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Historical Data on Australian Whale Vessel Strikes

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INTERNATIONAL
WHALING COMMISSION

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ABSTRACT

Based on existing data of the occurrence of vessel strike in Australia, Australian records represent approximately 7% of all worldwide vessel strikes reported to the International Whaling Commission. However, to date there has not been a dedicated Australian collation of historical data sources. Therefore we conducted a search of historical newspapers and other sources to discover reports of vessel strikes in Australian waters. This updated analysis uncovered a significant number of new and previously unreported records which means that Australia's contribution of worldwide reported vessel strike has now increased to approximately 17%. It is very important to note from the outset that this does not necessarily reflect the actual proportion of global vessel strikes that have occurred in Australia, as national and international vessel strike data have inherent reporting biases and unknown coverage. However, the additional data collected in this study does challenge the notion that historically Australia has had low numbers of vessel strikes relative to the rest of the world. This data is yet to be cross-checked and validated but we present a preliminary summary and exploration of the data. One interesting finding was a distinct absence of large vessels in modern data but after examination we believe this is most likely a reflection of under-reporting due to large modern vessels possibly not detecting collisions.

INTRODUCTION

Collisions with vessels are a significant cause of anthropogenic mortality to baleen whales and other large marine fauna worldwide. Given the substantial current and projected increases in coastal/port development along the Australian coastline, and associated rise in recreational and commercial vessel traffic (Figure 1), there is an increasing potential for adverse interactions with marine species. Also contributing to this potential increase in risk are strong population growth rates in some recovering species in Australian waters, such as humpback whales (Jackson 2015, Noad 2008). These factors along with improved methods for reporting and potential under-reporting of vessel strikes in the past, demonstrate the importance of better understanding the risk of vessel strikes on whales in Australia. Note the use of the word 'vessel' rather than ship in this report. Although we do focus on larger commercial shipping, we are interested in all interactions with all vessel sizes including small recreational boats.

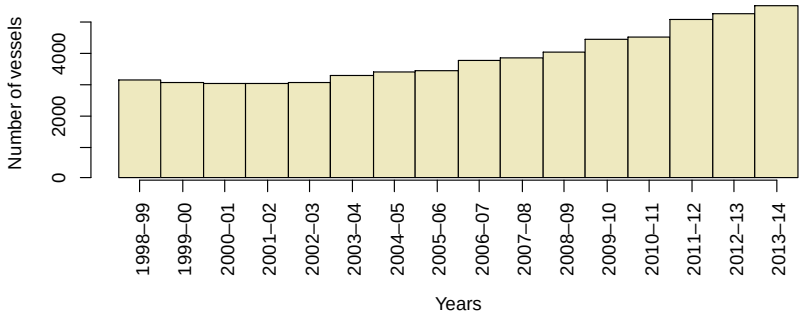

Figure 1 Increase in the number of cargo ships involved in coastal or international voyages that made Australian port calls (BITRE 2015).

Shipping occurs around the whole of the Australian coastline, but with concentrations of larger commercial shipping around the major ports, inside the Great Barrier Reef, the East coast and the North-west shelf of Australia (Figure 2).

To help in understanding the issue of vessel strike and its potential impacts, an accurate record of previous incidents is invaluable. To this end, considerable attention has already been given to collating records of national and international cetacean vessel strike incidents. For example: Laist et al. (2001), Jensen et al. (2004), Van Waerebeek et al. (2007), IWC (2010), Neilson et al. (2012), Ritter (2012) and Félix and Van Waerebeek (2005). The resulting data has relatively few Australian records (i.e., 35 Australian records out of 539 worldwide records up until 2010 (IWC 2010). Furthermore, the majority of the 35 Australian records are from the last 20 years. Australia began formally reporting vessel strike mortalities to the IWC in National Progress Reports in 1997, which is where 33 of the 35 Australian records appear to originate. So, for the purposes of this paper, we refer to 1997 onwards as modern data and pre-1997 as historic data.

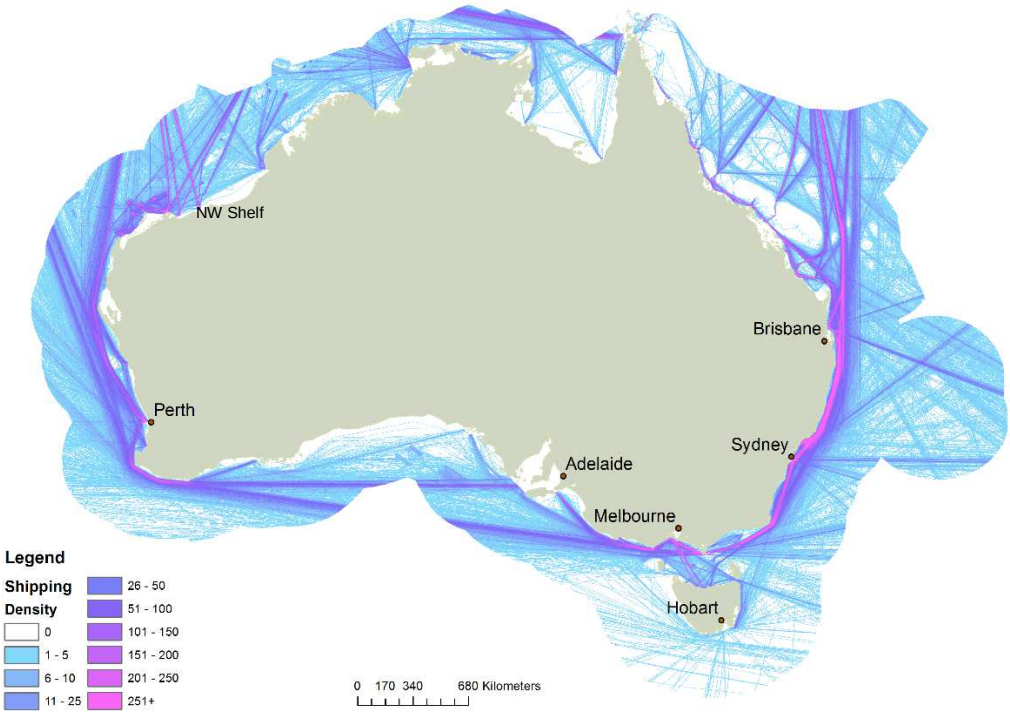

Figure 2 2014 shipping (>24m) density (nautical miles travelled in 1x1 nautical mile cell) for the Australian Economic Zone. Based on AMSA AIS data; credit data Geoff Hosack (CSIRO).

This small number of reported incidents has sometimes led to an assumption that, historically at least, vessel strike in Australian waters was low compared to worldwide rates. However, there has never been any systematic and comprehensive collation of *historic* Australian vessel strike records. As stated in Van Waerebeek et al. (2007) and Jensen et al. (2004), most of the attention has been given to the Northern Hemisphere. Van Waerebeek et al. (2007) worked towards addressing this by compiling data from the Southern Hemisphere. This was mainly from current state databases (e.g., strandings), so much of the data was modern. The only historic examination related to Australian vessel strike seems to be Kemper (2008) which examined human related mortality and injury for Australian Southern right whales, but this was mainly based on stranding records.

We suggest it is problematic deriving conclusions regarding the rate of vessel strike in Australia based on incomplete data and potentially biased and non-representative data. To help in understanding any possible bias of the existing Australian historic data, we completed a thorough review of vessel strike incidents to date. With the advent of digital media and digital archives we were able to search historical media for references to shipping incidents involving whales. This resulted in the discovery of a large number of previously unreported Australian vessel strikes. In addition to finding new Australian records, we also found a substantial number of non-Australian reports from around the world that do not appear to be in any existing databases.

In this paper, we present the new and updated Australian vessel strike data, along with some simple exploratory analyses, and discuss further the implicit issues with data of this type, such as reporting biases and the dangers of drawing conclusions based on limited data.

METHODS

We searched various online archives (see Table 1) for past newspaper reports and other records containing terms such as *whale collision*, *whale strike* and *whale struck*.

Table 1 Details of online archives searched

Database/Site	Dates	Address
Australian focus		
Australian National Library	1824-1954	trove.nla.gov.au/
ProQuest (paid)	1996-2016	search.proquest.com/
Google	Various	www.google.com
Google news archive	~2004-	news.google.com.au/newspapers
Non-Australian focus		
British Newspaper archive (paid)	1710-1959	www.britishnewspaperarchive.co.uk/
US library of Congress	1836-1922	chroniclingamerica.loc.gov/
California Digital Newspaper Collection	1846-2015	cdnc.ucr.edu/
NYS Historic Newspapers	1795-2015	nyshistoricnewspapers.org/
Fulton Historic Newspapers	Various	www.fultonhistory.com/Fulton.html
Internet Archive	Various	archive.org

The definition of what constitutes a vessel strike is not as straight forward as we initially thought. There have been incidents reported where whales were said to "attack" ships (see Results section) or collide with stationary vessels at anchor. These incidents were included in our collation as we are interested in all physical vessel-whale interactions. Therefore, for our purposes, the definition of a vessel strike is any physical interaction (both fatal and non-fatal) between a vessel and a cetacean. We excluded collisions with whaling vessels as these interactions are unlikely to be representative of typical vessel or typical whale behaviour. Upon finding a reported incident, we recorded various details (as per Table 2) and saved a pdf file of the article(s). For many records not all information was reported so there is incomplete details in our data.

Most of the newspaper articles and other online reports provided the name of the vessel involved. Through further online searches (i.e., Lloyd's Register of Ships) and general web searches, we found details such as vessel dimensions and type.

Table 2 Summary of information recorded for each incident.

