A selective, annotated bibliography for Hector's dolphin (*Cephalorhynchus hectori*)

DOC SCIENCE INTERNAL SERIES 124

Emmanuelle Martinez and Elisabeth Slooten

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

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy (CSL) are also included.

Individual contributions to the series are first released on the departmental intranet in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are listed in the DOC Science Publishing catalogue on the departmental website http://www.doc.govt.nz and electronic copies of CSL papers can be downloaded from http://www.csl.org.nz

ISSN 1175–6519

ISBN 0–478–22445–1

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 and layout by Helen O'Leary. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

CONTENTS

A selective, annotated bibliography for Hector's dolphin (*Cephalorhynchus hectori*)

Emmanuelle Martinez and Elisabeth Slooten

Department of Zoology, University of Otago, PO Box 56, Dunedin, New Zealand

ABSTRACT

This selective, annotated bibliography lists scientific publications relating to the biology, behaviour, conservation and management of Hector's dolphin (*Cephalorhynchus hectori*) from 1872 onwards. It also includes articles not solely on this species, if they contain important findings relevant to the research and management of *C. hectori*. Unpublished articles or popular books and articles are generally excluded, unless these contain important scientific information not available elsewhere. The bibliography is an on-going project and its authors would welcome updates, corrections or details of relevant articles that should be added.

Keywords: bibliography, *Cephalorhynchus hectori*, Hector's dolphin.

Martinez, E.; Slooten, E. 2003: A selective, annotated bibliography for Hector's dolphin (*Cephalorhynchus hectori*) . *DOC Science Internal Series 124*. Department of Conservation, Wellington. 40 p.

1. Introduction

In this selective, annotated bibliography, we have included scientific publications on Hector's dolphin (*Cephalorhynchus hectori*) and articles that are not solely on this species if they include important findings relevant to *C. hectori* research and management. We have generally not included unpublished articles or popular books and articles, unless these provided important scientific information not available elsewhere. We would like to continue working on this bibliography, expanding it and keeping it up to date. We would like to hear from anyone who has information on articles that they feel should be included in this bibliography, and encourage them to send us a copy of any such articles. Similarly, we would be happy to hear from anyone with updates or corrections to the information presented.

Within the bibliography, entries are listed alphabetically by author. Each author's publications are listed chronologically within the following groups. Works by a single author are listed before those written in collaboration with others. The joint works are listed as follows: author with one co-author, in alphabetical order of second author; author with two co-authors in alphabetical order of second (and if necessary, third) author; and so on. Entries by the same author(s) in the same year are ordered alphabetically by title and distinguished by roman letters in alphabetical sequence after the date (a, b, c etc.).

2. Bibliography

Abel, R. S.; Dobbins, A. G.; Brown, T. 1971. *Cephalorhynchus hectori* subsp. *bicolor* sightings, capture, captivity. *Investigations on Cetacea 3*: 171–179.

Information on the little 'Pied Dolphin' found around the New Zealand coasts. It includes early sightings of the species and their distribution around New Zealand. It also gives notes on their behaviour, in particular around boats, including fishing boats. Although the authors acknowledge that capture of a dolphin might be a little difficult, the article gives the account of the capture of four specimens for Napier Marineland. Observations on the captivity and general health of those dolphins are also provided as well as measurements from a fully grown male specimen in good condition. The subspecific status *bicolor* has since been dropped (see van Bree 1972).

Baird, S. J.; Bradford, E. 2000. *Estimation of Hector's Dolphins Bycatch from Inshore Fisheries, 1997/98 Fishing Year*. Published client report on contract 3024, funded by Conservation Services Levy. Department of Conservation, Wellington. 28 p. http://www.csl.org.nz

Results of an observer programme carried out in 1997–1998 with the objective of estimating the rate of entanglement of Hector's dolphins in set net fisheries in Pegasus Bay and Canterbury Bight. Analysis of the different statistical areas did not always give precise estimates of the total number of dolphins caught. The total estimated number caught was 18. Statistical analysis of the by-catch from observed trawls was not possible. Starr (2000) reanalysed these data. When stratified by area and season, he calculated that observed gillnet catches extrapolate to an estimated total catch of 17 (ignoring set net effort for spiny dogfish; Starr 2000).

Baker, A. N. 1978. The status of Hector's Dolphin, *Cephalorhynchus hectori* (van Beneden), in New Zealand waters. *Reports of the International Whaling Commission 28*: 331–334.

A summary of knowledge on Hector's dolphins, as at 1978, based on published material and new data at that time. Included are: characteristics, internal anatomy, distribution, habitat, population dynamics, reproduction, food habits, parasites, predators, behaviour and further remarks. The paper gives an estimate of total abundance (3000–4000 individuals) which is based on extrapolation from a small part of the species' distribution.

Baker, A.N.; Smith, A. N. H.; Pichler, F. B. 2002. Geographical variation in Hector's dolphin: recognition of new subspecies of *Cephalorhynchus hectori*. *Journal of the Royal Society of New Zealand 32 (4)*: 713–727.

A morphological study of skull and mandible features to examine variation between the west coast of the North Island population (the most genetically distinct population) and the populations of the South Island. Current genetic and morphological evidence indicate that the North Island population is in the process of speciation, however full specific status has not yet been reached. The authors therefore described the North Island population as a new subspecies *Cephalorhynchus hectori maui*, and the nominate South Island populations as *C. hectori hectori*.

Bejder, L. 1997. *Behaviour, Ecology and Impact of Tourism on Hector's Dolphins* (Cephalorhynchus hectori) *in Porpoise Bay, New Zealand*. MSc thesis, University of Otago, Dunedin. 101 p.

Thesis on the ecology and population biology of Hector's dolphins at Porpoise Bay, and the potential impacts of tourism. Most data in this thesis are published in Bejder et al. (1999) and Bejder & Dawson (2001).

Bejder, L.; Dawson, S. M. 2001. Abundance, residency and habitat utilisation of Hector's dolphins in Porpoise Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research 35*: 277–287.

A theodolite-tracking and photo-identification study showing a small resident population that is visited occasionally by members of neighbouring populations. Mark-recapture analysis of photographically identified individuals

indicated a local population of 48 dolphins (95% CI = 44-55) in 1996/97. Dolphins spent a large proportion of their time in a small area inside the bay. Dolphin sightings were more congregated in successive time periods from early morning to late afternoon. No pattern of diurnal movement into and out of the bay was observed.

Bejder, L.; Dawson, S. M.; Harraway, J. A. 1999. Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science 15(3)*: 738–750.

A theodolite-tracking study carried out in the summers of 1995/96 and 1996/97. Dolphins were accompanied by swimmers (within 200 m) for 11.2% of the total observation time, and by boats for an additional 12.4%. Dolphins were not displaced by either of these activities. Analyses of relative orientation indicate that dolphins tended to approach the dolphin-watching vessel in the initial stages of an encounter, but became less interested as the encounter progressed. By 70 min into an encounter dolphins were either actively avoiding the boat or equivocal towards it, approaching significantly less often than would be expected by chance. Analyses of group dispersion indicate that dolphins were significantly more tightly bunched when a boat was in the bay.

Bejder, L.; Fletcher, D.; Bräger, S. 1998. A method for testing association patterns of social animals. *Animal Behaviour 56(3)*: 719–725.

Description of new method that allows testing of the extent to which observed association index values differ from those of a randomly associating population. This method was applied to four data sets of associations from two populations of Hector's dolphins using half-weight index as a measure of association. The results highlight the benefits of using the new testing method in order to validate the analysis of association indices.

Beneden, P. J. van. 1873. Un nouveau dauphin de la Nouvelle-Zélande. *Bulletin de l' Académie Royale de Belgique, Serie. 3, 1(6)*: 1–11.

Description of a complete skeleton of a specimen caught in New Zealand waters and classified as *Electra hectori*.

Beneden, P. J. van. 1881. Notice sur un nouveau dauphin de la Nouvelle-Zélande. *Bulletin de l' Académie Royale de Belgique 1*: 877–888.

Description of Hector's dolphin specimen, then named *Electra hectori*.

Bowman, T. E. 1971. *Cirolana narica* n.sp., a New Zealand isopod (Crustacea) found in the nasal tract of the dolphin *Cephalorhynchus hectori*. *Beaufortia 252(19)*: 107–111.

Description of a new cirolanid isopod, *Cirolana narica*, from the vestibular diverticulum of the blowhole complex of the dolphin, *Cephalorhynchus hectori*. The isopod was believed to be a scavenger that entered the blowhole post mortem.

Bräger, S. 1998. *Behavioural Ecology and Population Structure of Hector's Dolphin (*Cephalorhynchus hectori). PhD thesis, University of Otago, Dunedin. 168 p.

Thesis on the behavioural ecology and population biology of Hector's dolphins in seven study areas along the east and west coasts of the South Island. In spring and early summer, Hector's dolphins exploited a short-term food source preying on small migrating fish close to the surface. They were found closer to shore in summer than winter, and individuals showed high site-fidelity. Hector's dolphins have a fission-fusion society with little stability in group structure. Stereo-photogrammetry and underwater-video systems showed that the majority of dolphins bow-riding were immature or subadults. Mean calving interval was estimated to be 2.2 years.

Bräger, S. 1999a. Association patterns in three populations of Hector's dolphin, *Cephalorhynchus hectori*. *Canadian Journal of Zoology* 77: 13–18.

Description of the association patterns in three populations of Hector's dolphins around the South Island using half-weight index. Overall association patterns from the populations off Kaikoura and Moeraki did not differ significantly from chance; whereas those in Jackson Bay were significantly different. These dolphins appear to have a typical fission-fusion society, with weak associations among individuals.

Bräger, S. 1999b. Feeding associations between white-fronted terns and Hector's dolphins in New Zealand. *Condor 100(3)*: 560–562.

Investigation of the relationship between white-fronted terns (*Sterna striata*) and Hector's dolphins feeding in the near-shore environment during spring and early summer. Terns were more often associated with significantly larger dolphin groups and under calmer sea conditions. Water clarity, however, appeared to have little influence in the association of birds with a group of foraging dolphins. The occurrence of feeding associations appeared to be restricted by the occurrence of small, inshore fish species. The associations are likely to constitute facultative commensalism by the birds and may be particularly advantageous during breeding when energetic demands are high.

Bräger, S.; Chong, A. K. 1999. An application of close-range photogrammetry in dolphin studies. *Photogrammetric Record 16(93)*: 503–517.

Description of a stereophotogrammetric technique developed to measure body length accurately at sea without having to capture the individual. Constant calibration with the use of a control frame allowed accurate body length measurements of dolphins to be made using this low cost system, with a measurement error of 4% to 6% of actual length. These measurements are very useful for demographic analyses of dolphin populations.

Bräger, S.; Schneider, K. 1998. Near-shore distribution and abundance of dolphins along the west coast of the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 32*: 105–112.

Description of the near-shore distribution and abundance of dolphins off the west coast of the South Island (Westport, Greymouth, Jackson Bay and Fiordland). Five delphinid species were recorded: Hector's dolphins, bottlenose dolphins, dusky dolphins, common dolphins and killer whales.

Bräger, S.; Harraway, J. A.; Manly, B. F. J. (in press). Habitat selection in a coastal dolphin species (*Cephalorhynchus hectori*). *Marine Biology*:

Quantification of the habitat used by Hector's dolphins. The preference of these dolphins for warm and turbid waters was tested using eight models. Abiotic factors (water depth, water clarity, sea surface temperature) and the study area explained dolphin presence to a significant degree. Habitat selection by dolphins differed between study area, particularly between east and west coasts, as well as in summer (December to February) and in winter (June to August). Dolphin abundance appeared to change seasonally in some study areas, possibly due to the more offshore distribution of their prey in the winter. In summer (the main reproductive season) dolphins tended to occupy shallow and turbid waters, whereas in winter this habitat was less used

Bräger, S.; Chong, A.; Dawson, S. M.; Slooten, E.; Würsig, B. 1999. A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins. *Helgoland Marine Research 53*: 122–128.

