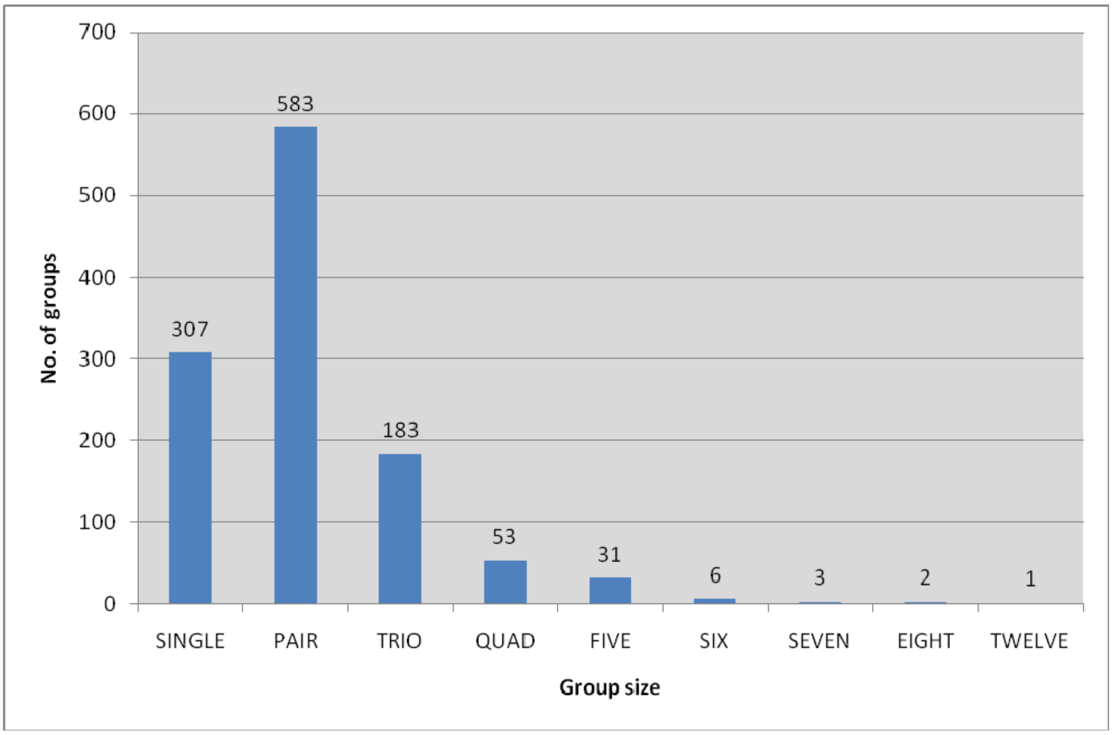

Figure 3. Number of groups observed for each size class from Frenchman's. Group size was recorded as the size when seen initially and so did not take into account subsequent joining together or splitting apart of groups.

