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CAUSES OF MORTALITY OF ALBATROSS CHICKS AT MIDWAY ATOLL

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ABSTRACT: As part of an investigation of the effect of plastic ingestion on seabirds in Hawaii, we necropsied the carcasses of 137 Laysan albatross (*Diomedea immutabilis*) chicks from Midway Atoll in the Pacific Ocean during the summer of 1987. Selected tissues were collected for microbiological, parasitological, toxicological or histopathological examinations. Dehydration was the most common cause of death. Lead poisoning, trauma, emaciation (starvation) and trombidiosis were other causes of death; nonfatal nocardiosis and avian pox also were present. There was no evidence that ingested plastic caused mechanical lesions or mortality in 1987, but most of the chicks had considerably less plastic in them than chicks from earlier years. Human activity (lead poisoning and vehicular trauma) caused mortality at Midway Atoll and represented additive mortality for pre-fledgling albatrosses.

Key words: Plastic, seabird, mortality, albatross, *Diomedea immutabilis*, dehydration, lead poisoning, trombidiosis, nocardiosis, avian pox.

INTRODUCTION

Seabirds ingest pieces of plastic refuse that are discarded in the marine environment (Pettit et al., 1981; Day et al., 1985; Ryan, 1986). Some reports speculate that ingested plastic may be a health problem causing debility or even mortality in seabirds (Kenyon and Kridler, 1969, Conners and Smith, 1982; Fry et al., 1987; Dickerman and Goelet, 1987). Parent birds seemingly pick up plastic on the ocean surface and later regurgitate it to the chicks along with food. The plastic accumulates in the chicks' proventriculi with potentially adverse health effects. Ingested plastic might cause erosions or lacerations of the proventricular mucosa leading to infection. A large mass of plastic in the proventriculus could also simulate satiation or, by mechanical displacement, could prevent a hungry chick from taking a full meal from its parents (Ryan, 1988).

Extensive epizootic mortality of fledgling albatross chicks at Midway Atoll has been a regular event in recent years (Sileo and Fefer, 1987). Lead poisoning from the ingestion of weathered paint chips was one of the causes. Affected chicks unable to hold up their wings are called droopwings (Sileo and Fefer, 1987). During these previous epizootics carcasses of some albatross chicks with large amounts of plastic were found; the mean volume of plastic was 85 cc and the maximum volume was 188 cc (Fry et al., 1987). In 1986 and 1987, stomach samples were collected from 2,176 seabirds of 18 Hawaiian species (P. R. Sievert, L. Sileo, and S. I. Fefer, unpublished data). Plastic was found in 16 of the species. Plastic was common in some species of albatrosses (Laysan and black-footed *Diomedea nigripes*) and rare or nonexistent in other species of seabirds. A mean volume of 46 cc of ingested plastic was found in Laysan albatross chicks at Midway Atoll in 1986 and a mean volume of 5 cc was found in 1987. The main objective of the present study was to determine if mechanical lesions from ingested plastic was causing mortality of albatross chicks at Midway Atoll. A secondary interest was to determine the association between "droopwing" and lead poisoning.

METHODS

During the June and July nesting season of 1987, when the albatross chicks were approximately 4-mo-old, 137 carcasses were dissected at Sand Island (28°11'N, 177°22'W) of Midway Atoll. Sand Island was the site of a U.S. Naval Air Facility with a combined military and civilian population of about 300 at the time of this study. The island was heavily vegetated primarily by introduced plants such as *Casuarina litorea* (ironwood), *Verbesina encelioides*, *Bidens alba*, and *Pluchea* spp. Eight study sites

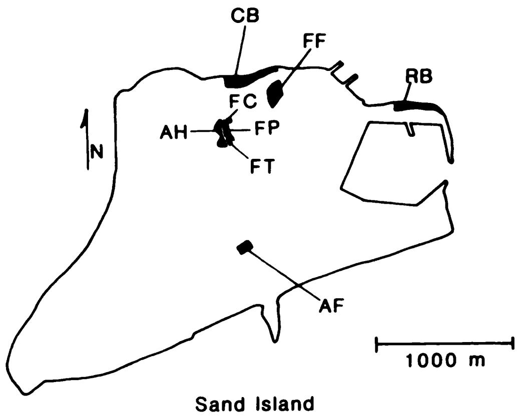

FIGURE 1. Locations of study areas on Sand Island, Midway Atoll. Designations FC, FP, FT are Foundation Chapel, Proper, and Triangle, respectively; AH is Abandoned Housing, CB is Clean Beach, FF is Fuel Farm, AF in Antenna Field, and RB is Reinforced Beach.