Information	Comment
Time/Date	The time of day and date of incident or when a body was found
Location	A description of the location and longitude/latitude or an approximate longitude/latitude based on the location description if not specified
IWC Data Ref	If the incident appears to be already in the IWC 2010 data base we recorded the IWC ID number
Species	The common name and scientific name of the species
Whale size	The length of the whale in metres
Whale sex	The sex of the whale
Maturity	If the whale was calf, juvenile or adult
Resulting whale injury	Was it reported as fatal or non-fatal, with a description of any injuries
Type of report	Whether the report arose from an observed collision or a discovered body
Vessel name	The name of the vessel involved
Vessel length and other dimensions	The length, beam and tonnage of the vessel (This was often discovered via further research)
Vessel Type	A general classification of the type of vessel e.g., cargo, passenger, navy, etc.
Collision Detection	Whether the collision was noticed visually and/or felt on-board
Impact location	Where on the vessel the impact occurred
Blunt and/or propeller	Was the collision a blunt force or did the whale interact with the propeller
Vessel damage	What damage occurred to the vessel?
Human Injury	What human injury resulted
Source of information	e.g., Newspaper, website, stranding database, IWC Progress report
Link	A hyperlink to the article(s)

General issues

There are a range of issues with the interpretation of vessel strike data. Most importantly it is generally accepted that many incidents will go unreported due to not being detected (Laist et al. 2001; Jensen et al. 2004). As well as this lack of detection, there are also likely to be reporting biases which relate to the following:

Species – different species may have differing reporting biases in terms of bodies being found (e.g., right whales float longer than humpback whales). Furthermore, for data based on witness accounts, there is potential for the eyewitness to report the most well-known species rather than the real species.

Spatial bias – discovery rates will vary depending on: (a) where the strike occurs; and/or (b) on where the body washes up (e.g., strikes near the coast are more likely to wash up and strandings near populated areas are more likely to be discovered).

Vessel bias – a strike is more likely to be noticed and reported on passenger vessels and smaller vessels and hence these vessels are likely to be better represented in the data. This is particularly the case for whale-watching vessels where even minor interactions are frequently noticed and documented.

RESULTS

The search of the sources in Table 1 found reports of numerous Australian vessel strikes reports between 1840 and 2015 (see Figure **3** and summary in the Appendix). Specifically, the 2010 ship strike database (IWC 2010) contained a total of 35 distinct records in Australian waters, roughly 7% of the worldwide records to 2010. As per Table 3, we found potentially 65 additional pre-2010 records (plus 9 records in annual Progress reports that did not seem to be in the IWC 2010 database). This brings the total to 109 which corresponds to approximately 23% of the world wide records. However, as a by-product of our search we also found potentially ~145 additional non-Australian records that do not appear to be in the existing 2010 IWC database. Assuming these records are valid, the Australian records would be approximately 17% of the world wide data to 2010. We collated records from Australian National Progress Reports post-2010 and identified 32 new potential records that have not been previously reported.

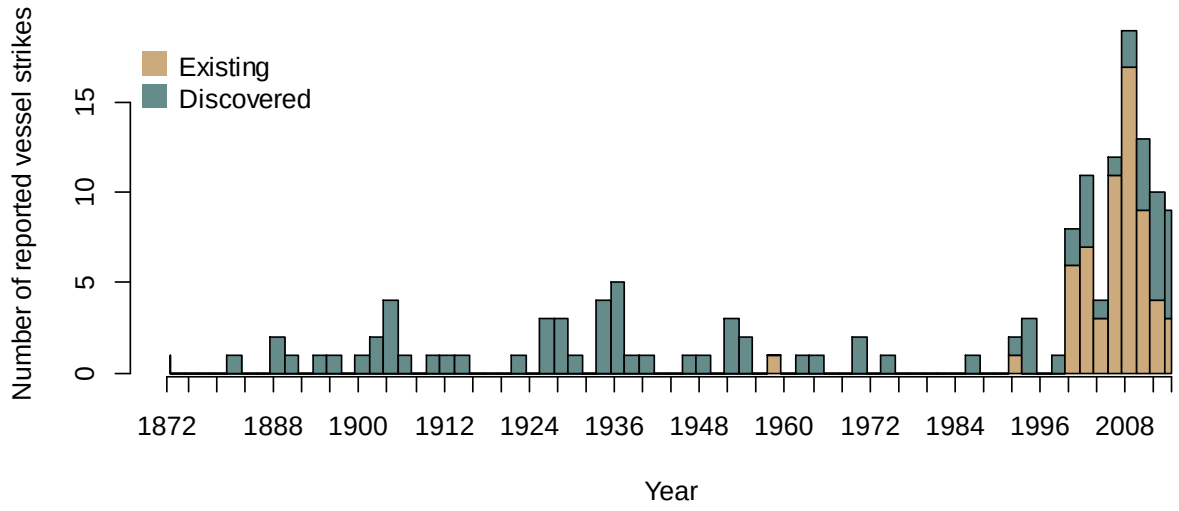

Figure 3 **Existing Australian vessel strike reports and our new data over time polled into 2 year blocks.**

Table 3 Summary of number of reports.

	Pre-2010	2010-2015
IWC 2010	35	-
Progress Rep. not in IWC 2010	9	16
Potentially newly found	65	16
Total	109	32

Data caveats

This paper is a very preliminary examination of the data. Further data processing/cleaning is required. Therefore, there are a number of caveats associated with the data collected:

1. The new records have not been thoroughly validated to the same standard criteria as used in the IWC database (IWC 2010). Furthermore, we only compared the new data to records within the 2010 version of the IWC database; if any new records have been added since 2010, they were not considered.
2. There is the possibility that some of our 'new' records could have already been identified and discounted. For example, we found some incidents in the Australian National Progress Reports that were not in the 2010 IWC database and added these to our data. We feel it is better to include these in the database, flag them and detail why they were discounted, so that they are not mistakenly added in future.
3. We found a large number of reports from racing yachts (particularly while competing in the Sydney to Hobart race held annually in late December). For the majority of these reports it is unknown exactly what species was hit and it is possible that rather than a whale, the animal involved could have been something else (e.g., ocean sunfish, shark or even shipping container).
4. Since much of our data is based on witness reports rather than officially reported data, there is always the possibility for incorrect details and information. We did find one instance of misreporting, where in initial reports witnesses described a collision with a whale, but later reports investigated the accident further and cast doubt on the original story suggesting it was a large wave that capsized the vessel. Again in our opinion, these incidents should be included in the data and flagged, to avoid the incident being mistakenly added in future.

Vessel strike rate

It would not be wise to take the reported vessel strike rate too literally as it is a reporting rate and, as per the caveats already discussed, it may not reflect the true vessel strike rate. However, it is a worthwhile exercise to examine the data and investigate any patterns in reporting rate.

Laist et al. (2001) found pre-1951 reported vessel strike incidents worldwide to be 'rare' with only 14 records (Note: Laist et al. (2001) only considers motorised vessels). Similarly, the 2010 IWC database only lists 18. However, online newspaper archives provided additional pre-1951 strikes, with 40 Australian and potentially 140 non-Australian new incidents discovered (Figure **4**). Therefore, the historic incidence of vessel strike may not be as rare as previously thought. Furthermore, Laist et al. (2001) found a large increase in vessel strike data post-1951, which they attribute to increased vessel numbers, size and speed. However, this was not seen in the Australian data, where we found a lull in reports for this period, with only 17 records up until 1999 (Figure **4**). We expected to see some decrease in vessel strikes due to the extreme sequential depletion of whales stocks in Australian waters, leading up to the early 1960's. To illustrate this potential interaction, we can look at the Australian humpback

whales estimated historical population trajectory (Jackson 2015) and shipping fleet size (we only have worldwide data for this) together (Figure 5). From these figures, we would expect the rate of humpback-vessel strikes to increase after approximately 1960 due to recovering whale stocks and increasing vessel traffic and speed. The most likely reason that this was not seen in our data is the temporal coverage of the main online data bases (Table 1) that were available. The online databases mainly cover up until 1954 and from 1996 onwards (see Figure **6**). Although, we did find some data between 1950 and 1996 with general web searches and within the diminished coverage of TROVE. So therefore, there is a distinct gap in data coverage between 1954 and 1996 meaning that reporting rate from this period is likely to be even more negatively biased.

In the more recent data there was an obvious increase in vessel strike reports around 1998 (Figure **3**). As outlined previously, this is most likely an artefact of the instigation of a formal vessel strike reporting regime to the IWC via National Progress Reports, but also highlights that reporting rates prior to this time were likely to be negatively biased.

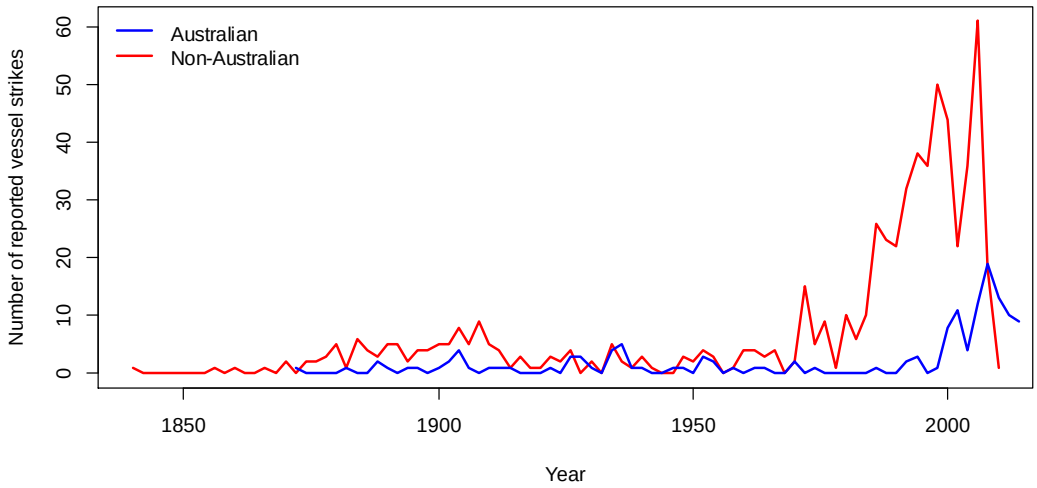

Figure 4 Comparison of Australian and non-Australian records over time, as discovered in this study (based on IWC 2010 data and our additional new worldwide records). Note that extra non-Australia records were not the focus of this study but were discovered incidentally when searching for Australian records.