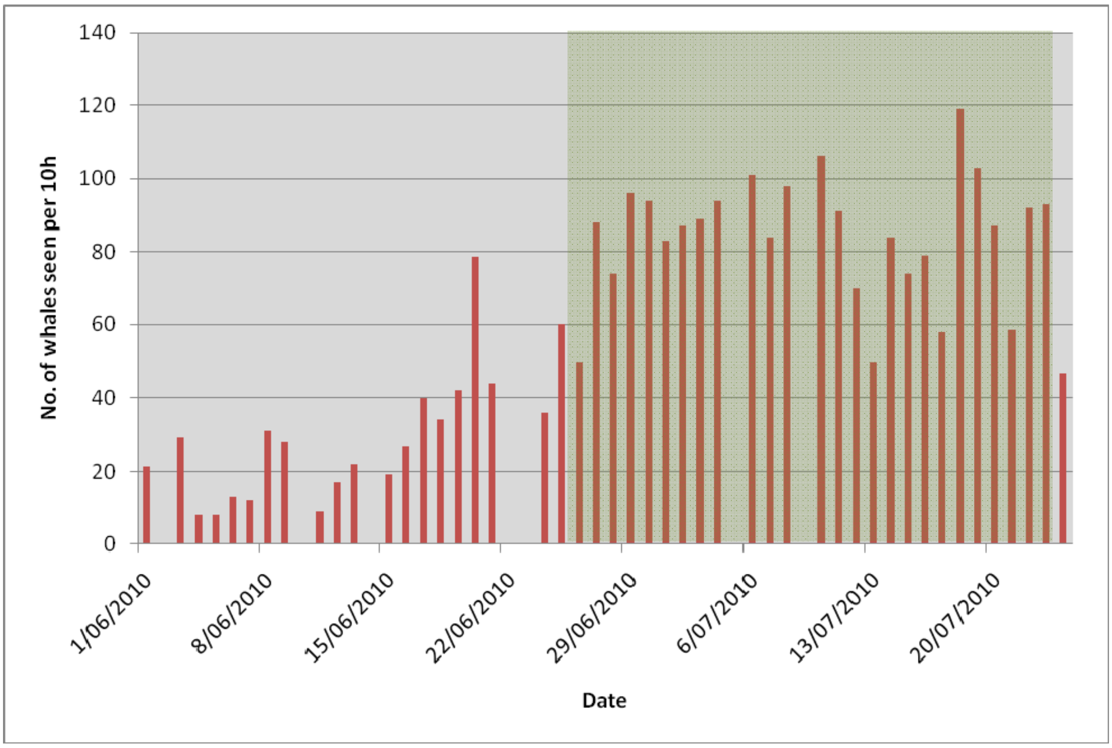

Figure 4. Daily counts normalised to 10h from Frenchman's Lookout. The peak four weeks are shaded.

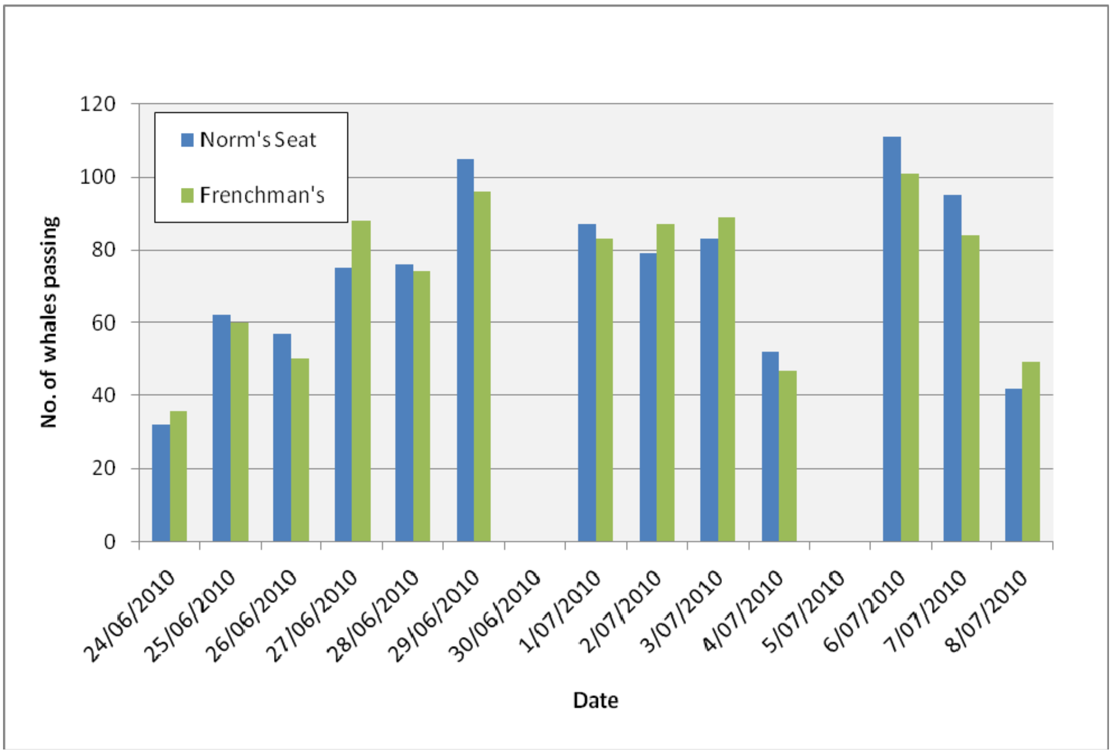

Figure 5. Whales observed independently from the two platforms, Frenchman's and Norm's Seat. Only days with matching periods of observations (usually a full 10h day) are shown so data are directly comparable.