were selected on the basis of accessibility, presence of Laysan albatross chicks, and expected sources of mortality (paint chip poisoning, vehicular impact, or drowning; Fig. 1). For this report, plastic ingestion, paint chip poisoning and vehicular impact were considered human-related causes of mortality. All other causes were considered natural. Future studies may eventually show these supposed natural causes to be directly or indirectly influenced by human activities.

The Foundation Proper study site (FP, 0.13 ha) contained the concrete foundations of eight razed buildings. The vegetation cover was sparse mowed grass with an ironwood overstory. The site was bounded on one side by a street. We expected lead poisoning to be prevalent at this site. The smaller Foundation Chapel (FC) and Foundation Triangle (FT) sites were adjacent to the FP site. They had no concrete foundations, but otherwise they were similar to FP. The Abandoned Housing (AH, 1.34 ha) site had eight unused but intact two-story apartment buildings. About one-half of the area surrounding the apartments was mowed lawn and one-half was open sandy soil with patches of shrubs. This site was bounded on one side by the same street that bounded FP and there was also an overstory of ironwood trees. The Clean Beach (CB, 1.72 ha), a strip of sandy beach, was selected to determine the prevalence of drowning and if drowning occurred as a sequel to other health problems. There were no nests on the beaches. The Fuel Farm (FF, 1.49 ha) was relatively isolated from human activity, with open sandy soil and patchy brush. There were few trees to produce shade, virtually no vehicular traffic, and no buildings. This site was partly enclosed by an 8-foot-high chain-link fence. The Antenna Field (AF, 0.59 ha) also was relatively isolated with little human activity and no vehicular traffic or buildings. The cover was open mowed lawn with no overstory. The Reinforced Beach (RB, 0.84 ha) was a strip of sandy beach littered with discarded cables, coiled wire, metal beams, and other metal refuse. We were unable to visit this site after 25 June. Carcasses found at locations other than the established study areas were occasionally examined. The results from these were tabulated in an arbitrary Off-Site (OS) category regardless of the actual location.

Each study area on Sand Island was examined every morning from 16 June to 6 July 1987. Plastic numbered legbands were placed on sick (droopwing) chicks. On the last day of the study, the stomach contents of all surviving banded chicks were collected by induced vomiting to check for the presence of paint chips. Carcasses were collected daily from each study area for dissection. Sex, weight, degree of decomposition, and condition of the major organs were recorded. The proventricular contents were examined. The feet of the carcasses were examined against the light for pinpoint hemorrhages in the webs. Proventricular plastic contents subjectively estimated to be greater than 15 cc were measured by water displacement. Provisional diagnoses of the causes of death were based on the dissection results. Ancillary examinations (31 microbiological, 3 parasitological, 107 toxicological and 136 histopathological) of selected tissues were performed to confirm provisional diagnoses or to eliminate other possibilities. Financial and logistical limitations precluded complete diagnostic testing for all carcasses. The entire right kidney was frozen for lead analysis if the carcass met one of the following criteria: (1) it came from the Foundation or AH study areas and trauma was not the cause of death, (2) the carcass was one of the first 10 collected from one of the other study areas, (3) the carcass had paint chips in the proventricular contents, or (4) bile was thin, watery and yellow, suggesting lead poisoning. The lead concentrations in the renal tissue samples were determined by atomic absorption spectrophotometry (Williams, 1984). Lead poisoning was diagnosed if the liver lead concentration was >20 ppm dry weight (dw); Friend et al. (1987) report 20 to 30 ppm as suggestive of lead poisoning in waterfowl. We assumed that starvation was the cause of death of an emaciated carcass with no other significant lesions.

