Lessons Learnt from post-release monitoring of oiled-penguins: New Zealand C/V Rena

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Abstract

The value of rehabilitating oiled wildlife is an on-going global debate. On October 5, 2011, the cargo vessel C/V Rena grounded on Astrolabe Reef, New Zealand (NZ), spilling over 300 tonnes of heavy fuel oil. As part of the Rena oil spill response, 383 little blue penguins (LBP, *Eudyptula minor*) were captured, cleaned, rehabilitated and released back into a cleaned environment. Over the last four years, since the C/V Rena spill, we have undertaken survival, diving behaviour, diet and stress hormone response research on these and non-rehabilitated LBPs from the spill area to assess the success of the rehabilitation process, determine what lessons could still be learnt and to help determine if the environment has returned back to its natural state. Findings from this research showed that the survival was reduced for both rehabilitated and non-rehabilitated groups in the first six months following the spill and clean-up process however, the survival probabilities of both groups increased thereafter and remained high and stable over a two year period directly after the spill. The foraging behaviour and diet studies showed there were no foraging behaviour differences between rehabilitated and non-rehabilitated LBPs and the overall diving behaviour of these LBPs were

similar, if not less energetic, than other LBPs in NZ, indicating that the environment appeared to have also returned to pre-oiling state. Concurrently, the stress hormone response study showed no differences between groups, suggesting the rehabilitation process for LBP did not affect their long term physiological responses to humans, meaning no habituation or excessively stress caused by humans over the long term. Together these results suggest the rehabilitation process and clean-up undertaken after the C/V Rena appears effective and helps validate the rehabilitation of oiled wildlife.

Introduction

Oil is a significant contributor to the pollution and contamination of the marine environment (Peterson et al., 2003). One of the most visible and publically scrutinised effects of an oil spill is the impact on wildlife, with both oiled carcasses and live effected animals on beaches and shorelines (Piatt *et al.,* 1990; Furness and Camphuysen, 1997). Without human intervention, the majority of oiled wildlife will die and of those that survive, many could suffer long term sub-lethal toxic effects of oil ingestion (Fry and Lowenstine, 1985; Burger and Fry, 1993). Seabirds are particularly vulnerable to oiling as external contamination results in exhaustion, drowning and / or hypothermia due to the disruption of their feather structure by oil (Clark, 2001). On October 5, 2011, the *C/V Rena* grounded on the Astrolabe Reef, Bay of Plenty, New Zealand (NZ), spilling over 300 tons of heavy fuel oil and cargo. Over 2000 animals were recorded to die during the oil spill and clean-up process, while 383 little blue penguins (LBP, *Eudyptula minor*) and 37 other bird species were captured, cleaned, rehabilitated and released back into a cleaned environment (Sievwright, 2014). A two-year post-release research program to monitor survival, diving behaviour and stress response of both oiled/rehabilitated and non-oiled/non-rehabilitated LBPs was undertaken (Sievwright, 2014; Chilvers et al., 2015; Chilvers et al., 2016).

Methods

Little Blue Penguins and Study Site

Little blue penguins are the smallest penguins in the world, reaching approximately 40 cm in length and 1 kg in weight as an adult. LBPs generally breed September to February, however timing can vary with latitude and between years. Post release monitoring research was undertaken at Leisure Island/Moturiki, Mt Maunganui, Tauranga, NZ (37º 37’51”S, 176º 11’06’E). Leisure Island is a 3.1 ha rocky island that is 100 m offshore and connected to the mainland by a 20 m wide strip of sand. The island and surrounding area was oiled during the *C/V Rena* oil spill in October 2011. 383 LBP were captured and cleaned during the spill, with 347 of these released back on to the island and surrounding areas after being microchipped (Allflex Compact Pocket Microchip). Concurrently, 361 penguins from the same area that were not oiled during the oil spill were captured and microchipped in-situ and identified as "non-rehabilitation" birds in the post-release monitoring study. The average time the rehabilitated penguins spent in the rehabilitation facility was 53. days from capture to release.

Survival

From November 2011 to December 2013, fortnightly or monthly monitoring surveys checking and recording individual penguin microchip numbers were conducted at dusk for 2h periods along the rocky shorelines of Leisure Island. Data was summarised into monthly resighting records and survival probabilities assessed using Program MARK 2.8. See Sievwright 2014 for full analysis details.

Diving

Twenty penguins (10 rehabilitated and 10 non-rehabilitated) were captured and tagged with time-depth recorders (TDRs, Lotek LAT1400, 6 g, 30 × 10 mm) and VHF transmitters (3 g, 20 × 8 mm, Sirtrack, Havelock North, NZ) in late October 2014. TDRs were programmed to record depth every 2 seconds when wet. The instruments were recovered 1–3 days after deployment. The TDRs could only store data from one foraging trip for each bird. However, at the time of tagging, penguins were at late guard stage, when parents predominantly make 1-day foraging trips.

