MEDICAL HISTORY AND POST-RELEASE SURVIVAL OF REHABILITATED CALIFORNIA BROWN PELICANS *PELECANUS OCCIDENTALIS CALIFORNICUS*, 2009–2019

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ABSTRACT

DUERR, R.S., JAQUES, D.H., SELBY, B.G., SKOGLUND, J.S. & KOSINA, S. 2023. Medical history and post-release survival of rehabilitated California Brown Pelicans *Pelecanus occidentalis californicus*, 2009–2019. *Marine Ornithology* 51: 157–168.

California Brown Pelicans (*Pelecanus occidentalis californicus*) rehabilitated in 2009–2019 were released with metal federal and blue plastic auxiliary leg bands. Resighting data were obtained from the US Geological Survey's Bird Banding Laboratory, International Bird Rescue's citizen science reporting forms, and non-breeding communal roost site surveys. Medical problems and demographic data were assessed in relation to whether birds were resighted, whether they were alive at the most recent resighting, and by longevity after release. The 1418 blue-banded individuals in the study were admitted for rehabilitation and released 1465 times, and 49.9% were resighted at least once. At the most recent re-encounter, 79.2% were alive. Fifty-five birds were not resighted until 5–11 years after release. Mean (± standard deviation) post-release longevity inclusive of all birds was 3 (3.1) years, which represents minimum survival time for those last encountered alive. Survival analysis was performed utilizing annualized resightings and dead recoveries for each bird. Survival probability differed with intake age, averaging 0.70 for birds admitted as post-fledge hatch-year to 0.80 for birds admitted as after-hatch-year. Dedicated surveys beginning in 2015 resulted in a much higher probability of live detections in the latter half of the study. Annual survival estimates averaged 0.83 during this period, when age at rehabilitation was not an important factor. Mean longevity of the 2015–2019 cohort was estimated at 5.67 years post release. Of 224 birds receiving blue bands during 2009–2010, 13.8% of sub-adults or after-third-years at rehabilitation have been resighted older than 10 years of age, including 11 birds resighted since 2021 at minimum ages of 13.1–15.2 years. This study shows that Brown Pelicans can be successfully rehabilitated and returned to the wild, with some demonstrating greater than expected longevity than previously estimated for the species.

Key words: California Brown Pelican, *Pelecanus occidentalis californicus*, rehabilitation, post-release survival, MARK, medical problems

INTRODUCTION

California Brown Pelicans *Pelecanus occidentalis californicus* (CABRPE) are one of five subspecies of Brown Pelican. Its current breeding range extends from littoral mainland western Mexico and Baja California to the Channel Islands off the coast of California, USA (Shields 2020). The species was listed as Endangered (under the USA's Endangered Species Act) in 1970 due to wholesale reproductive failures resulting from pesticide-related eggshell thinning. The banning of dichlorodiphenyltrichloroethane (DDT) and active protection of the bird, especially at breeding sites, enabled delisting in 2009 (see Anderson *et al.* 2017).

CABRPE face numerous risks to survival, including fishing gear injuries, roost disruption, periods of poor forage fish availability, oil spills, harmful algal blooms, and adverse weather events (Dau *et al.* 2009, Duerr 2016, Lamb *et al.* 2018). One such example is the unprecedented breeding failure that occurred in the Gulf of California during the prolonged period of Pacific warming that occurred in 2014–2016 (Anderson *et al.* 2017). CABRPE also periodically experience mass-stranding events, such as the one that occurred during the winter of 2009/10, when thousands of breeding-age adult birds were found distressed, dying, or dead throughout their range for unknown reasons (Nevins *et al.* 2011). A newly identified risk is a potential large-scale resurgence in exposure to DDT and associated compounds, which have been found to be leaching from thousands of corroding barrels of DDT waste littering the ocean floor between the Channel Islands and the mainland (Wood 2021). In late 2021, another new threat appeared: a strain of highly pathogenic avian influenza that has been devastating birds, especially wild seabirds, around the globe (Ramey *et al.* 2022), reaching coastal California in fall 2022 (APHIS 2022).

Wild birds may enter captive care when found in a debilitated or helpless state, but data regarding the fates of rehabilitated animals after release back to the wild are rare and not well-represented in the scientific literature. Survival rates of avian species after rehabilitation have varied widely. Owls, for instance, have shown both short survival times (Fajardo *et al.* 2000, Chien & Ritchison 2011) and comparable longevity (Griffiths *et al.* 2010) relative to wild counterparts. Some studies have short follow-up periods due to tracking methods that did not last long enough to assess whether birds successfully recruited into breeding populations (Griffiths *et al.* 2010, Raine *et al.* 2020). In general, few published studies discuss factors related to medical problems prior to release. Carnaby's Black Cockatoos *Zanda latirostris* rehabilitated due to traumatic injuries showed a high rate of annual survival and were observed with behavioral evidence of successful reintroduction into wild flocks (Groom *et al.* 2018), while rehabilitated Cape Vultures *Gyps coprotheres* released after recovery from traumatic injuries, poisoning, gunshot, or electrocution showed shorter survival times compared to wild control birds (Monadjem *et al.* 2014). Sharp

(1996) found very short survival times for rehabilitated oiled seabirds based on leg-band returns and concluded that rehabilitation of oiled birds was not a good use of resources. Anderson *et al.* (1996) found short survival times in CABRPE that were rehabilitated after oiling as well. More recent studies regarding CABRPE affected by oil spills have shown longer post-release survival than previously reported (Lamb *et al.* 2018, Jaques *et al.* 2019, Fiorello *et al.* 2021).

Beyond US Fish and Wildlife Service (USFWS) prohibitions against releasing birds with certain types of injuries, such as amputated legs or complete blindness (USFWS 2003), there is scant guidance from regulatory agencies regarding acceptable disabilities. Hence, caregivers must subjectively assess whether recovered birds are fit for release. Captive care inflicts pain, discomfort, and stress on wild animals; requires funding, facilities, people, and equipment; and often inflicts physiological and psychological stress on caregivers. Only a few wildlife rehabilitation organizations hold banding permits or work with permitted bird-banders to mark released animals, and those that do typically lack staffing support or expertise to analyze resighting data if it becomes available. Consequently, refinement of release criteria that might maximize post-release survival remains elusive for most species.

The goal of this study was to explore and describe in detail the post-release survival of a conspicuous and relatively well-monitored species: CABRPE. Specifically, we aimed to ascertain overall survival duration, plus whether specific conditions, injuries, or other medical problems during care affect post-release survival. We hypothesized that, because all birds treated by International Bird Rescue (IBR) must meet similar pre-release criteria, there should be no difference in post-release survival based on the bird's problems during care, while age and sex may well show differences. We also assessed available data for information that may guide future decision-making regarding releasability.

