An Overview of Anthropogenic Causes of Avian Mortality

by Janelle Harden

Introduction

A wealth of published material indicates that much avian mortality around the globe can be attributed to human activities. A complete examination of the topic is beyond the scope of this paper, as any one of the four major categories of anthropogenic causes of avian mortality identified here easily could become the subject of an entire book. This study provides an introduction to the most common types of human-caused avian mortality and specific examples of each.

Methods

An examination of annual report data from Wildlife Rescue, Inc. of New Mexico (WRI) suggests that anthropogenic threats to avian survival may be more common than natural causes. Rehabilitation data, by the very nature of its collection, may be weighted toward anthropogenic causes. However, examination of the published literature confirmed that human-caused avian mortality is widespread and affects many millions of birds each year.

A review of the published literature from 1969 to 2000 was conducted using BIOSIS and SciSearch. The most common causes of avian mortality were identified and organized into four general categories: chemicals, collisions, commercial fishing, and domestic animals. A more specific search of the literature followed in order to identify representative cases to use as examples and to provide background on the issues surrounding each mortality category.

Background

The natural world presents many survival risks to avian populations. These include, but are not limited to, migratory mishaps, endemic diseases, natural predation, disturbances that lead to abandonment of nestlings, and climatic factors (e.g., inclement weather and cyclical disruptions such as El Niño).

Initial examination of 5 years of annual report data from WRI (Table 1) indicated that the majority of birds received by rehabilitators were admitted for care as the result of interaction with humans, directly or indirectly.

Forty-two (42)% of birds admitted to WRI are reported as "unknown cause." This is due, in part, to the fact that rehabilitators must depend on the finder for information. When asked, "Why do you think the bird was down?" the answer is frequently, "I don't know." In addition, many causes of avian mortality, including poisoning (direct or through biomagnification) and endemic diseases (i.e., salmonellosis in Fringillidae, trichomoniasis in Columbidae or their raptor predators, and avian cholera in waterfowl), are difficult to confirm, especially without access to laboratory equipment. Because of these factors, some categories presented may not reflect the true numbers involved.

Other causes of injury are obvious, (e.g., gunshot wounds, predator teeth marks, glue from sticky traps, and so forth). Often, the circumstances under which a bird is found reveal a great deal about the cause of mortality. Birds found in or on a roadside are likely to have collided with a vehicle; extensive impact injury such as neurological disorder(s) can provide confirmation. Birds found under a window are also probably strike victims. Birds found under power lines are likely to have experienced line-associated injuries. This review of the literature supports WRI findings and indicates that, around the world, great numbers of birds are killed annually by a variety of anthropogenic causes. Clearly, avian populations are seriously threatened by human activities.

Discussion

Anthropogenic causes of avian mortality have been organized into four discrete categories: chemicals, collisions, commercial fishing, and domestic animals. Some of the categories included here were divided into subcategories for further examina-

ABSTRACT: The natural world presents many survival risks to avian populations. Examination of 5 years of wildlife rehabilitation data from Wildlife Rescue, Inc. of New Mexico suggest that anthropogenic (human-caused) threats to avian survival are perhaps equally common; a review of the published literature confirms those suspicions. This study provides background on the most common types of human-caused avian mortality, along with specific examples of each.

KEY WORDS: anthropogenic, avian mortality, birds, commercial fishing, domestic predation, nontarget species, pesticides, tower strikes, window strikes

JANELLE HARDEN began rehabilitation in 1986 when she became a subpermittee under Wildlife Rescue, Inc. of New Mexico. A professional graphic artist and typographer for 30 years, she is now pursuing her undergraduate degree in the Department of Biology at the University of New Mexico, Albuquerque.

***J. Wildlife Rehab.* 25(1): 4–11**

tion. Topics left for another time include habitat destruction, toxic diatom blooms caused by contamination of waterways, the impact of fire ants, hunting, poaching, and legal scientific collecting.

Chemicals

For the purposes of this review, chemical causes of avian mortality include both pesticide use and contamination from mining and industrial activities. Of the two, problems related to pesticide use have a higher public profile (e.g., Rachel Carson's famous 1962 book, *Silent Spring*). Research on the nontarget hazards of pesticides have resulted in some regulatory attention, at least in the United States. A ban on DDT (dichloro-diphenyl-trichloroethane), the chemical once touted as key to eradicating malaria, was achieved. However, as quickly as "pesticides" are proved dangerous to nontarget species, and their use is brought under control, other innovative humans create new toxic molecules. Industrial and mining activities are also cause for concern. Mishaps such as the *Exxon-Valdez* oil spill in 1989 may garner worldwide attention, but in general the mainstream public remains ignorant of the environmental effects of mining and industrial activities.

Pesticides

Most modern pesticides fall into one of two large groups of chemicals: chlorinated hydrocarbons and organophosphates. The Smithsonian Migratory Bird Center website (2000) reports that more than 2.3 x 10^9 kg (5 x 109 lbs) of conventional pesticides are used annually on a global scale. The U.S. is responsible for more than 0.5 x 10^9 kg (1.2 x 109 lbs), or 20%, of the total volume. Areas of use include agriculture, forest and rangeland management, insect-borne disease control, and private use in homes and on lawns, gardens, and golf courses.

TABLE 1. CAUSE OF AVIAN INJURY/MORTALITY
WILDLIFE RESCUE, INC. OF NEW MEXICO
ANNUAL REPORTS 1994–98

Cause (N=2157)	% of Total	1994	1995	1996	1997	1998	Totals
NATURAL	22%						
Natural causes		–	80	36	143	6	263
Disease		–	1	6	21	3	31
Downed by storm		–	2	–	–	–	2
Fell from nest		10	48	26	56	12	152
Abandoned		13	–	–	1	8	21
Caught by predator		–	5	9	4	7	34
CAUGHT	35%						
Caught by cat		127	130	121	140	59	567
Caught by dog		32	31	32	20	15	130
Caught in building		17	9	10	7	6	49
Caught in trap		–	3	3	2	2	10
COLLISION	26%						
Collision w/ motor vehicle		48	43	29	33	9	162
Collision w/ train		–	3	–	1	1	5
Collision w/ window		15	29	28	44	16	132
Collision: unknown		51	40	45	52	26	223
CHEMICAL	1%						
Poisoned		3	6	1	4		14
Contact w/ oil		5	1	–	3		9
GENERAL	16%						
Human Disturbance		52	9	62	46	12	181
Nest disruption		63	–	–	–	–	63
Contact w/ fire		1	2	–	–	–	3
Gunshot		17	15	8	14	8	62
Totals: known causes (57%)		**479**	**478**	**720**	**600**	**180**	**2157**
Totals: unknown causes (43%)		256	449	243	326	323	1597

The Smithsonian estimates that about 672 million birds are exposed to pesticides on U.S. agricultural lands, and no fewer than 10%—67 million—are killed. An example outside the U.S. involved the deaths in 1995 of more than 20,000 Swainson's hawks (*Buteo swainsonii*) in Argentina due to monocrotophos, a pesticide used to kill grasshoppers (Woodbridge et al. 1995).

The organophosphate diazinon, an insecticide commonly used for lawn care, is a major cause of avian mortality. U.S. Environmental Protection Agency (EPA) data indicate "diazinon has caused the second largest number of total known incidents of bird mortality of any pesticide" (American Bird Conservancy [ABC] website 2000). Seven hundred (700) birds died in a single diazinon incident at a Long Island, New York, golf course in 1985 (ABC 2000). Although its use was restricted in 1990, at least 4.5 x 10^6 kg (10 x 106 lbs) of diazinon are still used annually in the U.S. Stone and Gradoni (1985) detailed 54 wildlife mortality incidents involving the use of diazinon. Kendall et. al. (1992) researched the application of diazinon on nine golf fairways in Bellingham, Washington; 85 American wigeon (*Anas americana*) died after grazing on a single fairway. Direct ingestion of pesticides is probably the greatest cause of mortality, according to the Smithsonian Migratory Bird Center (website 2000), but it is important to note that ingestion of residue may also occur while birds are preening, or bathing in or drinking tainted water.

Pesticides also can affect birds indirectly through reduction of available food and/or alteration of habitat. Insecticide-caused decreases in insect populations are particularly harmful to obligate insectivores; in addition, many other bird species rely on insects during the reproductive season to provide nestlings with protein for growth and development (Ehrlich et al. 1988; Martin et al. 1951). Beyond insecticides, herbicides reduce the vegetation in which many insects thrive, indirectly reducing insect populations. Herbicides also reduce plant cover used for nest concealment and avoidance of predators by galliforms, anseriforms, and other ground-nesting birds.