Representative tissue samples from lesions of suspected bacterial etiology in 31 chicks were frozen for later microbiological tests. Impression

TABLE 1. Laysan albatross (live chicks/carcasses) counted at study areas on Sand Island, Midway Atoll.

	Laysan albatross study areas[a]							
Month-day	FC	FP	FT	AH	CB	FF	AF	RB
6-11		201/1				—/0		4/0
6-12		207/0		326/0	5/0	477/0		7/0
6-13		190/0		311/1	11/1	—/0	—/0	9/2
6-14		—/2		—/0	—/1	—/0	—/1	6/4
6-15	—[b]/0	—/0		—/0	15/2	—/0	—/0	6/3
6-16	—/0	186/0	77/0	337/0	18/1	—/2	347/1	3/1
6-17	59/0	188/0	85/0	325/0	15/0	469/2	—/0	5/2
6-18	57/0	170/1	85/2	310/1	17/0	—/0	342/1	3/0
6-19	—/0	—/2	—/1	—/0	13/0	444/0	—/2	6/3
6-20	—/0	—/1	—/0	—/1	15/3	—/1	—/2	4/0
6-21	—/0	—/1	—/0	—/3	12/1	—/2	346/3	—/—
6-22	54/0	142/4	75/0	318/1	13/0	483/2	—/0	7/2
6-23	—/1	—/1	—/0	—/2	14/5	—/3	351/0	3/0
6-24	57/0	164/0	85/0	315/1	10/0	497/0	—/0	2/0
6-25	—/0	—/0	—/0	—/0	9/1	—/0	328/0	
6-26	48/0	173/2	89/0	298/0	9/0	494/2	—/0	
6-27	—/0	—/2	—/0	—/0	11/0	—/1	—/0	
6-28	46/0	160/2	78/1	302/2	17/0	—/0	351/0	
6-29	—/0	—/0	—/0	—/1	21/0	339/2	—/0	
6-30	54/0	171/0	85/0	304/0	22/2	—/4	356/2	
7-01	—/0	—/1	—/0	—/0	29/2	470/0	—/0	
7-02	50/0	148/1	76/0	298/0	36/0	—/0	376/1	
7-03	—/0	—/1	—/0	—/0	83/1	465/1	—/2	
7-04	48/0	148/0	84/0	279/0	83/1	514/0	358/0	
7-05	44/0	160/1	76/0	284/0	86/2	490/1	349/1	
7-06	36/0	152/0	58/0	275/1	63/3	487/3	311/3	

[a] FC, Foundation Chapel; FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach.

[b] "—," not counted.

smears of these samples were stained by the gram, acid-fast, and calcofluor white (SpotTest, DIFCO Laboratories, Detroit, Michigan 48232, USA) methods. Inocula prepared from the lesions were streaked on 5% sheep blood agar, eosin methylene blue, or Sabaraud's dextrose agar plates; these were incubated aerobically at 37 C for at least 24 hr. Unusual bacterial isolates were referred to the National Veterinary Services Laboratory (Ames, Iowa 50010, USA) for confirmatory identification. Skin lesions were frozen for later examination by parasitologists. Formalin-fixed tissues were processed by routine histological procedures and stained with hematoxylin and eosin or methenamine silver methods.

To confirm that dehydration was causing mortality, 16 moribund chicks from areas other than the defined study sites, were force-fed a salt solution (Gatorade®, Stokely-Van Camp, Inc., Chicago, Illinois 60604, USA; use of this product does not imply endorsement by the federal government) by syringe and esophageal feeding tube. The chicks were force-fed twice a day, 70 to 100 cc the first time and 140 cc thereafter, until they recovered, died, or the study was terminated.

