Causes of mortality in stranded Common Dolphin (*Delphinus* sp.) from New Zealand waters between 1998 and 2008

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Post-mortem examinations provide valuable information on sources of mortality for marine mammal populations. However, no published data exist to describe causes of death in the New Zealand population of Common Dolphin (*Delphinus* sp.). In order to examine the proportion of human and non-human induced mortality affecting this population, necropsies were conducted on 133 individuals that stranded around the New Zealand coastline between 1998 and 2008. Of these, 92.5% (n=123) were found as beach cast carcasses, with just 7.5% (n=10) as live strandings that subsequently died or that were euthanized on humane grounds. The sample included 54 males, 67 females and 12 animals of unknown sex from a range of age classes. Of the individuals for which cause of mortality could be established, 41.2% (n=35) were classified as human induced, with 28.2% (n=24) of carcasses exhibiting evidence of net entanglement. A further 10.6% and 32.9% of mortality was attributable to disease and natural (non-human related) causes, respectively. Few examples of disease were detected, but this may be at least partly a consequence of sampling constraints. Of the carcasses assessed, 68.6% of individuals exhibited some form of parasitism. Parasites identified were typical of the genus and considered to be present in low to moderate burdens. The proportion of beach cast carcasses exhibiting evidence of net entanglement suggests that fisheries-related mortality maybe higher than that previously considered for the New Zealand Common Dolphin population.

Key words: Common Dolphin, *Delphinus* sp., Mortality, Set nets, Conservation, Management, New Zealand

INTRODUCTION

VARIATION in mortality is a principal determinant of any population's stability, especially for threatened species (Gaillard *et al.* 1998). Therefore, describing trends and causes of mortality is important to both conservation research and management. Mortality in marine mammals can result from natural events (e.g., birthing difficulties and/or neonatal separation) and disease (e.g., morbillivirus and epizootics, see Van Bressem *et al.* 1999; Van Bressem *et al.* 2007) and human activities (e.g., entanglement in fishing, see Jefferson and Curry 1994; Kuiken *et al.* 1994) and boat strike (e.g., Visser and Fertl 2000; Laist *et al.* 2001; Fèlix and Van Waerebeek 2005). In New Zealand, there is generally inadequate resourcing to routinely perform post-mortem examinations in all stranding and beach cast events. However, since the instigation of the New Zealand Common Dolphin Project (NZCDP) in 2002, Massey University has made concerted efforts to recover carcasses and/or undertake post-mortem sampling. Although studies examining cause of death in marine mammals are numerous (e.g., Baker and Martin 1992; Kuiken *et al.* 1994; Kirkwood *et al.* 1997; Silva and Sequeira 2003; Kemper *et al.* 2005), few data are available within the published literature to describe mortality in New Zealand marine mammals. Those available have primarily focused on threatened endemic species, such as Hector's Dolphins *Cephalorhynchus hectori hectori* (e.g., Duignan *et al.* 2003; Duignan and Jones 2005; Roe 2007) and New Zealand Sea Lions *Phocarctos hookeri* (e.g., Wilkinson *et al.* 2003; Castinel *et al.* 2007; Chilvers 2008).

Common Dolphins (*Delphinus* sp.) have one of the greatest stranding frequencies of all New Zealand marine mammals (Childerhouse 2002; 2004; 2005) and remain the most frequently bycaught cetacean species within the commercial fishery for Jack Mackerel (*Trachurus novaezelandiae*) (Rowe 2007). However, no abundance estimates are available for this population, despite Common Dolphins being classified as *not threatened* under the current New Zealand Threat Management System (Hitchmough *et al.* 2007). This is of concern considering the apparent threats (e.g., Stockin *et al.* 2007; Meynier *et al.* 2008; Stockin *et al.* 2008a) facing the New Zealand population.

In order to better understand sources of mortality, data collected by Massey University veterinarians and researchers during systematic necropsies were analysed to assess trends and potential causes of death. We examined for evidence of human and non-human related pathology including disease, natural mortality and trauma and/or injuries typical of human-induced mortality, for example entanglement and boat strike. Such human interactions have been implicated in the decline of other New Zealand marine mammals, particularly the Hector's Dolphin, Maui's Dolphin *Cephalorhynchus*

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hectori maui (e.g., Dawson 1991; Stone and Yoshinaga 2000; Slooten 2007) and New Zealand Sea Lion (e.g., Duignan *et al*. 2003; Wilkinson *et al*. 2003; Duignan and Jones 2005). Data presented here offer first insights into causes of mortality in Common Dolphin obtained by Massey University during the period 1998 to 2008. Where data were available, cause of mortality, disease and parasites are discussed. Stomach contents were also included in order to determine recent feeding activity pre-mortem. Pollutant burdens were not considered in the present study, since a recent examination of trace elements, organochlorine pesticides and PCBs present within New Zealand Common Dolphins suggest pollutant loads are below threshold levels required to induce mortality and/or reproductive or immune system impairment (Stockin *et al*. 2007).