Mortality studies are common in the published literature. Dietrich et al. (1995) describe the death of buzzards (*Buteo buteo*) from fields treated with granular carbofuran. Elliot et al. (1996) analyzed 278 bald eagle (*Haliaeetus leucophalus*) carcasses for PCBs and organochlorine pesticides. Ohlendorf et al. (1981) examined 72 dead or moribund herons associated with organochlorine residues. Finally, Littrell (1988) investigated waterfowl and raptor losses in California rice fields treated with the carbamate carbofuran.

The American Bird Conservancy estimates that 62–92% of bird carcasses are scavenged by predators within 24 hours, and those that remain are rarely found because they are concealed in underbrush. These estimates suggest that the actual number of birds killed cannot be accurately determined. Additionally, although no data were found, scavenger predators killed through biomagnification is another source of avian mortality.

Mining and Industrial Contamination

While open pits and slag piles are commonly recognized remnants of mining, other byproducts are less well known. Heap leach gold mines collect wastewater in huge holding ponds laden with cyanide, some of which cover as much as 24 ha (60 acres). In addition to local bird populations, these large ponds attract high numbers of migratory species. A U.S. Fish and Wildlife Service (USFWS) Bulletin (website 2000) report refers to law enforcement officers investigating bird deaths at Colorado, Nevada, South Dakota, and Montana gold mines. Hundreds of birds died at a single Montana location.

Industrial activity also takes its toll. Acute fluoride poisoning from a facility in Oklahoma caused severe gastric and intestinal hemorrhage, and ultimately death, in 97 migratory snow geese (*Chen caerulescens*). Andreasen and Stroud (1987) found the on-site waste lagoons were laden with bromine, boron, and fluoride.

Crude oil spilled into ocean waters is the most likely of all chemical causes of avian mortality to receive widespread media attention, particularly if the volume of oil lost is large. The details surrounding avian mortality attributed to oil spills could fill many volumes and are beyond the scope of this review; one example is included.

As a result of the 1996 M/V Citrus oil spill, 1765 bird carcasses washed onto the beaches of St. Paul Island, Alaska, and a total of 1930 birds were impacted (Flint et al. 1999). The report did not provide details on the 165 birds described as "impacted." They were not included in the death count, and it is not known if they were rehabilitated and released. Fifty-four (54)% (867) of all birds affected were king eiders (*Somateria spectabilis*).

Oil creates serious problems on land as well, in the form of oil pits, also termed "contained oil." The USFWS began an initiative in 1987 to study the problem. Special Agent Robert C. Lee (pers. comm.) reports that the service estimated that 500,000 migratory birds (including 100,000 waterfowl) were being killed annually in "contained oil" in the oil production areas of Oklahoma, New Mexico, and Texas (Region 2, which also includes Arizona.) Lee stated this was a "very conservative estimate" derived from an intensive BLM research project in the early 1980s. The 500,000 mortalities reflect an annual toll greater than the 300,000 estimated to have died during the more recent *Exxon Valdez* oil spill. Lee reports that many of these threats have subsequently been eliminated through cooperation with the various state agencies, many oil producers, and many hundreds of criminal cases—but this success concerns Region 2 only: just last year the USFWS discovered a situation in Arkansas that is worse than anything seen thus far.

Collisions

For the purpose of this review, the collision category was separated into two subcategories: collisions with vehicles and collisions with structures. Road-kill mortality has often been investigated. Additionally, the effect of buildings and transmitter towers on birds has been tracked over many years. Until quite recently, however, these studies did not received widespread attention.

Collisions with vehicles

People who bring birds struck by vehicles into rehabilitation centers often express surprise that the bird didn't know how to avoid being hit. WRI avian rehabilitation records include many impact injuries and deaths as a result of collision with vehicles. On an annual basis, falconiform (hawks, falcons, etc.) and strigiform (owl) species appear to be most susceptible, possibly because they hunt along roads and highways. Strigiforms are generally nocturnal, which may add to their risk of collision, as they can be blinded by the headlights of on-coming vehicles. A good example involves a study done by the New Jersey Audubon Society, Cape May Bird Observatory. Loos and Kerlinger (1993) monitored a 145 km (90 mi) stretch of road in southern New Jersey over a 10-year period. Two hundred and fifty (250) road-killed raptors were found, representing six hawk and six owl species. Resident eastern screech-owls (*Otus asio*) and migrating northern saw-whet owls (*Aegolius acadicus*) were the most frequent victims. The researchers collected data from mid-October to early April, a prime window of migratory activity.

Massemin and Zorn (1998) found owls to be frequent victims of road kill along a 150 km (93 mi) stretch of highway in northeastern France. Of the 187 strigiform species collected during the 1990–94 study, 148 were barn owls (*Tyto alba*), 15 were long-eared owls (*Asio otus*), and 10 were tawny owls (*Strix aluco*). Sixty-four (64)% of the mortalities occurred along embanked stretches that crossed open fields—a sobering reminder of negative "edge effects" of habitat fragmentation (also see Mumme 1996).

Automobiles are not the only vehicles that affect avian survival. WRI records include collisions with trucks and even trains. Birds and airplanes are a dangerous combination, for both parties (USDA Environmental Assessment Report 1999). The U. S. Air Force funds a program that identifies birds by the feathers remaining inside jet engines or on other strike areas. The Bird/Wildlife Aircraft Strike Hazard Team (BASH) is located at the Air Force Safety Center, Kirtland AFB in Albuquerque, New Mexico (M. Heacker-Skeans, Smithsonian Institution 2001, pers. comm.). BASH involves two main activities: (1) Determining which birds are involved in bird strikes allows airfield personnel to better assess, predict, and ultimately prevent bird-aircraft collisions, and (2) Resulting airfield habitat management to discourage birds from frequenting the area is a key part of bird strike prevention. Skeans added that while there are many conservation activities on military installations, prevention is the primary goal of the bird strike issue.

Collisions with structures

Bird collisions with structures is another situation the public finds hard to understand; buildings and transmitter towers are so large it seems implausible they would not be seen by birds. What is generally not understood is that these structures look very different through a bird's eyes, especially when lit at night or when sunlight turns windows into mirrors.

During certain daylight hours, windows may reflect the sky in such a way that there appears to be open air space rather than a solid barrier. Klem (1990) reports that the annual mortality resulting from window collisions in the U.S. alone is estimated to be 97.6–975.6 million birds. Collisions at just one house during two 4-month periods in consecutive years from September to December resulted in 26 and 15 fatalities, respectively. "At least one out of every two birds were killed when striking the windows" (Klem 1990). Klem reports that both small and large birds seem equally at risk from mortality caused by window strikes.

Klem does not indicate whether birds that survived the collision (the other "one out of every two birds") and flew away were subsequently monitored. WRI experience indicates that many birds with window-strike injuries die shortly thereafter if corticosteroid treatment is not administered. This suggests that many birds that flew away may have died later. The confirmed mortality rate reported by Klem could thus be less than half the actual (eventual) mortality rate.

At night, lighted buildings become hazardous for birds, especially during seasonal migrations. Many migratory birds navigate by the stars (Gill 1995), and thus many species are attracted to lights, particularly those of large office buildings and building complexes. The Fatal Light Awareness Program (FLAP) of Toronto, Ontario, Canada, has conducted some of the few long-term studies of bird mortality from building strikes. Many of Canada's 250 migratory bird species are in decline, and FLAP found that approximately 10,000 birds are killed or injured annually in Toronto's downtown core alone. FLAP's Michael Mesure (FLAP website 1999) reports that more birds are killed this way each year than died in the *Exxon Valdez* oil spill. Many of these species are known to be in long-term decline, with some already designated as threatened.

It has become clear that structures other than buildings are also responsible for high avian mortality—communications towers in particular. Researchers agree the taller the tower, the greater the strike threat to birds, particularly night-migrating songbirds, although the tower's location can play a role as well.

The tower strikes presented in Table 2 reflect mortalities over periods of from 12 to almost 40 years. An unpublished report details an event in southwestern Kansas; a 128 m (420 ft) tower killed an estimated 5000–10,000 Lapland longspurs (*Calcarius lapponicus*) during the night of 22 January 1998 (M. C. Thompson 2000, pers. comm).