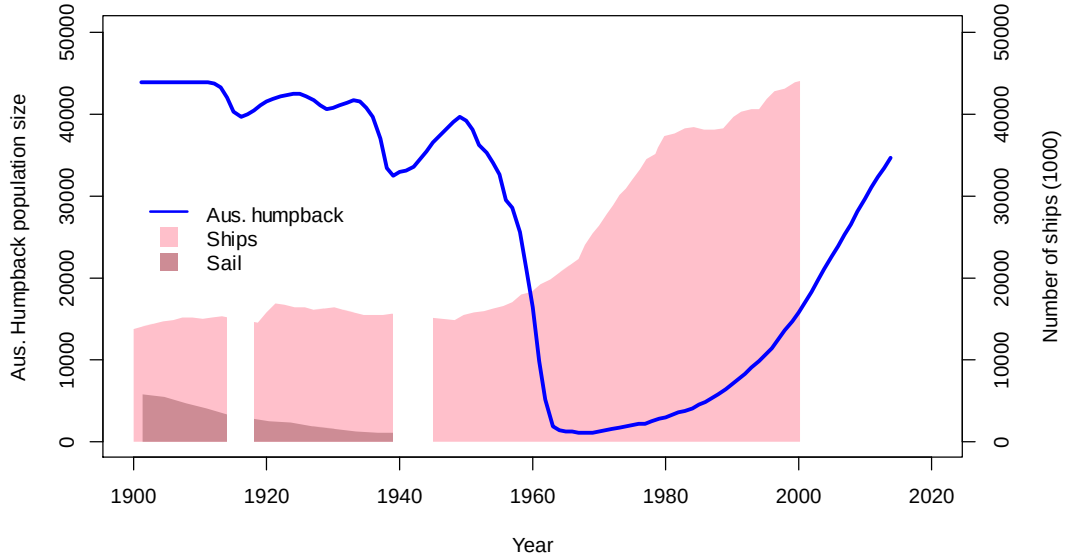

Figure 5 General shape of estimated population trajectory for Australian humpback whales (i.e., a summation of Breeding Stocks D and E; (Jackson 2015) as the blue line, compared to worldwide ship numbers, given as pink areas, based on Lloyd's Register of Ships (Endresen et al. 2007).

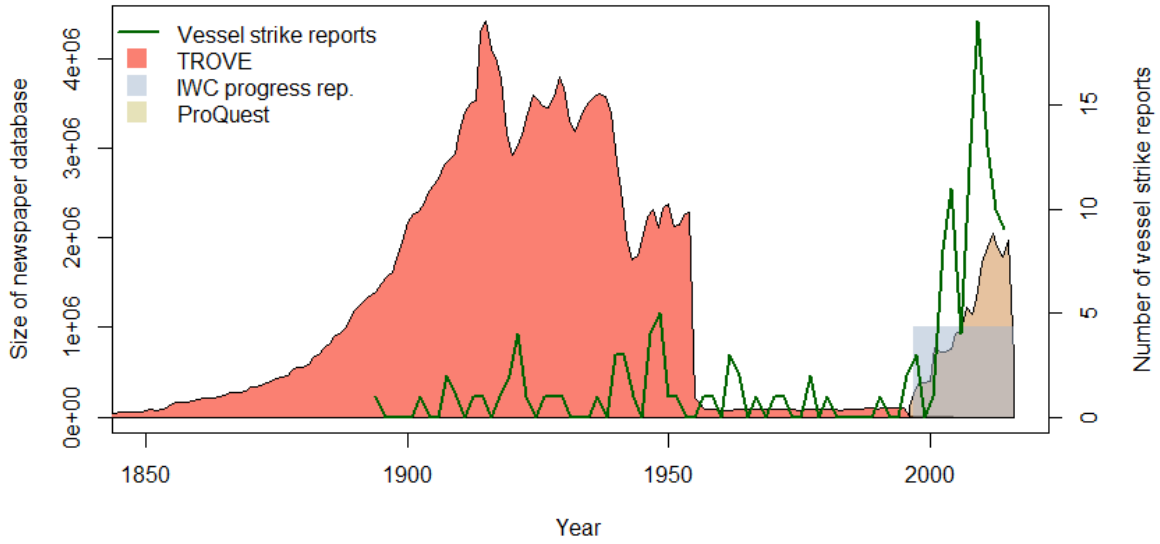

Figure 6 A comparison of search effort in terms of the number of digitised newspaper articles searched in data bases and IWC National Progress Report timing relative (coloured blocks) to the number of Australian vessel strike data points per 2 years (green line).

Australian vessel strike data

In essence, the Australian data series consists of two disparate data sets: a historic (pre-1997) and a modern (post-1997) data set. The historic series primarily arises from newspaper reports and the modern series, predominantly from IWC data collection via National Progress Reports (i.e., more direct reporting of incidents from Government agencies and researchers).

One complication of having these two underlying data sources, is that historical newspaper reports mainly dealt with actual witnessed collisions whereas strandings were infrequently reported. If a stranding was reported, there was often little or no information included on the likely cause of death. In contrast, modern data has a significant proportion of data arising from strandings (Figure 7). Furthermore, the data available from a stranding is quite different from a report of a collision. As an example, for strandings we generally have a known species but unknown vessel, whereas collision reports generally provide the opposite. This is reflected in the modern data, with a higher proportion of known species (Figure 8) and a decreasing proportion with known vessel (Figure 9).

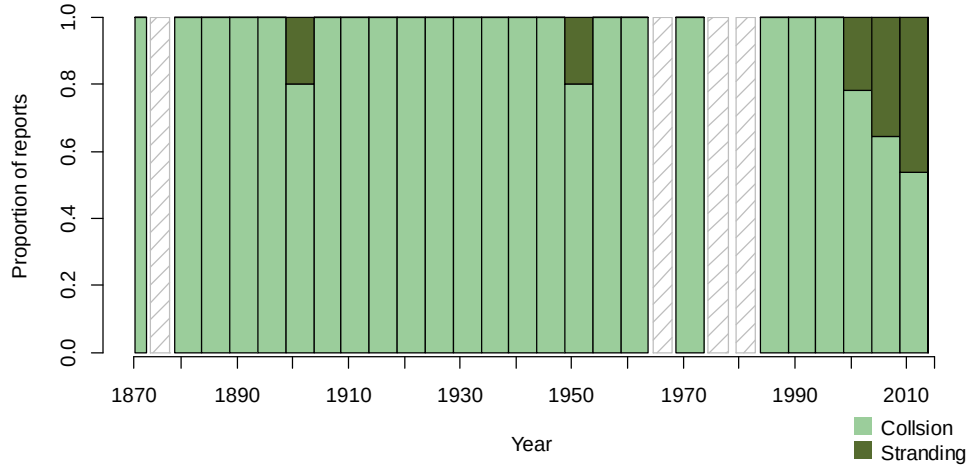

Figure 7 Proportion of Australian reported vessel strikes that came from observed collisions (light green) or discovered bodies (dark green) in each 5-year block, with hatched grey indicating no recorded reports.

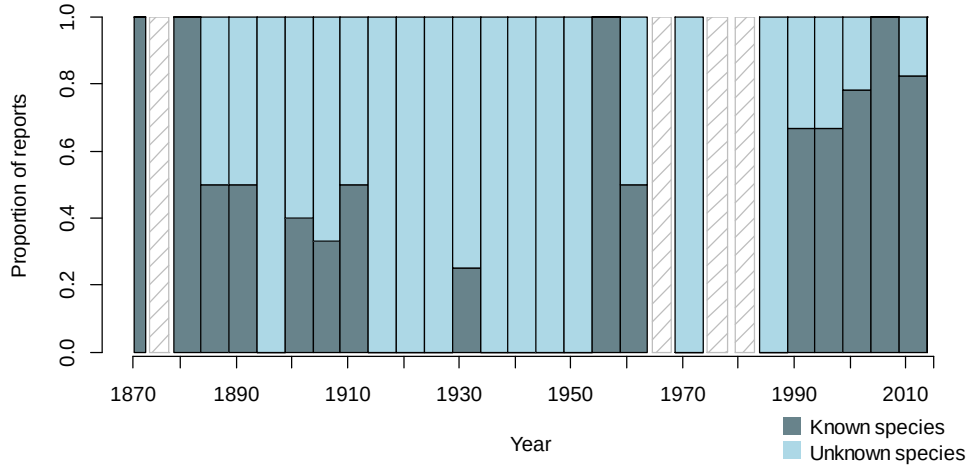

Figure 8 Proportion of Australian vessel strike reports with known species.

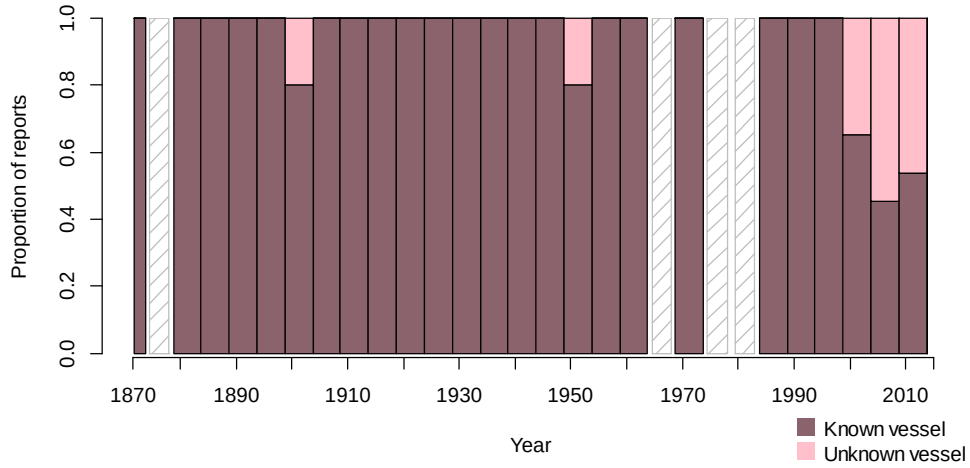

Figure 9 Proportion of Australian vessel strike reports with known vessel.