The authors developed a system combining stereo-photography and underwater-video to record dolphin group composition. The system consists of two downward-looking cameras and a video camera in an underwater housing mounted on a small boat. Bow-riding Hector's dolphins were photographed and videotaped at close range in coastal waters around the South Island. Measurements of the distance between the blowhole and the anterior margin of the dorsal fin were calibrated by including a frame with reference points in each set of photographs. Growth functions were derived from measurements of 53 dead Hector's dolphins to provide the necessary reference data.

Bräger, S.; Dawson, S. M.; Slooten, E.; Smith, S.; Stone, G. S.; Yoshinaga, A. 2002. Site fidelity and along-shore range in Hector's dolphin, an endangered marine dolphin from New Zealand. *Biological Conservation 108*: 281–287.

Analysis of movements of photographically identified Hector's dolphins from Banks Peninsula. The furthest two sightings of the same individual were 106 km apart. All other individuals ranged over less than 60 km (mean ± SE = 31.0 ± 2.43 km) of coastline. Gender did not significantly influence alongshore range (females = 30.4 ± 3.21 km, n = 18; males = 27.4 ± 5.68 km, n = 5). Site-fidelity was high. On average, individuals were seen in Akaroa Harbour in about two-thirds of the years they were known to be alive. This strong site-fidelity and small range of movements is very probably the mechanism by which genetic differences between populations have arisen (see Pichler et al. 1998; 2001). These data suggest that impacts will have a localised effect. Localised mortality, such as by-catch in fisheries, could profoundly impact a local dolphin population while having little if any impact on those 100 km away. This also means that there is limited potential for individuals removed from a population to be replaced by individuals from nearby populations. For these reasons, it is important that impacts on Hector's dolphins are managed on an appropriate scale. For example, protected areas should normally extend for at least 30 km alongshore beyond the range of the local dolphin population.

Bree, P. J. H. van. 1972. On the validity of the subspecies *Cephalorhynus hectori bicolor* (Oliver, 1946). *Investigations on Cetacea 4*: 182–186.

Discussion on the validity of the subspecies *bicolor*. Van Bree argued that the creation of a new subspecies of Hector's dolphins by Oliver in 1946 was invalid. There was no sub-specific difference between *bicolor* and the nominate form and patterns and colour in *Cephalorhynchus hectori* might vary considerably. Gaskin (1968) also described Oliver's records as an 'unusual variety of *Cephalorhynchus hectori*'. Dimensions of the skulls of the species were also provided.

Brown, J.; Young, J.; Rutledge, M. 1992. Aerial monitoring of Banks Peninsula Marine Mammal Sanctuary. C1–C11 in: *Banks Peninsula Marine Mammal Sanctuary Report, 1992. Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch.

Report on the aerial monitoring of the Banks Peninsula Marine Mammal Sanctuary, which was initiated by DOC to determine the trend in Hector's dolphin population numbers. The results are discussed as well as possible modifications to the survey procedure.

Buckland, S. J.; Hannah, D. J.; Taucher, J. A.; Slooten, E.; Dawson, S. M. 1990. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans in New Zealand's Hector's dolphin. *Chemosphere 20*: 1035–1042.

Levels of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were estimated from Hector's dolphin blubber samples. These are fat-soluble, anthropogenic pollutants with a range of toxic effects on mammals. This analysis provided information on the levels of these contaminants in New Zealand's most endangered marine mammal. It also provided data on pollutant levels in New Zealand's coastal waters and the extent of the distribution of PCDDs and PCDFs throughout the global environment. The dolphin samples were found to contain unexpected levels of PCDDs and PCDFs. These pollutants are mainly derived from agricultural and industrial chemicals, car emissions, high temperature combustion processes and chlorine bleaching. One would, therefore, expect relatively low levels in a sparsely populated area like New Zealand. The relative levels in males and females suggests that females pass on these pollutants to their offspring through lactation, as is known to occur for other fat-soluble toxins.

Burkhart, S. 1998. *Population Viability Analysis (PVA) of Hector's Dolphin* (Cephalorhynchus hectori). MSc thesis, University of Otago, Dunedin. 182 p.

This thesis contains a more detaled description of the work in Burkart & Slooten (in press). See Burkhart & Slooten (in press) for a summary of the results.

Burkhart, S. M.; Slooten, E. (in press). Population viability analysis for Hector's dolphin (*Cephalorhynchus hectori*): a stochastic population model for local populations. *New Zealand Journal of Marine and Freshwater Research 37*:

Paper on the use of population viability analysis (PVA) to assess the survival prospects of Hector's dolphins over a range of maximum population growth rates, entanglement rates and fishing effort levels in a stochastically varying

environment. Hector's dolphins were modelled as 16 discrete, closed populations corresponding to the 16 fisheries management areas. Increases to either the entanglement rate or fishing effort significantly increased the risk of population decline. Ten of the 16 populations were likely to decline under current fishing levels, five were indefinite, and only one was likely to increase (population partly protected by a marine mammal sanctuary created in 1998). The authors recommend urgent conservation measures to protect the highly threatened North Island populations.

Cameron, C. 1994. *Modelling Survival of Hector's Dolphins around Banks Peninsula, New Zealand*. MSc thesis, University of Otago, Dunedin. 120 p.

This thesis contains a more detailed description of the work in Cameron et al. (1999). See below for a summary of the results.

Cameron, C.; Baker, R.; Fletcher, D.; Slooten, E.; Dawson, S. M. 1999. Modelling survival of Hector's dolphins around Banks Peninsula, New Zealand. *Journal of Agricultural, Biological and Environmental Statistics 4(2)*: 126–135.

This describes a mark-recapture analysis of photographic-identification data, in order to estimate survival rates for Hector's dolphins at Banks Peninsula and to ascertain the effectiveness of the Banks Peninsula Marine Mammal Sanctuary. The sanctuary has had no detectable effect on Hector's dolphin survival. A population viability analysis indicated that the survival rate was not high enough for the Banks Peninsula Hector's population to grow, and recover from past losses through gillnet entanglement. Recent work on the offshore distribution of Hector's dolphins at Banks Peninsula in summer and winter helps to explain why survival rates are still so low. This (as yet unpublished) study shows that a substantial proportion of the population is found outside the sanctuary in summer and especially in winter.

Cawthorn, M. W. 1988. Recent observations of Hector's dolphin, *Cephalorhynchus hectori*, in New Zealand. *Reports of the International Whaling Commission (Special Issue) 9*: 303–314.

Report on observations of Hector's dolphins, including life history parameters, sightings, behaviour, distribution, seasonality, predation, strandings, incidental catches and population numbers. The paper contains an estimate of total abundance (5000–6000 individuals) based on anecdotal reports from fishers and other boat crew. This estimate was not based on survey data, and should not be interpreted as quantitative.

Chavez-Demoulin, V. 1999. Bayesian inference for small-sample capture-recapture data. *Biometrics 55(3)*: 727–731.

Data from Hector's dolphins at Banks Peninsula were used to develop a new method of survival rate analysis. The author describes analysis methods involving multiple capture-recapture sampling and Bayesian inference. They propose a practical method of deriving a posterior distribution for survival rate based on Laplace methods. The Bayesian credibility interval for survival rate of Banks Peninsula dolphins (0.82–0.89) was very similar to conventional estimates of the confidence interval, using a profile likelihood (0.83–0.90) or percentile bootstrap method (0.84–0.88).

Clement, D.; DuFresne, S.; Slooten, E. 2001. *Potential Effects of a Proposed Mussel Farm on the Whales and Dolphins of the North Otago Coastline*. Unpublished report for Sanford South Island Ltd, Bluff. 25 p.

This report summarises data on whales and dolphins off the North Otago coastline, including Hector's, dusky, bottlenose and common dolphins, humpback and southern right whales. It outlines the potential effects of placing a mussel farm in the North Otago area, including habitat competition and fragmentation, organic sediment build-up, shell drop, organic enrichment, oxygen depletion of the sediment, effects on water quality, noise from support vessels, potential boat strikes of marine mammals, construction noise, loss of lines, buoys and plastics, dolphin and whale entanglement in farm structures and changes to food availability for whales and dolphins. The potential impact on local whale and dolphin populations is evaluated, in the light of other (cumulative) human impacts. Hector's dolphin abundance in the area is relatively low. However, there are concerns for the slowly recovering humpback and right whale populations. The main concern for these species is that, due to their low population size and vulnerability to entanglement, even just one incidental mortality could have a significant impact. An adult Bryde's whale was entangled in New Zealand waters in mussel farming gear. This whale was of a similar size to humpbacks and right whales.

Clement, D.; Jones, G.; Slooten, E. 1999. *Report on the Potential Effects of Mussel Farming in Clifford Bay on the Hector's Dolphin Population in the Area*. Unpublished report for Clifford Bay Marine Farms Ltd, Marlborough. 11 p.

This report summarises data on the distribution and abundance of Hector's dolphins in Cloudy Bay and Clifford Bay, comparing dolphin densities there with data from other parts of the Marlborough region. The report outlines the potential impacts of mussel farming on Hector's dolphins, through direct and indirect effects. Direct effects include habitat competition, organic sediment build-up and entanglements. Potential indirect effects include habitat fragmentation and ecosystem changes, in particular changes in the distribution and abundance of Hector's dolphin prey. These potential impacts are discussed in the light of the endangered status of Hector's dolphin populations, and the existing threats to the Clifford Bay population (from gillnet entanglement in particular). A precautionary approach is recommended, including further research on the distribution, behaviour and diet of Hector's dolphins in the area, and the effects of mussel farming on fish communities and benthic ecology, before any approval is granted for the construction of a mussel farm in this area.

Clement, D.; Slooten, E.; Dawson, S.; DuFresne, S. 2001. *Line-transect Survey of Hector's Dolphin Abundance between Farewell Spit and Motunau.* Published client report on contract 3075, funded by Conservation Services Levy. Department of Conservation, Wellington. 15 p. http://www.csl.org.nz

The third in a series of four line-transect surveys, which together cover the South Island habitat of the species. Design principles and methods are as for previous surveys (Dawson et al. 2000; Dufresne et al. 2001). The abundance estimate for Farewell Spit to Motunau was 285 individuals (CV= 38.55%). The greatest abundance within this area was in Cloudy/Clifford Bays (162, CV = 55.53%).

Collins, D. W.; Huysen, J. J. van. 1995. Banks Peninsula Marine Mammal Sanctuary review. A summary and analysis of submissions. *Canterbury Conservancy Miscellaneous Report Series 23*. Department of Conservation, Christchurch. 23 p.

This review was conducted under the Marine Mammals Protection Act 1978 and focuses on set netting impacts on dolphins. The aim of this review was to evaluate current measures for management of the Sanctuary, to evaluate all the available information relevant to the review, in the light of the Sanctuary objective and to determine an appropriate management regime for the future.

Constantine, R. 1999. Effects of tourism on marine mammals in New Zealand. *Science for Conservation 106*. Department of Conservation, Wellington. 60 p.

Report on the rapid growth in marine mammal-based tourism in New Zealand. Marine mammal watching is a wide-ranging industry, involving several species of marine mammals, and there is an increasing demand for permits for land-, boat- and air-based operations. The region with the most concentrated whale and dolphin tourism is Kaikoura. Past and current research projects in New Zealand evaluating the effects of tourism on marine mammals are reviewed. This report highlights the importance of assessing the costs and benefits of this kind of tourism. It also identifies a need to consider further revisions to the regulations, given the recent findings of species-specific research on responses to marine mammal-based tourism and the rapid growth of this industry.

Dawson, S. M. 1988. The high-frequency sounds of free-ranging Hector's dolphins, *Cephalorhynchus hectori*. *Reports of the International Whaling Commission (Special Issue) 9*: 339–344.