The Federal Aviation Administration (FAA) considers any tower 60 m (200 ft) or higher to be a potential aviation hazard. Shorter towers can present a risk to migrating birds if they are placed on hillsides. New Mexico alone has 370 communication towers, ranging from 60–245 m (200–800 ft). Since the Rio Grande River, which transects New Mexico, is one of five major migratory routes in the United States, these communication towers represent a significant threat to many migratory species. Similar conditions exist along the other four U.S. migratory routes.

Electrical power supply structures also contribute to avian mortality. McCrary et al. (1986) mention a solar energy power plant, and Osborn and Shillinger (1996) describe raptor mortality from wind turbines. However, the vast majority concern collisions with power lines.

Podolsky et al. (1998) illustrates this problem in relation to Newell's shearwaters (*Puffinus auricularis newelli*) on the island of Kauai, Hawaii. In eastern and southern Kauai, where approximately 3,000 shearwater pairs breed, the Save Our Shearwaters (SOS) program estimated that at least 70 breeding adults and 280 subadult shearwaters die each year mostly as the result of power line collisions. The adult shearwaters were killed by lines stretched across river valley flyways used to pass to and from breeding colonies. Fledglings often were grounded by what

SOS terms "fallout," whereby fledglings successfully fly to the sea upon leaving the nest, but are then attracted back to land by coastal lights. SOS rehabilitates these individuals when possible. Dark-rumped petrels (*Pterodroma phaeopygia sandwichensis*) are also killed in the same small area (Cooper and Day 1998). Because the birds fly to the ocean each morning and return inland each night, these power lines present a daily mortality risk, particularly during the summer months covered by the study. Most deaths occurred during the morning flights to the sea. (No data were found concerning mortalities outside the summer months.)

Even a limited review of the published literature indicates how widespread power line collisions have become. Specific cases are described, such as the electrocution in an urban population of Harris' hawks (*Parabuteo unicinctus*) (Dawson and Mannan 1995); electrocution of golden (*Aquila chrysaetos*) and bald eagles (*Haliaeetus leucocephalus*) in areas of high prey concentration (Woodridge and Garrett 1993); and wading bird mortality at power lines in coastal South Carolina (Savereno et al. 1996). Cranes (*Grus canadensis* and *Grus americana*), waterfowl, and other birds suffer high mortality at power lines in the San Luis Valley of Colorado (Brown and Drewein 1995).

Other countries around the world report similar mortality. Twenty-eight (28) endangered Dalmatian pelicans (*Pelecanus crispus*) were killed by power line collisions in Porto-Lago, Greece (Crivelli et al. 1988); 10 species (including herons, egrets, pelicans, gulls, and terns) were represented in the 611 deaths at a power transmission line in northeastern Venezuela (McNeil et al. 1985); and collisions with power lines appear to be a source of systematic mortality for tetraonids (grouse) in boreal forest habitats in central Norway (Bevanger 1995).

Commercial Fishing

According to Ligon (2000), fully one-third of Class Aves is adaptively tied to water (fresh or sea). The entire lifecycle of some avian species is spent at sea, with the exception of infancy and reproduction. Many of these species are impacted by commercial fishing activities.

With the exception of coastal communities, the public is generally unaware of the scope of commercial fishing, especially commercial operations based in Scandinavia and the Pacific Rim. For the purposes of this review, the commercial fishing category has been divided into three subcategories: gillnet fishing, longline fishing, and drift-net fishing. Each method poses threats to avian survival.

Gillnet fishing

Gillnets are generally 15 km-long (9 mi) nets made from varying mesh sizes of monofilament. Set near dusk and retrieved near dawn, the nets form a curtain that hangs approximately 8 m (26 ft) into the water from the ocean surface.

In 1991 DeGrange and Day published results from an assessment of Japanese gillnet salmon fishing in the north Pacific Ocean. Fishing is done both by land-based vessels that trawl the shorelines and by offshore "mothership" vessels. In 1977 it was estimated that the offshore vessels killed 151,000 seabirds annually. Suspecting that mortality from land-based fisheries would also be high, Sano (1978; in Degrange and Day 1991) estimated, from a limited sampling, that more than 160,000 seabirds may be killed annually along shorelines.

The birds, searching for prey themselves, follow commercial fishing vessels and become entangled in nets that may trail the ships by as much as 64 km (40 mi). DeGrange and Day recorded 16 species of seabirds, predominantly shearwaters (*Puffinus sp.*), followed by tufted puffins (*Fratercula cirrhata*), and thick-billed murres (*Uria lomvia*). Of particular concern are the implications for breeding populations these data reveal; all short-tailed shearwaters (*Puffinus tenuirostris*) mortalities examined in 1984 were immature, and 65% were female.

Longline fishing

This fishing method is used predominantly by the tuna industry. Longline vessels drop a main line up to 100 km (62 mi) in length, from which extend 40 m (130 ft) unweighted branches. Collectively, 2400 to 3000 barbed, steel hooks are attached to these lines. The hooks are baited with whole fish and squid approximately 300 mm (12 in) in length—sufficient size to attract albatrosses.

In a 1991 report on a decline in some albatross populations, Brothers described the deaths of 45 albatross during seven voyages of a Japanese longline vessel off Tasmania's east and south coasts. Of the 45 albatross Brothers collected, 32 were identified to species, including 14 black-browed albatross (*Diomedea melanophris*).

Japanese vessels travel south of latitude 30ºS in the Southern Ocean to fish for tuna (*Thunnus* spp.), an area where albatross congregate. Of the 14 species that compose the albatross

TABLE 2. USA TOWERKILL SUMMARY

Location	Tower Height	Study Period	No. of Spp.	Total No. of Birds	Total Years	Avg. No. Birds Killed/Year
Nashville, Tenn	1368'	1960–97	112	19,800[1]	37	537
Tallahassee, Fla.	1010'	1955–80	190	42,386[2]	25	1695
Eau Claire, Wisc.	1000'	1957–94	123	121,560[1]	37	3285
Elmira, N.Y.	850'	1963–83	n/a	7,500[1]	20	375
Weston, W. Va.	529'	1978–86	58	841[3]	8	105

[1] checked only during migration [2] checked year-round [3] checked irregularly during migration
Source: Fatal Light Awareness Program (FLAP), Toronto, Ontario, Canada

family (Diomedeidae), 10 are confined to the Southern Ocean and usually come ashore only to breed on remote islands. Longline hooks and branchlines quickly sink to a depth of 60–150 m (195–490 ft), but the birds are caught on the baited hooks during the brief time the longlines are ejected from the vessel. Some birds die immediately, some trapped on the hooks die during hauling, and some are eaten by fish or torn off hooks during retrieval. Weimerskirch and Jouventin (1987; in Brothers 1991) described albatross that escaped the hooks only to die on their nests from wounds received. This suggests that actual mortality rates are considerably higher than the data indicate; indeed, Brothers offers a conservative estimate of 44,000 albatross killed annually in southern oceans.

The Wildlife Conservation Society website (2000) also lists black-footed (*Phoebastria nigripes*) and Laysan (*Phoebastria immutabilis*) albatross as victims of longline fishing. Additionally, the society reports that more than 55 seabird species are killed annually, including northern fulmars (*Fulmarus glacialis*) and kittiwakes (*Rissa* spp.).

In 1996 Cherel et al. found that diving birds were the only avian species caught by longline fisheries. The research team was investigating avian mortality from longline fishing in the vicinity of South Georgia and Kerguelen islands of the South Atlantic Ocean, both of which are important internationally as breeding areas for procellariform birds. Gales et al. (1998) discuss the impact of Japanese longline fishing within the Australian Fishing zone, the same area studied by Nigel Brothers. Estimating seabird mortalities of 1000–3500 per year, they concur that actual numbers are probably far greater because of the many which escape the hooks, only to die later, uncounted.

Drift-net fishing

This form of fishing has received a great deal of negative publicity due to the high mortality rates of nontarget species such as dolphins (*Odontoceti* spp.), other cetaceans, and various pinnipeds, including seals and walrus (*Odobenus rosmarus*). Unlike gillnets, drift-nets float only 8–15 m (25–50 ft) below the surface. Made of fine nylon mesh, they extend from 2–90 km (1.2–56 mi) beyond the vessel and are described as "walls of death" by the Earthtrust DriftNetwork Program's website (2000).

Earthtrust's website also explains that many nets are lost: referred to as "ghost" nets, they continue to "fish" as they float at sea. They eventually become so heavy from the weight of their victims, they sink or wash ashore where they entangle both birds and mammals.

The Earthtrust site states drift-netting is widely considered to be "the most destructive fishing technology ever devised by human-kind," and that millions of seabirds are killed in these nets annually. The website offered no data or references, but a literature search did provide one pertinent article.

