

Stingray spines: A potential cause of killer whale mortality in New Zealand

Pádraig J. Duignan¹, Jane E. B. Hunter¹, Ingrid N. Visser², Gareth W. Jones¹ and Alan Nutman¹

¹New Zealand Wildlife Health Centre, Institute of Veterinary Animal and Biomedical Sciences, Massey University, Private Bag 11222, Palmerston North, New Zealand

²The Orca Project, Aorangi, Matapouri Road, RD3, Whangarei, New Zealand

Abstract

Stingrays are a significant component of the diet of killer whales (*Orcinus orca*) in New Zealand waters. However, encounters between stingrays and several marine mammal species are known to have fatal consequences for the latter. Thus, it was speculated that similar injuries could be a mortality factor among killer whales in New Zealand. An autopsy examination of a sub-adult female killer whale found floating in the Hauraki Gulf, revealed deep body penetration by two stingray spines and superficial penetration by a third spine. One of the deeply-embedded spines appeared to be recently acquired as it was still covered by an intact integument. It was located posterior to the cranium in the region of the vascular cranial *rete mirabile* and in close proximity to three major arteries. Otherwise, the whale was in good body condition and there was no evidence of pre-existing disease or injury. It is likely that death occurred either as a result of blood loss, or as a result of an acute reaction to toxins released by the stingray spine. Predation on stingrays is probably a learned behavior among killer whales in New Zealand, and given its prevalence among the resident whales, it is generally a successful foraging strategy. However, this case indicates that the strategy is not without risk. Thus, stingray spine injury should be considered a potential cause of stranding or beaching among killer whales in New Zealand.

Key words: Killer whale, *Orcinus orca*, stingray, *Dasyatis* sp., foreign-body penetration, cranial *rete mirabile*.

Introduction

Killer whales (*Orcinus orca*) exhibit a diverse range of foraging behaviors and often appear to specialize in particular prey species in different geographic locations (Martinez & Klinghammer, 1970; Guinet,

1992; Fertl *et al.*, 1996). Although elasmobranchs are consumed, they infrequently are found in the stomachs of beached whales and there are few records of foraging on these species (Martinez & Klinghammer, 1970; Castello, 1977; Fertl *et al.*, 1996). Recently, stingrays were reported as a significant component of the diet of killer whales in New Zealand and it was speculated that this behavior could have costly consequences (Visser, 1999). Indeed, six stingray spines were found embedded in the skin of a killer whale beached in Brazil (Castello, 1977). However, in that case at least, the spines were not the cause of death. Certainly, foraging on, or interaction with stingrays is a documented cause of severe injury and even mortality among bottlenose dolphins (*Tursiops truncatus*) in coastal waters of the eastern United States and Western Australia (Walsh *et al.*, 1988; McFee *et al.*, 1997; Main, 1995). Here we present the first evidence of deep foreign body penetration by stingray spines in a killer whale found dead in New Zealand waters.

Materials and Methods

On 23 November 1998 a recently-dead sub-adult female killer whale was found floating near the Noises Islands in the Hauraki Gulf (36°39'S, 175°01'E). On closer inspection, a large volume of frank blood was observed issuing from the mouth and staining the water around the carcass. The eye patches were photographed, but could not be matched with reference photographs of known individuals in the New Zealand population (Visser & Mäkeläinen, 2000). It was towed to an island and anchored in the water while awaiting necropsy.

Results

Upon examination 24 h after discovery, the carcass was mild to moderately decomposed with patchy

