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Characterisation of Hector’s and Māui dolphin (*Cephalorhynchus hectori*) incident data focusing on temporal patterns

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A publicly available database of Hector’s and Māui dolphin (*Cephalorhynchus hectori hectori* and *Cephalorhynchus hectori maui*, respectively) mortalities and other incidents is maintained by the New Zealand Department of Conservation. Previous summaries indicate that it may be possible to use these data to infer changes in the mixture of threats affecting Hector’s and Māui dolphins through time.

A characterisation of these data found evidence for strong seasonality in the major causes of death, including entanglement mortalities in fishing gear (i.e., ‘bycatch’), disease mortality, neonate deaths, and others. However, the seasonal pattern of detected deaths varied by cause of death, with some being more prevalent in summer (e.g., fishery-related deaths), others being more prevalent in spring (disease — which could include pneumonia, toxoplasmosis, and others), and others appearing to be less seasonal (general natural causes).

Mortalities in spring months appear to primarily affect females, and this was coincident with the period when all known toxoplasmosis mortalities have occurred to date. The female bias in mortalities during spring was evident from 2000 to 2020, but not in the preceding decade, although the estimate in this earlier time period was based on a small sample size.

There was only tentative, non-significant evidence for changes in the demographic composition of fishery entanglement mortalities with the implementation of area restrictions for different fisheries around New Zealand. Few females were confirmed amongst incidental mortalities since the implementation of wide-ranging fishing restrictions in 2008/09, although a large component of the mortalities during this period that were in the database were not necropsied and sexed.

This study also developed a rudimentary proxy for seasonal carcass detection probability, based on seasonal beach count data. This suggested that carcass detection probability is likely to be highly seasonal, such that threats that primarily kill dolphins outside the summer period may be greatly under-represented in the beachcast sample of dolphins relative to those that kill dolphins in summer.

Future assessments using beachcast dolphins to infer the causes of death in the wider population would ideally use an index of seasonal carcass recovery rate to account for seasonal biases affecting various causes of death. This could use data specific to the South Island when relating to Hector’s dolphin mortalities. In addition, targeting search effort outside the summer period appears to be good option for increasing the carcass detection rate, and to better understand the causes of mortality outside the summer period.

1. INTRODUCTION

A publicly available database of Hector's and Māui dolphin (*Cephalorhynchus hectori hectori* and *Cephalorhynchus hectori maui*, respectively) mortality events — including dolphins found entangled in fishing gear, beachcast carcasses, and other types of mortalities — is maintained by the New Zealand Department of Conservation (DOC) (DOC 2020). This is hereafter referred to as the "Hector's and Māui dolphin incident database". Previous summaries of these data indicate that they may be informative of temporal patterns of Hector's and Māui dolphin mortalities attributed to different causes of death (DOC 2008, Slooten & Dawson 2016). Also, a previous, unpublished pilot analysis found evidence for changes in the demographic composition of mortalities through time, that could be informative of a changing mix of threats to Hector's and Māui dolphins (Roberts, unpublished data).

This project used the latest available extract of the Hector's and Māui dolphin incident database to briefly characterise some specific temporal patterns:

- Changes in the rate and demographic composition of recorded deaths attributed to fishing, in relation to changes in fisheries restrictions;
- How these compare with potential temporal changes in the rate and demographic composition of non-fishery deaths; and
- The annual rate of non-fishery deaths in spring that were not already attributed to a primary cause of death other than toxoplasmosis.

Potential hypotheses were then identified to explain any observed temporal patterns, with respect to seasonal variability, and potential longer-term changes.

From other species it is known that many causes of death will be highly seasonal, and this seasonality can vary with causal factor (e.g., ten Doeschate et al. 2019). It is also acknowledged that seasonal variation in carcass detection rate (typically high in summer and low in winter) can bias the relative detection probability of different causes of death, when basing this on beachcast individuals (ten Doeschate et al. 2018, Roberts et al. 2019). To gain an indication of what this might mean for the detection of different causes of death affecting Hector's and Māui dolphins, an exploratory proxy of seasonal carcass detection rate was developed based on beach use information.

2. METHODS

2.1 Dolphin incident data

The latest extract of the Hector's and Māui dolphin incident database (DOC 2020) was provided by DOC (extracted 21 April 2020). This includes incidents observed between 1921 and January 2020, and included records of individual mortalities and other incidents, including entanglements in fishing gear, beachcast dolphins, individuals recovered at-sea, and other sources.

All temporal subsets and summaries were based on the recorded date that the event was observed, rather than the date of reporting. A "breeding year" was used for annual data summaries, which began on 1 October each year, and was reported as the end year of each breeding year (e.g., 1 October 2000 occurred in breeding year 2000/01 and would have been referred to as "2001"). A subset of the database extract was used by this characterisation, excluding records collected prior to 1984/85 because necropsies were not undertaken for the earlier records. Note that the resulting subset included a number of dolphins that were not necropsied.

Sex was determined from genetic analysis (field name = "Sex confirmed by DNA") where this information was available. Otherwise, the sex determined visually during necropsies was used (field name = “sex”). The sex of one individual (“MarMam_individual_ID_num_PK” = “351”) was updated (female), based on a genetic analysis not yet included in the latest incidents database extract (Rochelle Constantine unpub. data).

Some additional processing of the data was undertaken to facilitate the characterisation and analyses of the data, relating to the “Observation type” and “Necropsy results” fields. The “Observation type” field was used to create a new field giving the status of an individual (i.e., dead or alive). Records under the “Observation Type” field were then reclassified by removing status information (e.g., “at_sea_dead" [called “Dead sighting at sea” in the incident database) and “at_sea_live" (a single individual found at sea and recorded as “Live sighting sick/wounded”), became "at_sea”], reducing the total number of categories, accordingly.

With respect to the “Necropsy results” field, the only changes were to streamline their naming to facilitate the processing of the data, e.g., "Natural causes- maternal separation" became "maternal_sep".

All data processing was undertaken in *R* and plots made using the *ggplot*2 package (Wickham 2017, R Core Team 2019).

2.2 Beachgoer observations

Hourly counts of beach users made by surf live saving (SLS) clubs of the New Zealand North Island were used to derive a ‘beachgoer index’. This was then used by this study as a proxy for seasonal carcass detection rates of Hector’s and Māui dolphins.

The beachgoer index used the data from all SLS clubs for which there was at least one count in the period from May to September. This analysis excluded: records from the Hotwater Beach, which was anomalously busy and had an atypical seasonal pattern of beach use; and Tolaga Bay, which had an anomalously low rate of beach use. The index was then calculated by simply taking the arithmetic mean of all counts (including people counted on the beach and in the water) by month across all clubs.

No attempt was made to standardise these data for factors known to affect beach use (such as time of day, weather, day of the week) or to account for holes in the data, due to time constraints. As such, the beachgoer index can be considered indicative of relative beach use, rather than a robust estimate.