Piatt and Gould (1994) observed the effects of commercial squid and drift-net fishing in the North Pacific Transitional Zone. From August–December 1990, 26 *Synthiliboramphus* murrelet deaths were attributed to drift-nets. The American Ornithologists' Union (AOU) Checklist (1999) lists three species of *Synthiliboramphus* murrelets. The Piatt and Gould article itself was unavailable, and the abstract does not clarify whether the 26 deaths involved one, two, or all three species. It does mention that "Japanese" murrelets are endangered and that "high-seas drift-net fishery mortalities represent a significant portion of the total world population of this rare and endangered species."

Although it might at first appear that the majority of avian mortalities were due to fishing vessels from Japan, a BBC News report (website 2000) states that drift nets "are used mainly by British, French, and Irish fisherman in the North Atlantic and the Bay of Biscay." The Earthtrust website says fleets embark not just from Japan, but also from South Korea and Taiwan, and operate in the Pacific, Atlantic, and Indian Oceans. Regulation of commercial fishing activities known to cause avian mortality is difficult, in part, because of the large number of countries involved.

Domestic Animals

Domestic cats (and occasionally dogs) account for a significant number of avian deaths each year. The American Bird Conservancy (ABC) developed its Cats Indoors! campaign in an attempt to educate people across the U.S. about the benefits, to both cats and birds, of keeping cats indoors. Many research papers on this subject are abstracted on the ABC website (2000); unfortunately, the author was not able to find copies of the full journal articles for this review.

A study done in England by the Mammal Society (website 1998) examined capture or kill records of 964 cats. During five months in 1997, the cat kills were in excess of 14,000 prey items. While this report did not specify how many were birds, the ABC (website 2000) mentions studies over the last 50 years indicating approximately 20–30% of cat kills are birds. By estimating the British domestic cat population at 7.5 million, the Mammal Society suggests at least 300 million birds and mammals are killed annually. This number becomes even more enormous when one considers the uncounted kills (those prey items not recovered), as well as the kills of the 800,000 feral cats estimated to live in Great Britain.

The ABC (website 2000) suggests that habitat fragmentation caused by human development provides domestic cats with easier access to wildlife forced to live on smaller and smaller parcels of land. Cats also compete with native predators by reducing species that would normally support wild predators. Rodents taken by domestic cats are unavailable to raptors, cuculiforms, and corvids. Research into the negative impact of domestic cats on native predators is fraught with difficulties, so an assessment of the problem inevitably involves speculation. Cole Hawkins, in a 1998 paper said, "Cats at artificially high den sites, sustained by supplemental feeding, reduce abundance of native rodent and bird populations" (ABC website 2000).

The introduction of domestic cats onto islands where native bird populations have evolved in the absence of mammalian predators has resulted in the elimination of entire populations of birds. New Zealand is the most notable example of such an island where avian species have not developed defense mechanisms against this kind of predation. (ABC website 2000)

WRI data indicate the majority of cat-caught birds die, even when no external injuries are visible (unpublished). Cat bites result in a warm, dark, narrow, hard-to-clean environment that is perfect for rapid multiplication of microorganisms. Cat saliva carries some very virulent bacteria, including a gram negative bacillus referred to as *CSD bacillus* or *Bartonella henselae* (Busen and Scarborough 1997). Cats' teeth generally do less damage to the tissues than dogs', but their bites are generally the more infectious. Cat- and dog-caught birds also exhibit bone fractures, soft tissue damage, and internal hemorrhage.

Summary

The anthropogenic causes of avian mortality are varied enough to exceed the scope of a single paper. Topics not addressed here include the impact of fire ants on Northern bobwhite (*Colinus virginianus*) chick mortality, and seabird mortality at Cabo San Lucas, Mexico due to toxic diatom blooms caused by contamination of waterways (Barker 1997). In addition, the range of effects of habitat destruction, illegal hunting/poaching, and even legal collecting practices by the scientific community have not been explored herein.

Birds of every order are threatened by direct and indirect human activity on a global scale. The categories and studies discussed in this review only touch on countless examples available in the literature. Action is needed in a variety of areas if the planet's avifauna is to be conserved at sustainable levels for the enjoyment of future generations and for the long-term health of ecosystems worldwide.

Acknowledgements

John P. Hubbard, J. David Ligon, Kieran Lindsey.

Note

Common and scientific names, when not supplied by the authors, are taken from the American Ornithologists' Union 1999 Checklist of North American Birds.

References

Literature Cited

Barker, R. 1997. *And the waters turned to blood: The ultimate biological threat*. New York: Simon & Shuster.

Bevanger, K. 1995. Estimates and population consequences of tetraonid mortality caused by collision with high tension power lines in Norway. *J. Applied Ecology* 32(4): 745–53.

Brothers, N. 1991. Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biol. Cons*. 55: 255–58.

Brown, W. M. and R. C. Drewein. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. *Wildlife Society Bull*. 23(2): 217–27.

Busen N. H., and T. Scarborough. 1997. Diagnosis and management of cat-scratch disease in primary care. *Internet J. Advanced Nursing Practice*. 1(2).

Cooper, B. A., and R. H. Day. 1998. Summer behavior and mortality of dark-rumped petrels and Newell's shearwaters at power lines on Kauai. *Coln. Waterbirds* 21(1): 11–19.

DeGrange, A. R., and R. H. Day. 1991. Mortality of seabirds in the Japanese land-based gillnet fishery for salmon. *The Condor*. 93: 251–58.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. *The birder's handbook*. New York: Simon & Schuster.

Elliott, J. E., L. K. Wilson, K. W. Langelier, and R. J. Norstrom. 1996. Bald eagle mortality and chlorinated hydrocarbon contaminants in livers from British Columbia, Canada, 1989–1994. *Environ. Pollut*. 94(1): 9–18.

Gill, F. B. 1995. *Ornithology*, 2nd ed. New York: W. H. Freeman and Company.

Kendall, R. J., L.W. Brewer, R. R. Hitchcock, and J. R. Mayer. 1992. American wigeon mortality with turf application of Diazinon AG500. *J. Wildife Diseases*. 28(2): 263–67.

Ligon, J. D. 2000. Ornithology 486; University of New Mexico. Lecture notes, 26 Jan. 2000.

Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. *American wildlife and plants: A guide to wildlife food habits*. Toronto: General Publishing Company.

Piatt, J. F., and P. J. Gould. 1994. Postbreeding dispersal and drift-net mortality of endangered Japanese murrelets. *Auk*. 111(4): 953–61.

USDA Environmental Assessment (EA) 1999. PreDecision. Bird damage management in the New Mexico Wildlife Services Program. USDA Animal and Plant Health Inspection Service (APHIS); Wildlife Services (WS).

Wildlife Rescue, Inc. of New Mexico. 1994–98. Annual Reports filed with the U.S. Fish and Wildlife Service.

Woodbridge, B., K. K. Finley, and S. T. Saeger. 1995. An Investigation of the Swainson's hawk in Argentina. *J. Raptor Res*. 29: 202–04.

Abstracts Cited

Andreasen, J. K., and R. K. Stroud. 1987. Industrial halide wastes cause acute mortality of snow geese in Oklahoma [USA]. *Environ. Toxicol. Chem*. 6(4): 291–94.

Cherel, Y., H. Weimerskirch, and G. Duhamel. 1996. Interactions between longline vessels and seabirds in Kerguelen waters and a method to reduce seabird mortality. *Biol. Conserv*. 75(1): 63–70.

Crivelli. A. J., H. Jerrentrup, and T. Mitchev. 1988. Electric power lines: A cause of mortality in *Pelecanus crispus Bruch*, a world endangered bird species, in Porto-lago, Greece. *Coln. Waterbirds* 11(2): 301–5.

Dawson, J. W., and R. W. Mannan. 1995. Electrocution as a mortality factor in an urban population of Harris' hawks. *J. Raptor Res*. 29(1): 55.

Deitrich, D. R., P. Schmid, U. Zweifel, C. Schlatter, S. Jenni-Eiermann, H. Bachman, U. Buhler, and N. Zbinden. 1995. Mortality of birds of prey following field application of granular carbofuran: A case study. *Arch. Environ. Contam. Toxicol*. 29(1): 140–45.

Flint, P. L., A. C. Fowler, and R. F. Rockwell. 1999. Modeling bird mortality associated with the *M/V Citrus* oil spill off St. Paul Island, Alaska. *Ecol. Model*. 117(2–3): 261–67.

