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Large Whale and Vessel Collisions in Northern New Zealand

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ABSTRACT

Several major shipping lanes run towards the north eastern coast of New Zealand, with the main port located in Auckland, in the Hauraki Gulf. Significant numbers of recreational boats, commercial vessels and ferry services are also present in this region. Vessel movements coincide with whale habitat, in particular Bryde's whales, and collisions between vessels and animals have resulted in fatalities. A review of New Zealand's stranding data (held at the Museum of New Zealand - *Te Papa Tongarewa* and the Department of Conservation) shows between 1989 and 2007, 38 Bryde's whale carcasses have been reported in northern New Zealand. Of these, 13 whales have been confirmed or suspected to have died due to vessel strike injuries. More information is needed to determine the effect of vessel collisions on large whales in this region; in particular the Bryde's whale population, estimated to be between 46 and 159 individuals, some of which are found year-round in the Hauraki Gulf area. Discussions have been held with key stakeholders to alert them to the problem of vessel collisions with whales and possible mitigation strategies.

INTRODUCTION

Globally, vessel collisions with whales have been the subject of much research and are a recognised source of whale mortality. An increase in the number of fatal collisions since the late 19th Century has been clearly established and is attributed to a worldwide increase in the number, size and speed of vessels now passing through whale habitat (Laist *et al.,* 2001; Weinrich *et al.,* 2005; Douglas *et al.,* 2008). The population level effect of collisions on whales is difficult to assess given limited species knowledge and the unknown number of fatalities or injuries. However, concern about the role of vessel collisions on vulnerable populations has engendered several studies. Widely cited is the failure of the highly endangered North Atlantic right whale (*Eubalaena glacialis*) population to recover, principally because of vessel strike and entanglement in fishing gear (Knowlton & Kraus 2001; Kraus 1990, 2005; Cole *et al.,* 2006; Campbell-Malone *et al*., 2008). Reported strikes in the Mediterranean Sea are considered unusually high for baleen whales, and fin whales (*Balaenoptera physalus*) in particular appear to be threatened by vessel-caused fatalities in this region (Panigada *et al.,* 2006). Laist *et al.,* (2001) compiled data from 58 fatal collisions around the world involving 11 species of large whale, and concluded that vessel speed and size were contributing factors. Challenges presented by the lack of awareness by a ship's crew that a collision has occurred, especially with large vessels, mean that the number of whales hit by vessels is likely to be an underestimate that represents an

unknown proportion of incidents (Kraus 1990; Jensen & Silber 2003; Weinrich *et al.*, 2005; Panigada *et al.,* 2006; Douglas *et al.,* 2008; van Waerebeek *et al.,* in press).

A broad range of vessels are implicated in whale strike including recreational, commercial whale-watch and military vessels, ferries and transport ships (Jensen & Silber 2003). Fast ferries and whale-watch boats consistently attain higher incident rates, consistent with the suggestion that vessel speed and size contribute to the severity and frequency of strikes (Laist *et al.,* 2001; Panigada *et al.,* 2006; Vanderlaan 2007). There is significant potential for bias in these data however as smaller vessels are more likely to report an incident than larger vessels, in part because of their ability to witness and record an incident (Jensen & Silber 2003) and because larger vessels are often unaware of a collision (Laist *et al.,* 2001). Moreover, ferries and whale-watch vessels are more likely to operate in shallow, easily accessible areas that are also inhabited by whales at predictable (often seasonal) intervals, e.g., humpback whales (*Megaptera novaeangliae*) and southern right whales (*Eubalaena australis*).

The area in northern New Zealand between Whangarei and Auckland comprises one of the busiest shipping lanes in New Zealand and the Hauraki Gulf is the primary sea access to Auckland, New Zealand's largest city. Increasing numbers of cruise ships, commercial ferries and recreational vessels are forecast to use the port as populations on the many islands in the gulf and in the city continue to grow. Both recreational and commercial vessel movements in these waters coincide with habitat use by cetaceans.

Research on Bryde's whales (*Balaenoptera brydei*) in New Zealand has primarily focused on the Hauraki Gulf and has shown that whales are present in that region throughout the year with individual differences in residency (O'Callaghan & Baker 2002; Baker & Madon 2007; Wiseman, 2008). Bryde's whales are balaenopterids with a broad temperate to tropical distribution. They are unique amongst baleen whales in that they do not undergo extensive seasonal migrations and are thought to remain in waters warmer than 15° – 20°C, limiting their range to between latitude 40°N and 40°S (Best 2001, Kanda *et al.,* 2007). The paucity of information on Bryde's whales means that little is known about behaviour, abundance and breeding areas or cycles, although the spread of calving indicates that calving occurs year round (Tershy 1992; Best 2001). Baker & Madon (2007) suggest that calving may peak late winter to early spring. Wiseman (2008) noted the presence of calves throughout the year within the Hauraki Gulf, with an increase in observations between January and May. Both Baker and Madon (2007) and Wiseman (2008) reported calves 4 - 6m in length which suggests that births may occur in the area.