Species

Jensen et al. (2004) found world-wide reported vessel strikes predominantly involved fin, followed by humpback, Northern right, gray, minke, sperm, Southern right and blue whales. For the Southern Hemisphere, Van Waerebeek et al. (2007) describes reports for mainly Southern right (56 reports), humpback (15) and Bryde's whales (13), sperm (8), blue (5), sei (4) and fin whales (2). In the majority of vessel strike records for our Australian data, the species was unknown. In the records with known species, the majority involved humpback, Southern right and sperm whale (in descending order of occurrence). As mentioned in the data caveats section, there is likely to be bias in the reporting rates (e.g., witnesses may simply report the most commonly known whale *viz.* humpbacks). When the historic and modern data are considered separately (Figure 10), we can clearly see the disparity between the types of species recorded; specifically, the large number of unknown species in the historic data. For the modern data, comparing the species reported in Australian waters to the worldwide records, the most common species and their relative order are similar, with the notable exception of fin whales (Figure 10). Only one fin whale appears in the modern Australian data set, but they are the second most commonly recorded species internationally. Van Waerebeek et al. (2007) also observed this lack of fin whales in their Southern Hemisphere data.

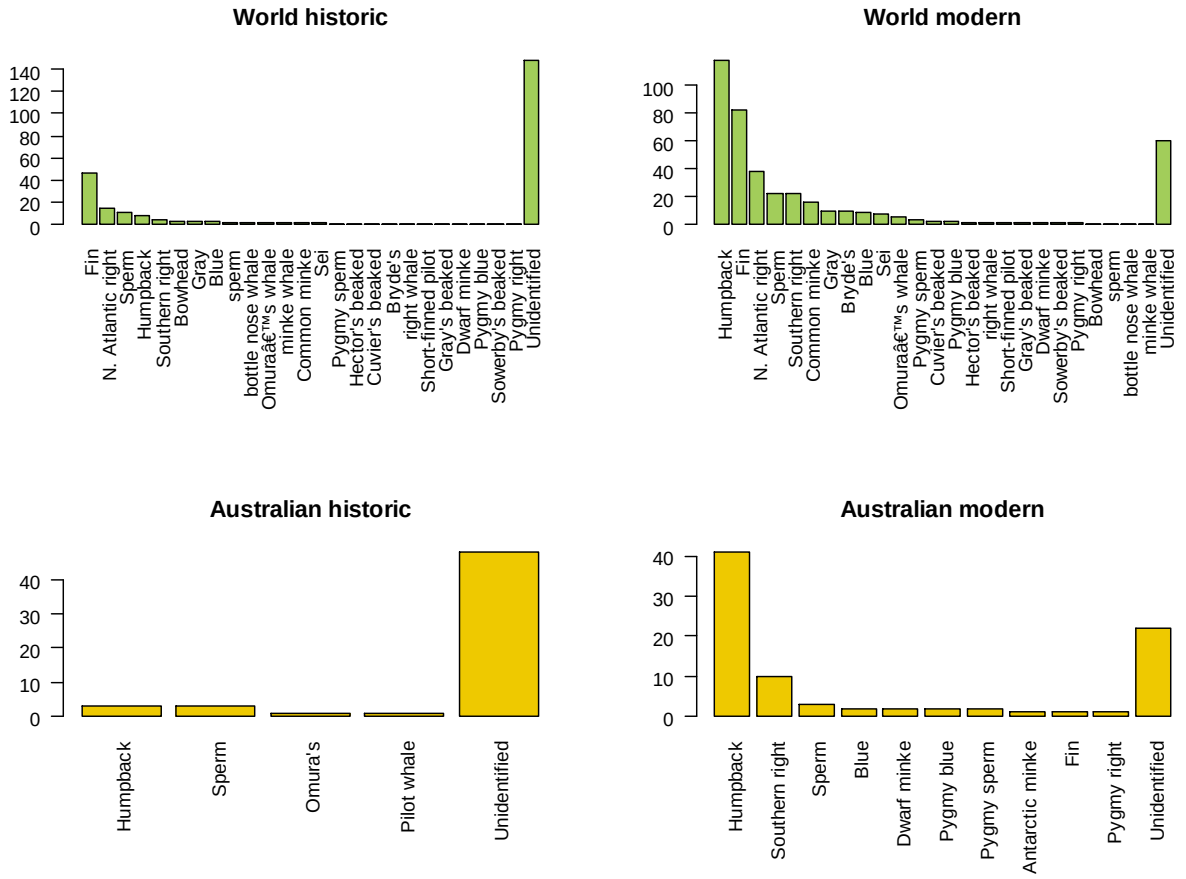

Figure 10 Vessel strike records by species for historic (up to 1997) and modern (from 1997) data for Australian and worldwide reporting (IWC 2010+potential new records).

Spatial and temporal distribution

Vessel strikes were reported around the whole Australian coastline, except for the unpopulated Northern coast (Figure 11). Reports were predominately from Queensland and New South Wales, but there were reports from all other States (Figure 12). Figure 11 and Figure 12 also clearly demonstrate the increase in modern reporting over time.

Looking at the distribution of reported incidents within the year, the pattern follows the migratory timing of the main vessel struck species (Figure 13). Specifically, reports for humpbacks and Southern right whales peak in August, corresponding to the peak time when whales are migrating and/or have reached their mating/calving grounds near the Australian coastline.

We found information on the time of day that the incident occurred for 19 records. However, there did not seem to be any discernible pattern.

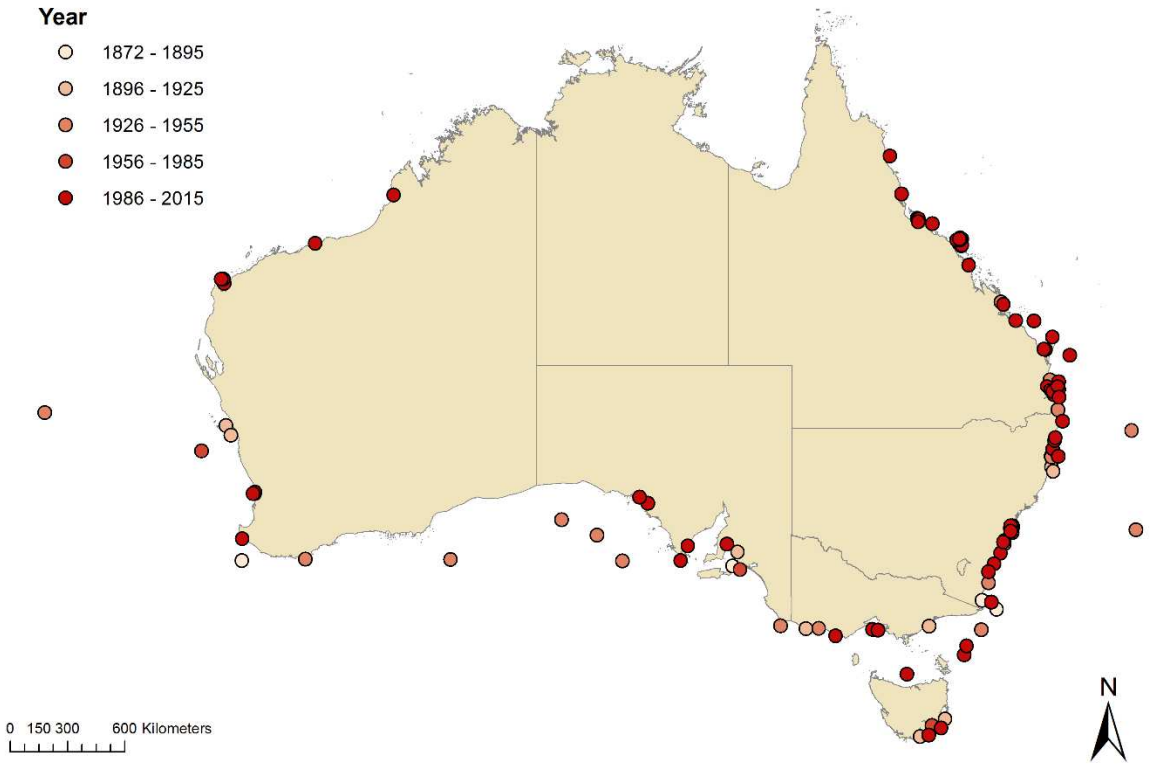

Figure 11 Approximate locations of reported vessel strike collisions and strandings where the cause of death was attributed to vessel strike, by period for Australia.

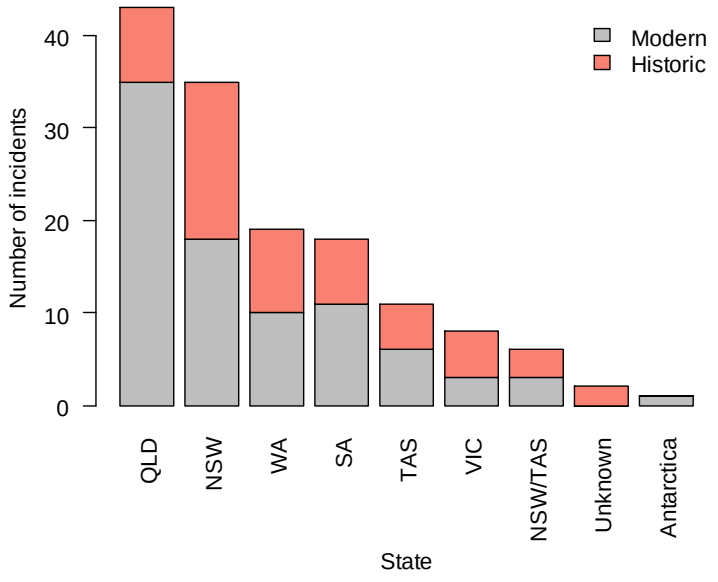

Figure 12 Total number of reported vessel strikes by Australian state and territory from historic (<1995) and modern (≥1995) data (NSW/TAS denotes mainly Sydney to Hobart yacht race reports where exact location is unknown).