METHODS

Dolphin carcasses

A total of 586 common dolphins stranded or were found beach cast along the New Zealand coastline between 1998 and 2008. Of these, 133 carcasses were opportunistically obtained via the New Zealand Department of Conservation (DoC) for post mortem examination and/or tissue sampling. Where feasible, individuals underwent immediate necropsy and sampling procedures after refrigerated transportation of the carcass to Massey University. In some circumstances, carcasses were preserved frozen until an examination was conducted or examined/sampled directly in the field by the first author without freezing. All carcasses were divided subjectively into four categories (*Freshly dead, mildly decomposed, moderately decomposed* and *severely decomposed*) based on the level of post-mortem autolysis. Animals described as *fresh* typically live stranded and either subsequently died or were euthanized by gunshot *in situ* by DoC personnel. *Mild* was assigned to any carcasses that exhibited *rigor mortis* but which showed no external signs of obvious decomposition (e.g., skin discoloration, odour, discharges from orifices, bloating). Carcasses that showed early signs of decomposition (e.g., skin discoloration and/or sloughing) were classified as *moderate*. Animals exhibiting advanced stages of decomposition (*severe*) did not typically undergo a systematic necropsy.

Pathology

Pathological examination and sampling was conducted according to published protocols (e.g., Geraci and Lounsbury 1993; Kuiken *et al*. 1994). Carcasses were measured (cm) and where possible weighed (kg) prior to careful inspection for external lesions, such as tissue loss, trauma and net marks. Features including intra- and inter-specific tooth rake marks and skin infections were also noted. Each carcass was laid left flank down and an incision made through the blubber from the cranial insertion of the dorsal fin to the ventral midline. Blubber thickness (mm) was measured dorsally, laterally and ventrally along this incision. Carcasses were then carefully flensed and the subcutis examined for evidence of trauma. Lesions in the blubber and subcutis were collected for histopathology by fixing tissue in 10% buffered formalin. Internal organs were examined systematically for lesions, both superficially, on cross-section, and palpated. In *fresh* carcasses, lung, liver, kidney, spleen, lymph nodes, adrenal glands, thyroid, heart, muscle, gastrointestinal tract and gonads were routinely sampled for histopathology, along with any lesion visible grossly. However, funding constraints limited the examination of *moderate* and *severely decomposed* carcasses to a gross post-mortem. Furthermore, sampling requirements of Maori iwi often precluded damage to bone which consequently prevented the examination of brain tissue in most animals.

Where possible, cause of death was classified as *human interaction* (HI), *disease* (DI), *natural causes* (NT), *entanglement* (EN), *unknown trauma* (TR) or *unknown* (UK) based on necropsy findings (Table 1). Carcasses for which a post-mortem examination was not feasible, or for which cause of death could not be determined due to condition of the carcass (e.g., decomposition, fragmentation) were defined as *not assessed* (NA).

All individuals were examined post-mortem for signs of human interaction, irrespective of whether injuries uncovered were likely to have resulted in mortality. Carcasses exhibiting lesions and/or injuries indicative of net entanglement (Figure 1) were classified as *entanglement.* Trauma criteria used to diagnose entanglement in fishing gear included: (i) skin indentations or incisions apparently produced by net material or a sharp instrument; (ii) amputated fins or flukes; (iii) excised blubber and/or musculature from the flanks, and (iv) rope marks around the tail stock or head (Kuiken *et al*. 1994). Additional injuries such as acute pulmonary oedema and congestion consistent with asphyxia, petechial haemorrhages on internal organs such as the epicardium, and bone fractures consistent with bycaught animals (Duignan *et al*. 2003; Duignan and Jones 2005) were not considered definitive of incidental capture in nets unless they were supported by at least one of the aforementioned trauma categories. All injuries in each carcass were recorded and photographed. Any parasites located during the necropsy were removed and

Table 1. Definitions used to categorize cause of mortality in New Zealand Common Dolphin *Delphinus* sp. obtained opportunistically between 1998 and 2008. Note: Drowning* refers to *death by immersion* as described in Kuiken *et al*. 1994.

Category	Definition
Not assessed (NA)	Carcass not recovered, necropsy not completed, or no assessment of cause of death undertaken
Unknown (UK)	Cause of death not able to be determined due to condition of the carcass (e.g., decomposition, fragmentation)
Natural (NT)	Cause of death not considered to be a direct result of human contact (e.g., mother-calf separation)
Disease (DI)	Cause of death likely induced by a pathogen and/or disease
Trauma (TR)	Trauma without a known cause i.e. could be natural or human-induced (e.g., live stranding, predator attack, boat strike)
Human interaction (HI)	No sign of net entanglement but definite signs of other types of human interaction (e.g., gunshot wounds
Entanglement (EN)	Presence of net marks on the carcass. Additional indicators of capture (e.g., drowning*, mutilation) may also be present