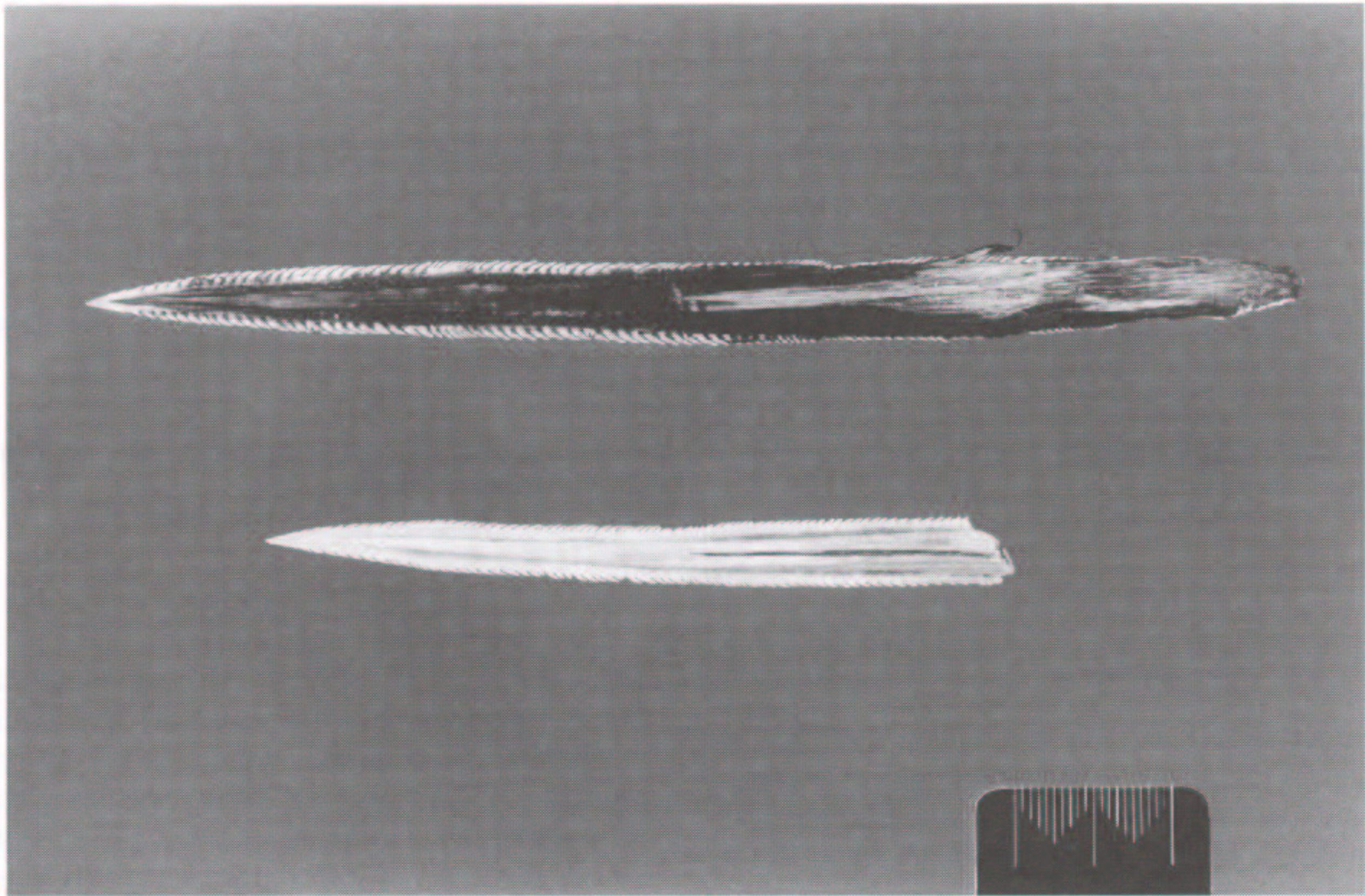


Figure 1. Stingray (*Dasyatis sp.*) spines found in a killer whale (*Orcinus orca*). The top spine was located in the neck of the whale while the lower spine was located in the thoracic region. The scale bar is 2 cm.

sloughing of the skin and mild distention of the abdomen. However, the internal organs were intact. After remaining overnight in the water, there was no longer any blood evident in the mouth. There was no evidence of trauma or apparent perforation of the skin or blubber and no distinguishing features on the flippers, dorsal fin, or flukes. The whale had a standard length of 3.95 m and had lateral and ventral blubber depths between 3 and 4 cm. Body condition was thought to be adequate for a killer whale of this size in waters off northern New Zealand. The teeth had mild wear on the occlusal surfaces and one tooth from the left mid-mandibular arcade was removed for sectioning, etching, and aging (Pierce and Kajimura, 1980).