First wide-band recordings of Hector's dolphin sounds. Sounds were low-level, high-frequency (c. 120 kHz), single and double pulses that occur in sequences of very variable repetition rate. The structures of these sounds have much in common with those described from *Cephalorhynchus commersonii* and the distantly related *Phocoenoides dalli*.

Dawson, S. M. 1990. *Sounds, Acoustic Behaviour and Gillnet Entanglement of Hector's Dolphin*. PhD thesis, University of Canterbury, Christchurch. 136 p.

Thesis comprising chapters on cetacean sounds and communication, detailed analyses of Hector's dolphin sounds and their relationship to behaviour, an analysis of the incidental catch problem in Canterbury, and a critique of acoustic approaches to minimising gillnet entanglement. This thesis was published as seven papers, described elsewhere in this bibliography.

Dawson, S. M. 1991a. Clicks and communication: The behavioural and social contexts of Hector's dolphin vocalisations. *Ethology 88(4)*: 265–276.

An investigation of the relationship between high-frequency click types and behaviour. Hector's dolphins have a simple vocal repertoire, consisting almost entirely of ultrasonic clicks. They produce no whistles, and very few audible sounds. The proportion of complex click types was greater in large groups, suggesting that these sounds have social significance. Clicks having two peaks in their time envelope and two frequency peaks were strongly associated with behaviours indicative of feeding. High pulse rate sounds, in which the repetition rate of ultrasonic clicks was audible as a 'cry', were most strongly

associated with aerial behaviours. These data suggest that echo-location is not the sole function of Hector's dolphin clicks, and that echo-location and communication are likely to be closely linked. The paper proposes the 'eavesdropping hypothesis' which argues that dolphins may have the ability to gather information from the echoes of one another's sonar pulses. This may reduce the need for a large number of vocal signals, and may explain the apparent simplicity of the acoustic repertoires of some odontocetes.

Dawson, S. M. 1991b. Incidental catch of Hector's dolphins in inshore gillnets. *Marine Mammal Science 7(3)*: 283–295.

An assessment of the incidental catch of Hector's dolphins in gillnets in Pegasus Bay and Canterbury Bight, between 1984 and 1988, based on interviews with fishers. At least 230 Hector's dolphins were killed in groundfish gillnets by commercial and amateur fishers in this period. Approximately 91% of entanglements occurred from November to February. Seasonality of catch corresponded to increased commercial gillnetting inshore in spring and summer. Most entanglements (89%) occurred within 4 n.m. (7.4 km) of the shore, and most dolphins (86%) were caught in water less than 20 m deep. The dolphins' summer inshore movement also coincided with high levels of inshore gillnetting by amateur fishers. The age-frequency of net-caught dolphins suggested that young animals were particularly vulnerable to entanglement.

Dawson, S. M. 1991c. Modifying gillnets to reduce entanglement of cetaceans. *Marine Mammal Science 7(3)*: 274–282.

A critical analysis of progress for two forms of acoustic modifications intended to reduce takes of small cetaceans in gillnets. These modifications seek to make gillnets more obvious to cetaceans so they can avoid them, and include making gillnets more reflective to cetacean sonar and placing active sound-emitters in the nets. The relationship between sonar and net entanglement is discussed and the assumptions and logic of net-modification strategies assessed. The paper argues that neither strategy is likely to be effective, and that reductions in the number of cetaceans killed in gillnets are best achieved through the closure of specific areas to gillnetting.

Dawson, S. M. 1994. The potential for reducing entanglement of dolphins and porpoises with acoustic modifications to gillnets. *Reports of the International Whaling Commission (Special Issue) 15*: 573–578.

A further analysis of reducing entanglement by increasing the acoustic 'target strength' of gillnets, and using active sound-emitters in nets. A review of the literature shows that neither strategy has proven conclusively effective. Air-tube nets and multifilament nets used in the North Pacific Japanese driftnet fishery for salmon have caught fewer Dall's porpoises than equivalent standard gillnets. However, results were not consistently significant over several years, and have not been confirmed by a thorough study of modified gillnets in another driftnet fishery. Studies examining the effects of adding sound-emitters to gillnets have also proven inconclusive. There also appear to be serious problems with the logical basis for acoustic net modification strategies. The author argues that such strategies are not likely to achieve the reductions in cetacean by-catch that are required to conserve several dolphin and porpoise species and proposes alternative methods which are likely to be more effective.

Dawson, S. M. 2001a. Fine-scale abundance estimates from the 2000/2001 aerial survey of Hector's dolphins on the South Island west coast. *DOC Science Internal Series 21*. Department of Conservation, Wellington. 9 p.

Reanalysis of survey data, subsequently presented in Slooten et al. (2002a), on a finer spatial scale in order to provide abundance estimates in relatively small areas of management interest to DOC.

Dawson, S.M. 2001b. *Management of Gillnet By-catch of Cetaceans in New Zealand*. Contracted working paper for Workshop On Interactions Between Dolphins And Fisheries In The Mediterranean: Evaluation of Mitigation Alternatives. Roma 4–5 May 2001. Central Institute for Applied Cetacean Research (ICRAM), Rome.

Review of New Zealand management of gillnet by-catch, summarising: which species are affected, where, and to what extent; management options that have been taken, and whether they were effective; management actions that are pending; and the key unknowns in evaluating effectiveness of management actions in New Zealand.

Dawson, S. M. 2002. *Cephalorhynchus* dolphins. Pp. 202–203 in Perrin, W. F.; Würsig, B; Thewissen, J. G. M. (Eds): *Encyclopedia of Marine Mammals*. Academic Press, San Diego.

Encyclopaedia chapter describing the distribution, biology, behaviour and conservation problems of the *Cephalorhynchus* genus (a genus of four species, of which Hector's dolphin is one).

Dawson, S. M. (in press). Marine mammals. In Knox, G. A (Ed.): *The Natural History of Canterbury*. Canterbury University Press, Christchurch.

Chapter for a popular book on the natural history of Canterbury.

Dawson, S. M.; Slooten, E. 1988. Hector's dolphin, *Cephalorhynchus hectori*: Distribution and abundance. *Reports of the International Whaling Commission (Special Issue) 9*: 315–324.

Report on a small-boat, strip-transect survey of the distribution and abundance of Hector's dolphin, covering 4500 n.m. and undertaken during 1984/85. The species' distribution is described and discussed. Analysis of survey data included corrections for the proportion of dolphins outside the surveyed strip, and the proportion within the strip that were counted by the observers. The survey resulted in an abundance figure of 3408 animals. The authors suggest this figure represents a total population of 3000–4000 individuals. This work has been superseded by the line-transect surveys conducted during 1997–2001.

Dawson, S. M.; Slooten, E. 1992. Conservation of Hector's dolphins: A review of studies which led to the establishment of the Banks Peninsula Marine Mammal Sanctuary. B1–B16 in: *Banks Peninsula Marine Mammal Sanctuary Report, 1992. Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch.

A review of the studies of abundance, gillnet by-catch, survival rate and population modelling which provided the information base for the establishment of the Banks Peninsula Marine Mammal Sanctuary. This paper was written for the review of the Sanctuary, which took place between 1992–1996. A modified version of this paper was published by Dawson & Slooten (1993).

Dawson, S. M.; Slooten, E. 1993. Conservation of Hector's dolphins: The case and process which led to establishment of the Banks Peninsula Marine Mammal Sanctuary. *Aquatic Conservation: Marine and Freshwater Ecosystems 3*: 207–221.

Entanglement in gillnets is the greatest known threat to populations of small cetaceans. In 1988, in response to data on the distribution and abundance, incidental catch, reproduction and population biology of Hector's dolphin, and after an extended period of public consultation, DOC created a 1170 km^2 Marine Mammal Sanctuary. Within this area, gillnetting on a commercial scale is illegal and amateur fishers may only set gillnets in specific times and places. This paper summarises the main research results that led to the creation of the sanctuary, briefly describes the process by which the Sanctuary was established, and offers some comments on the information required for conservation management of small cetaceans.

Dawson, S. M.; Slooten, E. 1996. *Down-under Dolphins: the Story of Hector's Dolphin*. Canterbury University Press, Christchurch. 59 p

A book with public education information about Hector's dolphin. The book is extensively illustrated with photographs, summarising the biology and behaviour of Hector's dolphin and outlining its conservation problems.

Dawson, S. M.; Thorpe, C. W. 1990. A quantitative analysis of the sounds of Hector's dolphin. *Ethology 86*: 131–145.

A very detailed analysis of the structure of Hector's dolphin clicks, using automated digital signal processing methods to measure click features, and multivariate statistical methods to investigate the relationships among sounds. Hector's dolphins make only a very few types of pulsed 'clicks', most of which are centred around 125 kHz. None of these had an average frequency of less than 82 kHz, and the only audible sounds were made up of high-frequency clicks repeated at such high rates that the repetition rate was audible to the researchers as a tonal 'cry' or 'squeal'. In comparison to signal levels recorded from other cetaceans, all the Hector's dolphin signals were low-level; the maximum received sound pressure level was 163 dB (re 1μPa).

Dawson, S. M.; Read, A.; Slooten, E. 1998. Pingers, porpoises and power: uncertainties with using pingers to reduce by-catch of small cetaceans. *Biological Conservation 84(2)*: 141–146.

A paper considering the promise of, and uncertainties associated with, using pingers to reduce by-catch of dolphins and porpoises in gillnets. In 1994, a well-designed study demonstrated a 92% reduction in by-catch of harbour porpoises in sink gillnets equipped with acoustic pingers. This result had not yet been fully replicated either in the New Hampshire area where the experiment was conducted or elsewhere. Statistical power analyses indicate that such studies are feasible only in areas of high entanglement rate. Unanswered research questions include: whether the 1994 results can be replicated; whether habituation might decrease effectiveness over time; and the basis of the mechanism of deterrence. Practical constraints include the size, cost and battery life of current pingers, and whether their use could be monitored cost-effectively. From a management perspective, even if the effectiveness of pingers is confirmed, their widespread incorporation into gillnets may not

alone be sufficient to reduce by-catch to sustainable levels, as required under marine mammal protection legislation in the USA, New Zealand and many other countries. For this reason, scientists, managers and fishers must continue to explore other options, including time/area closures and encouragement of more selective fishing methods.

Dawson, S.; DuFresne, S.; Slooten, E.; Wade, P. 2000. *Line-transect Survey of Hector's Dolphin Abundance between Motunau and Timaru*. Published client report on contract 3072, funded by Conservation Services Levy. Department of Conservation, Wellington. 18 p. http://www.csl.org.nz

The first in a series of four line-transect surveys, which together cover the South Island habitat of the species. This was the first line-transect survey for any New Zealand marine mammal. Transect lines were run at a 45° angle to the coast out to 4 n.m., with lines out to 10 n.m. every 30 n.m. of coastline. The survey was conducted from a modified 15-m catamaran. A team of 5 observers was used, with 3 observers at a time on a purpose-built platform with an eye height of 6 m. Observers used binoculars with a compass and reticles to measure horizontal and vertical angles. Dolphins were strongly attracted to the vessel, and moved towards it from a distance of up to 400 m. Abundance estimates were corrected using data from combined ship/helicopter surveys, which assessed the effect of dolphin attraction and estimated the proportion of dolphins on the track-line that were counted by the observers (see DuFresne et al. 2001). The abundance estimate for Motunau to Timaru was 1198 individuals (CV = 27.3%), 897 dolphins of which were found inside the Banks Peninsula Marine Mammal Sanctuary (CV = 28.2%).

Dawson, S.; Pichler, F.; Slooten, E.; Russell, K.; Baker, C. S. 2001. The North Island Hector's dolphin is vulnerable to extinction. *Marine Mammal Science 17 (2)*: 366–371.

