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DOC SCIENCE INTERNAL SERIES 176

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Published by
Department of Conservation
PO Box 10-420
Wellington, New Zealand

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ISSN 1175-6519

ISBN 0-478-22569-5

In the interest of forest conservation, DOC Science Publishing supports paperless electronic publishing. When printing, recycled paper is used wherever possible.

This report was prepared for publication by DOC Science Publishing, Science & Research Unit; editing by Helen O'Leary and layout by Ian Mackenzie. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

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ABSTRACT

The morphological characteristics, estimated age, gender, reproductive status, stomach contents and cause of death were determined for 10 Hector's dolphins (*Cephalorhynchus hectori*), one dusky dolphin (*Lagenorhynchus obscurus*) and one common dolphin (*Delphinus delphis*). The dusky and common dolphins were killed incidentally in commercial fishing operations. The 10 Hector's dolphins were retrieved from set nets (3), floating at sea off the west coast of the North Island (1), beachcast on the west coast of the South Island (5), or east coast of the South Island (1). The stomachs of four Hector's dolphins were empty. The stomachs of all remaining dolphins contained the remains of teleost fish. Fish predominated in the stomachs of Hector's dolphins, but fish and squid were equally represented in the stomachs of the dusky and common dolphins. Age was estimated for all dolphins by counting dentinal growth layer groups in stained sections of teeth. Two female dolphins were sexed using molecular genetic analysis because their gonads had been scavenged. Four female Hector's dolphins were sexually immature, one was mature-anoestrus. They ranged from < 1 year old (neonatal) to approximately 7.5 years old. Four male Hector's dolphins had mature gonads and were between 5 and 7.5 years old. One other, estimated to be 3.5 years old, had histologically immature gonads. The male dusky and common dolphins were sexually mature, and were estimated to be 8.5 and 11 years old, respectively. All the Hector's, dusky, and common dolphins known to have been entangled in nets, had lesions consistent with death from entanglement and asphyxiation. One of the seven remaining beachcast Hector's dolphins had lesions indicative of entanglement, two had lesions consistent with trauma, asphyxiation and sudden death, two were too decomposed to determine cause of death, and two were neonates, their deaths possibly the result of separation from their mothers.

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Duignan, P.J.; Gibbs, N.J.; Jones, G.W. 2004: Autopsy of cetaceans incidentally caught in commercial fisheries, and all beachcast specimens of Hector's dolphins, 2001/02. *DOC Science Internal Series 176*. Department of Conservation, Wellington. 28 p.

1. Introduction

The objective of this study was to fulfill the requirements of DOC contract CSL00/3025 by recording and interpreting data on cetaceans submitted for autopsy. These data included species, sex, size, body condition, age, reproductive status, stomach contents, and cause of death. This report details the findings pertinent to this objective and includes data on 10 Hector's dolphins (*Cephalorhynchus hectori*), one dusky dolphin (*Lagenorhynchus obscurus*) and one common dolphin (*Delphinus delphis*) killed incidentally in fishing operations, found floating at sea, or found beachcast.

Hector's dolphin is a small coastal species, and New Zealand's only endemic cetacean (Baker 1978). The species is divided between at least four genetically distinct sub-populations, with a South Island population of approximately 7300 individuals, and a North Island population with fewer than 100 individuals (Ferreira & Roberts 2003). The North Island population is genetically and morphologically distinct and is now called Maui's dolphin (Pichler et al 1998; Baker et al. 2002). The South Island population has a New Zealand threat classification of 'nationally vulnerable[CD]', while the North Island population is listed as 'nationally critical[CD,HI]' (Hitchmough 2002; Ferreira & Roberts, 2003).

The life history characteristics of the species are similar to those of other members of the genus *Cephalorhynchu*s, such as Commerson's dolphin *(C. commersoni*) and are characterised by a low potential for growth (Lockyer et al. 1988; Slooten & Lad 1990). This, combined with a low rate of female dispersal between populations, increases the vulnerability of the species to local extinction if mortality rates exceed recruitment. Entanglement in nets appears to be one of the most significant factors negatively impacting the species and was the impetus for establishment of a Marine Mammal Sanctuary around Banks Peninsula in November 1988 (Dawson & Slooten 1992) and in the Manukau Harbour and adjacent coast of the northwestern North Island in October 2003. Each year, particularly during the summer months of November–March, Hector's and Maui's dolphins are found beachcast or incidentally caught in the inshore set-net gill fishery. Life history parameters and cause of death have been reported for animals submitted for autopsy between 1997 to 2001 inclusive (Duignan 2003; Duignan et al. 2003a, b). This reports includes similar data collected on animals submitted during 2001 and 2002.

Causes of natural mortality are not well understood, but predation by sharks may be of significance (Slooten & Dawson 1994). Preliminary studies at Massey University based on bycatch and stranded animals suggest that disease may also be a significant cause of morbidity and mortality—particularly viral, bacterial, and fungal infections (Duignan 2000; Van Bressem et al. 2001). Although most research to date has focused on establishing life history parameters to construct predictive models of fisheries impacts (Slooten & Lad 1991; Martien et al. 1999), there is a need for a more research into natural causes of morbidity and mortality.

The dusky dolphin is also an inshore species, but it has a wider distribution in the southern hemisphere in warm temperate and cold temperate waters (Leatherwood et al. 1983). In New Zealand, dusky dolphins are found commonly from East Cape as far south as Campbell Island (Baker 1999). Group sizes vary seasonally—at least in Cook Strait, where hundreds may be seen in summer, but where, in winter, pods of 6–15 are more common (Leatherwood et al. 1983). Although not apparently under threat, causes of mortality for dusky dolphins include stranding (P. Duignan, unpubl. data), predation (Constantine et al. 1998) and entanglement (Leatherwood et al. 1983; Van Bressem et al. 1993). Little is known about causes of disease among New Zealand dusky dolphins, but dolphin pox and herpes-like viral infections are common in this species off Peru (Van Bressem et al. 1993, 1994). Parasitic mastitis, caused by *Crassicauda* sp., is thought to be a cause of reproductive failure for a related species, the Atlantic white-sided dolphin (*L. acutus*) (Geraci & St. Aubin 1987). A similar parasitic infection has been previously observed in stranded and bycatch-caught dusky dolphins in New Zealand (Duignan 2003). Further investigation of the causes of morbidity and mortality are required.