METHODS

IBR operates two wildlife rehabilitation centers within the CABRPE range, serving the greater metropolitan areas of San Francisco and Los Angeles in California, USA, under a USFWS wildlife rehabilitation permit (#MB763345) and a Memorandum of Understanding with the California Department of Fish and Wildlife. Annually, IBR receives a few hundred to nearly a thousand CABRPE for rehabilitation. Under permits from the US Geological Survey's Bird Banding Laboratory (BBL), IBR has been applying federal leg bands made of metal to rehabilitated wild aquatic birds since the 1970s under banding permits 20220 and 21214. Beginning in 2009, blue plastic auxiliary leg bands, which are more easily read, have also been applied to CABRPE at release whenever possible. These bands, in conjunction with increased public engagement in littoral wildlife viewing, internet access for reporting sightings, digital camera technology, plus specific and extensive survey efforts by two of us (BGS & DLJ), have generated a large number of post-release resightings of the blue-banded cohort of birds. Searches for banded CABRPE occurred in conjunction with communal roost surveys from the USA-Mexico border to the southwestern coast of the state of Washington, USA, as part of separate research efforts by DLJ, with most effort taking place during 2015–2019. Intensive surveys at two of the largest roost sites in central California were conducted two to three times per week by BGS beginning in 2015, from approximately May to December each year, when CABRPE are seasonally present. The central California surveys were performed by paddling along the breakwater roosts in a kayak during the early morning hours at locations where several thousand pelicans typically roosted overnight. All banded pelican sightings were documented with photographs during both efforts.

The blue-banded cohort includes adult birds treated and released during the winter mass-stranding event in 2009/10, birds from the mass-stranding events of juveniles during summer months of 2011–2013, and a yearly component of birds treated for other reasons. Initial care involved thermal support and fluid therapy, followed by physical examination, diagnostics, and assessment of injuries. All birds were treated once with ivermectin at 0.4 mg/kg orally at admission for control of lice and reduction of helminth burden. Other medical treatments were determined by individual needs.

Plastic auxiliary leg bands (blue with white lettering) were coded 00–99 for prefix letters A, C, E, H, J, K, M, N, P, R, S, T, V, X, and Y (Haggie Engraving; Crumpton, USA). Other letters were not used due to concerns about misreporting of letters easily mistaken for other letters or digits ('B' reported as '8', 'L' for '7', etc.). The vast majority of band codes were configured in a letter-number-number sequence, but a small number of bands were configured in a number-letter-number sequence in 2019. CABRPE that were admitted to IBR's two clinics prior to 31 December 2019 were included in the study if they were released with a blue auxiliary band in addition to a size 9 metal federal band. The study cohort excludes several other groups of banded pelicans. Birds released with only federal bands were excluded because of the high likelihood of a difference in ease of identification between the band types. Oiled birds treated and released during the Refugio oil spill (in 2015 off Santa Barbara, California, USA) were excluded because they were banded with different types of bands (green auxiliary bands and/or satellite transmitter backpacks); plus, treatment decisions were made by a different organization. However, pelicans individually oiled and not part of a declared oil spill were included, and birds re-entering care with a previously applied metal band that were re-released with a blue band were included as well. Wild-caught birds with blue bands specifically applied for research purposes were excluded because they did not undergo rehabilitation. If metal federal bands were reported to the BBL as found without being attached to a bird and if they were from birds that were released with both federal and blue auxiliary bands, they were included in tallies of band losses but excluded from other analyses if the status of the bird was unknown.

Data from paper and electronic medical records from each bird were extracted into spreadsheets (Excel, Microsoft Inc.), including stranding date and location, admission date, and numerous factors related to condition and care. Although CABRPE have distinctive plumage as fledged hatch-year birds and attain distinctive adult plumage by the time they exceed three years of age, intermediate plumages are complicated (Pyle 2008). Consequently, birds were divided into either four age categories [unknown, hatch year (HY), sub-adult (SA), after third year (ATY)] or two age categories [HY or after hatch year (AHY)] for modeling purposes. The SA category included both second- and third-year birds, while the AHY category combined all birds older than HY. The unknown category was assigned to birds with inadequate or absent age assessments, and this group was excluded from statistical comparisons regarding age.

Sex was determined by length of the exposed culmen (female < 324 mm, male > 334 mm, unknown = 324–334 mm; Pyle 2008). CABRPE do not breed on mainland California; hence, all birds were of fully-flighted, post-fledging age at rehabilitation. In Schreiber (1976), culmen length did not reach an asymptotic maximum prior to fledging but CABRPE chick tarsus lengths and weights reached an asymptote at approximately 30 and 50 days of age respectively, several weeks prior to fledging. In accord with this, several HY birds in this study were observed with culmen growth during care. Consequently, HY birds were designated male if culmen reached > 334 mm but no HY birds could be designated as female. HY birds were also designated as males if they reached an exit weight greater than 4800 g if other morphometrics were not collected, as no adult females (determined by plumage and culmen length) exceeded 4800 g at release.

The numeric biomedical parameters we assessed included admission and pre-release body weights (in grams), packed cell volume (PCV, measured as % by microhematocrit), total plasma protein (TP, measured as g/dL by refractometer), and admission body temperature (cloacal, measured as °F/°C). Because CABRPE weights vary quite widely by frame size and sex, each bird's state of nutrition at admission was assessed as a percent of release weight.

Each individual record was labeled as yes/no for 34 clinically important medical problems or findings such as: general debilitation (no major injuries but commonly anemic, hypoproteinemic, emaciated, hypothermic), severe emaciation (< 70% release weight at admission), severe anemia (PCV < 20% at admission), severe hypothermia (< 100 °F/37.8 °C at admission), suspected domoic acid toxicity, traumatic injury (all), fishing gear injury, (presumptive) California Sea Lion *Zalophus californianus* bite wound, plumage contamination (including contaminant and whether the bird was washed), gunshot, fracture (any), wing fracture, leg fracture, bill fracture, toe fracture (and whether amputated or not), other fracture, gular pouch laceration, pouch dermatitis/stomatitis, pouch bruising, thorns in feet, pododermatitis, foot web bruising, foot web blistering, knuckling toe digit #1, constriction injury (any), wing injury (any), wing constriction injury, patagium injury, and gastrointestinal bleeding. Joint luxations were counted as fractures. These case characteristics were assessed for frequency of occurrence and in relation to post-release data. Particular focus was placed on biologically relevant problems that may have created lingering disability for a plunge-diving species. Release readiness was judged on athletic fitness in a large 36.6×7.6×7.6 m flight aviary, waterproof plumage, active alert demeanor, substantial pectoral muscle mass palpable on physical exam, and medical problems resolved.

Resighting information for each bird was obtained from numerous sources, including reports submitted to IBR's web-based citizen science reporting system, IBR internal records for any birds that returned to care, and reports from field observers specifically surveying for leg bands at coastal locations where CABRPEs commonly roost (BGS, DLJ). Data from the BBL for re-encounters of CABRPE banded under permits 21214 and 20440 through 23 June 2021 were included. Imprecise dates for re-encounters from BBL reports were assigned to dates at the middle of the imprecise interval (e.g., March 2016 → 15 March 2016). Each individual was categorized as yes or no as to whether it was resighted after release; if resighted, its most recent status (alive, dead) was recorded.

