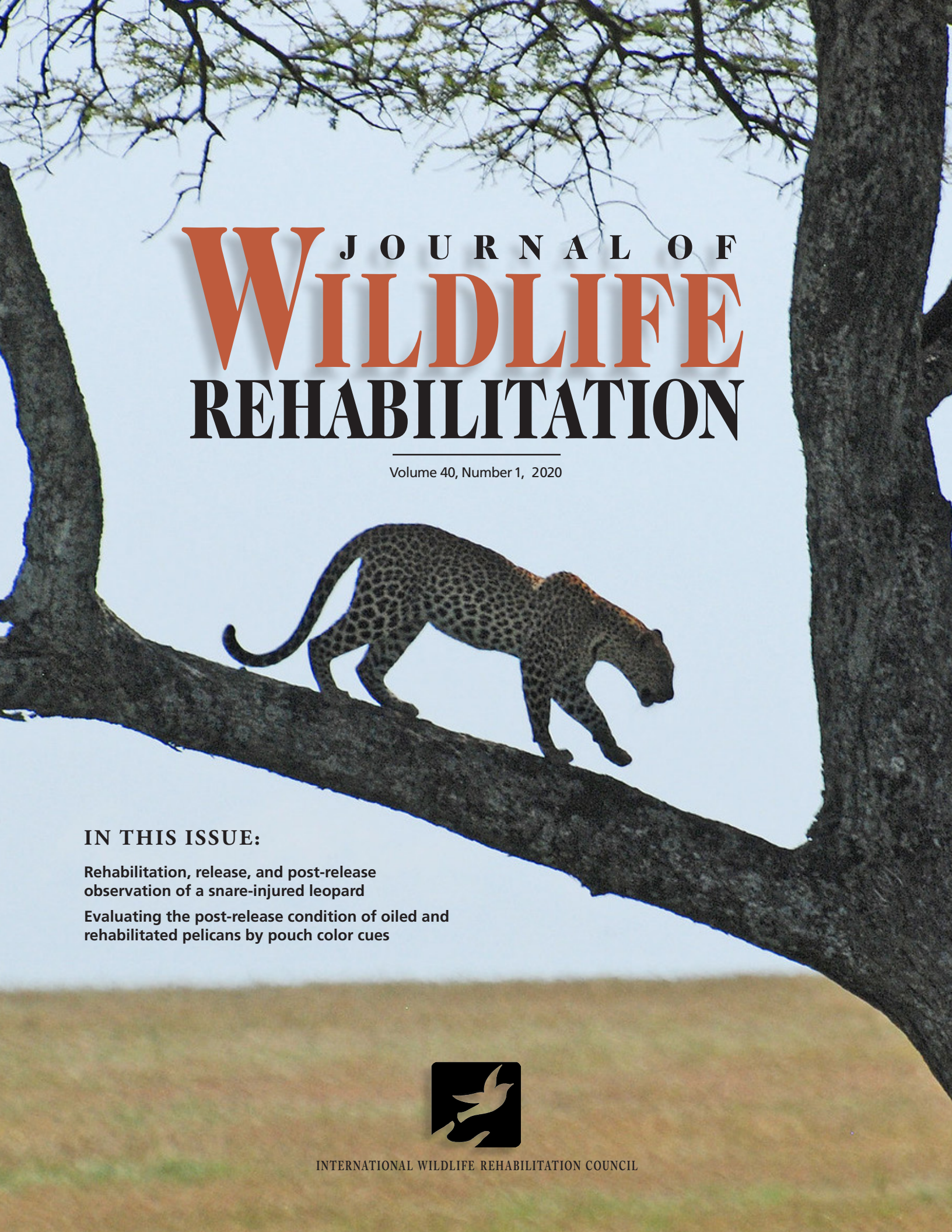

JOURNAL OF WILDLIFE REHABILITATION

Volume 40, Number 1, 2020

IN THIS ISSUE:

INTERNATIONAL WILDLIFE REHABILITATION COUNCIL

THE *Journal of Wildlife Rehabilitation* is designed to provide useful information to wildlife rehabilitators and others involved in the care and treatment of native wild species with the ultimate purpose of returning them to the wild. The journal is published by the International Wildlife Rehabilitation Council (IWRC), which invites your comments on this issue. Through this publication, rehabilitation courses offered online and on-site in numerous locations, and its outreach to those in the profession, the IWRC works to disseminate information and improve the quality of the care provided to wildlife.

ABOVE:
Caspian tern *(Hydroprogne caspia).*

ON THE COVER:
Leopard (*Panthera pardus*) in the Eastern Serengeti.

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We provide evidence-based education and resources on wildlife rehabilitation to move the field of wildlife rehabilitation forward; to promote wildlife conservation and welfare; and to mitigate human–wildlife conflicts worldwide, through better understanding of wild animal ecology, behavior, and welfare.

The *Journal of Wildlife Rehabilitation* is published by the International Wildlife Rehabilitation Council (IWRC), PO Box 3197, Eugene, OR 97403 USA. (ISSN: 2166-9198).

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EDITORIAL

Improving Wildlife Care Worldwide

In recent journal editorials I've foreshadowed our work in strategic planning. Here are the principles that drive our organization.

Vision:

We envision a world where the conservation and welfare of wild animals is well served by an effective symbiotic relationship between wildlife rehabilitators and other wildlife professionals.

Mission:

We provide evidence-based education and resources on wildlife rehabilitation to move the field of wildlife rehabilitation forward; to promote wildlife conservation and welfare; and to mitigate human-wildlife conflicts worldwide, through the better understanding of wild animal ecology, behavior, and welfare.

Values:

We work with passion. IWRC staff and board are passionate about sharing knowledge to improve care for individual animals and resiliency in wildlife populations and ecosystems.

Individuals matter. We understand that individuals are significant—whether the care-giver or the animal—and that the health, welfare and well-being of those individuals may impact entire populations, species, and ecosystems.

We value our members. The IWRC strives to reach, engage, and support all members on our journey towards a professional wildlife rehabilitation field that enables excellent animal welfare and conservation.

Welfare and conservation work in synergy. Populations are groups of individuals; without attention to the individual the larger population cannot excel. Successful conservation for biodiversity and system stability depends on the health, welfare, and well-being of functional individuals. We are committed to improving welfare awareness and standards for wildlife.

Wildlife doesn't recognize boundaries. Wildlife rehabilitation is a global challenge and must be met locally with global collaboration.

We pursue collaboration. We develop working relationships that allow constructive dialogue, building bridges with those who may not always be aligned with our thinking, with the aim of seeking joint goals of improving wild animal conservation and welfare.

We provide access to education. Improvement and excellence are only achievable with knowledge, thus it is important to share information. IWRC is committed to providing opportunities for rehabilitators and other wildlife professionals to develop and improve what they do. We believe access to education is critical to the success of wildlife rehabilitation efforts around the globe.

We practice professionalism. As we continue to grow our young field, professionalism amplifies our successes and helps us overcome challenges.

Science is our foundation. The knowledge we disseminate is based on the best available science.

—Kai Williams
Executive Director

Proposed Changes to USFWS Migratory Bird Treaty Act open to Public Input until March 19

WASHINGTON, DC (January 30, 2020)—The U.S. Fish and Wildlife Service (Service) is proposing a rule that defines the scope of the Migratory Bird Treaty Act (MBTA) to provide regulatory certainty to the public, industries, states, tribes and other stakeholders.

This proposed rule clarifies that the scope of the MBTA only extends to conduct intentionally injuring birds. Conduct that results in the unintentional (incidental) injury or death of migratory birds is not prohibited under the act.

This action codifies the 2017 Department of the Interior Solicitor's Office Opinion M–37050, which analyzed the scope of the MBTA and determined the act only applies to the intentional take of migratory birds and that the take of birds resulting from an activity is not prohibited when the underlying purpose of that activity is not to take birds. The Endangered Species Act and the Bald and Golden Eagle Protection Act, as well as state laws and regulations, are not affected by the Solicitor's Opinion M-37050 or the proposed regulation.

The proposed rule will change how the Service administers the MBTA, and the Service has determined an Environmental Impact Statement under the National Environmental Policy Act is the most efficient and comprehensive approach for considering the potential impacts of this action on the environment. This is the first step in an open and transparent public process that the Service will continue to manage throughout the development of the rulemaking process. The public is encouraged to provide input to help ensure that these changes are clear, effective and advance the goal of migratory bird conservation.

When this Notice of Intent publishes in the Federal Register, it will begin a 45-day scoping process during which we solicit public input to help define the range of issues and possible alternatives to be addressed in the Environmental Impact Statement. The public scoping period will take place from February 3, 2020 - March 19, 2020.

The proposed rule will publish in the Federal Register on February 3, 2020, beginning a 45-day public comment period and will include details on how to submit comments. Written comments and information must be received on or before March 19, 2020, by one of the following methods:

- *Federal eRulemaking Portal:* http://www.regulations.gov. Follow the instructions for submitting comments to Docket No. FWS-HQ-MB-2018-0090.
- *U.S. mail or hand-delivery:*

Public Comments Processing
Attn: FWS-HQ-MB-2018-0090
U.S. Fish and Wildlife Service
MS: JAO/1N
5275 Leesburg Pike
Falls Church, VA 22041–3803

Email or faxes will not be accepted. The Agency will post all comments on http://www.regulations.gov, including any personal information provided, so posters are suggested to take care in the personal information they include in their comments.

More information related to this proposed rule, including interim copies of the proposed rule and notice of intent, can be found online at https://fws.gov/migratorybirds/2020Regulation.php.

IWRC Works to Support Wildlife Carers Affected by Australian Bushfires

EUGENE, Oregon (January 14, 2020)—As animal lovers across the world collect veterinary supplies to send animal rescue organisations in Australia, the IWRC is working with Gather Voices and the National Wildlife Rehabilitation Council to collect messages of support for those working to rescue wild animals caught in

Eileen Wicker (February 6, 2020)

From Raptor Rehabilitation of Kentucky:

We are deeply saddened to announce that our director, Eileen Wicker, passed away on Thursday, February 6th after losing her fight with cancer. It is difficult to put into words what Eileen has meant to the rehabilitation community and her friends and family. She was known as a "Force of Nature for Nature" by those around her. [Eileen was] a true icon in the pioneering and education of rehabilitation of raptors for 30+ years. She has instilled her passion for these animals in all of her volunteers throughout the years.

While she will be missed, her legacy will live on through Raptor Rehabilitation of Kentucky. We will miss her warm heart, leadership, and fighting spirit for the animals that have no voice that she cared so deeply about.

Wicker is survived by her husband, John R. Wicker; her twin sons, Jamie L. and Jerry N. Burke; seven grandchildren; and four great-grandchildren.

If you would like to make a donation in her honor, you can do so to Raptor Rehabilitation of Kentucky, P.O. Box 206186, Louisville, KY 40250.

Blue Mountains bushfire (Gospers Mountain), New South Wales, Australia, December 2019.

the Australia bush fires.

In the wake of the devastating fires in Australia an outpouring of support has come from the international community. From large scale organizations collecting veterinary supplies, to individuals donating funds to the animal rescue organizations in Australia, support for injured and displaced wildlife has been profound. The International Wildlife Rehabilitation Council (IWRC) is lending support by collecting messages of support for those working to rescue wild animals caught in the Australia bush fires.

The IWRC's President Adam Grogan stated:

> "We have reached out to wildlife rehabilitators in Australia to offer any support that we can help with at this difficult time. They have replied saying that all messages of support are gratefully welcome. So we are working with local schools in Eugene to provide thank you cards and partnering with Gather Voices to solicit video messages of support. Our members are also working to gather cards globally in order to send as much support as we can."

According to executive director, Kai Williams:

> "Rehabilitators all over the world have been reaching out to help; people are heartbroken at the images of dead animals and the enormous swaths of land burned. They are looking ahead and realizing this isn't a short term problem. The after effects of these fires will dictate our Australian colleagues' work over the next few months and years and the messages or support are necessary to keep them motivated. Remembering that there is all this love for Australian wildlife all over the globe, is a great motivator."

Grogan explains,

> "We all share a passion and dedication for wild animal welfare and we have felt inspired to stand with wildlife rehabilitators at the other side of the world. Our colleagues in Australia are enormously grateful for the international support and it has helped many of us feel a bit more hope in this dark time."

Dr. Andrew Peters, a lecturer in veterinary pathology at Charles Sturt University also stresses,

> "It is really, really important that the world knows that these fires are not normal. Areas that should only burn once a century are burning again after only 15 years, the scale and intensity of the fires has never been seen before, and even areas of rainforest that have not burnt in more than 1500 years have burnt during this crisis."

The IWRC urges anyone wanting to help, to donate to one of the many fundraising appeals that have been set up in Australia.

As much as 30% of the koala population on the New South Wales mid-north

CONTINUED ON PAGE 33

Remediation of an injured leopard and its successful release back into the wild

R. John Power, Katja N. Koeppel, Francois le Grange, Mia Vasti Botha, Constant Hoogstad, and Paul Bartels

Author affiliations, page 13.

ABSTRACT: Using both satellite and telemetric ground-truthing, it was ascertained that a collared leopard female was restrained by a wire snare, and needed emergency care. She was immobilised by airborne means and the extent of her injuries warranted advanced veterinary care, as she had been ensnared for five days. She had endured a wound that had enveloped her forequarters with an incision about three cm deep along her entire circumference. It was determined by radiographs that she was pregnant with three cubs in the last trimester of pregnancy. Remedial treatment was applied while housed at the Johannesburg Zoo, and she was isolated from visitors. She was discharged after 12 days, and repatriated into her known home range. Success was evaluated by appraising her survival and reproductive success, by examining her satellite collar downloads and GPS clusters. She made a remarkable recovery, as was evident from her making kills; residing in her home-range; and giving birth to cubs two months later, and again a year later. Leopards are robust animals and efforts to rehabilitate injured animals are worthwhile considering their threat status.

KEYWORDS: animal care, ex-situ conservation, Felidae, GPS clusters, leopard, nature conservation, post-treatment monitoring, rehabilitation, satellite collars, urban ecology, veterinary treatment, wildlife husbandry, wildlife research, wound care.