The common dolphin is a pelagic, offshore species and has a very wide distribution, occurring in all warm temperate, subtropical and tropical waters worldwide (Leatherwood et al. 1983). In New Zealand, it is frequently found in coastal waters of both the North and South Islands (Baker 1999). Group sizes vary seasonally and diurnally, but they are regularly found in herds of hundreds, and sometimes of more than a thousand, individuals (Leatherwood et al. 1983). This species is apparently not under threat. However, causes of mortality include stranding (usually of single animals), entanglement, and capture in direct-drive fisheries in some countries (Leatherwood et al. 1983).

A scapula from a decomposed southern right whale (*Eubalaena australis*), was dredged up in one trawl. The species was confirmed with the assistance of Anton van Helden, Marine Mammal Collection Manager, National Museum of New Zealand—Te Papa, in Wellington. No further work was conducted on this specimen. Catch details are in Table A1.1 in Appendix 1.

2. Methods

2.1 NECROPSY PROTOCOL

Carcasses were delivered to Massey University frozen and wrapped in clear plastic bags and woven nylon sacks. One dolphin was identified by a Conservation Services Levy (CSL) observer data sheet, 10 dolphins had orange tags attached around the tailstock, and one had no identification but stranding forms were obtained at a later date. On receipt, the dolphins were stored at –20°C until necropsy. The species and sex was recorded based on external morphology and photographs taken of the external characteristics of each carcass. A unique code and pathology number was assigned to each animal as in the following example:

WB02-10Chh

WB—whale bycatch, 02—year, 10—animal number, and Chh—abbreviation of species (and/or subpopulation or subspecies) scientific name; in this case *Cephalorhynchus hectori hectori*.

Pathological examination and sampling was conducted according to a standard protocol adapted from published small cetacean necropsy protocols (Geraci & Lounsbury 1993; Jefferson et al. 1994). The procedure included recording the body weight (kg), external measurements (m), and examination of the carcass for external lesions such as trauma, net marks, tissue loss, scars, etc. Carcasses were placed with the left side down and an incision made through the blubber from the cranial insertion of the dorsal fin to the ventral midline. Blubber depth (mm) was measured dorsally, laterally and ventrally along this incision. Then the carcass was carefully flensed and the subcutis examined for evidence of trauma. Lesions in the blubber and subcutis were sampled for histopathology by fixing tissue in 10% buffered formalin. A sample of blubber (10 × 10 mm) was taken from the lateral thorax and stored frozen at –80°C for analysis of fatty acid signatures. A sample of blood (10 mL) was collected from one of the large vessels of the heart. The internal organs were examined systematically for lesions, and tissues were sampled for histopathology, virology, parasitology, bacteriology (faeces routinely and tissues where appropriate), toxicology (blubber), genetics (skin), and anatomical studies. The stomach was removed, tied off, and stored chilled until the contents could be examined the following day. At least three of the largest teeth from the middle of the dental arcade of the mandible were extracted, washed and stored in 70% ethanol until they were prepared for age determination. The reproductive organs were carefully dissected, measured (mm), weighed (g), and stored in 10% buffered formalin.

2.2 STOMACH CONTENTS

The full stomachs were weighed (kg) and then opened with scissors and the contents washed through a 1 mm sieve. The stomach was then re-weighed to allow the weight of the stomach contents to be determined. Large, relatively undigested material was removed at this stage and, if possible, an axial length (mm) was measured for fish and squid. Intact food items were also weighed. Smaller, more digested material was gradually sorted using a black-bottomed tray. Otoliths are clearly visible against this background, and as they are denser than most of the other material, they sink to the bottom of the tray. Squid beaks and other relevant food material were also removed and stored in 70% ethanol. Parasites were counted, collected and preserved in 70% ethanol. Lesions in the gastric mucosa were described, counted, and examples were photographed.

2.3 AGE DETERMINATION

Age determination was based on a modification of a published protocol for this species (Slooten 1991). The teeth were washed in tap water and decalcified for 24 h in 5% nitric acid using at least 100 mL/g of tooth. After an overnight wash in water the teeth were immersed in formic acid for 24 h and then washed overnight in running tap water. The teeth were then soft enough to cut away approximately one-third, using a microtome blade. Sections were cut from the remaining tooth at 2–4 mm using a microtome (Microtek Cut 4055F) and stainless steel disposable microtome blades (S35 Feather Safe Razor Co. Medical

Division, Japan). Multiple sections were cut through each tooth and at least two teeth were processed per animal. The sections were then stained with toluene blue, washed in water, dehydrated in absolute alcohol, cleaned in xylene and mounted on glass slides using rapid mounting medium. The dentinal growth layers were counted five times by one observer using a microscope at 16×–80× magnification and the number of growth layer groups (GLGs) assigned by calculating the average value of the readings.

2.4 REPRODUCTIVE STATUS

Females

The reproductive tracts were dissected out and examined grossly. The uterine horns were opened and examined for signs of pregnancy. A sample of each horn was removed then fixed in 10% buffered formalin, embedded in paraffin, sectioned at 4 mm, and stained with hematoxylin for microscopic examination. The length, width and diameter of both ovaries were measured (mm) using Vernier calipers and the ovaries weighed (g) using a Mettler PM 4800 Delta Range balance. The ovaries were sliced at 2 mm intervals along their long axis with a scalpel. The slices were examined for the presence of corpora lutea (CL) and corpora albicantia (CA), both macroscopically and using a dissecting microscope at 10× magnification. Sections were processed for microscopic examination as described above. Sexual maturity was defined as the age at which a female has ovulated at least once, and indicated by the presence of at least one corpus in the ovaries (Harrison et al. 1972). The CAs were classified as per Marsh & Kasuya (1984) and Slooten (1991) as follows:

Large CAs (mean diameter 7–10 mm) were clearly visible as a mass on the surface of the ovary and had a clearly defined stigma. Based on microscopic examination, there were few if any luteal cells, abundant fibrous connective tissue and numerous blood vessels. As the CA ages, the volume of connective tissue decreases relative to the number of vessels.

Medium CAs (mean diameter 3.5–7 mm) protruded less from the surface of the ovary. Histologically, most of the connective tissue had been removed and the blood vessels were more prominent.