A summary of knowledge on the North Island Hector's dolphin indicating that this population is threatened with extinction. The paper summarises studies showing that: the population is genetically distinct and its genetic diversity is declining; its distribution has contracted over the last few decades, and that abundance is very low, perhaps as few as 100 animals; individuals from this population are taken incidentally in gillnets; and that population viability analyses indicate a declining population. The paper urges urgent conservation action.

Department of Conservation. 1988. *Protection of Hector's Dolphins around Banks Peninsula—a Paper for Public Comment*. Department of Conservation, Wellington. 22 p.

Paper for public comment regarding the protection of Hector's Dolphins around Banks Peninsula. Background information on Hector's dolphins and the issue of set net entanglement are presented as well as the options available for the protection of the dolphins. One of the options was a proposal for a Marine Mammal Sanctuary.

Department of Conservation. 1992. *Banks Peninsula Marine Mammal Sanctuary Technical Report, 1992. Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch. 111 p.

This contains several reports relating to Hector's dolphins in Banks Peninsula: Hector's dolphin research program, 1990–1992 (Stone, G.); Conservation of Hector's dolphins: a review of studies which led to the establishment of the Banks Peninsula Marine Mammal Sanctuary (Dawson, S. M; Slooten, E.); Aerial monitoring of Banks Peninsula Marine Mammal Sanctuary (Brown, J. et al.); Analysis of incidents involving Hector's dolphin since the establishment of the Banks Peninsula Marine Mammal Sanctuary (Rutledge, M.); Review of the Banks Peninsula Marine Mammal Sanctuary (Young, E.); Entanglement of Hector's dolphins in set nets between Motunau and Timaru (Voller, V.).

Department of Conservation and Ministry of Agriculture and Fisheries. 1994. *Review of the Banks Peninsula Marine Mammal Sanctuary. A Paper for Public Comment. Canterbury Conservancy Miscellaneous Report Series 3*. Department of Conservation and Ministry of Agriculture and Fisheries, Christchurch. 34 p.

Document prepared after consultation with key interest groups, inviting the public to participate in the review of the Banks Peninsula Marine Mammal Sanctuary. The focus of the review was on the future management of the Banks Peninsula area to ensure the conservation of Hector's dolphins.

Donoghue, M. 1996. The New Zealand experience—one country's response to cetacean conservation. Pp. 423–455 in Simmonds, M. P.; Hutchinson, J. D. (Eds): *The Conservation of Whales and Dolphins: Science and Practice*. John Wiley & Sons, New York.

Collection of information on New Zealand's historical experience with cetaceans. This includes: Maori cultural heritage; early whaling days and 20th century whaling; IWC; national legislations (Marine Mammals Protection Act 1978 and Marine Mammals Protection Regulations 1992); New Zealand leading advocacy for the improvement of international protection for cetaceans (drift-netting, UNCED); Banks Peninsula Marine Mammal Sanctuary; effects of whale- and dolphin-watching opportunities in New Zealand; the problem of strandings, the whale rescue network and the study of their welfare; pollution, marine debris and captivity; and the opportunity of creating the Southern Ocean Whale Sanctuary, and the role of communities and volunteers.

Duffy, C.; Williams, B. 2001. Preliminary aerial survey for Hector's dolphin (*Cephalorhynchus hectori*), northwest North Island. *Conservation Advisory Notes 332*. Department of Conservation, Wellington. 13 p.

Report on aerial survey for Hector's dolphin between Urenui and Tirua Point in April 1999, carried out by DOC. All coastal waters within 2 km (1.1 n.m.) of shore were searched using a high-wing aircraft flown at an altitude of 120 m. Counts were made of common dolphins, bottlenose dolphins and 14 other species of marine mammal, sea bird and pelagic fish. No Hector's dolphins were observed. Reasons for the apparent absence of Hector's dolphins are discussed. The report concludes with recommendations on the design of future aerial surveys for Hector's dolphins off the northwest North Island.

DuFresne, S. 2000. *Abundance Estimation of Hector's Dolphin*. MSc thesis, University of Otago, Dunedin. 97 p.

Thesis reporting the results of the first boat-based line-transect survey to be carried out in New Zealand waters in January and February 1998. Boat and helicopter surveys were used to estimate a correction factor that accounted for both vessel attraction and dolphins missed on the track-line. The total inshore abundance estimate was 1596 dolphins (CV = 24.13%) between Motunau and Long Point. The effect of survey design on abundance estimates was explored, as a step towards developing guidelines for the design of inshore line-transect surveys. Results indicated that systematic surveys will be more precise than those with random line selection. The effect of stratification on abundance estimates and precision was negligible.

DuFresne, S.; Dawson, S. M.; Slooten, E. 2001. *Line-transect Survey of Hector's Dolphin Abundance between Timaru and Long Point, and Effect of Attraction to Survey Vessel*. Published client report on contract 3074, funded by Conservation Services Levy. Department of Conservation, Wellington. 19 p. http://www.csl.org.nz

The second in a series of four line-transect surveys, which together cover the South Island habitat of the species. This report summarises results of line-transect surveys to quantify the abundance of Hector's dolphins in the coastal area between Timaru (east coast, South Island) and Long Point (12 n.m. west of Te Waewae Bay, Southland). Design principles and methods are as described in Dawson et al. (2000) The greatest dolphin densities were found in Te Waewae Bay and between Timaru and Oamaru. No sightings were made beyond 4 n.m. offshore. Simultaneous boat and helicopter surveys were conducted to measure the effect of dolphins being attracted to the survey vessel and the proportion of sightings missed by the observers. The population estimate from Motunau to Long Point was 1597 individuals (CV = 24.13%).

DuFresne, S.; Slooten, E.; Rayment, W.; Clement, D.; Jones, G. 2000. *Report on the Potential Effects on Hector's Dolphins of a Proposed Mussel Farm in Port Levy*. Unpublished report for Southern Marine Farms Ltd, Wellington 17 p.

This report summarises data on the distribution, abundance and habitat use of Hector's dolphins in the Port Levy area (Banks Peninsula). It outlines the potential direct and indirect effects of placing a mussel farm at Port Levy, including habitat competition and fragmentation, organic sediment build-up, dolphin entanglement and changes to food availability. The potential impact on the local Hector's dolphin population is evaluated, given that it was already declining due to gillnet entanglement and also at risk from pollution, tourism and other human impacts. A precautionary approach is recommended.

Ferreira, S. M.; Roberts, C. C. 2003. Distribution and abundance of Maui's dolphins (*Cephalorhynchus hectori maui*) along the North Island west coast, New Zealand. *DOC Science Internal Series 93*. Department of Conservation, Wellington. 19p

Paper presenting the results of aerial surveys conducted primarily to determine the current distribution of the North Island Hector's dolphins during the summers of 2000/01 and 2001/02. Dolphins were recorded between Kawhia

Harbour and Kaipara Harbour, with most sightings between Port Waikato and Manukau Harbour. Results also suggest that the population could be as small as 75 individuals (CI = 48–130). The authors conclude that strong conservation actions might allow the recovery of this population.

Fletcher, D.; Dawson, S.; Slooten, E. 2002. Designing a mark-recapture study to allow for local emigration. *Journal of Agricultural, Biological and Environmental Statistics 7(4)*: 1–8.

This paper develops a method for estimating the rate of emigration from a population in order to correct estimates of survival. One of the questions addressed is how much fieldwork would be required in order to estimate the rate of emigration, and therefore the degree by which the survival rate estimate would need to be corrected for emigration (individuals that disappear from the study area through emigration rather than death). A follow-up paper will use data on photographically identified individuals from Banks Peninsula and areas to the north and south to estimate a correction for survival rates from that area.

Freeman, D. 2003. A review of records of Hector's dolphins (*Cephalorhynchus hectori*) from the East Coast of the North Island, New Zealand. *East Coast/ Hawke's Bay Conservancy Technical Report Series 11*. Department of Conservation, Gisborne. 13 p.

Review of both confirmed and unconfirmed sightings of Hector's dolphins on the east coast of the North Island, particularly on the southeast coast between Mahia and Wellington. The presence of the species in that area is of particular significance and worthy of further investigation. It has not yet been determined whether these animals are stragglers from the South Island populations, are part of the North Island Hector's dolphin population, or are a completely separate population.

Gaskin, D. E. 1972. Hector's dolphin, *Cephalorhynchus hectori*. Pp. 127–128 in: *Whales Dolphins and Seals. With Special Reference to the New Zealand Region*. Heinemann Educational Books, London.

Description of the species, including morphology, colour and length. The distribution of Hector's dolphins around New Zealand and the biological information available at the time of publication was also summarised.

Harrild, K. 2000. *An Investigation into the use of Acoustic Pingers to Prevent Hector's Dolphin Entanglement in Gillnets*. MSc thesis, University of Canterbury, Christchurch. 53 p.

Thesis presenting the analysis of data from a pilot trial of acoustic pingers aimed at preventing entanglements. There was no evidence of any differences in group size or the distance of dolphin groups from the acoustic device between control and active pingers. Dolphins, however, did exhibit different behaviour depending on the pinger used. This pilot study took place in Akaroa Harbour where commercial gillnetting does not take place. Further investigations, placing pingers on gillnets, is necessary before applications for commercial fishing are clear.

Hawke, D. J. 1994. Seabird association with Hector's dolphins and trawlers at Lyttelton Harbour mouth. *Notornis 41*: 1–4.

Notes on the association between seabird aggregations, trawlers and Hector's dolphins at the mouth of Lyttelton Harbour. The most common three-way association of seabirds, Hector's dolphins and working trawlers involved spotted shags (*Phalacrocorax punctatus*) or Black-backed gulls (*Larus dominicanus*). No white-fronted terns (*Sterna striata*) were observed associating with these dolphins.

Hector, J. 1872a. On the New Zealand Bottlenose (*Lagenorhynchus clanculus*, Gray). *Annals and Magazine and Natural History 4(9)*: 436–438.

Description of a Hector's dolphin specimen, including colouration, shape, measurements and dentition. This paper describes differences in external characteristics and dentition between Hector's dolphin and the genus *Lagenorhynchus* (Gray).

Hector, J. 1872b. On the whales and dolphins of the New Zealand seas. *Transactions and Proceedings of the New Zealand Institute 5*: 154–170.

Notes on specimens of various cetacean species in the Colonial Museum. Guidelines are given on what information should be collected and which bones of the skeleton are most important to preserve. Taxonomic information of Hector's dolphin is included (description, measurement, skull, skeleton, colouration, dentition). Confusion and instability in the nomenclature regarding this species is also mentioned.

Hector, J. 1884. Notes on the dolphins of the New Zealand seas. *Transactions and Proceedings of the New Zealand Institute 17*: 207–211.

Notes on information collected on dolphins frequenting New Zealand coasts. Species were distinguished according to the mode of classification adopted by Gray. This includes Hector's dolphins. Also refers to the confusion in the nomenclature when Hector's dolphins, then called *Electra clancula*, was confounded with *Clymenia obscura*. Taxonomic details are also given and include: teeth, skull, nose and forehead.

Hughey, K. 2000. An evaluation of a management saga: the Banks Peninsula Marine Mammal Sanctuary, New Zealand. *Journal of Environmental Management 58(3)*: 179–197.

Evaluation of the issues surrounding the Sanctuary's establishment, including the process of sanctuary implementation, management and review, conservation costs and benefits.

Hutton, J.; Blair, D.; Slooten, E.; Dawson, S. M. 1987. Case studies of fluke induced lesions in the mesenteric lymph node of Hector's Dolphins (*Cephalorhynchus hectori*). *Diseases of Aquatic Organisms 2*: 83–86.

Fluke eggs (most probably of the genus *Campula*) were found in the mesenteric lymph node of a Hector's dolphin, dissected at the Lincoln Animal Health Laboratory near Christchurch. Another dolphin was found to have a

bacterial infection, which yielded *Eikenella corrodens*, a bacterium previously unknown from marine mammals. The underlying problem in both cases appeared to be an inflammatory response to flukes and eggs, with secondary bacterial infection.