Morphological and genetic variance between Bryde's whale populations has been cited in several studies, and it is widely recognised that there are three forms; the larger offshore *Balaenoptera brydei*, and the smaller inshore variant, *B. edeni* and the recently classified *B. omurai* (Wada *et al.* 2003) although the taxonomy of this genus remains unresolved. The New Zealand population of Bryde's whales has long been regarded *B. edeni*, although their larger size infers that they are *B. brydei* (Baker & Madon 2007) and genetically they have been confirmed as *B. brydei* (Dalebout *et al.,* 2002). Behaviourally, Bryde's whales also vary. Those found in the Gulf of California are known to be relatively resident (Tershy 1992) whereas of the three distinct populations of Bryde's whales in southern African waters, one is migratory, one is resident and a third co-occur with the non-migratory stock although they demonstrate differences in size, baleen shape, seasonality of reproduction and prey (Best 2001).

METHODS

Stranding data

Original documentation on whale strandings held by the Department of Conservation (DoC) Warkworth, Auckland, Coromandel, Great Barrier Island and Whangarei offices as well as records held by local Māori were sourced, verified and each case assessed for possible causes of death. Incidents were assigned to one of three categories based on common diagnostics first portended by Kraus (1990), expanded upon in Laist *et al.* (2001) and further refined in Douglas *et al.* (2008). Species identification was confirmed where possible through photographic evidence, and/or from tissue samples archived at the University of Auckland. Data were then compared to the New Zealand Whale Stranding Database administered at the Museum of New Zealand, *Te Papa Tongarewa* (Te Papa).

Standardised forms are completed by DoC officials for each stranding incident. However, the information recorded on forms varied in both the amount and quality of detail. DoC standard operating procedure requires that copies of the forms are sent to Te Papa where they are recorded in the New Zealand Whale Stranding Database, although this does not always occur. Anomalies and missing incidents were noted between the numbers and dates of area office reports and those data held at Te Papa. Where data were not consistent, incidents were matched through other parameters including the length of the animal, details of injury, co-ordinates where the animal was found and discussion with people involved at the time of stranding.

Incidents were then assigned to one of three categories: 1) Known vessel strike: Where examination revealed injury showing that the animal was alive at the time of collision (bruising, oedema, haemorrhaging, or internal bleeding), accompanied by broken bones indicative of massive trauma. 2) Probable vessel strike: The animal showed indications of blunt force trauma but there was a possibility that injuries were gained post-mortem; this includes whales found on the bow of a vessel and no necropsy was performed. 3) Unknown: Either no evidence of ship strike based on the diagnostics above, no necropsy performed, no photographic record taken, or too decomposed to tell. Records that provided inadequate information, such as those without species confirmation, were not included in the data set. Using these categories, Appendix 1 includes the first two categories and represents a minimum number of vessel strike mortalities.

Injury

A photo-identification catalogue of Bryde's whales found within the Hauraki Gulf has been compiled and curated at the University of Auckland over the past 12 years. It is continually being updated through ongoing research, and opportunistic sightings from whale-watch vessels and other researchers. This catalogue was examined for whales bearing propeller scars or other scarring indicative of injury caused by vessel strike.

Characterisation of vessel traffic

The Ports of Auckland provided operating procedures for vessels, details on the number of ship visits and future development plans. Publicly available documents were sourced for material related to shipping movements. The Auckland City Council Harbourmaster's directives were researched and the Auckland Regional Council's plans were reviewed for future development of ferry services within the Hauraki Gulf.

RESULTS

Known and probable strike events

In total, 38 Bryde's whale mortalities were recorded in the National Whale Stranding Database and/or in the Department of Conservation archives between 1989 and 2007. Of these, 13 Bryde's whales were either known or suspected to have died due to vessel strike (Appendix 1, Figure 1). This

represents 34% of all whales although the cause of death remains undetermined for the majority of the other 25 whales. There were anomalies in the data records including a single event that was recorded by two separate DoC offices, one noting head injury indicative of ship strike, the other reporting no obvious injury. Further inquiry revealed that although there was no obvious external injury, damage consistent with vessel strike was uncovered during a necropsy (Appendix 1, 9 September 1997). Another event was unable to be confirmed as a Bryde's whale on site due to damage to the head. However, the experienced DoC officer who attended the event was confident of species identification and the animal was therefore included in the data set. Of the 13 known or probable vessel strike mortality events, significant physical injury, including broken bones, dislocated vertebrae, severed tail flukes, damaged spinous processes and intensive bruising was noted in the archived records. Twelve of the 13 whales were sexed (7 females and 5 males), nine using molecular markers and four by visual observation of the genital region. Measurements were attained for 10 whales and averaged 12.15m in length from the tip of the rostrum to the notch in the fluke, with the smallest being an 8.6m female and the largest a 15.4m female.