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Introduction

Leopards *Panthera pardus* (Linnaeus, 1758) are notoriously elusive, and are frequently fitted with either radio-collars or satellite collars so as to monitor and learn more about them,[1,2,3] whereas GPS cluster analysis is used to study leopard behaviour, in particular feeding.[4,5]

A particular leopard monitored by a provincial conservation agency needed remedial attention as a result of "clustering of concern" being noted of the animal's daily satellite collar downloads. GPS clusters are locational fixes via a satellite collar which are temporally and spatially aggregated to suggest certain behaviour, i.e., feeding.[1,4,5] We have thus adapted this framework to a situation where a study animal may be restrained, and in so doing serve a protectionist purpose.

On South Africa's Heritage day, 24 September 2014, one such cluster was followed up on of a particular female leopard, code named "LF02" (viz "Brandy") in the Magaliesberg mountains, North West Province, South Africa (25°46.872′S, 27°41.076′E). She turned out to be restrained by a noosed-wire snare, and we documented the whole operation, including the rescue, treatment, and outcome of the animal's eventual release.

Methods undertaken

LF02 was *a priori* fitted on 30 May 2014 with a dual VHF/GPS/satellite collar (900 g) (African Wildlife Tracking cc, 106 Nuffield Street, Rietondale, Pretoria) as part of state sanctioned management. A standing permit issued from the national Department of

J. Wildlife Rehab. 40(1): 7–13.

FIGURE 1. Female leopard LF02 being immobilized from a hovering helicopter.

FIGURE 2. This animal had a deep incision from the snare around her forequarters.

FIGURE 3. Female leopard LF02 underwent immediate treatment upon arrival at the zoo's hospital.

Environmental Affairs (DEA) covered such restricted activities for two of the authors (Permit No. S03005).

The GPS coordinates of this animal registered four times per day, and so too were the uplinks via the Argos Satellite system. Upon remotely noticing intense clustering of points, we followed up on the point at the center of the cluster using a hand-held Garmin Oregon GPS and the use of Radio-telemetry (R-1000 telemetry receiver, Communications Specialists, Inc, 426 West Taft Avenue, Orange, CA), with a 4-element Yagi receiving antenna, to walk into the position. Upon first approach on foot, LF02 aggressively lunged toward us from 60 m, so we could confirm she was alive, but likely restrained. We realized any further stress could impact negatively upon this animal.[6] An airborne approach was then opted for using a 206 Bell Jet Ranger Helicopter, from which we confirmed that LF02 was indeed restrained by a wire snare attached to a low-growing tree. We then undertook to sedate her from the air, as we realized we could approach her from a farther position, have a clear shot unhindered by branches, and also have a quicker evacuation from the site. The net effect of the airborne vs. the on-foot approach was less stress incurred upon her. Sedation required using standard immobilization drugs,[7] i.e. 5 mg/kg of tiletamine-zolazepam (Zoletil 100,® Virbac) with a CO_2 powered Dan-inject® dart gun pressure set for 15–20 m. Her weight was estimated at 35 kg.

Darting from a hovering helicopter was executed (Fig. 1). We hauled her onto the still-hovering helicopter and then flew her to the nearby Nyoka Ridge Wildlife Center, where we removed the snare, applied first aid treatment to flush her wounds, and ascertained that her wounds were serious enough to warrant advanced veterinary attention (Fig. 2).

Given the seriousness of the wound, and heavy vehicular holiday traffic in the Hartbeestpoort Dam area on the day, we decided to airlift her to the Johannesburg Zoo for hospitalization (~60 km, 20 minutes ferry time).

The veterinarians started immediately to stabilize LF02 and monitored her vitals during the surgical procedure to follow (Fig. 3). The snare had lacerated her entire chest to the spinal process on the dorsal aspect of the thoracic vertebrae (T4) and the sternum on the ventral aspect. Right lateral radiographs were taken to evaluate underlying injuries. The wire had cut into the spinal process and would have resulted in spinal cord trauma in due course, so any delay in retrieving her could have been detrimental to her, *viz.* >5 days (we extricated her on the 5th day of ensnarement).

The wounds were lavaged using 0.05% chlorhexidine solution. The wound was closed in a three-layer technique using absorbable suture material (PDS, 2-0, polydioxanone, Ethicon®) and a Penrose drain was placed to allow drainage of the infected wound.[8] She was given 20 ml/kg Ringer's lactate IV fluids (Ringers, Sabax, Adcock Ingram Critical Care), antibiotics (Synulox,® amoxicillin and clavuanic acid, Pfizer, 8.75 mg/kg twice daily for 12 days), and a non-steroidal anti-inflammatory drug was administered (Metacam,® meloxicam injectable, Boehringer Ingelheim, 0.2 mg/kg initial then 0.1 mg/kg once daily orally for 5 days).

It was also noted from the radiographs that she was pregnant with three cubs. It was estimated that the cubs were in the last trimester of pregnancy and she would give birth soon. To minimize the stress of captivity and foster her chances of a successful birth in the wild, it was decided to return LF02 to her home-range as soon as she was judged sufficiently recovered, given that carnivores are known to endure stress when held in temporary captivity.[9]

Findings and discussion

On 5 October 2014, 12 days after admittance, LF02 was discharged, re-collared, and released back into the Magaliesberg mountains (Fig. 4) by helicopter.

LF02's movements were plotted to ascertain whether she would start denning. Owing to the difficulty in pinpointing denning locations, daily records were increased to eight locations per day.[1] GPS clusters for denning sites were examined remotely,[10] and confirmed via camera trap placement: we placed three Camera traps (Model 119437C, Bushnell Trophy Cam™) around suspected den sites. Later on, when her satellite collar component had terminated, we plotted den sites with the use of aerial radio-telemetric triangulation via helicopter.

LF02 successfully hunted and moved around as she had done before (Fig. 5). For the first week after release, she moved short distances (0.4–3.3 km/day), and for the first month averaged 2.8 ± 2.5 km/day (range 0.04–8.7 km), which was slightly less than her average mileage before the incident, i.e averaging 3.5 ± 3.2 km/day (range 0.34–11.2 km), though given the variance, the ranging behaviour was similar (Fig. 5).

We also placed camera traps at kill sites by following up on these GPS clusters[1,4,10] for the purpose of appraising her condition and extent of healing. She killed a warthog (*Phacochoerus africanus*) shortly after release on 18 October 2014, and this was her first recorded kill (https://youtu.be/7ygjka-JKMo?t=10). It was evident from video that the scar wound was indistinct, suggesting healing had taken place.

Most significantly, LF02 gave birth, with two cubs confirmed in December 2014 of the year, just two months after repatriation. At least one survived to see the end of the following year, and dispersed. A year later, in January 2016, another birth was recorded of at least two other cubs (Fig. 6). In total, at least five cubs were produced in a period of 16 months, and one was known to have survived for at least a year.

Mass media coverage, including a television production, chronicled this event and brought further awareness to the plight of leopards, in particular from snaring.

Leopards are frequent by-catch of the informal "bushmeat" trade, caught by snares[11,12] which, owing to their cruel means of death, are outlawed by many countries.[13] Were it not for a collar, we

FIGURE 4. Leopard LF02 repatriated on the 5th October 2014.

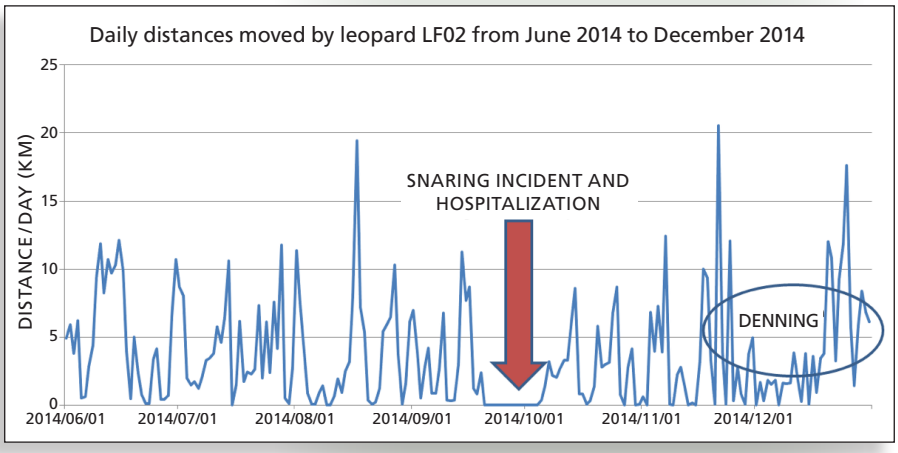

FIGURE 5. Leopard LF02 and daily distances moved from release in June 2014 until the end of December 2014, with events of the snare incident, hospitalisation, and denning indicated.

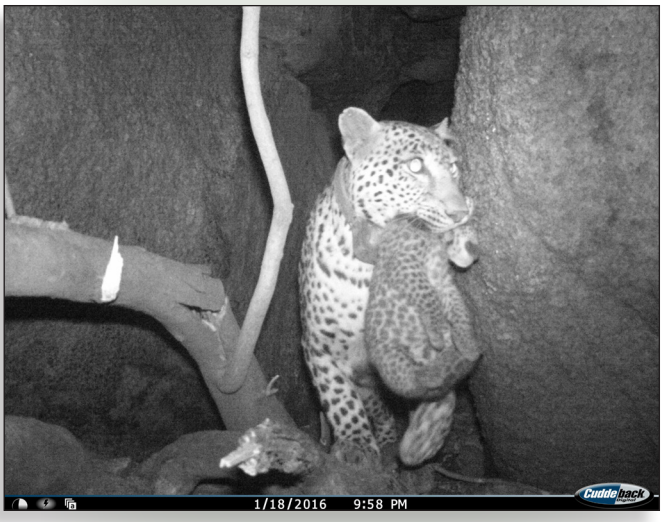

FIGURE 6. Female LF02 with a second set of cubs at a den in a sandstone outcrop.

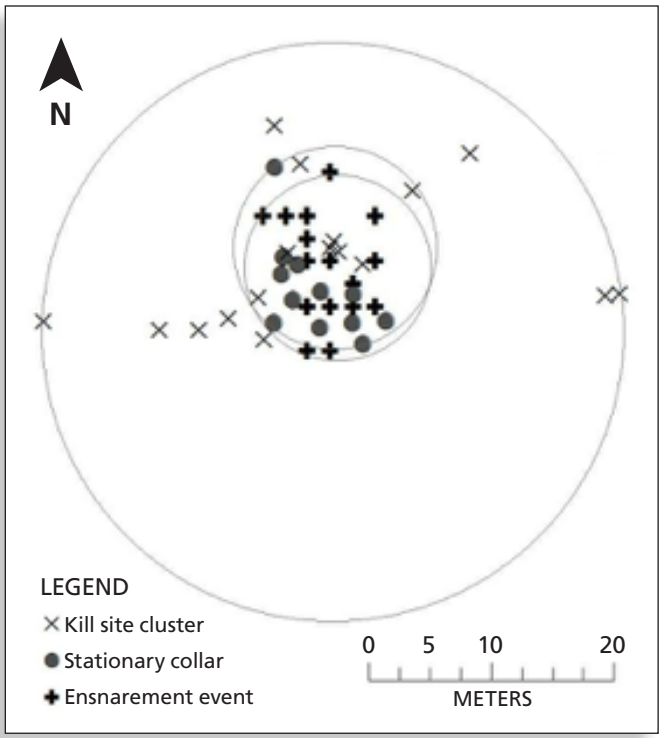

FIGURE 7. Clustering of leopard LF02's satellite collar from three clustering types placed on the same axis: from this incident (ensnarement event); with randomly selected clusters from a time when the collar was not on her (stationary collar); and when at one of her feeding sites, which was filtered from all her locations (kill site cluster).

TABLE 1. Summary of cost breakdown of the entire operation (staff salaries excluded). Monetary values reflect the South African Rand (ZAR) and U.S. Dollar (USD), respectively. The actual amounts at the time (2014) were brought forward to reflect inflation at the time of writing (~10% per annum).

ITEM	DESCRIPTION	COST	
		ZAR	USD
EQUIPMENT			
SATELLITE COLLAR*	Daily locational fixes of study: animal x 1 collar	R 37,500	$2,550
CAMERA TRAPS	Photographing study animal at kill and den sites to confirm condition, behavior, and reproduction (x 3 cameras)	13,500	920
OPERATIONAL			
SUBSISTENCE & TRAVEL	Travel from workplace to incident site and to base of mountain	6,870	470
HELICOPTER WORK*	Flying to dart animal; ferries to hospital and again to release area	30,375	2,070
VETERINARY			
IMMOBILISATION*	Chemical sedation of animal	1,800	12
TREATMENT**	Initial sedation, surgery and treatment, including husbandry where food provided	7,095	485
TOTAL		**R 97,140**	**$6,620**

*Costs waivered/sponsored, **Costs incurred by Joburg Zoo

would not have been alerted as to this female leopard's compromised state; it is the collar that ultimately saved her life.

Leopards are relatively resilient at the population level.[14] The same can probably be said at the individual level, as they are clearly very hardy and robust. LF02 demonstrated great resilience in her ability to withstand five days in a snare, then to undergo hospitalization for 12 days including recovery, to be released again, and to later reproduce. In many instances where wounds from snares are severe, practitioners may consider euthanasia, but given adequate resources, treatment can be successful for individuals of this species.

Given that snare-related mortality has been reported in various leopard studies,[2,3,15] as a conservation agency leading this work, we show that there is often a case to intervene. Intervention is especially important given leopards have been categorised as Vulnerable in South Africa,[14] and local populations are ailing.[3] Intervention is especially pertinent when veterinary expertise can be accessed,[15] and when in reasonable proximity to a veterinary hospital with the required facilities. At the risk of admonishing those that have not done so[2,3] because of extenuating circumstances—i.e. technological logistics, funds, *inter alia*—we believe that all researchers have an ethical responsibility to intervene when study animals are collared, and especially when an animal is uncharacteristically stationary. GPS clusters can be statistically analysed to interpret their nature,[5] or analysed manually (as we have done). If they are clustered anywhere less than 20 m (see Fig. 7) over a 1–3 day period, concern should be raised and the situation assessed on the ground, whether on foot or airborne. The nature of clustering will vary with collar type, however, and practitioners should test this before deployment on an actual animal. It must be cautioned that such predictive capabilities are only possible if the margin of error around the collar's location fixes is very low. Otherwise, mortality sensors can give reliable indications of immobility within 6 hours.[16,17]

Costs, as can be expected, would be exorbitant (Table 1), were it not for support that such projects generally have from wider stakeholder groups with conservation interests.