Survival rates for chicks on the study sites at Sand Island were calculated using the Kaplan-Meier (KM) method (Kaplan and Meier, 1958; Kalbfleisch and Prentice, 1980; Cox and Oakes, 1984). The KM or product-limit estimator is a nonparametric method used to estimate the survival function from the number of animals at risk and the number that die. The KM method also allows for censoring due to emigration from the study area and animals surviving past the end of the study period. Further, the KM method can be used to obtain marginal survival curves for different causes of death. Cause specific survival curves are obtained by treating deaths from any other cause as censored observations. "Natural" survival rates for the study sites were calculated by censoring any chicks that died from lead poisoning or trauma from all study sites. Our censoring approach assumes that mortality caused by these two factors was independent of natural causes of mortality. Time was not suf-

TABLE 2. Ancillary diagnostic tests performed on juvenile Laysan albatross carcasses dissected at Midway Atoll in June and July 1987.

Study area[a]	Carcasses dissected	Bacteriology	Renal lead tests	Histology
FP	23	0	18	13
FT	3	0	2	2
AH	16	1	15	13
CB	23	1	10	17
FF	23	1	9	16
AF	19	0	9	10
RB	15	3	14	14
OS	15	5	9	13
Total	137	11	86	98

[a] FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach; OS, Off-site.

ficient for a complete daily count of all the chicks at each study site. Periodic counts (3 to 5 times/wk) were used to determine the number of chicks on each site (Table 1). We applied linear regression methods to these periodic counts to obtain daily estimates and associated variances of the population at risk on days when the chicks were not counted. The carcasses found during the daily searches were considered to represent all mortality on the study sites. Variance estimates for the Kaplan-Meier survival curves were obtained by modifying Greenwood's formula (Cox and Oakes, 1984:50) for estimates of the number of animals at risk. Similar modifications were made in the log-rank test (Cox and Oakes, 1984: 104) to compare differences between survival curves.

Percent mortality and prevalence data were tested by Chi-square procedures (Daniel, 1978). Continuous variables were analyzed using ANOVA procedures (Kirk, 1982).

RESULTS

Laysan albatross chicks proved to be ideal subjects for our study. They were docile, tame and sedentary with high fidelity to the nest site. High nesting densities made statistically adequate sampling a simple matter, and the absence of predators or scavengers other than black rats (*Rattus rattus*) made carcass censusing reliable. We dissected the carcasses of 137 chicks (Table 2). Decomposition, due to autolysis and sarcophagid fly infestation prevented reliable diagnosis of 12 of the carcasses (Table 3). The cause of death was not determined for an additional eight birds. No deaths were attributed to ingested plastic; none of the chicks contained more than 15 cc of plastic. No proventricular impactions, lacerations of the mucosa, or any other lesions attributable to plastic were found.

Dehydration and suspected dehydration were the most prevalent causes of death (Table 3). Criteria for a diagnosis of dehydration included dry thoracic viscera; insufficient pericardial fluid; copious, tenacious and sometimes coagulated bile; excessive urates in the collecting ducts of kidneys; inspissated feces in the ileum; ur-

TABLE 3. Causes of death of juvenile Laysan albatross carcasses necropsied at Midway Atoll in June and July 1987.

Study site[a]	FC	FP	FT	AH	CB	FF	AF	RB	OS	Total
Carcasses dissected	0	23	3	16	23	23	19	15	15	137
Decomposed	0	1	0	0	2	5	2	1	1	12
Unknown	0	0	0	2	3	1	1	1	0	8
Dehydration	0	1	2	8	10	8	8	5	4	46
Suspect dehydration	0	2	0	2	5	5	6	2	2	24
Lead poisoning	0	10	0	1	0	2	0	0	2	15
Trauma	0	8	1	3	0	0	1	0	2	15
Chiggers	0	0	0	0	0	0	0	0	2	2
Drowning	0	0	0	0	1	0	0	4	0	5
Multiple	0	1	0	0	2	0	0	2	2	7
Starvation	0	0	0	0	0	2	1	0	0	3

[a] Midway study sites: FC, Foundation Chapel; FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach; OS, Off-site.

TABLE 4. Laysan albatross chicks force-fed a salt solution[a] on Midway Atoll.