Small CAs (mean diameter 1.5–3.5 mm) were visible on the surface of the ovary as small wrinkled scars. Histologically, there was very little fibrous tissue and blood vessels formed the bulk of the tissue.

Histological sections of the uterine horns were classified according to the criteria by Lockyer & Smellie (1985) and Bacha & Wood (1990), as follows.

Immature The endometrium was thin and lined by a simple cuboidal epithelium. The glands were sparse and small with no clear lumen. The tunica vasculare was poorly developed and the arteries had a thin tunica intima and smooth muscle tunic.

Mature-anoestrus The endometrium was thicker than in the immature uterus but the glands were equally sparse and relatively small. However, the tunica vasculare was prominent and the arteries had a tunica intima thickened by elastic fibres and smooth muscle.

Mature-lactating Similar to the previous except that the endometrium appeared more vascular post parturition. The mammary gland was secretory.

Mature-pro-oestrus and mature-oestrus These stages were characterised by increasing depth of the endometrium and progressively greater development and complexity of the endometrial glands.

The mammary glands of all females were dissected to determine the degree of development and to look for evidence of milk secretion. Where milk was present, a sample was stored frozen at –80°C for future research.

Males

The length and midline diameter of the testes (excluding epididymis) were measured (mm) using Vernier calipers and weighed (g) using a Mettler PM 4800 Delta Range balance. The epididymis was weighed (g) separately. Testes were sectioned at 5-mm intervals using a scalpel and examined for evidence of pathological changes. Histological samples were taken from the centre of the testis and epididymis, embedded in paraffin wax, sectioned at 4 mm, mounted on glass slides and stained with haematoxylin and eosin. The sections were then examined microscopically at 16×–80× magnification to assess the maturity of the seminiferous tubule epithelium and for the presence of spermatozoa. Because the cell associations forming the epithelium vary segmentally in mammalian testes, the predominant association in the section was used to classify the stage of maturity. The gonads were classified as immature, pubertal, mature-inactive, or mature-active (Collet & Saint Girons 1984; Slooten 1991).

Immature The seminiferous tubules/cords were narrow and often with no apparent lumen. Sertoli cells and spermatogonia lined the tubules but no further differentiation of germinal cells was apparent. There were abundant interstitial cells. The duct of the epididymis was lined by simple cuboidal epithelium and had a completely empty lumen.

Pubertal The seminiferous tubules were larger than for immature animals and there was consequently less interstitial tissue. The epithelium of the tubules contained spermatogonia, spermatocytes and occasional spermatids but no spermatozoa.

Mature-inactive The seminiferous tubules occupied most of the cross-sectional area and had a defined lumen. The epithelium had sertoli cells, spermatogonia, spermatocytes and early spermatids. Occasional tubule sections may have contained late spermatids. The interstitial cells occupied very little space between the seminiferous tubules. The ducts of the epididymis did not contain spermatozoa.

Mature-active The majority of tubule sections in the testis were lined by an epithelium that had a sequence of differentiation from spermatogonia through to spermatozoa. There was relatively little interstitial tissue present. The lumen of the epididymis might be full of spermatozoa.

3. Results

3.1 CATCH DATA AND OBSERVERS' REPORTS

A total of 10 Hector's dolphin carcasses were received, consisting of 5 females and 5 males. In addition, there was one male dusky dolphin and one male common dolphin. For the common dolphin retrieved from a trawl net, the observer data was recorded with the catch date, time and co-ordinates (see Appendix 1, Table A1.1). The Hector's dolphins were either found entangled in set nets (n = 3), beachcast (n = 6), or floating at sea (n = 1). Of the three Hector's dolphins entangled in set nets, one was removed from a set net and left on the beach near Greymouth, and two had been found on the beach entangled in set nets that had become adrift in Waiuku and Manukau Harbour, Auckland (Table A1.2). The remaining dolphins came from the west and east coasts of the South Island (n = 6) and the northwest coast of the North Island (n = 1) (Table A1.2).

3.2 MORPHOMETRICS

An extensive set of standard measurements was taken from each carcass (Table A1.3).

3.3 STOMACH CONTENTS

The stomach weight (full and empty) and the weight of its contents were recorded, where possible, together with the weights of each compartment of the stomach (Table A1.4). The contents were not identifiable to species for any animal. Six Hector's dolphins had contents in at least one stomach compartment. Most of these contents were indigestible remains of teleost fish such as bones, eye lenses and otoliths. Four Hector's dolphins had empty stomachs. The dusky dolphin contained two whole fish, indigestible fish otoliths, lenses, and squid beaks in the first chamber. Most of the stomach contents of the common dolphin were indigestible, consisting of fish bones and squid beaks, with the latter found in all three compartments. Otoliths and invertebrate parts have been stored in alcohol for more detailed analysis of diet at or immediately before the time of death. Blubber samples were stored for future analysis of fatty acid signatures.

3.4 AGE DETERMINATION

Data on the number of GLGs counted are given in Table A1.5. For Hector's dolphins (n = 10) the teeth did not have obvious incremental layers in the cementum, but there were clearly defined bands in the dentine of most animals.

The accepted protocol for small cetaceans is that one dark band (stained) and one light band (unstained) constitute 1 year's growth (Perrin & Myrick 1980; Slooten 1991). Based on this assumption, the Hector's dolphins ranged in age from neonates (teeth not erupted and not sectioned) to at least 7.5 years. The male dusky dolphin was approximately 8.5 years old, and the male common dolphin was 11 years old. The ages given are minimum estimates based on clearly defined bands. The Hector's dolphin sample consisted of an equal representation of young and mature animals, with no apparent age bias. This differs from previous bycatch investigations in which an age bias has been reported, with the sample consisting mostly of animals ≤ 5 years old. An age bias of 68% was reported by Slooten (1991), of 92% by Duignan (2003), of 81% by Duignan et al. (2003a), and of 65% by Duignan et al. (2003b).

