VESSEL SURVEYS AND PHOTO-IDENTIFICATION OF MĀUI DOLPHINS IN 2017

RICHA GARG[1], RENEE HARBERS[2], BRIGITTE HARBERS[2], GARRY HICKMAN[3], ROCHELLE CONSTANTINE[1], C. SCOTT BAKER [1,4]

[1]*School of Biological Sciences, University of Auckland, Auckland, New Zealand.*
e-mail: r.constantine@auckland.ac.nz
[2]*Harbers Family Foundation, Woodinville, WA 98072, USA*
[3]*New Zealand Department of Conservation, New Zealand*
[4]*Marine Mammal Institute, Oregon State University, Newport, Oregon, USA.*
e-mail: scott.baker@oregonstate.edu

SUMMARY

Vessel surveys of Māui dolphins during February of 2017 were dedicated to photographing dorsal fins for individual identification and for matching these photographs to a catalogue that includes photographs collected since 2005. From the 14th to 25th of February 2017, 11 surveys were completed along the North Island's west coast from north of Muriwai to Raglan Harbour. Over 884 km and 80 hours of survey effort was conducted with a cumulative total of 48 Māui dolphin groups encountered with an average of 4.4 groups per day (range = 1-9 groups per day). Group size ranged from 1-18 individuals (minimum and maximum average = 3.9 and 5.0, SE = 0.4 and 0.6, respectively). From a cumulative count of 154 sightings, including an unknown number of replicates, 2 sightings were calves and eight sightings were juveniles. Dolphins were sighted from north of Muriwai to south of Port Waikato, but were congregated between Cochrane's Gap and Hamilton's Gap, as has been reported in previous years. A total of 10,605 digital images were taken during the 2017 surveys. Based on quality control criteria, 640 images of dorsal fins were cropped and selected for further use in individual identification. The unique mark rate of juvenile and adult dolphins was estimated to be 25% using a relaxed criterion, and 7.5% using a stricter classification of distinctiveness. From the quality-controlled photographs, we identified 16 individuals by matching to the existing Māui dolphin catalogue and added another three individuals not previously identified. The final photo-identification catalogue now contains 33 individual Māui dolphins sighted sometime between 2005 and 2017. Six mothers were identified between 2005 and 2017; including one female with two different calves. These results contribute to the long-term study of naturally marked individuals in this population and complement efforts to estimate abundance and life history parameters of Māui dolphins using genetic samples.

INTRODUCTION

New Zealand's endemic Māui dolphin *Cephalorhynchus hectori maui,* a sub-species of the Hector's dolphin *Cephalorhynchus hectori*, is listed as Critically Endangered by the IUCN and Nationally Critical under the New Zealand Threat Classification System (Baker et al., 2016a). Further conservation measures have been implemented to protect them, supported by recent abundance estimates and distribution analyses (Oremus et al., 2012, Hamner et al., 2014, Baker et al., 2016b). Here we summarise initial results of small-vessel surveys dedicated to the photo-identification of Māui dolphins during 2017. To date, a comprehensive assessment of photo-identification data from Māui dolphins has not been undertaken so these data will help inform a population viability analysis model for the 2018 review of the Hector's and Māui Dolphin Threat Management Plan. The research will complement and extend the genetic data, by using photo-identification of individuals through dorsal fin nicks, and further inform demographic features of the population such as individual movement patterns and calving rates (Oremus et al., 2012, Hamner et al., 2014, 2017). Although Hector's dolphins have a low rate of distinctive marks (e.g., 10-15%, Gormley et al., 2005), preliminary analyses show that some Māui dolphins are distinctive, making it possible to identify and track individuals over time (Harbers, 2016). This report determines an estimate of the population mark rate and assesses potential mother-calf pairs from photographs taken since 2005.

SURVEY EFFORT

Coastal surveys were conducted from the charter vessel the *Sea Thief* (an 8m aluminium 'Westcoaster' powered by a 350 hp 4-stroke outboard), from the 14th to 25th February 2017, along the North Island's west coast, from north Muriwai in the north to Raglan in the south (Figure 1, Table 1). Effort was focused alongshore (usually within 1 km from shore and often within 400 m of the surf break), as per previous surveys, to maximise the success rate of group encounters. The boat was launched from Raglan Wharf (n = 1 survey) and operated out of the Manukau Harbour, from Clarks Beach (n = 10 surveys).

In total, 80 hrs and 5 mins were spent on the water, covering a distance of 884.73 km (Table 1). As in the previous surveys in 2015 and 2016 (Baker et al., 2016b), start and end time reflected 'on effort' as recorded from the time leaving the Raglan Harbour or from Cornwallis Point, when operating from the Manukau Harbour (Figure 1). Overall, weather conditions were good, with most surveys conducted in a Beaufort 1 sea state. Conditions ranged from Beaufort 1-4, but only short periods of the surveys were conducted in Beaufort 3-4 for surveys 4 and 5.

The research team included:

- Skipper: Craig Bridgman (Raglan)
- Chief scientist: Scott Baker (OSU-UoA)
- Photographers: Pippa Low (UoA), Renee Harbers (HFF), Brigitte Harbers (HFF), Krista Hupman (DOC)
- Data recorders: Nevé Baker, Garry Hickman (DOC), Cara Hansen (DOC)
- Iwi representative: Berenize Peita (Ngati Te Ata)
- Auxilary: Anjanette Baker, Steve Hathaway (YOE), Ian Angus (DOC), Laura Boren (DOC), Kristina Hillock (DOC)

*DOC – Department of Conservation; OSU – Oregon State University; UoA – University of Auckland; HFF – Harbers Family Foundation; YOE – Young Ocean Explorers

Table 1. The routes, duration and number of groups encountered during Māui dolphin surveys along the North Island's west coast, from 14th to 25th February 2017.