Date first fed	Days from first to last observation	Number of feedings	Total volume (cc) force-fed	Outcome	Stomach pump sample	Diagnosis
6-25-87	5	1	70	Recovery	—[b]	—
6-19-87	11	4	700	Recovery	—	—
6-26-87	4	4	490	Recovery	—	—
6-28-87	4	7	910	Recovery	—	—
6-30-87	8	7	910	Partial recovery	Paint chips	Suspect lead poisoning
6-30-87	10	8	1,000	Unknown, partial recovery	Paint chips	Suspect lead poisoning
6-29-87	9	7	910	Unknown, partial recovery	Paint chips	Suspect lead poisoning
6-29-87	9	7	940	Unknown, no change	Paint chips	Suspect lead poisoning
6-22-87	13	24	3,120	Unknown, no change	—	—
6-30-87	9	5	660	Unknown, no change	Paint chips	Suspect lead poisoning
6-22-87	1	1	140	Died	—	Dehydration
7-03-87	2	5	660	Died	No paint	Chiggers + dehydration?
6-30-87	1	5	520	Died	—	Lead poisoning
7-03-87	3	1	70	Died	—	Aspergillosis, chiggers
6-28-87	3	6	770	Died	—	Lead poisoning
6-22-87	1	1	140	Died	—	Unknown—dehydration, chiggers

[a] Gatorade®.
[b] Not performed.

ate concretions in the cloaca; and no other significant lesions. These dehydrated carcasses were in excellent condition with abundant subcutaneous, visceral and epicardial fat and no muscular or organ atrophy. Provisional diagnoses of dehydration or suspected dehydration were confirmed microscopically by the presence of urate spherules in the collecting ducts of the medullary rays of the kidney. Gross evidence of visceral gout was not present in any of these carcasses but mild to moderately severe renal gout with tophus formation was evident microscopically in 14 of them. Dehydration was considered the cause of death if the gross and microscopic changes were present and no other significant lesions were seen. If either the gross necropsy or microscopic findings were equivocal, the diagnosis was "suspect dehydration."

The condition of seven of the 16 moribund chicks that were force-fed Gatorade® changed from weak and depressed to strong and alert within a day of the first feeding (Table 4). Four of these seven chicks fully recovered and the therapy was discontinued. Three of the seven chicks recovered partly; at the end of the study, paint chips were removed from each, suggesting that they were suffering from lead poisoning. The force-feeding caused no appreciable change in the condition of three additional chicks. We suspected that the parents were no longer returning to one of these chicks, and paint chips were removed from the other two. The remaining six of the 16 treated chicks died. One died of dehydration a few hours after it was treated, and the others died of single or combined effects of dehydration, lead poisoning, chiggers or aspergillosis.

Trauma was the cause of death of 15 of the chicks (Table 3). All of these chicks were hit by vehicles and all were found on or immediately adjacent to a street except one carcass at the Antenna Field. This chick's right leg was crushed; the chick

TABLE 5. Renal lead concentration (ppm − dw) from juvenile Laysan albatross carcasses examined in the northwestern Hawaiian Islands in June and July 1987.

Study area[a]	Lead poisoning				Other causes of death			
	n	$\bar{x}$	Minimum	Maximum	n	$\bar{x}$	Minimum	Maximum
FP	10	102.74	21.87	245.33	8	3.40	0.23	11.11
FT	0	—	—	—	2	0.36	0.18	0.53
AH	1	152.57	—	—	14	1.08	0.00	10.80
CB	0	—	—	—	10	0.50	0.00	1.53
FF	2	37.23	28.92	45.53	7	0.24	0.00	0.67
AF	0	—	—	—	9	0.52	0.00	3.00
RB	0	—	—	—	14	0.18	0.00	0.53
OS	2	47.24	36.98	57.49	7	3.81	0.09	13.81

[a] FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach; OS, Off-site.

apparently moved 50 to 100 m from the nearest road before dying.