3.5 REPRODUCTIVE STATUS

Females

Morphometric data on reproductive tracts are given in Table A1.6. One female Hector's dolphin (WB02-10Chh) was classified as mature-anoestrus. This animal was aged as 7 years old and had 17 CAs on her ovaries (7 right, 10 left) that, on histological examination, were found to be composed of a mature, collagen-rich, fibrous stroma with well-developed blood vessels. There were no apparent luteal cells. The histology of the uterine horns was consistent with this female being mature, but anoestrus, based on criteria given in Section 2.4. It is likely that this female had given birth because the histology of the uterus was consistent with that of animals that have experienced parturition (Bacha & Wood 1990). The mammary gland was well developed, but inactive. One female dolphin (WB02-24Chh) classified as pubertal, could not be accurately aged. There were no CAs or CLs on either ovary, but there were numerous tertiary follicles in both ovaries. The uterine wall was histologically mature although it was unlikely that this animal has experienced parturition. The mammary gland was well developed but inactive. One female neonate (< 1 year old) Hector's dolphin (WB02-18Chh) had small smooth ovaries with no evidence of either CLs or CAs. The uterine wall was also histologically immature and there was no evidence of lactation. This finding is similar to those for immature female Hector's dolphins aged ≤ 6 years, reported by Slooten (1991), Duignan (2003), and Duignan et al. (2003a, b).

The gonads of the two remaining dolphins had been scavenged and were not available for examination. They were sexed as female from genetic analysis of skin samples. These animals were both neonates and would have been sexually immature.

Males

Of the male Hector's dolphins, two were classed as mature-active, one as mature-inactive, and one as immature/pubescent, based on histological characteristics (Table A1.7). One animal (WB02-12Chm) was too decomposed to undertake histological examination of the testes, but was likely to have been mature, based on the large size of the gonads and its estimated age of 5 years. The two mature-active males had active spermatogenesis, and there were spermatozoa in the testes, epididymis, and penis. The estimated age of these two animals was at least 6 and 7.5 years, and they had combined testicular masses (including epididymis weight) of 666 g and 928 g (Table A1.7). The mature-inactive male was aged at 7.5 years old, and had a combined testicular mass of 313 g. These data are within the range of testicular maturity masses reported by Slooten (1991), Duignan (2003), and Duignan et al. (2003a, b), in which mature males had combined testicular masses ranging from 219 g to 1210 g.

The remaining Hector's dolphin was classed as being immature/pubescent with a combined testicular mass of 60 g and an estimated age of 3.5 years. Although the gradation between immaturity, puberty and maturity is probably indistinct, pubescent males would be expected to have intermediate combined testicular masses. Immature animals have previously been reported with combined testicular masses of between 2 g and 29 g (Duignan 2003; Duignan et al. 2003a, b). Pubescent males are more difficult to classify solely by combined testicular mass, as this overlaps with values for immature animals. Previously reported combined testicular masses for pubescent males were 18 g, 40 g, and 65 g (Duignan et al. 2003a; Slooten 1991).

The male dusky and common dolphins both had mature-active testes and were approximately 8.5 and 11 years old, respectively, based on dentinal GLGs.

3.6 PATHOLOGY

Data on entanglement-related pathology is included in this report (Table A1.8). It should be noted that freezing compromises the interpretation of subtle pathological changes.

Among the dusky and common dolphins incidentally caught in commercial fishing operations, only the dusky dolphin had distinct net marks in the skin encircling the rostrum and along the leading areas of the dorsal fin, pectoral flippers and tail flukes. Evidence of blunt trauma with erythema of blubber, haemorrhage, and oedema of muscle along the mandible and thorax was also observed in both dolphins. Both dolphins had moderate to severe pulmonary oedema and congestion, and myocardial hyper-contraction and hyper-eosinophilia (Table A1.8). In both animals examined there were no other apparent pathological changes that could have caused death.

Among the three Hector's dolphins known to have been entangled in commercial or recreational set nets (WB02-10Chh, -15Chm, and -16Chm), all had distinct net marks in the skin encircling the rostrum and along the leading areas of the dorsal fin, pectoral flipper, and tail flukes. Evidence of blunt trauma with erythema of blubber, haemorrhage and oedema of muscle along the mandible and cranium was also observed in two of the same three dolphins. Both of these animals also had moderate to severe pulmonary oedema and congestion as a gross post-mortem finding. Two of the dolphins were too decomposed to allow histopathological examination of tissues, but of these, one (WB02-16Chm) had regurgitated stomach contents in the mouth, and the other (WB02-15Chm) had sand in the trachea and bronchi.

Of the remaining seven dolphins, the probability of entanglement was high for one (WB02-24Chh) based on skin lesions and lesions that suggested pulmonary asphyxiation and recent trauma. It was moderate for two dolphins (WB02-09Chh and -28Chh) with lesions that suggested pulmonary asphyxiation, and signs of sudden death and trauma. (One of these dolphins also had myocardial hyper-contraction and fibre fragmentation.) Two of the seven dolphins were too decomposed and scavenged for conclusive assessment of the cause of death. However, one of them (WB02-17Chh) was a neonate and may have died following separation from its mother. The probability of entanglement was low for two dolphins, both of which were young animals, whose death may have been a result of separation from their mothers.

4. Discussion

The dolphins examined for this contract were received frozen and double bagged. In general, the packaging was of a high standard and the animals were identified by CSL observer or Independent Fisheries Ltd data sheets, or by orange tags attached around the tailstock. The orange tags around the tailstock of Hector's dolphins were very effective for animal identification. It was beneficial to have a list of animals being shipped forwarded by email to allow a cross-check between animals shipped and those received. In that way, any animal that arrived without a CSL tag or stranding form could be traced. From a health and safety perspective, the packaging was sufficient to prevent contamination of the environment by the carcasses, provided they are maintained frozen.

The number of dusky dolphins examined was too small to make any statements about the ecology of the species, but the life history characteristics of the individuals examined conform to published data for this species (Leatherwood et al. 1983). Dusky dolphins are thought to reach sexual maturity at a standard length of approximately 1.65 m. The only animal submitted was a sexually mature male dusky dolphin which exceeded this length. The dusky dolphin was caught as a result of commercial fishing activities, and had pulmonary and cardiac lesions suggestive of asphyxiation, trauma and unequivocal skin lesions attributable to entanglement.

The life history characteristics of the common dolphins examined in this study are similar to those examined in previous CSL contracts (Duignan et al. 2003a, b), and in previous studies (Leatherwood et al. 1983). The only animal submitted was a sexually mature male that, at 2.28 m, should have attained breeding size based on published data (Leatherwood et al. 1983). The dolphin was caught as a result of commercial fishing activities and had pulmonary and cardiac lesions suggestive of asphyxiation. There were no skin lesions attributable to entanglement. This demonstrates that pathological lesions, other than skin lesions alone, need to be considered in determination of cause of death.