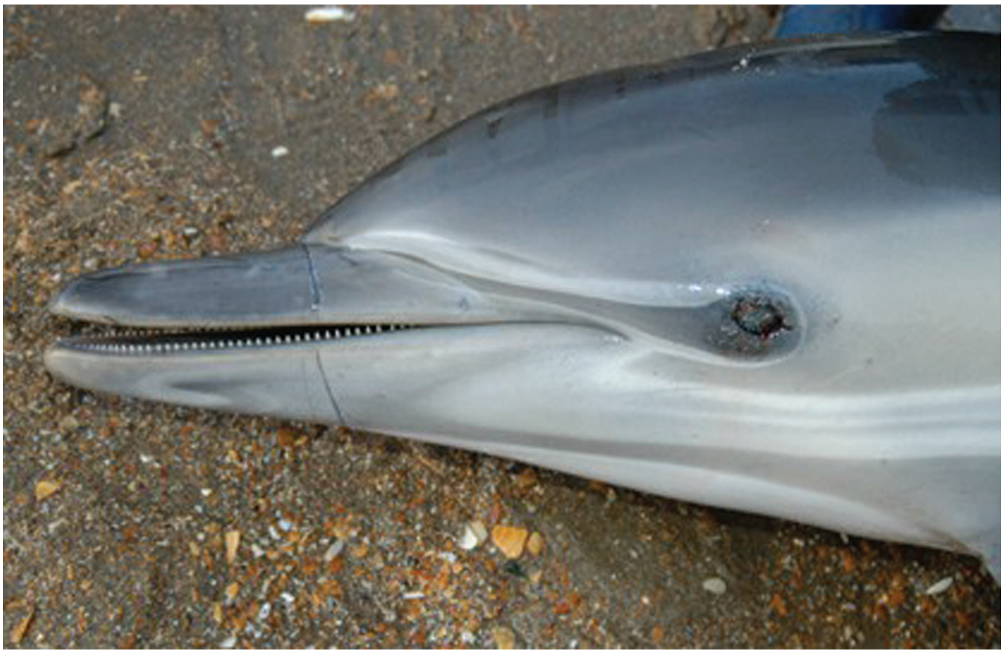

Fig. 1. A fresh juvenile Common Dolphin (KS05-25Dd) recovered from the Hauraki Gulf, Auckland. Note the fine linear lesions across the rostrum indicative of net entanglement within a monofilament gillnet.

stored in 70% ethanol for subsequent examination (Duignan *et al*. 2003).

Age class

Reproductive organs were dissected out of each carcass *in situ* and examined macroscopically. Females were classified as immature if no *corpora albicantia* or *lutea* were observed on either ovary and mature if at least one corpus on either ovary was recorded (Duignan *et al*. 2003; Westgate and Read 2007). Males were classified as immature or mature based on gonad size and morphology. Sexual maturity was confirmed microscopically via presence of a germinal epithelial differentiation sequence in the tubules and/or mature spermatozoa present in the epididymides where possible (Duignan *et al*. 2003; Westgate and Read 2007). However, this was primarily limited to fresh carcasses only.

Stomach content analysis

Stomach contents were inspected to establish the occurrence of recent feeding activity premortem. In summary, the oesophagus and forestomach was examined for evidence of freshly ingested prey (Figure 2). In a subsample of examined carcasses (n=53), all prey remains were subsequently washed through a 0.25 mm mesh sieve before diagnostic hard parts were recovered and identified to the lowest possible taxonomic level (Meynier *et al*. 2008). Each prey item was scored according to its degree of digestion, thus allowing for the determination of a fresh fraction (representing recent meals) and a digested fraction (with remains ingested from one to several days prior to death) (Tollit *et al*. 2003). Results presented here only consider the presence/absence of fresh fractions as an indicator of recent feeding and/or immediate

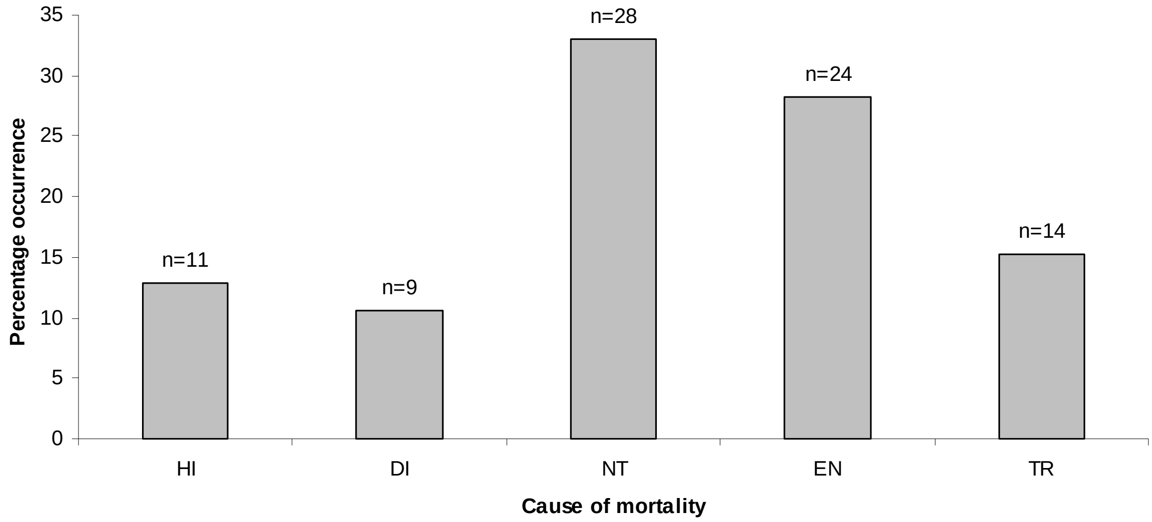

Fig. 2. Percentage mortality of stranded and beach cast New Zealand Common Dolphins *Delphinus* sp. examined between 1998 and 2008. HI=*human interaction*, DI=*disease*, NT=*natural*, EN= *entanglement*, TR=*trauma* (unidentified).

death. All additional data including taxonomic identity of digested fractions are further detailed by Meynier *et al*. (2008).