Lead poisoning was diagnosed as the cause of death of 13 chicks from the defined study sites. Eleven were from the FP or AH areas and two from the FF. Correct provisional diagnoses for 12 of 13 were based on the location of the carcass, the clinical history (droopwing), presence of paint chips in the proventriculus and yellow, watery bile. These carcasses were in good flesh with abundant subcutaneous and visceral fat. One of these cases was not suspected as lead poisoning based on necropsy observations. Diagnoses were confirmed by toxicological analyses. The lowest renal lead concentration associated with lead poisoning as a cause of death was 37.2 ppm dw (Table 5). The highest concentration found in a chick dying of other causes was 13.8 ppm dw. Chicks with droopwing succumbed to both lead poisoning and dehydration, but the average elapsed time between banding and death was longer for lead poisoned chicks (8.5 days) than for dehydrated chicks (2.6 days, $t = 2.46$, $P = 0.02$, df $= 17$). Droopwing was much more prevalent at the FP site where 20% of the population at risk was affected (Table 6). Ten of the 14 banded carcasses found at FP had succumbed to lead poisoning and 10 of the 12 banded chicks there that were still alive at the end of the study had paint chips in their proventriculi. Thus lead poisoning was confirmed in 20 of the 26 banded (droopwing) chicks or carcasses that were recovered by the end of the study. Nine banded chicks from the FP and six banded chicks from the other study areas were not found. We suspect that the sanitation crew collected the carcasses of some of these from the FP site and disposed of them before learning of the initiation of our study.

Drowning was characterized by the presence of water or sand in the trachea or bronchi, lungs that were wet, frothy, and pallid on cut surface, and the presence of excess fluid in the airsacs. Drowning was found only from the beach sites; three of the five drowned chicks had concurrent dehydration (Table 3).

Several chicks had mild infections of chiggers (*Womersia midwayensis*; Goff et al., 1989). Extensive, severe dermatitis associated with the chiggers was the apparent cause of death of three additional chicks. There was massive edema and focal hemorrhaging in the subcutis of the crura and abdomen. These carcasses had an unusual aromatic odor, generalized pallor, and pink rather than red blood. The more severe cases histologically exhibited necrotizing dermatitis and cellulitis with chronic organized edema, congestion, thrombosis, focal necrosis associated with ectoparasites and secondary bacterial infection.

TABLE 6. Final condition of Laysan albatross chicks with droopwing banded Sand Island, Midway Atoll.

Study area[a]	Banded droopwing chicks	Mean population at risk[b]	Prevalence of droopwing (%)
FC	2	52	4
FP	35	175	20
FT	2	82	2
AH	6	309	2
CB	1	—	—
FF	1	481	<1
AF	3	350	<1
RB	0	—	—
OS	1	—	—
Total	51		

[a] FC, Foundation Chapel; FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach; OS, Off-site.

[b] Mean population at risk derived from regression analyses of census data.

TABLE 7. Prevalence of hemorrhages in the foot webs of Laysan albatross chicks examined at Sand Island, Midway Atoll, in June and July 1987.

Study[a] area	n	Percent with hemorrhages	Average number of hemorrhages per affected bird			
FP	21	14[b]***	2.0[c]		B	
FT	3	67	2.5		B	C
AH	16	44	6.1		B	C
CB	22	68	11.0			C
FF	20	35[b]*	7.3		B	C
AF	18	78[b]**	8.1			C
RB	14	79[b]*	18.3	A		
OS	11	73	7.5		B	C

[a] FP, Foundation Proper; FT, Foundation Triangle; AH, Abandoned Housing; CB, Clean Beach; FF, Fuel Farm; AF, Antenna Field; RB, Reinforced Beach; OS, Off-site.

[b] Indicates probability that prevalence at a study site was different from the overall prevalence (χ^2 test, df = 1). * ($P \leq$ 0.10), ** ($P \leq 0.05$), and *** ($P \leq 0.01$).

[c] Similar letters indicate no significant ($P \leq 0.05$) difference among study sites (least significant difference test).

Five carcasses had elongate, pale papules or flattened nodules (3 to 14 mm diameter) on the plantar surface of the webs or phalanges. Some of the lesions were smooth, others were rough and fissured. The cut surfaces were solid, white, and proliferative. Microscopic examination of lesions from four affected chicks revealed superficial exudate, hyperkeratosis, marked proliferation of the stratum spinosum associated with cytomegaly, karyomegaly and eosinophilic intracytoplasmic inclusion bodies. These lesions were consistent with a diagnosis of avian pox. In all five cases, pox was a secondary finding seemingly unrelated to the cause of death.