The Hector's dolphins caught by commercial or recreational nets, and those found beachcast, were from areas of the west and east coasts of the South Island—areas that have a high Hector's dolphin population (Slooten & Dawson 1994; Slooten et al. 2002)—and from along the west coast of the North Island where a relict population occurs (Russell 1999). The morphological features of these animals were consistent with those reported previously (Mörzer Bryuns & Baker 1973; Slooten 1991; Slooten & Dawson 1994). The life history data collected from these dolphins complements data from 12 animals examined in 1999, 16 examined in 2000, and 18 in 2001 (Duignan 2003; Duignan et al. 2003a, b). The sex ratio of dolphins submitted was equal (compared with a bias in previous years when males comprised 62% of the animals submitted in 2001, 56% in 2000, and 83% in 1999). This male bias over the previous 3 years differs from a female bias reported by Slooten (1991). Whether the bias represents a population bias or a sampling artifact is unknown. For 2001/02 there was no bias towards immature or mature animals, which contrasts with previous reports on bycatch of Hector's dolphins, where most of the animals examined were sexually immature (Dawson 1991; Slooten 1991; Duignan 2003; Duignan et al. 2003a, b).

Determination of the species of fish and invertebrates ingested by the dolphins was beyond the scope of this investigation, but all hard parts removed from the stomachs were archived for future studies. The stomach contents of Hector's dolphins were similar to those examined by Duignan (2003) and Duignan et al. (2003a, b). As in previous studies, the stomach contents predominately consisted of indigestible teleost fish and invertebrate remains, with fish predominating in the stomachs of Hector's dolphins, but fish and squid equally represented in the stomachs of dusky and common dolphins. The presence of mostly indigestible remains suggests the dolphins had not eaten shortly before death, except for one dusky dolphin whose stomach contained two partially digested teleost fish. The occurrence of regurgitation in the Hector's dolphins is but one of the biases inherent in the use of stomach contents or faeces as an indicator of diet in marine mammals (Jobling & Brieby 1986; Bowen & Harrison 1996). This is because both techniques rely on identifying the remains of prey species and, if regurgitation has occurred, there are no hard parts available for analysis. Recently, blubber fatty acid signature analysis has been advanced as a more sensitive method of investigating diet. This technique is currently under development at Massey University for future studies on the foraging ecology of marine mammals (Iverson et al. 1997).

Age determination based on counting growth layers or annuli in teeth is commonly used on a variety of cetacean species (Perrin & Myrick 1980). Although it is widely used, the technique is subject to difficulties in methodology, interpretation, reader variability, variability among teeth, and the lack of known-age animals (Dapson 1980). The method used to section teeth can also introduce marked biases into the interpretation of age. A method similar to that used previously on this species (Slooten 1991; Duignan 2003) and the related Commerson's dolphin (Lockyer et al. 1988) was used in this study because teeth from known-age Hector's dolphins were not available and this would allow comparison between data sets. The age of animals in this study, as determined by counting dentinal GLGs, corresponded to the morphometric data and reproductive status for the animals examined.

However, caution should be applied when using the ageing data presented in this report because there is no measure of accuracy between the estimated and actual age of the animals.

Entanglement in fishing gear may result in traumatic lesions which are immediately apparent on the exterior of the carcass, such as abrasions, amputations, penetrating wounds, and fractures of limb bones, mandibles, or teeth (Garcia Hartman et al. 1994; Kuiken 1994; Kuiken et al. 1994). For cetaceans, diagnosis of the aetiology is relatively simple because the sensitive, hairless skin is easily damaged and characteristic net marks are often left as impression marks around the rostrum, melon and flippers or dorsal fin. Acute blunt trauma to the body may result in contusions, haemorrhages, and skeletal fractures that are apparent at necropsy. More specific are the cardio-pulmonary changes associated with asphyxiation. These changes include diffuse pulmonary oedema, congestion, emphysema, blood-stained froth in the airways, and pleural congestion. There may also be congestion of pericardial vessels and ecchymotic haemorrhages (haemorrhagic spots) on the endocardium or epicardium. On histological examination, hyper-contraction of myofibres is seen along with fibre fragmentation and vacuolation (Lunt & Rose 1987). Contraction banding is also seen in the media of coronary arteries of people who have died from drowning (Factor & Cho 1985; Lunt & Rose 1987). These acute changes are associated with hypoxia of the myocardium and end in coagulative myocardial necrosis if the individual survives long enough. Similar changes, described as coagulative myocytolysis, are associated with excessive endogenous catecholamine (adrenaline) release typical of trapped and stressed animals (Szakacs et al. 1959; Pack et al. 1994). This lesion also occurs in people who have experienced head trauma (Bakay & Glasaur 1980), victim assault (Cebelin & Hirsch 1980), cocaine abuse (Lipscomb 1992), and drowning (Lunt & Rose 1987). Hypoxia, as occurs during drowning or asphyxiation, may exacerbate the effects of catecholamines on the myocardium (Leitch et al. 1976; Pack et al. 1994). Similar pathogenesis is likely in traumatised and asphyxiated dolphins.

External skin lesions, characteristic of net marks, were observed on four Hector's dolphins and the dusky dolphin. Two dolphins were too decomposed to definitely determine any skin lesions.

Acute pulmonary changes indicative of asphyxiation (i.e. pathologies 1, 2, I, II, III and IV in Table A1.8) were present in many Hector's dolphins (6 of 10, or 60%), and in the dusky and common dolphins. This took the form of acute diffuse congestion and oedema of the lungs, congestion and haemorrhage in the airways, and blood-stained froth in the airways. Many Hector's dolphins (50%) and the dusky and common dolphins also appeared to have acute subendocardial cardiomyopathy (hyper-contraction and fibre fragmentation) of the thickest part of the left ventricular wall, consistent with coagulative myocytolysis or coagulative necrosis. Both lesions are morphologically similar particularly in the peracute to acute stage of lesion development. Cardiac lesions generally take hours to develop to a stage where necrosis is unequivocal. In humans with myocardial infarction, necrosis is not seen for up to 12 h post infarction (Kumar et al. 1992). However, ultrastructural changes as determined by electron microscopy can be seen after 2 h. In this study, light microscopy was used to examine pre-frozen cardiac tissue (rather than electron microsopy as this cannot be applied to pre-frozen tissue). While cardiac damage was sustained by many of the animals examined, beause of the limitations of the techniques and length of time before necrosis becomes apparent, cardiac lesions would not have been detected. This problem needs to be addressed by conducting necropsies on fresh, unfrozen Hector's dolphins as soon as possible after death. Three Hector's dolphins were too decomposed or had been too scavenged to allow the determination of pulmonary and cardiac pathology. These animals have not been included in the following discussion.