IUCN. 1996. *IUCN Red List of Threatened Species*. IUCN, Gland. http://www.redlist.org

List of all threatened species world-wide, classified according to IUCN criteria into different risk categories. In 1996, Hector's dolphin was classified as Vulnerable.

IUCN. 2000. *IUCN Red List of Threatened Species*. IUCN, Gland. http://www.redlist.org

List of all threatened species worldwide, classified according to IUCN criteria into different risk categories. By 2000, Hector's dolphin was classified as Endangered and the North Island population as Critically Endangered.

Jones, P. D. 1998. Analysis of organic contaminants in New Zealand marine mammals. *Conservation Advisory Science Notes 184*. Department of Conservation, Wellington. 8 p.

Chlorinated organic contaminants were analysed in samples of blubber collected from Hector's dolphins and dusky dolphins. PCBs were detected in all samples, and polychlorinated dibenzo-*p*-dioxin (PCDD) and polychlorinated dibenzofuran (PCDF) congeners were also detected in many of the samples. These compounds were more common and present at higher concentrations in Hector's dolphins than in dusky dolphins.

Jones, P. D.; Hannah, D. J.; Buckland, S. J.; Maanen, T. van.; Leathem, S. V.; Dawson, S. M.; Slooten, E.; Helden, A. van.; Donoghue, M. 1999. Polychlorinated dibenzo-*p*-dioxins, dibenzofurans and polychlorinated biphenyls in New Zealand cetaceans. *Journal of Cetacean Research and Management (Special Issue 1) 1*: 157–167.

This paper presents data on blubber concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) in Hector's dolphins, dusky dolphins, southern right whales, blue whales, minke whales, Gray's beaked whales, Cuvier's beaked whales and pygmy right whales stranded in New Zealand. Both concentrations and toxic equivalents were found to be highest in Hector's dolphins, probably because of their inshore distribution compared to the other species which are more oceanic. The baleen whales, which are oceanic and feed at lower trophic levels, presented the lowest levels of pollutants, with PCDD and PDCF concentrations usually below detection limits. Overall, pollutant levels were lower than those reported for comparable species in the Northern Hemisphere. The relative abundance of PCBs in New Zealand cetaceans, as compared with those from northern waters, suggests that the origin of these compounds is mostly atmospheric deposition.

Jones, P. D.; Leathem, S. V.; Hannah, D. J.; Day, P. J.; Dye, E. A.; Hoffman, K. A.; Lister, A. R.; Porter, L. J.; Maanen, T. van.; Symons, R. K.; Helden, A. van.; Buckland, S. J.; Slooten, E.; Dawson, S. M.; Donoghue, M. 1996. Biomagnification of PCBs and 2,3,7,8-substituted polychlorinated dibenzo-*p*-dioxins and dibenzofurans in New Zealand's Hector's dolphin. *Organohalogen Compounds 29*: 108–113.

Comments on this paper were not available when the bibliography went to press.

Lincoln, R. J.; Hurley, D. E. 1980. *Scutocyamus antipodensis* n.sp. (Amphipoda: Cyamidae) on Hector's dolphin (*Cephalorhynchus hectori*) from New Zealand. *New Zealand Journal of Marine and Freshwater Research 14(3)*: 295–301.

Description of the whale-louse (*Scutocyamus antipodensis*) an ectoparasite on Hector's dolphins. Samples were collected from Cloudy Bay, Cook Strait. This species of ectoparasite differs from the only other species of the genus, in the detailed structure and spinosity of the body and pereopods.

Martien, K. K. F. 2001. *Conservation of Spatially Structured Populations: Lessons from Population Genetics*. PhD thesis, University of California, San Diego. 162 p.

Thesis focusing on conserving spatially structured populations. Three populations of different species were studied, one of them being Hector's dolphin. The results of sensitivity analysis of the model highlight the importance of the source/sink dynamics often displayed by spatially structured populations in determining the dynamics of the population. Attention was focused on the highly imperilled North Island population, which had been previously overlooked in conservation efforts.

Martien, K. K.; Taylor, B. L.; Slooten, E.; Dawson, S. M. 1999. A sensitivity analysis to guide research and management for Hector's dolphin. *Biological Conservation 90*: 183–191.

A density-dependent population model is used to predict the future abundance and geographic distribution of Hector's dolphin under different scenarios of fisheries management. The study examines the sensitivity of this model to several of the input parameters. Three populations are modelled. Two of these, the North Island and South Island west coast populations, were predicted to continue to decline due to by-catch in fishing gear. The status of the remaining population, off the South Island east coast, was uncertain and depended on fishing effort, population growth rate and other model inputs. In all three populations, the rate of population decline depended on the maximum population growth rate, the level of fishing effort and the entanglement rate. The North Island Hector's dolphin population was at greatest risk and, therefore, the top priority for conservation efforts.

Martinez, E.; Green, E.; Dawson, S.M.; Slooten, E. 2002. *Hector's Dolphin* (Cephalorhynchus hectori) *Population Size, Habitat Utilisation, Behaviour, and Response to Tourism in Porpoise Bay*. Unpublished report to the Department of Conservation, Invercargill. 71 p.

Report on the population of Hector's dolphins in Porpoise Bay that has become increasingly popular with tourists. This theodolite-tracking and photo-identification study was carried out in the summer 2001/2002. Photo-identification indicated a local population of 41 individuals. Dolphins tended to

use a small area inside the bay, confirming Bejder & Dawson's (2001) findings. No obvious change in their use of the bay was observed. Dolphins were accompanied by boats for 10% of the total observation time, and by swimmers (within 200 m) for an additional 29% (a significant increase since the 1995–1997 period: Bejder et al. 1999). None of these activities displaced the dolphins from the area. Analyses of relative orientation, indicated that dolphins tend to approach the tour operator vessel during the initial stages of an encounter and swimmers during the first 20 min of an encounter. In both cases, dolphins became less interested as the encounter progressed.

McCutchen, D. 1993. *Comparison of PCB and DDT Levels found in Hector's Dolphin* (Cephalorhynchus hectori) *with an International Literature Review of Organochlorines in Marine Mammals*. Diploma in Wildlife Management thesis, University of Otago, Dunedin. 59 p.

Thesis on the comparison of pollutant levels in Hector's dolphins with levels found in other cetaceans, marine mammals and some land mammals and birds. Possible impacts on the dolphin population are discussed. Management recommendations are aimed at reducing impacts.

McKenzie, J.; Blair, D. 1983. Parasites from Hector's dolphin (*Cephalorhynchus hectori*). *New Zealand Journal of Zoology 10*: 126–127.

Description of the parasites found in carcases of Hector's dolphins around New Zealand. These include digeneans (e.g. *Braunina cordiformis*), acanthocephalans (e.g. *Corynosoma* sp.), a few different species of nematodes (e.g. *Acuaria* sp.) and a larval cestode (*Phyllobothrium delphini*)

Mörzer Bruyns, W. F. J. ; Baker, A. N. 1973. Notes on Hector's Dolphin, *Cephalorhynchus hectori* (van Beneden) from New Zealand. *Records of the Dominion Museum 8(9)*: 125–137.

Notes on observations and measurements from skeletal material in several New Zealand museums. Notes on distribution and behaviour are also included.

Nichols, C.; Stone, G.; Hutt, A.; Brown, J.; Yoshinaga, A. 2001. Observations of interactions between Hector's dolphins (*Cephalorhynchus hectori*), boats and people at Akaroa Harbour, New Zealand. *Science for Conservation 178*. Department of Conservation, Wellington. 49 p.

Report on interactions between Hector's dolphins, boats and people at Akaroa Harbour during the summers of 1999 and 2000. The aim of the study was to assess whether there were changes in dolphin distribution, or behaviour, due to boat activity. Although recreational boats were the most common boat type, dolphins were most commonly associated with kayaks. Dolphin density was independent of boat density and group size did not change with boat presence.

Northern Inshore Fisheries Company Ltd. 2000. *Proposal for Managing the Interaction between the Set Net Fishery and North Island Hector's Dolphin*. Northern Inshore Fisheries Company Ltd, Auckland. 56 p.

A proposal for managing the interaction between the set net fishery and North Island Hector's dolphins which was developed following consultation with other interested groups. Includes a management proposal and a Code of Practice, setting out guidelines for set net fishers. The management proposal

includes a protected area from Manukau Harbour to Aotea Harbour. No gillnetting would be allowed on the open coast, to 4 n.m. offshore. Acoustic 'pingers' would be used in Hector's dolphin habitat north of the protected area, in the hope of warning the dolphins of the nets' presence (unfortunately, there is no scientific evidence that this method works for Hector's dolphins). An additional, seasonal closure is proposed for the area south to Mokau for January, February and March each year, to 2 n.m. offshore. The total protected area (seasonal and year-round protected areas combined) is about half of the habitat of the North Island Hector's dolphin. This option does not include protection for Hector's dolphins in the harbours on the North Island west coast, nor reductions in the amount of trawling.

Oliver, W. R. B. 1946. A pied variety of the coastal porpoise. *Dominion Museum Records in Zoology 1*: 1–4.

Description of a Hector's dolphin seen in Pelorus Sound, including length and colouration. The author proposed that a different form of *Cephalorhynchus hectori* exists around Cook Strait, and named this subspecies *Cephalorhynchus hectori*, subspecies *bicolor*. This subspecies designation has since been abandoned.

Parkins, E. M. 1996. *The Banks Peninsula Marine Mammal Sanctuary. A Recreation Conservation Conflict*. Masters thesis in Park, Recreation and Tourism Management. University of Lincoln, Lincoln. 133 p.

Thesis investigating the underlying causes of the Banks Peninsula Marine Mammal Sanctuary conflict using a questionnaire survey, in-depth interviews, participant observation and archival searches. The author proposes that the main source of the conflict is the removal of traditional recreational access to a commons resource, and that this is an inevitable result of the different perceptions of appropriate use held by those who have interest in the resource. It is suggested that an inadequate public participation and a decision making that relies heavily on scientific information, has exacerbated the problem. Giving full consideration to the values that are important to traditional user groups is proposed as a solution.

Pichler, F. 2002a. A genetic assessment of population boundaries and gene exchange in Hector's dolphin. *DOC Science Internal Series 44*. Department of Conservation, Wellington. 37 p. http://www.csl.org.nz

Report on the genetic assessment of local populations and dispersal rates in Hector's dolphins to inform conservation management. Results confirm analyses of mitochondrial DNA population structures, which show the presence of at least four regional populations (west coast North Island, west coast South Island, east coast South Island, south coast South Island). A measure of exposed mitochondrial DNA diversity suggested a decline in 80% of local populations.

Pichler, F. 2002b. *Population Structure and Genetic Variation in Hector's Dolphin* (Cephalorhynchus hectori). PhD thesis, University of Auckland, Auckland. 200 p.

Thesis using molecular genetics as a tool to uncover information about population structure and genetic variation in Hector's dolphin, to track population declines, and to assess the evolutionary origins and taxonomic

status of this species. The results indicate the presence of four genetically isolated regional populations (North Island, east, west and south coasts of the South Island). They also show that the population declines of the east coast South Island and the North Island populations are of recent origin, implicating by-catch mortality as the principal threat to the species. Inbreeding depression may be contributing to the current decline of the North Island population. It is also suggested that the genus *Cephalorhynchus* originated in the waters off South Africa and, following the West Wind Drift, colonised New Zealand and then South America.

Pichler, F.; Baker, C. S. 2000a. Genetic variation and population structure of Hector's dolphins along the South Island's west coast. *West Coast Conservancy Technical Report Series 4*. Department of Conservation, Hokitika. 24 p.