Diving data were analysed using the software Multitrace (Jensen Software Systems) to produce summary statistics for each dive and LBP, including the number of dives per trip, number of dives per hour, mean and maximum dive depths, dive duration, surface intervals, percentage of time spent at the bottom of dives and dive shapes. Only dives > 1 m were used for analysis. See Chilvers et al. 2015 for full analysis details.

Stress response

Four blood samples (each 0.2ml) were collected from the 20 adult penguins (10 rehabilitated and 10 non-rehabilitated) caught and tagged with TDRs (above) from the Leisure Island area. Samples were collected sequentially at 0, 15, 30 and 60 min intervals after initial capture with birds returning to capture boxes between samples and then released at their capture site after the 60 min sample. Blood samples were stored in a refrigerator within 4h of being taken and then within 12h, centrifuged, plasma extracted and then stored frozen until analysed.

Corticosterone concentrations in plasma diluted in phosphate buffered saline with gelatine (PBSG) were measured by radioimmunoassay following the method of Cockrem et al., (2009) with reagents from MP Biomedicals (USA). See Chilvers et al. 2016 for full analysis details.

Results

Survival

No rehabilitated penguins and only one non-rehabilitated penguin were found dead during the two year monitoring study. In total, 578 individuals (217 rehabilitated and 361 non-rehabilitation penguins) survival was analysed. MARK model analysis estimated survival probability was estimated separately for the first 6 months but was otherwise constant over time, and unaffected by oiling status (rehabilitated vs. non-rehab.). Overall the estimated monthly survival probability was 0.90±s.e. 0.012 (95% CI=0.88–0.92) in the first 6 months and 0.97±0.006 (95% CI=0.96–0.98) during the rest of the study. Therefore, annual survival probability of non-rehab and rehabilitated penguins was lower in the first year (0.52±0.102) than the second year (0.84 ±0.129) studied. These results are similar and comparable to the survival of other LBPs across NZ (Sievwright, 2014).

For variables that were analysed that may affect survival, there were no significant differences in physiological, oil-related and captive-related parameters (oiling degree (Mann-Whitney U=6270, p=0.8117), admission body mass index (BMI, t=-1.0727, p=0.2863), admission packed cell volume (Mann-Whitney U=3483.5, p=0.3902), admission total protein (Mann-Whitney U=2797.5, p=0.1734), admission blood glucose (Mann-Whitney U=3743, p=0.8353), release BMI (t=-1.0727, p=0.2863), or captive duration (Mann-Whitney U=6232, p=0.8737)) between rehabilitated and non-rehab penguins seen and not seen during survival monitoring surveys.

Table 1. Summary statistics of the diving records of little blue penguins (*Eudyptula minor*) from Leisure Island oil spill rehabilitated (n = 8) and non-rehabilitated (n=6). Data are from one foraging trip for each bird. Means ± SE.

Group	Penguin VHF #	No. dives per trip	Dives per hour	Mean depth (m)	Max depth (m)	Mean duration (sec)	Mean surface interval (sec)	% bottom time	% U dives	% V dives	% W dives
R	24a	1959	160.6	7.0	14.8	20.8	5.5	15	40.5	48.0	11.5
R	32a	2733	202.4	3.3	15.0	12.4	5.7	8	20.8	71.6	0.08
R	32b	1408	100.6	8.3	18.5	25.1	11.1	19	68.4	27.2	4.4
R	40a	1486	108.0	8.3	17.8	24.0	9.4	15	51.5	39.7	8.7
R	42-1	1954	150.3	4.0	12.2	15.3	8.9	15	25.7	55.8	18.5
R	46	2184	158.3	2.6	17.4	14.7	8.3	21	32.8	49.9	17.3
R	50	1385	106.5	7.5	23.7	26.9	10.1	25	49.8	27.8	22.4
R	50-1	945	76.8	5.1	13.5	18.2	7.4	11	44.4	47.1	8.5
	Average		**132.9±14.7**	**5.8±0.8**	**16.6±1.3**	**19.7±1.9**	**8.3±0.7**	**16 ± 2**	**41.7±5.4**	**45.9±5.1**	**11.4±2.7**
N-R	24-1	1547	119.0	7.0	18.1	22.8	7.3	18	37.1	45.8	17.1
N-R	24b	1441	110.8	6.7	12.5	20.2	13.1	18	65.8	26.9	7.2
N-R	32-1	1866	138.2	6.1	20.3	19.6	6.8	14	35.8	49.0	15.2
N-R	40	1305	98.3	9.8	18.7	27.9	8.7	15	55.0	35.8	9.2
N-R	44	2114	153.6	4.6	14.1	17.3	6.2	16	46.0	41.8	12.2
N-R	48	2181	155.8	4.3	11.4	16.0	6.8	18	38.8	46.1	15.1
	Average		**129.3±9.6**	**6.4±0.8**	**15.9±1.5**	**20.6±1.7**	**8.2±1.0**	**16 ± 1**	**46.4±4.8**	**40.9±3.4**	**12.7±1.6**
Significance			$F_{(1,12)}$=0.03, n.s.	$F_{(1,12)}$=0.3, n.s.		$F_{(1,12)}$=0.13, n.s.	$F_{(1,12)}$=0.01, n.s.				
Overall average		**1750±125.7**	**131.3±9.0**	**6.1±0.6**	**16.3±0.94**	**20.1±1.3**	**8.2±0.58**	**16 ± 1**	**43.7±3.7**	**43.8±3.2**	**11.9±1.6**