Two Hector's dolphins also appeared to have myopathy of the diaphragm that was probably caused by agonal spasm of the muscle associated with asphyxia. As with cardiac myopathy, the diaphragmatic lesions should be further investigated by sampling from fresh carcasses.

Four Hector's dolphins and both the dusky and common dolphins had evidence of blunt trauma before death as indicated by erythema of the blubber, oedema and haemorrhage of the muscle. Of the Hector's dolphins with trauma, one animal had mild trauma limited to the mandible, two animals had moderate trauma limited to the cranium, and one had more severe cranial trauma. The severe trauma would probably have compromised survival had the dolphin not asphyxiated (Bakay & Glasau 1980; Cebelin & Hirsch 1980; Szakacs et al. 1959). A neonatal Hector's dolphin (WB02-02Chh) had broken ribs bilaterally that had, in turn, punctured a lung; there was no evidence of haemorrhage although, as there was advanced decomposition, this was difficult to assess. The fractures may have occurred post mortem or at birth, with death occurring immediately. The dusky dolphin had mild trauma to the mandible that would have been unlikely to cause death. In the case of the common dolphin, there was severe and extensive trauma of the thorax and mandible that would probably have proved fatal.

Because the morphology of the dolphin larynx keeps the alimentary tract and respiratory tracts separate, reflux in dolphins is less likely to pose a risk of aspiration than in pinnipeds or terrestrial mammals. However, captive dolphins are known, on occasion, to eject food material through their blowhole, suggesting that the larynx is not necessarily fixed in place (J.R. Geraci pers. comm.). Gastric contents and fish scales have been found previously in the lungs of a dusky dolphin, suggesting that aspiration can occur. In this study, one Hector's dolphin had regurgitated stomach contents in the mouth. It also had evidence of moderate blunt trauma to the cranium. Trauma may have been implicated in the regurgitation.

In conclusion, the results indicate that entanglement resulted in the death of the dusky and common dolphins, and three Hector's dolphins. There is also a high probability that entanglement caused the death of one other Hector's dolphin examined. The probability of entanglement was moderate for two Hector's dolphins that appeared to have died suddenly; and low for two dolphins that appeared to have died from natural causes. Two animals were too decomposed to establish the cause of death. Most of the animals that were entangled died of acute asphyxiation and cardiomyopathy probably induced by hypoxia and catecholamine release. Many animals had also been subjected to mild to severe trauma that would probably have compromised survival in some dolphins had they not asphyxiated. Such trauma can result in severe muscular and abdominal haemorrhages and may also result in intestinal accidents such as intusussception. Trauma to the head may result in concussion which cannot be diagnosed in frozen carcasses, and may also cause endogenous catecholamine release from the adrenal glands. This is known, at least in humans, to cause lesions in cardiac muscle that result in heart failure. Animals so affected would be unlikely to survive. Impacts that do not necessarily result in visible trauma may cause reflux which, if aspirated, can cause foreign-body pneumonia in animals that survive the initial impact.

5. Acknowledgements

Carcasses were submitted by government observers (Ministry of Fisheries); and by the following DOC staff: M. Abel, A. Hutt, K. McLeod, S. Mowbray, D. Neale, M. Smith and A. van Dijk. Assistance with necropsies and sorting and identifying stomach contents was provided, on occasion, by Maurice Alley, Simon Childerhouse, and Kirsty Russell. Pat Davey and Evelyn Lupton provided assistance with tooth sectioning and preparation of histological slides. Barb Adlington processed intestinal contents for parasitology. We acknowledge the goodwill of the Institute of Veterinary Animal and Biomedical Sciences in provision of additional funds, facilities, storage space, use of the chiller, space for freezers. Mike Hogan was particularly helpful in assisting with carcasses and disposal. This is a client-funded report from the CSL (DOC Science Investigation no. 3025).

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Appendix 1

TABLES OF RESULTS

TABLE A1.1. CAPTURE DATA FOR CETACEANS, 2001/02.

CODE	PATHOLOGY NO.	CSL NO.	DATE	TIME (24 h)	TRIP	HAUL	LATI-TUDE	LONGI-TUDE	SEX
Common dolphin									
WB02-01Dd	32789	1481	14 Oct 01	0220	1558	104	40°S	174°E	M
Southern right whale*									
–	–	–	1 Sept 01	0149	1548	28	42°S	170°E	–
Dusky dolphin									
WB02-11Lo	32951	–	5 Nov 01	–			†	†	M

* Scapula only.

† Co-ordinates not reported, but captured at Oraka, Mahia peninsula.

– Indicates data is not available.

TABLE A1.2. STRANDING DATA FOR BEACHCAST AND BYCATCH-CAUGHT HECTOR'S DOLPHINS 2001/02.

CODE	PATHOLOGY NO.	DOC TAG NO.	DATE	CIRCUMSTANCES	LOCATION
South Island Hector's dolphins—Female					
WB02-02Chh	32848	H41/01	31 Oct 01	Beachcast	2 km north of Buller River mouth, Westport
WB02-10Chh	32950	H43/01	22 Dec 01	Incidental to fishing	300 m south of Paroa Hotel, Greymouth
WB02-17Chh	33151	H47/02	18 Feb 02	Beachcast	Three mile beach, Hokitika
WB02-18Chh	33152	H49/02	14 Mar 02	Beachcast	Paroa, Greymouth
WB02-24Chh	33330	H55/02	13 Apr 02	Beachcast	Kaihina, Hokitika
South Island Hector's dolphins—Male					
WB02-09Chh	32949	H42/01	1 Dec 01	Beachcast	Karoro Beach, South Greymouth
WB02-28Chh	33351	H44/01	24 Dec 01	Beachcast	Washdyke, Timaru
North Island Hector's dolphins—Male					
WB02-12Chm	32972	H45/02	3 Feb 02	Floating at sea	6 m out from Manakau Harbour entrance, Auckland
WB02-15Chm	33111	H46/02	21 Feb 02	Incidental to fishing	35 m mark northwest Wattle Bay, Manakau Harbour
WB02-16Chm	33112	H48/02	21 Feb 02	Incidental to fishing	Karoioitahi Beach, Waiuku, Auckland

TABLE A1.3. MORPHOMETRIC DATA FOR HECTOR'S, COMMON AND DUSKY DOLPHINS, 2001/02.