We defined minimum longevity as the length of time between release and the most recent date each individual bird was encountered (unless repeatedly encountered after death, in which case the first carcass resighting was used); this is a final value for those reported as dead but a minimum value for those still alive. Longevity was calculated in days by subtraction of dates. Information regarding band loss of both metal federal bands and auxiliary bands was also tabulated.

For birds that were re-admitted to care, admissions to rehabilitation were labeled as the first, second, third, or fourth hospitalization, as indicated by previous medical records linked to each re-admitted bird's leg bands. If a bird did not survive to re-release, the number of days between initial release and final disposition was calculated as post-release longevity. If a bird was re-released, the number of days between the initial release date and the most recent resighting served as the minimum longevity.

Data analysis

Data were tabulated in Excel spreadsheets (Microsoft Excel 2016, Microsoft Office, version 2205, build 16.0.15225.20028). Basic descriptive statistics [mean, median, standard deviation (SD), range] were calculated for all numeric variables by age and sex, when appropriate, with assessment of normality through Shapiro-Wilk tests. Statistical tests were chosen dependent on the type and distribution of data compared, and included Kruskal-Wallis tests, chi-squared analyses, and Fisher's exact tests. All statistical analyses were conducted using JMP (version 15.2.1, SAS Institute Inc., Cary, USA). P values smaller than 0.05 were considered statistically significant. Outcome variables for these comparisons included whether birds were re-encountered (yes/no), whether bird was alive versus dead at most recent re-encounter, and minimum longevity post release (in days/year).

Program MARK (White & Burnham 1999) was used in a separate but complementary analysis to estimate average annual survival by age group (HY or AHY). Live resighting data were combined with known recoveries of banded dead birds into a single live encounter–dead recovery model to generate mean annual survival estimates (Burnham 1993, Cooch & White 2018). Dead pelicans were defined as carcasses found with a band still on. Recoveries of bands without a carcass were ignored, since they may have represented band loss from a live bird.

Binomial individual encounter histories were created for each bird: for each calendar year, status was designated as "1" if the bird was either released or re-encountered alive during the year and "0" if the bird was not encountered during that calendar year. Each year ("encounter opportunity") also included a binary field to incorporate the dead encounters. For models that included the full dataset (2009–2021), this resulted in a maximum of 13 encounter opportunities. The first encounter began with the year of release—for example, all the birds released in 2009 were coded with a one, and the first opportunity for live re-encounter of the 2009 cohort was 2010. The first opportunity for dead recovery was in the same year as release.

The live encounter–dead recovery model developed by Burnham (1993) incorporates the following parameters: survival estimate (S), probability of recapture/live encounter (p), probability of dead recovery (r), and fidelity to the sampling region (F). In this model, F assumes that the area where dead birds are recovered is larger than the area where live birds might be detected (F < 1). In our study, although live banded pelican reports may have come from contributors throughout the range of the subspecies, including

TABLE 1
Annual tallies of California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation, 2009–2019

Year released	No. blue-banded	No. resighted, alive/dead[a]	No. observed alive in 2020 or 2021 (%)
2009	105[b]	38/7	2 (1.9)
2010	120	41/22	11 (9.2)
2011	294	94/30	18 (6.1)
2012	482	149/51	26 (5.4)
2013	102[c]	40/8	4 (3.9)
2014	59	27/4	13 (22.0)
2015	42	22/7	12 (28.6)
2016	46	26/6	13 (28.2)
2017	51	35/3	25 (49.0)
2018	79	64/6	41 (51.9)
2019	35	22/2	21 (60.0)
2020[d]	3	2/1	3 (100.0)
Total	1418	560/147	189 (13.3)

[a] As of June 2022
[b] Includes one restranded bird originally federal banded in 2002, re-released with blue auxiliary band in 2009
[c] Includes one restranded bird originally federal banded in 2006, re-released with blue auxiliary band in 2013
[d] Birds admitted in 2019 but released in 2020

Mexico, band search efforts were limited to the US. Proportionately more dead banded pelicans than live ones were recovered outside the US, so the assumption of F < 1 seemed appropriate.

After experimentally running every possible combination of the parameters (256 models), a series of 12 candidate models was constructed to evaluate S, given apparent group and time effects. The model with the lowest Akaike information criterion (AIC) score was selected to provide survival estimates, as this model best explained the variation in the data while using the fewest parameters (Burnham & Anderson 2004). When the best-supported model indicated an effect of time or an interaction of group and time on survival, the variance feature in MARK was used to generate means and standard errors for S. Eight candidate models were used to generate estimates of S for the period 2015–2021. In the latter analysis, the only difference was that p was held constant. Lifespan was calculated by the equation $1/(-1\ln(S))$.

RESULTS

Of 3645 CABRPE admitted during 2009–2019, a total of 2009 (55.1%) birds were released following rehabilitation, and the remainder either died or were humanely euthanized. Of the released birds, 1418 individuals received auxiliary blue bands in addition to a metal federal band. These 1418 individuals were admitted for rehabilitation 1465 times, and 707 of them (49.9%) have been resighted at least once. At each bird's most recent resighting, 560 (79.2%) were alive and 147 (20.8%) were dead (Table 1). Eight of the 147 dead birds were reported to BBL as skeletonized or bone only. Mean (SD) longevity, inclusive of all birds, was 3 (3.1) years and represents minimum survival time for those last encountered alive. Fifty-five of the birds released before 2017 were

TABLE 2
Minimum longevity of California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation 2009–2019, live and dead resightings are combined. Birds with multiple admissions (n = 42) are included at first admission only.

Age class[a]	Sex	*n*	*n* resighted (alive/dead)	Minimum longevity (days)		
				Mean (SD)	Median	Range
HY	All	814	270/71	896 (1081.8)	378	0–3777
	Male	251	82/28	926 (1135.0)	311	0–3750
	Unknown[b]	563	188/43	882 (1057.8)	387	0–3777
SA	All	219	102/25	1134 (1087.0)	892	1–4195
	Female	84	39/6	1208 (1202.2)	847	1–4195
	Male	105	54/14	1140 (991.9)	1084	7–4033
	Unknown	30	9/5	868 (1181.1)	251	5–3604
ATY	All	375	183/49	1344 (1205.7)	1120	5–4505
	Female	124	70/8	1331 (1182.7)	1105.5	9–4442
	Male	210	99/31	1431 (1251.5)	1194	7–4505
	Unknown	41	14/10	910 (944.8)	482.5	5–3038
Unknown	All	10	5/2	1090 (914.7)	878.0	83–2182
	Male	3	3/0	1048 (1059.7)	818.0	83–2182
	Unknown	7	2/2	1123 (959.9)	1061.5	244–2123
Grand total		1418	560/147	1088 (1138.8)	746.0	0–4505

[a] SD = standard deviation, HY = hatch year, SA = sub-adult, ATY = after-third-year adults
[b] Includes HY males with culmen < 334 mm and all HY females

not re-encountered for the first time until 5–11 years after release: two were reported as dead, one has unknown status due to band loss, seven were re-encountered when re-admitted to rehabilitation, and the others were live resightings. Admission year showed a significant relationship to alive/dead status within those that have been resighted, with an increased proportion of birds resighted alive in more recent years than earlier in the study period ($P = 0.0002$). Re-encounters of birds from all release years continue and multiple-year gaps are common between resightings of each individual.