3. RESULTS

3.1 Characterisation of incidents data

Annual summary

The sample of dolphins included in the Hector’s and Māui dolphin incident database is displayed by year (since 1984/85), observation type (e.g., beachcast, bycaught, and other categories), and status (dead or alive) (Figure 1). The majority of the sample comprised beachcast individuals (320 out of 507 for which the type was known), fishery bycatch (138 individuals) (obtained from active gear, as opposed to beachcast individuals later attributed to bycatch), dolphins recovered at-sea (28 individuals), and others.

Summary tables of the necropsy sample of dolphins by year, month, sex, reported sub-species, and region of carcass recovery are shown in Tables A-1, A-2, A-3, A-4, and A-5, respectively, in Appendix A. Of the total sample of 571 individuals, necropsies have been completed for 354, and results were recorded as “pending” for a further 17 dolphins. Of those for which the necropsy was recorded as completed, “entanglement” in fishing gear was the most frequent primary cause of death (152 dolphins), followed by disease (30), then maternal separation (25), and miscellaneous other causes of death. The primary cause of death was “indeterminable” for 106 out of 354 dolphins for which a necropsy was completed, and “unknown” for 13 individuals.

The annual composition of primary causes of death is shown for the beachcast portion of the necropsy sample (Figure 2). This composition changes through time: e.g., the dataset primarily comprises dolphin mortalities attributed to bycatch or indeterminable cause of death from 1984/85 to 2000/01; and more frequently of non-fishery causes of death thereafter, including disease, maternal separation (typically assigned to neonates for which the primary cause of death was not apparent) (Roberts et al. 2019), and general natural causes. It is likely that any temporal changes in the relative prevalence of different causes of death will be confounded with known changes in methods with respect to the acquisition and necropsy of dolphins. However, long-term trends could potentially be identified for causes of death that primarily affect some demographics or have pronounced or atypical seasonality (examples are given in the following sections).

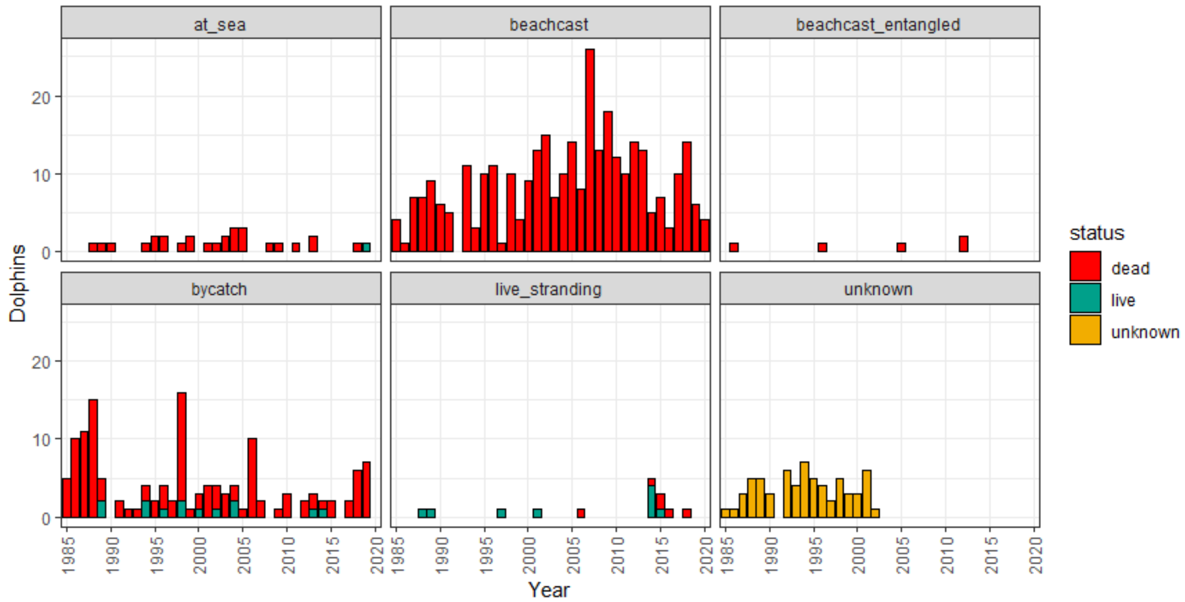

Figure 1: Observation type (origin) of Hector’s and Māui dolphin incident records by year and status (dead or alive), since 1984/85. This plot omits a single record of a “Vessel strike” mortality in 1998/99.

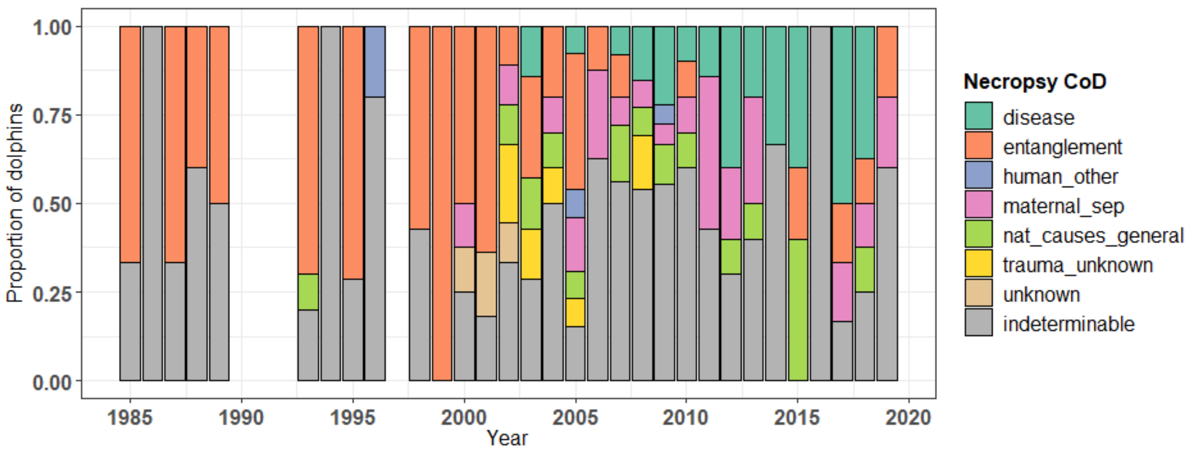

Figure 2: The annual composition of beachcast Hector’s and Māui dolphins by primary cause of death (CoD) (“Necropsy results”) since 1984/85. This plot omits a single foetus that was recovered from a female recorded as dying from disease.

Seasonality

There was a pronounced seasonality in the reporting of Hector's and Māui dolphin incidents, although the monthly distribution varied by observation type (e.g., whether from bycatch, beachcast, etc.) (Figure 3 and Figure 4). Approximately two-thirds (89 out of 138 records) of entanglements in fishing gear were reported in the summer period from December to February. The relative reporting rate of beachcast dolphins was also greatest in the summer period (148 out of 320 dolphins), although slightly more than half were reported in other seasons (59 in autumn, 26 in winter, and 87 in spring).