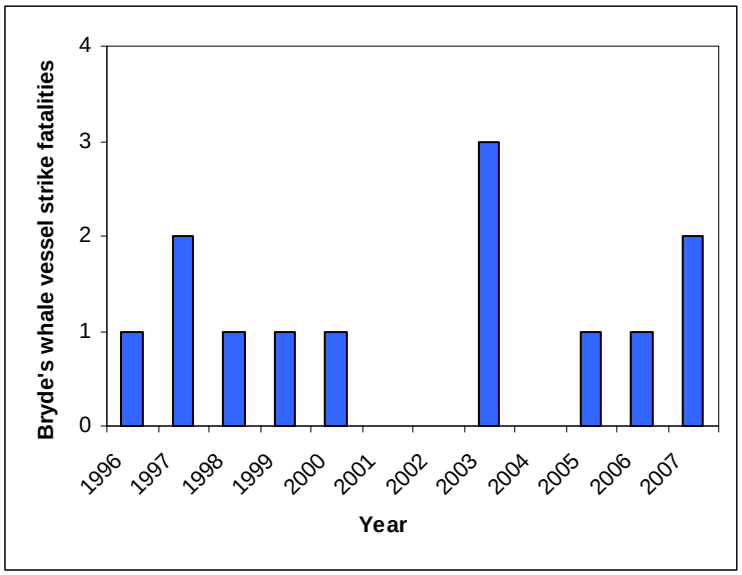

Figure 1: Number of known and probable Bryde's fatalities from vessel strike (n = 13).

Other Bryde's whale mortality events

Twenty-five additional Bryde's mortalities have been recorded since 1989. No obvious signs of vessel strike were noted in any of these events, although it should be noted that most of them were not closely examined through a detailed necropsy. Three whales (12%) stranded alive but died subsequent to the stranding; the cause of death was not determined. The confirmed (n = 1) or suspected (n = 2) cause of three fatalities (12%) was entanglement in mussel farm gear. In five cases (20%) they were in an advanced state of decay or only partial carcasses were found, and species identification was confirmed genetically. Of these 25 Bryde's whales, the gender was determined for 21 individuals (12 males and 9 females), 16 were determined using molecular markers and five by visual observation of the genital region. The largest whale was 15m and the smallest 7.8m, both female.

A further six records of unidentified baleen whales were recorded in the DoC archives, one was recorded as larger than 10 metres, and another whale was recorded at 4.87 metres. Two of these six carcasses were not recovered and remained at sea.

Photo-identification
Examination of the photo-identification catalogue of 72 individuals revealed only one whale (1.4%) that demonstrated the 'zipper' type markings characteristic of small boat propeller marks. Others had markings and scars used for individual identification that are commonly found on the dorsal fin and body of cetaceans, but none of these could be directly linked to vessel strike.

Vessel characterisation
The number of ship calls to Auckland's Waitemata Port is approximately 1,750 vessels per annum and is expected to remain steady (Figure 2). Ship calls to the port of Auckland made a slight increase from 1,739 in 2006, to 1,771 in 2007. Cruise ship visits for the 2007-08 season will total 73, up 58% from the previous season, with 78% of passengers arriving on vessels of 50,000 tonnes or more (Ports of Auckland Development Plan, 2008). A new ferry service is planned for Bayswater and expanded ferry services are planned for several ferry terminals (Auckland Regional Council Summary Draft Annual Plan 2008/09).

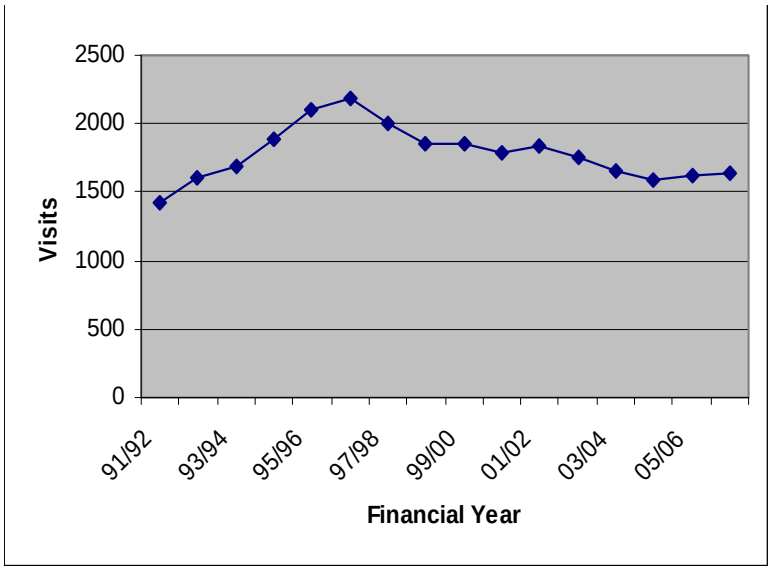

Figure 2**:** Number of ship calls to the Waitemata Harbour per annum. Source: Ports of Auckland.