CODE	PATHOLOGY NO.	Wt (kg)	Std L (m)	Sn-An (m)	Sn-Gen (m)	Sn-ODF (m)	Sn-OF (m)	FL (m)	FW (m)	DF Ht (m)	DFB L (m)	Flk W (m)	Flk L (m)	Gt Pec (m)	Blub.D (m)	Blub.L (m)	Blub.V (m)
South Island Hector's dolphins—Female																	
WB02-02Chh	32848	5.6	0.77	0.54	0.51	0.36	0.20	0.16	0.06	0.07	0.13	0.24	–	0.47	0.100	0.008	0.012
WB02-10Chh	32950	43.0	1.36	0.96	0.89	0.62	0.32	0.22	0.09	0.10	0.23	0.42	0.14	0.82	0.018	0.016	0.018
WB02-17Chh	33151	–	0.64	0.45	0.43	0.34	0.18	0.14	0.04	0.04	0.10	0.18	0.07	–	–	–	–
WB02-18Chh	33152	8.1	0.80	0.59	0.55	0.39	0.21	0.17	0.06	0.06	0.13	0.27	0.08	0.48	0.009	0.100	0.009
WB02-24Chh	33330	41.5	1.27	0.96	0.92	0.58	0.30	0.24	0.09	0.12	0.24	0.50	0.12	0.86	0.014	0.014	0.012
South Island Hector's dolphins—Male																	
WB02-09Chh	32949	33.0	1.21	0.87	0.77	0.57	0.28	0.22	0.08	0.10	0.23	0.48	0.13	0.82	0.012	0.014	0.012
WB02-28Chh	33351	31.5	1.27	0.88	0.78	0.60	0.33	0.21	0.08	0.09	0.21	0.34	0.13	0.76	0.014	0.011	0.009
North Island Hector's dolphins—Male																	
WB02-12Chm	32972	–	–	–	–	–	–	0.21	0.07	0.09	0.20	0.47	0.11	–	–	–	–
WB02-15Chm	33111	32.0	1.33	0.97	0.88	0.61	0.34	0.25	0.09	0.10	0.23	0.47	0.11	0.81	–	–	–
WB02-16Chm	33112	39.4	1.37	0.98	0.87	0.67	0.32	0.25	0.09	0.10	0.23	0.46	0.13	0.90	0.012	0.008	0.010
Common dolphin—Male																	
WB02-01Dd	32789	134.0	2.28	1.63	1.49	0.91	0.53	0.37	0.13	0.25	0.32	0.62	–	1.16	0.012	0.011	0.017
Dusky dolphin—Male																	
WB02-11Lo	32951	72.0	1.70	1.22	1.06	0.72	0.41	0.37	0.12	0.21	0.26	0.48	–	0.95	0.008	0.011	0.009

Wt = weight; Std L = standard body length; Sn-An = snout to anus length; Sn-Gen = snout to genital slit length; Sn-ODF = snout to origin of dorsal fin length; Sn-OF = snout to origin of flipper; FL = flipper length; FW = flipper width; DF Ht = dorsal fin height; DFB L = dorsal fin length at base; Flk W = fluke width; Flk L = fluke length; Gt Pec = girth at pectoral flippers; Blub.D = dorsal blubber depth; Blub.L = lateral blubber depth; Blub.V = ventral blubber depth.

– Indicates data is not available.

TABLE A1.4. STOMACH MORPHOMETRICS AND CONTENTS FOR HECTORS, COMMON AND DUSKY DOLPHINS, 2001/02.

CODE	PATH-OLOGY NO.	STOMACH		COMPARTMENT 1		COMPARTMENT 2		COMPARTMENT 3		PARA-SITES (Y/N)	ULCERS
		FULL WT (kg)	EMPTY WT (kg)	CONTENTS WT (kg)	COMPOSITION	CONTENTS WT (kg)	COMPOSITION	CONTENTS WT (kg)	COMPOSITION		
South Island Hector's dolphins—Female											
WB02-02Chh	32848	–	–	–	–	–	–	–	–	–	–
WB02-10Chh	32950	1.06	–	–	Fish otoliths, lenses, fluid	–	–	TLTM	Yellow fluid	N	–
WB02-18Chh	33152	1.00	–	–	–	–	–	–	–	N	–
WB02-24Chh	33330	1.07	0.82	–	Fish bones, otoliths, sand	–	–	–	–	Y	–
WB02-17Chh	33151	–	–	–	–	–	–	–	–	–	–
South Island Hector's dolphins—Male											
WB02-09Chh	32949	0.46	–	–	Fish otoliths, lenses	TLTM	Fish otoliths	–	–	Y	C2
WB02-28Chh	33351	0.58	–	–	–	–	–	TLTM	Fluid	Y	C2,3
North Island Hector's dolphins—Male											
WB02-12Chm	32972	–	–	–	2 × fish otoliths	–	–	–	–	Y	–
WB02-15Chm	33111	1.85	0.67	1.18	1 × fish, otoliths, bones	–	–	–	–	N	N
WB02-16Chm	33112	0.74	–	–	Fish bones	–	–	–	–	N	–
Common dolphin—Male											
WB02-01Dd	32789	2.20	1.95	0.15	Fish bones, squid beaks	TLTM	Squid beaks	0.10	Squid beaks, fluid	Y	C1
Dusky dolphin—Male											
WB02-11Lo	32951	1.28	0.84	0.44	2 × fish, otoliths, lenses, squid beaks	–	–	TLTM	Fluid	Y	C2

C1, C2 = compartment 1, compartment 2, etc.

TLTM = too little to measure.

