APPENDIX 9B

Bird Collision with Man-made Structures with Reference to the Proposed Shenzhen Western Corridor

9B1. SUMMARY

Views have been expressed during consultations with NGOs that the proposed bridge linking Hong Kong with Shekou (Shenzhen Special Economic Zone, Guangdong Province, PRC), referred to as the Shenzhen Western Corridor, may cause bird mortality.

The objective of this Study is to test the null hypothesis that bridges do not cause significant bird fatalities. This was undertaken by means of a comprehensive and international literature review, and through observations made in Hong Kong Special Administrative Region and its environs, and in Macau Special Administrative Region.

To present the issue in context, based on data from USA, only 1% of human caused bird fatalities are attributable to collisions with tall structures. Potentially this represents less that 0.02% of all bird mortality.

The findings of a comprehensive literature review and regional observations support our null hypothesis that bridges do not cause significant bird mortality.

9B2. INTRODUCTION

9B2.1 Purpose of the Study

Views have been expressed during recent consultations with NGOs that the proposed bridge linking Hong Kong with Shekou (Shenzhen Special Economic Zone, Guangdong Province, PRC), referred to as the Shenzhen Western Corridor, may cause bid mortality. The purpose of this report is to describe and quantify how various types of human-made structures including bridges affect bird mortality.

9B2.2 Objective

The objective is to test the null hypothesis that bridges do not cause significant bird fatalities. This was undertaken by means of a comprehensive and international literature review, and through observations made in Hong Kong Special Administrative Region (HKSAR) and its environs, and in Macau Special Administrative Region (MSAR).

9B2.3 Structure of the Report

A literature review and findings of observations are presented in Chapters 2, 3, and 4. How that information is related to the Shenzhen Western Corridor is presented as conclusions and recommendations in Chapter 5. Chapters 6 and 7 list the personnel communications and references cited.

9B2.4 Data Review

The published history of human-caused bird fatalities is long, and there is a large volume of literature. Whilst many people have seen or are aware of birds colliding with buildings (in particular windows) or vehicles, most people are not familiar with other anthropogenic agents of bird mortality. There are known and documented design features of structures that can increase bird mortality, and in some cases combinations of those features work together to attract and sometimes kill birds.

More than 1,500 publications on bird collisions with man-made structures were reviewed to write this report. Most of the data were obtained from studies in North America, Europe, Asia, Africa and South America. The reviewed literature covered a 117-year period from 1884-2001. In addition input was sought from biologists actively involved in bird research, conservation and management. This report reflects the combined results of personal communications and literature reviews. The primary published sources included the following:

1. Avery, M. L., P. F. Springer, and N. S. Dailey. 1980. Avian mortality at man-made structures: An annotated bibliography (revised). U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program, FWS/OBS-80/54, July 1980.
2. CEC. 1995. Avian collision and electrocution: An annotated bibliography. California Energy Commission, Sacramento, California, USA, Publication number P700-95-001, October 1995.
3. Trapp, J. L. 1998. Bird kills at towers another human-made structures: An annotated partial bibliography (1960-1998). U.S. Department of the Interior, Fish and Wildlife Service, Office of Migratory Bird Management, Arlington, Virginia, USA (website: *http://migratorybirds.fws.gov/issues/tower.html*).

9B2.5 Context of Mortality Caused by Man-made Structures

Banks (1979) estimated that approximately 10 billion birds die annually in USA from all causes. Anthropogenic causes accounted for 196 million bird deaths, less than 2% of total mortality.

Only 1% of human caused bird fatalities was attributable to collisions with tall structures. So potentially this represents less that 0.02% of all bird mortality.

Figures 9A-1 and 9A-2 show the relative impacts of human activities on bird mortality in the USA.

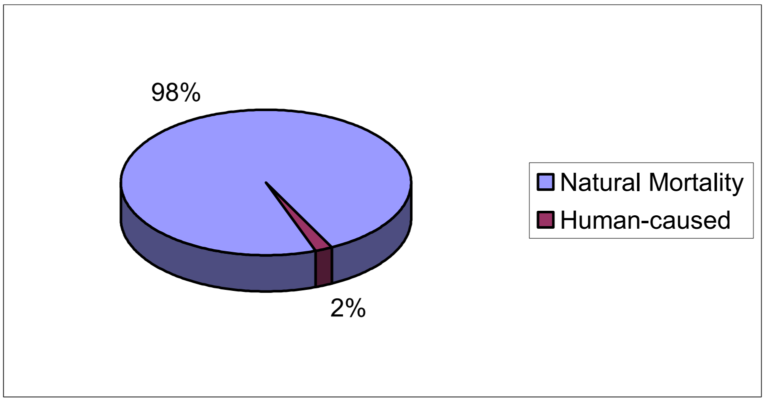

Figure 9A-1. Natural bird mortality and human-caused bird mortality as proportions of total annual bird mortality of 10 billion birds in USA (data from Banks 1979).

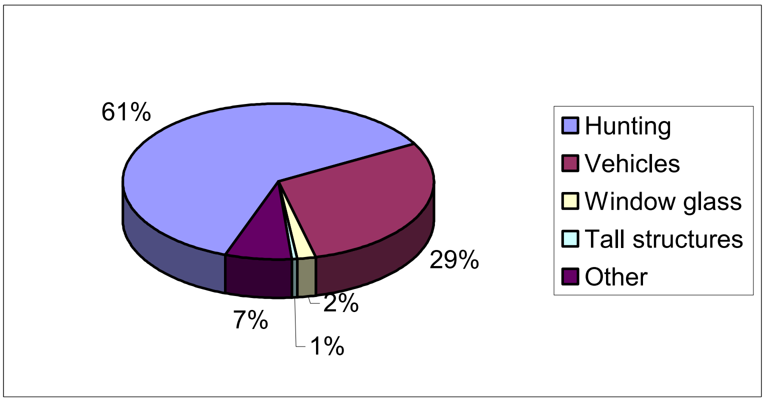

Figure 9A-2. Agents of human-caused bird mortality in USA accounting for an estimated 196 million annual fatalities (data from Banks 1979).

9B2.6 Structures Causing Fatalities

Structures reported to cause bird kills are:

- telecommunication or radio transmission towers;
- chimneys or stacks;
- glazed windows;
- lighthouses;
- power transmission and distribution lines; and
- airport ceilometers (towers for determining the altitude of the cloud "ceiling" above ground level).

The causes of bird collisions with man-made structures are normally considered to be:

- invisibility, for example power lines or guy-wires, particularly at night;
- deception, caused by glazing in buildings; and
- confusion , caused by light refracted or reflected by mist) (Jaroslow 1979)

Structures that do not exhibit these features are seldom implicated in the published literature as agents of bird mortality.

9B3. DOCUMENTED CAUSES OF BIRD MORTALITY

9B3.1 Seasonality of Bird Mortality

Bird collisions with structures in North America usually happen during migration seasons, particularly during the autumn migration (e.g., Anonymous 1902, Finch 1970, Able 1973, Johansen 1975, Goodwin 1978, Scott and Cutler 1971). This is because autumn storms are often accompanied by strong northerly winds and cloudy, misty, rainy, or snowy skies. Spring losses are generally uncommon as southerly monsoon winds usually come with clear skies (Barrington 1900, Gunn *et al*. 1972, Clark 1978).

Harness (1977) observed that most eagle electrocutions on electric power distribution lines in North America were reported during winter. He qualified that conclusion, however, by noting that rate of carcass decay would be slower, and scavenger activity possibly less in winter than during other seasons. Some researchers noted late summer increases in electrocutions, at a time when young birds fledge from their nests (Harness 1977, Dawson and Mannan 1995, Ferrer *et al*. 1991).

Migrating birds, particularly small insectivorous species (e.g., warblers), usually fly at night (e.g., Kumlien 1888, Schorger 1952, Graber and Cochran 1960, Ogden 1960, Stout 1967, Robertson 1968), apparently an adaptation to reduce predation losses (Schmidt-Koenig 1979). However flying in darkness also increases the risks of collisions with nearly invisible man-made structures such as electric power lines.