The whole operation, had it taken place today, would have cost just under ZAR 100,000, or between 6,000–7,000 USD (Table 1). Fortunately, many of the costs were either waivered or accrued through sponsorships, as this government organisation would have been hard pressed to foot the whole bill. Many government organisations in Africa, as they are in Asia,[18] are supported financially by NGOs and their sponsorships.[19] In many cases, one can apply basic treatment when in the field, so intervention would only be a matter of immobilisation and the application of basic antibiotic ointments, as has been done before.[15,21]

LF02 never returned to the exact site of this

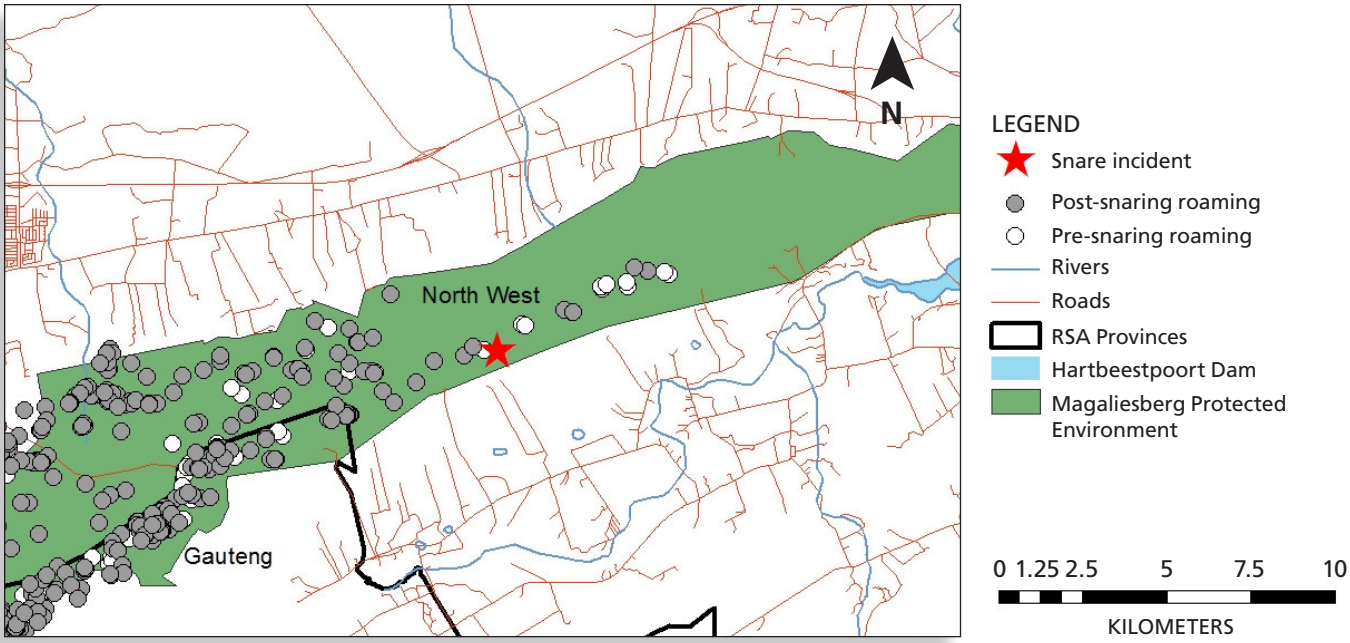

FIGURE 8. Female leopard's home-range both before (31 May 2014–24 September 2014) and after the snaring incident (5 October 2014–30 November 2015), where roaming is indicated by location points that are taken six hours apart. Only the eastern part of the home-range is shown for clarity.

incident, which suggests a "Landscape of fear,"[20] where the trauma of the snaring event, and even rescue, were enough to make this animal more cautious of using the exact same area. However, as the same general area was still used (Fig. 8), this inference is speculative at best.

Elsewhere, in Asia, leopards have been successfully rescued from snares in Iran[15] and India.[21] While rescuing this species is not altogether rare, as many conservation organisations have done so, many have simply not documented it. The aide of satellite telemetry to do so is a novel application.

In India, of 78 leopard deaths on record, 15.4 % were attributed to snares; two individuals were rescued and so averted certain death.[21] In the Iranian study (2012–2017), five leopards were reported in snares; only two were releasable, with one dying after two months.[21] Snares were set unintentionally for leopards, and after prolonged restraint, suffered a significant loss of condition as a result of struggling and starvation. Cases involved leopard caught by the limbs, waist and neck; snaring by the neck induced strangulation and hastened death.[21] Just as we have done (Fig. 3), leopards were rehabilitated with veterinary assistance, and kept temporarily before being released in the wild; one had to remain in a sanctuary owing to the extent of its injuries.[21] Unfortunately, neither of these studies[15,21] monitored the rehabilitated leopards post-release with satellite collar telemetry, so no data on actual success is known.

The "bushmeat" trade is a thriving industry in central African forests,[22,23] and wire snares are indiscriminate.[23] Snares are said to be the biggest threat to another felid, the African golden cat (*Caracal aurata),*[24] and other large felids have also been locally threatened. Both lions *(Panthera leo)*[25] and tigers (*Panthera tigris)*[18] are killed in snares, though tigers are mostly affected by their prey being caught.[26]

Wire snares are more prominent in the developing countries,[11,15,22,23,26,27,28] and the use of these snares in the bushmeat industry is economically driven, especially for subsistence.[27] Other than socio-economic reforms, active snare removal campaigns are well worth conducting as a conservation measure.[18] It has also been suggested to place camera traps at snare sites to document and so potentially apprehend poachers.[26]

In this case study the snaring event took place in a protected environment (Fig. 8), though normally snaring appears to be more common on the edges of protected areas.[27,28] Each area should be examined on its merits when seeking to rid an area of snares.

Conservation implications

Given imminent threats to carnivore populations throughout the world, and where studies of satellite collared animals takes place, there is potential for veterinarians, zoo managers, rehabilitators, researchers, and conservation authorities to work together to avert harm from anthropogenic causes, such as the threat posed by entanglement in wire snares. Collared study animals can be used to identify snaring "hotspots," while ensnared prey items can also indicate such areas. Snare removal operations should thus commence in such "hotspots", so as to reduce the incidence of snare-related mortality for all wildlife from an area.

Acknowledgements

We thank the collar sponsors Companion Care Vet Clinic UK in Harlow and Chingford, United Kingdom, in particular Drs. Chris Venter and Garrick Ponte. We thank Mr. Tokkie Botes of

Flying for Freedom SA for availing the use of his helicopter, and his pilot, Mr Frank Molteno.

We thank the Johannesburg City & Parks (Johannesburg Zoo) who housed this animal during recovery. We thank the landowners who assisted with logistics at the capture site, and eventual release site.

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Use of plumage and gular pouch color to evaluate condition of oil spill rehabilitated California brown pelicans (*Pelecanus occidentalis californicus*) post-release

Deborah L. Jaques[1], Kyra L. Mills[2], Barton G. Selby[3], Richard R. Veit[4], Michael H. Ziccardi[2]

Introduction

Wildlife exposed to petroleum products after spill incidents can be negatively affected in multiple ways. The primary acute impact to these animals is from external contamination by oil and subsequent hypothermia, increased metabolic effort, and emaciation.[1-4] Ingestion or inhalation of polyaromatic hydrocarbons can cause liver and kidney damage, compromised immune function, and hormone disruption.[2,5,6] Oil-contaminated seabirds may succumb immediately to oiling or may endure several days of exposure leading to death if not rescued and rehabilitated. Capture, washing, handling, and time in captivity can both reverse the effects of exposure or, possibly compound the initial impacts of oiling.[7,8] Sublethal effects of oil spills on seabirds may result in failure to thrive despite plumage restoration and other rehabilitation efforts.[4,9,10] Such impacts are difficult to measure once birds are released but may play an important role in population restoration.[11-13]

Researchers have used a variety of techniques to track the fate of oiled seabirds following rehabilitation and release. These include quantifying band recoveries of live and dead birds, monitoring movement patterns with electronic tracking, and documenting reproductive success.[9,10,14-17] Electronic tracking methods have improved knowledge of near-term postspill bird survival;[18-20] however, these devices introduce another variable to post-release studies.

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ABSTRACT Sub-lethal effects of oil spills may dampen seabird rehabilitation success due to lingering negative impacts of contamination and stress on reproduction and long-term survival. These effects can be difficult to measure while birds are in care as well as once released. Expression of sexually selected traits sensitive to condition can provide information on physiological status of birds. We evaluated plumage molt and gular pouch skin color of California brown pelicans *(Pelecanus occidentalis californicus)* following oil contamination and rehabilitation for differences between oiled and rehabilitated (post-spill) and presumably uncontaminated birds. Post-spill pelicans released with color leg bands alone, or bands plus harness-mounted satellite GPS tags, were relocated and visually assessed in the field at non-breeding communal roosts and compared to surrounding unmarked pelicans in the general population. Non-oiled pelicans bearing GPS tags were also included. Post-spill pelicans lagged the general population in molt of ornamental yellow crown feathers, but hind neck transition into white plumage did not significantly differ. Post-spill and non-oiled pelicans wearing GPS tags had lower gular redness scores than unmarked,

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Reprint: *PLoS ONE* 2019;14(2): e0211932.
https://doi.org/10.1371/journalpone.0211932

Brown pelicans (*Pelecanus occidentalis*) are a seabird commonly oiled following nearshore spills in the United States. Survival and dispersal of previously oiled and rehabilitated California brown pelicans (*P. o. californicus*) were examined in the early 1990's by Anderson et al.[9] Conventional VHF radiotelemetry and auxiliary color banding were used to track movements and association with breeding colonies up to two years post-release. None of the previously oiled pelicans were known to breed and only 9% were detected alive two years after the spill. Anderson et al. concluded that oiling, and possibly handling stress, resulted in long-term injury to pelicans, including failure to breed, and lower survival than controls. Those results supported the supposition that long term sub-lethal effects of oiling may preclude restoration of some seabirds to the breeding population. More recently, Miller et al.[21] detected a small number (approx. 2% of those rehabilitated and released) of color banded Eastern brown pelicans (*P. o. carolinensis)* successfully breeding one year after oiling from the Deepwater Horizon spill. An increasing number of studies have demonstrated that seabird oil spill rehabilitation efforts can succeed in restoring birds to normal function, but further evidence is needed—specifically projects that extend beyond acute survival.[22,23]

Identification of visible external features that indicate physiological responses to contaminant exposure have helped advance the field of ecotoxicology.[24-26] Variation in expression of carotenoid-based colors has been used as a tool for evaluation of contaminant effects and overall condition of birds,[12,27-29] but evaluation of plumage and soft-part colors have not previously been used in studies of post-spill rehabilitated seabirds. Little information is available on impacts of oil exposure, washing, and rehabilitation on seabird molt and plumage condition after release, but endocrine disruption or other stressors that affect body condition could feasibly affect subsequent molt and feather pigmentation. Molt is energetically expensive (up to 5–30% of daily energy budget) and is generally regulated by photoperiod and hormonal cycles.[30] Timing and duration of molt can be influenced by factors such as age, sex, reproductive and nutritional status, geographic origin, and variable environmental conditions[30-34] complicating application to pollutant studies.

Brown pelicans gradually develop definitive adult plumage over a period of 3–5 years and are sexually monomorphic.[34,35] Adults have a complex annual molt cycle that results in radically different seasonal appearances of the head and neck.[34-36] Adult head and neck feathers are generally replaced in the late summer-fall as part of the prebasic molt.[37] Faded dark hindneck feathers are replaced with white feathers, creating a gray appearing hindneck during the transition. Around the same time, yellow feathers begin to grow into the white or speckled crown until the crown is completely yellow and the neck is white in definitive basic plumage. As part of the prealternate molt later in winter, dark brown-black feathers return to the hindneck and crest. The crown's golden hue may intensify during this time, creating dramatic contrast with the dark hindneck during the courtship period. The yellow crown is thus an ornamental feature that is present in both basic (non-breeding) and alternate (breeding) plumage.[37,38] The crown transitions to white specked with brown during the nesting season and the brown neck plumage becomes faded and worn by the end of the typical chick-rearing period.

Both sexes of California brown pelicans (hereafter 'pelicans') develop a red gular pouch prior to the breeding season, when the dull grayish gular pouch blooms with redness proximally.[35] The pouch is multi-layered, including a highly vascular muscle layer and sub-epithelial melanocyte layer.[39] Pouch redness is thought to indicate hormonal activity and breeding readiness.[40] Red gular sac color in the great frigatebird (*Fregata minor)* during the breeding season has been related to a combination of carotenoids, hemoglobin, and increased blood flow.[41] The specific physiological and biochemical mechanisms surrounding display of gular redness have not been described for pelicans but are likely similar to frigatebirds.

Coloration has been found to indicate health and fitness in many species of birds.[42,43] Carotenoid pigments are acquired by diet and typically give a red, orange, or yellow hue,[29,44,45] such as the pelican's pre-breeding crown and gular pouch colors. Expression of carotenoid colors for sexual signaling is thought to have evolved as an honest advertisement of individual quality since there are physiological costs associated with using these valuable antioxidants for display.[43,46,47] The outward expression of sexual characteristics can be a particularly sensitive and readily observable indicator of physiological responses resulting from stressful events.[24,48] Carotenoid-based coloration has been found to have a negative relationship to environmental toxins.[28] For example, Perez et al.[12,16] provided experimental and field evidence that during the courtship period, the red spot (a carotenoid-based signal) in yellow-legged gull (*Larus michahellis*) beaks was smaller in birds exposed to polyaromatic hydrocarbons compared to those that were not exposed. Similarly, the hue and brightness of skin colors of kittiwakes during the breeding season showed a negative relationship to endogenous pollution levels.[49]

We designed a study to test the null hypothesis that post-spill pelicans observed in the wild would not differ visually from conspecifics with respect to their outward physical appearance. Here, we provide a field-based comparison of molt progression in the head and neck, and expression of redness in the gular pouch between previously oiled/rehabilitated pelicans and the general, presumably never oiled, wild population. We further report on

ABSTRACT
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non-oiled birds. Pre-breeding gular pouch redness of post-spill pelicans was more strongly influenced by wearing of a GPS tag than prior oil contamination and rehabilitation. Gular pouch redness of post-spill pelicans in the first 18 m after release was positively correlated with long-term survivorship. If gular pouch color is a condition-dependent sexual signal, and overall health influences molt progression, our results indicate that many post-spill pelicans marked with bands alone were in relatively good condition entering breeding season, but those released with electronic tags experienced additional stress from the equipment, introducing a confounding variable to the post-release study.

unexpected differences between post-spill pelicans bearing electronic tags versus post-spill birds released with only leg bands, and the relationship of gular color to known survival amongst rehabilitated birds.