Examination of the population structure of Hector's dolphins along the entire west coast of the South Island, using mitochondrial DNA. Genetic diversity was low in each of the populations (Westport, Greymouth and Jackson Bay). This result was consistent with small effective population sizes.

Pichler, F. B.; Baker, C. S. 2000b. Loss of genetic diversity in the endemic Hector's dolphin due to fisheries-related mortality. *Proceedings of the Royal Society of London, Series B: Biological Sciences 267(1438)*: 97–102.

Paper providing evidence of reduction in genetic variation (significant loss of mitochondrial DNA diversity) in two regional populations of Hector's dolphins; and further evidence of the severity of population decline and habitat contraction resulting from fisheries and possibly additional human activities. The timing of the loss of diversity at Banks Peninsula closely coincides with the expansion of inshore gillnetting. Given its small size, reproductive isolation and reduced genetic diversity, the North Island population is likely to become extinct in the near future. The diversity of the South Island east coast population has also declined significantly and the authors predict that this population will lose all mitochondrial DNA diversity within the next 20 years.

Pichler, F.; Baker, C. S.; Dawson, S.M.; Slooten, E. 1998. Geographic isolation of Hector's dolphin populations described by mitochondrial DNA sequences. *Conservation Biology 12(3)*: 676–682.

A description of the genetic structure of Hector's dolphin populations, using mitochondrial DNA. Samples from 34 beachcast or gillnet-caught dolphins were analysed. Variation in the DNA sequences identified 11 distinct haplotypes differing from one another by 0.28–1.67 % and by an average of 4.47% from the closely related Commerson's dolphin. The genetic differences match the geographic distribution of the samples. An analysis of variance showed that 74% of the variation could be explained by the three primary sampling regions: North Island, east and west coast of the South Island. Such marked genetic difference across a small geographic range is unusual among whales and dolphins. The low rate of female dispersal, as indicated by this mitochondrial DNA structure, could increase the vulnerability of local populations to extinction due to human impacts. The analysis underscores the vulnerability of Hector's dolphin populations to fisheries-related mortality, and indicates that populations need to be managed separately.

Pichler, F. B.; Robineau, D.; Goodall, R.N.P.; Meyer, M.A.; Olivarria, C.; Baker, C.S. 2001. Origin and radiation of Southern Hemisphere coastal dolphins (genus *Cephalorhynchus*). *Molecular Ecology 10(9)*: 2215–2223.

An investigation of the hypotheses that *Cephalorhynchus* is a monophyletic genus or, alternatively, that the four species arose separately from pelagic lissodelphine species and have converged morphologically. There is a description of the origin and radiation of the species of the genus *Cephalorhynchus* by examining mitochondrial DNA. These sequences were then compared to sequences from other members of the subfamily Lissodelphininae. The results support the monophyly of *Cephalorhynchus* within the Lissodelphininae and a pattern of radiation by colonization. The results suggest that coastal, depth-limited odontocetes are prone to population fragmentation, isolation and occasionally long-distance movements, perhaps following periods of climatic change.

Russell, K. 1999. *The North Island Hector's Dolphin: a Species in Need of Conservation*. MSc thesis, University of Auckland, Auckland. 137 p.

Thesis on the distribution of the North Island Hector's dolphin. A change in dolphin distribution was demonstrated. A preference for shallow, murky, near-shore waters was identified during the summer to autumn months. Although the public has a relatively low level of knowledge about New Zealand whales and dolphins, members of the public displayed a high level of interest in conservation projects and a level of dissatisfaction concerning conservation information, funding and effort.

Rutledge, M. 1992. Analysis of incidents involving Hector's dolphin since the establishment of the Banks Peninsual Marine Mammal Sanctuary. D1–D6 in: *Banks Peninsula Marine Mammal Sanctuary Report, 1992*. *Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch.

Report analysing incidents involving marine mammals, including Hector's dolphins, that have occurred since the establishment of the Marine Mammal Sanctuary. Incidents were reported from within and outside the Sanctuary.

Shorten, R. 1990. *An Educational Booklet about Hector's Dolphins, Cephalorhynchus hectori*. Diploma in Wildlife Management, University of Otago, Dunedin. 23 p.

A concise, easy-to-read booklet providing general information on Hector's dolphins. It covers general biology, distribution and abundance, reproduction, behaviour, sounds, threats to Hector's dolphin, management strategies, and what is still unknown about these dolphins.

Slooten, E. 1990. *Population Biology, Social Organisation and Behaviour of Hector's Dolphin*. PhD thesis, University of Canterbury, Christchurch. 118 p.

Thesis describing a detailed study of the population biology, social organisation and behaviour of Hector's dolphins. It includes data on survival, reproductive rates, age at first reproduction and maximum age. It uses these data to estimate maximum population growth rates and the risk of population decline due to by-

catch in gillnets. As well as providing basic ecological data, the social organisation and behaviour sections indicate features of the population biology of Hector's dolphin (e.g. small, localised populations, increase in reproductive behaviour when groups come together) that affect the impact of human activities on the species. This thesis was published as six papers, described elsewhere in this bibliography.

Slooten, E. 1991. Age, growth and reproduction in Hector's dolphins. *Canadian Journal of Zoology 69*: 1689–1700.

This paper provides data on the reproductive biology and life history of Hector's dolphin. Samples were taken from 60 dolphins found beach-cast or killed incidentally in fishing gear. Male and female reproductive tracts were examined macroscopically and histologically, and tooth sections provided an age estimate for each individual. The maximum observed age was 19 years for females and 20 for males. Females reach a larger body size than males, and are apparently larger than males at any given age. Males appear to reach sexual maturity at between 6 and 9 years old, while females give birth to their first calf at 7 to 9 years. Mature males have very large testes relative to their body size. The maximum found in this study was a 41.5kg male with testes (including epididymides) totalling 1.21 kg.

Slooten, E. 1994. Behaviour of Hector's dolphins: classifying behaviour by sequence analysis. *Journal of Mammalogy 75(4)*: 956–964.

Behaviour sequence analysis was used to classify Hector's dolphin behaviour patterns into five categories: 'feeding', 'sexual', 'aggressive', 'play' and 'aerial'. Feeding behaviours were among the most closely associated behaviours, and were negatively associated with most other behaviours. Biting was closely associated with other apparently aggressive behaviours like tail-splashing and chasing. Copulations and possible copulations were associated with other behaviours one might have intuitively classified as sexual or social (e.g. belly present, penis out and body contact). Aerial behaviours were most strongly associated with sexual and aggressive behaviours. Of the two play behaviours, 'play with weed' was most strongly associated with feeding, and 'bubbleblow' was most strongly associated with aggressive and aerial behaviours. The relationship between the sexual behaviour category and its social context was investigated. The rate of sexual behaviours per individual was highest in groups of 11–15 dolphins, and tended to increase after groups came together.

Slooten, E.; Dawson, S. M. 1988. Studies on Hector's dolphin, *Cephalorhynchus hectori*: a progress report. *Reports of the International Whaling Commission (Special Issue) 9*: 325–338.

This paper summarises work carried out as part of an ongoing research programme on Hector's dolphin, since November 1984. It includes data on distribution and abundance, external characteristics, ecology, behaviour and human-dolphin interactions. In particular, the paper raises concern about incidental catches in gillnets and recommends further work to determine the conservation status of the species.

Slooten, E.; Dawson, S. M. 1989. Hector's dolphin: a case study for integrating conservation and fishing. Pp. 112–114 in Norton, D. A. (Ed.): *Management of New Zealand's Natural Estate: Proceedings of a Symposium of the New Zealand Ecological Society held at the University of Otago, Dunedin, 22–25 August 1988*. New Zealand Ecological Society Occasional Publication No. 1. New Zealand Ecological Society, Christchurch.

A paper summarising data on Hector's dolphin by-catch in fishing operations and its likely impact on the Banks Peninsula population. At the time that this paper was written, the Department of Conservation had recognised gillnet entanglement as a major conservation issue, requiring urgent attention, and had prepared a public discussion document outlining management options. The authors argue in favour of one of the options, a year-round ban on inshore gillnetting in the Banks Peninsula area. This option would be the most effective in terms of the biological and conservation issues, and would affect only two to five commercial fishers. Fishers could continue fishing in the area, and continue to target the same fish species, but would have to change fishing method.

Slooten, E.; Dawson, S. M. 1994. Hector's Dolphin *Cephalorhynchus hectori* (van Beneden, 1881). Pp. 311–333 in Ridgway, S. H.; Harrison, R. (Eds): *Handbook of Marine Mammals, Volume 5. The First Book of Dolphins*. Academic Press, New York.

Paper summarising all research data on Hector's dolphins available at the time, including distribution, abundance, external characteristics, internal anatomy, life history, population dynamics, behaviour, sounds, parasites, disease and human impacts (including by-catch and pollution). Similar information on the other *Cephalorhynchus* species and other dolphin species is included in this handbook.

Slooten, E.; Dawson, S. M. 1995. Conservation of marine mammals in New Zealand. *Pacific Conservation Biology 2*: 64–76.

New Zealand has a diverse fauna of marine mammals, comprising 35 cetacean and 6 pinniped species. None of these is hunted within its 200 mile Exclusive Economic Zone, but several species are killed incidentally in coastal or deep-water fisheries. Particularly affected are Hector's dolphin, Hooker's sea lion (New Zealand sea lion), and the New Zealand fur seal. Detailed information on the nature and magnitude of incidental catches is patchy at best, and inadequate for national assessment of the impact on any one species except for Hector's dolphin and Hooker's sea lion. Other species are known to be caught, but a quantitative assessment of how many are caught each year is impossible. The impact of whale watching on sperm whales has attracted more attention, and the impacts of tourism on other marine mammals are just beginning to be studied. The paper critically reviews the nature and management of the potential threats facing New Zealand marine mammals, including by-catch, entanglement in plastic debris, chemical pollution, and tourism. Research needs and management recommendations are outlined, for each conservation problem.

Slooten, E.; Lad, F. 1991. Population biology and conservation of Hector's dolphin. *Canadian Journal of Zoology 69*: 1701–1707.

During the 1980s, Hector's dolphins were subject to a very high level of entanglement mortality in commercial and amateur gillnets. This paper develops two Leslie matrix population models that incorporate known features of dolphin reproduction and mortality. The simplest model specifies constant survival rates over many age classes. The second model uses more realistic curves of age-specific survival rates. The results indicate that Hector's dolphin, like most other small cetaceans, has a low potential for population growth. Growth rates of 1.8% to 4.9% per year are likely to be the maximum possible for Hector's dolphin populations, which are likely to be declining under existing levels of net entanglement. Survival rate estimates from free-living populations, subject to natural and net-entanglement mortality, resulted in decreasing populations. Even with the most optimistic reproductive parameters, survival rates would need to be some 5% to 10% higher than those observed in populations subject to gillnet entanglement, before population growth could occur. The likely consequences of a reduction in entanglement mortality through conservation management are explored, using the survivorship curve model. These simulations show that the age structure of the population can have an important effect on changes in the size and growth rate of the population during the recovery phase following a reduction in entanglement mortality.

Slooten, E.; Dawson, S. M.; DuFresne, S. 2001. *Report on Interactions between Hector's Dolphins* (Cephalorhynchus hectori) *and a Golden Bay Mussel Farm*. Unpublished report for Environment Canterbury, Christchurch. 11 p.