9B3.2 Bird Mortality and Weather

Bird kills are typically reported on cloudy, overcast or foggy nights when visibility is low (Merriam 1885, Culver 1915, Brooks 1951, Bagg 1965). Although bird collisions also occur on clear nights (Tufts 1928, Chamberlain 1961, Anon. 1975), birds normally avoid obstacles in clear skies (Avery *et al*. 1975, Avery 1976). Birds also tend to fly at lower altitudes under low cloud ceilings or in rain (Alerstam 1978, Podolsky *et al*. 2000). Fatalities have been reported to be most numerous on low overcast or foggy nights when low cloud ceilings obscure obstacles such as tall buildings (Potter and Murray 1949, Parmalee and Parmalee 1959, Szczepski 1965, Weir 1972, Mosman 1975, Jaroslow 1979). As many as 1801 birds of 44 species were killed by collision with two floodlit buildings near Elizabethton, Tennessee (USA) on the foggy nights of 30 September and 1 October 1972 (Herndon 1973).

Rain or drizzle can make the problems worse (Anon. 1962, 1966a, Brooke 1951, Case *et al*. 1965). Birds may be confused by the refraction and reflection of light by rain droplets, become disoriented, and then collide with structures (Elkins 1988). Mass mortalities have also been reported as common after the passage of cold fronts (Post 1963, Baird 1964, Green 1964, Bagg 1971, Gunn *et al*. 1972, Peterman 1974, Carter and Barnell 1976, Crawford 1981). Inclement weather tends to force birds to fly at lower altitudes (Sterling 1890, Pough 1948) where the chance of colliding with tall buildings is higher.

Moon phase is an important factor affecting the size of bird kills (e.g., Anonymous 1972, Wylie 1977), since it affects the visibility of structures. Several authors reported few or no kills on full moon nights but larger numbers of kills on moonless nights (Barrington 1900, Mercer 1905, Verheijen 1981, Telfer *et al*. 1987). A full moon can dramatically reduce the degree of bird attraction to or confusion by artificial lights (Reed and Sincock 1985).

9B3.3 Bird Mortality and Glazing

Windows and building curtain-walls may be the most destructive structures causing bird kills. Birds collide with all forms of glass windows, from small windows in private homes to glass walls on high-rise urban buildings. Klem (1990) estimated at least 98 million, and possibly as many as 976 million, birds die annually in USA from striking glass. The larger figure would represent 10% of the estimated annual total bird mortality in USA of 10 billion (Banks 1979).

About 25% (225) of 917 bird species in USA and Canada have been reported striking windows (Klem 1989). It is estimated that 200,000-300,000 Blackbirds *Turdus merula* are killed annually by windows in Holland (Bruijns and Stwerka 1961).

Reflection of an outdoor scene or a view through a window may appear to a bird as a potential flight path or habitat (Bradley 1975, Macdonald 1978, Jaroslow 1979). Bird species such as Swainson's Thrush (*Catharus ustulatus*), which tend to fly through understorey vegetation where they are guided by a view of light ahead of them, are the most likely species to be killed by striking windows (Ross 1946, Synder 1946).

Various design or management practices have been recommended to reduce the frequency of bird collision with plate glass. These include use of translucent or opaque glass in windows; attachment of predator silhouettes to windows; drawing of curtains; planting of shrubs or trees in front of glass surfaces; and extinguishing lights behind large glass surfaces at night (Lohrl 1962, Raible 1968, Valum 1968).

The Fatal Light Awareness Program (FLAP; website, *http://www.flap.org*) is a non-government organisation (NGO) founded in 1993 in Canada to seek solutions to the problem of bird fatalities due to building or window glazing. Apart from using nylon nets to help capture confused or dazed birds, FLAP also launched a successful campaign to reduce night-time illumination in homes and office buildings during migration season (WWF Canada 1997).

9B3.4 Bird Mortality and Towers

Towers, including television-radio-telecommunication towers, water towers, and smoke stacks cause more reported bird fatalities than other types of structures (e.g., Mumford 1960, Graber 1962, Hosford 1962, Janssen 1963, Gramlich 1973, Broderick 1995, Crawford and Engstrom 2001).

Towers that are stayed by guy wires (television, radio, telecom towers) appear to cause the greatest numbers of bird deaths. Although such towers are lighted for aircraft safety, the guy wires are not lighted, therefore are invisible at night. Such guy wires are small, typically less than 1 cm in diameter, which decreases the liklihood that a flying bird could see the wire before colliding with it. Under misty or foggy weather conditions (see above) the combination of invisible guy wires, bird disorientation due to light refraction or reflection, and lack of visibility due to cloud or mist cover appears to be particularly lethal to birds.

Annual mortality in USA due to collisions with radio and television towers is estimated to range from 1 to 1.25 million birds (Banks 1976). Several authors report more than 1,000 birds found killed beneath a tower in a single night (e.g., Kleen 1975). The numbers of bird kills normally increase on cloudy nights (Herndon 1954). The biggest reported bird kill was 30,000 birds at the Eau Claire, Wisconsin telecommunication tower on the nights of 18-19 and 19-20 September 1963 (Kemper 1964).

Heights of towers reporting bird kills ranged from 9 m to 606 m. The "effective tower height" is often greater than the height of the structure itself because towers are normally erected on prominent topographic features that may rise tens or hundreds of meters above the surrounding landscape (Herndon 1954, Sawyer 1961, Nisbet 1968).

Some authors suggest that the size of kills on a given night depends solely on local weather conditions and the number of birds aloft, and is not determined by tower height, terrain, or tower location (Clark 1973, Seets and Bohlen 1977). However, Karlsson (1977) concluded that tall towers cause more bird deaths, and that birds are rarely threatened by towers shorter than 250m.

Aldrich *et al*. (1966) anticipated that the problem of bird kills would intensify as tall telecommunication towers become more numerous on the landscape. In an effort to minimise future increases in tower-related bird mortality, Ogden (1996) advised the communication industry to reduce the number of new towers by co-locating new transmitters on existing towers.

Characteristics of telecommunications towers that appeared most frequently in reports of bird fatalities included:

- height of tower structure (some over 600 m, most threatening over 250 m);
- siting of tower on prominent topographic feature that may be used by birds as a navigation guide;
- isolation of tower to avoid signal interference;
- lighting of tower using floodlights; and
- staying of tower by guy-wires that are unlighted, therefore invisible at night.

9B3.5 Bird Mortality and Power Lines

Overhead wires such as telephone lines and powerlines cause large numbers of bird collisions (e.g., Arnold 1918, Borell 1939, Benton 1954, Griffin 1956, Anonymous 1966b, Glue 1971, Boeker 1972, Andersen-Harild and Bloch 1973, Cochrane *et al*. 1991). Birds either fly directly into power lines (mainly at night when lines are invisible), or are electrocuted when they attempt to land on or take flight from power poles or towers. In the latter case conducting wires or ground (earth) wires are incorrectly positioned such that they can be simultaneously contacted by the wingtips of a single bird, thus causing electrocution.

Bird collisions with power lines have long been considered an important cause of mortality for some species (Michener 1928, Janss and Ferrer 1998, Podolsky *et al*. 1998). Heijnis (1976) estimated 800,000 to 1,000,000 birds are killed annually by collision with overhead wires in Holland. Electrocution is considered to be the main cause of mortalities of Bonelli's Eagle *Hieraaetus fasciatus* in Europe (Manosa and Real 2001).

Meyer (1978), however, showed that collisions caused negligible losses at population levels. The percentage of observed birds colliding with overhead lines was 0.03-0.07% for ducks, 0.04% for Red-winged Black-birds, 0.003 to 0.06% for gulls and 0.67% for shorebirds (Meyer 1978). Most birds reacted to lines by changing height, flight speed, or flight direction, and most birds flew over rather than under the lines (Meyer 1978, Wiese 1979). However, for rare or declining species such as the California Condor (global population 184 individuals; see http://www.peregrinefund.org/condor_factsheet.html), the impact at the population level of collisions with power lines can be significant (Jurek 1994).