Figure 3: Distribution of Bryde's whales in the Hauraki Gulf and the north-eastern coast of New Zealand. Shaded areas indicate the likely annual distribution of Bryde's whales with darker shading indicating areas of higher concentration and lighter shading showing the full extent of the range. N.B. this information is limited by data collection which has typically focused on coastal regions. Source: Ministry of Fisheries NABIS, Version 1.7.8

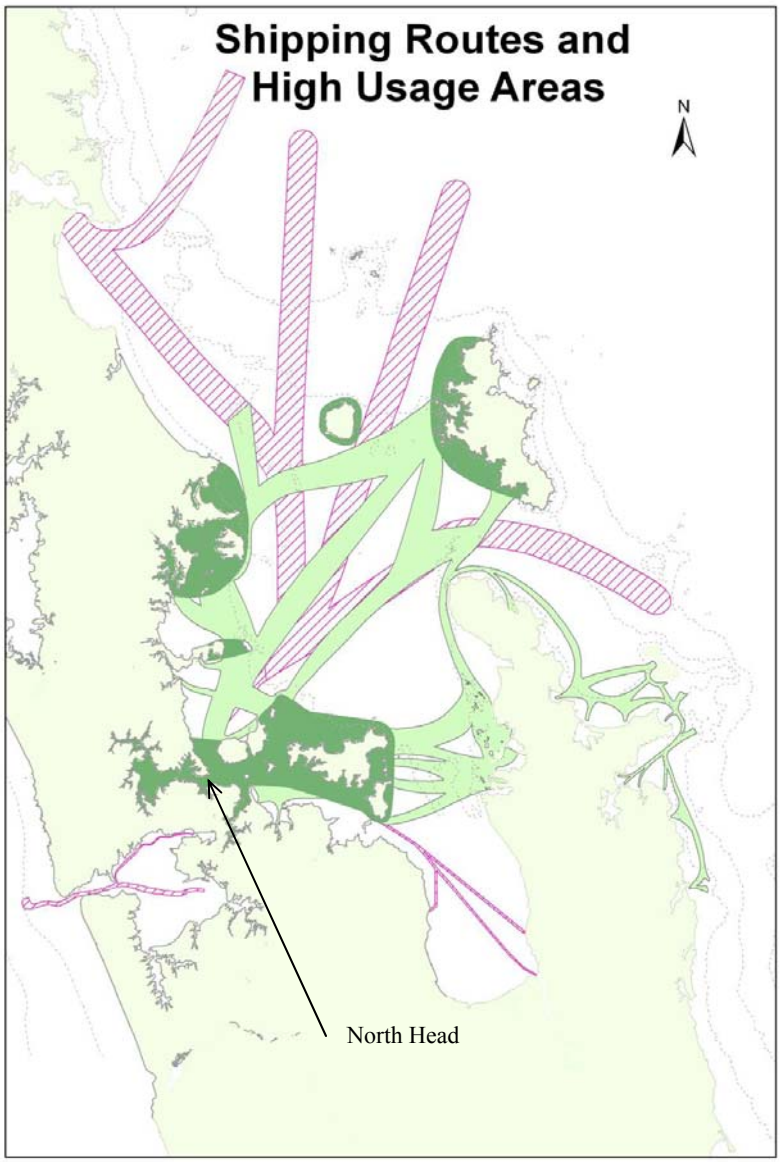

Figure 4: Shipping routes and high usage areas in the Hauraki Gulf, New Zealand. Pink striped areas indicate the commercial shipping lanes, light green shows ferry routes, and dark green areas are those most frequented by recreational vessels. Modified from Auckland Regional Council source data

DISCUSSION

The year-round presence of whales, and in particular Bryde's whales, in New Zealand's busiest shipping and boating area has resulted in a number of whale fatalities caused by collisions with vessels. Thirteen Bryde's whale vessel strike fatalities are either confirmed or likely to have occurred since 1996. The highest rate of mortality occurred in 2003 with three fatal strikes.