	Date	**Location**	**Launch**	**Time start***	**Time end**	**Duration hh:mm**	**Distance km**	**# groups**
1	14-Feb	Raglan to Clarks Beach, Manukau	Raglan	12:15	20:00	7:45	99.00	5
2	16-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	11:40	19:05	7:25	71.40	4
3	17-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	11:45	18:15	6:30	61.00	6
4	18-Feb	Manukau/Cornwallis north past Muriwai	Clarks Beach	10:55	18:25	7:30	133.00	1
5	19-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	12:15	18:30	6:15	69.00	4
6	20-Feb	Manukau/Cornwallis south to Port Waikato	Clarks Beach	10:25	19:00	8:35	106.00	3
7	21-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	10:30	17:00	6:30	56.27	5
8	22-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	09:10	17:10	8:00	49.43	2
9	23-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	08:00	16:30	8:30	69.51	6
10	24-Feb	Manukau/Cornwallis south to the gaps	Clarks Beach	10:20	16:15	5:55	58.12	9
11	25-Feb	Clarks Beach south to Raglan	Clarks Beach	10:30	17:40	7:10	112.00	3
					Total	80:05	884.73	48
					Average	07:16	80.43	4.36

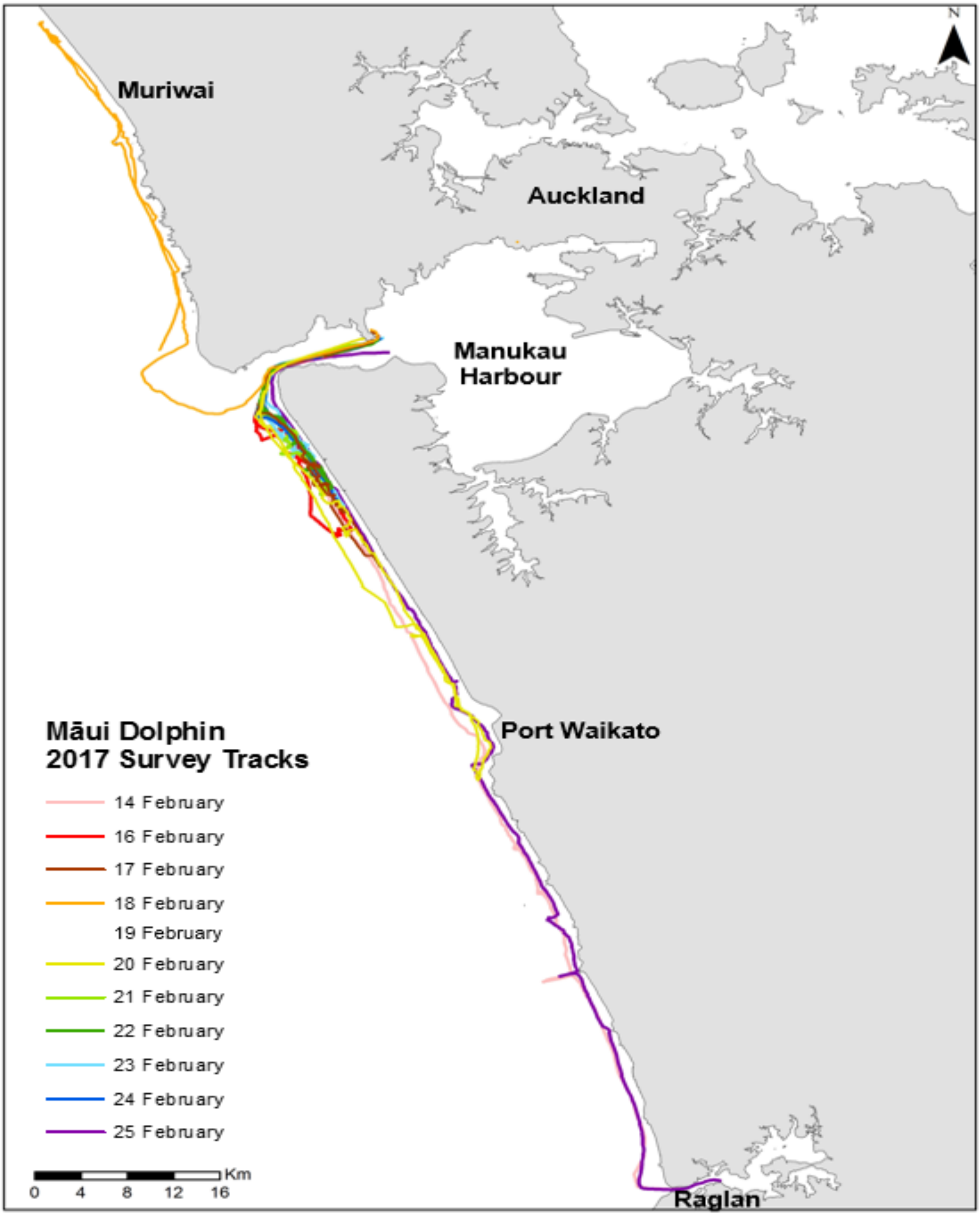

Figure 1. Map of the study site and GPS-logged tracks of the vessel for the 11 Māui dolphin surveys. The survey track for the 19th of February was not recorded but the survey was conducted south of the Manukau Harbour in the core of the dolphin range.

GROUP SIZE AND DISTRIBUTION

A total of 48 groups of Māui dolphins were encountered during the 2017 summer surveys (Tables 1 and 2, Figure 2). Māui dolphins were encountered on every survey with an average of 4.4 groups sighted per survey (range = 1-9 groups). Of the 48 groups, 43 were encountered within about 12 km of the coastline centered around Cochrane's Gap and Hamilton's Gap, one group was sighted north of Muriwai, and five groups were sighted south of Port Waikato (Figure 2). In total, 18 hrs and 24 mins were spent with dolphins across all surveys, with an average of 23 mins (range = 1 min to 2 hrs) spent with dolphin groups for each survey.

Group size ranged from 1-18 dolphins with a minimum average of 3.9 (SE = 0.4) or a maximum average 5.0 (SE = 0.6) dolphins per group, based on visual counts (Table 2). We judged calves to be dolphins of approximately one-half or less the size of an accompanying adult and juveniles to be approximately two-thirds the size of an adult. Based on this assessment, calves and juveniles were sighted in 2.1% (n = 1) and 12.5% (n = 6) of groups, respectively. Using a cumulative count of individual sightings (n = 185), which includes multiple sightings of individuals in different groups, a minimum of two sightings were calves (n = 2; range = 0 - 2 calves/group) and eight sightings were juveniles (n = 8; range = 0 - 2).

It was difficult to judge the dolphins' behavioural states due to their attraction to the boat and the absence of other cues. Consequently, these were recorded for very few groups and were not included in this report as has been done in previous years.

Table 2. Summary of Māui dolphin groups encountered from the 14th-25th February 2017 including GPS location, estimated group size (minimum, best and maximum), age-class composition and the number of photographs taken. The number of images include those where at least some part of a dolphin was visible, and these were then graded into categories G1, G2 or G3 based on image quality criteria developed by Slooten et al. (1992). A small number of photographs marked ‘x’, could not be assigned to group encounters.