For more common birds of prey such as the Bald Eagle population impacts of frequent collision fatalities may be less significant (global population estimate 70,000 birds, see http://www.baldeagleinfo.com/). At least 20-30 Bald Eagles die each winter in Texas due to power line electrocution (Sprunt *et al*. 1973), and another 15-25 are electrocuted at the Adak, Alaska Navy base each year (Trapp 1978). Because juveniles, which are less adept flyers and less knowledgeable of the hazards of powerlines, tend to initiate migration before the mature birds, mortality in the juvenile age class of the migratory Bald Eagle populations may be considerable.

Bird species reported injured or killed from collisions with overhead wires are typically medium to large birds (e.g., Peregrine Falcons *Falco peregrinus*, Kestrels (*Falco sparverius*), Common Buzzards *Buteo buteo*, eagles, California Condor (*Gymnogyps californianus*), Black Vulture *Aegypius monachus*, owls, ducks, swans, cranes, storks, bustard *Otis spp*.) (Boyd and Ogilvie 1954, Boylan 1956, Brunetti 1965, Brown and Amadon 1968, Herren 1969, Jaago 1970, Harwin 1971, Beer and Ogilvie 1972, Bijileveld and Goeldlin 1976, Janss and Ferrer 1998). Such large birds have wingspans wide enough to contact two powerlines simultaneously, or they have limited flying maneuverability that increases the probability of collision with stationary objects encountered during flight (Savereno *et al*. 1996, Kochert and Olendorf 1999). Small bird collisions with overhead wires are only occasionally reported (e.g., hummingbirds, martins) (Anderson 1933, Hendrickson 1949, Mead 1979). Wires are reported to be especially lethal where they cross above rivers or canals, or near concentrations of birds at roosts or communal nesting sites (Beer and Ogilvie 1972, Harrison 1963, Heijnis 1980).

Several factors affect the size of bird losses due to collision with powerlines: the number of birds present, visibility of the lines, the frequency of disturbances that flush birds into flight, the species present and the degree of familiarity of the birds with the area (Anderson 1978). Mitigation measures have been suggested to reduce mortalities from collisions with overhead wires (Anderson 1978, Leitner and Grant 1978, Steenhof 1978, Willard 1978, Armbruster 1990):

- avoid building lines over water or places where waterfowl or raptors congregate;
- enhance visibility of power lines using markers (e.g., Rigby 1978, Benson and Dobbs 1985, Janss and Ferrer 1998);
- in waterfowl areas with existing power lines minimise bird disturbance by controlling human access;
- do not install power lines across known bird flight paths.

Electrocution is considered the most important cause of death of raptors in USA (Kochert and Olendorff 1999). During 1969-1971, over 300 eagles died by electrocution in the western USA (Anderson 1975, Boeker and Nickerson 1975). Most eagle electrocutions (mostly Golden Eagles) occur during winter when the birds are more concentrated. Some 98% of electrocuted birds are inexperienced juveniles (Miller *et al*. 1975, Nelson and Nelson 1976, Steenhof 1978). Modification of overhead power poles by installing taller insulators and ensuring adequate spacing of conductors has been suggested to reduce electrocution hazard to eagles (Nelson 1975). Since eagles selectively use certain poles as perches (e.g., poles with cross-arms perpendicular to prevailing winds) (Anderson 1975, Craig 1978), it has been estimated that 95% of bird electrocutions could be avoided by modifying only 2% of the poles (Nelson and Nelson 1976). Annual mortalities of Golden Eagles (*Aquila chrysaetos*) due to electrocution declined from 109 to 15 between 1980 and 1984. This was attributed to co-operation between government, the power industry and conservation efforts (Phillips 1986).

9B3.6 Bird Mortality and Illumination

Lights on buildings, vehicles and ships are important causes of bird collisions (e.g., Gastman 1886, Anonymous 1930, Hansen 1954, Green 1964, Laskey 1964, Bernard 1966, Kale 1971, Gochfeld 1973). Birds are attracted or directed to lights on buildings (e.g., Kumlien 1888, Stuart-Sutherland 1922, Hachisuka 1926, Phelps 1961, Pettingill 1970, Avery and Springer 1975, Merrie 1979), and may collide with man-made structures if they are blinded and lose the ability to navigate (Herbert 1970, Gunn *et al*. 1972, Byrd 1978, Byrd *et al*. 1978). This is evident in the large number of reports of kills at lighthouses, ceilometers and searchlights (e.g., Merriam 1885b, Lewis 1927, Howell and Tanner 1951, Imhoff 1954, Herndon 1962, Bagg 1958, 1964, Medway and Wells 1970). Sincock and Swedberg (1969) reported that Newell's Shearwaters (*Puffinus puffinus newelli*) are frequently attracted to lighted highways, parks, football fields and buildings. In dry inland areas of Australia ducks flying at night have crashed into corrugated steel roofs that reflect moonlight and are apparently mistaken for ponds (Braithwaite 1975). Birds have even been reported flying into fires (Mailliard 1898, Newman 1960, Bourne 1979) or being burned to death after flying into or congregating around gas flares on oil rigs (e.g., Sage 1979a, 1979b).

The attraction of birds to light is stronger on foggy or overcast nights (Brewster 1886, Carpenter and Lovell 1963, Peterson 1963, Savage 1965, Swales 1965). Birds usually leave the vicinity of lights when flying under clear skies (Harvie-Brown and Cordeaux 1880). Birds attracted to illumination have been reported to flutter around lights on buildings or towers (Cooke 1888, Bartlett 1952, 1956, Burton and Woodford 1960, Webster 1960, 1973, Gochfeld 1973, Vickery 1978), often flying into the lights or crashing into windows, or fluttering around lights until dying of exhaustion (Bretherton 1902, Squires and Hanson 1918, Schotzho 1962, Polshek 1977).

Several hypotheses have been put forward to explain the reactions of birds to artificial lights. Bourne (1976) hypothesized that birds lost in mist or fog would fly to the nearest light as a guide to find a route out of the fog. For migrating birds using stars or constellations for navigation, fixed lights (e.g., lanterns atop lighthouses) may look like stars. On foggy nights birds will fly toward these lights because they are the only visible fixed points (Bretherton 1902, Kemper 1964). Imber (1975) hypothesized that the reactions of young birds of some maritime species (e.g., petrels) to artificial lights may be related to their food preferences for bioluminescent organisms.

Many authors investigated the relationship between bird kills and characteristics of light sources. Publications indicated a general consensus, but not unanimous opinion. In most reports revolving or intermittent lights (strobe lights) apparently caused fewer problems than fixed (flood) lights (e.g., Barrington 1900, Cooke 1915, Velie 1963, Taylor 1981, Maehr *et al*. 1983). Tufts (1928) reported a 99% reduction in kills after the replacement of a flood light with a strobe. White floodlights are considered most hazardous to birds flying at night (e.g., Dixon 1897, Mercer 1905, Lewis 1927, Overing 1936, Lincoln 1939, Lord 1951, Weir 1972). However, in a few cases white floodlights were considered to result in fewer bird kills (Munro 1924, Baldwin 1965, Swirski 1965). Reduced or zero mortality has been reported after white floodlights were screened with red filters, or when floodlights on buildings were extinguished on overcast nights during the spring and fall migration seasons (e.g., Lewis 1927, Goodwin 1971, Anonymous 1972, Webster 1979). Lower bird kills have been reported at exhaust stacks and cooling towers with diffuse red, orange or blue lights (Jackson and Peterman 1977). Installation of ultraviolet filters to block visible light has been shown to reduce bird losses on ceilometers in Nashville and Knoxville, Tennessee, USA (Anonymous 1955). Sound-emitting devices have also been used as bird deterrents (Avery and Springer 1973). For example, lighthouses equipped with foghorns caused only slight bird losses (Bretherton 1902).