Three stingray spines were located during dissection of the carcass (Fig. 1). The first spine was broken into two fragments (19 mm × 2.5 mm and 10 mm × 4 mm) located in the hypodermis, 10 cm from the tip of the left mandible and approximately 4 cm ventral to the gingiva. There was no apparent inflammatory reaction associated with the fragments. The second spine (156 mm × 12.5 mm × 6.5 mm) was located in the cranial cervical vascular *rete mirabile* and oriented parallel to the caudal surface of the skull. The pointed end of the spine was directed dorsally and medially (Fig. 2). The spine appeared fresh and was covered by some of the stingray's integument, suggesting that it had only been in the whale's body for a short period of time. There was no evidence of perforation of the

buccal or pharyngeal mucosae or of the oesophagus. However, there was epithelial sloughing that could have obscured a small entry site. The third spine (94 mm × 9 mm × 5 mm) was located in the hypaxial muscle (*m. hypaxialis lumborum*) dorsal to the oesophagus and ventral to the thoracic spinal column on the left side at the level of the 7th and 8th thoracic vertebrae. This spine was white and had no remnants of stingray integument (Fig. 1). It was also enclosed in a capsule of fibrous tissue suggesting a chronic host inflammatory response to the foreign body.

The pleural surfaces and lungs were congested and fluid was expressed easily from cut surfaces of the parenchyma. Fine froth also was present in the bronchi and bronchioles. The stomach was empty, apart from some sand and shell debris in the first chamber. The reproductive tract was immature. The right ovary weighed 11 g and measured 38 × 45 × 24 mm, while the left ovary was 9 g and measured 35 × 23 × 26 mm. The ovaries were quiescent with small (1–2 mm) uniform follicles and no evidence of ovulatory activity. Histological examination was conducted on formalin-fixed samples of the skin, skeletal muscle, lungs, kidneys, liver, heart, arteries, gastro-intestinal tract, and ovaries. Although the finer architectural features of the tissues were lost due to autolysis, acute diffuse pulmonary congestion and hemorrhage was apparent bilaterally. Histological changes consistent with septicaemia were not evident. An incidental finding

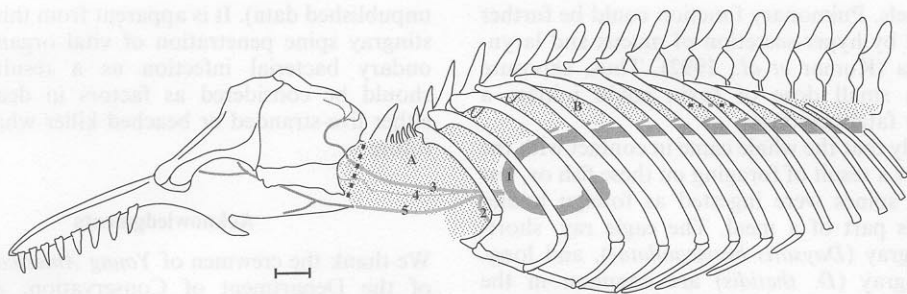


Figure 2. Semi-schematic representation of the skull (without the mandibles) and cranial axial skeleton of a killer whale showing the location of some major arteries and the *rete mirabile* (stippled) in relation to the embedded stingray spines (broken bars). *Rete mirabile*, A in neck, B in thorax; 1, aorta; 2, subclavian artery; 3, presumptive occipital artery; 4, internal carotid artery; 5, external carotid artery. Scale bar is 10 cm.

was a stalked polyp (7 mm × 3 mm) attached to the ileal mucosa.