At least 73 of 1418 (5.1%) metal bands were lost. Sixty-four birds were resighted without their metal bands but with auxiliary bands intact. Ten metal bands found without a bird were reported to BBL: one was reported in 2015 and the bird was resighted alive with blue band intact in 2018, but the other nine have not been resighted. Seventeen of 707 resighted birds (2.4%) were identified by metal band number alone, with their auxiliary band missing; all 17 birds are photo-documented. BBL did not receive any reports of birdless blue auxiliary bands. Since band loss of the field-readable auxiliary bands was relatively rare, it was not incorporated into the MARK analysis.

Ages and sexes of birds included in the study are shown in Table 2. HY birds were less likely to be resighted than ATY or SA birds ($P < 0.0001$) and had a shorter mean number of days to resighting than ATY or SA birds ($P < 0.0001$). Considering only birds that were resighted, there was no difference in alive/dead status by age class ($P = 0.9557$); by sex, a significantly higher proportion of male ATY birds were resighted dead than alive than female ATY birds ($P = 0.0105$), but there was no difference by sex in the number of days to the most recent resighting, whether alive or dead.

Body weights generally increased prior to release, on average to 130%–145% of admission weight (Table 3). PCV, TP, and thermoregulatory ability normalized prior to release (Table 4), with resolution of anemia, hypo- or hyperproteinemia, and/or hypothermia. Longevity summarized by selected medical problems showed that 41%–58% of birds that recovered from any given problem were resighted, and 76%–89% of these were alive at most recent resighting (Table 5).

Trauma

Trauma cases (n = 822 individuals) included fishing gear injuries (n = 462), fractures (n = 160), gular pouch lacerations (n = 115), large (presumptive) California Sea Lion bite wounds (n = 110), collision (with a car, boat, window, or powerline; n = 6), gunshot (n = 5), and entanglement by non-fishing gear cordage or line (n = 4). Several birds merited inclusion in more than one of these categories (e.g., gunshot plus fishing gear). Considering all birds with traumatic injuries together, no significant differences were found in the proportion resighted by age or sex, and birds that were treated for traumatic injuries were more likely to be alive at their most recent resighting than were birds treated for other problems ($P = 0.0131$). The 822 birds admitted for care due to trauma had 1793 medically notable injuries, which required 493 surgical procedures and innumerable other care events not tallied for this study (e.g., bandage changes, physical therapy, etc.) to facilitate recovery to releasable condition.

Recreational fishing gear caused at least 1111 of 1793 (62.0%) of these injuries, including punctures, gear ingestion, limb strangulation, abscesses, or other wounds caused by hooks or line. Ingestion of gear where a pelican had ingested a hook was less common than external hooking and entanglement. Of 462 birds with fishing gear injuries, 27 birds (5.8%) had hooks in the esophagus or proventriculus, 75 (16.2%) had hook injuries to the bill or pouch, and 131 (28.4%) had fishing line constriction injuries to various anatomic locations. Fifty-one of these birds had these injuries on more than one body part, most commonly one leg and one wing (n = 21), followed by one leg and both wings (n = 16). Five birds had constriction injuries affecting all four limbs. Constriction injuries were often associated with the patagium (55 of 131, 42.0%), with lacerations of varying severity, many which severed or damaged the patagialis longus tendon that forms the leading edge of the patagium. Twenty-four birds

TABLE 3
Intake and exit weights of California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation 2009–2019[a]

Sex/age class		Intake weight (g)				Exit weight (g)			
		n	Mean	SD	Range	*n*	Mean	SD	Range
Female									
	SA	97	2871	497	2005–4168	96	3730	366	2772–4730
	ATY	134	2992	501	2018–4330	133	3725	370	3020–4785
Male									
	HY	245	3190	532	2075–5000	243	4579	394	3140–5780
	SA	99	3421	604	2230–4960	100	4590	456	3386–5882
	ATY	220	3636	521	2640–4950	219	4637	425	3492–5605
Unknown									
	HY[b]	587	2724	550	1468–4560	578	3904	391	2605–4784
	SA	31	3159	511	2120–4408	31	4058	455	3096–4760
	ATY	36	3268	482	2372–4332	36	4175	415	3362–4794

[a] SD = standard deviation, HY = hatch year, SA = sub-adult, ATY = after-third-year adults
[b] Includes HY males with culmen < 334 mm and all HY females

had severed patagialis longus tendons with variable severity (mild, moderate, or severe) in associated wounds, and 12 of the 24 birds were resighted after release: 3 scored as moderate severity were found dead at 329, 331, and 216 days after release, while the remaining 9 were observed alive at mean (SD) = 999.2 (822.87), median = 832, and range = 15–2353 days. These live resighted birds' patagium wounds had been scored as mild (n = 1), moderate (n = 3), and severe (n = 5); mean minimum longevity for these birds was shorter than for birds without patagialis longus injuries, but not significantly so (P = 0.8202). No significant differences were found among the following parameters: whether resighted (P = 0.3076), alive/dead status if resighted (P = 0.2124), or minimum longevity in birds of any age class with patagium injuries (P = 0.0587). Hook injuries to wings included damage to flight feather follicles, abscesses, periosteal responses when hooks were lodged against the bone, and often-severe damage to muscles and tendons. Constriction injuries at the distal tibiotarsus above the hock joint sometimes resulted in loss of control and resultant folding under ("knuckling") of the 1st digit (the hallux, n = 24). Knuckling sometimes resulted in necrosis that required amputation of the toe (n = 8). Other toe amputations were largely due to fish-hook punctures that resulted in open fractures, osteomyelitis, or tendonitis; or to necrosis resulting from constriction of the whole foot with disruption of blood flow to the lateral toes.

Pouch lacerations (n = 115) ranged from small to enormous and from innocuous to lethal in severity (if not surgically repaired). Fifty-nine pouch lacerations were known to be caused by fishing gear; others were due to unknown causes (n = 56). The most severe of these appeared as incisions with a sharp object, resembling a straight cut though one or both sides of the pouch, all the way to the caudal aspect of the pouch or continuing around the back of the head, severing the pouch and degloving the neck. These were suspected to be maliciously caused.