Gales, R., N. Brothers, and T. Reid. 1998. Seabird mortality in the Japanese tuna longline fishery around Australia, 1988–1995. *Biol. Conserv*. 86(1): 37–56.

Hawkins, C. 1998. Impact of a subsidized exotic predator on native biota: Effect of house cats (*Felis catus*) on California birds and rodents. PhD dissertation, Texas A & M University, College Station.

Klem, D. Jr. 1990. Collisions between birds and windows: Mortality and prevention. *J. Field Ornithol*. 61(1): 120–28.

Littrell, E. E. 1988. Waterfowl mortality in rice fields treated with the carbamate, carbofuran. *Calif. Fish & Game*. 74(4): 226–31.

Loos, G. and P. Kerlinger. 1993. Road mortality of saw-whet and screech-owls on the Cape May peninsula. *J. Raptor Res.* 27(4): 210–13.

Massemin, S., and T. Zorn, 1998. Highway mortality of barn owls in northeastern France. *J. Raptor Res.* 32(3): 229–32.

McCrary, M. D., R. L. McKernan, R. W. Schreiber, W. D. Wagner, and T. C. Sciarotta. 1986. Avian mortality at a solar energy power plant. *J. Field Ornithol.* 57(2): 135–41.

McNeil, R., S. Rodriguez Jr., and H. Oeullet. 1985. Bird mortality at a power transmission line in northeastern Venezuela. *Biol. Conserv.* 31(2): 153–66.

Mumme, R. L. 1996. Roadside mortality in the Florida scrub jay. Implications for demography and conservation. *Bull. Ecol. Soc. Am.* 77(3): 316 (Suppl. Part 2).

Ohlendorf, H. M., D. M. Swineford, and L. N. Locke. 1981. Organochlorine residues and mortality of herons. *Pesticides Monitoring J.* 14(4): 125–35.

Osborn, J. G., and G. L. Shillinger. 1996. Wind turbines and raptor mortality: Risk reduction through the application of GIS and remote sensing technologies. *Bull. Ecol. Soc. Am.* 77(3): 336 (Suppl. Part 2).

Podolsky, R., D. G. Ainley, G. Spencer, L. Deforest, and N. Nur. 1998. Mortality of Newell's shearwaters caused by collisions with urban structures on Kauai. *Coln. Waterbirds* 21(1): 20–34.

Saverno, A. J., L. A. Saverno, R. Boettcher, and S. M. Haig. 1996. Avian behavior and mortality at power lines in coastal South Carolina. *Wildlife Society Bull.* 24(4): 636–48.

Stone, W. B., and P. B. Gradoni. 1985. Wildlife mortality related to the use of diazinon. *Northeast Environ. Sci.* 4(1): 30–38.

Woodbridge, B., and M. Garrett. 1993. Electrocution mortality of golden and bald eagles in an area of high prey concentration. *J. Raptor Res.* 27(1): 85.

Websites Cited

Note: If no date was given for the most recent update of information, citations are shown as "2000" for the year this paper was written.

American Bird Conservancy website. 2000. http://www.abcbirds.org/pesticideindex.htm. FAQ: Pesticides and Birds.

American Bird Conservancy Cats Indoors! website. 2000. http://www.abcbirds.org/catsindoors.htm.

AOU. 1999. AOU Checklist of North American Birds. Downloaded from website: http://pica.wru.umt.edu/aou/birdlist.html.

BBC News website. 1997. http://news1.thls.bbc.co.uk/low/english/uk/ newsid_18000/18728.stm. UK: Britain backs drift net ban.

Earthtrust website. 2000. http://www.earthtrust.org/dnw.html. DriftNetwork Program.

Mammal Society website. 1998. http://www.mammal.org.uk/catkills.html . Look what the cat's brought in!

Mesure, M. 2000. Fatal Light Awareness Program website. http://www.flap.org

Smithsonian Institute, Smithsonian Migratory Bird Center website. 2000. http://www.si.edu. When it comes to pesticides, birds are sitting ducks.

U.S. Fish and Wildlife Service website. 2000. http://news.fws.gov/cyanide3.html. Bulletin: Service, industry partnerships protect migratory birds from cyanide mine wastes.

Wildlife Conservation Society website. 2000. http://www.wcs.org/news/magazine. Online magazine for March/April 2000.

To Contact the Author

Janelle Harden
(Wildlife Rescue, Inc. of New Mexico)
2710 San Rafael SE
Albuquerque, NM 87106-3031
Tel: 505/256-7607
E-mail: jharden@nmia.com

NEO-REHABILISMS...

acclimbatized
a young woodpecker who's ready to go

great horned dowl
a perch that needs cleaning

mallard
a duck that likes to shop

nuthatch
a small climbing bird; the destination of a rehabber with more than 30 nestlings

Cream of the Crop: An Improved Handrearing Diet for Hatchling and Nestling Columbids

by Astrid MacLeod and Janine Perlman

Introduction

All young animals require “baby foods”—easily digested nutrients that promote growth. Each species has evolved to provide particular baby foods using a specific feeding strategy, and while strategies may seem diverse, they have interesting commonalities.

Neonate mammals drink milk, which provides water, protein, energy, minerals, and other essential nutrients. Many birds feed insects or other prey to their young; insects and prey also provide moisture, protein, energy, and essential nutrients. Other birds regurgitate partially digested food to their young. Columbids (doves and pigeons), however, have evolved to something entirely different and much more similar to mammals.

The plant-based diets of adult columbids do not offer the nutrients required for growth, in the same way they don’t offer passerines those nutrients. To provide nutrient-dense, high-protein food for their young, doves of both sexes secrete crop milk. Crop milk has a pudding-like texture and is about 70% water. The remaining portion is composed of approximately 50% protein, 45% fat, and 5% ash. Carbohydrates are present in mere trace amounts. Crop milk is actually similar in composition to the milks of some mammals, but not to those of cows, goats, etc. Such milks should *not* be fed to columbids.

The process that produces crop milk is also, in many ways, similar to lactation in mammals.

Prolactin is a hormone secreted by the pituitary gland of all vertebrates. It influences the onset of lactation in mammals and in columbids (Riddle et al. 1933), and it stimulates parental behavior in birds and mammals.

When parent columbids brood (incubate) their eggs, prolactin secretion is stimulated. At approximately the sixth day of incubation, changes begin to occur in the crop lining, and by the 13th day, the lining has thickened and is full of blood vessels. The cells of the crop lining accumulate protein and fat, and at this point they are described as “milk-laden.” These milk-laden cells are shed into the crop cavity (lumen) and are then regurgitated to the young.

This phenomenon was described at least as early as 1786 (Hunter, as described in Reed et al. 1932). The great physiologist Claude Bernard actually analyzed the macronutrients of crop milk in 1859 (op. cit.), and his findings have been confirmed in numerous studies since.

While different species feed crop milk in its *pure* form for differing periods of time, it is fed to the squab, pure and then with seed or grain, for a total of 2–3 weeks. At first, the parent birds only slough milk-laden cells when the crop is empty; this ensures that the milk is not diluted by adult foods. Later, as the squab develops and matures, the milk is combined with other foods that the parent eats.

Crop milk is rich in the nutrients essential to extremely fast-growing squabs. Its constituents—high-quality (animal-based) protein for body mass and fat for caloric requirements—are present in *exactly* the amounts and kinds to which squabs have evolved. Feeding them a diet that is significantly different results in impaired growth, illness, and death. Rehabilitators have great difficulty in successfully raising very young columbids; in many cases, that is surely the result of inadequate food, consistent with the very common incidence of crop impaction, poor weight gain, and droppings of undigested food.

Plant foods do not support normal squab growth; the quality and quantity of their protein and fat are inadequate. Young squabs do no better on grain-based diets than do songbird babies raised on bread.

In addition, even if they were nutritionally adequate, seeds and grains are unavailable to the nestling squab, because it cannot break down or digest the grains and seeds of the adult diet. Its gizzard is not strong enough for the necessary grinding,

ABSTRACT: In nature, young doves are fed crop milk by their parents. This article examines crop milk synthesis and constituents and traditional hatchling/nestling handraising diets. It presents a new crop milk replacer that, unlike commonly used foods, is formulated so that it closely resembles the crop milk made by adult columbids. Also discussed are crop problems, feeding methods, and weaning to adult diet.

KEYWORDS: avian nutrition, Columbidae, Columbid nutrition, dove, pigeon, crop milk replacer, nestling pigeon diet, crop milk analysis, squab hand-rearing diet, crop impaction, tube feeding

ASTRID MACLEOD is a writer and experienced avian rehabilitator who works for Manitoba Conservation. She has researched avian nutrition for much of the past decade.