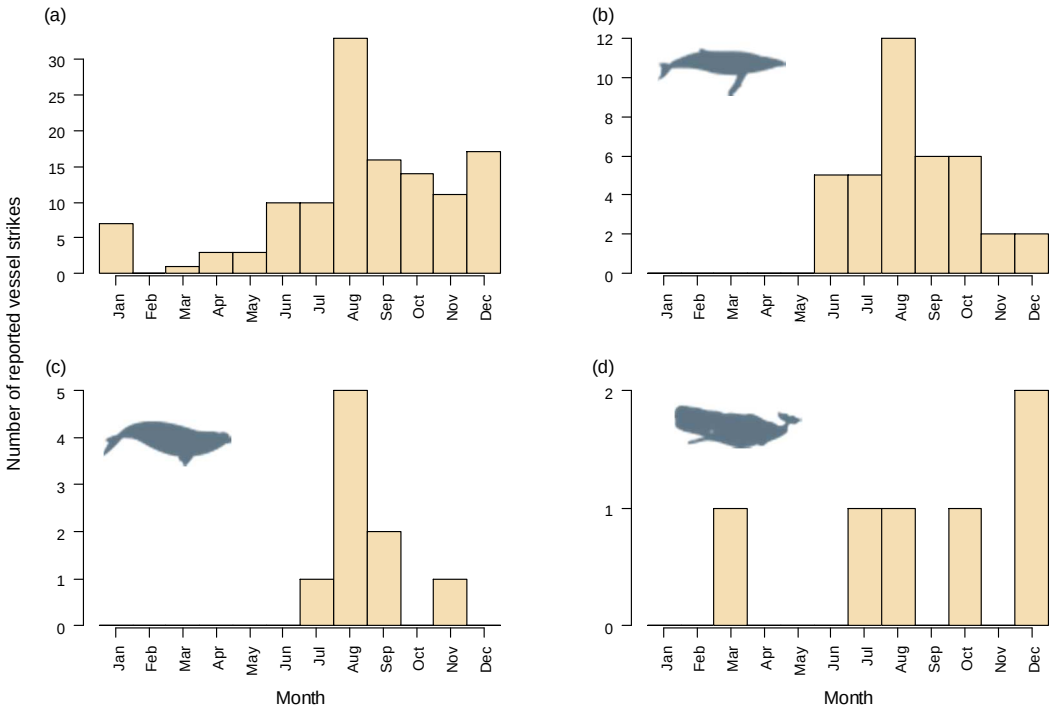

Figure 13 Seasonal distribution of Australian vessel strike reports by species: (a) all whales; (b) humpback whales; (c) Southern right whales; and (d) sperm whales. images:credit: http://phylopic.org/

Vessels

Interestingly, if we look at the length of the known vessels involved in collisions through time, there is a clear increase in vessel length from the beginning of records through to around 1941 (Figure 14). By contrast, for modern data, lengths of vessels involved in ship strike incidents are much smaller than historical lengths. The historic data predominantly contains reports from passenger vessels (Figure 15), which is consistent with the idea that passenger vessels have an increased likelihood of the collision being witnessed and reported to the newspapers. However, there were reports from all vessel types and sizes. Vessel strikes making up the modern records mainly involved small vessels or (reflecting the stranding data source) unknown vessel type. There does appear to be a distinct lack of reports involving larger vessels in the modern data.

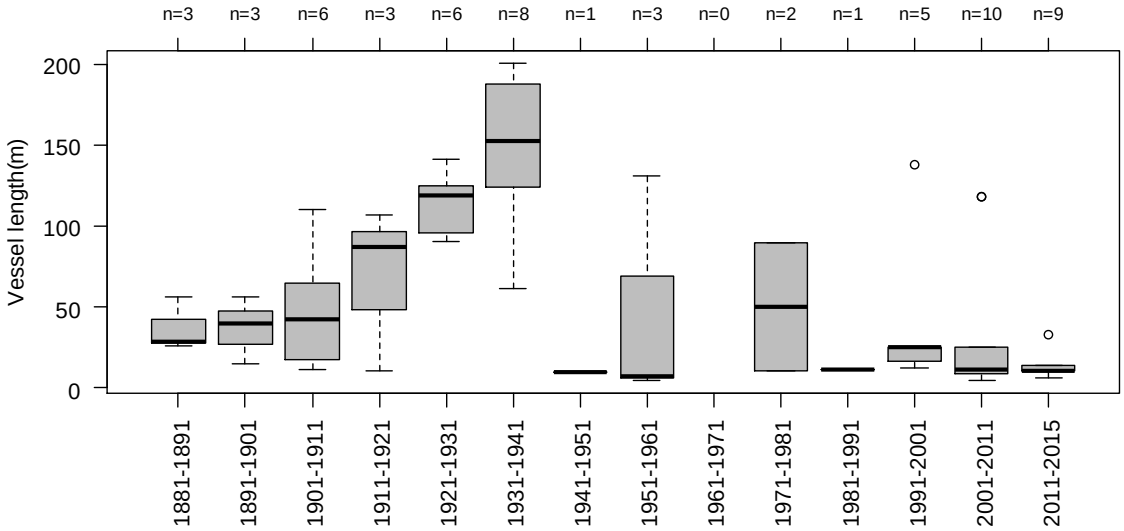

Figure 14 Distribution of known vessel lengths from Australian vessel strikes by 10-year period for Australian vessel strike data.

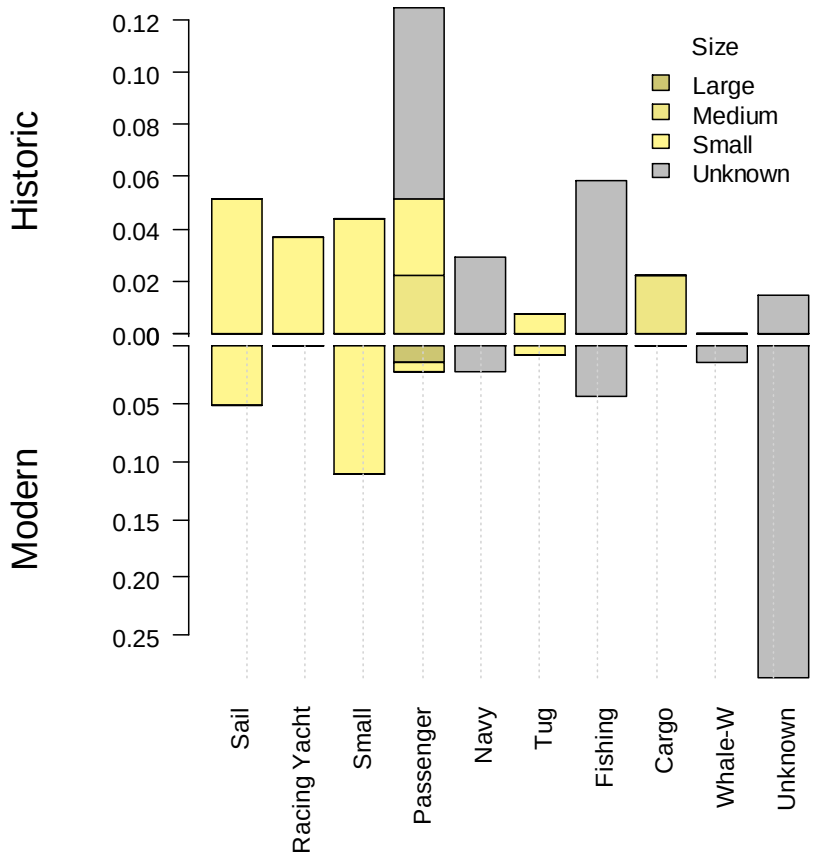

Figure 15 Distribution (proportion of total) of vessel types, broken down into sizes[1]: small (approx. <25 m), medium (approx. 25- 150 m) and large (> 150 m) for Australian vessel strike data. Historic pre-1997 (top) and modern post-1997 (bottom).

The proportions of the various vessel types in our data does seem different to other data sets, e.g., Jensen et al. (2004) found in order of prevalence: navy (17%), container/cargo (15%), whale-watching (14%) passenger cruise (13%), ferry (12%), US coast guard (7%), tanker (6%), recreation and steamship (5%), fishing (3%) and dredge (1%). However, as discussed in Jensen et al. (2004), care must be taken interpreting numbers, as the reporting rate between types of vessels is likely to be considerably different.

Laist et al. (2001) only considered motorised vessels as they found a lack of evidence that collisions with non-motorised vessels caused significant injuries to whales. We did find historical sail vessels could potentially cause injury to whales with the example of the sailing ship the *Barrossa* reportedly killing a whale in 1903.

Confirming the point raised by Ritter (2012), we found a significant number of reports from racing yachts competing in races. In Australia, as discussed in the section on data caveats, this over-representation is possibly due to the media coverage of yacht races, such as the Sydney to Hobart race. Furthermore, a limitation of this data is that the species or taxa involved are often unidentified.

One of the stranger vessels in the data was the submarine HMAS Otway which, on 1 September 1971, damaged its periscope mast in a collision with a whale. This isn't the only potential incident involving a submarine: the US Submarine V1 collided with a whale off New Hampshire coast in 1926; a German U-boat collided with a whale in the Atlantic in 1940; and a report mentions the HMS Affray (P421) in 1948.

[1] At this stage for a quick comparison the size categorisation was very approximate

Behaviour

Laist et al. (2001) commented that a few of their reports suggest "a last-second flight response". We are yet to analyse this aspect of our reports. A preliminary examination did provide some common witness accounts of whale behaviour. Five incidents had witnesses refer to the whales being asleep/unmoving prior to the collision (based on movement and the reaction to the collision, these animals were actually alive and not simply already dead). As mentioned previously, there were also some accounts (~4) of whales "attacking" vessels. Given the possible lack of understanding of whale behaviour in historic times, and overall view of whales (informed by popular literature, such as Moby-Dick), the veracity of some reports is potentially questionable and also the concept of intent on the whales' part is murky. However, it is interesting that a few of these accounts refer to sperm whales. One incident reports after an initial accidental collision the whale turned and "retaliated" with a second collision.

Injury

If there was ever any question of the potential for injury, this is confirmed by the descriptive accounts of whale injuries. Many describe the sea turning crimson, which while dramatic, may be an accurate description in some cases. Based on our assessment of all the new reports where the fate of the whale could be reliably determined (n=95), 52% were deemed to be fatal or likely to be fatal, 23% were reported as injuries or likely to be injuries, and 25% were unharmed (i.e., non-fatal/uninjured) (Figure 16). However, these results have high uncertainty as in all cases the medium to long term effect on the animal from the collision is unknown.