California Sea Lion bite injuries typically consisted of one or more large (~10×10 cm, as large as 40×30 cm) wounds where the skin of the ventrum is missing (avulsed). These were present at the chest (n = 86), abdomen (n = 16), neck (n = 9), or leg/caudal hip (n = 3). These wounds were graded as mild (n = 58), moderate (n = 35), or severe (n = 21), based on characteristics of the wounds such as whether the injury was limited to skin only, included damage to underlying muscle or exposed vital structures such as the trachea, included tooth gouges into the keel itself, or was infested by maggots. Many of these wounds were managed with routine wound care, but 45 anesthetic procedures were required to manage the more severe wounds.

Fractures were present in 160 birds, 72 of which had wing fractures. By age class, HY birds treated for wing fractures were less likely to be resighted than ATY or SA birds (P = 0.0223). A non-significant higher proportion of the resighted HY birds treated for wing fractures were dead at resighting than SA or ATY birds (P = 0.3786; 40% versus 16.7% and 20%, respectively); low numbers precluded more meaningful

TABLE 4
Basic biomedical values of California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation 2009–2019, with comparison to published values[a]

Packed cell volume (%), intake/pre-release					
Age class	***n***	**Mean**	**SD**	**Median**	**Range**
HY	806/795	32.6/43.9	9.35/3.88	34/44	8–55/31–57
SA	223/220	34.2/44.1	9.27/3.74	36/44	10–54/33–54
ATY	382/371	34.6/43.9	8.94/3.88	36/44	9–57/29–56
Wild ATY[b]	6	44	2		41–47
Wild pre–fledge[b]	14	39	2		36–42
Total protein (g/dL), intake/pre-release					
Age class	***n***	**Mean**	**SD**	**Median**	**Range**
HY	802/793	3.7/4.5	1.32/0.69	3.8/4.4	0.3–9.0/3.0–8.8
SA	222/220	4.0/5.0	1.38/0.75	4.0/4.9	0.1–8.0/3.0–6.8
ATY	377/371	4.0/5.1	1.43/0.88	4.0/5.0	0.3–9.5/2.4–8.7
Wild ATY[b]	5	3.4	0.2		3.2–3.7
Wild pre–fledge[b]		3.5	0.3		3.2–4.2
Admission body temperature (°F/°C)					
Age class	***n***	**Mean**	**SD**	**Median**	**Range**
HY	809	102.7/39.3	2.14/1.17	103.1/39.5	90.9–107.4/32.7–41.9
SA	217	102.7/39.3	1.87/1.04	103.0/39.4	97.2–107.8/36.2–42.1
ATY	377	102.7/39.3	1.94/1.08	103.0/39.4	91.0–106.3/32.8–41.3
Captive normal[c]					> 103.5/39.7

[a] SD = standard deviation, HY = hatch year, SA = sub-adult, ATY = after-third-year adults
[b] Newman 1998
[c] Duerr 2017

TABLE 5
Minimum longevity of California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation 2009–2019, by selected medical problems during care

Selected medical problems	*n*	*n* resighted (alive/dead)	Minimum longevity (days)		
			Mean (SD)[a]	Median	Range
All birds	1418	560/147	1104 (1146.3)	746	0–4505
Severe emaciation[b]	631	223/53	1024 (1129.6)	554	0–4218
General debilitation	510	185/60	1221 (1253.4)	554	0–4218
Fishing gear injuries (all)	463	187/39	1067 (1096.1)	768	1–4442
Wing injuries (all)	456	185/49	1057 (1082.2)	657.5	1–4442
Patagium damage	182	72/13	1311 (1244.5)	982	5–4442
Fracture (all)	160	66/18	789 (861.8)	482	9–3973
Severe hypothermia[c]	127	56/11	1053 (1109.6)	562	7–3997
Severe anemia[d]	126	50/8	1158 (1392.2)	429.5	11–4496
Pouch laceration	116	38/9	932 (1015.4)	655	12–3741
Bite wound (California Sea Lion)	110	44/11	1169 (1140.0)	1023	6–3973
Wing fracture	72	32/10	918 (998.6)	468.5	11–3973
Toe fracture	56	26/3	611 (731.9)	399	11–3258
Toe amputation	53	23/4	875 (824.6)	673	5–3035
Petroleum oiled	21	11/1	1473 (1335.8)	741	69–4238

[a] SD = standard deviation
[b] Severe emaciation defined as < 70% of release weight at intake
[c] Severe hypothermia defined as < 100 °F/37.8 °C at intake
[d] Severe anemia defined as packed cell volume < 20% at intake

statistical comparison. Fifty-six birds had toe fractures. Birds with toe fractures had a significantly shorter time to most recent resighting than birds without toe fractures ($P = 0.0365$) but were more likely to be alive than birds treated for other problems ($P < 0.0001$). Birds with toe amputations showed no significant resighting or longevity differences from birds without toe amputations. There was partial overlap of these two subsets of foot problems: 18 birds with toe fractures also had toe amputations. Thirteen birds had bill fractures: four were resighted alive at 11, 464, 1130, and 1522 days after release, three were found dead at 49, 75, and 1078 days, and six were not resighted. Eight birds had femur, tibiotarsus, or tarsometatarsus fractures: three were resighted alive at 292, 516, and 807 days after release and five were not resighted. Among other fractures, one bird had a coracoid fracture (found dead 360 days after release), two had broken clavicles (one was not resighted, one was resighted alive 1862 days after release), one had a scapula fracture (same bird as coracoid), and three others had vertebrae, synsacrum, or pubic bone fractures (two were resighted alive at 1466 and 1480 days, one was not resighted).

General debilitation

Birds stranding due to general debilitation ($n = 510$) showed various combinations of emaciation, anemia, dehydration, and hypothermia (Table 6) but no major injuries or evidence of disease. There was no difference in the likelihood of re-encounter after release for this admission category compared to birds treated for other reasons ($P = 0.4872$), but those resighted were significantly more likely to be dead than birds treated for other problems ($P = 0.0156$). At admission, TP values in this subset were often abnormally high or low ($n = 493$, mean (SD) = 3.2 (1.35) g/dL, range = 0.1–9.5 g/dL) but normalized before release ($n = 480$, mean (SD) = 4.6 (0.74) g/dL, range = 3.0–7.2 g/dL).

TABLE 6
Common problems of generally debilitated California Brown Pelicans *Pelecanus occidentalis californicus* released with blue auxiliary leg bands after rehabilitation 2009–2019. These birds did not have other evidence of injury or disease.