		Position start		**Group size**						
Group #	**Date**	**Latitude S**	**Longitude W**	**Min.**	**Best**	**Max.**	**# calves/ juveniles**	**Time w/ dolphins hh:mm**	**Total # images**	**# images graded G1-G3**
1	14-Feb-17	37.52743	174.74144	1	2	2	0/0	00:11	2	0
2	14-Feb-17	37.48827	174.72302	4	4	5	0/1	00:24	72	3
3	14-Feb-17	37.46115	174.70935	1	1	1	0/0	00:06	0	0
4	14-Feb-17	37.41948	174.69054	1	1	2	0/0	00:10	0	0
5	14-Feb-17	37.40628	174.69373	1	1	1	0/0	00:15	7	0
6	16-Feb-17	37.12805	174.55533	9	9	11	0/2	01:02	393	7
7	16-Feb-17	37.19552	174.59145	1	1	1	0/0	00:23	13	1
8	16-Feb-17	37.20072	174.58249	3	3	3	0/0	00:13	6	0
9	16-Feb-17	37.10921	174.53253	3	4	4	0/1	00:07	19	0
10	17-Feb-17	37.14746	174.56726	2	2	2	0/0	00:25	165	21
11	17-Feb-17	37.15247	174.56508	5	8	9	0/0	00:41	263	37
12	17-Feb-17	37.1766	174.58542	4	4	4	0/0	00:18	13	0
13	17-Feb-17	37.17986	174.58719	4	4	4	0/2	00:29	137	17
14	17-Feb-17	37.22942	174.61547	4	4	4	0/0	00:36	355	21
15	17-Feb-17	37.1345	174.56369	3	3	3	0/0	00:11	25	2
16	18-Feb-17	36.74745	174.36511	4	4	4	2/0	00:38	53	2
17	19-Feb-17	37.16689	174.57593	7	9	12	0/0	01:27	468	67
18	19-Feb-17	37.16656	174.57714	8	8	12	0/0	00:32	261	29
19	19-Feb-17	37.17318	174.58201	-	-	-	0/0	00:17	96	24
20	19-Feb-17	37.13788	174.56329	1	1	1	0/0	00:08	0	0
21	20-Feb-17	37.19656	174.59134	2	2	2	0/0	00:24	12	0

		Position start		Group size						
Group #	Date	Latitude S	Longitude W	Min.	Best	Max.	# calves/ juvs	Time w/ dolphins hh:mm	Total # images	# images graded G1-G3
22	20-Feb-17	37.19981	174.58870	2	2	2	0/0	00:11	21	4
23	20-Feb-17	37.16864	174.58253	5	5	5	0/0	00:51	185	55
24	21-Feb-17	37.11571	174.54520	3	3	3	0/0	00:26	183	22
25	21-Feb-17	37.12597	174.55511	3	3	3	0/0	00:38	168	8
26	21-Feb-17	37.1447	174.56644	4	4	4	0/1	00:39	609	64
27	21-Feb-17	37.1629	174.57030	7	9	12	0/0	02:00	1278	172
28	21-Feb-17	37.10965	174.54826	8	10	10	0/0	00:33	321	67
x	21-Feb-17	-	-	-	-	-	-	-	126	6
29	22-Feb-17	37.10038	174.54236	6	7	8	0/0	01:20	722	150
30	22-Feb-17	37.15715	174.57629	12	15	18	0/0	02:08	515	80
31	23-Feb-17	37.12012	174.55704	12	12	16	0/1	01:25	186	13
32	23-Feb-17	37.12054	174.55765	7	8	8	0/0	00:55	75	9
33	23-Feb-17	37.13007	174.55731	2	2	2	0/0	00:10	3	0
34	23-Feb-17	37.15838	174.57481	3	3	3	0/0	00:14	11	0
35	23-Feb-17	37.14897	174.57190	2	2	3	0/0	00:20	25	1
36	23-Feb-17	37.12702	174.54718	1	2	2	0/0	00:13	2	0
x	23-Feb-17	-	-	-		-	-	-	26	3
37	24-Feb-17	37.11516	174.55034	4	6	8	0/0	00:40	0	0
38	24-Feb-17	37.12003	174.55433	3	3	3	0/0	00:25	56	0
39	24-Feb-17	37.14291	174.56975	5	7	7	0/0	00:25	48	2
40	24-Feb-17	37.13136	174.56213	5	7	7	0/0	00:40	40	1
41	24-Feb-17	37.13813	174.56509	1	1	1	0/0	00:04	10	1
42	24-Feb-17	37.14077	174.56480	5	7	7	0/0	00:08	21	0
43	24-Feb-17	37.15857	174.57687	3	3	3	0/0	00:10	26	1
44	24-Feb-17	-	-	1	1	1	0/0	00:01	0	0
45	24-Feb-17	37.16945	174.57997	6	6	6	0/0	00:25	116	15

		Position start		Group size						
Group #	**Date**	**Latitude S**	**Longitude W**	**Min.**	**Best**	**Max.**	**# calves/ juvs**	**Time w/ dolphins hh:mm**	**Total # images**	**# images graded G1-G3**
x	24-Feb-17	-	-	-	-	-	-	-	192	26
46	25-Feb-17	37.12734	174.55789	3	3	3	0/0	00:15	6	0
47	25-Feb-17	37.14113	174.57063	1	1	1	0/0	00:10	4	0
48	25-Feb-17	37.16047	174.58241	3	3	3	0/0	00:23	28	8
x	25-Feb-17	-	-	-	-	-	-	-	8	0
			Total	185	210	236	2/8	18:24	7,371	939
			Average	3.85	4.38	5.02		00:23		