9B4. BIRD MORTALITY AND BRIDGES

Bridges, by their absence from the published scientific and popular literature, appear to be largely free from features that increase bird mortality. During a review of over 1,500 abstracts or summaries of published reports on bird mortality in relation to man-made structures there were no publications documenting bird collisions with or bird mortality due to collisions with bridges or bridge stays. There is an argument that birds killed by collisions with bridges would be undetected because bridges usually cross water bodies. However, a study on mortality of Newell's Shearwaters due to collisions with power lines over water bodies (Podolsky *et al*. 2000) relied in part on the detection of dead birds floating on rivers. Also, bird mortality during severe storms along the western Atlantic coast in USA have been documented based upon floating bird carcasses seen from the Chesapeake Bay Bridge-Tunnel. These records demonstrate that bird mortality over water bodies does leave detectable evidence.

One publication described the Pensacola Bay Bridge (Florida, USA) where birds died after colliding with a power distribution line suspended above the bridge between light poles. The bridge was constructed in the late 1930s, before power lines were known to cause bird deaths. Some 740 dead birds representing 75 species were counted during irregular checks between 1938 and 1949 (an average of 67 birds annually over the 11 year period). The power line was lowered from the light poles to the bridge deck in 1949, and no further bird deaths were reported (Weston 1966).

A second publication described the situation in San Sebastian State Recreation Area (Florida, USA) where Royal Terns and Brown Pelicans sought refuge on a bridge deck during high or erratic wind conditions. The birds did not collide with the bridge or any associated structure.

Scott and Cutler (1971) documented bird mortality related to harsh weather along the Atlantic seaboard of USA. Birds migrating southward were blown offshore, and large numbers of dead birds were later seen near the mouth of Chesapeake Bay by bird watchers viewing from purpose-built birdwatching sites along the Chesapeake Bay Bridge-Tunnel alignment. The report indicates that the bird mortality was due to the adverse weather conditions. The Chesapeake Bay Bridge-Tunnel is over 32 km in total length, and portions of the bridge are similar to the design proposed for the Shenzhen Western Corridor. It should also be noted that Chesapeake Bay is world-renowned for the richness of its biodiversity, particularly its avian species. The Bay supports the world's largest population of Osprey (*Pandion haliaetus*), a resident, breeding species numbering some 3,000 birds. The Bridge-Tunnel includes four man-made islands, each of which includes car parking and bird watching facilities. There appears to be no adverse impact from the bridge on birds in Chesapeake Bay, and in fact the bridge provides bird watchers an opportunity to observe bird from near the center of the mouth of the Bay, an area through which birds migrate. This represents a positive aspect of the bridge in terms of bird conservation.

Bridges were found in the study area of Podolsky *et al*. (2000), who studied the mortality of Newell's Shearwater due to collisions with man-made structures, primarily powerlines. Bridges were not identified as causes of bird kills.

Many researchers have concluded that bird collisions with power lines are due to the invisibility of powerlines, particularly at night. Researchers recommend solving this problem by incorporating powerlines into more visible structures, including bridges (Weston 1966, Sisson 1975, Heijnis 1976, McKenna *et al*. 1976, Podolsky *et al*. 2000).

Heijnis (1976) recommended incorporating overhead powerlines into structures such as bridges to clear landscapes of powerlines that are obstacles to bird flight, thereby avoiding bird fatalities (that number as high as 800,000 to 1 million annually in Holland). This approach might be most beneficial where river or other water corridors are heavily used by birds and are also crossed by bridges and powerlines.

McKenna *et al*. (1976) suggested that bird mortality due to collision with powerlines could be minimized by burying powerlines or masking them with structures such as bridges or trees. This was in response to collection of 244 dead birds beneath high voltage powerlines near two wetlands in central North Dakota within a 3-month period (*ibid.*). This recommendation was made for areas where natural flyways are present.

Birds fly either over or under bridges depending to some extent upon the bird species. Gulls and cormorants in Holland tend to fly over low bridges, and collisions with bridges or bridge cables or other associated structures are unknown (C. Swennen, pers. comm.).

Cormorants, pelicans, falcons, terns and gulls in San Francisco Bay (California, USA) typically fly over bridges. Cormorants nest in San Francisco Bay, and many have built nests on bridge structures. The California Transport Department recently authorised installation of 700 m^2 of stainless steel cormorant nesting platforms on a new bridge in San Francisco Bay to increase opportunities for cormorant nesting on the bridge (M. Rauzon, pers. comm.). Some birds, most often juveniles with poorly developed flight skills, occasionally collide with vehicles (normally tall trucks) crossing bridges in San Francisco Bay. The frequency of such incidents is not considered by government to be adequate to justify monitoring.

Shorebirds on the Texas (USA) coastline tend to fly over bridges, and some infrequently collide with passing vehicles (R. Harness, pers. comm.). As in San Francisco Bay, collisions typically involve young birds that have poorly developed flight skills.

9B5. STUDIES OF FLIGHT BEHAVIOR OF BIRDS IN HONG KONG

The study on birdstrike hazards and control at Kai Tak Airport by Melville (1980a, 1980b) was the first systematic survey on bird migration in Hong Kong. Migration was studied using radar between April 1975 and April 1979 (Melville 1980b). Peak migration activity was observed in April-May and September-November. Most birds migrated southwestward in autumn and northeastward or northward in spring (*ibid*.). Birds flew at altitudes of about 3700 m. Large scale of migration along a "narrowly defined flyway" was not observed in Hong Kong.

Apart from flight-line studies associated with use of feeding habitats by nesting ardeids (e.g., Wong 1991, Kwok and Dahmer, in press), there has been no systematic study of flight behaviours/heights/paths of birds in Hong Kong. Flight behavior of birds in relation to man-made structures was carried out as part of the ecological impact assessment of the proposed Shenzhen Western Corridor (SWC). Flight behaviors and altitudes over three vehicle bridges in Hong Kong and one in Macau were studied between November 2001 and March 2002. The study sites were the Route 3 flyover at Kam Tin River Channel 60 CD Contract B (15 m above MSL); the Shatin Road above Shing Mun River Channel (15 m height), Tsing Tsuen Bridge (17 m height) and the Lotus Bridge in Macau SAR (15 m height). These bridges were chosen because their heights above the water surface are comparable to the proposed SWC Bridge. The Lotus Bridge connects Macau's Taipa-Coloane Reclamation Area with Zhuhai's Hengqin Island; and the Route 3 flyovers span over intertidal mudflat. Birds flying above and below these flyovers were identified and counted. For birds flying above the flyover, the height above the bridge surface was estimated.

Many bird species were recorded, including raptors, wagtails, bulbuls, mynas and spoonbills. Most birds recorded flying above the four studied flyovers were ardeids. Black-faced Spoonbills *Platalea minor* and European Spoonbills *P. leucorodia* were recorded flying over the Lotus Bridge in Macau. Ardeids have been recorded feeding on exposed mudflats under the Route 3 flyover since 1998 (H. K. Kwok, pers. obs.). Ardeids and spoonbills were observed feeding on mudflat near the Lotus Bridge in Macau SAR during field studies for the Shenzhen Western Corridor EIA (Arup 2002). More birds flew over the flyovers in evening, and below during mid-day. In all study areas no flying bird was observed after 30 minutes past sunset. All birds reacted to flyovers by changing altitude and reacted to vehicles on bridges by changing flight direction or altitude. The mean heights of flying birds above the bridge surface ranged from 9-12 m.

No bird collision with a bridge was observed during the study. In fact, no bird kills due to collisions with flyovers have ever been reported in Hong Kong. The Lotus Bridge in Macau SAR began operation in 2000, and to date no bird death has been attributed to collision with the bridge or with vehicles on the bridge. Bird kills have, however, been reported in Macau at the base of the marble monument "Gateway of Understanding" near Nam Van Lake, Macau (Leung Va, pers. comm.). The reflective surface of the monument is thought to confuse flying birds thereby causing collisions.