Future vessel traffic in the Hauraki Gulf

Increases in the number of cruise ship visits to New Zealand for the 2007-2008 season mirrors international trends. Larger and faster commercial ships are being developed in several countries (Weinrich 2004) and the Ports of Auckland's plans to accommodate larger vessels and increased container volumes reflect this trend (Ports of Auckland Development Plan, 2007). The demand for ferry-based commuter services is also forecast to continue growing (www.aucklandcity.govt.nz). Currently, commuter ferries service 10,000 Aucklanders who live on islands within the gulf. New ferry services for some areas, and more frequent services for several other terminals, are planned as the populations of people living on islands within the Hauraki Gulf and commuting to the mainland increase (Auckland Regional Council Summary Draft Annual Plan 2008/09).

A high proportion of lethal injuries to whales occur when vessels travel at speeds of 14 knots or greater (Laist *et al.,* 2001; Vanderlaan 2007). Vessel speeds in New Zealand waters depend on conditions and individual vessel capability although generally in open waters container vessels travel between 15 and 22 knots; tankers, bulk cargo ships, and general cargo ships between 12 and 17 knots; and fishing vessels between 8 and 12 knots (N. Meek, Ports of Auckland, pers. comm.). It is standard practice for vessels to reduce speed when entering congested waters such as the shipping lanes within Hauraki Gulf and those vessels under pilotage are restricted by the Ports of Auckland to 15 knots outside North Head, and 10 knots west of North Head (Figure 4). There is significant overlap of known whale habitat and areas where commercial vessels can travel at 14 knots or faster (Figures 3 and 4). Growth in the numbers of faster commercial traffic may increase the risk of collision for all cetaceans in this region.

In addition to commercial vessel traffic, a number of recreational vessels ply the Hauraki Gulf. Smaller vessels are also implicated in vessel strike around the world and cause injury in whales (Kraus 1990; Cole *et al.,* 2006; Panigada *et al.,* 2006). Only one Bryde's whale from the photographic catalogue of 72 individuals presented scars characteristic of a non-fatal collision and a search of the literature on non-fatal collisions with Bryde's whales in other regions yielded little information. This may due to the current lack of information on this species, or it may reflect a biological characteristic that causes Bryde's whales to be less subject to injury from smaller vessels. It is equally feasible that survival rates from such interactions may be low and it is suggested that further study is needed.

Susceptibility to vessel strike

It is unclear why some species of whale are more prone to vessel collision than others. Although other whale species are recorded within the Hauraki Gulf, none is sighted with the frequency of the Bryde's whale and this is reflected in the low numbers of other species in the vessel strike statistics in this region (van Waerebeek *et al*., in press). It has been hypothesised that the gliding phase of ascent from a deep dive by some baleen whales (e.g., blue, fin and North Atlantic right whales) reduces the ability to change trajectory and may therefore contribute to collisions with vessels (Nowacek *et al.,* 2001). For those whales found in the Hauraki Gulf, it is not known where whales have been struck, but the gulf has a relatively flat and shallow benthic topography, reaching only 46m in depth (Morrison *et al.,* 2003) thereby decreasing the likelihood of a deep dive ascent as a contributing factor. Bryde's whales in the Hauraki Gulf feed primarily on krill, amphipods and small ray-finned fishes (Jarman *et al.,* 2006) and have been observed using skim and lunge-feeding behaviours (Wiseman, 2008). Gliding may contribute to collisions that take place in deeper waters. Other behaviours such as feeding or resting may cause whales to be less attentive to the presence of vessels, resulting in collision.

Several researchers (Laist *et al.,* 2001; Jensen & Silber, 2003; Panigada *et al.,* 2006) have noted the disproportionate susceptibility of fin whales to ship strike, in particular to being hit by the bow of a moving ship. Other similarly streamlined balaenopterids, including Bryde's whales, appear much less frequently on global ship-strike databases. The reasons for this are unknown but may be because of fin whales' tendency to concentrate for feeding in areas that coincide with seasonal increases of

recreational and passenger vessel traffic (Panigada *et al.*, 2006). Increasing anthropogenic sound in the marine environment may decrease aural sensitivity and so interfere with the ability to respond to the sound of approaching vessels, an idea currently garnering much attention (André *et al.,* 2005). A disproportionate number of the fin whales subject to vessel strike in the Mediterranean (Panigada *et al.,* 2006), North Atlantic right and humpback whales (Laist *et al.,* 2001), and southern right whales (Best, 2001) are juveniles suggesting that naiveté or increased surface time may be contributing factors.