Materials and Methods

To further improve estimates of seabird recovery following oiling, the Oiled Wildlife Care Network (OWCN), a program led by the School of Veterinary Medicine at the University of California at Davis, initiated a study to track rehabilitated brown pelican movement patterns and survival following the May 2015 Refugio Beach Oil Spill near Santa Barbara California using Global Positioning Satellite platform transmitter terminal (GPS–PTT) tags.[50] We developed this field investigation as a companion to the remote tracking project. We assumed that adequate numbers of post-spill pelicans could be located with the aid of recent position data from the transmitters and that measures of field observable characteristics, including plumage transitions and gular pouch color, could provide an independent measure of post-spill pelican health in the wild. Non-breeding brown pelicans spend much of their daily time budget onshore at traditional coastal communal roosts[51,52] where, in certain settings and with appropriate techniques, they can be observed closely without causing disturbance. Surveys at breeding colonies were not feasible for this study due to potential disturbance and remote nesting locations.[53]

The Refugio Beach Oil Spill occurred on 19 May 2015, in Santa Barbara County, California, USA at 34.46˚ N, 120.09˚ W (Fig. 1). The spill affected over 100 miles of coastline with oil sheen and tar balls persisting on the water for several weeks. Brown pelicans contaminated with crude oil from the spill were captured with hand nets 1–10 days after the initial event. The extent of oiling on individuals in the study was variable (2–100%) and the duration of exposure was unknown but ranged from 2 to as many as 15 days. The birds were washed, rehabilitated and released approximately 3–5 weeks after oiling just outside the spill zone.[54] All released pelicans (N = 42) were outfitted with aluminum federal bands and field-readable green color leg bands. Thirty-three of the birds were aged as adult based on typical after third year (ATY) plumage.[34,35] Of these, a subset of 12 adults were fitted with GPS–PTT devices (65g solar units from GeoTrak Inc, Apex, North Carolina). Transmitters were attached back-pack style with Teflon ribbon harnesses (Fig. 2).[50,55] Eight additional adult pelicans that did not appear to have been directly exposed to oil were captured in early July 2015 by baiting near the spill site and fitted with the same GPS–PTT tags for comparative studies of movement patterns. These control birds were released within hours of capture. Electronic tagging equipment and procedures are further described in Lamb et al.[56]

Work was completed in accordance with all appropriate State, Federal and university regulations and policies including the U.S. Geological Survey Bird Banding Laboratory with Federal Master Bander permit #23539, the U.S. Fish and Wildlife Service Scientific Collection Permit #MB191637-0, and the California

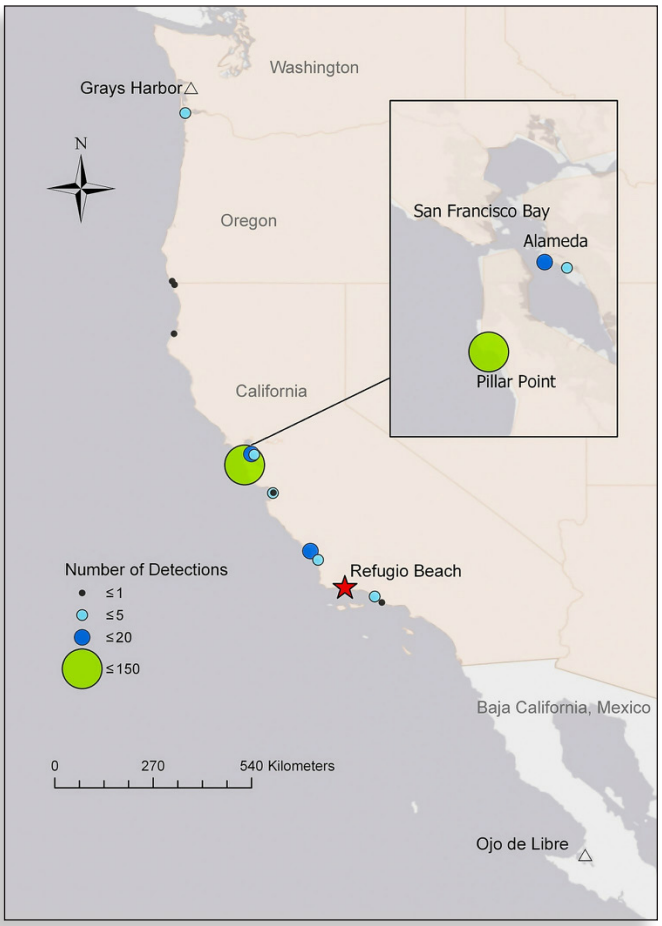

FIGURE 1. Refugio oil spill site and distribution of post-spill pelican field sightings. Locations of Refugio spill green banded pelican sightings from August 2015 through November 2016 are shown (N = 190 sightings). North and south limits of field surveys are indicated by triangles. Base map credit: Esri, HERE, Garmin, OpenStreetMap contributors, and the GIS users community. https://doi.org/10.1371/journal.pone.0211932.g001

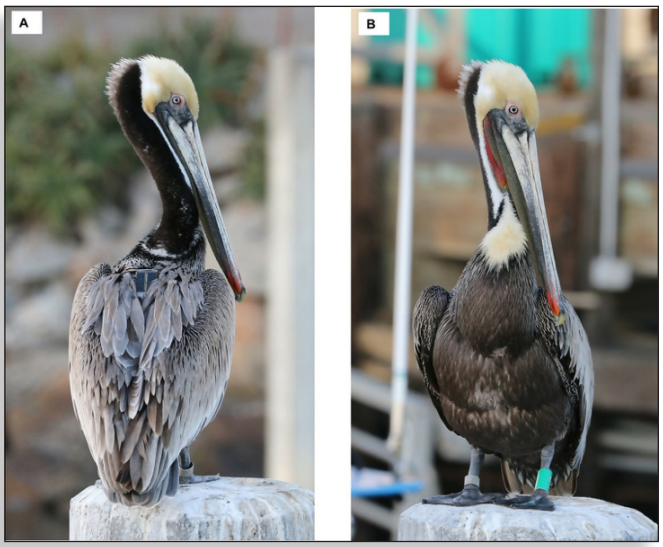

FIGURE 2. Configuration of GPS–PTT tags on brown pelicans observed in the field. Dorsal (A) and ventral (B) views shown on Z11, 17 March 2016, after about 9 months of wearing the equipment. https://doi.org/10.1371/journal.pone.0211932.g002

Score	1	2	3	4	5
Crown Molt	White and brown speckled crown, yellow absent (A)	Yellow feathers emerging into white or speckled crown (B)	Crown fully yellow or yellow receding posteriorly (C-E)	Crown all white, yellow and dark feathers absent (F)	N/A
Nape Molt	Faded brown neck (A)	Gray neck, white feathers emerging (B)	White neck (C)	Gray neck, dark feathers emerging (D)	Dark brown-black neck (E-F)

FIGURE 3. California brown pelican crown and nape index scoring system. The scores shown were the numbers used for the crown and neck molt indices (CMI and NMI).
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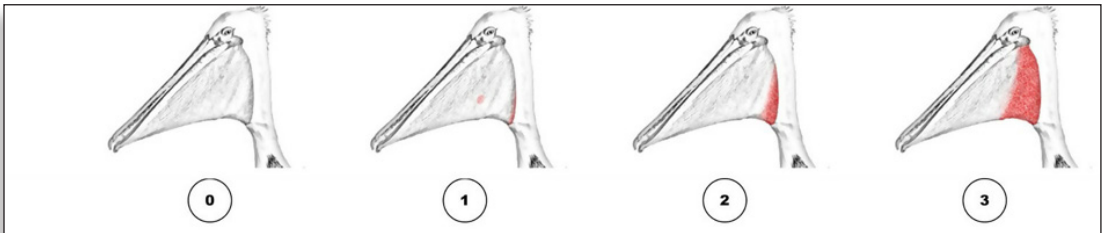

Gular Redness Index (GRI)	0	1	2	3
Extent	N/A	Trace or small patch of red	Red area < 1/3 gular pouch	Red area > 1/3 gular pouch
Color	Redness absent	Red (often dull)	Red (may be dull)	Bright red
Position	N/A	Along basal edge or within lower gular region	Lower gular region, does not extend to mandible	From base of pouch to at least proximal edge of lower mandible
Pigment Homogeneity	N/A	Generally patchy mixed with other skin colors	May be patchy mixed with other skin colors	Solid red appearance

FIGURE 4. California brown pelican gular pouch scoring system. The gular redness index (GRI) was based primarily on extent of red; other characteristics that typically accompany each score are also included here.
https://doi.org/10.1371/journal.pone.0211932.g004

Department of Fish and Wildlife Scientific Collection Permit #SC-003855. All procedures were conducted under University of California at Davis Institutional Animal Care and Use Committee Protocol #18823. Brown pelicans are protected under the Migratory Bird Treaty Act.

Field reconnaissance was initiated approximately three months after release of the previously oiled birds. Data collection on plumage and color comparisons took place primarily from September 2015–March 2016. Field work occurred in seasonal sessions of 7–10 days and ranged along the coast from Grays Harbor, Washington, USA (46.54˚N, 124.06˚W) to Ojo de Liebre, Baja California Sur, Mexico (27.50˚N, 113.57˚W; Fig. 1). Permission to access Naval Base Ventura County lands was granted by Martin Ruane (U.S. Navy) and access to Año Nuevo Island Reserve was provided by Patrick Robinson (U.C. Santa Cruz). All other field locations were open to the public. Pelican roost site atlases were used to help plan search effort within a region and surveys took place from both ground and small boats. The basic survey strategy was non-intrusive searches and observations of post-spill and control transmitter pelicans at non-breeding communal roosts and fish handling areas, with initial effort focused on regions where GPS positions indicated past occurrence of electronically tagged birds. After transmissions ceased and/or these birds moved out of the study range, search effort was focused on large roost sites where leg-banded pelicans were most likely to be detected. For the duration of the study, another observer conducted routine kayak-based searches for banded pelicans at major harbor breakwater roosts in Central California nearly weekly, without consideration of the electronic tracking data. Both observers photographed post-spill pelicans with high resolution DSLRs and image stabilizing telephoto lenses.

Comparisons to the general population were made at the same place and time by evaluating the five nearest neighbors surrounding a marked focal bird. The 'general population' consisted of unmarked, presumably never oiled or rehabilitated pelicans. Focal birds included any individual in one of the following three groups; 1) previously oiled pelicans released with color band-only, 2) previously oiled pelicans with band plus GPS–PTT, and 3) non-oiled pelicans with band and GPS–PTT. Plumage aspect and soft-part color characteristics were based on classifications in Schreiber et al.[35]

Molt phase and color assessments were limited to adult birds and focused on three distinct and readily visible body parts—the hind neck, the crown feathers, and the gular pouch. These features were visually scored using a combination of direct field observa-

tions and digital photographs. The hind neck and crown were categorized as either in a definitive plumage aspect or transitioning between states.[37] An ordinal grading system was developed (Fig. 3) resulting in five different potential scores for the neck molt index (NMI) and four for the crown molt index (CMI). We did not attempt to discern differences in yellow crown feather hue but simply the occurrence of yellow feathers. Data for crown and neck analyses were restricted to September 15–December 15, 2015. A third ordinal grading system, the gular redness index (GRI) was based primarily on visual estimation of spatial extent of red in the pouch (0–3) using data collected during September 15–March 21, 2016 (Fig. 4). Plumage and color were scored only by the primary observer to reduce potential bias. Occurrence of wetted plumage and shivering was also noted in the field, which can be normal in some circumstances but can also indicate structural failure of plumage and a need to produce endogenous heat.[57]

Surveys of banded pelicans to document survival continued through the summer of 2018 and each post-spill bird was photographed. A separate analysis of post-spill survival of the Refugio incident pelicans, incorporating demographic and biomedical factors, is planned.[54]

Statistical analyses were conducted using R package v. 3.5.1(R Core Team 2018).[58] Pelicans were assigned to four different groups as follows: post-spill rehabilitated birds without GPS–PTT tags; post-spill birds with GPS–PTT tags, non-oiled pelicans with GPS–PTT tags; and the general population of wild, non-oiled, unmarked pelicans. Loglinear analyses were used to test for interactions between factors. These analyses included a date factor to incorporate variation in plumage and color over the sampling period. Data were binned into three sampling periods as follows (Sep–Oct, Nov–Dec, and Feb–Mar). The effects of oil and GPS–PTT were modeled separately. In addition, the association between highest GRI observed during 2015–2016 and survival of post-spill birds, was tested using Spearman rank correlation. The survival index was the number of days elapsed between release and latest observation in the field, including detections in 2018.

Results

Most of the Refugio post-spill pelicans (79%) were re-sighted at least once following release.

By September 2017, 220 sightings of 33 birds were documented (mean = 6.7 sightings/bird, range = 1–45, SD = 9.2). Frequent surveys of large communal roosts resulted in a greater number of visual encounters of target animals than did attempts to relocate electronically tagged pelicans based on GPS–PTT data feeds showing past positions. Sightings of the post-spill birds were most common in summer and fall (especially July–October) and relatively rare during late winter–spring (Fig. 5) when pelicans generally retreat to offshore islands in the breeding range.[59] Tracking data showed that all of the electronically tagged post-spill pelicans moved out of the zone affected by the spill during summer and fall 2015—some as far north as Oregon, and most retreated south into Mexico during winter.[50]

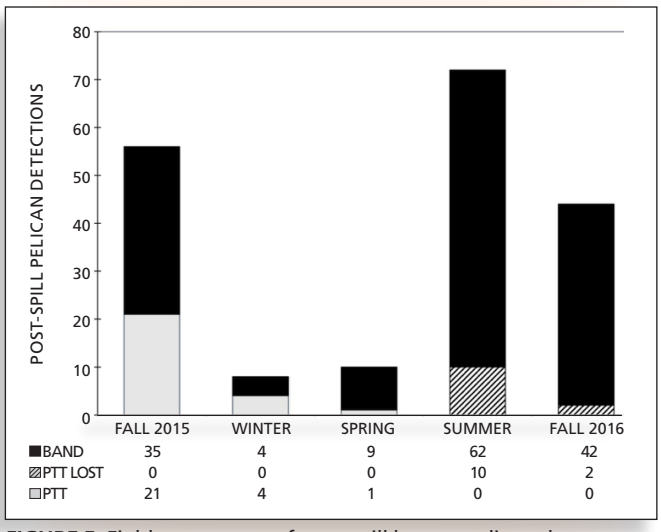

FIGURE 5. Field encounters of post-spill brown pelicans by season (2015–2016). Data are separated for previously oiled birds released with only leg bands (BAND), equipped with GPS–PTT transmitters (PTT) and birds that shed transmitters but retained bands (PTT LOST). N = 190 sightings of 33 individual post spill birds of all ages.
https://doi.org/10.1371/journal.pone.0211932.g005

Most visual sightings of post-spill birds occurred over 300 km north of the spill region in Central California (Fig. 1). This was due to a combination of focused survey effort at two harbor roosts where there were exceptionally large concentrations of pelicans and favorable band-sighting conditions. We counted as many as 2,800 and 3,900 pelicans at two key breakwater roosts, in Pillar Point and Alameda harbors, respectively, during the summer of 2016, while as few as zero occurred in late winter-early spring surveys. Band sightings indicated high turnover of individuals and suggested a well-mixed migratory population, although a few birds were resident to the area during much of the non-breeding season.