For necropsy records, the seasonal pattern of recorded deaths varied markedly by cause of death (Figure 5). A breakdown of the monthly distribution of records by sex and the most frequent primary causes of death determined by necropsy is given in Figure A-1 in Appendix A. Of 30 deaths caused by disease, slightly more than half (17) were reported in spring months, and around a third of those (11) were in October; whereas, approximately half (12 out of 25) of recorded maternal separation mortalities were recovered in December. The monthly distribution of mortalities attributed to general natural causes was more even by comparison.

The seasonality of recorded bycatch incidents in the database is very similar to that of the beachgoer index of people visiting beaches (Figure 3) (also see summary tables of this sample presented in Tables A-6 and A-7). This was also true for neonate mortalities attributed to maternal separation (Figure 5). As such, these and other types of mortality that are more frequent in the summer period are likely to have a relatively high chance of being detected if they subsequently wash up on a beach. By comparison, the higher proportion of deaths attributed to disease and general natural causes in winter and early spring, when beachgoer numbers are very low, suggests that these causes of death may be under-represented in the recovered portion of beachcast individuals (Figure 5). However, the total sample sizes are low for drawing concrete conclusions with respect to the prevalence of these causes of death.

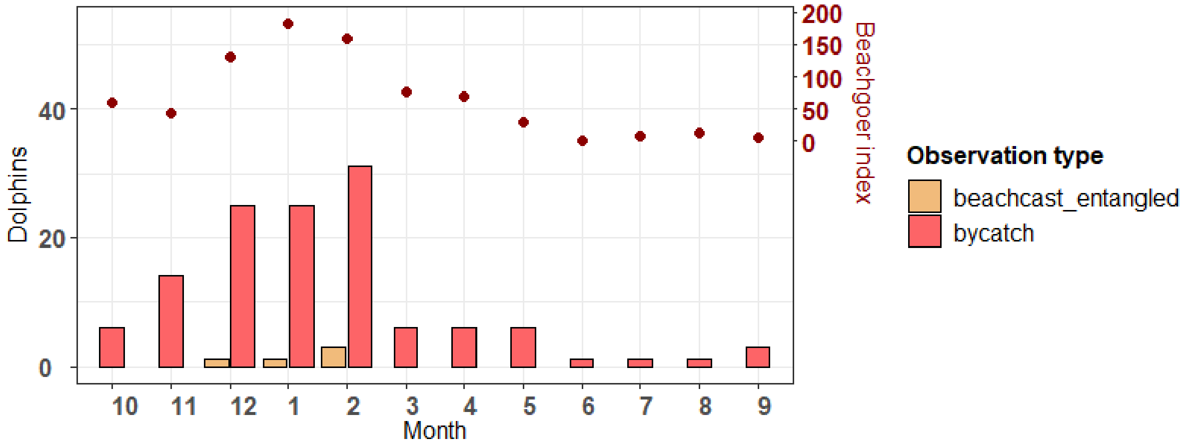

Figure 3: **Monthly frequency of Hector’s or Māui dolphins recorded as bycatch (“Entangled – caught in gear (dead)”, “Entangled – caught in gear (live and died)”, “Entangled – caught in gear (combination)”, or “Entangled beachcast” in the “Observation type” field, including all records since 1984/85. Also, the “beachgoer index” of the mean count of people using beaches by month. Month “10” is October.**

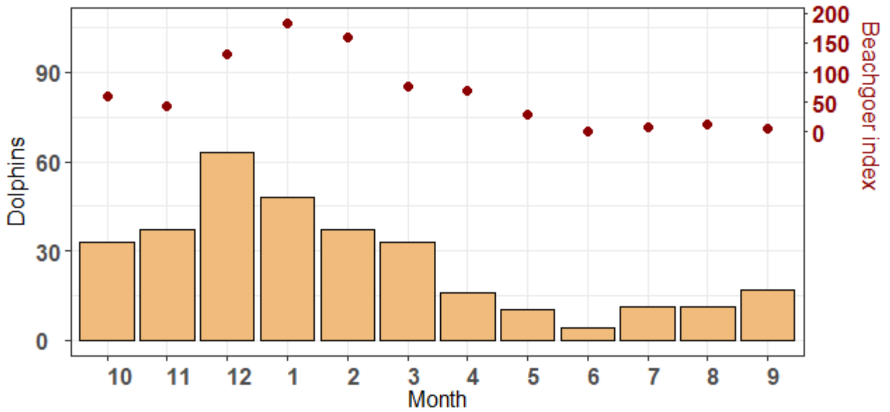

Figure 4: **Monthly frequency of Hector’s or Māui dolphins recorded as “Beachcast (dead on shore)” in the “Observation type” field, including all records since 1984/85. Also, the “beachgoer index” of the mean count of people using beaches by month. Month “10” is October.**

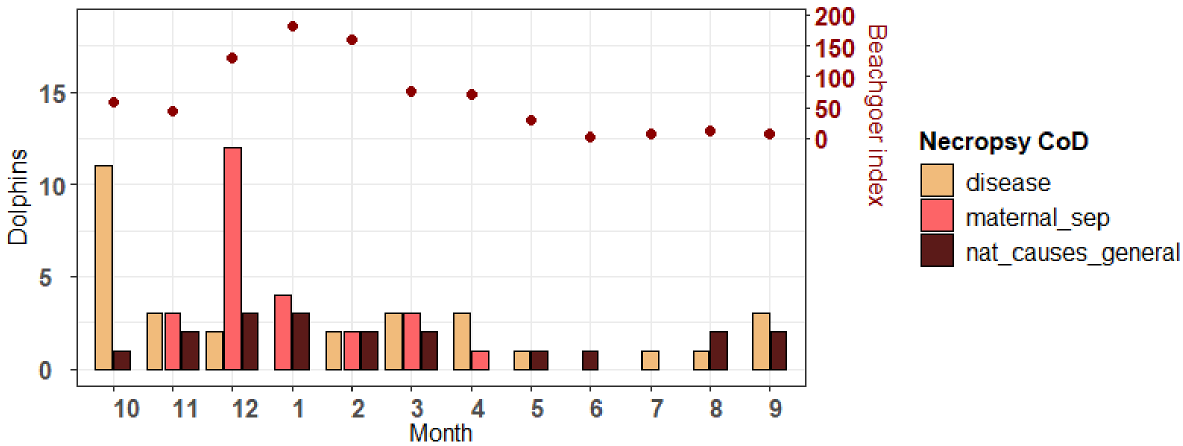

Figure 5: **Monthly frequency of Hector’s or Māui dolphins recorded as “Natural causes – disease”, “Natural causes – maternal separation”, or “Natural causes – general” in the “Necropsy results” field, including all records since 1984/85. Also, the “beachgoer index” of the mean count of people using beaches by month. Month “10” is October.**

3.2 Changes in demographic composition

The sex composition of fishery entanglement cases was similar to that of beachcast dolphins before 2008/09 (Figure 6), although with relatively more females from 1984/85 to 1987/88 (up to the implementation of the Banks Peninsula Marine Mammal Sanctuary), and slightly more males from 1988/89 to 2008/09 (i.e., up to the implementation of coastal fishery restrictions around most of New Zealand). Since 2008/09, the number of female bycatch mortalities in the database has been low (3 across 12 years) compared with the preceding period when there was less extensive protection of coastal waters (41 across 20 years). This decrease was less apparent for males, although a binomial test indicated that the proportion of females of 0.27 was not different from 0.50 in this period, given the available sample (exact binomial test, $p = 0.227$, 2-sided). A regional breakdown is given in Figure A-2, which highlights the high relative contribution of fishery entanglement mortalities along the Canterbury Coast. Note that many reported bycatch events were not sexed in this period.