Potential biases in the dataset

There are several sources of potential bias in the data gathered during this research, most of which contribute to an underestimate of the true rate of mortality caused by vessel strike. Large vessels are often unaware of a collision due to their size and speed, and the size and shape of the animal as well as its position if struck by the bow of the vessel influences the likelihood of it remaining long enough to be found (Laist *et al.,* 2001). Most international shipping companies have standardised requirements upon entering a port including testing reverse propulsion and steering systems (N. Meek, Ports of Auckland, pers. comm.). Such manoeuvres may dislodge whales pinned to ships with a bulbous bow (Douglas *et al.,* 2008). Further, some vessels are more likely to report incidences such as smaller vessels, and passenger, military and coast guard vessels (Jensen & Silber 2003; Douglas *et al.,* 2008).

Incidents can go unrecorded as carcasses sink, wash out to sea, or wash up in remote locations. This is especially relevant to rorqual whales as they sink at the time of death due to their lower body fat, and only rise to the surface upon decomposition, and only then if they are in relatively shallow water (Allison *et al.,* 1991). Deep propeller cuts can release gases during decomposition reducing the chance of a carcass floating, and may help to explain the greater proportion of fatalities observed caused by blunt force trauma (Douglas *et al.,* 2008). Advanced decomposition can obscure the cause of death as was the case for five incidents recorded in this study. Disease, parasitic infection or entanglement may increase the amount of time a whale spends at the surface, or impede avoidance reactions to an approaching vessel (Laist *et al.,* 2001). Animals seriously injured by vessel strike may travel out of the survey area before dying.

Finally, human error due to inexperience and a lack of established necropsy protocols can result in misdiagnosis of death and/or misidentification of species. In this study, the majority of Bryde's whales were buried without examination so the cause of death is unknown. Six records stated the carcass was an unidentified baleen whale and of these, two carcasses were not recovered. Instances of inaccurate and sporadic record keeping, combined with the fact that not all vessel struck whales are found, suggest that the data should be considered as indicative of the situation rather than truly quantitative.

Bryde's whale population in northern New Zealand

In keeping with findings concerning vessel strike and large whales around the globe, it is likely that the number of Bryde's whale fatalities in northern New Zealand is an underestimate. The impacts of vessel strike on the population are difficult to ascertain given the paucity of both species' knowledge and accurate vessel strike data. Population estimates of Bryde's whales in north eastern New Zealand and the Hauraki Gulf are currently unknown. A closed population model estimated 159 (95% CI 97 – 337) individuals and an open population model estimated 46 (95% CI 39 – 53) individuals per annum for the inner Hauraki Gulf area (Wiseman 2008). Reproduction rates, natural mortality and the number of whales that are transient, resident or migratory are unknown for this population although a number of whales are found in the study area either seasonally or throughout the year (O'Callaghan and Baker 2002; Wiseman 2008). Any increases in the numbers of vessels transiting the shipping lanes between Whangarei and Auckland, and within the Hauraki Gulf may result in increasing rates

of mortality with unknown long-term consequences. Bryde's whales are listed as a nationally, critical threatened species by the Department of Conservation (Suisted and Neale 2004), and there is considerable concern about the level of anthropogenic mortality. Rigorous monitoring is essential to understand the impacts of vessel strike on Bryde's whales in this region. There is urgent need for accurate reporting of vessel strike, a centralised data base with broad-reaching and established reporting procedures, and clearly defined and observed protocols to establish the cause of death for any beachcast or floating dead whales. Ongoing research on Bryde's whale behaviour, distribution and population dynamics, as well as potential measures to mitigate strike incidents, could contribute to a reduction in the number of future fatalities.

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References

Allison, P.A., Smith, C.R., Kukert, H., Deming, J.W. and Bennett, B.A. (1991) Deep-water taphonomy of vertebrate carcasses: A whale skeleton in the bathyl Santa Catalina Basin *Paleobiology* 17(1): 78-89

André, M., Johansson, T., Delory, E. and van der Schàar, M. (2005) Cetacean biosonar and noise pollution. *Oceans 2005 – Europe* 2: 1028-1032

Auckland Regional Council. (2008) Summary Draft Annual Plan 2008/09 ISBN: 1174-2478

Baker, A.L. and Madon, B. (2007) Bryde's whales (*Balaenoptera* cf. *brydei* Olsen 1913) in the Hauraki Gulf and northeastern New Zealand waters. *Science and Technical Publishing,* Department of Conservation, Wellington, New Zealand.