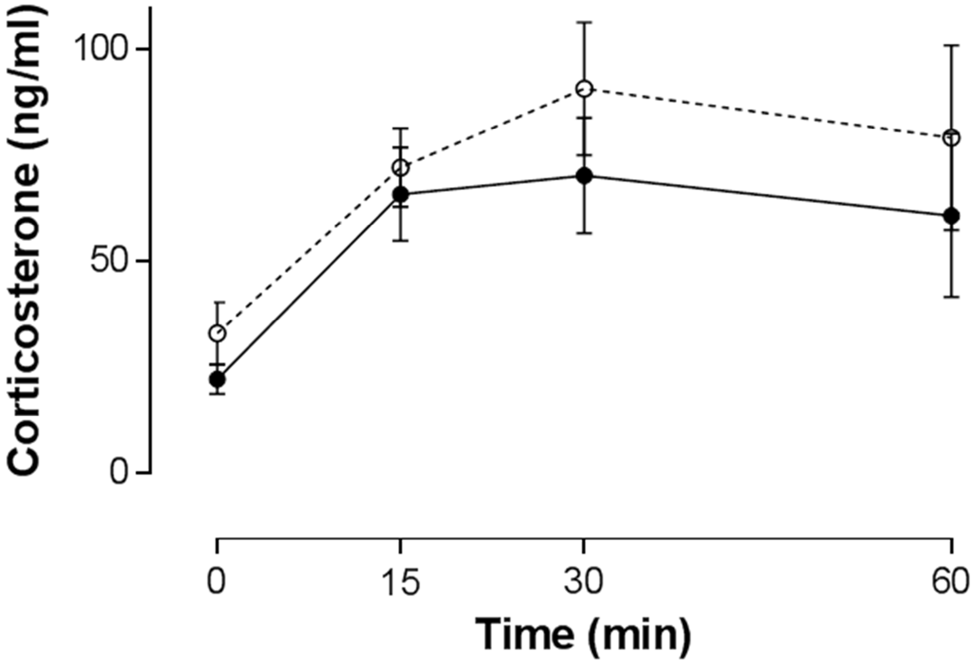
Diving

In total 14 rehabilitated (n=8) and non-rehabilitated (n=6) LBPs tagged and recaptured, a single foraging trip was recorded with a total of 24,508 individual dives recorded (Table 1). For all other penguins the tags came loose and fell off before the penguins were re-captured. There were no significant differences in the diving parameters between rehabilitated and non-rehabilitated LBPs (Table 1). Diving behaviour of penguins from Leisure Island were shallower and shorter in duration than any other LBPs studied in NZ indicating low energy foraging behaviour was being undertaken (Chilvers et al. 2015).

Stress response

There was a wide range of individual responses, with little change in corticosterone levels in some birds and a large response in other birds. Overall there were significant increases in plasma corticosterone from initial concentrations to concentrations at 15 min in both groups ($P < 0.001$), then no significant changes from 15 to 30 min or from 30 to 60. There was no significant difference between groups in mean integrated corticosterone responses (t_{17} = 0.867, P= 0.398) with mean overall integrated corticosterone response across the 60 minutes being 0.77 $\pm$ 0.39 ng min/ml in rehabilitated penguins and 0.64 $\pm$ 0.30 ng min/ml in non-rehabilitated penguins (Fig. 1).

Fig. 1. Mean (± S.E.) corticosterone responses of little penguins at Mt Maunganui, New Zealand, that had been rehabilitated after oiling (— ● — , n = 9) or not affected by oil (--- ○---, n=10).



Discussion

These are the first studies to investigate the diving behaviour or long-term corticosterone stress responses of any rehabilitated seabird after an oil spill or comparing between rehabilitated and non-rehabilitated seabirds impacted by an oil spill.