RESULTS

Dolphin carcasses

A total of 586 common dolphins stranded or were reported beach cast along the New Zealand coastline between 1998 and 2008. Only 133 carcasses were examined post mortem, of which 7.5% (n=10) represented live animals which subsequently died or were euthanized, and 92.5% (n=123) which were recovered as beach casts. The examined carcasses comprised 54 males, 67 females and 12 individuals of unknown gender. Male and female body lengths ranged from 89 to 241 cm (mean=173.6, SD=43.6, n=50) and 90 to 208 cm (mean=172.3, SD=38.2, n=65), respectively. Body weight recorded from a subset of animals (n=106) ranged from 6.8 to 150 kg (mean=46.9, n=22) in males and 7.6 to 91.0 kg (mean = 50.6, n=41) in females. Foetuses (n=3) recovered from pregnant females ranged from 15.5 to 101 cm in total body length. Mean body length of male and female Common Dolphins was not significantly different between the sexes (t-value= 0.04, p=0.966, df=97).

Sexual maturity was assessed in 81.3% (n=78) of examined carcasses. Of the females whose maturity could be determined (n=50), over half (56%, n=28) were sexually mature with 44% (n=22) classified as immature. Of the males categorized (n=28), 14.3% (n=4) and 85.7% (n=24) were classified as mature and immature, respectively. Gender and maturity were not independent (Pearson χ^2=12.245, df=1, p<0.01), with on average more than 40% more mature females than males evident. Of all examined carcasses, 27.8% were classified as *fresh* or originally *live* stranded, while a further 27.1% (n=36) and 21.0% (n=28) were deemed as *mild* and *moderately* decomposed, respectively. The remaining 24.1% (n=32) of carcasses comprised animals exhibiting *severe* (n=17) or unrecorded (n=15) levels of decomposition. Of the carcasses which were deemed to be no more than *mildly* autolysed, 32.9 % comprised males (n=24) and 67.1% were females (n=49).

Pathology

Of the 133 animals examined post-mortem, 37 were *not assessed* owing to excessive decomposition, fragmentation and/or access. Of the 96 remaining carcasses, a probable cause of mortality could be determined in 87% of individuals (n=85). For the Common Dolphins that could be classified, 41.2% (n=35) exhibited evidence of human-induced mortality. Of these, 28.2% (n=24) were classified as *entanglement* based on trauma indicative of net entanglement (Kuiken *et al*. 1994). The majority of carcasses designated as *human interactions* related to live stranding events in which dolphins underwent euthanasia via gunshot (n=9). A further 32.9% (n=28) were considered a likely consequence of non-human interaction and thus categorized as *natural* mortality. *Trauma* of unknown origin was evident in 15.3% of carcasses (n=13), with *Disease* accounting for less than 11% (n=9) of recorded mortalities observed within this study (Figure 2).

Stomach content analysis

A total of 53 stomachs from New Zealand Common Dolphins were examined, of which 42 belonged to stranded and beach cast carcasses

(Meynier *et al*. 2008). Stomach content was assessed in 66.7% (n=16) of examined carcasses classified as *entanglement*. Of these, 56.3% (n=9) contained prey remains within the stomach, with 37.5% (n=6) consisting of a fresh fraction comprising either fresh and/or partially digested prey items in the oesophagus and/or forestomach (Figure 3). Only one individual suspected of fisheries-related mortality (WS02-05Dd) was found to have an empty stomach, with stomachs from the remainder of carcasses containing predominantly milk (n=6). The most prevalent prey items recovered via the fresh fractions of carcasses classified under the *entanglement* category included pilchard (*Sardinops neopilchardus*) and garfish (*Hyporhamphus ihi*).

Parasites

Of the 67 carcasses examined for parasites, 68.6% (n=46) were reported to have some form of parasitism. Of these, 30.4% (n=14) and 69.6% (n=32) were males and females, respectively. Generally, parasites were more prevalent in mature animals, with the exception of lungworms, which were more frequent in immature individuals. Parasites were commonly found in the blubber (*Phyllobothrium delphini*, Figure 4), under the serosa of the abdominal cavity (*Monorygma grimaldii*) and in the bronchi, bronchioles and parenchyma of the lungs (*Parafilaroides* sp). Round worm (*Crassicauda* sp.) was occasionally detected in the subcutaneous tissue, particularly in the mammary duct of

Fig. 3. Freshly ingested pilchard *Sardinops neopilchardus* extracted from the oesophagus and forestomach of Common Dolphin (WS04-19Dd). Note: This individual exhibited trauma indicative of net entanglement.