Plumage of post-spill band-only pelicans appeared normal with respect to waterproofing and overall integument condition (e.g., none were observed with saturated wet plumage or seen shivering), while four of the 12 pelicans seen wearing transmitters were observed shivering (two post-spill, two control). Plumage disruption around the harness was generally visible around the ventral surface (Fig. 2B) and excessive preening around the straps was observed, but not quantified for this study. Ultimately, four pelicans were encountered alive that had shed their transmitters but retained leg bands.

During the mid-September–December sampling period, nearly all non-oiled pelicans (98%) displayed solid yellow crown plumage (Fig. 3). Emergence of yellow crown feathers was more variable and lagging in the post-spill group (Fig. 6); 71% of post-spill birds had solid yellow crowns and the remainder were transitional or entirely lacking yellow feathers. Loglinear analysis incorporating non-oiled pelicans bearing GPS–PTT tags indicated that both previous oiling/rehabilitation and equipment burden significantly influenced emergence of yellow feathers in the crown (Table 1, $p < 0.001$).

Most pelicans (93%) in the non-oiled general population had

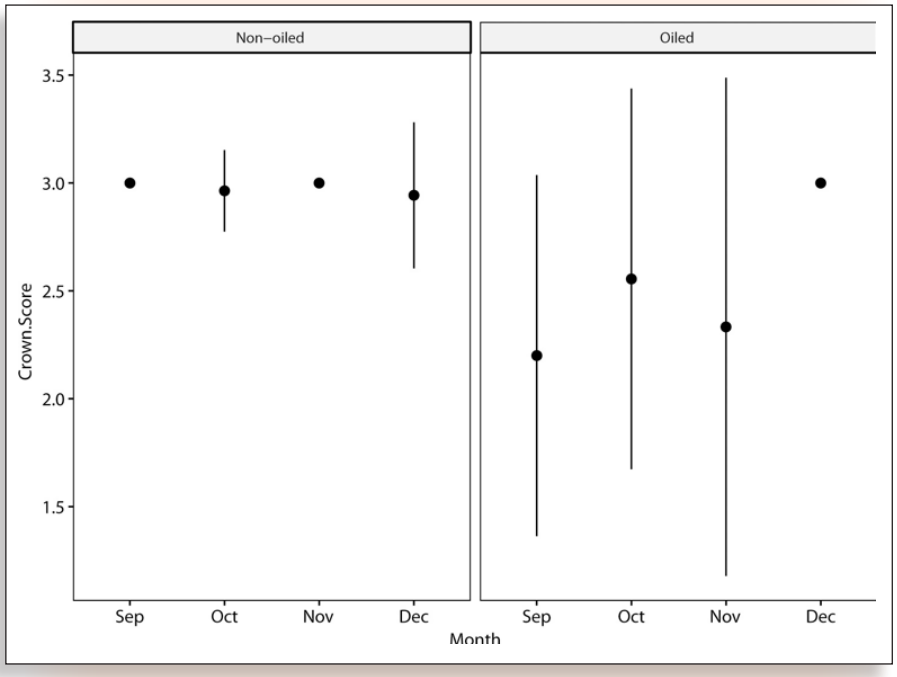

FIGURE 6. Crown scores compared for non-oiled and oiled pelicans, showing monthly mean and standard deviation. The oiled group includes pelicans released with band-only and GPS–PTT tags (N = 21). The non-oiled group includes only unmarked pelicans (N = 135) and does not include pelicans bearing PTT tags. Data are from September 15-December 15, 2015. Statistical analysis results are presented in Table 1. https://doi.org/10.1371/journal.pone.0211932.g006

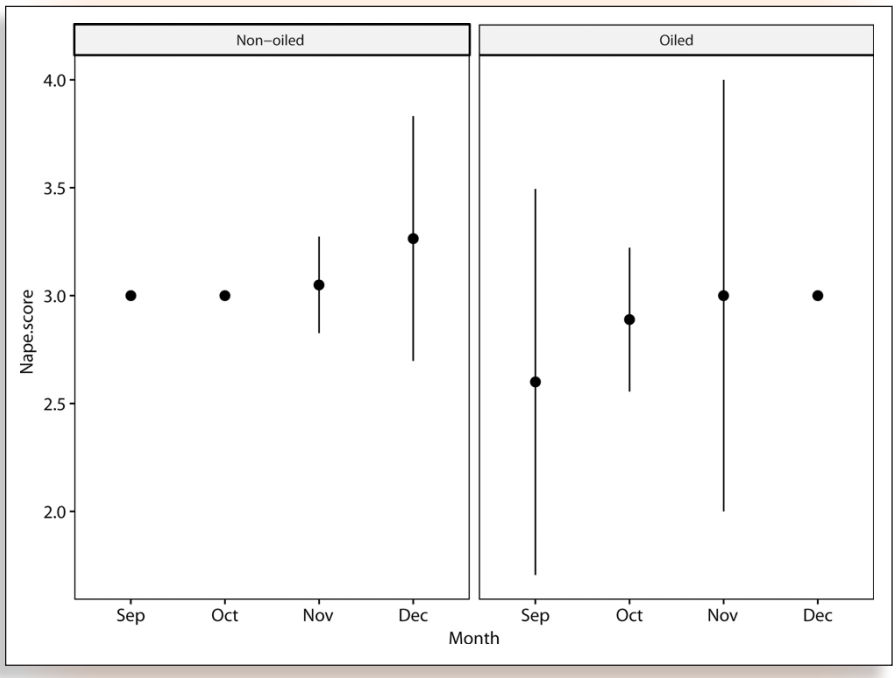

FIGURE 7. Hindneck scores compared for non-oiled and oiled pelicans, showing monthly mean and standard deviation. The oiled group includes pelicans released with band-only and GPS–PTT tags (N = 21). The non-oiled group includes only unmarked pelicans (N = 135) and does not include pelicans bearing GPS–PTT tags. Data are from September 15–December 15, 2015. Differences in neck molt between groups were not significant according to loglinear analysis (see text). https://doi.org/10.1371/journal.pone.0211932.g007

definitive basic white neck plumage during the sampling period (Fig. 3), although some (~6%) had progressed further, into prealternate and alternate phase dark hindneck plumage by mid-December. The post-spill group lagged slightly behind the general population in molt of the hindneck, and none of the post-spill birds acquired the dark alternate phase hindneck by mid-December (Fig. 7).

Replacement of overall body plumage apparently also lagged in some cases but was not quantified (Fig. 8). Loglinear analysis indicated that neither previous oiling/rehabilitation or the burden of GPS–PTT tags significantly influenced the molt progression of the neck in this study ($Z = -0.65$, $p = 0.5$ and $Z = -0.99$, $p = 0.3$, respectively).

Pelicans began to display red pouches at nonbreeding roosts by mid-September 2015, and red pouches were observed through March 2016. Expression of redness in the non-oiled/ unmarked population was variable each month within the sampling period but scores tended to be highest in November-February (Fig. 9). Previously oiled pelicans and non-oiled GPS–PTT-bearing birds were less likely to express gular redness than the general population. Although both factors (oil and PTT) significantly influenced gular redness according to loglinear analysis (Table 2), the effect of wearing a GPS–PTT was more significant ($p < .001$). Pelicans wearing electronic tags were more likely to have a GRI score of zero than other groups. For example, in November–December, only 13% of PTT-bearing birds (N = 8) had any discernable trace of pouch redness, while 66% of the post-spill birds released with bands only and 93% in the unmarked non-oiled group showed redness in the pouch (Table 3).

Sightings of banded birds through summer 2018 indicated high survival rates of the Refugio post-spill pelicans overall; at least 60% (25 of 42 pelicans) were alive one year after release and 43% (18 pelicans) were seen alive three years after the spill. Long-term survival of adult post-spill birds was positively correlated with the highest GRI score documented in the

first 18 months after oil exposure (Fig. 10; S = 138.7, rS = 0.796, p < 0.001). None of the birds with gular scores of zero (no redness in the pouch) were encountered >247 days post-release. Gular redness scores of zero were also associated with known mortality. Of four confirmed pelican mortalities in this study, three were seen alive in the field during the period of expected pouch redness, and all had a score of zero. Three of the pelican carcasses were GPS–PTT-bearing and found by searching in areas where electronic signals suggested lack of normal movement (one previously oiled, two non-oiled). The fourth carcass was from a color band-only bird and found incidentally by a member of the public.

TABLE 1. Results of generalized loglinear analysis of crown molt showing interaction terms.

Variables	Coefficient	Standard Error	Z score	*P*-value
Effect of Oil on Crown				
(Intercept)	-5.3831	2.7926	-1.928	0.0539
Oil	6.0731	1.8366	3.307	0.0009***
CMI	3.1004	0.9368	3.309	0.0009***
Month	-1.3155	1.7672	-0.744	0.4566
Oil*CMI	-2.6741	0.5907	-4.527	<0.0001***
Oil*Month	-0.2747	0.5465	-0.503	0.6153
CMI*Month	0.3513	0.5915	0.594	0.5525
Effect of PTT on Crown				
(Intercept)	-2.5764	2.4887	-1.035	0.3005
PTT	3.7307	1.6149	2.310	0.0209*
CMI	2.2058	0.8381	2.632	0.0085**
Month	-2.6561	1.7756	-1.496	0.1347
PTT*CMI	-2.4798	0.5496	-4.512	<0.0001***
PTT*Month	0.7059	0.5984	1.180	0.2382
CMI*Month	0.7748	0.5953	1.302	0.1931

Oil = previously oiled and rehabilitated (N = 21). PTT = wearing an electronic GPS–PTT tag, both oiled and non-oiled birds (N = 16). The model incorporates non-oiled, unmarked pelicans (N = 135). CMI = crown molt index. Month = data compiled in 2-month bins (Sep–Oct, Nov–Dec). Significance codes: ***= .001 **= .01 *= .05 https://doi.org/10.1371/journal.pone.0211932.t001

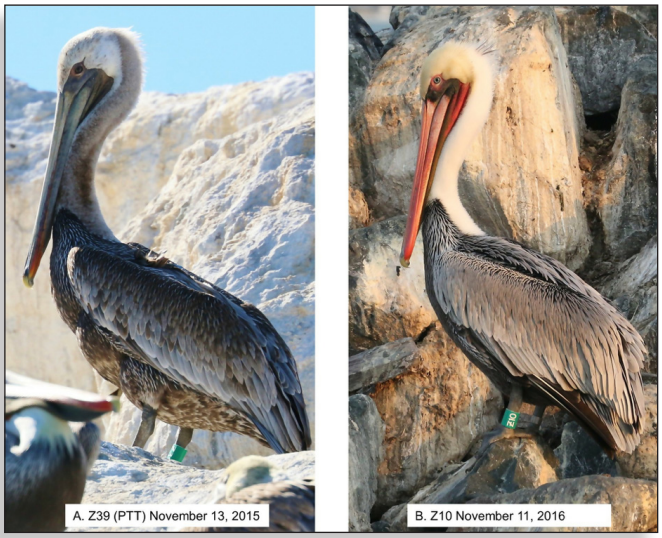

FIGURE 8. Mid-November brown pelican plumage aspect comparison, lagged versus typical. This example shows lagged molt of a post-spill bird carrying a GPS–PTT tag photographed 6 months after the spill (A) versus seasonally typical molt status in a post-spill bird marked with band only, photographed 18 months after the spill (B). https://doi.org/10.1371/journal.pone.0211932.g008

Discussion

We developed a novel approach to evaluating condition of California brown pelicans in the field following oil spill rehabilitation and release. We found that it was possible to locate adequate samples of post-spill birds without the aid of electronic tracking devices, although it required a lot of survey effort at roost sites that were both heavily used and conducive to close observations. Our results suggest that there were subtle lingering physiological effects of pollution exposure and rehabilitation in the first year after the spill that caused significant differences in crown and gular pouch appearance, contrary to the null hypothesis. Condition-dependent signals represent the sum of environmental pressures on an animal.[24] In this case, the burden of wearing electronic transmitters appeared to be a hindrance to recovery of previously oiled, rehabilitated pelicans and confounded the results of the study. While GPS–PTT tagged birds survived and initially appeared to move normally,[50,56] there was evidently ongoing stress that resulted in a general failure to express gular redness prior to the breeding season for both oiled and non-oiled birds bearing the tags. We recommend that a similar study be repeated without the additional variable of electronic transmitters and with a focus on documenting gular pouch redness in the pre-breeding phase.