Throughout the study, survival rates did not differ between rehabilitated and non-rehabilitation penguins. Survival for both groups were reduced in the first six months following release/PIT-tagging, however thereafter, survival rates increased and remained high and reasonably constant. Oil pollution can severely impact the marine environment and its biodiversity at all trophic levels by smothering the shore and seabed environment, disrupting macro-fauna such as krill, salps and detritivores, causing the death and contamination of shellfish and fish, and ongoing disruption up the food chain to the higher predators such as seabirds and mammals (ITOPF, 2008). This type of food chain disruption and environmental impact was thought to be seen in the LBPs of the *C/V* Rena with lowered survival immediately after the oil spill for both rehabilitated and non-rehabilitated individuals (Sievwright, 2014). One of the reasons for the reduced sighting history for the 347 rehabilitated penguins released was that emigration from the study site is likely to have been a contributing factor as there is uncertainty about which colonies these penguins were resident at. When oiled, penguins come ashore at the nearest landmass, regardless of whether or not it is the colony they reside at. Oiled penguins recovered were assumed to have originated from the sites they were recovered from and were subsequently released back to the same area. If some of these birds were actually from other sites, it is likely that after release they would return to their historical 'home', therefore lowering the number of animals sighted during the survival study. This was not the case for the non-rehab animals as they were caught where they were known to be nesting and therefore their "home".

An inseparable component of survival of any organism is its ability to find and consume nutrients and energy (prey). The reduction in survival and reproduction immediately after the *C/V* Rena spill was likely to have been affected by the ability of LBPs to find prey in the environment impacted by oil (Sievwright, 2014). This research shows that the diving behaviour of LBPs from Leisure Island two years after the oil spill is characterised as being the shortest, shallowest diving for LBPs recorded in NZ (Chilvers et al. 2015). There were no significant differences in diving behaviour between rehabilitated and non-rehabilitated individuals and no significant differences in stable isotope values from feathers taken from the penguins in these two groups indicating similar diet and foraging locations (Chilvers et al. 2015).

Corticosterone stress responses of LBP at Leisure Island two years after an oil spill did not differ between rehabilitated and non-rehabilitated penguins. This indicates that the penguins had not become habituated or over sensitised to human interactions despite their time in rehabilitation. Studying physiological mechanisms in wildlife allows us to understand how effectively wildlife are responding to challenges in their environment before changes in demographic parameters could be detected (Adams and Ham, 2011). Changes in stress responses, particularly increases in stress, may be correlated with changes in survival and reproduction. However, if there are other mechanisms that could also be influencing these biological parameters, such as the effects of oil, it is important to be able to try and differentiate between the two influences. Interpreting the relationship between physiological parameters and biological outcomes can be challenging (Buscha and Hayward, 2009). The significant elevations of corticosterone after capture in both groups indicates that penguins affected by disturbance and handling are able to respond effectively to unexpected events and do not exhibit desensitisation of the hypothalamic-pituitary-adrenal axis which could be a sign of chronic stress (Rich and Romero, 2005). These are positive findings for the rehabilitation process undertaken for LBP as it appears that the intense rehabilitation process that occurred during the *C/V Rena* spill did not lead to habituated interactions with humans (Chilvers et al. 2016).

Conclusion

For many species there is grounds and justification from a conservation perspective alone to rehabilitate wildlife after an oil spill (Ryan, 2003; Wolfaardt *et al.,* 2009). However, regardless of post-release studies, it must be taken into consideration that despite debate, rehabilitation is likely to continue to occur due to public expectation to clean and alleviate the suffering of wildlife impacted by oil (Estes, 1998). Given this is the case, we should know and understand the best way to rehabilitate oiled wildlife to limit any behaviour and population level impacts. Such information is only available through post-release monitoring of rehabilitated wildlife after an oil spill event. The post-release monitoring of LBPs, after the oil-rehabilitation process used during the *C/V Rena* oil spill, shows that the LBPs were effectively treated and the negative effects of oil-contamination reversed in terms of post-release survival and productivity (Sievwright, 2014) and diving behaviour (Chilvers et al., 2015), and at the same time did not appear to have any long-term impact on physiological stress responses in relation to human interactions (Chilvers et al. 2016).

Despite the increasing regularity of wildlife rehabilitation efforts, post-release monitoring studies are rare. One of the main limits of rehabilitation post-release monitoring from oil spill is financial constraints, particularly as during an oil spill, where the spiller is generally liable for the costs of all response activities, post-release monitoring is not considered a response activity. The inclusion of post-release monitoring, particularly for site specific species such as penguins, into oil spill operational planning and therefore clearly as a response activity is critical to further enhance a more effective and efficient oil spill response, increasing our understanding of the success of an oil response and the rehabilitation process.

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