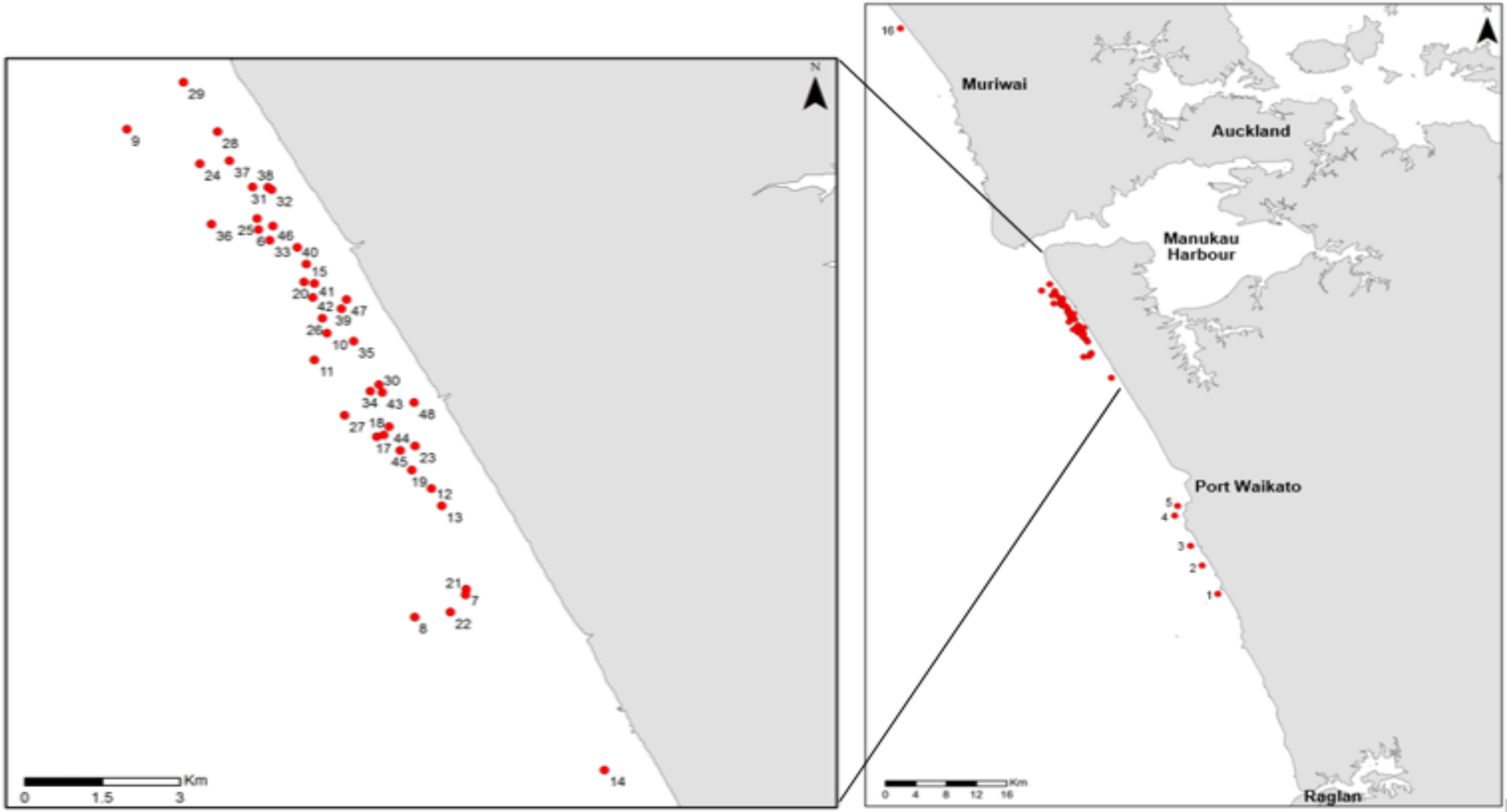

Figure 2. Geographic locations of all Māui dolphin encounters (n = 48) from 14th-25th February 2017. Inset on the left shows the location and group numbers (Table 2) of encounters near Hamilton's and Cochrane's Gaps. The full range of groups encountered is included on the map on the right.

PHOTOGRAPHIC QUALITY CONTROL AND DISTINCTIVENESS

A total of 10,605 digital images were taken during the 2017 surveys (Table 2). There were up to five digital SLR cameras used during the surveys; a Nikon D700, Nikon D750, Sony A7RII, Sony A6000, and Nikon D7000, equipped with 70-200mm or 70-300mm lenses. These images were organised into the encounters (singles and groups), based on data records and checked using time-stamps. Any images that had not captured a dolphin (e.g. images of just water, people or the boat) were removed, leaving 7,371 images (Table 2). These were then categorised according to image quality based on criteria from previous Hector's dolphin research (Slooten et al., 1992). This is based on the image's retention of information content once cropped to a standard size of 1,741 pixels (width) by 1,212 pixels (height). Good quality images have good focus and exposure, with the animal perpendicular to the camera, the entire fin and preferably part of the back is visible and identifying marks are also clearly visible (Appendix 1). These images were graded G1 (n = 8), G2 (n = 96) or G3 (n = 835) (Tables 3A and 2) for a total of 939 images of sufficient quality to be evaluated for distinctiveness (Table 2). This represents ~9% of raw images and ~13% of images that contained a dolphin.

These quality-controlled images were then cropped and inspected for serial replicates. When it was clear that a series of images captured the same individual, only the best image of the series was selected. After this selection there were 640 images of G1+G2+G3 quality (Table 3A) retained for evaluation of distinctiveness and matching to other 2017 distinctive individuals, then finally to the catalogue. Of these, the dolphin images had the following distinctiveness grades; D1 (n = 8), D2 (n = 74), D3 (n = 188) and D4 (n = 370) (Table 3B).

Table 3. A) Photographic quality and B) distinctiveness criteria used to classify Māui dolphin photographs (adapted from Slooten et al., 1992), with examples for each of these categories shown in Appendix I.

A)

Scale	Rank	Attributes
G1	Excellent images	Animal perpendicular to camera with sharp focus, and exposure of the whole fin and part of the back to provide a clear view of the identifying mark(s)
G2	Good images	One attribute failed to comply, but the information content is contained. Whole fin visible but animal may be partially obscured by spray
G3	Fair images	Two attributes failed to comply, but information content is not compromised by image quality. Animal may be partially obscured but the whole fin is visible
G4	Poor images	Exposure and/or focus is too poor to determine details of marks, and/or the fin is at a bad angle. Information content is compromised

B)

Scale	Rank	Description
D1	Highly distinctive	Large, obvious marks or extensive fin nicks/damage to the dorsal fin, or grossly abnormal fin shape that makes recognition easy from short distance. Very unlikely to be missed in the field and high chance of being identified from images
D2	Distinctive	Obvious marks that are highly unlikely to be misidentified from good images, but more likely to go unnoticed, difficult to identify from poor images
D3	Subtly marked	More subtle marks useful for short-term identification
D4	Undistinctive	No markings (i.e. no quality categories)