9B6. CONCLUSIONS AND RECOMMENDATIONS

9B6.1 Key Findings

Less than 0.02% of total annual North American bird mortality is attributable to bird collisions with tall, man-made structures, thus indicating that this is an insignificant cause of bird fatalities.

The most lethal of man-made structures are cable-stayed telecommunication towers. Other structures that cause collisions are windows and building glazing, electric power lines, light-houses, and exhaust stacks.

Characteristics of tall structures causing bird fatalities are:

- height of tower structure (some over 600 m, most threatening over 250 m);
- siting of tower on prominent topographic feature that may be used by birds as a navigation guide;
- isolation of tower to avoid signal interference;
- lighting of tower using floodlights; and
- staying of tower by guy-wires that are unlighted, therefore invisible at night.

With the exception of lighting (which can be designed to advantage), cable-stayed bridges share none of the above tower characteristics. Fatalities are avoided because:

- heights of bridges are typically lower (less than 150 m);
- bridge locations are not on prominent topographic features (ridges, mountain peaks);
- cable-stayed portions of bridges are not isolated, but attached to the rest of the bridge;
- entire bridges are lighted, not just the tower supporting the cables;
- cable-stays are visible at night because they are larger in diameter than guy wires (±30 cm versus <1 cm); and
- bridge cable-stays are visible at night because they can be directly lighted.

The literature review shows that bridges may be used beneficially to serve as conduits for power cables that would otherwise pose a known threat to birds.

In Hong Kong with its many bridges and many kilometers of elevated transport infrastructure, there are no reports of bird fatalities from collisions with these structures.

Observations in Hong Kong and Macau made within the duration of this study did not identify any bird fatalities through collision with bridges.

Based on the findings of this comprehensive literature review and local observations, there is no scientific evidence to support the view that bridges are a cause of increased bird mortality. Thus the null hypothesis posted at the outset of this report must be accepted: Bridges do not cause significant bird mortality.

9B6.2 Recommendations

Even through this study finds no evidence to indicate bird collision with bridges is a cause of fatalities, it is considered good practice to adopt a precautionary approach. A number of design recommendations are suggested, these are:

- No power lines should be suspended above the bridge deck.
- Cable-stayed portions of the bridge (the navigation channels) should be flood-lit in good weather to increase the visibility of the cables at night to birds.

- Cable-stayed portions of the bridge should be visible to birds in all weather conditions. Consideration should be given to use special lighting, such as red-coloured strobe lighting, to supplement fold lighting in adverse weather conditions including mist, fog and rain. Details should be reviewed in the detailed design stage.
- Standard highway lighting will increase visibility of the top of the deck to birds that fly over the bridge at night.
- The undersurface of the bridge should be lit to increase visibility of the piers and deck undersurface to birds that fly beneath the bridge at night, subject to detailed design.
- Bridge management and maintenance personnel should be required to collect (if possible) and report all cases of bird mortality on the bridge (protocols for collection of carcasses and reporting will be provided).

9B7. PERSONAL COMMUNICATIONS CITED

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9B8. REFERENCES CITED

Able, K. P. 1973. The changing seasons. American Birds 27(1): 19-23.

Aldrich, J. W., R. R. Graber, D. A. Munro, G. J. Wallace, G. C. West and V. H. Cahalane. 1966. Report of committee on bird protection. Auk 83(3): 465-467.

Alerstam, T. 1978. Analysis and a theory of visible bird migration. *Oikos* 30: 273-349.

Anderson, A. H. 1933. Electrocution of Purple Martins. Condor 35: 204.

Anderson, W. W. 1975. Pole changes keep eagles flying. Transmission and Distribution 27: 28-31.

Anderson, W. L. 1978. Waterfowl collisions with power lines at a coal-fired power plant. Wildlife Society Bulletin 6(2): 77-83.

Andersen-Harild, P., and D. Bloch. 1973. En forelobig underspgelse over fugle draebt mod elledninger. (Birds killed by overhead wires on some locations in Denmark) [in Danish, English summary]. Dan. Ornithol. Foren. Tidsskr. 67(1-2): 15-23.

Anonymous. 1902. Birds that struck the city hall tower, 1902. Cassinia 6: 49.

Anonymous. 1930. The Cooper River bridge as a factor in the destruction of migration birds. Bird-Lore 32(1): 92-95.

Anonymous. 1962. 28 die in U. S. fog. The Globe and Mail, 2 February: 1. Toronto.

Anonymous. 1966a. News of the birds, summer and early fall, 1966. Nova Scottia Bird Society 8(3): 15-23.

Anonymous. 1966b. Towers deadly for birds. Detroit Free Press, 27 April: 12C.

Anonymous. 1972. An examination of the bird impact problem at the Nanticoke plant of the Ontario Hydro Electric System, Phase II. LGL Limited. Unpubl. report.

Anonymous. 1975. Youngstown member studies TV tower kill. bulletin of Audubon society West. Pa. 40(3): 4.

Armbruster, M. J. 1990. Characterization of habitat used by Whooping Cranes during migration. U. S. Fish and Wildlife Service Report 90(4).

Arnold, W. W. 1918. A bird hospital. Bird-Lore 20(3): 259-262.

Arup. 2002. Report No. 3 on Ecological Survey Results (Ref. 076). Agreement No. CE 39/2001, Shenzhen Western Corridor Investigation and Planning. Ove Arup & Partners Hong Kong Limited, February 2002, 26pp+app. A-Z.

Avery, M. L. and P. F. Springer. 1973. Investigation of bird migration and mortality at the Omega Navigation Station, LaMoure, North Dakota, fall 1972 and spring 1973. Proceedings of Bird Control Seminar. Bowling Green State University 6: 169-170.

Avery, M. L., P. F. Springer and J. F. Cassel. 1975. Progress report on bird losses at the Omega tower, southeastern North Dakota. North Dakota Academic Science 27(2): 40-49.

Avery, M. L. 1976. The effects of a tall tower on nocturnal bird migration – a portable ceilometer study. Auk 93(2): 281-291.

Bagg, A. M. 1958. (untitled). Rec. New England Birds 14(9): 1.

Bagg, A. M. 1964. Fall migration: northwestern maritime region. Audubon Field Notes 18(1): 7-17.

Bagg, A. M. 1965. The changing seasons. Audubon Field Notes 19(4): 438-446.

Bagg, A. M. 1971. The changing seasons. American Birds 25(1): 16-23.

Baird, J. 1964. The changing seasons. Audubon Field Notes 18(1): 4-6.

Baldwin, D. H. 1965. Enquiry into the mass mortality of nocturnal migrants in Ontario – progress report II. Ont. Nat. 1(2): 7-15.

Banks, R. C. 1976. Reflective plate glass – a hazard to migrating birds. BioScience 26(6): 414.

Banks, R. C. 1979. Human related mortality of birds in the United States. U. S. Fish and Wildlife Service Special Science Report – Wildlife 215.

Barrington, R. M. 1900. The migration of birds as observed at Irish lighthouses and lightships. R. H. Porter, London and Edward Ponsonby, Dublin.

Bartlett, G. A. 1952. A wholesale attraction, but not destruction, of migrating birds by the Albany (N. Y.) airport ceilometer. Feathers 14(11): 61-66.

Bartlett, G. A. 1956. Albany's ceilometer – killer of migrants. Feathers 18(11): 57-60.

Beer, J. V. and M. A. Ogilvie. 1972. Mortality. Pages 125-142 in Peter Scott and the Wildfowl Trust, the Swans. Houghton Mifflin Co., Boston.

Benson, P. C. and J. C. Dobbs. 1985. collisions of Cape Vultures (*Gyps coprothers*) with towers. Annual Meeting, Raptor Research Foundation, Sacramento, California.

Benton, A. H. 1954. Relationships of birds to power and communication lines. Kingbird 4(3): 65-66.