JANINE PERLMAN, an avian rehabilitator, has a PhD in biology and has conducted laboratory research in biochemistry and molecular genetics for twenty years.

***J. Wildlife Rehab.* 25(1): 12–17**

and it does not possess the digestive enzymes needed for starches. Feeding a nestling a plant-based diet is analogous to feeding a fawn nothing but alfalfa from the moment of its birth. Neither animal is equipped, when young, to survive and grow on its adult diet.

All studies agree that crop milk is about 70% water and 30% solids, and that there are almost no carbohydrates present. Earlier studies report that, of the dry matter, about 2/3 is protein and 1/3 is fat (Bernard, in Reed et al. 1932; Hegde 1973; Ferrando et al. 1971), while later ones report that crop milks of Carneaux pigeons (Kirk Baer 1999) and ring-necked doves (Harmuth et al. 1977) have nearly equal amounts of protein and fat.

Protein

Unlike passerines, doves do not hatch with significant levels of proteases—in fact, research shows that they hatch with very low levels of digestive enzymes (C. Kirk Baer, pers. comm.). Approximately 17% of the protein in crop milk is in the "predigested" form of free amino acids (Kirk Baer 1999); this may help obviate the initial need for the squab's own digestive capabilities.

Fat

Crop milk is about 35% fat on a dry milk basis, which provides calories for the metabolic demands of a fast-growing bird. The energy-dense food allows the parents to go off on extended foraging trips, and the squabs need to be fed far less frequently than do passerines.

The fatty acids that occur in crop milk are very similar to those found in mammal milk; they are mainly of long chain length. Crop milk fat is rich in essential fatty acids, as might be expected for the needs of its rapidly growing recipients.

Carbohydrate

The hatchling dove or pigeon, like passerines, does not use dietary carbohydrate for energy. Crop milk contains only traces of carbohydrate. Squabs possess virtually no carbohydrases, which is one reason why columbid rehabilitators who feed grain-based diets have experienced problems with these birds.

Rehabilitation Diets

As has too often been the case for many bird species, traditional rehabilitation diets for young columbids have been based on what the adults eat. Conventional diets for hatchling/nestling doves and pigeons include cereal grains and egg, or are premixed diets formulated for psittacines.

In these diets, levels of carbohydrate are very high, while proteins and fats do not approach levels found in crop milk. The poor-quality proteins in grains do not fill the birds' growth requirements. Obviously, hatchling doves cannot make do with a grain-based diet; if they *could* thrive on those "easy pickings" foods, it would be less energetically costly for the parents to regurgitate seed or grain to the young, without going to the metabolic expense of secreting crop milk.

Methods

Nutritional analyses presented in this paper were conducted using data from manufacturers or from the United States Department of Agriculture (USDA) Nutrient Database.

Results

Crop milk is comprised of sloughed milk-laden cells from the crop's lining. Its protein composition is much more like meat than grain. One grain-based product in common use is Kaytee Exact®. The mixing instructions of Exact® for "day 1" birds are 2–3 parts water to 1 part powder. For the purposes of this comparison, this paper analyzes the product mixed 1 part powder to 2 parts water. Its macronutrient composition and caloric content are compared with natural crop milk.

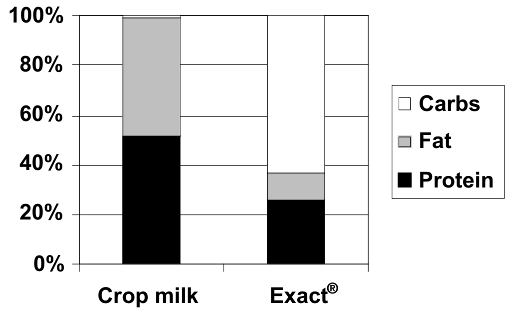
TABLE 1: MACRONUTRIENTS OF NATURAL CROP MILK AND KAYTEE EXACT®

Nutrient	Crop Milk day 1	Kaytee Exact® day 1
Water	70.0%	78.3%
Protein	14.5%	5.0%
Fat	14.0%	2.3%
Carbohydrate	0.2%	12.5%(starch)
Kcal/g	1.92 Kcal/g	0.9 Kcal/g

As shown in Table 1, Exact®, mixed 1 part powder to 2 parts water, is severely deficient when compared to crop milk. The protein and fat percentages are far too low, and given the fact that pigeon milk contains only a trace of carbohydrate, the carbohydrate levels of this product are far in excess. In fact, carbohydrates make up 57% of the calories in this recipe—and those carbohydrates are not bioavailable to the growing bird in its early days. It follows that, of the 0.9 Kcal/gram of Exact®, only **0.4 Kcal** would be available. Compared with the **1.92 Kcal** in a gram of pigeon crop milk, this is clearly deficient in energy content as well as macronutrients.

Even if the amount of water in the recipe were changed to reflect the 70% water that occurs in pigeon crop milk, the density of nutrients would only improve marginally.

FIGURE 1. MACRONUTRIENT LEVELS IN THE DRY MASS OF NATURAL CROP MILK COMPARED TO KAYTEE EXACT®



Crop Milk Replacer

Following the laboratory analysis of the nutrients in crop milk by Kirk Baer and Thomas (1996), the authors compared a number of possible ingredients and formulated a crop milk replacer based on the gross composition, amino acids profile, lipids, and minerals of crop milk.

MACMILK®: CROP MILK REPLACER RECIPE

- 1 jar (71 g) strained chicken baby food
- 1 hard-boiled egg yolk (16.6 g)
- 15.3 g (1 tbsp.) low-fat, plain, live-culture yogurt
- 1.13 g (1/4 tsp.) corn oil
- 0.62 g calcium carbonate
- 2 drops cod-liver oil (from gel cap)
- 1 drop vitamin E (diluted 1:10 in corn oil; see notes)
- 1 small pinch vitamin B complex (see notes)
- 25 mg vitamin C (ascorbic acid)

Method: Mix all ingredients in a blender. Keep the diet in the refrigerator, taking out and warming only as much as is needed for one feeding.

NOTES

Days 1–3:

For birds days 1 to 3, digestive enzymes are necessary. Use Pancrezyme® (available from vets); 0.6 cc (1/8 tsp.) per unit recipe (above). Do not use digestive enzymes from the healthfood store; they have almost no activity. Mix the enzyme in the food and let sit at room temperature for 15–30 minutes. This is crucial for neonates. Mix and use only what will be needed in one feeding; *discard the remainder*.

Vitamins: Vitamin E, as purchased, is too potent for what is required in this diet. Mix one drop of vitamin E (from a 400 IU capsule) with 10 drops of corn oil. Shake or stir well. Then, use 1 drop of the diluted vitamin E in the recipe. The remainder can be kept in an airtight container, stored in a cool, dark place, and used over the next few days. Because vitamin E degrades, it will have to be mixed fresh after a few days, so don't make too much at once. The amount of B complex required is too small to weigh on a gram scale. The amount required for this recipe is a pinch the size of about two sesame seeds. Vitamin C is an absolute requirement for some birds and a conditional requirement for others, particularly during times of growth, illness and stress (summarized in Klasing 1998). It is not harmful when added in moderate amounts, and it has been shown to be either helpful or necessary in many species. Adding it to all captive diets is recommended.

Day Four and Later:

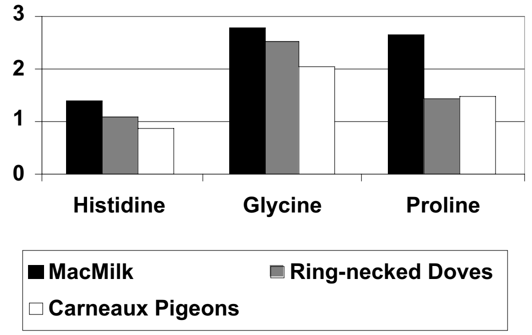
Use crop milk replacer alone for at least the first week of life, and begin to gradually mix in other foods over a period of the next 2 weeks. During the first days of new additions, the baby bird will not yet be digesting all the carbohydrates, and the high-protein food is still needed for growth and feathering, thus a gradual changeover is necessary. Good choices might be the gradual addition of Kaytee Exact® handrearing formula, mixed baby cereal, and strained baby food corn. Be sure that any dry ingredients are mixed with water before adding to the diet.

Amino Acids

The optimal amino acids profile of a young bird's food closely matches the body composition of the growing bird. This is because the preponderance of dietary protein is deposited as new body mass in the very rapid growth that is characteristic of altricial birds.