INDIVIDUAL IDENTIFICATION, MATCHING AND CATALOGUE REVIEW

A total of 19 individual dolphins were identified based on distinctive marks (mean = 1.7 individuals identified per survey, range = 0-9) over 36 group encounters, across 11 field days in 2017 (Table 4). Of these 19 individuals, 5.3% were D1 (n = 1), 57.9% were D2 (n = 11) and 36.8% were D3 (n = 7). The greatest number of individuals was identified on the 22nd of February 2017, and the fewest on the 14th of February 2017 (Table 5). Dolphins M005 and M010 were sighted the greatest number of times in 2017 (n = 4 surveys; Table 5). The 19 dolphins identified in 2017 have been sighted 6.7 times on average (SE = 1.16, range = 1-19) since first being identified either by genetics or dorsal fin, and 6.0 times on average using photo-identification only (SE= 1.02, range = 1-16) (Table 4).

Of the 19 individuals identified in the 2017 surveys, 16 (84%) were successfully matched to the existing photo-identification catalogue (Table 4). The other three; M039, M040 and M041, were captured in high quality images (G1 or G2) and were distinctive enough (D1, D2 or D3) to meet the criteria for inclusion in the catalogue as newly identified individuals (Table 4). Dolphin M001 was a highly distinctive individual (D1) due to a barnacle attached to the dorsal fin and was sighted in 2017 and twice previously; once in 2005 and once in 2007. Although the barnacle fell off sometime between 2007 and 2017, leaving behind no permanent mark, the dolphin was recognisable as it had a sufficiently distinctive dorsal fin shape (and other body or fin markings for secondary confirmation of identification). As M001 is no longer distinctive, however, it has been demoted to D4, removed from the catalogue, and excluded from further analyses. As expected, individuals identified earlier tend to have been sighted more times in total since 2005. Most dolphins were identified photographically first (16/19) and three were identified genetically first (Table 4). Seven catalogued animals have now been identified both genetically and photographically, and four of these were sighted during the 2017 surveys (Table 4).

Upon review of the distinctiveness scores of all dolphins, eight other individuals (in addition to M001) were assessed as insufficiently distinctive (D4), using the criteria in Table 3B, and were removed from the previous version of the catalogue. Including the three newly identified dolphins from 2017, the revised final working catalogue now contains 33 individual Māui dolphins photo-identified sometime between 2005 and 2017. Besides M001 (a previously highly distinctive individual), all individuals removed from the preliminary catalogue had not been sighted/identified in 2017. The final catalogue contains four D1 individuals (12.1%), 18 D2 individuals (54.5%) and 11 D3 individuals (33.3%).

Table 4. Details of matches of individuals identified during the 2017 summer surveys. From left to right; unique identification (ID) code, photo-ID code, sex identification using genetic markers, date and location of encounter (latitude S and longitude W), year the dolphin was first identified genetically (genetic sample code given in brackets) or photographically, total independent sightings (photographic and genetic) and total independent photographic sightings for each dolphin since its first sighting. M027 has also been identified genetically but was identified photographically first, thus its genetic code has not been listed. Some dolphins have been identified genetically and some photographically; as these have separate code systems, a unique-ID is used to encompass both systems and hence track the individual.

Unique-ID	Photo-ID	Sex	Date (2017)	Latitude S	Longitude W	Year first identified (genetic code)	Total sightings (genetic and photo-ID)	Total photo-ID sightings
35	M005	F	17-Feb	37.1345	174.56369	2003	19	17
35	M005	F	21-Feb	37.1629	174.5703	(ChemNI74)		
35	M005	F	24-Feb	37.14291	174.56975			
35	M005	F	25-Feb	37.16047	174.58241			
60	M010	F	17-Feb	37.17986	174.58719	2010	12	8
60	M010	F	19-Feb	37.16689	174.57593	(ChemNI10-09)		
60	M010	F	20-Feb	37.19981	174.5887			
60	M010	F	22-Feb	37.10038	174.54236			
63	M012	F	22-Feb	37.10038	174.54236	2010	11	8
63	M012	F	23-Feb	37.12012	174.55704	(ChemNI10-13)		
63	M012	F	24-Feb	-	-			
84	M027	F	24-Feb	-	-	2011	5	3
120	M006	-	21-Feb	37.12597	174.55511	2007	16	16
121	M007	-	21-Feb	37.1447	174.56644	2007	7	7
121	M007	-	22-Feb	37.10038	174.54236			
127	M016	-	17-Feb	37.15247	174.56508	2010	3	3

127	M016	-	22-Feb	37.10038	174.54236			
129	M019	-	19-Feb	37.16689	174.57593	2010	10	10
129	M019	-	24-Feb	-	-			
133	M023	-	19-Feb	37.17318	174.58200 8	2011	6	6
135	M025	-	18-Feb	36.74745	174.36511	2011	2	2
139	M030	-	19-Feb	37.1629	174.5703	2012	4	4
140	M031	-	19-Feb	37.16689	174.57593	2015	9	9
140	M031	-	22-Feb	37.10038	174.54236			
141	M032	-	19-Feb	37.22942	174.61547	2015	7	7
141	M032	-	21-Feb	37.1629	174.5703			
142	M033	-	18-Feb	36.74745	174.36511	2011	5	5
144	M035	-	21-Feb	37.1629	174.5703	2015	3	3
144	M035	-	22-Feb	37.10038	174.54236			
145	M036	-	20-Feb	37.16864	174.58253	2016	4	4
145	M036	-	22-Feb	37.10038	174.54236			
145	M036	-	24-Feb	37.16945	174.57997			
148	M039	-	22-Feb	37.10038	174.54236	2016	2	2
149	M040	-	16-Feb	37.12805	174.55533	2017	1	1
150	M041	-	22-Feb	37.10038	174.54236	2017	1	1

Table 5. Resighting records of distinctive individual dolphins (n = 19) on each survey during February 2017, including photo-identification catalogue codes and distinctiveness grades.