The Australian data, included 2 human fatalities from vessel collisions with whales, 8 records of vessels sinking, capsizing and/or being abandoned and 20 vessels being badly damaged.

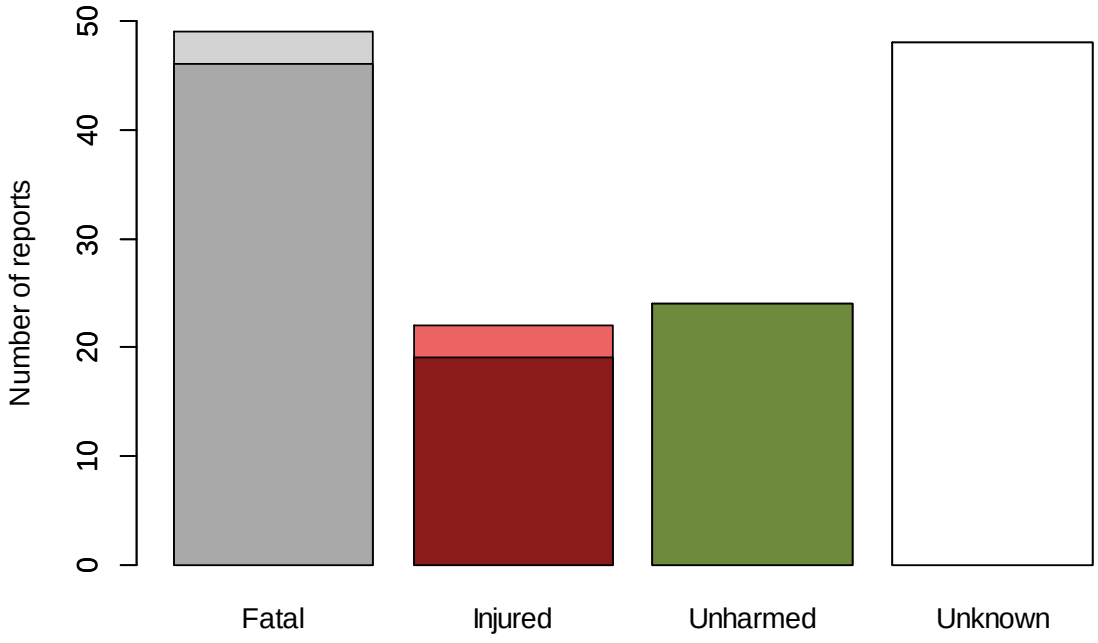

Figure 16 Outcome of collisions for struck whales from Australian vessel strike data. Lighter shaded boxes denote probable outcomes (e.g., light red is highly likely to be injured from the description of the collision).

Collision detection

Reported vessel strikes often included information on whether the whale collision was seen and/or felt by individuals on the vessel. As expected, individuals on smaller vessels were more likely to notice and feel the collision than those on larger vessels (Figure 17).

We fitted a binomial GLM to the data (Figure 18), to further explore the relationship between reported impacts being felt versus the size of the vessel and also whether the vessel had passengers.

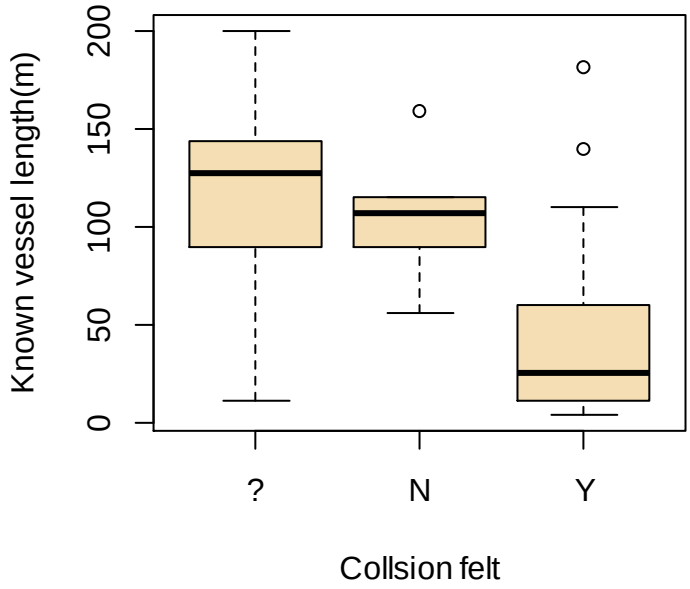

Figure 17 Box plot showing different distribution of length for vessels where the collision was felt to those where it was not. From Australian vessel strike data.

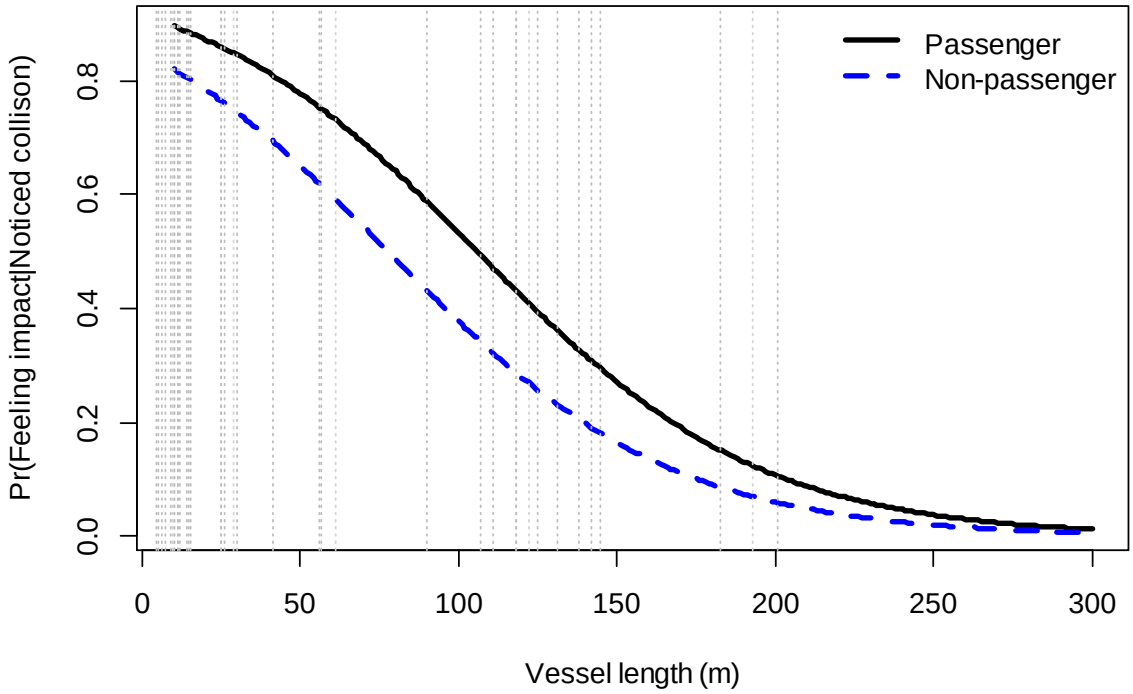

Figure 18 Modelled probability of detection (i.e., it being felt) of a vessel strike versus vessel length from Australian vessel strike data (vertical gray dotted lines = data, i.e., known length and information on if the collision was felt).

There are some limitations/issues with this analysis. The main one is that what is being estimated is not the actual probability of feeling a strike (as we have no data on incidents that were not felt or seen) but rather relates to how many of the collisions that were detected in some way, were felt on-board the vessel. So we are estimating the Pr(Felt | Noticed). The unconditional probability of a collision being felt on a vessel will obviously be much lower if all unfelt strikes (witness plus un-witnessed) were considered. What we did find was that there is a large drop in probability of feeling a strike as vessel size increased, with non-passenger vessels having the lowest relative probability across all lengths (see Figure 18). This makes sense considering passenger vessels carry significantly more people and therefore are more likely to detect a strike either visually or feeling an impact on the vessel.

We did not look any further at this, given the caveats of the data. However, there are further potential analyses that may give some interesting insights into the issue of under-detection/reporting.

DISCUSSION

The advent of accessible online newspaper archives has allowed the discovery of a large number of vessel strike incidents (both Australian and worldwide) that have not been included in any of the existing vessel strike databases. However, whilst our search was not exhaustive—and additional records no doubt exist—the search has made a reasonable attempt to capture most of the publically available records.

As we have discussed, there is a difficulty when considering vessel strike data due to potential reporting bias and other issues. Consequently, there is the danger that any conclusions will reflect the biases of the data rather than representing the real world situation. In this paper, we tried to make some useful inferences about vessel strikes, while acknowledging the potential biases and their effect on the results.

Incidence/rate of vessel strikes

Due to differences in the underlying data collection mechanism between historic and modern data, we saw a significant increase in the number of reported vessel strikes in the late 1990's. Modern data was collected directly from Government agencies (i.e. State and/or Commonwealth) and/or researchers each year, compared with the uncoordinated collection of reports prior to this which had no formal reporting mechanism or centralised collection point. These factors are highly likely to have contributed to the increase in reporting rate in recent times compared that found in the historic data.

There are two additional factors that may have contributed to this increase: 1) modern data will include incidents that may not reach the media, due to independent, direct reporting systems now being in place; and 2) all contemporary reports appearing in the media are likely to be discovered given their coverage by existing search engines and formal reporting mechanisms, whereas historically, not all newspapers and articles are available to search engines.

Laist et al. (2001) found ship strike "remained infrequent until about 1950, and then increased during the 1950s-1970s as the number and speed of ships increased". In contrast, we have a low number of reports from 1950 right up until 1999. Some reduction in rate was expected given Australian whale populations were so severely depleted around this time, and the resulting lag time before recovery. However, as populations recovered we would have expected the reported rate of vessel strike to have increased, especially

given significant increases in fleet size and average speed. As detailed in the results section, it was evident this lack of a clear increase was most likely due to a coverage gap in our newspaper databases rather than a real effect. This demonstrates the problem with not identifying biases in the reporting rates and not considering the underlying data collection/collation issues when formulating conclusions from the data. While research of non-digitised media could help fill the coverage gap, this would be a considerably lengthy process.