The amino acids profile of the replacer matches very closely that of crop milk. This is to be expected, since both crop milk and the milk replacer are of animal origin. While all birds require nine essential amino acids, growing birds require three additional ones: histidine, glycine, and proline. Using these amino acids as illustrative, Figure 2 compares their levels in MacMilk© to those in the milks of Carneaux pigeons (Kirk Baer 1999) and ring-necked doves (Harmuth 1977). MacMilk© exceeds the levels of these three amino acids, as it meets or exceeds the levels of all the others.

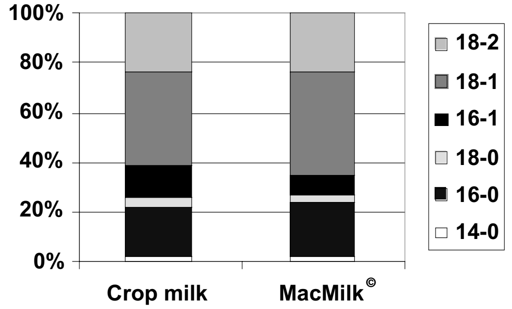
FIGURE 2. PERCENT OF DRY WEIGHT OF MACMILK© AND NATURAL CROP MILKS COMPRISED BY THREE GROWTH-ESSENTIAL AMINO ACIDS



Fatty acids

Fatty acids supply a concentrated source of calories (at about 10 Kcal/g). Some fatty acids cannot be made by animals; they are "essential," and supply components of cell membranes and intracellular messenger molecules associated with immune response. One essential fatty acid is linoleic acid, or "18:2," composed of 18 carbon atoms with 2 double bonds. Linoleic acid comprises 20% of crop milk lipids; MacMilk© is identical. The other major fatty acids are also present in very similar levels in the two foods, as shown in Figure 3.

FIGURE 3. FATTY ACID CONSTITUENTS OF CROP MILK AND MACMILK©



Minerals

The few studies measuring macro- and microminerals in crop milk are both internally inconsistent and in disagreement with each other (Shetty et al. 1990; Kirk Baer 1999). For that reason, the ranges of reported values are shown in Table 2, with a comparison to MacMilk©. The reported values are not inconsistent with a calcium:phosphorus ratio of 2:1, and since that is the ratio that is estimated to be ideal (Klasing 1998), it was chosen for the crop milk replacer.

With the abovenoted exception of calcium, the macrominerals and trace minerals in MacMilk© match very well the values found in studies of natural crop milk. This, too, is to be expected, since animal-based foods generally offer amounts of minerals comparable to one another and to the needs of youngsters. Plants are highly variable, and often deficient, in a number of minerals—another of the many reasons they should not be the basis of diets for altricial young.

The sole mineral not in the range described for crop milk is manganese, which is only about twice as high as in authentic crop milk, and is well tolerated at levels even a thousand-fold higher (Klasing 1998).

Probiotics (Summarized in Jeffrey 1999)

Birds hatch (and mammals are born) with sterile GI tracts. Their survival depends on colonization by several hundred kinds of beneficial gut bacteria (flora). To various extents depending on the animal's species, gut flora contribute crucially to the nutritional status of their host. Even more importantly, they create "competitive exclusion" of pathogens. The most effective way to establish an optimal flora population is to feed the newly hatched young some feces from a healthy conspecific adult. This is probably the case for all vertebrates.

Yogurt is added to MacMilk© for several reasons. One is that the Lactobacillus (and other) bacteria may serve as competitive excluders of pathogens, both in the birds' gut and in the food. If yogurt cultures do not colonize avian GIT's, they produce an environment conducive to the growth of beneficial autochthonous species (Eichinger 1990). All animal-based liquid foods are excellent media for pathogenic bacteria, and the yogurt cultures appear to be protective against food-borne illness as well as pathogens from elsewhere in the environment. In addition, while significant amounts of lactose are not tolerated well by birds, the small amount of lactose in MacMilk© may act as a "prebiotic," which encourages the growth of probiotics and inhibits pathogens (Corrier et al. 1997).

The GITs of a very wide variety of animals (including birds) are normally colonized by lactobacilli (Todar 2000). Lactobacillus is the predominant bacterium in pigeon crops (Baele et al. 2001).

Pancreatic Enzymes

Because of the lack of digestive enzymes in doves 1– 3 days after hatch, Pancrezyme® was added to the food 30 minutes before feeding, to predigest the nutrients. This substitutes for the free amino acids found in authentic crop milk. Pancrezyme® contains a mixture of digestive enzymes (proteases, carbohydrases, lipases) and is available from a veterinary clinic. It is added to the amount needed for one feeding, and not to an entire recipe. (Do *not* use enzymes for humans from the healthfood store; they have very low activity and are inadequate.)

Immunoglobulins

Crop milk contains significant levels of immunoglobulins, particularly IgA, similar to colostrum (Kirk Baer 1999). This is likely to be important in protecting the GIT and overall health of the neonate. The authors are investigating adding colostrum containing intact IgG to MacMilk© fed to neonates and urge other rehabilitators to consider such an addition.

MacMilk on Trial

Before field trials commenced, the authors compared the major nutrients in crop milk, MacMilk©, and Kaytee Exact®. As summarized in Table 3 and Figure 4, MacMilk© compares very favorably to natural crop milk and is quite different from Exact®.

TABLE 3. MACRONUTRIENTS IN CROP MILK, MACMILK©, AND EXACT®

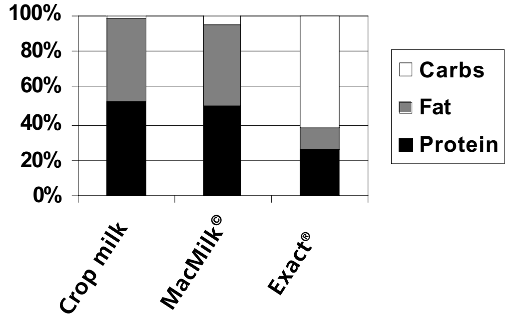
Crop Milk/MacMilk©/Exact® Comparison: As Fed

NUTRIENT	CROP MILK DAY 1	MACMILK© DAY 1	EXACT® DAY 1
Water	70.0%	73.0%	78.3%
Protein	14.5%	13.0%	5.0%
Fat	14.0%	12.0%	2.3%
Carb.	0.2%	1.4%	12.5% (starch)
Kcal/g	1.92 Kcal/g	1.7 Kcal/g	0.9 Kcal/g

TABLE 2. PERCENT (EXCEPT AS NOTED) DRY WEIGHT COMPRISED BY VARIOUS MINERALS (CROP MILK DATA FROM SHETTY ET AL. 1990; KIRK BAER 1999)

	Ca	P	K	Na	Mg	Fe ppm	Zn ppm	Mn ppm	Cu ppm
Crop milk	0.2–0.8	0.2–0.9	0.15–0.6	0.05–0.6	0.01–0.2	60–570	19–59	15–35	4–33
MacMilk©	1.22	0.61	0.54	0.18	0.05	566	54	55.5	13.5

FIGURE 4. COMPARISON OF MACRONUTRIENTS IN CROP MILK, MACMILK©, AND EXACT®



MacMilk© was tested by a number of experienced columbid rehabilitators. The first trial was performed on a group of 17 hatchling doves that included birds that hatched in captivity. When all the birds in the test group fledged, the authors felt safe in expanding the trial and many more birds were tested. Subsequent species included rock doves (pigeons), mourning doves, Inca doves, white-winged doves, and ring-necked doves.

The rehabilitators who were using MacMilk© reported good growth rates and good feathering. The droppings of birds fed MacMilk© were quite different from the watery droppings seen with Exact® or other plant-based diets. The droppings were well formed, of dark feces and white urates, as opposed to watery droppings with pale feces (indicating the nutrients were not well-digested). There were no cases of crop stasis or impaction on MacMilk©.

Feeding Hatchling and Nestling Columbids

Some columbid rehabilitators feed hatchlings 4x/day, although more frequent feedings may be advisable for very young birds. When the bird is in pinfeathers, the feedings are gradually reduced, and birds immediately preweaning are usually fed 2x/day.

Some rehabilitators prefer to tube feed, while others syringe-feed or encourage the young birds to drink.