In response to a request from mussel farming operators, the authors carried out a study of Hector's dolphin distribution with respect to a musselfarm in Golden Bay. Dolphin surveys covered the coastline from Separation Point to Puponga, and included mussel farming operations at Collingwood, Wainui and the 'Ring Roads' in the middle of the bay off Tarakohe. Detailed searches were also made of the Collingwood mussel farm, because staff working there had reported seeing Hector's dolphins within the farm. Five groups of Hector's dolphins were observed. Only one of these groups of dolphins was briefly seen within the boundaries of the mussel farm. These dolphins were seen to move through one of the access lanes that run between the mussel farming blocks, but not between the mussel lines themselves. It is still unclear to what extent Hector's dolphins might use the habitat within Golden Bay mussel farm. This would require a minimum of several months of research. The report recommends further research at this and other existing mussel farms, before any further expansion of mussel farming into Hector's dolphin habitat is considered. Such research would be aimed at answering questions about the dolphins' behavioural responses to farm structures, and the effects of mussel farming on fish communities and benthic ecology. Research recommendations include experimental approaches, moving or removing some or all of the mussel farming blocks to determine if dolphin distribution changes as a result.

Slooten, E.; Dawson, S. M.; Lad, F. 1992. Survival rates of photographically identified Hector's dolphins from 1984–1988. *Marine Mammal Science 8(4)*: 327–343.

Re-sightings of photographically identified individuals were used to estimate survival rates for Banks Peninsula Hector's dolphins. Two complementary models were used to calculate survival rates: A modified Jolly-Seber model and a simpler method which corrects in a more explicit way for individual dolphins being alive but not sighted. The mean ± SE estimated survival rates were very similar (0.85 ± 0.083 and 0.86 ± 0.074 respectively). These survival rates included natural and gillnet mortality, and led to a high probability of population decline (0.78 to 0.99) indicating that gillnet entanglement was a serious risk to the population.

Slooten, E.; Dawson, S.; Rayment, W. 2002. Quantifying abundance of Hector's dolphins between Farewell Spit and Milford Sound. *DOC Science Internal Series 35*. Department of Conservation, Wellington. 18 p. http://www.csl.org.nz

This report summarises the results of an aerial line-transect survey to quantify Hector's dolphin abundance in the coastal area off the South Island's west coast between Farewell Spit and Milford Sound. The primary set of transect lines was placed at 45° to the coast, extending to 4 n.m. offshore. Lines were spaced at 2- or 4-n.m. intervals, in three strata, based on existing distribution data. A secondary set of offshore lines ran 4 to 10 n.m. offshore, and were spaced approximately 30 n.m. apart. Two independent teams of two observers were used in order to estimate the proportion of dolphins missed by each observer. In addition, dive times were recorded from a helicopter to estimate the proportion of time that dolphin groups are visible at the water surface and 'available' to be counted. No sightings were made on the transects 4 to 10 n.m. offshore. Fifty Hector's dolphin groups observed from the helicopter (161 dive/surface cycles) were visible, on average, for about half the time (availability = 46.3%; CV = 4.2%). Data from the two independent observer teams suggest that 96.2% (CV = 2.3%) of dolphin groups at the surface on the track-line are seen. Correcting abundance estimates for both of these factors results in an estimated population of 5388 Hector's dolphins (CV = 20.6%) off the South Island's west coast. The total population estimate for South Island Hector's dolphins is 7270 (CV = 16.2%).

Slooten, E.; Dawson, S. M.; Whitehead, H. 1993. Associations among photographically identified Hector's dolphins. *Canadian Journal of Zoology 71*: 2311–2318.

Associations among Hector's dolphins at Banks Peninsula were studied using cluster analyses of simple and half-weight association indices. In addition, a temporal analysis of associations was carried out, plotting changes in the re-association rate over time. Some individually identified dolphins were photographed in successive seasons and years, indicating they were resident in the area. Social organisation was characterised by relatively fluid association patterns, with little stability over periods longer than a few days. Both male and

female Hector's dolphins interacted with a large number of other individuals, males more so than females. Association patterns and other evidence support the hypothesis that Hector's dolphins have a promiscuous mating system, with each male and female mating with several partners.

Slooten, E.; DuFresne, S.; Clement, D. 2000. *Potential Effects of Mussel Farming on Hector's Dolphin in the Banks Peninsula Region*. Unpublished report for Environment Canterbury, Christchurch. 41 p.

This report summarises data on the distribution, abundance, movements, diet and population dynamics of Hector's dolphins in the Banks Peninsula area. It outlines the potential direct and indirect effects of placing a mussel farm in the Banks Peninsula area, including habitat competition and fragmentation, organic sediment build-up, dolphin entanglement and changes to food availability. The potential impact on local Hector's dolphins is evaluated, given that this population has already suffered a major population decline due to gillnet entanglement and is also at risk from pollution, tourism and a variety of other human impacts. The report recommends that management take into account the cumulative impact of all human activities on Hector's dolphins. The precautionary management recommendation is to allow no further aquaculture development in the Banks Peninsula area. Further research into the effects of mussel farming on Hector's dolphins at existing farms is also recommended, including studies of the distribution and diet of Hector's dolphins in the area, their behaviour towards existing farms and the effects of mussel farming on fish communities and benthic ecology.

Slooten, E.; Fletcher, D.; Taylor, B. L. 2000. Accounting for uncertainty in risk assessment: case study of Hector's dolphin mortality due to gillnet entanglement. *Conservation Biology 14(5)*: 1264–1270.

The authors develop a method that incorporates uncertainty into estimates of the risk of population decline, so that delays in management action can be reduced or eliminated. The management question is whether sufficient risk is posed to the dolphins by mortalities in gillnets to warrant regulating fisheries. The quantitative risk assessment uses a population model that incorporates both demographic (between-individual) and environmental (between-year) stochasticity. Uncertainty in the estimates of model parameters is incorporated by repeatedly running the model for different combinations of survival and reproductive rates. Each value is selected at random from a probability distribution that represents the uncertainty in estimating that parameter. Before drawing conclusions, sensitivity analyses are performed to see whether model assumptions alter the conclusions and to recommend priorities for future research. The study shows that uncertainty did not alter the conclusion that there is a high risk of population decline if current levels of gillnet mortality continue. Sensitivity analyses revealed this to be a robust conclusion. The analysis removes uncertainty in the scientific data as an excuse for inaction.

Slooten, E.; Dawson, S. M.; Pichler, F.; Russell, K. 2000. North Island Hector's dolphin working paper summarising main research results. In: *Record of Support Papers and Presentations to Workshop on North Island Hector's Dolphin, Tuesday 9 and Wednesday 10 May 2000, The Guildhall Room, Abel Tasman Hotel, Willis Street. Wellington*. Department of Conservation and Ministry of Fisheries. c. 8 p.

This paper summarised research results on North Island Hector's dolphin, relevant to management of the population. Following discussion of these data at the public meeting, the authors revised and published the paper as Dawson et al. (2001).

Slooten, E.; Rayment, W.; DuFresne, S.; Clement, D. 2002. *The Whales and Dolphins of the Marlborough Region*. Unpublished report for Marlborough Regional Council. 59 p.

The Marlborough region is important habitat for several whale and dolphin species; in particular Hector's, bottlenose and dusky dolphins, orcas, humpback and southern right whales. The rare and threatened status of Hector's dolphins, humpback whales and southern right whales make the region particularly important for these species. The potential effects of fishing, aquaculture, tourism, pollution and marine traffic are discussed. Incidental catch in gillnet fisheries is the most serious threat and is most likely to affect smaller dolphin species, including Hector's, dusky and common dolphins. Mussel farming dominates aquaculture in the region. It may potentially affect a number of species in a variety of ways. The most likely effects are displacement of resident dolphins, entanglement of large whales and knock-on ecosystem effects on food availability. The most effective way to reduce impacts on whales and dolphins is to avoid the overlap between harmful activities and vulnerable species. Solutions to avoid this overlap are presented, and include shifting fishing effort away from important dolphin populations and re-routing shipping to avoid calving areas and migration routes of large whales. Future research is recommended in order to identify the overlap between harmful activities and important populations, and allow informed decision making on management priorities and solutions. A precautionary and integrated approach to conservation management is recommended, ensuring that the cumulative impact of all potentially harmful activities is considered.

Slooten, E.; Rayment, W.; Clement, D.; Jones, G.; DuFresne, S. 2000. *Report on the Potential Effects on Hector's Dolphins of Proposed Mussel Farming in Akaroa Harbour*. Unpublished report, University of Otago, Dunedin. 17 p.

This report provides data on the distribution, abundance and movements of Hector's dolphins in Akaroa Harbour. The Akaroa Harbour area and Banks Peninsula waters immediately adjacent to the harbour are heavily used by Hector's dolphins, in particular in summer. The report addresses the potential impacts of placing a mussel farm in Akaroa Harbour, including habitat competition and fragmentation, organic sediment build-up, dolphin entanglement and changes to food availability. The potential impact on the local Hector's dolphins is evaluated in the context of existing impacts including gillnet entanglement, pollution, tourism and a variety of other human impacts. The authors recommend that management take into account the cumulative impact of all human activities on Hector's dolphins at Akaroa Harbour. Research

recommendations include investigation of dolphin behaviour towards existing aquaculture operations as well as the effects of existing musselfarms on fish communities and benthic ecology. Given that Akaroa Harbour is centred on one of the regions of densest Hector's dolphin concentration and the population is already endangered and protected by a Marine Mammal Sanctuary, this is not recommended as a suitable area for further aquaculture development.

Smith, S. L. 1992. *Distribution, Movements and Abundance of Hector's Dolphin around Banks Peninsula*. MSc thesis, University of Canterbury, Christchurch. 97 p.

Thesis providing information of the distribution, movements and abundance of Hector's dolphins around Banks Peninsula which is important for effective management of the population and also to assess the effectiveness of the Marine Mammal Sanctuary. The results suggest that dolphins resident around the Peninsula are a single interacting population. Dolphin numbers could not be estimated reliably from mark-recapture methods with the available data. Instead, surveys were an appropriate sampling strategy to estimate abundance. Estimates of abundance for the northern portion of Banks Peninsula for 1990/1991 and 1991/1992 were in the range of previously reported for Banks Peninsula.

SouthEast Finfish Management Company Ltd. 2000. Voluntary code of practice—commercial set netters. In: *Record of Support Papers and Presentations to Workshop on North Island Hector's Dolphin, Tuesday 9 and Wednesday 10 May 2000, The Guildhall Room, Abel Tasman Hotel, Willis Street. Wellington*. Department of Conservation and Ministry of Fisheries. c. 25 p.

Report aimed at providing guidance to commercial set net fishers to minimise, reduce or avoid interaction with Hector's dolphins. It includes actions to be taken on capture of dolphins, gear deployment and fishing monitoring. The effectiveness of this voluntary code of practice is untested.

Starr, P. 2000. *Comments on 'Estimation of the Total By-catch of Hector's Dolphins* (Cephalorhynchus hectori) *From the Inshore Trawl and Set Net Fisheries off the East Coast of the South Island in the 1997–98 Fishing Year'*. Unpublished paper presented to Conservation Services Levy Working Group. Department of Conservation, Wellington, New Zealand. 4 p.

Report providing a reanalysis of the observer data presented in Baird & Bradford (2000). When stratified by area and season, observed gillnet catches (ignoring set net effort for spiny dogfish) extrapolate to an estimated total catch of 17.

Starr, P.; Langley, A. 2000. *Inshore Fishery Observer Programme for Hector's Dolphins in Pegasus Bay, Canterbury Bight, 1997/1998*. Published client report on contract 3020 funded by Conservation Services Levy. Department of Conservation, Wellington. 28 p. http://www.csl.org.nz

Report on the results of an observer programme carried out in 1997–1998 with the objective of estimating the rate of entanglement of Hector's dolphins in set net fisheries in Pegasus Bay and Canterbury Bight. Five entanglement incidents were observed in set net fisheries for a total of 8 animals. Two were released alive. One dolphin was caught in a the trawl fishery. All incidents occurred near the shore, in shallow depths of less than 30m

Stone, G. 1992. Hector's dolphin research programme, 1990–1992. A1–A68 in: *Banks Peninsula Marine Mammal Sanctuary Report, 1992. Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch.