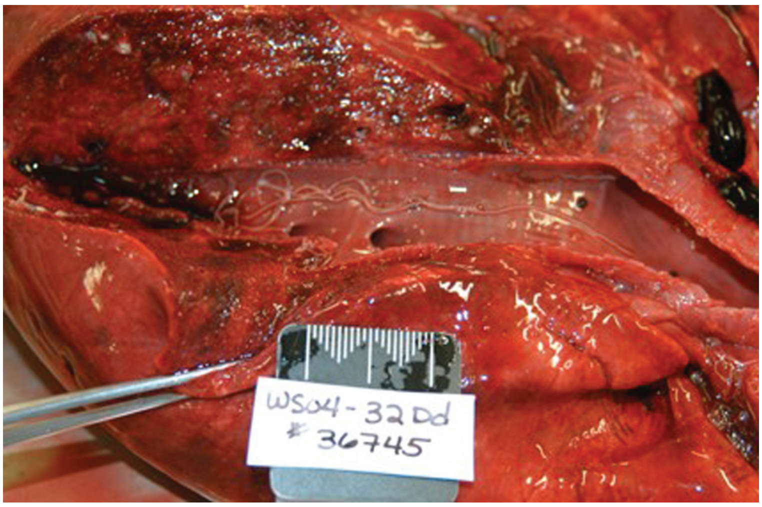

Fig. 4. Lungworms *Parafilaroides* sp. in the bronchi of Common Dolphin (WS04-32Dd) recovered from the Hauraki Gulf, New Zealand.

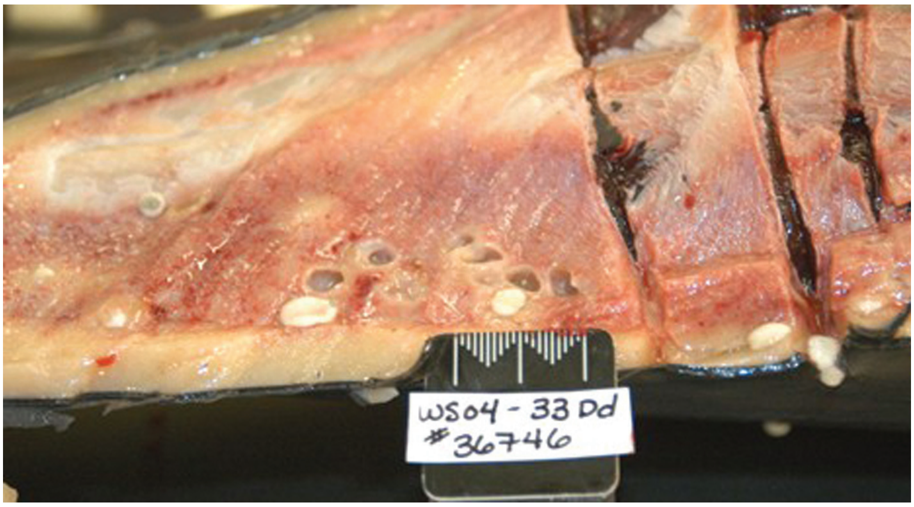

Fig. 5. Pleroceroid cysts *Phyllobothrium* sp. in the blubber of Common Dolphin (WS04-33Dd) recovered from the Hauraki Gulf, New Zealand.

mature females. The majority of larval cysts of *P. delphini* were primarily located around the genital area. Lungworms in New Zealand Common Dolphins varied from light to moderate burdens frequently characterized by collections of nematodes surrounded by an acute inflammatory cell reaction. Nematode clusters were primarily located towards the periphery (pleural surface) of the lung, although in some instances lungworms were observed in the bronchi (Figure 5). In most carcasses, parasite loads were considered low to moderate, with

Table 2. Mortality categories of beach cast or stranded New Zealand Common Dolphins *Delphinus* sp. between 1998 and 2008. Note: sex mat = sexual maturity, TBL = total body length, NA=not assessed, UK=unknown, NT=natural, DI=disease, TR= trauma (unknown), HI=human interactions, EN=entanglement, FR=fresh, MD=mild, MO=moderate, DC=decomposed.