Bernard, R. F. 1966. Fall migration: western Great Lakes region. *Audubon field Notes* 20(1): 45-46, 50-53.

Bijileveld, M. F. I. J., and P. Goeldlin. 1976. Electrocution d'un couple de Buses *Buteo buteo* a Jongny (VD). Nos. Oiseaux 33(6): 280-281.

Boeker, E. L. 1972. Powerlines and bird electrocutions. U. S. Dep. Inter., Denver Wildlife Res. Cent. Unpubl. rep.

Boeker, E. L., and P. R. Nickerson. 1975. Raptor electrocution. Wildlife Society bulletin 3(2) 79-81.

Borell, A. E. 1939. Telephone wires fatal to Sage Grouse. Condor 41(1): 85-86.

Bourne, W. R. P. 1976. Petrels and lights at night. Notornis 23(2): 201-202.

Bourne, W. R. P. 1979. Birds and gas flares. Marine Pollution Bulletin 10(5): 124-125.

Boyd, H. and M. Ogilvie. 1954. Losses of Mute Swans in England in the winter of 1962-63. Wildfowl Trust Annual Report 15: 37-39.

Boylan, B. T. Jr. 1956. Lake Andes birdlife 40 years ago. S. Dak. Bird Notes 8(3): 40-41, 43.

Bradley, M. 1975. A study and analysis of man-made navigational hazards to birds in the vicinity of Richmond, Indiana. Earlham College, Richmond, Ind. Unpubl. report.

Bretherton, B. J. 1902. The destruction of birds by lighthouses. Osprey 1(5): 76-78.

Brewster, W. 1886. Bird migration. Memoirs of Nuttall Ornithology Club 1: 1-22.

Broderick, B. 1995. Why be concerned about light pollution? Royal Astronomical Society of Canada Bulletin.

Brooks, M. 1951. Fall migration: Appalachian region. Audubon Field Notes 5(1): 14-16.

Braithwaite, L. W. 1975. Waterfowl on a dry continent. Natural History 84(5): 60-69.

Brown, L. and D. Amadon. 1968. Eagles, hawks and falcons of the world. McGraw-Hill book Co., N. Y. Vol. 1.

Bruijns, M. F. M. and L. J. Stwerka. 1961. Het doodvligen van vogels tegen ramen. Levende Nat. 64(1): 253-258.

Brunetti, O. A. 1965. Supplementary report, cause of death of the Pinehurst Condor. Calif. Dep. Fish Game. Unpubl. rep.

Burton, D. E. and J. Woodford. 1960. The spring migration: Ontario-western New York region. Audubon Field Notes 14(4): 383-386.

Byrd, V., Hawaiian Islands National Wildlife Refuges, Kilauea, Hawaii. 1978. Letter to Paul Springer, Wildlife Research field station, Humboldt State University, Arcata, Calf.

Byrd, V., J. Sincock and T. Telfer. 1978. The status of Newell's Manx shearwater, a threatened species. Pacific Seabird Group 5th Annual Meeting, Asilomar, Calf.

Carpenter, F. and H. B. Lovell. 1963. Bird casualties near Magnolia, Larue County September 25, 1962. Ky. Warbler 39(2): 19-21.

Carter, J. H., III and J. F. Parnell. 1976. TV tower kills in eastern North Caroline. Chat 40(1): 1-9.

Carter, J. H., III and J. F. Parnell. 1978. TV tower kills in eastern North Carolina: 1973 through 1977. Chat 42(4): 67-70.

Case, L. D., H. Cruickshank, A. E. Ellis and W. F. White. 1965. Weather causes heavy bird mortality. Fla. Nat. 38(1): 29-30.

Chamberlain, B. R. 1961. Tower casualties at Columbia S. C. Chat 25(1): 18-19.

Clark, A. R. 1973. Avian mortality at three western New York television towers. M. A. Thesis. State University College, Buffalo, N. Y.

Clark, A. R. 1978. Erie County television tower casualties: 1978. Prothonotary 44(2): 186-189.

Cochrane, K. L., Crawford R. J. M. and F. Kriel. 1991. Tern mortality caused by collision with a cable at Table Bay, Cape Town, South Africa in 1989. *Colonial Waterbirds* 14(1): 63-65.

Cooke, W. W. 1888. Report on bird migration in the Mississippi Valley in the years 1884 and 1885. U. S. Dep. Agric., Div. Econ. Ornithol. Bull. No. 2.

Cooke, W. W. 1915. Bird migration. U.S. Department of Agricultures Bulletin: 185.

Craig, T. H. 1978. A car survey of raptors in southeastern Idaho 1974-1976. Raptor Research 12(1/2): 40-45.

Crawford, R. L. 1971. Predation on birds killed at TV tower. Oriole 36(4): 33-35.

Crawford, R. L. 1976. Some old records of TV tower kills from southwest Georgia. Oriole 41(4): 45-51.

Crawford, R. L. 1981. Weather, migration, and autumn bird kills at a north Florida TV tower. Wilson Bulletin 93: 189-195.

Crawford, R. L. and R. T. Engstrom. 2001. Characteristics of avian mortality at a North florida television tower: a 29-year study. *Journal of Field Ornithology* 72(3): 380-388.

Culver, D. E. 1915. Mortality among birds at Philadelphia, May 21-22, 1915. Cassinia 19: 33-37.

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

Dixon, C. 1897. The migration of birds: an attempt to reduce avine season flight to law. Horace Cox, London. 2nd ed.

Evink, G. L. 1996. Florida Department of Transportation initiatives related to wildlife mortality. In: Evink, G. L., P. Garrett, D. Zeigler, and J. Berry (eds), Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the Transportation Related Wildlife Mortality Seminar, State of Florida, Department of Transportation, Environmental Management Office, Tallahassee, Florida. June 1996, report no. FL-ER-58-96.

Ferrer, M., M. De La Riva, J. Castroviejo. 1991. Electrocution of raptors on power lines in southwestern Spain. J. Field Ornithology 62(2):181-190.

Finch, D. W. 1970. The fall migration: northeastern maritime region. Audubon field Notes 24(1): 13-21.

Gastman, E. A. 1886. Birds killed by electric light towers at Decatur, Ill. Am Nat. 20: 981.

Glue, D. E. 1971. Ringing recovery circumstances of small birds of prey. Bird Study 18(3): 137-146.

Gochfeld, M. 1973. Confused nocturnal behavior of a flock of migrating Yellow Wagtails. Condor 75(2): 252-253.

Goodwin, C. E. 1971. Fall migration: western Great Lakes region. Audubon field Notes 19(1): 37-41.

Goodwin, C. E. 1978. The fall migration: Ontario region. American Birds 32(2): 197-200.

Graber, R. R. 1962. Fall migration: middle western prairie region. Audubon Field Notes 16(1): 35-37, 41-43.

Graber, R. R. and W. W. Cochran. 1960. Evaluation of an aural record of nocturnal migration. Wilson Bulletin 72(3): 253-272.

Gramlich, F. J. 1973. Bird mortality – microwave towers. U. S. Fish Wildl. Serv. unpul. rep.

Green, J. C. 1964. Fall migration: western Great Lakes region. Audubon Field Notes 18(1): 33-34, 39-42.

Green, J. C. 1965. Fall migration: western Great Lakes region. Audubon Field Notes 19(1): 37-4, 44.

Griffin, W. W. 1956. Unexpected birds killed at Atlanta are ceilometers. Oriole 21(2): 21-22.

Gochfeld, M. 1973. Confused nocturnal behavior of a flock of migrating Yellow Wagtails. condor 75(2): 252-253.

Gunn, W. W. H., J .A. Livingston and F. A. Lewis. 1972. A preliminary examination of the bird impact problem at the Nanticoke plant, Onterio Hydro electric system. LGL Limited, Toronto, Canada.

Hachisuka, M. U. 1926. Birds of the Eiffel Tower. Ibis 2(4): 834.