Report on research carried out by Dawson, Slooten, Stone and Yoshinaga, between 1990 and 1992. Population structure, movements and population trends in the Sanctuary are discussed, in the context of conservation management.

Stone, G. 1995. Diurnal movement patterns of Hector's dolphin as observed from cliff tops. *Marine Mammal Science 11(3)*: 395–402.

Observation of Hector's dolphin movements within Akaroa harbour, from 4 locations on 19 days from 28 January to 19 February 1993. The data suggest that Hector's dolphins do not move randomly, with slightly greater numbers of dolphins moving into the harbour early in the day, and out of the harbour late in the day. Unfortunately, there were some problems with data gathering and analysis. For example, from the two headland observation posts, virtually all possible dolphin movements were scored as either into or out of the harbour (as opposed to equal probabilities for in, out, neutral left and neutral right movements). Further work on dolphin movements is needed to test hypotheses about diurnal movements.

Stone, G. 1999. *Conservation and Management Strategies for Hector's Dolphins in the Coastal Zone*. PhD thesis, University of the South Pacific, Suva, Fiji. 243 p.

Behavioural observations and studies of tagged dolphins suggest that dolphins in Akaroa Harbour move inshore during the day and offshore at night. Tests of different pingers suggested that dolphins respond more strongly to higher frequency (>100 kHz) pingers with even harmonics. The death of two calves from ship strikes was reported, and future risks for the species are reviewed, including loss of habitat, fishing gear entanglement, ship strikes and behavioural changes associated with frequent human contact.

Stone, G. S.; Yoshinaga, A. 2000. Hector's dolphin (*Cephalorhynchus hectori*) calf mortalities may indicate new risks from boat traffic and habituation. *Pacific Conservation Biology 6*: 162–170.

Report on the deaths of two Hector's dolphin calves in Akaroa Harbour in 1999. The most likely cause of death was boat strike, indicating that boat traffic may pose a threat to the species. These deaths are discussed in the context of increasing human contact with Hector's dolphins and risks to the dolphins caused by this habituation.

Stone, G.; Goodyear, J.; Hutt, A.; Yoshinaga, A. 1994. A new non-invasive tagging method for studying wild dolphins. *Marine Technology Society Journal 28(1)*: 11–16.

Description of the use of non-invasive suction-cup radio tags on free-swimming Hector's dolphins. These tags do not penetrate the animal's skin and thereby avoid potential harm from irritation and infection. Trials indicate that this technique is useful and feasible for studying movement patterns and surfacing rates of Hector's dolphins, and possibly other dolphin species. Movement

information provided by this tracking technique could provide information for wildlife managers with regard to the potential for entanglement and other forms of impact from coastal development issues. Very little information is provided on the behavioural responses of Hector's dolphins to the tags.

Stone, G.; Cavagnaro, L.; Hutt, A.; Kraus, S.; Baldwin, K.; Brown, J. 2000. *Reactions of Hector's Dolphins to Acoustic Gillnet Pingers*. Published client report on contract 3071, funded by Conservation Services Levy. Department of Conservation Wellington. 29 p. http://www.csl.org.nz

Report on the testing of acoustic gillnet pingers to measure the *in situ* behavioural and acoustic reactions of Hector's dolphin groups in Akaroa Harbour. Group size, behavioural response and vocalisation of these groups were examined in the presence of three different pinger types (different frequency characteristics) and one control. The white pingers elicited the strongest reaction, suggesting that the dolphins react strongest to a higher-frequency pinger.

Stone, G.; Hutt, A.; Brown, J.; Yoshinaga, A.; Joy, L.; Burleigh, R. 1998. Respiration and movement of Hector's dolphin from suction-cup VHF radio tag telemetry data. *Marine Technological Society Journal 32(1)*: 89–93.

Study of the respiration patterns and movements of nine Hector's dolphins using suction-cup radio tags during the summers of 1993, 1994, and 1995. All animals were tagged in Akaroa Harbour. Animals were neither captured nor detained. The movement patterns observed in these Hector's dolphins were remarkably consistent. Each dolphin remained in Akaroa Harbor for a period of between 1 and 5 hours, after which each swam out of the harbour in a westerly direction, always in the late afternoon or early evening. Two dolphins returned to Akaroa Harbour the next morning. The remaining animals either lost their tags overnight or did not return. These patterns suggest either that there are diurnal patterns of movement or that dolphins left the area where the tagging took place, with some dolphins returning to the same location and/or group of dolphins after a period of time. Respiration rates and parameters are also presented.

Stone, G.; Kraus, S.; Hutt, A.; Martin, S.; Yoshinaga, A.; Joy, L. 1997. Reducing by-catch: can acoustic pingers keep Hector's dolphins out of fishing nets. *Marine Technological Society Journal 31(2)*: 3–7.

This describes the testing and evaluation of the potential effectiveness of underwater acoustic pingers in preventing entanglement and death of Hector's dolphins in gillnets. This research was carried out in Akaroa Harbour, where dolphin approach distances to active and passive pingers were measured by theodolite. The analysis suggested that sightings made during active pinger trials were distributed further from the sound source than were sightings during passive trials. However, shortcomings of the statistical analysis (e.g. use of several theodolite fixes from each dolphin sighting, violating the assumption that samples were independent) cast doubt on this conclusion. The diagrams in the paper show no obvious difference in approach distance between active pingers and passive pingers. A follow-up study (Harrild 2000) found no evidence of different approach distances for control and active pingers.

Taylor, P. R. 1992. *Incidental Catch of Non-fish Species in Set Nets in New Zealand Waters*. New Zealand Fisheries Assessment Research. Document 92/21. Ministry of Agriculture and Fisheries, Wellington. 22 p.

This paper describes set net usage since the early 1980s and compiles data on turtle, seabird and marine mammal by-catch. For marine mammals, areas close to resident dolphin populations and close to rookeries and haul-outs of pinniped species are identified as geographical areas of concern. The limited information available on by-catch indicated that set nets cause considerable injuries and mortalities to seabirds and marine mammals. An estimate of the magnitude of non-fish by-catch by set nets could not be made because of the absence of continuous, reliable data. The author recommended the use of observers to estimate the scale of the problem, and advised: 'Concurrently, a range of procedural and management options to reduce or eliminate mortality should be developed and discussed.'

Thorpe, C. W.; Dawson, S. M. 1991. Automatic measurement of descriptive features of Hector's dolphin vocalizations. *Journal of the Acoustical Society of America 89(1)*: 435–443.

Reliable and accurate measurement of descriptive features to enable accurate description and statistical comparison of animal sounds has presented one of the major difficulties in bioacoustics. This paper describes a computer-based measurement system developed to facilitate a quantitative analysis of the acoustic repertoire of Hector's dolphins. The automatic nature of the system makes it possible to easily measure descriptive features from 7661 dolphin clicks. The reliablility of the measurement system was confirmed by reconstructing some of the clicks from their measured features. The measurement and reconstruction techniques are described. Analyses of the measured data showed that most Hector's dolphin vocalisations are simple, high-frequency, narrow-band 'clicks'. A few examples of wide-band clicks were found, as was a sound comprising two frequency components.

Thorpe, C. W.; Bates, R. H. T.; Dawson, S. M. 1991. Intrinsic echolocation capability of Hector's dolphin *Cephalorhynchus hectori*. *Journal of the Acoustical Society of America 90(6)*: 2931–2934.

The ambiguity function of a sonar or radar signal describes that signal's ability to resolve range and velocity. The computed ambiguity distributions of Hector's dolphin sonar clicks indicate that the clicks should be capable of resolving the ranges of targets as close together as 2 cm, but target velocities cannot be resolved to any useful degree from a single echo. Information on target velocity would, however, be available to the dolphin from the trend of range measurements in a click train.

Voller, R. 1992. *Entanglements of Hector's Dolphins in Set Nets between Motunau and Timaru*. Ministry of Agriculture and Fisheries, Dunedin (unpublished). 21 p.

Report on the Ministry of Agriculture and Fisheries analysis of set net entanglements. It contains a description of different types of set nets used in the area and their history. It then presents the results of interviews conducted with fishers who have had Hector's dolphins entangled in their nets and others

who have not. The interview data follow the usual pattern of suggesting a lower level of by-catch than in interviews conducted before management action had taken place, and a lower level than estimated from observer programmes (see Baird & Bradford 2000).

Webb, B. F. 1973. Dolphin sightings, Tasman Bay to Cook Strait, New Zealand, September 1986–June 1969. *New Zealand Journal of Marine and Freshwater Research 7(4)*: 399–405.

Record of sightings of 71 groups of dolphins from Tasman Bay to Cook Strait, in which four species were identified: Dusky, bottlenose, common and Hector's dolphins. Sightings of albino specimens are also reported. The paper includes information on dolphin swimming speeds and sea surface temperatures (and attempts to relate temperatures to the presence or absence of each species).

Young, E. 1992. Review of Banks Peninsula Marine Mammal Sanctuary. Pp. E1–E7 in: *Banks Peninsula Marine Mammal Sanctuary Report, 1992. Canterbury Conservancy Technical Report Series 4*. Department of Conservation, Christchurch.

This report attempts to reconcile, from documents available at the time, data on the number of entanglement in set nets, population estimates and the boundaries of the sanctuary.

Young, J. 1991. *Hector's Dolphin Aerial Transect Survey: Analysis of 1990 and 1991 Data, Banks Peninsula Marine Mammal Sanctuary*. Unpublished report to the Department of Conservation, Christchurch. 13 p.

Report on the analysis of the first two years of aerial surveys to determine the abundance of Hector's dolphin in the Banks Peninsula Marine Mammal Sanctuary.

Young, J. 1993. *Hector's Dolphin Aerial Transect Survey: Analysis of Data from 1990 to 1993*. Unpublished report to the Department of Conservation, Christchurch. 8 p.

Report presenting preliminary results of the analysis of data from aerial surveys around Banks Peninsula.

Young, J. 1994. *Hector's Dolphin Aerial Transect Survey: Provisional Analysis of Data from 1990 to 1994*. Unpublished report to the Department of Conservation, Christchurch. 7 p.

Report on the preliminary results of the analysis of data from aerial surveys around Banks Peninsula between the given dates.

Young, J. 1995. *Hector's Dolphin Aerial Transect Survey. Analysis of Data from 1990 to 1995*. Unpublished report to Department of Conservation, Christchurch. 22 p.

Report on the results of the analysis of data from aerial surveys around Banks Peninsula. Results suggest an increase in dolphin abundance between 1990 and 1992, and a relatively constant probability of observing dolphins after 1992. For future monitoring of the population, this paper suggests that five flights per year might be sufficient. Futher analyses for these data are also proposed.

Young, J. 1998. *Hector's Dolphin Aerial Transect Survey: Analysis of Data from 1990 to 1996*. Unpublished report to Department of Conservation, Christchurch. 7p.

Report on the results of the analysis of data from aerial surveys around Banks Peninsula over the 6-year period, updating Young (1997).

Young, J. R 1997. Using flexi to detect a trend in longitudinal count data. *New Zealand Statistician 32(1)*: 23–35.

This paper describes the analysis of data from the DOC aerial transect surveys to monitor the number of Hector's dolphins around Banks Peninsula. The analysis uses Flexi, Bayesian software to detect a trend in longitudinal count data. This software is useful to check the reliability of 'population averaged' estimates from a generalised estimating equation model. Trends in population size may be accompanied by trends in weather conditions experienced during the surveys, and other changes in the way the surveys were done (e.g. different observers in early as compared to later surveys).

3. Acknowledgements

We would like to thank the following people for providing information on articles and with updates: A. Baker, L. Bejder, D. Clement, S. M. Dawson, S. DuFresne, E. Green, F. Pichler, W. Rayment, K. Russell, E. Secchi, C. Schröder. We also would like to thank DOC Canterbury and R. Voller for making unpublished material available to us. This bibliography was funded by DOC (investigation no 3456).