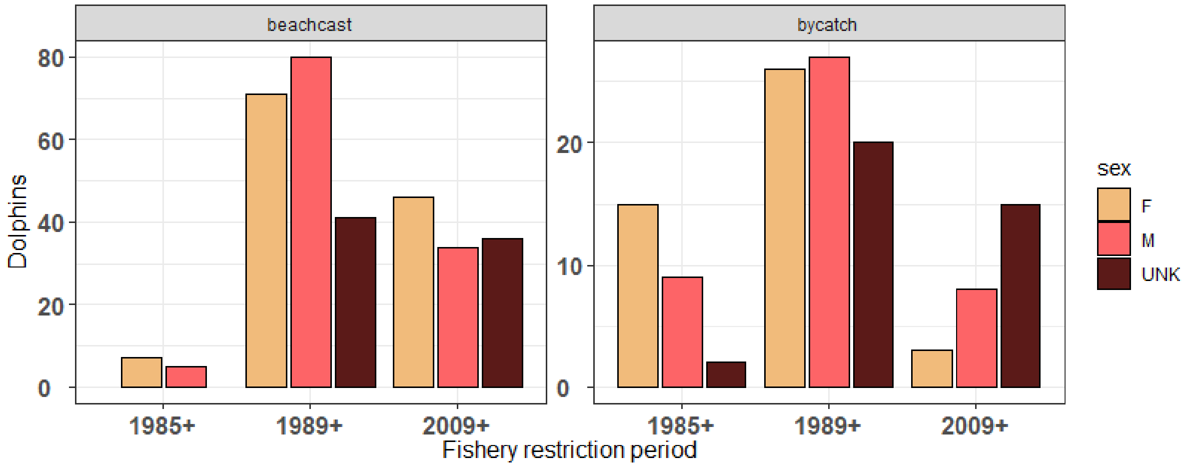

Figure 6: Sex composition of Hector's or Māui dolphin records of "Observation type": "Beachcast (dead on shore)" (left-hand panel) or "Entangled – caught in gear (live and died)" or " Entangled – caught in gear (combination)", or "Entangled beachcast" (right-hand panel) by fishery restriction period ("1985+" includes records since 1984/85 and prior to the implementation of the Banks Peninsula Marine Mammal Sanctuary effective from 1988/89; "1989+" includes records prior to the implementation of additional coastal fishing area restrictions around New Zealand in 2008; and "2009+" includes all records since 2008/09).

Where the sex was determined, the sex composition of reported beachcast mortalities was similar in all months except from August to October, when 36 out of 43 non-calves (approximately 85%) were females (Figure 7). More males were seen in the beachcast sample in other months also, e.g., December and February, although these were not continuous in time, like female mortalities in August to October. The proportion of females (0.84) was significantly different from 0.50 (exact binomial test, $p < 0.001$, 2-sided). More females were observed in the beachcast sample of spring months (September-November) in each of the top-four geographic regions in terms of sample size (Figure A-3). This corresponds with the timing of all known toxoplasmosis mortalities of Hector's and Māui dolphins to date (all in September–November) (Roberts et al. 2019, Roe et al. 2013, updated by Wendi Roe pers. comm.); toxoplasmosis appears to disproportionately affect breeding age females (Roberts et al. 2019). Note that some of the female mortalities in these months were already attributed to other causes of death. The apparent female bias in beachcast mortalities during spring months was observed in the 2000s and 2010s, but not in the preceding period (Figure 8).

Also during August–October, a significant female bias was detected in disease mortalities confirmed from necropsies (12 out of 13 cases for which the sex was determined) (exact binomial test, $p < 0.01$, 2-sided), and also a (only just) statistically significant female bias in the sample for which a cause of death could not be determined (18 out of 25 cases) (exact binomial test, $p < 0.05$, 2-sided). A female bias was not evident from fishery entanglements confirmed from necropsies (6 out of 13 were females) (Figure 9).

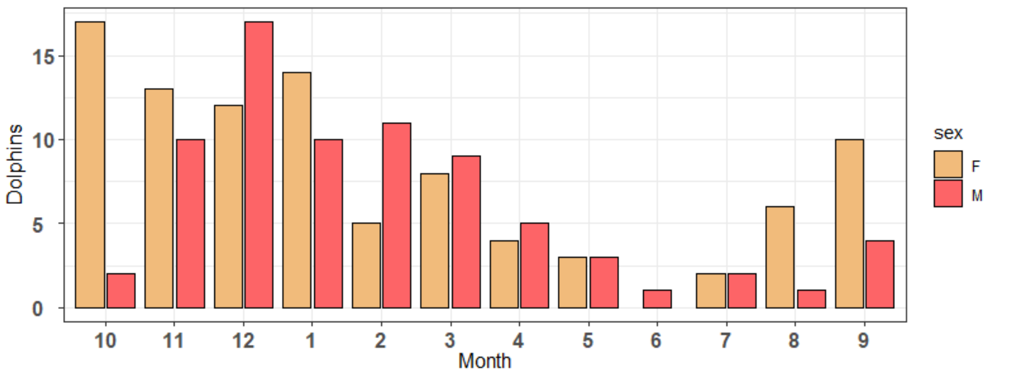

Figure 7: Sex composition of Hector's or Māui dolphin records of "Observation type": "Beachcast (dead on shore)" by month since 1984/85. This plot excludes juveniles or individuals for which the sex was not determined. Month "10" is October.

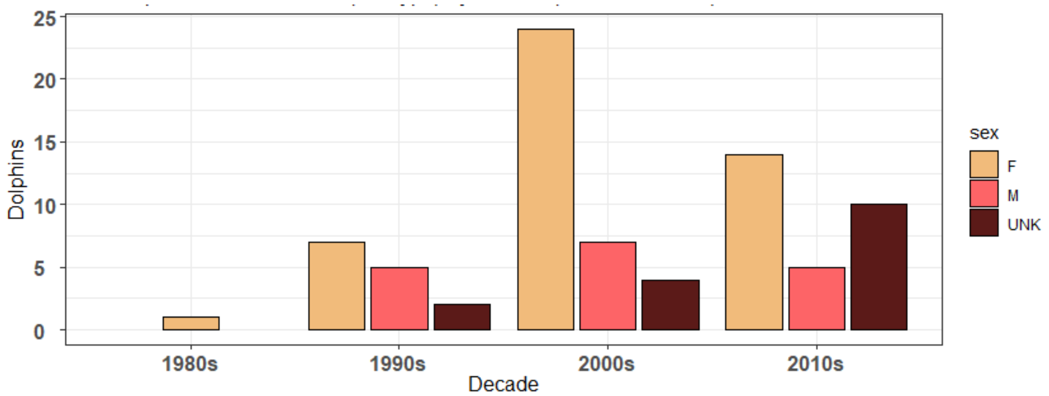

Figure 8: Sex composition of Hector's or Māui dolphin records of "Observation type": "Beachcast (dead on shore)" from August to November by decade. This plot includes records since 1984/85.