Severity	Hypothermia[a]	Dehydration[b]	Anemia[c]	Emaciation[d]
None	156	9	77	37
Mild	148	230	166	59
Moderate	120	141	171	105
Severe	73	23	81	301
Total	497	403	495	502

[a] Hypothermia: none = greater than 103.5 °F/39.7 °C), mild = 102–103.4 °F/38.9–39.7 °C), moderate = 100–101.9 °F/37.8–38.8 °C, severe = less than 100 °F/37.8 °C at intake
[b] Dehydration: none = less than 5%, mild = 5%–6%, moderate = 7%–8%, severe = greater than 9% at intake
[c] Anemia: none = packed cell volume greater than 40%, mild = 30%–39%, moderate = 20%–29%, severe = less than 20% at intake
[d] Emaciation: none = greater than 90%, mild = 80%–89%, moderate = 70%–79%, severe = less than 70% of release weight at intake

Plumage contamination

Plumage contamination (n = 198) was caused by unknown substances (n = 126), fish or vegetable oil (n = 44), petroleum oil (n = 21), or glues/sewage/other (n = 7). Most contaminated birds were washed to facilitate reacquisition of waterproof plumage (n = 169). Those that were only mildly contaminated and not washed were able to re-establish waterproof plumage on their own through preening and bathing. Birds that were washed were more likely to be resighted after release (P = 0.0240), but there was no difference in most recent alive/dead status (P = 1.000).

Restranded birds

Forty-two birds (3.0%) underwent rehabilitation twice, three were rehabilitated three times, and one bird was rehabilitated four times over nearly a decade. Time between admission varied widely: mean (SD) = 344 (680) days, range = 2–2467 days. Birds typically were re-admitted for different problems, but five were (in retrospect) erroneously determined to be ready for release. Seven birds restranded within 90 days and were euthanized or died: three suffered from suspected muscle necrosis (after a fish quality problem was discovered), one was accidentally released while still anemic (PCV = 32%), one bird had case notes where two staff held widely divergent pre-release assessments regarding the bird's flight ability (not flying versus flying very well), and two became badly injured in fishing gear after release. Of the 42 individuals that were rehabilitated twice, 34 were re-released and 17 of the 34 have been resighted after their final release. Of the 17 that were resighted, five were dead at 89, 241, 425, 1218, and 1441 days after their final release. The 12 birds alive at the most recent resighting comprise a long-lived subset of birds (mean (SD) = 2309 (1469) days, median = 2063.5, range = 89–4238 days). For the three birds that were rehabilitated three times, one was a HY that was euthanized on the third admission for failure to thrive in the wild 89 days after the original release, one was last seen alive 3936 days after release, and one has not been resighted. The bird that entered care four times originally stranded as an emaciated and weak ATY during the

TABLE 7
Model fit for 12 candidate models selected in Program MARK to evaluate survival of 1412 banded California Brown Pelicans *Pelecanus occidentalis californicus* released following (A) rehabilitation by International Bird Rescue 2009–2019 and (B) 8 candidate models using a subset of the same data

A. Models (2009–2019)	AICc	Delta AICc	AICc weights	Model likelihood	Number of parameters	Deviance	−2log(L)
{S(g*t) p(t) r(g) F(.)}	6352.284	0	0.62323	1	41	1520.725	6268.937
{S(g*t) p(t) r(g) F(g)}	6353.401	1.1172	0.35649	0.572	42	1519.776	6267.988
{S(g*t) p(t) r(.) F(.)}	6360.162	7.8783	0.01213	0.0195	40	1530.668	6278.88
{S(g*t) p(t) r(.) F(g)}	6361.939	9.655	0.00499	0.008	41	1530.38	6278.592
{S(t) p(t) r(g) F(g)}	6362.995	10.7112	0.00294	0.0047	29	1556.105	6304.318
{S(t) p(t) r(.) F(g)}	6368.291	16.0073	0.00021	0.0003	28	1563.447	6311.659
{S(t) p(t) r(g) F(.)}	6375.505	23.2209	0.00001	0	28	1570.661	6318.873
{S(t) p(t) r(.) F(.)}	6382.261	29.9774	0	0	27	1579.461	6327.673
{S(g) p(t) r(g) F(.)}	6426.158	73.8738	0	0	17	1643.708	6391.921
{S(g) p(t) r(g) F(g)}	6427.732	75.4477	0	0	18	1643.254	6391.467
{S(g) p(t) r(.) F(.)}	6432.429	80.1449	0	0	16	1652.006	6400.218
{S(g) p(t) r(.) F(g)}	6434.191	81.9067	0	0	17	1651.741	6399.954
B. Models (2015–2019 release cohort)	**AICc**	**Delta AICc**	**AICc weights**	**Model likelihood**	**Number of parameters**	**Deviance**	**−2log(L)**
{S(t) p(.) r(.) F(g)}	1192.168	0	0.2815	1	11	201.4011	1169.735
{S(g*t) p(.) r(g) F(.)}	1192.98	0.8124	0.18753	0.6662	18	187.5119	1155.846
{S(g*t) p(.) r(.) F(.)}	1193.399	1.2311	0.15211	0.5403	17	190.0518	1158.386
{S(g*t) p(.) r(.) F(g)}	1193.646	1.4777	0.13446	0.4776	18	188.1772	1156.511
{S(t) p(.) r(g) F(g)}	1194.136	1.9676	0.10525	0.3739	12	201.2892	1169.623
{S(g*t) p(.) r(g) F(g)}	1195.097	2.9294	0.06507	0.2312	19	187.5008	1155.835
{S(t) p(.) r(.) F(.)}	1195.449	3.2815	0.05457	0.1939	10	206.7552	1175.089
{S(t) p(.) r(g) F(.)}	1197.507	5.3387	0.01951	0.0693	11	206.7398	1175.074

Results from the top-ranking model (i.e., that with the lowest AICc score) were used for estimates. Data were grouped by two age classes (hatch year and after hatch year) to test the effects of age group (g) at entry into rehabilitation on survival. AICc = Akaike Information Criterion corrected for small sample sizes, S = survival estimate, p = probability of recapture/live encounter, r = probability of dead recovery, F = fidelity to sampling region, t = time (year), L = likelihood mass-stranding event in the winter of 2010. The second admission in 2016 was for a deep abdominal puncture wound, a luxated toe, and osteomyelitis of a carpometacarpal-phalangeal (wingtip) joint. The third admission in 2017 was for a large, deep, and infected presumptive sea lion bite wound. The fourth admission two months later was for a head injury with a scalp laceration. Since the fourth release in 2018, this bird has been resighted many times, most recently on 22 October 2021 at Half Moon Bay, California, USA, 4265 days (11.7 years) since its original release.

Post-release survival models

During the 2009–2021 resighting interval, survival (S) was influenced by the interaction of age group (g) and time (t), according to the best-fitting models in MARK (Table 7). Probability of encounter was strongly influenced by time, which is calendar year in this analysis. The probability of dead recovery was influenced by age but not time. Fidelity to the sampling region was constant, that is, unaffected by time or age group. The mean annual survival of pelicans admitted in their first year of life was lower than that of older, more experienced birds that were admitted during the same time frame (mean = 0.70 versus 0.80 per year for HY versus AHY birds, respectively; Table 8). These results do not reflect survival of the HY birds in their first year of life, as none were in care while chicks, but rather the cumulative annual survival of the group of birds admitted as fledged hatch-years throughout their lives.