Animal ID	Gender	Sex Mat	State	TBL	Parasites	Mortality
KS00-01Dd	M	-	FR	216.0	-	NA
KS00-02Dd	F	-	FR	148.0	-	NA
KS01-01Dd	M	-	-	205.0	-	NA
KS02-01Dd	M	-	-	183.0	-	NA
KS02-02Dd	-	-	-	-	-	NA
KS03-01Dd	M	-	FR	215.0	-	EN
KS04-04Dd	F	-	FR	168.0	-	NA
KS04-05Dd	M	-	MD	203.0	-	NA
KS05-38Dd	-	-	MO	216.0	-	NA
KS05-39Dd	M	N	DC	117.0	-	NA
KS05-40Dd	F	-	DC	184.0	-	NA
KS05-41Dd	-	-	DC	-	-	NA
KS06-03Dd	F	N	MO	109.5	Y	NT
KS06-04Dd	F	Y	MO	205.5	Y	EN
KS06-05Dd	M	-	MO	216.0	-	NA
KS07-01Dd	F	N	LV	100.0	N	HI
KS07-02Dd	-	-	DC	-	-	TR
KS07-03Dd	-	-	DC	187.0	-	NA
KS07-04Dd	M	-	-	212.0	-	EN
KS07-05Dd	F	-	-	206.0	-	NA
KS07-06Dd	M	-	MO	212.0	-	NA
KS07-07Dd	M	-	FR	156.0	-	NA
KS07-08Dd	M	-	MO	110.0	-	NA
KS07-09Dd	F	-	DC	208.0	-	NA
KS07-10Dd	M	-	MO	167.0	-	NA
KS07-11Dd	F	-	MO	172.0	-	NA
KS07-12aDd	M	N	FR	101.0	-	NT
KS07-12Dd	F	Y	FR	207.0	N	NT
KS07-13Dd	-	N	-	95.0	-	NA
KS08-01Dd	M	-	DC	217.0	-	TR
KS08-02Dd	M	-	MD	197.0	-	NT
KS08-03Dd	F	-	MD	200.0	-	NA
KS08-04Dd	M	-	MO	198.0	-	NA
KS08-06Dd	-	-	MD	-	-	HI

Table 2. — *continued.*

Animal ID	Gender	Sex Mat	State	TBL	Parasites	Mortality
KS08-07Dd	M	-	MO	161.0	-	NT
KS08-08Dd	M	N	MD	118.0	-	NT
KS08-09aDd	M	N	FR	15.5	N	NT
KS08-09Dd	F	Y	FR	206.0	Y	TR
KS08-10Dd	M	Y	MO	212.0	Y	TR
KS08-11Dd	M	Y	MO	234.0	N	NT
KS08-12Dd	-	-	DC	-	-	NT
KS08-13Dd	-	-	LV	181.0	-	HI
KS08-14Dd	F	Y	DC	-	-	TR
KS08-15Dd	F	-	-	154.0	-	NA
KS08-16Dd	F	-	MO	200.0	-	NT
KS08-17Dd	M	-	MO	183.0	-	NA
KS08-18Dd	M	-	MO	211.5	-	EN
KS98-01Dd	F	-	FR	198.0	-	EN
W08-06Dd	F	Y	FR	208.0	Y	NT
W08-07Dd	M	N	FR	138.0	-	UK
W08-08Dd	M	N	FR	132.6	-	TR
W08-11Dd	F	N	MD	159.0	Y	HI
W08-17Dd	F	Y	FR	208.0	-	UK
W08-28Dd	-	-	-	-	-	NA
WB01-43Dd	F	Y	MO	203.5	N	EN
WB04-02Dd	-	-	-	-	-	NA
WB05-26Dd	M	N	FR	160.0	N	EN
WB05-27Dd	F	N	MD	165.0	Y	EN
WB99-01Dd	M	N	LV	197.0	Y	HI
WS00-01Dda	F	-	MD	200.0	-	EN
WS00-01Ddb	F	-	MD	200.0	-	EN
WS00-01Ddc	M	-	MD	196.0	N	PR
WS00-26Dd	F	N	-	103.0	-	UK
WS00-33Dd	F	Y	MO	210.0	Y	NT
WS00-34Dd	F	Y	MD	198.0	Y	DI
WS00-35Dd	F	N	MD	93.0	Y	NT
WS00-39Dd	M	N	MD	89.0	Y	TR
WS00-41Dd	F	Y	-	194.0	Y	DI
WS00-42Dd	F	N	MD	96.0	N	NT
WS00-43Dd	M	N	MO	95.0	N	NT
WS00-44Dd	F	N	MD	90.0	N	NT
WS01-30Dd	M	N	MD	119.5	Y	UK
WS01-39Dd	F	N	MD	167.0	Y	DI
WS01-44Dd	F	N	MD	105.0	Y	TR
WS02-03Dd	F	Y	MD	197.0	Y	EN
WS02-04Dd	F	Y	MD	210.0	Y	DI
WS02-05Dd	F	N	MD	117.5	Y	EN
WS02-06Dd	F	N	MO	115.0	Y	EN
WS02-07Dd	M	N	MD	120.0	Y	EN
WS02-08Dd	M	N	MD	106.0	Y	EN
WS02-14Dd	M	N	MO	172.0	Y	EN
WS02-37Dd	F	N	FR	128.0	Y	TR
WS02-38Dd	F	Y	MD	191.0	Y	DI
WS02-39aDd	M	N	MD	72.5	N	NT
WS02-39Dd	F	Y	MD	187.0	Y	DI
WS02-40Dd	M	-	MO	-	-	NA
WS02-44Dd	-	-	-	-	-	NA
WS03-15Dd	M	N	-	99.0	Y	EN
WS03-20Dd	M	N	FR	156.0	Y	TR
WS03-41Dd	F	N	MO	162.0	Y	NT
WS03-42Dd	F	Y	MO	189.0	Y	DI
WS03-43Dd	F	Y	MO	183.0	N	NT
WS04-19Dd	M	N	MO	174.0	N	EN
WS04-28Dd	F	Y	FR	195.0	Y	NT
WS04-29Dd	F	Y	FR	195.0	Y	DI
WS04-30Dd	M	N	FR	118.0	N	NT
WS04-32Dd	F	N	FR	99.0	Y	NT
WS04-33Dd	F	Y	LV	195.0	N	HI
WS04-34Dd	F	Y	FR	189.0	Y	EN
WS04-35Dd	F	Y	LV	200.0	Y	HI
WS04-36Dd	F	Y	LV	195.0	Y	HI
WS04-37Dd	F	N	DC	91.0	-	UK
WS05-03Dd	F	-	DC	190.0	-	NA
WS05-04Dd	M	N	DC	95.0	-	NA
WS05-05Dd	F	-	DC	194.0	-	NA