The Reinforced Beach and the Antenna Field had the highest prevalence of web hemorrhages (Table 7). The Reinforced Beach also had the highest average number of web hemorrhages per bird. These hemorrhages were punctate and 3 to 5 mm in maximum diameter. On microscopic examination, focal hemorrhage and mild acute focal necrosis was seen in the dermis. An epidermal puncture was present in one section. Ectoparasite bites, perhaps ticks, were one possible explanation for these lesions.

Three carcasses from the Reinforced Beach had mild fibrinous airsacculitis. This condition was characterized grossly by small (1 mm) tightly adherent fibrinous plaques or by 1 to 2 cc of fibrinous exudate loosely adherent to the walls of the abdominal airsac or the pectoral diverticulum of the interclavicular airsac. Mic roscopic examination revealed microabscesses and fibrinous exudate containing many basophilic, branching, filamentous bacteria. *Nocardia asteriodes* was isolated from the lesions of two of the three chicks. One of these chicks had drowned and the other two simultaneously suffered dehydration, chigger infections and nocardiosis.

Nine carcasses had combinations of the aforementioned conditions, which precluded diagnosis of any one as the single proximate cause of death.

Laysan albatross chick survival rates for the 4-wk study period ranged from 0.875 at FP to 0.981 at FC (Fig. 2). Log-rank tests showed a significant difference in survival curves between FP and FC ($P <$ 0.05), AH ($P < 0.01$), FF ($P < 0.01$), and AF ($P < 0.01$). However, survival at FP was not significantly lower ($P = 0.10$) than

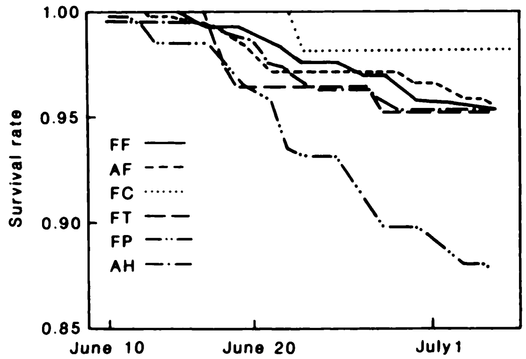

FIGURE 2. Survival of Laysan albatross chicks from 11 June to 5 July 1987, at five different study sites on Sand Island of Midway Atoll. Designations FC, FP, FT are Foundation Chapel, Proper, and Triangle, respectively; AH is Abandoned Housing, FF is Fuel Farm, and AF is Antenna Field.

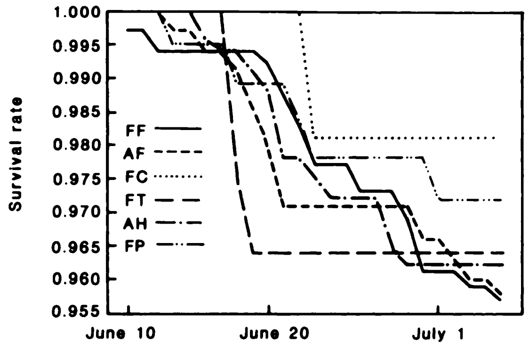

FIGURE 3. Survival, censored of human-related mortality, of Laysan albatross chicks from 11 June to 5 July 1987, at five different study sites on Sand Island of Midway Atoll. Designations FC, FP, FT are Foundation Chapel, Proper, and Triangle, respectively; AH is Abandoned Housing, FF is Fuel Farm, and AF is Antenna Field.

FT. Because sample sizes were relatively small at FT and the survival curve for FT was similar to AH, we believe that survival at FP was biologically different from FT.

Natural survival rates for the study period ranged from 0.957 at FF to 0.982 at FC (Fig. 3). Comparison of survival curves indicated no differences among the study sites (smallest $P > 0.40$). The average daily natural survival rate was calculated by combining natural survival rates from all sites. The daily average was estimated at 0.9984 (SE = 0.0005), which yields an estimated survival rate of 0.961 for the 25-day period of the study or 0.768 for a 165 day chick-rearing period. This latter estimate is obviously limited by the short time period of the study relative to the long chick-rearing period.