The two larger spines (Museum of New Zealand catalogue # NMNZ P. 35932) were identified as likely those from a stingray (*Dasyatis sp.*) rather than from an eagle ray (*Myliobatis tenuicaudatus*, Hector 1877). However, it was impossible to determine which of the three *Dasyatis sp.* commonly found in New Zealand waters (Paulin *et al.*, 1989). The fragmentary spine from the mandible was too small to identify with confidence (C. Paulin, Museum of New Zealand, pers. comm.). Based on standard aerobic and microaerophilic bacteriological culture of lung, spleen, kidney, *Proteus vulgaris* was the only bacterium isolated. There were no bacteria isolated from the liver and only *Escherichia coli* and *Proteus vulgaris* from the intestine. None of these isolates were considered significant. Based on dentinal layers in the sagittally-sectioned tooth, the whale was estimated to be between four and six years old (Mitchell & Baker, 1980). This estimate of age is in general agreement with growth of captive killer whales in British Columbia where animals achieved 3.8 m total body length in 5 years and exceeded 4.3 m in 6 years (Bigg, 1982).

Discussion

It is likely that this whale died from blood loss associated with penetration of the stingray spine, or as a result of a reaction to a toxin in the tissues of the spine. The spine was located in the highly vascular cranial cervical *rete mirabile*, and in an area that is traversed by the occipital artery, and the external and internal carotid arteries as indicated in Figure 2 (De Kock, 1959). At *post mortem* it was not possible to determine whether any of the larger vessels were lacerated by the spine because the latter was only discovered while disarticulating the head. Thus, some of the vessels were already severed

before the spine was found. However, the observation by one of the authors of frank blood issuing from the mouth while the carcass was fresh suggests hemorrhage into the pharynx. This would imply that the spine penetrated from the pharynx, rather than from the external surface and, as such, penetration probably occurred as a result of attempted prey apprehension by the whale. However, the exact site of penetration was not located due to sloughing of the buccal and pharyngeal mucosa.

A second possible scenario is that on penetration of the pharyngeal mucosa, venom was released from the integument of the spine into the surrounding tissues (Halloway *et al.*, 1953). The venom reputedly is located in secretory cells in the ventrolateral grooves of the spines (Halstead & Modglin, 1953). The venom is thought to be vasoactive, causing increased vascular permeability, edema, ischemic necrosis, and extreme pain (Russell, 1965; Halstead, 1988). Such a reaction, although painful, would not likely be life threatening in a superficial location. However, acute tissue swelling in a confined location, such as the retro-pharynx, could exert constricting pressure on the upper respiratory tract or compromise blood flow to or from the brain. This whale had acute pulmonary congestion, hemorrhage, and excessive airway froth, all consistent with asphyxiation and similar to pathology observed in by-caught marine mammals (Duignan, unpublished data) and reported for various species of by-caught dolphins and porpoises (Baker & Martin, 1992; Kuiken *et al.*, 1994). Indeed, the acute pulmonary pathology could have been the result of circulating toxin acting directly on the pulmonary blood vessels, or indirectly by initiating an anaphylactic response in an animal previously exposed to the toxin, as in this case (Kumar *et al.*, 1992). In the latter scenario, acute systemic anaphylaxis often affects the lungs and more specifically the smooth muscle of bronchioles and pulmonary

blood vessels. Pulmonary function could be further obstructed by hyper-secretion of mucus and laryngeal edema (Kumar *et al.*, 1992). Thus, exposure to even a small dose of toxin could initiate a potentially fatal response.

It is likely that the whale came in contact with the stingrays as a result of foraging on these fish or, less likely, the spines were ingested as foreign bodies and not as part of a meal. The eagle ray, short-tailed stingray (*Dasyatis brevicaudatus*), and long-tailed stingray (*D. thetidis*) are common in the Hauraki Gulf (Anderson *et al.*, 1998). Benthic foraging by killer whales on these species has been reported in the area where the carcass was found (Visser, 1999). As this activity is not commonly reported for killer whales in other parts of their range, it is presumably a learned behavior in the New Zealand population. As such, there is likely a high level of skill required in the successful utilization of a potentially lethal prey species and perhaps this young female paid the ultimate cost for poor technique.