The probability of receiving a live bird report (p) in the first five years of the study was about the same as someone recovering and reporting a dead adult banded pelican (r) during the full course of the study, averaging 0.16 for a live sighting of any pelican in 2010–2014 compared to 0.15 for recovery of a dead AHY pelican during 2010–2021 (Table 8). After 2014, live bird sightings became much more likely than dead bird recoveries. The probability of recapture/live-encounter reports more than doubled in 2015 and generally rose through 2021, up to 0.84. Fidelity was estimated at nearly 1, as is the case where recoveries of both dead and live birds occur within the same sampling area.

TABLE 8
Estimates of survival of rehabilitated California Brown Pelicans *Pelecanus occidentalis californicus* based on the Burnham method for live vs. dead recoveries in Program MARK[a]

Dataset	Best model	Parameter	Estimate	Standard error	95% Confidence interval (lower, upper)
2009–2021	{S(g*t) p(t) r(g) F(.)}	S*(HY)	0.705416	0.040193	0.665223, 0.745609
n = 1412 birds		S*(AHY)	0.801847	0.025931	0.775916, 0.827778
	2010	p	0.156483	0.042762	0.089513, 0.259289
	2011	p	0.059455	0.019656	0.030763, 0.111820
	2012	p	0.163501	0.022547	0.123952, 0.212607
	2013	p	0.209634	0.024100	0.166280, 0.260756
	2014	p	0.229727	0.025961	0.182813, 0.284490
	2015	p	0.461975	0.036794	0.391136, 0.534383
	2016	p	0.598986	0.038551	0.521655, 0.671683
	2017	p	0.643187	0.038514	0.564710, 0.714665
	2018	p	0.721067	0.035432	0.646680, 0.784999
	2019	p	0.654696	0.035871	0.581454, 0.721266
	2020	p	0.739092	0.036151	0.662357, 0.803560
	2021	p	0.842698	0.047299	0.726926, 0.915119
	2010–2021 mean	p*	0.455782	0.079768	0.376014, 0.535550
		r(HY)	0.093001	0.010790	0.073901, 0.116417
		r(AHY)	0.153799	0.017059	0.123249, 0.190280
		F	0.980979	0.016808	0.898211, 0.996694
2015–2021	{S(t) p(.) r(.) F(g)}	S*	0.838417	0.070254	0.779664, 0.894442
n = 254 birds		p	0.753491	0.026112	0.698839, 0.801049
		r	0.199261	0.078126	0.087016, 0.393836
		F(HY)	0.835795	0.075677	0.634115, 0.938772
		F(AHY)	0.941063	0.079418	0.491007, 0.996231

[a] SS = survival estimate, p = probability of recapture/live encounter, r = probability of dead recovery, F = fidelity to the sampling region, * = beta hat means derived from the variance component for time-dependent parameters, HY = hatch year, AHY = after hatch year

When data were analyzed separately for only the birds released in 2015–2019, the survival estimate rose to 0.83 for both age groups (HY, AHY) combined. There was a 75% chance that a banded bird would be detected alive and a 20% chance that a dead bird would be recovered each year.

Using the simulated means in MARK and the 95% confidence intervals, the number of birds in the 2015–2019 release cohorts expected to be alive in 2021 was 100–165, with a likelihood of encountering 75–124 individuals. The actual number of live bird detections in 2021 was 89, slightly below the expected mean. The average lifespan of the 2015–2019 release cohort was estimated at a mean 5.67 years (1/−ln(0.838417)).

DISCUSSION

These findings support that CABRPE meeting IBR's criteria for release are generally fit to resume life in the wild. Estimated annual survival of rehabilitated CABRPE during 2009–2021 was high overall (0.70–0.80). As expected, differences in annual survival were found based on age class at admission. We found few significant differences in post-release survival that were related to medical problems during care, notwithstanding the few instances of obvious human failures in judgment regarding readiness for release. All categories of medical problems showed a broad range of minimum longevity, from a few days to more than 10 years. Birds with plumage contamination from petroleum oil showed the longest mean minimum longevity of all medical problems investigated. Although birds with toe fractures showed the shortest mean and median minimum longevities, most of these birds were last resighted alive; thus, these injuries may not affect long-term survival.

Some other specific injuries are of concern for causing lingering disabilities (e.g., wing fractures, especially in young birds). Interpretation of these findings suffers from low overall numbers of resighted birds that had any given problem. However, regarding recovery from wing injuries and fractures in general, results indicate that special attention should be paid to ensuring excellent flight ability prior to release. Severing of the patagialis longus tendon can change the width of the patagium in the extended wing, although data did not show patagial injuries to affect minimum longevity. Clinically, pelicans are renowned in the wildlife rehabilitation community as excellent healers compared to many other avian species. Gaps in their patagialis longus tendons are quickly filled with springy scar tissue that normalizes tension on the patagium. Nonetheless, close attention should be paid to post-injury shape changes that may affect wing loading. It is worth mentioning that the specific medical problems found in this cohort were not evenly distributed in time, as hazards to wild animals wax and wane as human behavior and environmental conditions change. For example, the winter 2010 event at the beginning of the blue band application period largely presented cold, wet, starving ATY birds, an event that has not recurred. During 2010, only 6% of ATYs were admitted with fishing gear injuries, compared to other years where 24–60% of ATYs have these injuries.

Birds with toe fractures had a significantly shorter time to re-encounter, whether dead or alive, while birds with more severe toe injuries that resulted in amputation did not. This could indicate that toe fractures allowed to heal on their own continue to cause chronic pain or other disability, or it could indicate birds that have metabolic or nutritional issues related to bone density or healing. Also, birds with toe fractures may spend more time in the vicinity of humans to be resighted, or birds that spend more time in proximity to humans may be at higher risk of injury. Interestingly, only three birds in this entire cohort of 1418 CABRPE are known to have become regular visitors at specific fishing piers, one of which bears a distinctive foot shape due to an amputation. Nonetheless, amputations of toes or portions of toes did not cause a detectable reduction in lifespan after release. IBR's treatment standard at time of this writing is 1) to not remove more than one half of one foot's surface area, 2) to ensure the bird is able to stand and walk comfortably, and 3) to ensure the bird is able to take off and land competently prior to release.

The utility of second chances for young birds that have failed to succeed as fledglings has long been a concern, considering the effort and resources that go into their rehabilitation. Schreiber & Mock (1988) note that only 30% of CABRPE chicks survive their first year of life. In an analysis of 2519 leg-band returns, they also found only 2% of Brown Pelicans banded as nestlings or fledglings in Florida and South Carolina, USA, living past 10 years and only three birds living past 20 years (31, 37, and 43 years); there was insufficient data available for birds banded at older ages to truly gauge life expectancy. In our study, 139 blue-banded HY CABRPEs were treated for general debilitation in 2012; at least 42 (30.2%) survived more than two years after release, 25 (18.0%) survived at least five years, and 14 (10.0%) were resighted in 2021. It is likely that all of these young birds would have died without captive care. Even so, 30 (21.6%) are known to have died during the year following release. Naturally, oceanic conditions that may have caused them to strand, weak and starving, may not have changed much by the time the birds were released. CABRPE chicks whose parents do not return to the nest have been observed fledging earlier than well-provisioned chicks (D. Anderson, pers. comm.). As time passes, a clearer comparison to Schreiber & Mock's data may emerge, as very few HY birds were blue-banded in 2009 or 2010. Results suggest that although HY CABRPE showed lower annual survival than older birds, rehabilitation of starving fledgling CABRPE is worthwhile.