Before feeding, of course, the bird's mouth must be opened. Many doves will open their mouths in a "gape" much like the gape of baby passerines. To encourage gaping, allow the bird to root with its bill, using the "V" between the index and middle fingers. It may take a little patience, but the bird may tilt back its head and open wide. With one hand, keep its mouth open and its neck stretched up. Then, the feeding tube or syringe can be placed and the bird can be fed. If the bird will not gape, it will be necessary to gently force open the bill. Using a fingernail to "slit" the bill, very gently open it with your fingers in a straight up and down movement. Do not exert undue pressure or side-to-side pressure. The bill is still soft and very delicate and it, or the jaw, can easily be injured.

Formula should always be wrist-temperature. The bird should be fed until its crop is full. The crop should feel like a three-quarters-full water balloon. *The bird should not be fed again until the crop is completely empty;* this will help prevent "sour crop" and crop stasis.

Tube Feeding is quick and efficient, but it is not without risks. If too much food is expressed, it will back up and the bird can aspirate it. If the tube is not crimped or removed properly, food can leak and the bird can aspirate it. If the tubing is not soft medical-grade tubing, it can injure the bird's throat.

Syringe Feeding or feeding with a large eyedropper or pipette is a good method for rock doves. Put the syringe or pipette into the right side of the mouth, past the glottis and to the back of the throat. Express the food and remove the syringe, allowing the bird to swallow and breathe before offering more. Care must be taken to not allow food into the glottis.

Drinking: To encourage the dove to self-feed, formula can be placed in a cylindrical container such as a large feeding syringe. Food is drawn up and the plunger is removed. The wide-top end of the syringe is covered with a piece of avian wing wrap that has a hole just large enough to accommodate the bird's bill. The wing wrap is secured with an elastic band. An alternative to this is to use a teat or nipple attached to a feeding syringe. Again, the teat must have a hole large enough to accommodate the bird's bill. This method allows the rehabilitator to depress the plunger so that more food is let down as necessary.

Weeks 1 and 2

The bird should be weighed daily to make sure it is gaining weight. If the growing bird is only maintaining weight or is actually losing weight, it has a problem that needs to be explored and addressed immediately.

During the first week of life, MacMilk© is fed alone. Then, other foods are gradually introduced, until the bird is weaned from MacMilk© by the end of 2–3 weeks. During the second week, you can begin to mix in Exact®, or make your own grain-based formula to add to MacMilk©. Remember that the bird is still growing rapidly during the second week, and growth continues through the third week as well. Be sure that the diet you feed is of high quality and contains the requisite protein, vitamins, and minerals in the correct amounts and proportions.

Weaning

Don't take anything for granted. When the bird begins to peck and pick up food, do not stop giving it crop milk replacer until you are sure it is digesting seeds and grains and that there are significant amounts in the crop. Young birds need to be 'topped up' while weaning because they don't obtain much nutritive value from their foods until their gizzards are strong and can grind down the adult diet, and until all the digestive enzymes have been induced. Make sure that one of the hand-feedings is given in the late evening so that the youngster has food in its crop to carry it through the night.

Be sure to provide plenty of clean, pesticide-free dirt and oystershell grit ad libitum, along with seeds. Dirt provides many beneficial minerals and microorganisms; oystershell grit provides crucial calcium, and assists in seed grinding.

Discussion

Columbids comprise a cosmopolitan order that populates many of the most challenging environments. It is postulated that much of their success stems from the crop milk provided by parents to nestlings (Horseman and Buntin 1995). Like mammals, young columbids are provided a "perfect food," regardless of their larger environment. Pigeons and doves occupy ecological niches that do not allow them to gather food that would permit the remarkably rapid growth of their young. One might hypothesize that, since columbids have not evolved to capture invertebrates, which would meet the macronutrient demands of growing nestlings, they secrete their own animal-based food, instead.

Passerines have solved the need for high-nutrient food differently. Unlike columbids, songbirds must raise their young in a time and place where insects abound. Many of them migrate in order to do so, an enormously expensive and risky endeavor. The songbird "baby diet" of insects is about 65% water, with dry matter comprising 62% protein, 20% fat, and 18% carbohydrate (in the form of glycogen and chitin). Passerines hatch with good levels of proteases, the enzymes required to digest dietary protein. In their first week, they largely depend on protein for both building blocks and energy. Lipases begin to function later, and they are relatively incapable of digesting carbohydrate until their second week.

Compared to the insect diet of baby passerines, crop milk is similar in the level of high-quality dry matter protein, much higher in fat, and much lower in carbohydrate.

The differences between columbid milk and insects fed to passerines (higher fat and virtually no carbohydrates in crop milk) reflect the physiological differences of the birds and the differences in feeding frequency. Whereas songbird babies need small, frequent meals of moderate caloric density, dove and pigeon nestlings have relatively large crops that allow large, high-calorie meals, fed less often.

Young pigeons and doves can digest only protein and fat—not carbohydrates. The enzymes to digest starches do not appear until well into the second week of life, and even then the birds only gradually acquire the ability to digest carbohydrates. As is true of all wildlife, to give them anything other than what they evolved to digest, and therefore are *able* to utilize, does them a grave disservice and puts their health and life at risk.

Like all young animals, nestling doves and pigeons are what they eat—so make sure they eat the cream of the crop.

Acknowledgements

We thank Charlotte Kirk Baer for her great generosity in sharing her published and unpublished data and her thoughts; Diane Winn for ever-helpful discussions and information; and R. nair Jayakumar for his generous assistance.

Product Information

Pancrezyme®
Daniels Pharmaceuticals, Inc.
Jones Pharma Inc.
1945 Craig Road
St. Louis, MO 63146
USA
Tel: 800/525-8466
Fax: 314/469-5749

References

Corrier, D. E., D. J. Nisbet, B. M. Hargis, P.S. Holt, and J. R. DeLoach. 1997. Provision of lactose to molting hens enhances resistance to *Salmonella enteritidis* colonization. *J. Food. Prot.* 60(1): 10–15

Eichinger, E. 1990. *Lactobacillen zur Bekampfung von Enterobacteriaceen im Darm von Psittaciformes,* DVG VII. Munich: Tagung Vogelkrankheiten, pp. 231–34.

Ferrando, R., R. Wolter, Cl. Fourlon, and M. Morice. 1971. Le lait de pigeon. *Ann. Nutr. Alim.* 25: 241–251.

Harmuth, D. 1977. Erlauterungen zur Kropfmilch der Tauben unter besonderer Berucksichtigung der Aminosaurenzusammensetzung, Prazipitation und Immunelektrophorese. *Zool. Garten N.F.*, Jena 47 3/4: 261–72.

Hegde, S. N. 1973. Composition of pigeon milk & its effect on growth in chicks. *Indian J. Exp. Biol.* 11: 238–39.

Horseman, N. D., and J. D. Buntin. 1995. Regulation of pigeon cropmilk secretion and parental behaviors by prolactin. *Ann. Rev. Nutr.* 15: 213–38.

Jeffrey, J. S. 1999. Poultry Fact Sheet #30, Cooperative Extension, University of California at Davis, USA.

Kirk Baer, C. 1999. Comparative nutrition and feeding considerations in young Columbidae. In *Zoo & Wild Animal Medicine*, 4th edition. (M. E. Fowler and R. E. Miller, eds.). Philadelphia: W. B. Saunders.

Kirk Baer, C. L., and O. P. Thomas. 1996. Comparative aspects of mammalian and avian lactation. *Proc. Symp. Comp. Nutr.* Soc. 1: 75–77.

Klasing, K. C. 1998. *Comparative avian nutrition.* New York: CAB International.

Reed, L. L., L. B. Mendel, and H. B. Vickery. 1932. The nutritive properties of the "crop milk" of pigeons. *Am. J. Physiol.* 102: 285–92.

Riddle, O. R., R. W. Bates, and S. W. Dykshorn. 1933. The preparation, identification and assay of prolactin—a hormone of the anterior pituitary. *Amer. J. Physiol.* 105(1): 191–216.

Shetty, S., B. Shenoy K., R. T. Jacob, and S. N. Hegde. 1990. Mineral composition of pigeon milk. *Experientia* 46: 449–50.

Todar, K., 2000. 'Handout' for Bacteriology 303, University of Wisconsin, Madison, Wisc.

To Contact the Authors

Astrid MacLeod
Box 17, Group 75 RR 1
Anola, Manitoba R0E 0AO
Canada
E-mail: sparrow1@mb.sympatico.ca

Janine Perlman
14817 Willy Lane
Alexander, AR 72002
USA
E-mail: jpandjf@swbell.net

NEO-REHABILISMS...

esophaguts
where you position the feeding tube

fincubator
a recycled fish tank used for housing baby birds