Species

Since we only really have substantial species identification in the modern data series, we are unable to reliably comment on species struck in the historic data. Given the sequential depletion of whale species due to commercial and illegal whaling in the 20th century, we would expect in the late 19th/early 20th Century there to be more diversity in species but unfortunately the data are insufficient to provide much insight into this.

Humpback whales are the most common species reported in the modern datasets, for both the world and Australia. This is likely to be representative of the fact that humpback whales are reasonably abundant and rapidly recovering in many parts of the world. They also are very coastal during periods of their migration and are the primary target of whale watching operations across the world due to their conspicuous aerial behaviour. These three factors mean that they are highly visible and interactions (of all types) with humans are common.

The other commonly struck species in Australian waters is the Southern right whale. In general, the species most commonly reported in Australia correspond to the most common species struck internationally. However, there is one exception in that though fin whales are the second most commonly struck species internationally, they are ranked eighth for Australia. Fin whales also did not feature highly in Van Waerebeek et al. (2007) data series for the Southern Hemisphere.

Vessels involved

Figure **3** indicates a pattern in the data, where the length of vessels involved gradually increased from 1840-1940, most likely reflecting the increase in length of the typical vessel in the international shipping fleet. By contrast, most modern (post-1997) Australian vessel strike reports involve much smaller vessels. This may in part be due to the different sources of data, considering historical data was from newspapers where large ships were bigger news and therefore more likely to be reported. Furthermore, there would have been few small-but-fast vessels around during this historic period, so it is likely that these types of vessel comprised a very small part of the overall shipping levels. This does seem to be reflected in an increase in smaller vessel strikes reported in the modern data, as the increase in the number of recreational vessels in Australian waters may also contribute to this rise.

Overall, we are seeing an absence of reports in modern data of vessel strike from large vessels, particularly cargo vessels, in modern data. This may reflect the natural progression of ship size and type over the last 150 years, with modern vessels reaching a size and a level of automation/crew size where collisions simply go un-noticed. As we saw from our exploratory analysis of the probability of feeling a strike given a known strike occurred, individuals on large non-passenger vessels have an acutely lower probability feeling any impact from a strike. Furthermore, historically, before air travel

was commonplace, many of the larger vessels were passenger ships, and hence had a higher likelihood of collisions being seen.

This idea of large modern vessels just not noticing collisions has already been proposed by Félix and Van Waerebeek (2005) and given the size and level of automation in modern vessels this seems both reasonable and plausible. Worldwide, there have been numerous cases (as well as in Australia) of whales being stuck on bulbous bows of ships and only being detected by people on the wharf upon docking. Finally, there has been at least 11 incidents in Australian waters since 1990 of large commercial vessels colliding with smaller yachts and fishing vessels (ATSB), and the large vessels not seeing, hearing or feeling the collision. Admittedly, potentially there may be a subterfuge to avoid liability. However, we would argue if this is the case, then a similar motivation would also hinder reporting of whale collisions. Therefore, overall, it would seem quite reasonable that the majority of whale collisions with large vessels would go unnoticed and/or unreported, if noticed.

Despite the lack of reported incidents with these larger vessels, there is some indication that collisions with larger vessels are still occurring. As seen in Figure 7 there were a reasonable number of strandings in modern times where it is not possible to attribute the strike to vessel of known size. Given the size of vessel required to fatally injure a large whale, we would posit that the incidents most likely involved large vessels. Given the issue of detection, together with the general increases and the sudden drop in vessel lengths over time (Figure 14), we would argue that despite the lack of witnessed incidents, large vessels are in fact still colliding with whales in Australian waters.

CONCLUSION

As stated at the beginning of the paper, this work is only a preliminary exploration of the Australian data. Next the data will be further cleaned, validated and then uploaded to the Australian Government vessel strike database. Further cross checking for duplication of existing IWC data needs to be done and then the data can be added to the existing IWC data base.

ACKNOWLEDGMENTS

This work was undertaken for the Marine Biodiversity Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Science Programme. AMMC for their support and advice. This work would not have been possible without the national library TROVE system which provided easy access to a large database of historical Australian newspapers. We would like to thank Mike Double for presenting the paper to the IWC; Natalie Kelly, Jessica Ford and Nic Bax for suggestions and comments on the paper; and Geoff Hosack (CSIRO) for providing the draft AIS density maps.

REFERENCES

ATSB Australian Transport Safety Bureau Transport Safety Reports; Marine Occurance Investigation. Reports: mair25, mair44, mair54, mair104, mair116, mair125, mair151, mair177, mair240, mo2008001, mo2014006.

BITRE (2015). Yearbook 2015: Australian Infrastructure Statistical Report. *Bureau of Infrastructure, Transport and Regional Economics*.

Endresen, Ø., E. Sørgård, H. L. Behrens, P. O. Brett and I. S. Isaksen (2007). A historical reconstruction of ships' fuel consumption and emissions. *Journal of Geophysical Research: Atmospheres* ***112*** *(D12).*

Félix, F. and K. Van Waerebeek *(2005).* Whale mortality from ship strikes in Ecuador and West Africa. *Latin American Journal of Aquatic Mammals* **4**(1): 55-60.

IWC (2010). 2010 Ship strike summary data. International Whaling Commision.

Jackson, J. A., Ross-Gillespie, A., Butterworth, D., Findlay, K., Holloway, S., Robbins, J., Rosenbaum, H., Weinrich, M., Baker, C.S., and Zerbini, A. (2015). Southern Hemisphere Humpback Whale Comprehensive Assessment A synthesis and summary: 2005-2015. *Rep. int. Whal. Commn* SC/66a/SH3, 38pp.

Jensen, A. S., G. K. Silber and J. Calambokidis (2004). *Large whale ship strike database*, US Department of Commerce, National Oceanic and Atmospheric Administration Washington, DC.

Kemper, C. (2008). Analysis of South Australian Museum's cetacean data: distribution, seasonal trends and circumstance of death, *South Australian Museum*.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet and M. Podesta (2001). Collisions between ships and whales. *Marine Mammal Science* **17**(1): 35-75.

Neilson, J. L., C. M. Gabriele, A. S. Jensen, K. Jackson and J. M. Straley (2012). Summary of reported whale-vessel collisions in Alaskan waters. *Journal of Marine Biology* **2012**.

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. *Rep. int. Whal. Commn*. SC/60/SH31.

Ritter, F. (2012). Collisions of sailing vessels with cetaceans worldwide: First insights into a seemingly growing problem. *Journal of Cetacean Research and Management* **12**(1): 119-127.

Van Waerebeek, K., A. N. Baker, F. Félix, J. Gedamke, M. Iñiguez, G. P. Sanino, E. Secchi, D. Sutaria, A. van Helden and Y. Wang (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals* **6**(1): 43-69.

APPENDIX: AUSTRALIAN DATA

Apx Table 1 Draft summary of preliminary Australian data 1872-2016. Dark shading indicates already in IWC 2010 database. Light shading indicates in an Australian IWC progress report.

Date	Location	Vessel	Source*
15/12/1872	30 miles East of Cape Howe, NSW	King Oscar	The Age 6/1/1872
4/3/1882	50 miles south of Cape Leeuwin, WA	Pet	Walaroo Times 8/3/1882
1888	Australian waters	HMS Myrmidon	Yorkshire Gazette 17/3/1888
1889	Between Cape Jarvis and Yankalilla, SA	James Comrie	Port Pirie Standard & Barrier Advertiser 31/5/1889
Dec/1891	10 miles North of Wollongong, NSW	Titus	Richmond River Herald & Northern Districts Advertiser 4/12/1891
1894	Two fold Bay, Sydney, NSW	Tea Tephi	The Evening Telegraph 13/10/1894
Sep/1897	Outside the heads, Perth, WA	Stormcock	Inquirer & Commercial News 1/10/1897
1//12/1900	Off Maria Island, TAS	Warrentinna	The Week/Brisbane 17/Dec/1900
Jan/1903	Lord Horne Island, (NSW?)	Barossa	Zeehan & Dundas Herald Tas. 24/1/1903