Although our results were unexpected with regard to the strong influence of the GPS–PTT tags,[56] broad literature reviews have concluded that transmitters negatively affect most aspects of bird behavior and ecology to some degree and may bias resulting data.[60,61] Kesler et al.[62] found that mallards (*Anas platyrhynchos*)

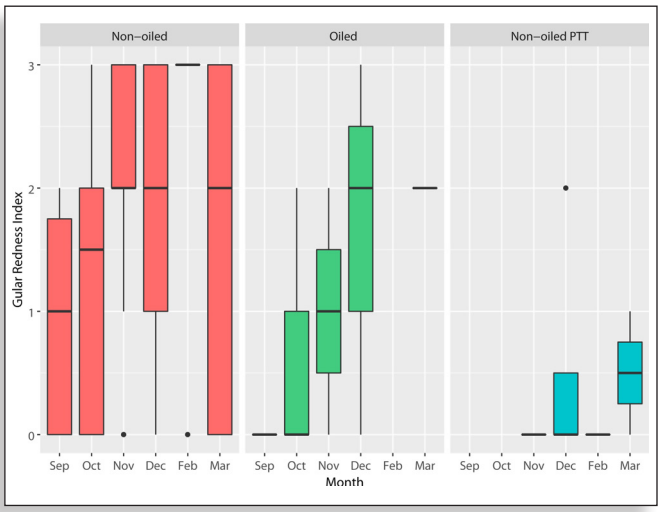

FIGURE 9. Gular redness scores for non-oiled, previously oiled, and non-oiled GPS–PTT bearing pelicans. Shown are medians, quartiles, and outliers across months. Sample sizes are as follows: non-oiled (N = 135), oiled (N = 17), non-oiled with GPS–PTT (N = 9). Data are from September 15, 2015–March 21, 2016.https://doi.org/10.1371/journal.pone.0211932.g009

TABLE 2. Results of generalized loglinear analysis of gular pouch redness with interaction terms shown.

Variables	Coefficient	Standard Error
Effect of oil on gular redness		
(Intercept)	3.1267	0.3276
Oil	-0.7535	0.6441
GRI	-0.3883	0.1769
Month	-0.7701	0.1865
Oil*GRI	-0.5486	0.2633
Oil*Month	-0.47801	0.3994
GRI*Month	0.2364	0.0926
Effect of PTT on gular redness		
(Intercept)	3.4993	0.3370
PTT	-2.3697	0.6891
GRI	-0.4878	0.1771
Month	-1.0612	0.2075
PTT*GRI	-1.5062	0.38446
PTT*Month	0.85622	0.35109
GRI*Month	0.33391	0.09782

Oil = previously oiled and rehabilitated. PTT = wearing an electronic tag (GPS–PTT). GRI = gular redness index. Month = data grouped in 2-month bins (Sept–Oct, Nov-Dec, Feb–Mar). Significance codes: ***= .001 **= .01 *= .05 https://doi.org/10.1371/journal.pone.0211932.t002

TABLE 3. Distribution of gular redness scores, separating the effects of previous oiling and wearing electronic tags for loglinear modeling.

			OIL			
GRI	*0*	*1*	*0*	*1*	*0*	*1*
3	1	0	22	1	9	0
2	27	2	20	2	3	1
1	12	1	10	0	2	0
0	20	8	9	2	9	0
			PTT			
GRI	*0*	*1*	*0*	*1*	*0*	*1*
3	1	0	23	0	9	0
2	29	0	21	1	3	1
1	12	1	10	0	1	1
0	24	4	4	7	7	2
	Sep-Oct		***Nov-Dec***		***Feb-Mar***	

Gular redness index scores (GRI) are shown for all previously oiled pelicans (OIL) and those bearing electronic tags (PTT) across binned months, where 0 = no OIL or no PTT, and 1 = previously oiled, or bearing PTT, respectively. https://doi.org/10.1371/journal.pone.0211932.t003

fitted with dummy transmitters attached with Teflon ribbon harness had lower body mass than controls without equipment. Fitted mallards also tended to avoid water, presumably due to greater energetic expenditure to thermoregulate in cold weather and compromised feather insulation caused by the equipment. In our study, one of the equipment-related stressors for pelicans was likely similar bodily heat loss due to plumage disruption around the chest harness and transmitter (see Fig. 2B); an issue that may have become aggravated over time.

The fact that there was no discernible difference in plumage quality with respect to water-proofing between previously oiled pelicans marked with leg band only and the general population was an important finding. Current rehabilitation methods include techniques to ensure that plumage integrity is restored through washing and self-preening and are not released until the birds have met restored waterproofing criteria.[63] This is a major advance compared to the early days of seabird oil-spill rehabilitation, when plumage restoration seemed impossible to achieve.[7]

Plumage phase differences between oiled and non-oiled birds could indicate stressors associated with oil exposure, rehabilitation, and/or tracking equipment. A wide range of debilitating sublethal impacts following oil exposure have been previously described,[4,8,13,26] but impacts on subsequent feather replacement have not been specified. Our finding that post-spill pelicans moved through the prebasic hindneck plumage transition (from brown to white feathering) at a rate insignificantly different from the general population indicated that this molt process proceeded normally despite the trauma of the spill event.

Sexual signals, including plumage colors that depend on antioxidants such as carotenoids, offer a more sensitive measure of the immunological and nutritional state of animals, since bodily antioxidants tend to be directed to other functions related to survival at the expense of the expression of the sexual traits.[64-67] The less frequent occurrence of yellow crown plumage observed in post-spill pelicans in this study seemed to indicate such a trade-off, but we could not determine if lack of yellow was due to lagging molt or absence of pigmentation in emerged feathers. In addition, brown pelican head rubbing on the uropygial gland may increase the crown's golden appearance due to adventitious coloring from the sebaceous oils after yellow feathers have emerged.[34,35] It seems important to note that some of the behaviors we observed in the field suggested that the backpack transmitters may have obstructed normal access to the preen gland by the head, which could result in a less intense yellow hue to the crown and represent another negative impact. Color deficiencies in ornamental plumage may affect mate acquisition and subsequent breeding success.[43] Future field researchers may be able to improve methodology by using calibrated photographs and spectrometers

to distinguish variation in the crown's yellow hue.[68]

If one assumes that the red gular pouch provides a positive measure of health in the California brown pelican, our results suggest that, although not equal to the general population, the post-spill birds released with only bands were in relatively good condition going into the first breeding season after the spill, that numerous complex interacting physiological mechanisms were functioning, and that many of these birds could afford the additional costs of color display.[46,69] Developing and maintaining bright gular coloration in the brown booby (*Sula leucogaster*) apparently incurs oxidative costs for both sexes.[47] Perhaps most importantly, our finding that post-spill pelicans with redder pouches tended to be encountered at a higher rate in subsequent years suggests that gular color may also predict overall survival. Parasite load, nutritional status, and immunocompetence are some of the possible links between survival and color of a dynamic avian integument feature.[70-72] The gular pouch will probably reflect a pelican's current condition better than plumage color during the pre-breeding season. Dey et al.[73] found that a bare-part ornament was a more reliable status signal than plumage color in a cooperatively breeding bird and recommended an increased focus on bare-parts to expand understanding of animal communication.

Relationships between body condition, integument color, and breeding success are relatively well-known for several seabird species but are not fully understood in the brown pelican. Investigation of the underlying mechanisms surrounding gular pouch color expression and how it relates to pelican fitness would increase the utility of using pouch color in future studies. In the sexually dimorphic great frigatebird, for example, the male displays a bright red inflated throat pouch during courtship that rapidly fades to orange at the onset of incubation. Astaxanthin, a carotenoid pigment, has been found in very high concentrations in the outer dermal layer of the pouch.[41] The spectral pattern of color and the vascularization of the pouch suggests that along with carotenoids, increased blood flow and the presence of hemoglobin may contribute substantially to the overall coloration of the pouch during the display period.[41] Variation in displaying male frigatebird pouch color has been positively correlated to breeding success.[74] The blue and green gular skin color in both sexes of breeding brown boobies is thought to be due to a combination of structural color mechanisms and allocation of carotene pigments.[47] Males expressing greener gular color were found to have increased parental investment in chicks.[47,75] Kittiwakes in good body condition displayed brighter carotenoid based integument colors around the eye, gape and tongue, than those in poor condition.[49] Pouch color of other brown pelican subspecies varies but none are typically red[35,36] adding interest to questions surrounding color mechanism and signaling function of the gular pouch in this species.

Targeted field surveys with large sample sizes and from wide geographic ranges are also needed to better establish or update baseline patterns and variation in molt and seasonal color change for California brown pelicans. Schreiber et al.[35] noted that there were many questions surrounding brown pelican molt, including how food supply, region of residence, age, sex, and the interaction between these and other factors, may affect feather replacement; these questions also apply to gular pouch color. For example, we found that gular pouch redness occurred three months earlier than previously described.[34,35] We saw many birds with red pouches by September at nonbreeding communal roosts, where pouch displays are often used in social interactions.[40]

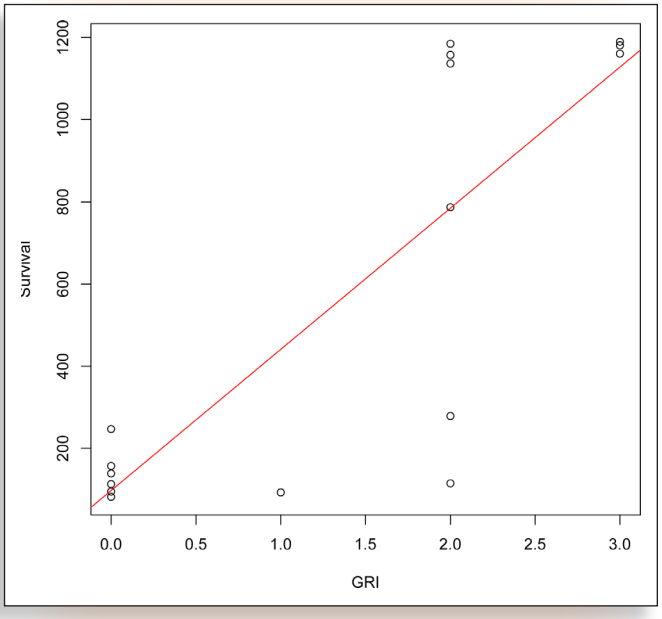

FIGURE 10. Gular pouch redness index and number of days that previously oiled pelicans were known to survive post-release. Gular redness index (GRI) is the highest score observed in the field (0–3) in the first 18 months after oil contamination; 'Survival' is the number of days elapsed between the last sighting of the bird and its release date following rehabilitation. All data (N = 16) are from ATY pelicans. GRI and the survival index were positively correlated (S = 138.7, rS = 0.796, p = 0.0002).
https://doi.org/10.1371/journal.pone.0211932.g010

Chronology and outcome of annual breeding effort can affect timing of avian molt[34,38] but it is not clear how that may have factored into our study results. During the period 2014–2016 there was unprecedented breeding failure throughout much of California brown pelican range due to environmental conditions.[76] Electronic tracking results[50] suggest that pelicans oiled in the Refugio spill included birds from Mexican breeding colonies that had failed or forgone breeding in 2015, and were migrating north along the California coast when caught in the spill. Although pelicans with GPS–PTT tags visited breeding colonies in 2016, none were known to successfully breed.[50]

Despite the challenges, field tracking and visual assessment of plumage and gular pouch color of marked brown pelicans has good potential for future ecotoxicology and post-release studies. The expression of gular pouch redness likely plays a role in behavioral ecology at non-breeding communal roosts, as well as breeding colonies, and may provide a valuable window into many aspects of California brown pelican health and fitness. This study also serves as a reminder to use caution when interpreting data

based on animals bearing a significant equipment burden and will hopefully help encourage development of improved remote tracking techniques for brown pelicans.

Acknowledgments

Assistance was provided by C. Fiorello and C. Clumpner (Oiled Wildlife Care Network), M. Harris and L. Henkel (California Department of Fish and Wildlife, Office of Spill Prevention and Response), R. McMorran (U.S. Fish and Wildlife Service), R. Golightly (Humboldt State University), and the International Bird Rescue (IBR) staff at the Los Angeles Oiled Bird Care and Education Center. The U.S. Geological Survey Bird Banding Laboratory and the South Carolina Fish and Wildlife Research Institute provided technical resources. Additional logistical assistance and site access was provided by M. Ruane (Ventura Naval Air Weapons Station), L. Feeney, (Golden Gate Audubon Society), M. Parker and J. Howard (Center for Ecological Studies), D. Mazurkewicz (National Park Service), Patrick Robinson (U.C. Santa Cruz), and the Port of Ventura. A. Esiner (USDA Wildlife Services), Tiffany Shepherd (Naval Base Coronado), J. Manley (Institute for Wildlife Studies), Michelle Maley (Naval Base Point Loma), and Marie Malloy (Wildlife Assist) assisted with carcass search and retrieval. We thank D.W. Anderson (U.C. Davis emeritus) for valuable input and encouragement throughout.

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CONTINUED FROM PAGE 6

coast along with 30% of their habitat has been destroyed. There have been similar levels of destruction in Victoria, Queensland and South Australia.The destruction of habitats means that not only have many wild animals been displaced, injured or killed in this catastrophe, many more will starve over the next few months due to lack of food and water. It is estimated that one billion animals may have died in wildfires.

Queensland wildlife carer, Linda Barret believes "the next few months will be especially challenging in relation to mass starvation, which we have already experienced in flying fox colonies due to drought and which will be compounded by the fires."

Our thoughts are with those dedicated animal carers battling each day to help rescue and rehabilitate the animal victims of this tragedy.

PHOTO © U.S. FOREST SERVICE - HURON-MANISTEE NATIONAL FORESTS. PUBLIC DOMAIN.

A US Forest Service employee dispatched to Australia rescues a kangaroo joey (*Macropus fuliginosus*) who approached him when fleeing from January's encompassing bush fires.

Dr. Peters emphasises "the most important thing the international community can do, is recognise this for what it is – it is our climate change future, and to take individual and community action now to prevent a much worse future for all of us, including the wildlife that we share this planet with."

AU Gov't Commits $50 Million for Emergency Wildlife and Habitat Recovery

CANBERRA, Australia (January 13, 2020)—In response to the devastating bushfires the Australian Federal Government made an investment of $50 million, as a down-payment to support the immediate work to protect wildlife, and work with scientists, ecologists, communities and land managers to plan the longer-term protection and restoration effort.

Treasurer Josh Frydenberg said the Government's focus was to support a coalition of groups to assist in the protection and restoration of our environment following the bushfires.

"This initial investment of $50 million into the protection and restoration of our wildlife and habitat is a critical step in creating a viable future for the animals that have survived," the Treasurer said.

"As part of the Government's support $25 million will be provided for an emergency intervention fund to be used on critical interventions where required and to help with the immediate survival of affected animals, plants and ecological communities and to control pests and weeds.

"A further $25 million will be made available to support wildlife rescue, our zoos, Natural Resource Management Groups, Greening Australia and Conservation Volunteers Australia with on the ground activities.

"This support will help provide much needed shelter and protection for our native animals and plants from feral predators and pests while local habitats are rehabilitated."