Dolphin	Distinctiveness	14th	16th	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	Total sightings
M040	D3	0	1	0	0	0	0	0	0	0	0	0	1
M005	D2	0	0	1	0	0	0	1	1	0	1	1	5
M010	D2	0	0	1	0	1	1	0	0	0	0	0	3
M016	D3	0	0	1	0	0	0	0	1	0	0	0	2
M025	D2	0	0	0	1	0	0	0	0	0	0	0	1
M033	D2	0	0	0	1	0	0	0	0	0	0	0	1
M019	D3	0	0	0	0	1	0	0	0	0	1	0	2
M023	D3	0	0	0	0	1	0	0	0	0	0	0	1
M030	D2	0	0	0	0	1	0	0	0	0	0	0	1
M031	D1	0	0	0	0	1	0	0	1	0	0	0	2
M032	D2	0	0	0	0	1	0	1	0	0	0	0	2
M036	D2	0	0	0	0	0	1	0	1	0	1	0	3
M006	D2	0	0	0	0	0	0	1	0	0	0	0	1
M007	D2	0	0	0	0	0	0	1	1	0	0	0	2
M035	D2	0	0	0	0	0	0	1	1	0	0	0	2
M012	D3	0	0	0	0	0	0	0	1	1	1	0	3
M039	D3	0	0	0	0	0	0	0	1	0	0	0	1
M041	D2	0	0	0	0	0	0	0	1	0	0	0	1
M027	D3	0	0	0	0	0	0	0	0	0	1	0	1
	Dolphins/survey	0	1	3	2	6	2	5	9	1	5	1	35
	G1+G2 photos	0	1	12	0	4	6	28	51	0	3	0	105
	G1+G2+G3 photos	3	8	98	2	120	59	339	230	26	46	8	939

POPULATION MARK RATE

The population's mark ratio was calculated across the 2017 survey period using high-quality images (G1 and G2; Table 3A) of adults and juveniles. Each dolphin was only included once in the analysis; therefore, G1 and G2 images of dolphins were matched to each other to remove multiple images of the same animal. This method was used to account for the low number of high quality pictures (G1 and G2). The mark rate calculation methods were taken from Chabanne et al. (2017) but as they did not use a D4 category, the methods in the current study were adjusted to include D4 dolphins. These dolphins were recognisable based on their fin shape and other body markings. Due to the small population size, concentrated locality and inclusion of D3 dolphins in the catalogue, D3 individuals were also considered to be distinctive for this mark rate calculation. The number of distinctive dolphins (D1, D2 and D3) was divided by the total number of dolphins encountered (D1+D2+D3+D4; Table 3B), to calculate an unbiased measure of the proportion of distinctive, uniquely identifiable individuals in the population (Gormley et al., 2005), as follows:
Mark rate = number of distinctive dolphins / total number of dolphins encountered

The mark rate was calculated from 40 high-quality (G1 and G2) images from the 2017 surveys, with each image showing a different individual. Of these 40 images, 10 contained distinctive dolphins (D1, D2 or D3) and 30 contained non-distinctive dolphins (D4). Note that this method assumes that D4 individuals can be recognised as different from each other within the context of this comparison. The mark rate is therefore:
10 *D1, D2 and D3* dolphins / 40 *dolphins* = 0.25, i.e., a population mark rate of 25.0%.

A more conservative mark rate was also calculated using the same images as follows:
3 *D1 and D2 dolphins* / 40 *dolphins* = 0.075, i.e., a population mark rate of 7.5%.

An alternative population mark rate estimate that uses only high-quality images (G1 and G2), regardless of how many times the individual is identified, was also calculated as follows:
Mark rate = (number of G1 and G2 images with a D1 or D2 dolphin) / (total number of G1 and G2 images)
Mark rate = 5/66 = 0.0758, i.e.., a population mark rate of 7.6%.

Lastly, the population mark rate estimate was calculated using G1, G2 and G3 images, regardless of how many times the individual is identified as follows:
Mark rate = (number of G1, G2 and G3 images with a D1 or D2 dolphin) / (total number of G1, G2 and G3 images)
Mark rate= (8 + 74) / 640 = 12.8125, i.e. a population mark rate of 12.8%.

Note that these mark-rate estimates assume that all individuals had an equal (random) chance of being photographed, regardless of their distinctiveness.

DISCUSSION

The 2017 summer surveys (n = 11) successfully matched previous efforts of the 2015 (n = 12) and 2016 (n = 12) summer surveys, in both number of surveys and survey period durations. The surveys in both years covered most of the Māui dolphins' known summer range. In 2017, however, the focus of the surveys was on photo-identification in the primary area of the summer distribution near Hamilton's and Cochrane's gaps. The 2017 surveys therefore covered approximately half the cumulative track-line distance covered by the 2015 surveys (1,655km) and 2016 (1,552.29km) surveys.

A lower average number of groups per survey (n = 4.4) were seen in 2017, compared to 2016 (n = 5.5), but this was still greater than previous surveys; 2015 (n = 4.0), 2010 (n = 3.2) and 2011 (n = 2.5). Average group size (n = 3.9-5.0) was similar to 2016 (n = 3.6-4.8), less than 2015 (n = 5.0-5.8) and 2010 (n = 5-6), but slightly higher than 2011 (n = 4). Based on visual counts, an estimated maximum number of 43 dolphins were sighted over a single survey; which is less than 2016 (n = 65), but comparable with 2015 (n = 36) and 2010-2011 (n = 40-48). These visual counts include an unknown number of replicate sightings.

Calves and juveniles were sighted in 2.1% and 12.5% of groups respectively (Table 6). There has been considerable variation in the number of calves and juveniles during surveys since 2010 (Table 6). This variation warrants further investigation. Despite the 2015 and 2016 observations that there was typically only a single calf per group, the two calves observed during the 2017 surveys were in the same group.

Table 6. The percentage of groups containing calves and juveniles from 2010 – 2017 surveys.

Year	**Calves**	**Juveniles**
2017	2.1%	12.5%
2016	10.6%	13.6%
2015	13.6%	4.5%
2011	46%	28%
2010	4%	30%

Building on previous work, the 2017 review of images led to a comprehensive assessment of the Māui dolphin photographic archive. The preliminary Māui dolphin catalogue has now been refined to its final form and includes high-quality images of distinctive individuals (n = 33), with four D1 individuals (12.1%), 18 D2 individuals (54.5%) and 11 D3 individuals (33.3%). These also include D3 individuals that have more subtle markings, however given the critically endangered status and concentrated range of this population, it is appropriate to include these individuals (e.g. Bejder & Dawson, 2001, Turek et al., 2013). This study has shown that it is possible to track D3 individuals over several years (n = 7, or 36.8% of all individuals identified in 2017) provided that the photograph used for photo-ID is high quality (G1 or G2) to avoid misidentification. The lowest standard required to match a dolphin to the catalogue thus appeared to either be a high-quality image (G1 or G2) of a less distinctive animal (D3), or a low-quality image (G3) of a more distinctive animal (D1 or D2) (Urian et al., 2015).