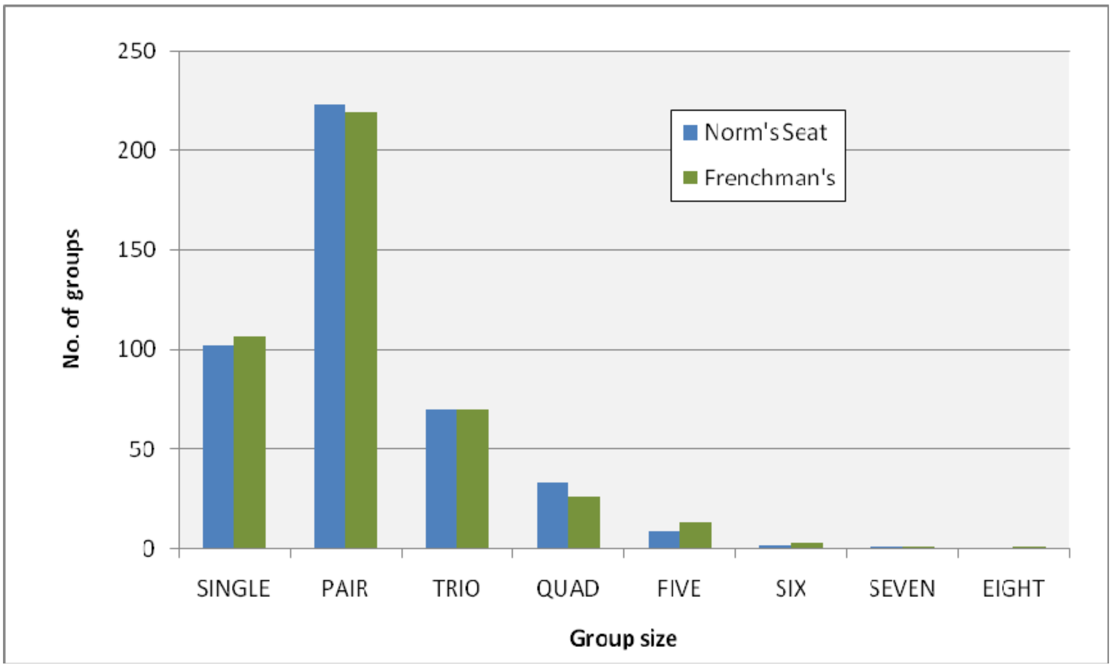

Figure 6. Groups size estim ates from the two survey sites for directly comparable days.