17/9/1903	Geraldton, WA	Viking	Kalgoorlie Miner WA 18/9/1903
Jul/1904	8 miles North East of Smoky Cape, NSW	Kyogle	North Western Advocate & the Emu Bay Times, Tas 23/7/1904
3/8/1904	Wollongong, NSW		Darling Downs Gazette 3/8/1904
Jan/1905	17 miles off Dongarra, WA		The Brisbane Courier 17/1/1905
Jan/1905	West of Olive Island, and off Streaky Bay, SA	Governor Musgrave	The Register, Adelaide 17/1/1905
26/10/1905	Off Southport Island, TAS	Houn Pine	TASMANIAN SHIPWRECKS
Oct/1907	South Solitary Island, NSW	Yongala	The Brisbane Courier 8/10/1907
Jun/1911	Between Gabo Island and Wilson Prom (off 90 mile beach), VIC	Grantala	Globe, Sydney 21/6/1911
Nov/1913	Between Sydney and Byron Bay, NSW	s.s. Wollongbar	Northern Star, Lismore 7/11/1913
14/1/1915	Cape Bridgewater-Point Danger, VIC	Nancy	Portland Observer & Normanby Advertiser 18/1/1915
1923	Few miles from Port Adelaide, SA	Treverbyn	News, Adelaide 29/10/1923
1926	500 miles from WA coast, WA	Nardana	Sydney Morning Herald 16/Jan/1926
1927	50miles South of Gabo Island, VIC	Zealandia	Sydney Morning Herald 18/1/1927
1927	30 miles at sea	Lamson	Bunbury Herald & Blackwood Express, WA 26/9/1927
Aug/1928	North of Yeppoon, QLD	Nellie	The Argus, Vic, 3/8/1928
Aug/1928	Between Fremantle and Adelaide, WA/SA	Ozarda	Examiner, Tas 11/8/1928
Jul/1929	150 miles west Neptune Is Lighthouse, SA	Kooliga	Sydney Morning Herald 26/7/1929
Jun/1930	Off Qld coast, QLD	Taiping	Advocate, Burnie 9/6/1930
28/8/1934	Sydney Harbour, NSW	Baragoola	The Mercury, Tas, 29/8/1934
Nov/1934	300 miles off Sydney Heads, NSW	Mariposa	Barrier Miner, NSW 8/11/1934
Nov/1934	Near Montague Island, NSW	Wanganella	Goulburn Evening Penny Post, NSW 2/11/1934
Oct/1935	Off Coffs Harbour, NSW	Ormonde	The Courier/Mail, Qld 1/10/1935
May/1936	Off Albany, WA	Imperial Star	Advocate, Tas 4/5/1936
Nov/1936	Mouth of Moyne river, VIC	Seaflower	Border Watch, SA 24/11/1936
Nov/1936	Mouth of Moyne river, VIC	Victory	Border Watch, SA 24/11/1936
Apr/1937	Mooloolaba, QLD		The Telegraph, QLD 26/4/1937
Aug/1937	Bight, about 350 miles east of Eclipse Island, WA	Almkerk	The Advertiser, SA 21/8/1937
Dec/1938	200 miles off Aus Coast Brisbane to Auckland, QLD	Orford	The West Australian 24/12/1938
1940	A mile off Currumbin Beach, QLD	Wonderbelle	The Courier/Mail, Qld 25/9/1940
Sep/1946	30 miles W of Lady Hamiliton Island, QLD		Canberra Times 5/9/1946
Nov/1948	Sydney to Broken Bay, NSW	Aloha	Canberra Times 15/11/1948
Jun/1952	Great Australian Bight, WA/SA	La Estancia	The Argus 5/6/1952
Aug/1952	2 miles to sea off Cape Moreton, QLD	Omar	Daily Mercury Mackay 25/8/1952
29/1/1953	Cape Douglas, SA		Border Watch Mt Gambier 29/1/1953
27/9/1954	Woolgoolga, NSW		The Courier/Mail, Qld 28/9/1954
28/9/1954	Coffs Harbour, NSW		Northern Star Lismore 28/9/1954
31/12/1958	Frederick Henry Bay-Slopen Island, TAS		IWC DATA
1963	Close off South Molle Island, QLD		Website - Anecdotal
25/1/1964	180 miles NW of Freemantle, WA	Iberia	Canberra Times 25/1/1964
8/8/1970	off the WA coast,WA	Alma Mary	Shipwreck website
1/9/1971	Off Sydney,NSW	Otway	The Age 2/9/1971

Aug/1974	2 miles SW of West Island,Near Waitpinga coastline, SA		Victor Harbour Times SA 28/8/1974
Dec/1986	Bass Strait, Syd to Hobart race, NSW/TAS	Amaroo III	Canberra Times 20/12/1986
15/5/1992	Bass Strait, TAS		IWC DATA
Dec/1993	Syd to Hobart race, NSW/TAS	Brindabella	Canberra Times 30/12/1993
Dec /1994	Bass Strait Syd to Hobart race, NSW/TAS	Tasmania	Canberra Times 30/12/1994
Dec /1995	Off Eden NSW - off Montague Island on the south coast of New South , 70 feet of water close to Victor harbour, NSW	Future Shock	Canberra Times 28/12/1995
Dec /1995	Syd to Hobart race, NSW/TAS	King Billy	ABC 27/12/1995
27/8/1999	Off Keppel Ilsands, Qld	HMAS Sydney	SC/52/ProgRepAustralia
Jan/2001	1.8km off Merimbula, NSW		New Straits Times 6/1/2001
2001	NSW		SC/54/ProgRepAustralia
21/5/2001	Off Barrenjoey headland,NSW		Daily Telegraph 28/6/2001
22/6/2001	Lower Hawesbury R., NSW		IWC DATA
21/7/2001	Cape Jervis, SA		IWC DATA
2001	Whitsunday Island, QLD		IWC DATA
2001	WA		SC/54/ProgRepAustralia
31/8/2002	Prosser Bay-Orford (Shelly Point), TAS		IWC DATA
3/10/2002	Exmouth Gulf, WA		IWC DATA
3/11/2002	Tasman Peninsula, TAS		IWC DATA
28/12/2002	Sydney to Hobart race	Sting	AAP Herald 30/12/2002
28/12/2002	Sydney to Hobart race	Fitness First	Daily Telegraph 30/12/2002
2003	Area V		SC/56/ProgRepAustralia
2003	SA		SC/56/ProgRepAustralia
27/5/2003	Station Creek, NSW		IWC DATA
1/8/2003	Hook Island, Whitsundays, QLD		ABC News 4/8/2003
16/8/2003	Townsville, QLD		IWC DATA
8/10/2003	Seven Mile Beach, Shoalhaven Heads, NSW		South Coast Register 8/10/2003
5/8/2004	Port Douglas, QLD		SC/57/ProgRepAustralia
2/8/2004	Cleveland Bay Townsville, Qld		SC/57/ProgRepAustralia
Sep/2004	off Hayman Island's Dolphin Point, Qld		Herald-Newcastle 10/9/2004
12/11/2004	East coast Bruny Island, TAS		IWC DATA
15/7/2006	Nata Inlet, Whitsundays, QLD		IWC DATA
25/8/2006	Whitsundays, QLD		IWC DATA
1//12/2006	Gage Roads Fremantle, WA		IWC DATA
1/8/2007	Hook Island, east of Airlie Beach, QLD		IWC DATA
2007	East Tasmania, TAS		IWC DATA
12/8/2007	Off south coast of Australia, SA		IWC DATA
2007	East Coast Tasmania, SA		IWC DATA
26/8/2007	Mission Beach		Cairns Post 29/8/2007
29/8/2007	Whitsundays, QLD		IWC DATA
17/9/2007	Near Dunk Island, QLD		IWC DATA
1//12/2007	Tasmania's East Coast, TAS		IWC DATA
12/1/2008	Lincoln National Park, SA		IWC DATA
14/8/2008	Stradbroke Island, QLD		Sailworld
16/8/2008	Between Hayman Island & mainland, QLD		IWC DATA
17/8/2008	Bundaberg, QLD		Sailworld
17/8/2008	Fraser Island, Australia, QLD		IWC DATA
21/8/2008	Off south west Australia, QLD		IWC DATA
8/9/2008	Clump Point, Mission Beach, QLD		IWC DATA

20/9/2008	20nm East Coffs Harbour, NSW		IWC DATA
6/10/2008	Twelve Apostles, VIC		SC/61/ProgRepAustralia
7/10/2008	Off Gladstone, QLD		IWC DATA
26/10/2008	Byron Coast, NSW		IWC DATA
26/10/2008	Richard River, NSW		IWC DATA
8/4/2009	Rye Ocean Beach, VIC		SC/62/ProgRepAustralia
28/7/2009	Hervey Bay, QLD		IWC DATA
2/9/2009	Exmouth Gulf, WA		IWC DATA
12/9/2009	Uladulla, NSW		SC/62/ProgRepAustralia
12/9/2009	Batemans Bay, NSW		IWC DATA
2/10/2009	NSW		IWC DATA
26/10/2009	Fremantle, WA	HMAS Perth	IWC DATA
- End of IWC 2010 Data -			
5/4/2010	Cyrlis Beach, Flinders, VIC		SC/63/ProgRepAustralia
17/7/2010	Broome, WA		SC/63/ProgRepAustralia
22/9/2010	Sandon Point, Illawara, NSW		SC/63/ProgRepAustralia
5/10/2010	Exmouth, WA		Express 6/10/2010
22/11/2010	Port Wakefield, SA		SC/63/ProgRepAustralia
19/6/2011	Moreton Bay, QLD		SC/64/ProgRepAustralia
24/6/2011	Sydney Harbour, NSW		Daily Telegraph 24/6/2011
26/6/2011	Red Cliff, Brooms Head NSW		Central Qld News 28/6/2011
28/6/2011	Blue Pearl Bay, Hayman Island, Whitsundays, QLD		SC/64/ProgRepAustralia
5/08/2011	Hervey Bay bar, QLD	Ally Jay	Fraser Coast Chronicle 6/7/2011
27/08/2011	10km ESE Border Village SA		SC/64/ProgRepAustralia
9/10/2011	Moreton Bay, QLD		SC/64/ProgRepAustralia
10/11/2011	Fremantle, WA		SC/64/ProgRepAustralia
24/7/2012	Hungry Beach, NSW		Bellingen Courier Sun 24/7/2012
25/7/2012	Brisbane/Moreton Bay, QLD		SC/65/ProgRepAustralia
6/8/2012	Sydney Harbour, NSW	ferry	Sydney Morning Herald 6/8/2012
20/8/2012	Bribie Island, 25 nm NE, QLD		news.com.au 20/8/2012
25/9/2012	Yamba, NSW	Kathmandu	Daily Examiner 27/9/2012
15/10/2012	32 km north of Streaky Bay, SA		SC/65/ProgRepAustralia
12/11/2012	Laura Bay, Great Australian Bight, SA.		SC/65/ProgRepAustralia
31/12/2012	Sydney to Hobart	Secret Men's Business	Australian 31/12/2012
3/8/2013	Hervey Bay, QLD	Yacht	Central Qld news 10/8/2013
2013	2.7km NNE Point Bolingbroke, SA		SC/66/ProgRepAustralia
14/8/2014	Gladstone, Lady Musgrave Island, QLD		Morning Bulletin 15/8/2014
15/8/2014	Moreton Bay, QLD		SC/67/ProgRepAustralia
16/8/2014	Moreton Bay, QLD		SC/67/ProgRepAustralia
8/12/2014	Ardrossan, SA		Mlssa website 10/12/2014
2014	Off Cape Moreton, QLD		SC/67/ProgRepAustralia
28/7/2015	Broome, WA		ABS News 4/8/2015
14/8/2015	Stradbroke Island, QLD		Redland City Bulletin 14/8/2015
21/8/2015	Port Hedland, WA		Facebook posting
8/9/2015	Hay Point, QLD	Tug	Sydney Morning Herald 10/9/2015