Since 2001, genetic research on the Māui dolphin has been supplemented with photo-ID data (Baker et al., 2016b). Seven animals have now been identified both genetically and photographically; this is 21% of the photo-identified individuals in the population. Photo-ID is not always the best way of identifying individuals, as the power of photo-ID depends on factors such as the proportion of uniquely identifiable individuals within the population and the ease of observation. As shown in this study, the number of uniquely marked individuals is still small compared to the 100% identification rate with genotyping. Consequently, genotype capture-recapture will continue to provide the more precise estimates of abundance for Māui dolphins (e.g., Hamner et al., 2014, Baker et al., 2016b). However, this does not invalidate the utility of photo-identification, especially for monitoring the population during the 5-year interval between the genotype surveys. Even with population characteristics that do not favour identification, over half of all individuals (n = 19) in the catalogue were photo-identified during 2017. When assessing resight rates across all years for the 19 dolphins identified during 2017, the average number of resights is very similar to the average number of resights from genetic-ID and photo-ID combined. Photo-ID can therefore supplement genetic approaches (e.g. Hamner et al., 2017; Carroll et al., 2011), and contribute to the monitoring of this critically endangered subspecies.

The 2017 surveys were dedicated entirely to photo-identification and were supported by high-resolution digital cameras and professional-quality lenses. This contributed to a great rate of success than in previous surveys where photo-identification was secondary to the biopsy sampling. Capturing high-quality photographs to use for identification of a dolphin depends on a good digital camera and lenses, the ability to approach the dolphin and the dolphin's behaviour (Würsig & Jefferson, 1990). It is possible that some individuals were boat shy, which has the potential to bias which individuals are photographed and affect the results. However, studies on the Hector's dolphin population at Banks Peninsula have shown that individuals are generally boat positive and do not tend to become more boat positive (drawn towards the boat based on previous encounters) or boat negative (driven away from the boat based on previous encounters) (Turek et al., 2013). Although 'capture' via photography is unlikely to cause a negative reaction (Seber, 1982), studies examining the behaviour of Māui dolphins in response to boats would be useful to ascertain whether Māui dolphins show any heterogeneity in response to boats. This can help ensure that the individuals identified continue to be a representative sample of the entire population.

The Māui dolphin population has been less well studied compared to Hector's dolphins, largely due to the challenges working in their west coast habitat. With many distinctive animals, it is possible citizen science could be useful in mapping dolphin movements. The estimate of mark rates for Māui dolphins based on inclusion of D1, D2 and D3 grades (25%) is higher than the 10.5% estimated for the Banks Peninsula Hector's dolphins during 1992-1996 (Gormley et al., 2005). This rate has reportedly decreased since that time, possibly due to fewer fisheries entanglement injuries (Wickman, 2017). However, when only D1 and D2 images were used, the mark rate for Māui dolphins was estimated to be only 7.5%. There is high variability in mark rates amongst different species, and it also typically varies amongst populations of the same species in different localities. Bottlenose dolphins have a mark rate of 72% for the Bay of Islands, New Zealand (Tezanos-Pinto et al., 2013) and 83% in Shark Bay, Western Australia (Scott et al., 2005). Hawaiian spinner dolphins *Stenella longirostris* (Norris & Dohl, 1980) and pilot whales (Shane, 1984) usually have a population mark rate of up to 20%. Mark rate and photo-ID is limited to dorsal fin marks in Māui dolphins, unlike another *Cephalorhynchus* species; the Commerson's dolphin (*C. commersonii*), in which the colour pattern on their head enables easy identification (Righi et al., 2013). Only one observed Māui dolphin had unusual colour markings, but these have changed over time, and are considered atypical for the species. Colour markings are thus unlikely to be reliable for identification of Māui dolphin individuals.

Ascertaining mother-calf associations for Māui dolphin was challenging due to unpredictable movement of individuals in groups and the turbidity of the water. The presence of foetal folds as evidence of a neonate was not observed on any dolphin photographed dating back to 2005. Only one individual was observed with two calves across the research period. The first sighting was a young-of-year calf; given an expected two- to four-year inter-birth interval (Slooten, 1991), we would expect to see this calf with its mother over two or more consecutive years. It is therefore plausible that the calf sighted in 2015 died, or that the calf seen with this adult was not its calf. It is challenging to study mother-calf associations in the Māui dolphin, as individuals are already small, and they grow relatively fast (Webster et al., 2010), thus there is only a short period of time, during the first year of life over which mother-calf pairs can be assigned accurately. With the small population size this adds an extra challenge to observing mother-calf pairs. Additionally, these dolphins have low mark rates on their fins compared to other species, which makes photo-ID of mother-calf pairs more challenging. However, there are an increasing variety of genetic tools and hormone assays available to study a population's reproductive ecology, including techniques for assigning parentage using genomic sequencing or for testing pregnancy using progesterone concentrations. For example, ddRAD-seq has been used to reveal population structure in the harbour porpoise (*Phocoena phocoena*) (Lah et al., 2016). Analysis of progesterone concentrations to detect pregnancy rates in delphinids has been successful for several species (Kellar et al., 2006) and preliminary work on Māui dolphin blubber samples collected during biopsy sampling is promising (R. Constantine unpub. data). Also, for at least four of the years when the most intensive surveys were taking place (2010-11 and 2015-16), the focus had been on taking biopsy samples for genetic studies. In future surveys, closer attention should be paid to mother-calf pairs and photographs focusing on dorsal fin identifications would be a valuable research contribution, especially during periods of biopsy sampling.

ACKNOWLEDGEMENTS

The 2017 summer surveys were supported by the Harbers Family Foundation in partnership with the Department of Conservation (DOC), the University of Auckland and Oregon State University. Many thanks to Craig Bridgman for the hard work dealing with logistics and boat handling during the surveys and to the dedicated field team; Pippa Low, Nevé Baker, Cara Hansen, Anjanette Baker, Krista Hupman, Steve Hathaway, Ian Angus, Laura Boren and Kristina Hillock. We thank the local DOC offices (Waikato and Auckland) and iwi for consultation on our research proposal, and Berenize Peita (Ngati Te Ata) for her participation. Many thanks to Leena Riekkola for her help with mapping and Júlia Pontes for initial organisation and archiving of the digital images.