Hansen, L. 1954. Birds killed at lights in Denmark 1886-1939 [in English, Danish summary]. Vidensk. Medd. Dan. Naturhist. Foren. 116: 269-368.

Harness, R. 1977. Raptor electrocutions caused by rural electric distribution powerlines. MSc. thesis submitted to Dept. Fishery and Wildlife Biology, Colorado Statue University, Fort Collins, Colorado, USA, 53pp.

Harrison, J. 1963. Heavy mortality of Mute Swan from electrocution. Wildfowl Trust 14th annual Report: 164-165.

Harvie-Brown, J. A. and J. Cordeaux. 1880. Report on the migration of birds in the autumn of 1879. Zoologist 4(41): 161-204.

Harwin, R. M. 1971. White Stork: longevity record. Ostrich 42(1): 81.

Heijnis, R. 1980. Bird mortality from collision with conductors for maximum tension. Okol. Vogel (Ecology of Birds) 2, Sonderheft 1980: 111-129.

Hendrickson, J. R. 1949. A hummingbird casualty. Condor 51(2): 103.

Herbert, A. D. 1970. Spatial disorientation in birds. Wilson Bulletin 82(4): 400-419.

Herndon, L. R. 1954. Bird mortality – Johnson City. Migrant 25(4): 65-67.

Herndon, L. R. 1962. A Texas bird-fall. Migrant 33(4): 60-61.

Herndon, L. R. 1973. Bird kill on Holston Mountain. Migrant 44(1): 1-4.

Herren, H. 1969. The status of the Peregrine Falcon in Switzerland. Pages 231-238 in J. J. Hickey, ed. Peregrine Falcon populations – they biology and decline. university of Wisconsin Press, Madison.

Hosford, H. V. 1962. Migrant bird casualties at TV towers. Manitoba Nat. Hist. Soc., Ornithol. Sec. Newsl. 1: 5-8.

Howell, J. C. and J. T. Tanner. 1951. An accident to migratory birds at the Knoxville airport. Migrant 22(4): 61-62.

Imber, M. J. 1975. Behavior of petrels in relation to the moon and artificial lights. Notornis 22(4): 302-306.

Imhoff, T. A. 1954. Bird mortality at Birmingham ceilometer. Ala. Bird Life 2(3&4): 38-39.

Jaago, M. 1970. Accident involving migrant birds at Marjama [in Estonian]. Eesti Loodus 1970: 184.

Jackson, W. B. and W. A. Peterman. 1977. Davis-Besse bird hazard monitoring contract. January: 1-21.

Janss, G. F. E. and M. Ferrer. 1998. Rate of bird collision with power lines: effects of conductor-marking and static wire-marking. Journal of Field Ornithology 69(1): 1-7.

Janssen, R. B. 1963. Destruction of birdlife in Minnesota – Sept. 1963. I. birds killed at the Lewisville television tower. Flicker 35(4): 110-111.

Jaroslow, B. N. 1979. A review of factors involved in bird-tower kills, and mitigative procedures. Pages 469-473 in G. A. Swanson (tech. coord.) The Mitigation Symposium: a National Workshop on Mitigating Losses of Fish and Wildlife Habitats. U. S. For. Serv. Gen. Tech. Rep.

Johansen, K. 1975. Review and analysis of bird impingement and stack illumination at Ontario Hydro generating stations. Rep. 75073.

Jurek, R. M. 1994. Condor information leaflet. California Department of Fish and Game, Sacramento.

Kale, H. W. II. 1971. Report on bird kill at construction site of Florida Power and Light Company's Hutchinson Island nuclear energy power plant, night of April 26-27, 1971. Unpubl. rep.

Karlsson, J. 1977. Bird collisions with towers and other man-made constructions [in Swedish, English summary]. Anser 16: 203-216.

Kemper, C. A. 1964. A tower for TV, 30,000 dead birds. Audubon Magazine 66(2): 86-90.

Kleen, V. M. 1975. The fall migration: middlewestern prairie region. American Birds 29(1): 64-68.

Klem, D. Jr. 1989. Bird-window collisions. Wilson Bulletin 101: 606-620.

Klem, D. Jr. 1990. Collisions between birds and windows: mortality and prevention. Journal of Field Ornithology 61: 120-128.

Kochert, M. N. and R. R. Olendorf. 1999. Creating raptor benefits from powerline problems. The Journal of Raptor Research 33(1):39-42.

Kumlien, L. 1888. Observations on bird migration in Milwaukee. Auk 5(3): 325-328.

Kwok, H. K. and Dahmer, T. D. (in press). Habitat utilization by Little Egrets Egretta garzetta breeding at Tai O Egretry. *Memoirs of the Hong Kong Natural History Society* 25.

Laskey, A. R. 1964. Data from the Nashville TV. tower casualties, autumn 1964. Migrant 35(4): 95-96.

Leitner, P. and G. S. Grant. 1978. Observations on waterbird flight patterns at Salton Sea, California, October 1976 – February 1977. Saint Mary's College of California, Moaga, California.

Lewis, H. F. 1927. Destruction of birds by lighthouses in the provinces of Ontario and Quebec. Canada Field Naturalist 41(3): 55-58, 41(4): 75-77.

Lincoln, F. C. 1939. The migration of American birds. Doubleday, Doran and Co., Inc., New York.

Lohrl, H. 1962. Vogelvernichtung durch moderne Glaswande. Kosmos 58: 191-194.

Lord, W. G. 1951. Bird fatalities at bluff's Lodge on the Blue Ridge Parkway, Wilkes County, N. C. Chat 15(1): 15-16.

Macdonald, D. 1978. Blackcaps killed by striking window panes. British Birds 71(3): 132-133.

Maehr, D. S., A. G. Spratt and D. K. Voigts. 1983. Bird casualties at a central Florida power plant. Florida Field Naturalist 11: 45-68.

Mailliard, J. 1898. Notes on the nesting of the Fork-tailed Petrel (*Oceanodrama furcata*). Auk 15(3): 230233.

Manosa, S. and Real, J. 2001. Potential negative effects of collisions with transmission lines on a Bonelli's Eagle population. *Journal of Raptor Research* 35(3): 247-252.

McKenna, M. G. and G. E. Allard. 1976. Avian mortality from wire collisions. *North Dakota Outdoors* 39(5): 16-18.

Mead, C. J. 1979. Mortality and causes of death in British Sand Martin. Bird Study 26(2): 107-112.

Medway, L. and D. R. Wells. 1970. Bird report: 1968. Malayan Naturalist Journal 23(2): 47-77.