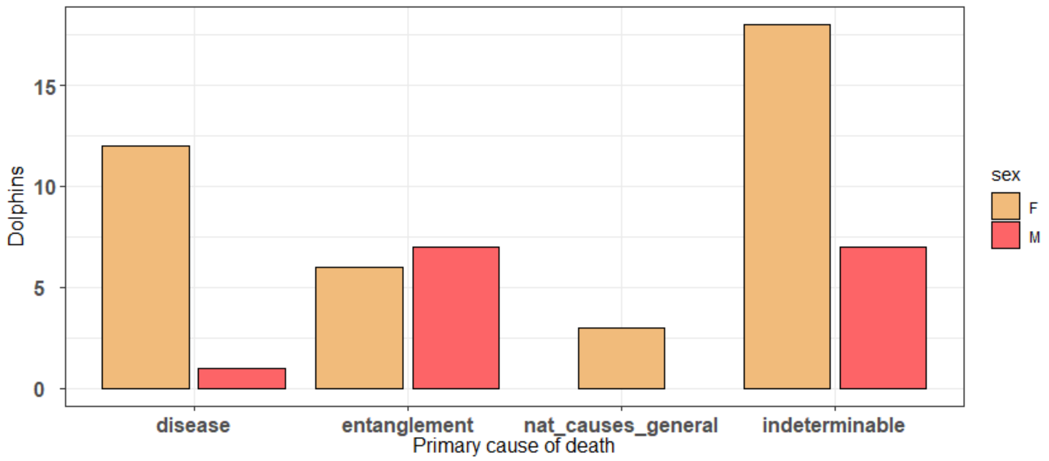

Figure 9: Sex composition of Hector's or Māui dolphin records of "Observation type": "Beachcast (dead on shore)" from August to November, by a selection of primary causes of death ("Necropsy results": "Natural causes – disease", "Entangled – caught in gear (live and died)", or "Entangled – caught in gear (combination)", or "Indeterminable", or "Natural causes – general"). This plot includes records since 1984/85 and excludes calves.

4. DISCUSSION

4.1 Limitations of this analysis

The total sample size of records in the Hector’s and Māui dolphin incident database was small for determining temporal, spatial, and demographic patterns with respect to different causes of death. The carcass recovery rate for Hector’s and Māui dolphins, based on the number of recoveries relative to the total number estimated to die each year, is low relative to other species (in the order of ~0.01 for Hector’s dolphin and ~0.10 for Māui dolphin, based on the outputs of Roberts et al. 2019). This compares with 0.08 for common dolphins (*Delphinus delphis*) along the coast of France and 0.33 for bottlenose dolphins (*Tursiops truncatus*) at Sarasota Bay, Florida, although the latter is high amongst delphinids (Peltier et al. 2012, Wells et al. 2015, Carretta et al. 2016). For many of the less frequent primary causes of death identified for Hector’s and Māui dolphins, the sample size is small enough that apparent seasonal and demographic patterns could arise out of random probability. Even for the more frequently recorded causes of death, the sample sizes precluded regional comparison.

Changes in methods with respect to the acquisition of carcasses for necropsy and then necropsy methods used have affected the relative detectability of different causes of death through time. Up until 1996, most carcasses were necropsied at Otago University and were primarily assessed for evidence of fishery bycatch only. Since 1997, necropsies were primarily undertaken at Massey University, and the focus was broadened to include non-fisheries causes of death (see Figure 2). As such, indirect methods (e.g., using changes in sex ratio to infer something about threats that affect sexes differently) may be preferable for inferring changes in the effects of different threats through time, though the results should be interpreted with caution.

The seasonal beachgoer index, used as a proxy for seasonal carcass detection rate, was based on beach counts by North Island SLS clubs. As expected, counts were much less frequent, or stopped all-together for some clubs in some months of winter and early spring (i.e., prior to the October school holidays). However, the index was comparable with another that was based on a formal survey of Waikato beaches that included year-round sampling, though with a much smaller sample size of counts (not reported here). Most records in the Hector’s and Māui dolphin incident database were of South Island dolphins, whereas the beach counts were made on the North Island, which is more densely populated and has a warmer climate. Beach counts are likely to also be made by South Island SLS clubs, such that the index produced here could be updated for the regions where most carcasses are recovered.

This exploration used a simple binomial test with respect to sex ratio. Other approaches, such as regression models including predictor variables, would be preferable for a more in-depth analysis. Thus, an appropriate level of caution should be exercised when using the various outputs.

4.2 Seasonal variation in threats and reporting

A few previous studies have described the seasonality of various causes of death in other cetacean species using beachcast samples (Prado et al. 2016, ten Doeschate et al. 2019). It is generally considered that seasonal variation in the carcass recovery rate of beachcast dolphins can create a biased sample relative to the true causes of death (ten Doeschate et al. 2018), particularly in temperate regions with low population density, such as New Zealand (Roberts et al. 2019). The lack of information about the seasonality of cetacean mortality, other than relating to fisheries, is likely to relate to this (no references directly addressing this were found).

However, there is a general paucity of research to understand and address these seasonal biases. Seasonal beach use information (such as the rudimentary beachgoer index developed for this project) provides a useful proxy for carcass recovery rate that can be used to explore and account for seasonal bias that would otherwise diminish the importance of threats that impact on cetaceans in the winter period. Note that seasonality in weather conditions and coastal currents would also be likely to affect the seasonality of beachcast events (Peltier et al. 2012) and this would be much less easy to correct than carcass recovery.

In the case of Hector’s and Māui dolphins, seasonal bias in carcass recovery rate means that non-neonate dolphins dying of natural causes are generally less likely to be detected than those dying of threats that primarily act in the summer period. To date, the carcasses of all Hector’s and Māui dolphins attributed to toxoplasmosis mortality were recovered from September to November (Roberts et al. 2019, Roe et al. 2013, updated by Wendi Roe pers. comm.). This study suggests that toxoplasmosis mortalities occurring in winter and early spring (up until the October mid-term school holidays) would be much less likely to be detected than those occurring later in the season. As such, estimates of toxoplasmosis risk based on proportional necropsy results without a seasonal correction (as by Roberts et al. 2019) may be negatively biased. Note that *spatial* biases in carcass detection probability could also cause the estimation of toxoplasmosis risk to be over- or under-estimated, and the potential for spatial bias has not yet been explored.

By comparison, fishery-related mortalities appear to be more frequent in the summer period when the carcass detection rate is also high, such that dolphins lost or removed from gear and subsequently beachcast would have a relatively high probability of detection relative to other causes of death. Fishery entanglements in the incident database include deaths attributed to recreational fishing, which is known to have increased activity in the summer period (Aranovus Research 2007, Roberts et al. 2019).