REFERENCES

Baker, C.S., Chilvers, B.L., Childerhouse, S., Constantine, R., Currey, R., Mattlin, R.H., van Helden, A., Hitchmough, R., & Rolfe, J. (2016a). Conservation status of New Zealand marine mammals. New Zealand Threat Classification Series 14. Department of Conservation, Wellington, pp.18.

Baker, C. S., Steel, D., Hamner, R. M., Hickman, G., Boren, L., Arlidge, W., & Constantine, R. (2016b). Estimating the abundance and effective population size of Māui dolphins using microsatellite genotypes in 2015–16, with retrospective matching to 2001-16. Report submitted to the New Zealand Department of Conservation.

Bejder, L., & Dawson, S. (2001). Abundance, residency, and habitat utilisation of Hector's dolphins (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* 35, 277-287.

Carroll, E.L., Patenaude, N.J., Childerhouse, S.D., Kraus, S.D., Fewster, R.M., Baker, C.S. (2011). Abundance of the New Zealand subantarctic southern right whale population estimated from photo-identification and genotype mark-recapture. *Marine Biology*, 158, 2565

Chabanne, D. B., Pollock, K. H., Finn, H., & Bejder, L. (2017). Applying the Multistate Capture-recapture Robust Design to characterize metapopulation structure*. Methods in Ecology and Evolution.*

Gormley, A.M., Dawson, S.M., Slooten, E. & Bräger, S. (2005). Capture-recapture estimates of Hector's dolphin abundance at Banks Peninsula, New Zealand. *Marine Mammal Science*, 21, 204-216.

Hamner, R. M., Constantine, R., Mattlin, R., Waples, R., & Baker, C. S. (2017). Genotype-based estimates of local abundance and effective population size for Hector's dolphins. *Biological Conservation*, 211, 150-160.

Hamner, R. M., Constantine, R., Oremus, M., Stanley, M., Brown, P., & Scott Baker, C. (2014). Long-range movement by Hector's dolphins provides potential genetic enhancement for critically endangered Maui's dolphin. *Marine Mammal Science*, 30(1), 139-153.

Harbers, B. (2016). Māui dolphin photo-identification and distribution 2010-2016. Unpublished Summer Student Report, University of Auckland.

Kellar, N.M., Trego, M.L., Marks, C.I., & Dizon, A.E. (2006). Determining pregnancy from blubber in three species of delphinids. *Marine Mammal Science*, 22, 1-16.

Lah, L., Trense, D., Benke, H., Berggren, P., Gunnlaugsson, Þ., Lockyer, C., ... & Siebert, U. (2016). Spatially explicit analysis of genome-wide SNPs detects subtle population structure in a mobile marine mammal, the harbor porpoise. *PloS One*, 11(10), e0162792.

Norris, K. S. & T. P. Dohl. (1980). Behavior of the Hawaiian spinner dolphin, *Stenella longirostris. Fishery Bulletin*, 77, 821-849.

Oremus, M., Hamner, R.M., Stanley, M., Brown, P., Baker, C.S., & Constantine, R. (2012). Distribution, group characteristics and movements of the Critically Endangered Maui's dolphin *Cephalorhynchus hectori maui* 1, 1-10.

Righi, C. F., Blanco, G. S., & Frere, E. (2013). Abundance and spatial distribution of Commerson's dolphin (*Cephalorhynchus commersonii*) at a breeding site: Ría Deseado, Patagonia, Argentina. *Aquatic Mammals*, 39, 1-9.

Scott, E. M., Mann, J., Watson-Capps, J. J., Sargeant, B. L., & Connor, R. C. (2005). Aggression in bottlenose dolphins: evidence for sexual coercion, male-male competition, and female tolerance through analysis of tooth-rake marks and behaviour. *Behaviour*,

142(1), 21-44.
Seber, G. A. F. (1982). The Estimation of Animal Abundance and Related Parameters, London: Charles Griffin.
Shane, S. H. (1984). Pilot whales and other marine mammals at Santa Catalina Island, California in 1983-84. Admin Rep LJ-84-28C. National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, CA.
Slooten, E. (1991). Age, growth and reproduction in Hector's dolphins. *Canadian Journal of Zoology*, 69, 1689-1700.
Slooten, E., Dawson, S. M., & Lad, F. (1992). Survival rates of photographically identified Hector's dolphins from 1984 to 1988. *Marine Mammal Science*, 8, 327-343.
Tezanos-Pinto, G., Constantine, R., Brooks, L., Jackson, J. A., Mourão, F., Wells, S., & Scott Baker, C. (2013). Decline in local abundance of bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands, New Zealand. *Marine Mammal Science*, 29, E390-410.
Turek, J., Slooten, E., Dawson, S., Rayment, W., & Turek, D. (2013). Distribution and abundance of Hector's dolphins off Otago, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* 47, 181-191.
Urian, K., Gorgone, A., Read, A., Balmer, B., Wells, R. S., Berggren, P., ... & Hammond, P. S. (2015). Recommendations for photo-identification methods used in capture-recapture models with cetaceans. *Marine Mammal Science*, 31, 298-321.
Webster, T., Dawson, S., & Slooten, E. (2010). A simple laser photogrammetry technique for measuring Hector's dolphins (*Cephalorhynchus hectori*) in the field. *Marine Mammal Science,* 26, 296-308.
Wickman, L. (2017). An observed decline in the mark rate of Hector's dolphins (*Cephalorhynchus hectori*) after area-based protection. New Zealand Marine Sciences Society Conference Handbook 2017, p75.
Würsig, B., & Jefferson, T. A. (1990). Methods of photo-identification for small cetaceans. Individual recognition of cetaceans: use of photo identification and other techniques to estimate population parameters, Report of the International Whaling Commission, Special Issue 12, 43-51.

Appendix I

Photographs representing the quality control criteria.

Figure 1a. An image in quality category 1 (G1).

Figure 1b. An image in quality category 2 (G2).

Figure 1c. An image in quality category 3 (G3).

Figure 1d. An image in quality category 4 (G4).

Figure 1e. An individual in distinctiveness category 1 (D1).

Figure 1f. An individual in distinctiveness category 2 (D2).

Figure 1g. An individual in distinctiveness category 3 (D3).

Figure 1h. An individual in distinctiveness category 4 (D4).