Although this is the first report of a likely fatal outcome of this foraging activity in killer whales, there are records of fatal encounters between stingrays and other marine mammals. Walsh *et al.* (1988) reported ray encounters as a major factor in the death of six Atlantic bottlenose dolphins (*Tursiops truncatus*) where vital organs including lung, liver, and pancreas were penetrated by spines. Off Western Australia, a stingray spine penetrated the thorax and lodged in the pericardium of a bottlenose dolphin causing pericarditis and pleuritis (Main, 1995). Similar pathology was reported in an Australian fur seal (*Arctocephalus pusillus doriferus*) following penetration by the 20 cm spine of *Urolophus paucimaculatus* which tracked from the esophagus into the heart (Obendorf & Presidente, 1978).

More commonly, stingray spines are an incidental finding when embedded in superficial or non-vital tissues. Thus, spines have been located in the scapula of a bottlenose dolphin (McFee *et al.*, 1997), the snout of a killer whale (Castello, 1977), the neck of a leopard seal, *Hydrurga leptonyx* (Rounsevell & Pemberton, 1994), and the mandible of a bottlenose dolphin (Duignan, unpublished data). Presumably, these superficially-located spines are the result of defensive strikes by rays on marine mammals involved in foraging or play behavior (Castello, 1977; Walsh *et al.*, 1988; Visser, 1999). Given the significance of benthic foraging for stingrays in the diet of killer whales in New Zealand waters, it is likely that non-fatal interactions are commonplace. However, the morbidity and mortality of killer whales resulting from stingray spine injury is unknown since beached killer whale carcasses are a relatively rare occurrence in New Zealand (Visser,

unpublished data). It is apparent from this case that stingray spine penetration of vital organs, or secondary bacterial infection as a result thereof, should be considered as factors in dealing with either live-stranded or beached killer whales in the future.

Acknowledgments

We thank the crewmen of *Young America* and staff of the Department of Conservation, Auckland, namely, Chris Roberts, Paul Keeling, and Philip MacDonald. We thank also Steve Mowbray, Terry Bell, Craig Jennings, Brooke Arnold of the Auckland Volunteer Coastguard. Field assistance was provided by Paul Prosée, Cheli Larsen, Natalie Patenaude (University of Auckland). Dean Whitehead provided a video camera. Chris Paulin, Te Papa, The Museum of New Zealand, Wellington, identified the stingray species. For continued support of our research program we thank Fujitsu New Zealand Ltd., Southmark Computers, Air New Zealand, Kodak NZ Ltd., and Golden Bay Cement. The work was partially funded by Massey University Research Fund, the Whale and Dolphin Conservation Society (UK), and the New Zealand Foundation for the Study of the Welfare of Whales. Thanks to John Craig, University of Auckland, for advice and support. The necropsy and sampling was conducted under a permit issued by the Department of Conservation, Wellington, April 1998.

Literature Cited

- Anderson, O. F., Bagley, N. W., Hurst, R. J., Francis, M. P., Clark, M. R., & McMillan, P. J. (1998) *Atlas of New Zealand Fish and Squid Distributions from Research Bottom Trawls*. National Institute Water and Atmospheric Research Technical Report 42. Publication Services, NIWA, Wellington, New Zealand. 303 pp.
- Baker, J. R., & Martin, A. R. (1992) Causes of mortality and parasites and incidental lesions in harbour porpoises (*Phocoena phocoena*) from British waters. *The Veterinary Record*. **130**, 554–558.
- Bigg, M. (1982) An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. *Report of the International Whaling Commission*. **32**, 655–666.
- Castello, H. P. (1977) Food of a killer whale: eagle sting-ray, *Myliobatis*, found in the stomach of a stranded *Orcinus orca*. *Scientific Reports of the Whales Research Institute*. **29**, 107–111.
- De Kock, L. L. (1959) The arterial vessels of the neck in the pilot-whale (*Globicephala melaena* Triall) and the porpoise (*Phocoena phocoena* L.) in relation to the carotid body. *Acta Anatomica*. **36**, 274–292.
- Fertl, D., Acevedo-Gutierrez, A., & Darby, F. L. (1996) A report of killer whales (*Orcinus orca*) feeding on a