Table 2. — *continued.*

Animal ID	Gender	Sex Mat	State	TBL	Parasites	Mortality
WS05-06Dd	M	N	MD	220.0	Y	EN
WS05-13Dd	F	-	-	175.0	-	UK
WS05-16Dd	F	Y	FR	207.0	Y	NT
WS05-18Dd	M	-	MD	213.0	-	NT
WS05-19Dd	M	-	MD	207.0	-	NA
WS05-20Dd	M	-	MD	210.5	-	NT
WS05-21Dd	M	-	MD	190.0	-	NA
WS05-22Dd	F	N	MD	132.0	N	DI
WS05-23Dd	F	Y	LV	185.0	Y	HI
WS05-24Dd	F	-	MD	189.0	-	NA
WS05-25Dd	F	N	MD	170.0	N	HI
WS05-28Dd	M	-	MD	-	Y	EN
WS05-37Dd	F	N	MD	233.0	Y	EN
WS06-04Dd	F	N	DC	128.0	N	UK
WS06-05Dd	F	-	DC	-	-	NA
WS06-06Dd	M	N	FR	182.0	Y	EN
WS06-08Dd	F	N	MO	167.0	-	UK
WS06-09Dd	F	Y	MO	212.0	N	TR
WS06-11Dd	F	N	DC	157.0	N	UK
WS06-13Dd	F	Y	FR	200.0	Y	TR
WS06-14Dd	F	N	LV	166.0	N	NT
WS06-15Dd	M	N	FR	153.0	N	NT
WS07-01Dd	F	Y	FR	189.5	-	NT
WS07-02Dd	M	Y	LV	241.0	-	UK
WS07-09Dd	M	-	DC	177.0	-	UK
WS07-25Dd	M	N	LV	169.5	Y	HI
WS98-36Dd	M	-	MD	208.0	-	NA
WS99-14Dd	M	Y	-	215.0	Y	TR

only three individuals exhibiting parasite levels thought to be contributory to death (Table 2).

DISCUSSION

While necropsies have previously indicated important sources of mortality in marine mammals endemic to New Zealand, no published data has previously been available to assess mortality in common dolphins. Between 1998 and 2008, a total of 586 common dolphins stranded or were found beach cast along the New Zealand coastline. Post mortem analyses conducted on 133 of these individuals raises important conservation issues relating to the proportion of human-induced mortality, in particular deaths attributable to net entanglement.

Human-induced deaths accounted for the highest mortality levels in the present study, of which 28% related to *entanglement* within fishing nets. The entanglement and subsequent drowning of cetaceans in fisheries is of world-wide concern (Reeves *et al*. 2003). Between 1990 and 1999, a mean annual by-catch of 6215 (SE ± 448) marine mammals (cetaceans and pinnipeds) was reported for the United States alone (Read *et al*. 2006). Within New Zealand waters, mortality from fishery interactions has proven problematic for a number of species including the New Zealand Fur Seal *Arctocephalus forsteri* (Manley *et al*. 2002), New Zealand Sea Lion (Wilkinson *et al*. 2003; Chilvers 2008) and Hector's dolphin (Slooten 2007). Although Common Dolphins are reported to be most at risk from trawl fisheries (Du Fresne *et al*. 2007; Rowe 2007), lesions identified in several of the carcasses examined during the present study indicate entanglement in fine monofilament nets (Figure 1). While commercial sets nets occur within New Zealand waters, they have not previously been considered a threat to Common Dolphins (Dawson and Slooten 2005; Rowe 2007). This is owing to the fact that until recently, Common Dolphins were thought less likely to use inshore waters. However, recent studies reveal Common Dolphins feed and breed in coastal waters as shallow as 7 m in the Hauraki Gulf, a coastal shallow embayment north of Auckland City (Stockin *et al*. 2009; Stockin *et al*. 2008).

The lesions considered in the present study to be specifically associated with entanglement in fishing gear were severed fins or flukes, circumscribing skin abrasions on one of the extremities (especially the beak) and amputation of fins or flukes (Kuiken *et al*. 1994). Additional suggestive lesions include congestion and pulmonary oedema (indicating death due to drowning/asphyxia), and the presence of partially digested prey in the oesophagus (Roe 2007). A number of carcasses exhibiting lesions indicative of net entanglement during the present study were recovered from areas used by recreational set net fishermen (e.g., Arkles Bay, Hauraki Gulf). Post-mortem examinations of

Common Dolphins suspected of being incidentally caught in set nets typically revealed fine linear lesions (Figure 1) in addition to drowning/asphyxia and intact ingested prey within the oesophagus and/or first chamber of the stomach.