4.3 Changes in threats through time

Information from the necropsy records about temporal changes in the relative importance of various threats is confounded with known changes in methods with respect to carcass acquisition and necropsies. This is exacerbated by small sample size issues, which preclude comparisons over shorter time periods. However, longer-term shifts in sex composition at certain times of year may provide clues with respect to changes in mortality patterns through time. For instance, the apparent female bias in the beachcast sample in spring months from 2000 to 2020, which is coincident with the seasonality of known toxoplasmosis deaths (Roberts et al. 2019), was not observed in the preceding decade (Figure 8).

The necropsied sample of dolphins attributed to entanglement in fishing gear is small for assessing temporal patterns. Fishery observer data provide a more direct means for assessing temporal patterns in commercial fishing mortality. Note that fishing gear entanglements recorded in the incident database will include a component of recreational fishing entanglements (particularly prior to 2008/09, when recreational setnet prohibitions were imposed in much of the dolphins’ range), and these mortalities may have a different seasonality. Changes in sex ratio of reported fishery-related mortalities through time could be informative of the relative degree of protection conferred to males and females (Figure 6). However, note that the sex was not determined for a large proportion of entangled dolphins in the most recent period that were not necropsied. As such, the accurate sexing and ageing of dolphin carcasses should be regarded as a high priority in future, to improve our understanding of the population risk from different threats.

5. MANAGEMENT IMPLICATIONS

The main management implications from this assessment are as follows:

- There is likely to be a strong seasonal variability in beach use, which this study used as a proxy for seasonal carcass recovery of Hector’s and Māui dolphins. Since various threats also appear to act seasonally, the beachcast sample of dolphins will give a biased picture of the causes of death of the wider population (a limitation of the multi-threat risk assessment by Roberts et al. 2019). Note that probable spatial biases were not explored here.

- Accounting for seasonal biases relating to carcass detection rate would better-represent mortalities that are relatively more prevalent outside the summer period (e.g., including diseases), when beach use, and therefore carcass detection rate, will be low around New Zealand.
- A statistically significant female skew in the beachcast sample in spring months was coincident with the timing of all confirmed deaths from toxoplasmosis to date (all September–November). This pattern was strongest for deaths attributed to disease (including diseases other than toxoplasmosis) and was not apparent for fisheries related deaths. There was no evidence that this seasonal sex ratio pattern occurred in the 1990s, based on a small sample.

Future research and recommendations to address issues identified by this research are as follows:

- Future assessments using beachcast samples to infer the causes of death in the wider population could use an index of seasonal carcass recovery rate (e.g., an index of beach use) to account for seasonal biases affecting various causes of death. Ideally, this would use data specific to the locations of the South Island where the bulk of carcasses are recovered.
- The lack of samples in the winter period appears to be a consequence of low beach activity in winter. Targeted search effort at this time of year appears to be a good option for increasing the overall sample, and to better understand the mortality of dolphins at this time of year.

6. ACKNOWLEDGMENTS

We would like to thank the New Zealand Department of Conservation for providing the Hector’s and Māui dolphin incident database used by this study. We also thank Surf Life Saving New Zealand for allowing the use of beach count data by this study, and Hannah Jones (Waikato Regional Council) for assistance with the interpretation of these data. This research was funded by Fisheries New Zealand, under project number SEA2019-21.

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APPENDIX – SUPPLEMENTARY TABLES AND PLOTS

Table A-1. Number of dolphins by primary cause of death at necropsy ("Necropsy results") and year since 1984/85. This omits a foetus recovered from a female recorded as dying of disease in 2004/05.

	Number of dolphins by year reported																	
Primary cause of death	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Disease	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entanglement	7	10	14	14	4	0	1	0	8	3	7	3	2	12	4	7	11	4
Euthanasia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Human other	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Maternal separation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Natural causes general	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Trauma unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Vessel strike	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Indeterminable	1	1	2	3	2	0	0	0	2	1	3	5	0	3	2	2	6	4
Unknown	0	0	0	1	0	0	0	1	0	1	1	0	2	2	0	1	2	2

Primary cause of death	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Disease	1	0	1	0	2	2	4	1	2	4	2	1	3	0	3	4	0	0
Entanglement	4	3	7	6	5	0	1	3	0	2	1	0	2	0	2	1	5	0
Euthanasia	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Human other	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Maternal separation	0	1	2	2	2	1	1	1	3	2	4	0	0	0	1	2	1	0
Natural causes general	1	1	1	0	4	1	2	1	0	1	1	1	2	0	0	1	0	0
Trauma unknown	2	3	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Vessel strike	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminable	3	5	3	5	14	7	11	6	3	3	5	2	0	1	1	2	3	0
Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2. Number of dolphins by primary cause of death at necropsy ("Necropsy results") and month since 1984/85.

Primary cause of death	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Disease	11	3	2	0	2	3	3	1	0	1	1	3
Entanglement	5	23	31	28	38	9	3	8	1	3	1	3
Euthanasia	0	0	1	0	0	0	0	0	0	0	0	0
Human other	1	0	1	2	0	0	0	0	0	0	0	0
Maternal separation	0	3	12	4	2	3	1	0	0	0	0	0
Natural causes general	1	2	3	3	2	2	0	1	1	0	2	2
Trauma unknown	1	1	3	2	0	1	1	0	0	0	2	0
Vessel strike	0	0	0	1	0	0	0	0	0	0	0	0
Indeterminable	15	11	25	12	12	13	5	3	1	3	4	7
Unknown	3	1	1	1	1	3	0	0	0	2	0	1

Table A-3. Number of dolphins by primary cause of death at necropsy ("Necropsy results") and reported sex.

Primary cause of death	Female	Male	Unknown
Disease	18	11	1
Entanglement	65	81	7
Euthanasia	1	0	0
Human other	1	2	1
Maternal separation	11	13	1
Natural causes general	10	9	0
Trauma unknown	6	5	0
Vessel strike	1	0	0
Indeterminable	42	45	24
Unknown	1	3	9

Table A-4. Number of dolphins by primary cause of death at necropsy ("Necropsy results") and reported sub-species.

Primary cause of death	Hector's dolphin	Māui dolphin
Disease	3	27
Entanglement	4	149
Euthanasia	0	1
Human other	0	4
Maternal separation	0	25
Natural causes general	6	13
Trauma unknown	0	11
Vessel strike	0	1
Indeterminable	8	103
Unknown	0	13

Table A-5. Number of dolphins by primary cause of death at necropsy ("Necropsy results") and <u>region</u> of recovery since 1984/85.

Primary cause of death	Auckland	Bay of Plenty	Canterbury	Manawatu-Wanganui	Marlborough	Nelson	Northland	Otago	Southland	Taranaki	Tasman	Waikato	Wellington	West Coast	Unknown
Disease	0	0	13	0	1	0	0	3	0	1	2	3	0	7	0
Entanglement	3	0	95	0	4	1	0	5	1	0	1	1	0	41	1
Euthanasia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Human other	0	0	2	0	0	0	0	1	0	0	0	0	0	1	0
Maternal separation	0	0	12	0	1	0	0	5	1	0	2	0	0	4	0
Natural causes general	2	0	4	0	1	0	1	1	3	0	0	3	0	4	0
Trauma unknown	0	0	5	0	0	0	0	0	1	0	1	0	0	4	0
Vessel strike	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Indeterminable	8	0	34	0	4	0	0	5	14	0	1	1	0	44	0
Unknown	0	0	4	0	0	0	0	0	1	0	0	0	0	8	0

Table A-6. Sample size of beachgoer counts (on beach or in the water) made by New Zealand North Island surf life-saver clubs, by month and club.