DISCUSSION

The absence of plastic-related mortality was unexpected, but is supported by other recent work (Furness, 1985; Ryan, 1986). Although ingested plastic was ubiquitous in albatross chicks at Midway Atoll in 1987, the average volume per bird was relatively low in comparison to earlier years (Fry et al., 1987; P. R. Sievert, L. Sileo, and S. I. Fefer, unpublished data) and it caused no mortality or mechanical lesions in the carcasses examined. In 1986, when the average volume was higher (46 cc versus 5 cc), ingested plastic caused fatal proventricular necrosis in one chick. Ingested plastic might be a greater problem in years when the mean volume ingested is higher.

The treatment of dehydration with electrolyte solution seemed effective if the chick's condition had not deteriorated too far. Although we assumed the recoveries following therapy resulted because many of the chicks were dehydrated, there were no controls for this work and the apparent recoveries may have been spurious. It seemed that chicks suffering from lead poisoning made partial recoveries and then stabilized, while those suffering only from dehydration recovered completely. Dehydration could be one of the important causes of the recurrent annual fledgling epizootics at Midway Atoll. There is a dearth of information about the pathology of this condition in birds in the veterinary diagnostic literature. Riddell (1987) mentions it as a common but poorly documented cause of death of poultry, and that it is associated with renal urate spherules, caused by precipitation and coalescence of uric acid. Siller (1981), in a classic review of avian renal pathology, stated that there is little information available on the pathology of birds that have "thirsted to death"; an association between dehydration and visceral gout was supported by some reports and negated by others. The pathogenesis of dehydration may include hemoconcentration, hyperthermia or dysuria. The microscopic lesions of dehydration-induced hemoconcentration may differ from those of dehydration-induced hyperthermia, which may explain why some of our diagnoses were equivocal. The explanation for the high prevalence of dehydration was unclear. Reduced feeding trips by parents may be involved. The albatross population at Midway Atoll has grown rapidly in recent years (Fefer et al., 1984) and may be approaching the limits of the food base. Parent birds that have to search longer for food may be unable to make enough return trips to the colony to rehydrate their chicks during hot weather even though they are providing ample food energy. Salt glands were not examined in this study. The potential role of the salt gland and osmolality of the nestling diet was unknown. Lead poisoning and trauma were directly associated with human presence on Sand Island. Lead poisoning occurred near abandoned housing where chicks ingested weathered paint chips, and vehicle trauma occurred in the immediate vicinity of roads. Because natural mortality rates were similar for all study sites, we concluded that human-related mortality was additive with natural mortality factors. The combined effects of lead poisoning and trauma may have a substantial effect on chick survival in localized areas. Both the high prevalence and the protracted clinical course of lead poisoning at FP increased the proportion of chicks with droopwing at FP in comparison to the other study areas. Although there may be some antagonistic association between dehydration and lead poisoning, it seemed more likely that the prevalence of dehydration was artificially lower at the FP site because a large number of chicks succumbed to lead poisoning and trauma at FP.

The other diagnoses were of passing interest. Drowning was often associated with underlying concurrent disease. Starvation, dehydration or behavioral dysfunction may have caused a chick to leave its nest site and enter the ocean before it was old enough to safely swim or fly. Epizootic pox with extensive, severe morbidity has occurred only irregularly in Laysan albatross chicks at Sand Island (unpublished data, National Wildlife Health Research Center, 6006 Schroeder Road, Madison, Wisconsin 53711, USA). The presence of mild avian pox in chicks examined in July may explain how the virus survived between epizootics. If the web hemorrhages were caused by tick or other ectoparasite bites, the high prevalence in carcasses from the Reinforced Beach may have reflected high ectoparasite populations there. Alternatively, chicks subjected to repeated irksome, or debilitating ectoparasite bites at their nest sites may have left and moved to the beaches. Apparently the ecological factors associated with web hemorrhages exhibit considerable spatial variation. Whether this variation is associated with vegetation characteristics warrants further investigation. Nocardiosis is an uncommon diagnosis in wild birds (Long et al., 1983). Its high prevalence at the Reinforced Beach at Midway deserves further study.

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