– Indicates data is not available.

TABLE A1.5. AGE ESTIMATION BASED ON DENTINAL GROWTH LAYER GROUPS (GLGs) FOR HECTOR'S, COMMON AND DUSKY DOLPHINS, 2001/02.

CODE	PATHOLOGY NO.	AGE	COMMENTS
South Island Hector's dolphins—Female			
WB02-02Chh	32848	–	Neonate
WB02-10Chh	32950	7.0	
WB02-17Chh	33151	–	Neonate
WB02-18Chh	33152	–	Neonate
WB02-24Chh	33330	> 2	Hard to read
South Island Hector's dolphins—Male			
WB02-09Chh	32949	7.5	
WB02-28Chh	33351	> 6	Hard to read
North Island Hector's dolphins—Male			
WB02-12Chm	32972	5.0	
WB02-15Chm	33111	7.5	
WB02-16Chm	33112	3.5	
Common dolphin—Male			
WB02-01Dd	32789	11.0	
Dusky dolphin—Male			
WB02-11Lo	32951	8.5	

– Indicates data is not available.

TABLE A1.6. FEMALE REPRODUCTIVE TRACT MORPHOMETRICS AND CHARACTERISTICS FOR HECTOR'S DOLPHINS, 2001/02.

CODE	PATHOLOGY NO.	RIGHT OVARY				LEFT OVARY				UTERINE MATURITY	GRAVID*	MILK (Y/N)
		Wt (g)	L×W×D (mm)	CA (mm)	CL (mm)	Wt (g)	L×W×D (mm)	CA (mm)	CL (mm)			
South Island Hector's dolphins												
WB02-02Chh	32848†			–	–	–	–	–	–	IM	N	–
WB02-10Chh	32950	3.0	23×16×13	10×7; 7×4; 5×4 (×2); 5×5 (×2); 8×6	–	1.0	23×14×8	7×7; 4×4 (×3); 8×4; 4×3; 6×3; 11×11; 6×4; 5×4	–	MA	N	N
WB02-17Chh	33151*			–	–	–	–	–	–	IM	N	–
WB02-18Chh	33152	< 1.0	14×6×2	–	–	< 1.0	13×7×2	–	–	IM	N	N
WB02-24Chh	33330	4.0	32×15×8	–	–	2.0	26×12×5	–	–	P	N	N

CA = Corpus albicans; CL = Corpus luteum; IM = Immature; MA = Mature-anoestrus; P = Pubertal.

* Determined by the presence of a grossly detectable embryo or foetus.

† Scavenged.

– Indicates data is not available.

TABLE A1.7. MALE REPRODUCTIVE MORPHOMETRICS AND CHARACTERISTICS FOR HECTOR'S, DUSKY, AND COMMON DOLPHINS, 2001/02.

CODE	PATH-OLOGY NO.	RIGHT TESTIS			LEFT TESTIS			TESTIS MATUR-ITY	COMB. TESTICLR MASS* (g)
		WT+EPID (g)	WT-EPID (g)	L×W×D (mm)	WT+EPID (g)	WT-EPID (g)	L×W×D (mm)		
South Island Hector's dolphins									
WB02-09Chh	32949	475.0	402.0	200 × 80 × 70	453.0	386.0	195 × 75 × 65	MA	928.0
WB02-28Chh	33351	337.0	288.0	170 × 65 × 50	329.0	292.0	195 × 70 × 50	MA	666.0
North Island Hector's dolphins									
WB02-12Chm	32972	–	–	170 × 35	–	–	150 × 50 × 50	M?	
WB02-15Chm	33111	148.0	110.0	–	165.0	131.0	–	MI	313.0
WB02-16Chm	33112	28.0	19.0	–	32.0	18.0	–	IM/P	60.0
Common dolphin									
WB02-01Dd	32789	3184.1	2941.5	480 × 120 × 115	3123.6	2855.5	470 × 140 × 105	MA	6307.7
Dusky dolphin									
WB02-11Lo	32951	2373.0	2173.0	460 × 100 × 90	2384.0	2155.0	440 × 110 × 100	MA	4757.0

MA = Mature-active; MI = Mature-inactive; IM = Immature; P = Pubertal.

* Includes epididymis weight.

– Indicates data is not available.

TABLE A1.8. PATHOLOGY OF HECTOR'S, COMMON, AND DUSKY DOLPHINS, 2001/02.

CODE	PATH-OLOGY NO.	ENTANGLEMENT-RELATED PATHOLOGY		ENTANGLE-MENT PROBABILITY
		GROSS	HISTOLOGICAL	
South Island Hector's dolphins—Female				
WB02-02Chh	32848	7, *	III, *	Low
WB02-10Chh	32950	1,3,5	I, III, V, VI, VII	High
WB02-17Chh	33151	*	*	Unknown
WB02-18Chh	33152	–	VI	Low
WB02-24Chh	33330	1,3,5	III, V, IX	High
South Island Hector's dolphins—Male				
WB02-09Chh	32949	3, *	III, V, IX, X	Moderate
WB02-28Chh	33351	1	I, III, V, VI	Moderate
North Island Hector's dolphins—Male				
WB02-12Chm	32972	*	*	Unknown
WB02-15Chm	33111	4,5	*	High
WB02-16Chm	33112	1,3,5,6	*	High
Common dolphin—Male				
WB02-01Dd	32789	1,3	III, V, VI	High
Dusky dolphin—Male				
WB02-11Lo	32951	1,3,5	III, V, VI	High

* Too decomposed to determine.

– Indicates data is not available.

LEGEND TO SYMBOLS ON TABLE A1.8

1 = Respiratory tract congestion and oedema
2 = Pulmonary emphysema
3 = Trauma (contusion +/– free blood in abdomen)
4 = Foreign matter in lungs
5 = External net entanglement marks
6 = Regurgitated food in oesophagus
7 = Bone fracture
I = Tracheal and bronchial congestion/haemorrhage
II = Excess mucus in bronchioles
III = Pulmonary interlobular/ lobular oedema/ congestion
IV = Pulmonary alveolar emphysema
V = Cardiac myofibre hypercontraction
VI = Cardiac myofibre fragmentation
VIII = Tricuspid valve oedema and haemorrhage
IX = Diaphragm myofibre hypercontraction
X = Diaphragm myofibre fragmentation