- carcharhinid shark in Costa Rica. *Marine Mammal Science*. **12**, 611–618.
- Guinet, C. (1992) Comportement de chasse des orques (*Orcinus orca*) autour des Isles Crozet. *Canadian Journal of Zoology*. **70**, 1656–1667.
- Halloway, J. E., Bunker, N. C., & Halstead, B. W. (1953) The venom of *Urobatis halleri* (Cooper), the round stingray. *California Fish and Game*. **39**, 77–82.
- Halstead, B. W. (1988) *Poisonous and Venomous Marine Animals of the World*. The Darwin Press, Inc. Princeton, New Jersey, 1168 pp.
- Halstead, B. W., & Modglin, F. R. (1953) A preliminary report on the venom apparatus of the batray, *Holorhinus californicus*. *Copeia*. **3**, 165–175.
- Kuiken, T., Simpson, V. R., Allchin, C. R., Bennett, P. M., Codd, G. A., Harris E. A., Howes, G. J., Kennedy, S., Kirkwood, J. K., Law, R. J., Merrett, N. R. & Phillips, S. (1994) Mass mortality of common dolphins (*Delphinus delphis*) in south west England due to incidental capture in fishing gear. *The Veterinary Record*. **134**, 81–89.
- Kumar, V., Cotran, R. S., & Robbins, S. L. (1992) *Basic Pathology*. 5th ed. W. B. Saunders Company, Philadelphia. 772 pp.
- Main, C. (1995) Necropsy report (dolphin *Tursiops* sp.). Unpublished report, Western Australian Department of Agriculture—Animal Health Laboratories, Perth, Western Australia. 4 pp. Available from: Animal Health Laboratories, Baron-Hay Court, South Perth, WA 6151, Australia.
- Martinez, D. R. & Klinghammer, E. (1970) The behaviour of the whale *Orcinus orca*: a review of the literature. *Zeitschrift für Tierpsychologie*. **27**, 828–839.
- McFee, W., Root, H., Friedman, R. & Zolman, E. (1997) A stingray spine in the scapula of a bottlenose dolphin. *Journal of Wildlife Diseases*. **33**, 921–924.
- Mitchell, E. & Baker, A. N. (1980) Age of reputedly old killer whale, *Orcinus orca*, 'Old Tom' from Eden, Twofold Bay, Australia. Pages 143–154 In: W. F. Perrin and A. C. Myrick Jr., eds. *Age Determination of Toothed Whales and Sireniens*. Reports of the International Whaling Commission, Special Issue 3, Cambridge.
- Obendorf, D. L. & Presidente, P. J. A. (1978) Foreign body perforation of the esophagus initiating traumatic pericarditis in an Australian fur seal. *Journal of Wildlife Diseases*. **14**, 451–454.
- Paulin, C., Steward, A., Roberts, C., & McMillan, P. (1989) *New Zealand Fish: A Complete Guide*. National Museum of New Zealand Miscellaneous series No. 19. Government Printing Office, Wellington, New Zealand, 279 pp.
- Pierce, K. V. & Kajimura, H. (1980) Acid etching and highlighting for defining growth layers in cetacean teeth. Pages 99–103 In: W. F. Perrin and A. C. Myrick Jr., eds. *Age Determination of Toothed Whales and Sireniens*. Reports of the International Whaling Commission, Special Issue 3, Cambridge.
- Rousevell, D. & Pemberton, D. (1994) The status and seasonal occurrence of Leopard Seals, *Hydrurga leptonyx*, in Tasmanian waters. *Australian Mammalogy*. **17**, 97–102.
- Russell, F. E. (1965) Marine toxins and venomous and poisonous marine mammals. Pages 255–384 In: F. S. Russell, (ed.) *Advances in Marine Biology*, Vol. 3. Academic Press, New York.
- Visser, I. N. (1999) Benthic foraging on stingrays by killer whales (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science*. **15**, 220–227.
- Visser, I. N., & Mäkeläinen P. (2000) Variation in eye patch shape of killer whales (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science*. **16**, 459–469.
- Walsh, M. T., Beusse, D., Bossart, G. D., Young, W. G., Odell, D. K. & Patton, G. W. (1988) Ray encounters as a mortality factor in Atlantic bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal Science*. **4**, 154–162.