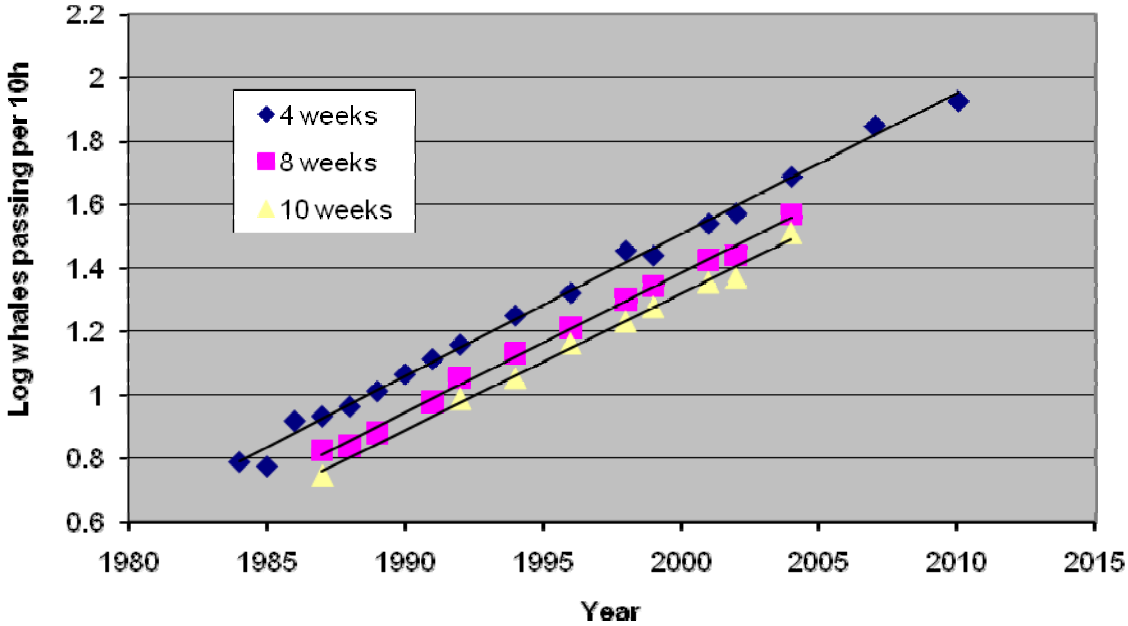

Figure 7. Log of the numbers of whales passing per 10h during the 4, 8 and 10 weeks of the peak in various years from 1984 to 2010. Data 1984 – 2002 from Paterson *et al.* (2004).

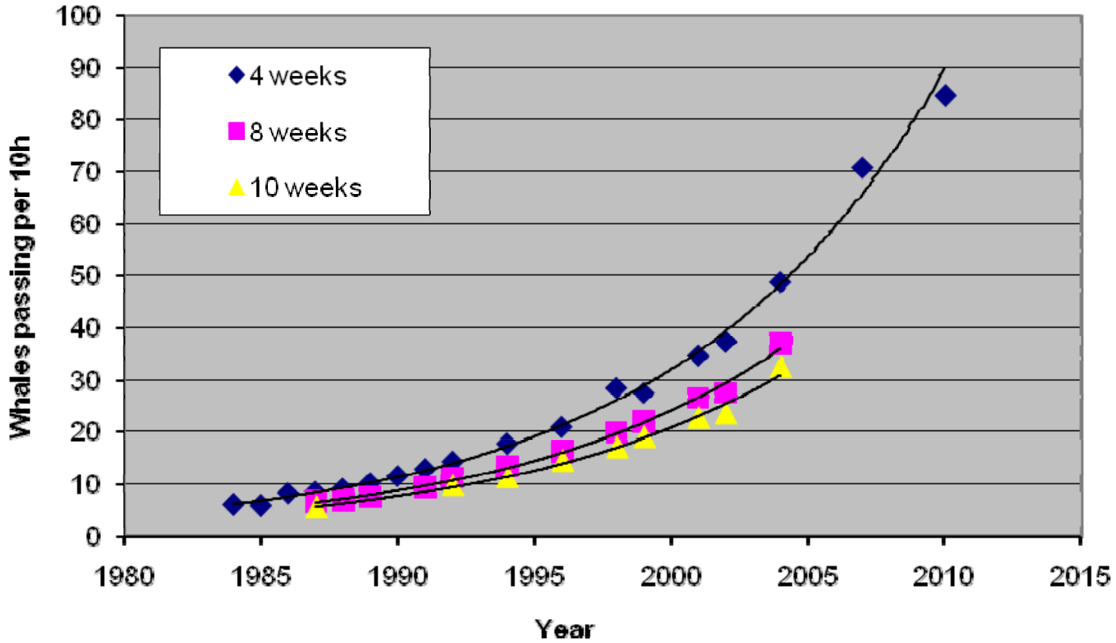

Figure 8. Linear scale version of Fig. 7.