Club location	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Bethells Beach	143	199	532	897	777	341	198	33	0	0	0	0	3 120
Kariaotahi	150	202	502	877	514	332	220	22	22	0	0	12	2 853
Mairangi Bay	231	347	916	1 977	756	550	242	11	0	8	0	44	5 082
Mt Maunganui	144	187	688	758	451	219	229	0	0	44	33	88	2 841
Muriwai	124	200	780	889	831	446	187	0	0	11	0	0	3 468
Omaha Beach	145	243	519	820	309	379	210	0	0	0	0	11	2 636
Orewa	177	383	968	1 394	788	591	311	11	0	0	11	12	4 646
Pukehina	64	153	450	759	407	11	0	0	0	0	0	38	1 882
Raglan	143	209	459	731	678	362	248	0	22	0	0	0	2 852
Waihi Beach	202	243	1 055	1 829	537	429	230	33	11	44	0	11	4 624
Whakatane	0	39	499	1 199	255	160	0	0	0	11	0	0	2 163
Whangamata	177	325	1 034	1 801	605	399	245	0	11	0	11	0	4 608
Total	1 700	2 730	8 402	13 931	6 908	4 219	2 320	110	66	118	55	216	40 775

Table A-7. Mean of beachgoer counts (on beach or in the water) made by New Zealand North Island surf life-saver clubs, by month and club.

Club location	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	All months
Bethells Beach	37.4	32.5	57.1	51.7	40.8	42.8	52.1	0.0	–	–	–	–	46.5
Kariaotahi	62.0	55.7	75.1	63.4	99.5	71.7	49.1	5.9	5.0	–	–	25.0	70.2
Mairangi Bay	21.9	16.1	130.3	164.1	304.9	20.1	24.4	0.0	–	39.0	–	0.0	138.2
Mt Maunganui	55.2	84.5	207.6	461.6	307.3	95.5	72.7	–	–	0.0	0.0	0.0	243.8
Muriwai	59.8	87.5	110.7	169.2	146.6	143.2	125.8	–	–	0.0	–	–	135.8
Omaha Beach	46.1	26.5	88.0	132.4	159.0.0	54.1	87.8	–	–	–	–	18.2	97.0
Orewa	84.2	53.4	102.2	168.5	156.4	93.0	66.7	0.0	–	–	57.3	31.7	122.5
Pukehina	15.3	18.4	60.0	63.3	35.2	26.9	–	–	–	–	–	5.2	49.8
Raglan	77.5	66.5	134.7	138.5	100.6	105.2	66.3	0.0	0.0	–	–	–	108.9
Waihi Beach	52.9	41.3	91.2	136.3	349.6	70.8	70.1	93.3	0.0	0.0	–	19.1	130.6
Whakatane	–	29.2	81.8	103.6	35.9	22.2	–	–	–	54.5	–	–	83.0
Whangamata	126	21.3	293.5	414.2	127.4	98.7	97.9	–	0.0	–	0.0	–	264.6
All clubs	59.8	43.3	129.8	182.2	159.6	76.2	70.2	29.2	1.7	7.7	11.5	6.0	133.5

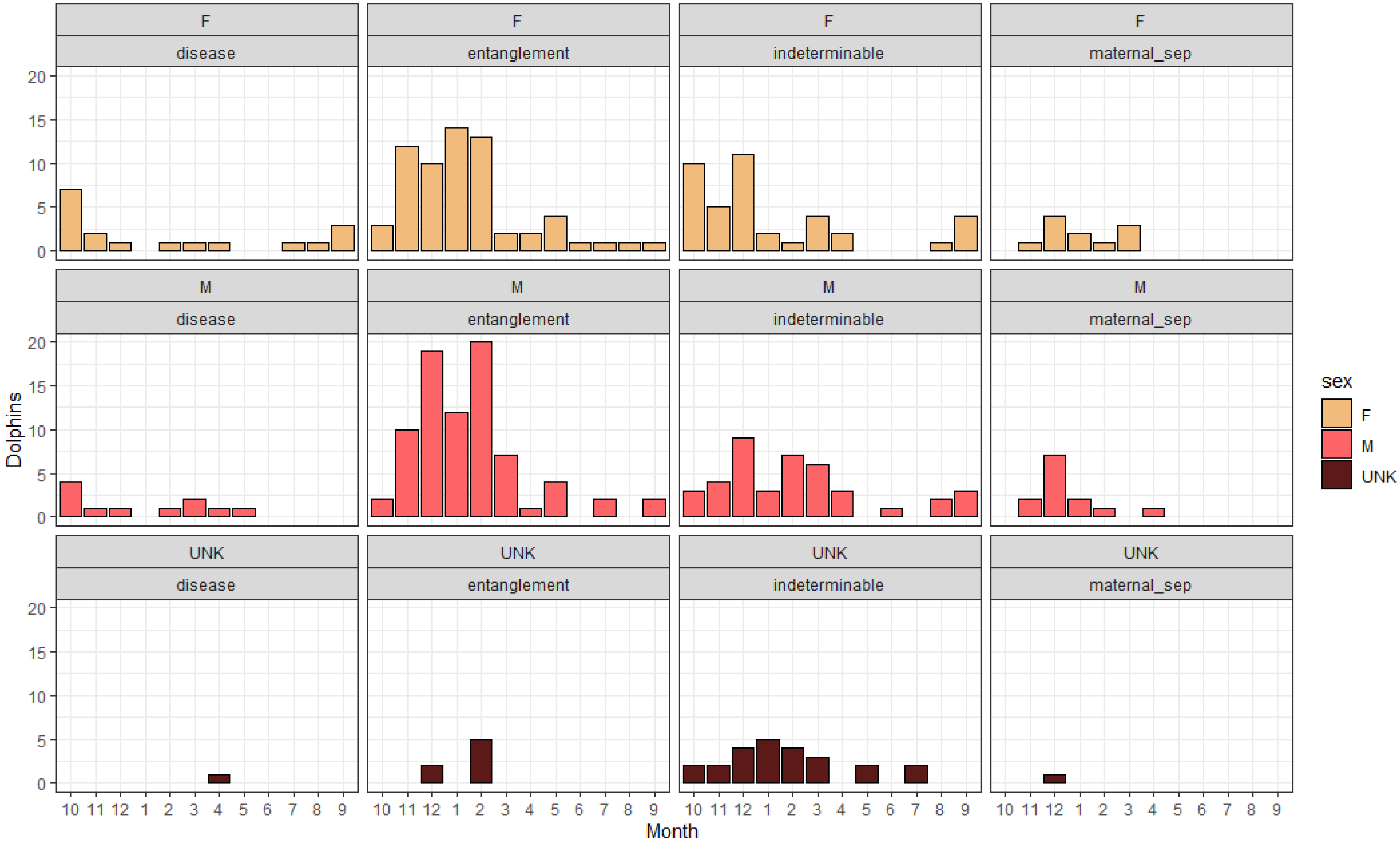

Figure A-1. Monthly frequency of Hector's or Māui dolphin records by month, sex, and primary cause of death at necropsy ("Necropsy results"), showing the top-four causes in terms of total numbers. This plot includes records since 1984/85. Month 10 is October.