The immediate priorities are to:

- Care for and rehabilitate injured wildlife, and secure viable populations of threatened species.
- Control feral predators, other pest animals and noxious weeds that are a major threat to vulnerable animals and plants at this time.
- Scientifically map and understand the true impact of these fires.
- Work with landowners to protect those precious remaining unburned areas, which will serve as "arks" and allow our native plants and animals to recover.

The Government will coordinate with organizations across Australia to ensure the money goes where it is needed and complements the wave of generous private donations that has flowed in recent weeks.

At a national level, the Threatened Species Commissioner, Dr. Sally Box, will chair a panel of experts charged with advising the federal government on further immediate actions funded through the $25 million emergency intervention fund and in developing a long-term wildlife protection and habitat restoration plan. She will work closely with the National Bushfire Recovery Coordinator, Andrew Colvin. Dr. Box and the panel will:

- Advise the Minister for the Environment on further critical interventions required to support the immediate survival of affected animals, plants and ecological communities and to control pests and weeds.
- Assess and map the scale of the impacts of the bushfires on our environment and prioritise recovery efforts, which will inform development of a strategy for building populations of native plants and animals back up again and ensuring their resilience into the future.

Minister for the Environment Sussan Ley said it is still too early to know the full impact of these fires other than it is catastrophic.

"The environmental recovery effort requires collaboration between governments, environment organisations,

scientists, farmers, communities, business, philanthropists and industry.

"This is an historic environmental challenge and we need to be guided by scientific experts in the field, by our national research bodies, the traditional owners who have managed this land over tens of thousands of years, our farmers whose passion and commitment to the land spans generations and our local communities.

"The resources and innovation of the private sector will also play a critical role in drawing this national effort together.

"A series of Ministerial roundtables comprising communities, farmers, environmental organisations, business and scientists will also be held and work closely with the expert panel."

The long-term plan will set out clearly the direction we need to go, the actions to take and outcomes to be achieved to restore our fire-damaged environment. It will guide funding allocation by Government and ensure all sectors are working together. [Source]

Flying Fox Emergency

BROOKVALE, Australia (December 19, 2019)—The NSW Wildlife Information, Rescue and Education Service Inc. (WIRES) is warning that thousands of flying foxes are expected to perish over the next week as temperatures across Australia continue to soar.

WIRES flying fox coordinator Storm Stanford said colonies across the Eastern states have been under stress for months due to ongoing food shortage and drought. Mass deaths have already occurred in Northern and Southern NSW.

With drought-stressed eucalypts producing little or no nectar or not flowering at all, flying foxes have vacated many established colonies and flown south in search of food or to escape the bushfires.

"Our flying foxes are in the worst situation I have ever seen, with underweight and dying pups that have been abandoned by their mothers as nature's way of encouraging them to at least save themselves,"

PHOTO ©SHEK GRAHAM. CC BY-NC 2.0 LICENSE.

Spectacled flying fox fruit bat *(Pteropus conspicillatus).*

said Stamford. "These next few days will literally see thousands more adult females and their young impacted by heat stress."

"And this is at a time when we most need this next generation of our natural pollinators to help regenerate the 2.7 million hectares of bushland in NSW already burnt out."

WIRES is partnering with other rescue organisations including Sydney Metropolitan Wildlife Service (SMWS) and Wildlife Rescue South Coast (WRSC). They are liaising with one another to manage the overwhelming number of bats currently coming into care.

SMWS Bat coordinator Sarah Curran said they are closely monitoring the most at-risk colonies in and around the Sydney metropolitan area.

"Conditions for the bats are already so bad, we expect they will suffer more than usual in these extreme temperatures. We are carefully observing these colonies from a safe distance and will be ready to rescue as many as we can within our limited resources."

WRSC spokesperson Janine Davies and her team have collected more than 1700 dead or dying bats in the NSW south coast area in the past month alone.

"Most of the rescues are infants that are literally falling from the sky because they're simply too weak to cling onto their mothers due to lack of nutrition. In all my years as a rescuer I have never seen such large numbers of starving baby flying foxes."

WIRES advises that the public should avoid any direct contact with flying foxes, alive or dead, as there is the risk of being scratched or bitten which could lead to a virus infection. For more information please visit wires.org.au. If you find a bat in distress please call WIRES on 1300 094737 or your nearest wildlife rescue organization. [Source]

Oldest Known King Eider is a Rehab Bird

ANCHORAGE, USA (December 20, 2019)—In 1996, International Bird Rescue cared for a male king eider oiled as an adult during the M/V Citrus Oil Spill in Alaska. The bird's band was recently reported to the Bird Banding Lab. The recovered bird survived 23 years after oiling and release, and according to federal banding information, this may well be the oldest known king eider.

According to the Cornell Lab of Ornithology and U.S. Geological Survey (USGS) Bird Banding Lab, which administers the scientific banding or ringing of wild birds in the U.S., the previously oldest recorded king eider was an unoiled female that was at least 22 years 1 month

King eider male *(Somateria spectabilis).*

In 1996 rescued king eiders were cleaned of oil after being flown to Anchorage from the Pribilof Islands.

PHOTO ©INTERNATIONAL BIRD RESCUE

Kangaroos on the beach outside the coastal town of Tura Beach, Australia in New South Wales, where more than 20 kangaroos were intentionally hit with a vehicle.

old when she was recaptured and re-released during banding operations in Nunavut, Canada.

This important news underscores what International Bird Rescue has been advocating from its beginnings: oiled birds can and *do* survive to live normal lives when rehabilitated after oiling, with appropriate resources and skilled staff. This is especially true when wildlife experts follow the protocols that have been refined over our nearly 50-year history.

Multiple Kangaroo Killing Leads to Arrest

TURA BEACH, Australia (September 28, 2019)—Over 20 kangaroos were intentionally hit with a vehicle in a coastal New South Wales town. Two men were apprehended by the police. In November one defendant received a two-year jail sentence and an order of 500 hours of community service; the other defendant goes to court in January of 2020.

The three survivors of the mass killing, all orphaned joeys, were brought to WIRES wildlife center for rehabilitation. In a Facebook post the center noted "Wildlife rescue and rehabilitation can be extremely challenging for all involved, especially when animals have been injured in an apparent act of cruelty." [Source]

Strigidae Car Collisions

WASHINGTON, USA (November 29, 2019)—Skagit County rehabilitation centers Sarvey Wildlife Care Center in Arlington and Wolf Hollow Wildlife Rehabilitation Center in Friday Harbor have reported an unusually high number of owls with the intake cause of hit-by-car (HBC) between mid-September and late November. A seasonal uptick in this region north of Seattle is expected in fall, but 2019 numbers were notable. [Source]

Two Years After Hurricane Harvey, Repair Continues

PORT ARANSAS, Texas, USA (November 20, 2019)—Amos Rehabilitation Keep (ARK) suffered massive damages in 2017's Hurricane Harvey. In fall of 2019 they finished the most recent repair, a new 100-foot flight pen. [Source]

Lake Tahoe Wildlife Care gets New Facility

SOUTH LAKE TAHOE, USA (November 20, 2019)—Lake Tahoe Wildlife Care now has a dedicated facility for rehabilitation. Lake Tahoe Wildlife Care now has a dedicated facility for rehabilitation.

Longtime rehabilitators Tom and Cheryl Millham have spent more than 40 years rehabilitating from their home, their patients including bears, bobcats, and other mammals, as well as raptors, waterfowl, and other avian species. A recent $3 million donation has jumpstarted their dream of a new facility, which will require about $5 million in total. Work continues on the expansion, to be 13 new buildings in all, but as of November 2019 the organization has been actively rehabilitating from the new location. One of the two sole resources in Nevada for the rehabilitation of bear cubs, they offer live webcam views of their current work.

The founders have recently announced their retirement.

Greenwood Melanistic Fox

GREENWOOD, Colorado, (November 24, 2019)—Chelsea Barrett notes that Greenwood Wildlife Rehabilitation Center was able to test their newly renovated fox enclosure earlier than expected with the late fall admission of a dark phase melanistic fox with mange. The enclosure is now confirmed ready for spring intakes and its first inhabitant back in the wild. [Source]

New Wildlife Center Approved in Sarawak

KUCHING, Malaysia (October 10, 2019)—Wildlife in northern Sarawak will no longer have to travel 1000 km to the Matang Wildlife Center in Kuching. Officials granted approval for the new center under the 11th Malaysia Plan, including a funding allocation to support building. [Source] ■

SELECTED ABSTRACTS

Health survey of free-ranging raccoons (*Procyon lotor*) in Central Park, New York, New York, USA: Implications for human and domestic animal health

Kimberly L. Rainwater, Krysten Marchese, Sally Slavinski, Lee A. Humberg, Edward J. Dubovi, Jodie A. Jarvis, Denise McAloose, and Paul P. Calle. *Journal of Wildlife Diseases:* April 2017;53(2), 272-84. https://doi.org/10.7589/2016-05-096

We conducted health assessments on 113 free-ranging raccoons (*Procyon lotor*) in Central Park, New York City, US, in February 2010, September 2010, and November 2011 in conjunction with a trap-vaccinate-release program to control a raccoon rabies epizootic. Five individuals were sampled at two time points for 118 raccoon examinations in total. We tested 13 of 13 and 8 of 13 euthanized raccoons for rabies and canine distemper virus (CDV), respectively, by antigen testing on brain tissue; all were negative for both viruses. Endoparasitism was the most common necropsy finding, with definitive identification of *Baylisascaris procyonis* in six of eight (75%) necropsied raccoons. Multiple intestinal parasites were detected in feces of living raccoons, including ascarid-type ova in 25 of 80 (31%) raccoons, with *B. procyonis* confirmed in one sample. Median blood lead level was 7.3 µg/dL (n=104). Rabies virus neutralizing antibody titer was ≥0.5 IU/mL in 9 of 88 (10%) raccoons naive to rabies vaccination and in 13 of 20 (65%) previously vaccinated raccoons. The majority of raccoons we tested were seropositive for canine parvovirus-2 (54/59, 92%) and *Toxoplasma gondii* (39/60, 65%). Fewer were seropositive for *Rickettsia rickettsii* (3/30, 10%). None were seropositive for CDV (n=108), canine adenovirus-1 (n=60), or *Borrelia burgdorferi* (n=30). Ectoparasites found during 16 of 118 (13.6%) physical examinations included *Ixodes texanus* ticks (15/118, 12.7%) and *Trichodectes octomaculatus* lice (1/118, 0.8%). We detected *Campylobacter jejuni* in 5 of 79 (6%) fecal samples. We detected 11 *Salmonella enterica* serotypes in 70 of 111 (63.1%) enteric cultures, the most common of which were *Salmonella Newport* (20/70, 29%) and *Salmonella Oranienburg* (20/70, 29%). These results indicate that raccoons in Central Park likely are involved in the environmental occurrence and potential disease transmission of a variety of infectious and noninfectious diseases of concern for human, wildlife, and domestic animal health.

PHOTO © CHRISTIAN ROGER DUCKHORN. CC PUBLIC DOMAIN.

The big-eared opossum (*Didelphis aurita*), whose opposable thumbs provide the answer to a long-held mystery.

Good heavens what animal can pollinate it? A fungus-like holoparasitic plant potentially pollinated by opossums

FW Amorim, CS Ballarin, and L Hachuy-Filho, G Mariano, DA Zabin, H Gonçalves-Dias Queiroz, JH Servilha, PA Lacerda-Barbosa, JG. Costa. *Ecology.* 2020. https://doi.org/10.1002/ecy.3001

The most effective pollinator principle developed by Stebbins (1970) postulates that floral traits are shaped through natural selection by the most frequent and effective floral visitors. Following this rationale, pollination syndrome hypothesis assumes that floral morphology is a result of convergent evolution of unrelated plant species to specific pollinator groups (Faegri and van der Pijl 1979). In this sense, floral traits such as visual and olfactory cues, reward properties, as well as the floral architecture, can be useful to predict the pollinator group of a given plant species.

[*Editor's note:* Several stories appeared simultaneously explaining the significance of this discovery. From *Science*: "Caught in the act: Opossums pollinate bizarre parasitic plant." From *In Defense of Plants,* including a camera-trap video: "Opossum pollination of a peculiar parasite."]

Extralabel drug use in wildlife and game animals

MO Clapham, KL Martin, JL Davis, RE Baynes, Z Lin, TW Vickroy, JE Riviere, and LA Tell. *Journal of the American Veterinary Medical Association.* 2019;255(5),555-68. https://doi.org/10.2460/javma.255.5.555

[*Editor's note:* no abstract was available.]

Spatial ecology of reintroduced American martens in the northern Lower Peninsula of Michigan

TM Gehring, LM McFadden, SA Prussing, SA Bickersmith, C Buchanan, E Nelson, and BJ Swanson. T*he American Midland Naturalist.* 4 October 2019;182(2),239-51. https://doi.org/10.1674/0003-0031-182.2.239

American martens (*Martes americana*) in the northern Lower Peninsula of Michigan (NLP) represent a re-introduced and isolated population that is the southern-most distributed marten population in eastern North America. During 2005–2006 we conducted a radiotelemetry and track-survey study of martens in the NLP. We estimated home-range size and patterns of habitat use in order to develop a spatial model to predict distribution of marten habitat. Marten home ranges were comprised of more (>75%) upland deciduous and upland mixed forest compared to the landscape, which included ≤60% of these cover types. Within core areas, martens selected upland conifer stands. Our Penrose habitat model identified <25% of the NLP as primary marten habitat. Further, 70% of marten habitat patches were <1000 ha in size and were isolated by an average of 5.3 km (SE = 2.0). Our marten habitat model identifies focal areas for surveying and monitoring populations and sites for

supplementation or re-introduction. Our model also highlights the need for managers to better coordinate active landscape-scale management of wildlife and forests to reduce fragmentation impacts on extant and reintroduced marten populations.