The proportion of fisheries-related deaths is likely to have been underestimated in the present study. This is due to the external lesions used to identify net entanglement in the first instance, and the degree of post-mortem decomposition often acquired which masks this evidence. Certainly, the decomposed state of some carcasses resulted in a reduced probability of detecting superficial lesions attributable to set nets. Furthermore, carcasses examined within the present study did not include any Common Dolphin incidentally killed within commercial trawl fisheries (n=115), since these animals were not recovered from stranding or beach cast events.

A small proportion of individuals whose mortality was listed as *human interaction* had injuries indicative of vessel strike, as evidenced by external injuries consistent with boat impact, such as extensive bruising and fractured vertebrae and ribs. Both injury and/or mortality as a result of boat strike have been reported in a range of other New Zealand marine mammals including Hector's Dolphin, Killer Whale *Orcinus orca* and Bryde's Whale *Balaenoptera brydei* (e.g., Stone and Yoshinaga 2000; Visser and Fertl 2000; Stockin *et al*. 2008b). However, the extent of boat-induced mortality in New Zealand marine mammals remains unclear given that the majority of carcasses are not subject to a systematic post mortem examinations.

In the present study, *trauma* of unknown origin accounted for 11.5% of mortality within examined Common Dolphins. Such trauma may result from natural (e.g., predator attack) or human-induced (e.g., boat or fisheries-related) sources. Physical trauma that occurs when a cetacean is captured in a fishing net, due both to the animals struggle to escape and to hauling up the net, may cause a variety of non-specific lesions, such as bruising and skeletal fractures. Without further entanglement-specific lesions, it was not possible to categorize these animals into either *natural* or *entanglement* categories, thus both categories are likely underrepresented. In terms of non-human induced mortality, *natural* and *disease* accounted for 39% of mortalities reported. Neonatal deaths accounted for a large proportion of *natural* mortality, a likely consequence of mother-calf separation, a conclusion supported by malnutrition in the absence of any other injury or disease.

The prevalence of disease as a cause of mortality within the New Zealand population maybe underestimated in the present study owing to limited pathological testing of carcasses. Furthermore, our inability to examine the brain in most animals means that cases of significant neurological disease would have been overlooked. Pathological findings that were detected in New Zealand Common Dolphins were considered typical of the genus (Van Bressem *et al*. 2006) and included various forms of pneumonia, abscesses and gastric ulcerations.

Infestation by parasites is universal in wild animals, and can be found to some degree in most cetaceans beyond the age of newborn (Geraci and Lounsbury 1993; Raga *et al*. 2002). Parasites have been implicated in strandings of several cetacean species, particularly where infection affects the brain, ears, or auditory nerves (Cowan 2002). However, the role of cetacean parasites in inducing disease is not clear, although some parasites have been linked with mortality. For example, lungworms *Pseudalius* and *Torynurus* are commonly associated with secondary bacterial infections and severe pneumonia in some Harbour Porpoise *Phocoena phocoena* populations (Jepson *et al*. 2000). Parasite loads in New Zealand marine mammals are generally accepted to be low (Duignan 2003). However, there have been several parasites observed in New Zealand species that can cause significant disease. For example, heavy infestations of nematodes *Crassicauda* sp. have been recorded in the kidneys of Cuvier's Beaked Whales *Ziphius cavirostris* (Duignan 2003). Parasites isolated from Common Dolphins in the present study were considered typical for the genus, for example, lung worm *Parafilaroides* sp, round worm *Crassicauda* sp and pleroceroid cysts *Phyllobothrium* sp (Van Bressem *et al*. 2006). The higher prevalence of nematode infections in the lungs of immature animals was consistent with that previously reported in South Australia (Tomo *et al*. in press). However, in the majority of individuals examined during the present study, parasite loads were considered low to moderate, and thus not likely to be implicated in mortality. Nonetheless, we acknowledge that our inability to examine the brain post-mortem compromised the likelihood of being able to detect all parasites within the New Zealand population.

In summary, data presented do not attempt to estimate the extent of mortality experienced by the New Zealand Common Dolphin population. Instead, this study offers first insights into the causes of mortality determined in a subsample of examined carcasses. Easily recognized gross lesions, such as injuries sustained via human interactions, were found to be proportionally higher than disease and parasites, which likely were underestimated due to sampling constraints. Nonetheless, the relatively high proportion of beach cast carcasses exhibiting evidence of net entanglement suggests that fisheries-related mortality maybe higher than that previously considered for New Zealand Common Dolphins. Furthermore, the role of recreational set nets within this category of mortality is, at least in part, clearly implicated. We recommend a closer examination of Common Dolphin mortality within New Zealand waters, with increased effort necessary to access fresh carcasses for more detailed analyses including histopathology.

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