During the mass stranding of ATY pelicans in 2009/10, there were news reports of birds landing on freeways; huddling, cold and wet, under trucks at the Port of Los Angeles; and taking chicken off barbecue grills at private homes (Nevins *et al.* 2011). Nonetheless, birds rehabilitated and released during this event have shown excellent longevity. In our study, of 224 blue bands applied during 2009/10, 31 birds (13.8%) that were SA or ATY at rehabilitation had been resighted older than 10 years of age (29 alive, 2 dead), including 11 birds resighted since January 2021 at minimum ages of 13.1–15.2 years.

Jaques *et al.* (2019) found that backpack harnesses used to track CABRPE may have a deleterious effect on breeding fitness following rehabilitation, as indicated by breeding coloration and molt. Other tracking methods have also been shown to have potentially deleterious effects on wild birds being studied. Small leg-band data loggers applied to Common Murres *Uria aalge* increased corticosterone levels compared to murres without data loggers (Elliott *et al.* 2012). Even simple leg bands were found to adversely impact diving performance in Imperial Shags *Leucocarbo atriceps* (Gómez-Laich *et al.* 2022). Nonetheless, although the blue-banded cohort of CABRPE discussed here had quite a few examples of both metal and auxiliary band loss, no instances of deleterious effects from either type of leg band were noted in this study. One bird has had its auxiliary band stuck above (instead of below) its hock joint for several years without apparent issues. Although several auxiliary bands were observed with damage prior to loss, overall, these leg bands have shown excellent long-term performance for more than a decade. Metal band loss was fairly common in this cohort. It is worth mentioning that for much of this span of years, aluminum federal bands were in use; since 2018, IBR has transitioned to using the much more secure stainless steel bands, which will hopefully result in fewer future losses.

Only four birds from this cohort have been directly observed at breeding colonies or with chicks, perhaps due to a lack of survey effort. Regardless, ATY birds of this cohort are routinely observed with vibrant breeding plumage as well as interacting and traveling with conspecifics, which suggests normal participation in breeding activities. Increased observation effort at breeding colonies would help resolve questions of whether rehabilitated CABRPEs return to normal breeding activities after release.

Entanglement in fishing gear remains an unfortunately common source of morbidity and mortality for CABRPE on the California coast. Schreiber & Mock (1988) concluded that fishing gear entanglement was an important cause of death during 1930–1970, and it appears little has changed in this regard. A large portion of the fishing gear–injured pelicans in this study were not injured by derelict gear or by commercial fishing operations but by recreational fishing gear. Although the type of gear was not matched to the injuries in this study, birds often had one or more fish hooks lodged in wings or legs, in combination with constriction injuries from the attached line. Some birds were entangled with multiple small hooks arrayed in Sabiki rigs, which are used to catch bait fish. The presence of these rigs suggest that people and pelicans were fishing at the same location. Other pelicans had hooks embedded in necks or wings or other parts of the body that suggest people may have cast their fishing gear into water where birds were foraging and snagged a bird, then cut it loose to later become entangled in trailing line. Although medical records of birds that were euthanized or died in care were not assessed for this study, IBR data (unpubl. data) shows that ingestion of gear rarely causes death in pelicans admitted for care in California, unlike other species such as terns and gulls that may have hooks lodged near (or in) the heart or great vessels. Lead ingestion is also thankfully uncommon in California due to the types of gear used. External damage by fishing gear, however, causes quite a few pelican deaths, especially due to severe constriction injuries. Faux fish lures that include multiple treble hooks affect numerous pelicans each year, but the birds are usually mortally wounded with barbs destructively lodged in joints and are thus largely absent from this study. An unknown number of CABRPE affected by fishing gear are never admitted as rehabilitation patients because they die before rescue or because they are euthanized or die after being deemed mortally wounded prior to arrival at wildlife rehabilitation centers. The birds represented in this study reflect only those with injuries survivable by the standard of being fit for release after recovery. The relative lethality of various types of recreational gear for pelicans and other avian species merits further work, as does mitigation of these often-horrendous injuries.

CABRPE conflict with California Sea Lions at certain commercial fishing docks and harbors, where the birds take refuse out of open waste containers (IBR unpubl. data) or where both birds and sea lions follow boats with catch into port (BGS pers. obs.). These injuries occur as the two species contest over the available food. At commercial docks, the birds fly to waters off the dock after foraging in waste containers, then are attacked by sea lions in an apparent effort to get the bird to regurgitate. The sea lions are apparently not trying to eat the birds, but these interactions may end with the bird tugged underwater, then resurfacing and floundering to shore while a piece of its pneumatized skin floats away. Although these interactions have been directly observed and captured on video, some injuries in this category may have been caused by other sources of trauma. Nevertheless, ongoing control of fish waste bins and mitigation of conflicts with sea lions are needed. Fish waste is also a common source of plumage contamination.

Annual survival estimates based on our modeling in MARK fit actual re-encounter data well. Estimates derived from the latter half of the dataset are likely more accurate due to greater survey effort. An example that exceeded expectations was the 2010 release cohort. Blue bands were applied to 120 pelicans in 2010. Most of those patients were ATY pelicans with general debilitation, an age class with high recovery prospects. Eleven of these birds were resighted in 2021, right at the upper end of the 2009–2021 model-based estimate of 5–11 birds predicted to survive 12 years post release ($S = 0.80$; 95% CI 0.78, 0.83). Increased survival in the 2015–2019 cohort supports IBR's release criteria and their detailed attention to physical therapy and fitness assessments for pelicans recovering from often-severe injuries.

CONCLUSIONS

In this study, our analysis showed that California Brown Pelicans may be successfully rehabilitated and returned to the wild, even when stranding with serious injuries or during mass starvation events. Rehabilitated CABRPE released from IBR facilities may be expected to live a mean of at least 6 years after release, and many birds survive much longer. We found higher proportions of birds surviving to reach ages > 10 years than previously described (Schreiber & Mock 1988).

A large proportion of the problems encountered by CABRPE in California that led to admission for rehabilitative care during this study were caused by humans, whether by fishing gear, conflict with California Sea Lions over anthropogenic food resources, oiling and other plumage contamination, or starvation likely related to forage fish depletion. Recreational fishing gear remains a major unnatural hazard to California Brown Pelicans. It is incumbent upon humans to reduce and mitigate hazards to wildlife, especially those directly caused by our activities.

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