Pododermatitis in raptors admitted in a wildlife rehabilitation centre in central Spain

CR Díez, F González, I López, L Suárez, V Moraleda, and C Rodríguez. *Journal of Preventive Veterinary Medicine*. February 2020;175, 104875. https://doi.org/10.1016/j.prevetmed.2019.104875

Pododermatitis is a chronic and progressive bacterial infectious disease of birds' footpads, especially associated with captivity, which could represent an important problem in wildlife rehabilitation centres, delaying the release of the birds to the environment and harming their conservation. The objectives of the present study were i) to estimate the incidence rate of pododermatitis, ii) to analyse the influence of environmental, physiological, and pathological factors which may influence the onset of the infection in raptors after their admission to a rehabilitation centre, and iii) to follow up the evolution and macroscopic characteristics of the lesion. An observational retrospective study was carried out on clinical cases of raptors (n = 2004) admitted in a rehabilitation centre in central Spain from 2009 to 2015. The proportion of pododermatitis was 6.9%, with an incidence density of 6.8 cases/100 bird-years at risk. Our results showed that the disease was more likely to occur in birds staying longer ($P < 0.001$). According to Cox analysis, the variables 'raptor family' ($P < 0.001$) and 'age' ($P = 0.002$) may have significant effects on pododermatitis development. Raptors from the *Falconidae* and *Strigidae* families were less likely to develop pododermatitis than those from the *Accipitridae* family, with a hazard ratio (HR) of 0.31 and 0.13, respectively. Regarding age, fully feathered raptors had a three-fold higher risk of having pododermatitis than non-fully feathered birds. Survival analysis of time of pododermatitis development revealed significant differences associated with the variables 'raptor family' ($P < 0.03$); 'age' ($P < 0.001$) and 'cause of admission' ($P = 0.001$). Duration of the pathology ($P < 0.05$) and lesion location ($P < 0.001$) seemed to be phylogenetic dependent. Injuries were primarily located in the toes area or the whole footpad of birds belonging to the *Accipitridae* or *Falconidae* families, respectively ($P = 0.003$).

Prevalence of box turtle adenovirus in eastern box turtles (*Terrapene carolina carolina*) presented to a wildlife rehabilitation center in Virginia, USA

D Franzen-Klein, L Adamovicz, D McRuer, SA Carroll, JFX Wellehan, MC Allender. *J. of Zoo and Wildlife Medicine*. 2020;50(4):769-77. https://doi.org/10.1638/2018-0238

Eastern box turtles (*Terrapene carolina carolina*) are a native North American species with a declining population trend that may be attributable to habitat fragmentation, vehicle collisions, and disease. Adenoviral infections can cause significant morbidity and mortality in captive reptile populations. Adenoviruses have been documented in box turtles, but their occurrence and impact in wild populations are unknown. A disease survey was performed at The Wildlife Center of Virginia, USA, to assess the prevalence of box turtle adenovirus (BTAdV) in wild eastern box turtles and evaluate potential associations with clinical disease. Swabs from the oral cavity, including the choanal slit, and the cloaca were collected from 106 eastern box turtles from July 2015 through June 2016. The quantitative polymerase chain reaction (qPCR) primer detected both ornate box turtle adenovirus 1 and eastern box turtle adenovirus. The resulting qPCR adenovirus prevalence was 55.7% (n = 59). Most animals (99.3%) that tested positive for BTAdV had fewer than 100 viral copies/ng DNA. This study did not find a statistically significant association between cause of admission, age, sex, outcome, and BTAdV qPCR status. However, the probability of BTAdV detection was 1.5 times higher in rehabilitation turtles compared with wild turtles ($P = 0.01$). Albumin was significantly lower in qPCR BTAdV-positive turtles ($P = 0.007$). Hypoalbuminemia is not generally associated with adenovirus infections in other species, and no obvious clinical cause for this abnormality was identified. The results of this study suggest that eastern box turtles may harbor BTAdV infections at low levels and that infection is rarely associated with clinical disease, potentially identifying BTAdV as a host-adapted pathogen. Future studies should focus on this pathogen's ability to induce clinical disease and its potential impact on recovery efforts for this species.

Survival and conflict behavior of American black bears after rehabilitation

CD Blair, LI Muller, JD Clark, WH Stiver. *Journal of Wildlife Management* 2020;84(1);75-84. https://doi.org/10.1002/jwmg.21783

Wildlife agencies face difficult situations when orphaned or injured American black bear (*Ursus americanus*) cubs (<12 months old) or yearlings (≥12 and <24 months old) are captured. One option is bear rehabilitation, the care and feeding of cubs or yearlings in a semi-natural environment, followed by release. Unfortunately, the survival and movements of bears released from rehabilitation facilities are often poorly documented and the ultimate reasons for success or failure poorly understood. Our goal was to assess survival and post-release conflict of orphaned bear cubs and yearlings following release from a rehabilitation facility, Appalachian Bear Rescue (ABR), in Townsend, Tennessee, USA, from 2015–2016. We predicted that rehabilitated bears would survive at similar rates, die from similar causes, and engage in similar conflict behavior to wild conspecifics. We equipped 42 black bear cubs and yearlings from ABR with global positioning system-collars and released them in Great Smoky Mountains National Park or Cherokee National Forest, Tennessee and North Carolina, USA. Estimated annual survival using known-fate methods for all released bears was 0.93 ± 0.06 [SE]). Survival for 13 bears released as cubs was 0.64 ± 0.14, whereas none of the bears released as yearlings died within 1 year after release (n = 29). Survival of rehabilitated bears was similar to or higher than

published rates for wild conspecifics. Three of 42 bears (7.1%) released from ABR engaged in conflict behavior up to 1 year following release, and those had spent time involved in conflict behavior with their mothers (e.g., approaching humans) prior to being orphaned. Despite not having the typical post-natal experience with their mothers, the bears in our study appeared to behave and survive similarly to their wild conspecifics. Rehabilitation is effective for managing orphaned or injured bears. Best survival occurred for bears released as yearlings; however, managers can maximize cub survival through fall releases when plentiful wild foods are available.

Effects of Deepwater Horizon oil on feather structure and thermoregulation in gulls: Does rehabilitation work?

KE Horak, NL Barrett, JW Ellis, EM Campbell, NG Dannemiller, and SA Shrinera. *Science of The Total Environment*. 18 Feb 2020. https://doi.org/10.1016/j.scitotenv.2020.137380

Impacts of large-scale oil spills on avian species are far-reaching. While media attention often focuses on lethal impacts, sub-lethal effects and the impacts of rehabilitation receive less attention. The objective of our study was to characterize effects of moderate external oiling and subsequent rehabilitation on feather structure and thermoregulation in gulls. We captured 30 wild ring-billed gulls (*Larus delawarensis*) and randomly assigned each individual to an experimental group: 1) controls, 2) rehabilitated birds (externally oiled, rehabilitated by washing), or 3) oiled birds (externally oiled, not rehabilitated). We externally oiled birds with weathered MC252 Deepwater Horizon oil (water for controls) and collected feathers and thermography imagery (FLIR) approximately weekly for four weeks to investigate feather structure (quantified using a barbule clumping index) and thermoregulatory ability (characterized by internal body temperature and external surface temperature). Post-oiling feather clumping was significantly higher in oiled and rehabilitated birds compared to controls, but steadily declined over time in both groups. However, feather microstructure in rehabilitated birds was indistinguishable from controls within three weeks of washing whereas the feathers of oiled birds were still significantly clumped a month post oiling. Internal body temperatures didn't differ in any of the groups, suggesting birds maintain thermoregulatory homeostasis in spite of moderate external oiling. External temperatures for rehabilitated birds didn't differ from controls within a week of rehabilitation. Overall, rehabilitation procedures were effective and washed birds were in better condition compared to non-rehabilitated, oiled birds. This study provides evidence that the benefits of rehabilitation for moderately oiled birds likely outweigh the costs with regard to feather structure and thermoregulation. While feather preening and time were insufficient to reestablish baseline fine scale feather structure in moderately oiled birds, the significant clumping reduction over time may indicate that rehabilitation of lightly oiled birds may not be necessary and deserves further study.

Responses to wildlife crime in post-colonial times. Who fares best?

RA Sollund and SR Runhovde. *The British Journal of Criminology,* azaa005. 18 February 2020. https://doi.org/10.1093/bjc/azaa005

Wildlife crime is an increasing problem worldwide. Based on empirical research, we examine how the criminal justice systems of Brazil, Colombia, Uganda and Norway perceive and respond to such crime, with Norway as the main case study and basis for comparison. While the general assumption is that Northern countries are more 'developed' in their response to environmental problems, we argue that Norway, despite its economic resources and international profile as a supporter of environmental protection, is failing to confront illegal trade in—and protection of—endangered species nationally. We propose that these Southern countries have developed more tools in terms of legislation, enforcement, awareness and wildlife protection and that Northern countries have expectations regarding conservation in Southern countries that they themselves neglect.

Zoonotic disease exposure risk and rabies vaccination among wildlife professionals

S Tarrant, J Grewal, H Yaglom, E Lawaczeck, and H Venkat. *EcoHealth*. 2020. https://doi.org/10.1007/s10393-020-01469-w

More than 70% of zoonotic diseases are wildlife associated putting wildlife professionals at increased risk of occupational exposure. In 2008 and 2018, the Arizona Department of Health Services surveyed Arizona wildlife professionals from multiple agencies to assess the risk of disease exposure, rabies pre-exposure prophylaxis (PrEP) history, personal protective equipment (PPE) use, and zoonoses knowledge. In 2008, a 12-question survey was distributed at a state wildlife professional meeting using an anonymous email link. In 2018, a 20-question survey was distributed using an anonymous email link to wildlife agency employees. We received 164 and 81 complete responses in the 2008 and 2018 surveys, respectively. Bites from rabies reservoir or spillover species were higher in 2008 (42%) than in 2018 (16%). More respondents received PrEP in 2018 (53%) than in 2008 (45%). Among 43 respondents who performed necropsies or collected animal samples within the past 5 years (2014–2018), only 60% always wore latex or nitrile gloves, and 79% never wore a facemask. Respondents indicated lower awareness of certain zoonoses, including brucellosis (72%) and leptospirosis (60%). Results on zoonoses awareness and reasons for non-use of PPE highlighted targets for education to improve practices, including facilitation of PPE training to prevent future disease transmission.

New record for the northern yellow bat (*Dasypterus intermedius*) in Mississippi

KR Shelton, KP Cross, and TL Hudson. *Southeastern Naturalist.* 2020;19(1). https://doi.org/10.1656/058.019.0108

An adult male *Dasypterus intermedius* (northern yellow bat) was captured at a shipyard on 12 October 2018 in Pasca-

goula, Jackson County, Mississippi. This specimen represents the first northern yellow bat documented from Mississippi since 1937. Mass of the bat was 17.5 g, forearm length was 50 mm, and hind-foot length was 9.5 mm. The specimen was found dehydrated and was rehabilitated at Possum Hill Wildlife Rehabilitation and Bat Education Center. The bat was kept over winter and released 5 km west of the capture site on 4 May 2019.

First report of chronic bacterial nephritis in a vulnerable *Mauremys leprosa* (Schweigger 1812)

A Garcês, V Soeiro, S Lóio, J Prada, and I Pires. *Herpetology Notes.* 2020;13;85-88. https://www.biotaxa.org/hn/article/view/43750/59517

A Mediterranean turtle, *Mauremys leprosa* (Schweigger 1812), was admitted to the Wildlife Rehabilitation Centre of Parque Biológico de Gaia [Portugal] with renal disease symptomology. In post-mortem examination, the animal presented pale and enlarged kidneys with cystic cavities containing a mucopurulent exudate. The histological examination confirmed the diagnose of chronic nephritis. The microbiological analysis of the exudate identified Enterococcus faecalis as the agent responsible for the infection. This report, to the authors' knowledge, is the first of its kind in this species.

Survival and recruitment of rehabilitated Caspian terns in southern California

JM Skoglund, RS Duerr, and CT Collins. "Survival and Recruitment of Rehabilitated Caspian Terns in Southern California." *Bulletin of the Southern California Academy of Sciences.* 2020;119(1). https://scholar.oxy.edu/scas/vol119/iss1/1

Thousands of birds are taken in by animal care centers each year for rehabilitation. Birds returned to health by some centers are banded for later identification, but very few are ever reencountered following their return to the wild. We report here, information on the post-release survival of Caspian terns (*Hydroprogne caspia*) in southern California as well as on their recruitment into a local breeding population and colony site fidelity.

Saharan pond turtle (*Mauremys leprosa saharica*) female

Unmonitored releases of small animals? The importance of considering natural dispersal, health, and human habituation when releasing a territorial mammal threatened by wildlife trade

M Campera, E Brown, MA Imron, and KAI Nekaris. *Biological Conservation.* February 2020;242,108404. https://doi.org/10.1016/j.biocon.2019.108404

Unmonitored release is a common practice, especially in small animals, that present a series of adverse conditions if not well-planned. Small research centers and non-governmental organizations in developing countries often receive animals that are then subject to unmonitored releases. We explored the patterns of post-release and natal dispersal in the Javan slow loris, a Critically Endangered venomous and territorial mammal that is highly threatened by wildlife trade. We then determined the importance of health status and human habituation for the survival of translocated and natally dispersing animals. We collected data from 2012 to 2018 on pre-release and pre-dispersal health conditions and human habituation, post-release and post-dispersal presence of wounds, behavior, and ranging patterns of 11 translocated and 11 natally dispersing individuals and compared them with 12 stable resident individuals. Translocated animals had a larger home range size (15.9 ± 4.1 ha) and higher wound presence during recaptures (0.47 ± 0.13) than stable resident individuals (3.2 ± 3.0 ha; 0.10 ± 0.06) but they did not differ from natally dispersing individuals (13.8 ± 3.7 ha; 0.28 ± 0.11). Both translocated and natally dispersing individuals can move to a different habitat type compared to their release area or natal range. The fate of both translocated and natally dispersing individuals was influenced by their health state ($p < 0.001$), and human habituation significantly affected the possibility of being captured for wildlife trade of translocated individuals ($p = 0.048$). We highlight the importance of considering natal dispersal, health state, and human habituation before the release of small animals to avoid death and capture for wildlife trade.

New books worth noting:

Medical Management of Wildlife Species: A Guide for Practitioners

SM Hernandez, HW Barron, EA Miller, RF. Aguilar, MJ Yabsley, editors. John Wiley & Sons, Inc; 2020. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119036708.

Hand-Rearing Birds, 2nd Edition

Rebecca S. Duerr, Laurie J. Gage. April 2020 Wiley-Blackwell. 816 pages. https://www.wiley.com/en-us/Hand+Rearing+Birds%2C+2nd+Edition-p-9781119167754.

TAIL END

Iguana take the side door, Mac. You go in the front.

Black Iguana *(Ctenosaura similis,* Gray 1831)

INSTRUCTIONS FOR AUTHORS

POLICY Original manuscripts on a variety of wildlife rehabilitation topics (e.g., husbandry and veterinary medicine) are welcomed. Manuscripts that address related topics such as facility administration, public relations, law, and education are invited as well.

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Grey-headed flying fox (*Pteropus poliocephalus*) in Sydney, Australia Botanical Garden.

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