Best, P.B. (2001) Distribution and population separation of Bryde's whale *Balaenoptera edeni* off southern Africa. *Marine Ecology Progress Series* 220: 277-289

Campbell-Malone, R., Barco, S.G., Daoust, P-Y., Knowlton, A.R., McLellan, W.A., Rotstein, D.S. and Moore, M.J. (2008) Gross and histologic evidence of sharp and blunt trauma in North Atlantic right whales (*Eubalaena glacialis*) killed by vessels. *Journal of Zoo and Wildlife Medicine* 39: 37-55

Cole, T., Hartley, D. and Garron, M. (2006) Mortality and Serious Injury Determinations for Baleen Whale Stocks along the Eastern Seaboard of the United States, 2000-2004. *U.S. Department of Commerce Northeast Fisheries Science Centre. Reference Document 6*-04; 18 p. Available from: National Marine Fisheries Service, Woods Hole, MA 02543-1026

Dalebout, M., Lavery, S. and Baker, C.S. (2002) Stock identity of Bryde's whales from New Zealand and origins of Bryde's and sei whale products sold on the Japanese and Korean markets. Report to the Scientific Committee of the International Whaling Commission SC/54/SD1

Douglas, A.B., Calambokidis, J., Raverty, S., Jeffries, S.J., Lambourn, D.M. and Norman, S.A. (2008) Incidence of ship strikes of large whales in Washington State. *Journal of the Marine Biological Association of the United Kingdom* doi:10.1017/S0025315408000295

Jarman, S.N., Wiseman, N., Baker, C.S. and Gales, N.J. (2006) Incidence of prey DNA types in Bryde's whale scats. Report to the Scientific Committee of the International Whaling Commission SC/58/E29

Jensen, A.S. and Silber, G.K. (2003) Large whale ship strike database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR, 37pp

Kanda, N., Goto, M., Kato, H., McPhee, M. and Pastene, L.A. (2007) Population genetic structure of Bryde's whales (*Balaenoptera brydei*) at the inter-oceanic and trans-equatorial levels. *Conservation Genetics* 8: 853-864

Knowlton, A. R. and Kraus, S.D. (2001) Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. *Journal of Cetacean Research and Management* (Special Issue) 2: 193-208

Kraus, S. D. (1990). Rates and potential causes of mortality in North Atlantic right whales *(Eubalaena glacialis). Marine Mammal Science* 6:278-29

Kraus, S.D., Brown, M., Caswell, H., Clark, C., Fujiwara, M., Hamilton, P., Kenney, R., Knowlton, A., Landry, S., Mayo, C., McLellan, W., Moore, M., Nowacek, D., Pabst, D., Read, A. and Rolland R. (2005) North Atlantic right whales in crisis. *Science* 309: 561-562

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., & Podesta, M. (2001) Collisions between ships and whales. *Marine Mammal Science* 17: 35-75

Morrison, M., Drury, J., Shankar, U., Middleton, C. and Smith, M. (2003) A broad scale, soft sediment habitat assessment of the Hauraki Gulf. NIWA client report prepared for the Department of Conservation, Auckland, New Zealand

Nowacek, D., Johnson, M., Tyack, P., Shorter, K., McLellan, W. and Pabst, D. (2001) Buoyant balaenids: the ups and downs of buoyancy in right whales *Proceedings of the Royal Society B., London* 268: 1811-1816

O'Callaghan, T.M. and Baker, C. (2002) Summer cetacean community, with particular reference to Bryde's whales, in the Hauraki Gulf, New Zealand. *Science Internal Series 55*, Department of Conservation, Wellington, New Zealand

Panigada, S., Pesante, G., Zanardelli, M., Capoulade, F., Gannier, A. and Weinrich, M.T. (2006) Mediterranean fin whales at risk from fatal ship strikes. *Marine Pollution Bulletin* 52: 1287-1298

Ports of Auckland Development Plan (2008) Corporate Affairs, Ports of Auckland Ltd. P.O. Box 1281, Auckland 1015, New Zealand

Suisted, R. and Neale, D. (2004) Department of Conservation Marine Mammal Action Plan 2005-2010. Marine Conservation Unit, Department of Conservation, Wellington, New Zealand

Tershy, B.R. (1992) Body size, diet, habitat use and social behaviour of Balaenoptera whales in the Gulf of California. *Journal of Mammology* 73: 477-486

Vanderlaan, A.S.M. and Taggart, C.T. (2007) Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine Mammal Science* 23: 144-156

Van Waerebeek, K., Baker, A., Felix, F., Gedamke, J., Iniguez, M., Sanino, G., Secchi, E., Sutaria, D., van Helden, A. and Wang, Y. (In Press) Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere; building a standardized database. *Latin American Journal of Aquatic Mammals*

Wada, S., Oishi, M. and Yamada, T.K. (2003) A newly discovered species of living baleen whale. *Nature* 426: 278-281

Weinrich, M. (2004) A review of worldwide collisions between whales and fast ferries. Report to the Scientific Committee of the International Whaling Commission SC/56/BC9

Weinrich, M., Panigada, S. and Guinet, C. Eds. (2005) Report of the Joint ACCOBAMS/Pelagos Workshop on Large Whale Ship Strikes in the Mediterranean Sea 14-15 November 2005

Wiseman, N. (2008) Genetic identity and ecology of Bryde's whales in the Hauraki Gulf, New Zealand. PhD Thesis, University of Auckland, New Zealand

Appendix 1. Known and probable vessel strike fatalities of Bryde's whales off northern New Zealand. Reference codes: UoA (University of Auckland); NW (Ngatiwai). Listed as either "Known" or "Probable" based on categories listed in the methods.