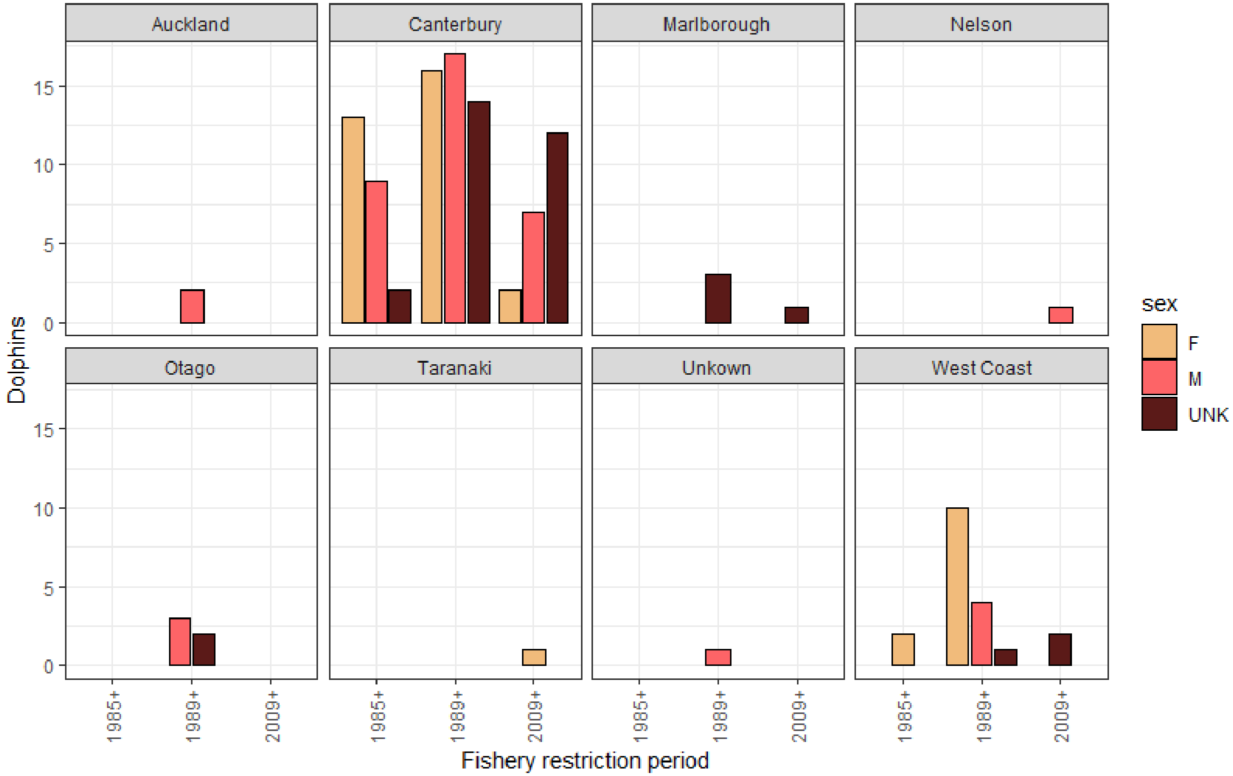

Figure A-2: Sex composition of Hector's or Māui dolphin bycatch records ("Observation type": "Entangled – caught in gear (died)", "Entangled – caught in gear (live and died)" or "Entangled – caught in gear (combination)") by sex, region in which carcasses were recovered, and fishery restriction period. This plot includes records since 1984/85.

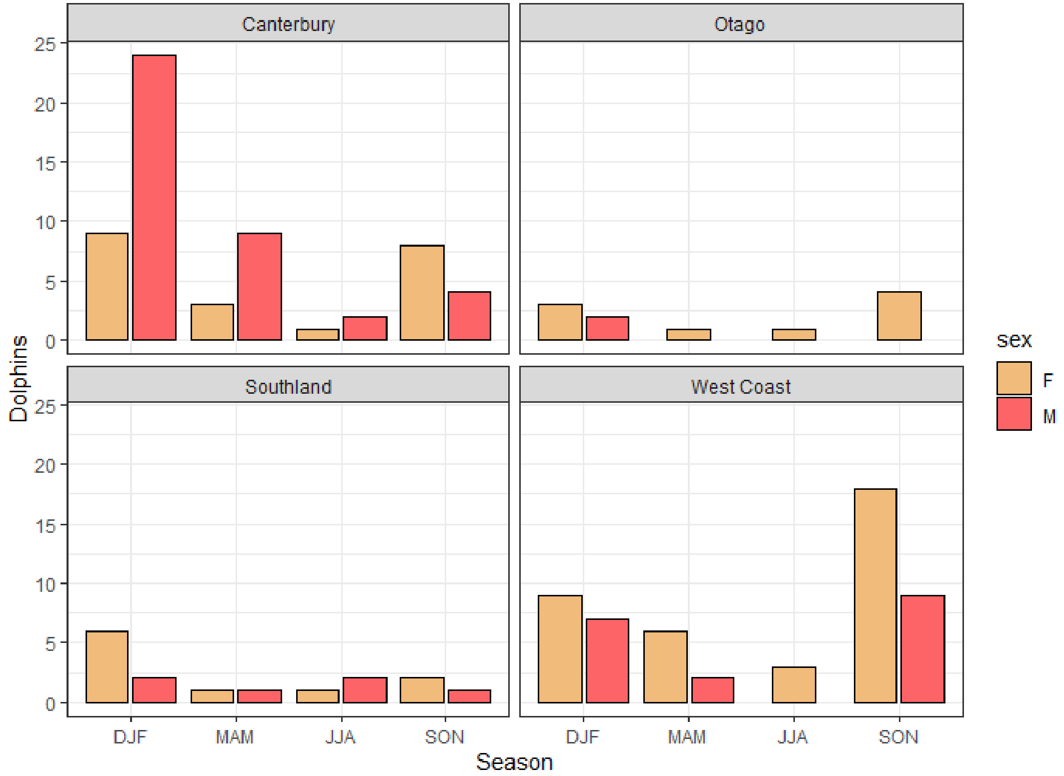

Figure A-3. Sex composition of Hector's or Māui dolphin records of "Observation type": "Beachcast (dead on shore)" by season and region. This plot includes records since 1984/85 and excludes calves. "DJF" = December, January, or February (summer); "MAM" = March, April, or May (autumn); "JJA" = June, July, or August (winter); and "SON" = September, October, or November (spring).