Date	Species	Sex	Length (m)	Location	Injury and Comments (Known/Probable Vessel Strike)	Photos	Tissue Sample	Reference Code	Source
5 November 1996	Bryde's	F	15.4m	Whangarei	Ngatiwai boned it out; injuries consistent with vessel strike. (Probable)		Y	Bed05 (UoA) Kaurinui (NW)	UoA Ngatiwai database
26 July 1997	Likely Bryde's			Main Landing offshore, Little Barrier Island	Main body floating past landing, badly broken jaw and some baleen found on rocks the next day. Looked like jaw broken prior to examination, but unable to confirm. Species unconfirmed but experienced DoC officer (Thelma Wilson) confident that it was Bryde's whale. (Probable)				DoC Warkworth Area Office Thelma Wilson
9 September 1997	Bryde's	F	14.6m	Pakari Beach	No external injuries, boned out by Ngatiwai and Rubin Williams (DoC Whangarei). Injuries to back of skull consistent with vessel strike. (Known)	Y	Y	Bed07(UoA)	DoC Warkworth Area Office Thelma Wilson/Jo Ritchie
20 April 1998	Bryde's				Arrived on bow of ship, buried at Station Bay, Rangitoto Island. (Probable)				DoC Auckland Are Office Karl McLeod
13 August 1999	Bryde's	F	13.3m	Westend Beach, Tawharanui	Bruising and vertebrae fractures top of spine and right hand side, boned out by Ngatiwai. (Known)		Y	Bed11 (UoA) Pukenihinihi (NW)	DoC Warkworth Area Office Thelma Wilson
27 October 2000	Bryde's	M	13.8m	Daniels Bay, near Leigh	Dead ~5-7 days. All vertebrae, from a segment three vertebrae behind the skull for several metres, plus many of the ribs were crushed. Flesh showed extensive bruising and the spinous process on most of the vertebrae were fractured close to the main vertebral bone. (Known)	Y		Te Riri(NW)	DoC Warkworth Area Office Thelma Wilson
7 January 2003	Bryde's	M	11.4	4 nautical miles east Takata Peninsula	Damage to base of skull and pectoral fins. Gangrene around neck wound suggesting whale survived impact and died later. Boned out by Ngatiwai. (Known)	Y	Y	Bed18(UoA)	DoC Warkworth Area Office Thelma Wilson
1 July 2003	Bryde's	M	11.8m	Fergusson Wharf, Auckland	Animal found on the bow of a vessel in port, massive cranial injuries posterior of blowhole. Large container ship *Hatoko Maru*. (Probable)	Y	Y	Bed19(UoA)	Doc Auckland Area Office Karl McLeod

Date	Species	Sex	Length (m)	Location	Injury and Comments	Photos	Tissue Sample	Reference Code	Source
6 November 2003	Bryde's	F	8.6m	Off North Cove, Tawharanui	Evidence of bruising to flesh around scapula region. (Probable)		Y	Bed 22(UoA)	DoC Warkworth Area Office Thelma Wilson
20 June 2005	Bryde's	F	7m (not including missing tail)	Between Great and Little Barrier Islands	Tail gone, large gash in one side. (Probable)	Y			DoC Great Barrier Area Office Helema Jamieson
31 December 2006	Bryde's	F	10.4m	4 nautical miles east of Tiritiri Matangi	Surface examination and incisions made to the haematomal region to define extent of bruising. Broken pectoral fin, large haematoma on ventral surface, clean lateral cut in right tail fluke. Extensive photos of this whale. (Known)	Y	Y	Bed30(UoA)	Doc Auckland Area Office Karl McLeod
4 February 2007	Bryde's	M	11.5m	SE of Tiritiri Matangi	Both pectoral fins broken, some ventral surface damage. Large area of tissue damage in mid right lateral region consistent with large vessel strike. Lateral cuts or slices on the right side although these are most likely to do with the decomposition causing tissue/blubber degradation. Extensive photos of this whale. (Known)	Y	Y	Bed28(UoA)	Doc Auckland Area Office Karl McLeod
1 October 2007	Bryde's	M	11.3m	Waipu Cove	Large dorso-transverse injury evident approximately 90cm posterior of dorsal fin. Three dislocated lumbar vertebrae, blubber displayed inflammatory reddening. Indications of severe life threatening injury to the lower back characteristic of propeller strike from large vessel. (Known)	Y			Ngatiwai post mortem report; DoC Whangarei Office Bryce Lummis