Melville, D. 1980a. *The Birdstrike Hazard at Kai Tak Airport, Hong Kong. Final Summary Report*. Agriculture and Fisheries Department, Hong Kong.
Melville, D. 1980b. *Bird Migration Through Hong Kong Observed by Radar and its Implications for Birdstrike Control*. Agriculture and Fisheries Department, Hong Kong.
Mercer, B. 1905. A municipal bird trap. American Ornithology 5(3): 53-55.
Merriam, C. H. 1885a. Preliminary report of the committee on bird migration. Auk 2(1): 53-57.
Merriam, C. H. 1885b. bird migration at the Straits of Mackinac. Auk 2(1): 376.
Merrie, T. D. H. 1979. Birds and North Sea oil production platforms. Scottish Birds 10(7): 271-275.
Meyer, J. R. 1978. Effects of transmission lines on bird flight behavior and collision mortality. Bonneville Power Administration, Portland, Ore.
Michener, H. 1928. Where engineer and ornithologist meet: Transmission line troubles caused by birds. Condor 30(3): 169-175.
Miller, D. E., E. L. Boeker, R. S. Thorsell and R. R. Olendorff. 1975. suggested practices for raptor protection on powerlines. Edison Electric Institute.
Mosman, D. 1975. Bird casualties at Alleman, Ia. TV tower. Iowa Bird Life 45(3): 88-90.
Mumford, R. E. 1960. Fall migration: middlewestern prairie region. Audubon Field Notes 14(1): 38-41.
Munro, J. A. 1924. A preliminary report on the destruction of birds at lighthouses on the coast of British Columba. Can. Field-Nat. 38(8): 141-145, 38(9): 171-175.
Nelson, M. 1975. Power lines and birds of prey. Aware Magazine 52: 9-12.
Nelson, M. W. and P. Nelson. 1976. Power lines and birds of prey. Idaho Wildlife Reserve 28(5) 3-7.
Newman, R. J. 1960. Spring migration central southern region. Audubon field Notes 14(4): 392-397.
Nisbet, I. C. T. 1968. Weights of birds caught at night at a Malayan radio tower. Ibis 110(3): 352-354.
Ogden, J. 1960. Observations at a T. V. tower during a bird fall. Migrant 31(4): 65-67.
Ogden, L. P. 1996. Collision course: the hazards of lighted structures and windows to migrating birds. World Wildlife Fund Canada and the Fatal Lights Awareness Program. WWF Canada.
Overin, R. 1936. The 1935 fall migration at the Washington Monument. Wilson bulletin 48(3): 222-224.
Parmalee, P. W. and B. G. Parmalee. 1959. Mortality of birds at a television tower in central Illinois. Bulletin of Illinois Audubon society 111: 1-4.
Peterman, W. A. 1974. II. Weather and bird mortality. Bird hazard monitoring contract, Davis-Besse site. Semi-annual report. June: 14-20.
Peterson, A. W. 1963. Destruction of birdlife in Minnesota – September 1963. IV. Birds killed at Park Rapids. Flicker 35(4): 113.
Pettingill, O. S. 1970. Ornithology in laboratory and field. Burgess Publ. Co., Minneapolis.
Phelps, W. H. 1961. Night migration at 4,200 metres in Venezuela. Auk 78(1): 93-94.
Phillips, R. L. 1986. Current issues concerning the management of golden eagles in western U.S.A. Birds of Prey Bulletin 13: 149-156.
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. Colonial Waterbirds 21(1): 20-34.
Polshek, P. 1977. Fox preys on nocturnal migrants. Kingbird 27(1): 28.
Post, W., Jr. 1963. Tower casualties at Aiken, South Carolina. Chat 27(1): 23.
Potter, J. K. and J. J. Murray. 1949. Fall migration: middle Atlantic coast region. Audubon Field Notes 3(1): 8-10.
Pough, R. H. 1948. Out of the night sky. Audubon Magazine 50(6): 354-355.
Raible, R. 1968. Vogelverluste an Glasflachen and Methoden zu ihrer Verhutung. Angenandte Ornithology 3(2): 75-79.
Reed, J. R. and J. L. Sincock. 1985. Light attraction in endangered procellariiform birds: Reduction by shielding upward radiation. Auk 102(2): 377-383.
Rigby, R. W. Refuge Manager, Bosque del Apache National Wildlife Refuge, Socorro, N. Mex. 1978. Letter to Michael Avery, National Power Plant Team, Ann Arbor, Mich.
Robertson, W. B. Jr. 1968. Spring migration: Florida region. Audubon Field Notes 22(4): 516-520.
Ross, R. C. 1946. People in glass houses should draw their shades. Condor 48(3): 142.
Sage, B. 1979a. Flare up over North Sea birds. New Scientists 81: 464-466.
Sage, B. 1979b. Bird flare. Birds 7(5): 24-25.
Savage, T. 1965. Casualties at ski resort, Gatlinburg. Migrant 36(4): 81-82.

Savereno, A. J., L. A. Savereno, R. Boettcher and S. M. Haig. 1996. Avian behavior and mortality at power lines in coastal South Carolina. Wildlife Society Bulletin 24(4): 636-684.

Sawyer, P. J. 1961. Bird mortality at the WENH-TV tower in Deerfield, New Hampshire. New Hampshire Audubon Q. 14(2): 46-49.

Schorger, A. W. 1952. Ducks killed during a storm at Hot Springs, South Dakota. Wilson Bulletin 64(2): 113-114.

Schotzho, J. 1962. Interrupted migration. Flicker 34(2): 61.

Schmidt-Koenig, K. 1979. Avian orientation and Navigation. Academic Press, London.

Scott, F. R. and D. A. Cutler. 1971. The fall migration: middle Atlantic Coast region. American Birds 25(1):36-40.

Seets, J. W. and H. D. Bohlen. 1977. Comparative mortality of birds at television towers in central Illinois. Wilson bulletin 89(3): 422-433.

Sincock, J. L. and G. E. Swedberg. 1969. Rediscovery of the nesting ground of Newell's Manx Shearwater (*Puffinus puffinus newelli*), with initial observations. Condor 71(1): 69-71.

Sisson, J. 1975. Death traps. *National Wildlife* 13(2): 18.

Sprunt, A. IV, W. B. Robertson, Jr., S. Postupalsky, R. J. Hensel, C. E. Knoder and F. J. Ligas. 1973. Comparative productivity of six Bald Eagle populations. N. Am. Wildl. Nat. Resource. Conf. 38: 96-106.

Squires, W. A. and H. E. Hanson. 1918. The destruction of birds at the lighthouses on the coast of California. Condor 20(1): 6-10.

Steenhof, K. 1978. Management of wintering Bald Eagles. U. S. Fish and Wildlife Service. FWS/OBS-78/79.

Sterling, E. 1890. Killed in migration. forest and Stream. 5 June 1890.

Stout, I. J. 1967. The nature and pattern of nonhunting mortality in fledged North American waterfowl. M. S. Thesis. Virginia Polytechnic Institute, Blacksburg.

Stuart-Sutherland, R. 1922. Round the lamp. Emu 22(1): 54-59.

Swales, M. K. 1965. The sea-birds of Gough Island. Ibis 107(1): 17-42 and 107(2): 215-219.

Swirski, Z. 1965. Bird migrations. U. S. Dep. Commerce, Off. Tech. Serv., Washington, D. C.

Synder, L. L. 1946. "Tunnel flier" and window fatalities. Condor 48(6): 278.

Szczepski, J. B. 1965. Palace of Culture and Science in Warsaw again a locality of bird tragedy [in Polish summary]. Przegl. Zool. 9(2): 178-184.

Tamisier, A. 1997. Barcarin bridge, a threat for the Camargue and birds. Alauda 65:47-52.

Taylor, W. K. 1981. No longer a bird killer. Florida Naturalist 9: 4-5, 10.

Telfer, T. C., J. L. Sincock, G. V. Byrd and J. R. Reed. 1987. Attraction of Hawaiian seabirds to lights: conservation efforts and effect of moon phase. Wildlife Society Bulletin 15: 406-413.

Trapp, J. L., U.S. Fish and Wildlife Service, Anchorage, Alaska. 1978. Letter to Paul F. Springer, Wildlife Research Field Station, Humbolt State University, Arcata, Calif. 16 November.

Temme, M. W., B. Jackson and W. A. Peterman. 1975. Davis-Besse bird hazard contract. Semi-annual rep. December: 1-22.

Tufts, R. W. 1928. A report concerning destruction of bird life at lighthouses on the Atlantic coast. Can. Field-Nat. 42: 167-172.

Valum, B. 1968. Fugledod mot glassvegger [in Norwegian, English summary]. Sterna 8: 15-20.

Verheijen, F. J. 1981. Bird kills at lighted man-made structures: not on nights close to a full moon. American Birds 35: 251-254.

Vickery, P. D. 1978. The fall migration: northeastern maritime region. American Birds 32(2): 174-180.

Webster, F. S. Jr. 1960. Spring migration: south Texas region. Audubon Field Notes 14(4): 401-407.

Webster, F. S. Jr. 1973. Spring migration: south Texas region. American Birds 27(4): 793-795.

Webster, B. 1979. New light-out policies save the lives of migrating birds. New York Times, 16 April: B6.

Weir, R. D. 1972. Autumn migration kills at the Lennox generating station. blue Bill 19(4): 49-51.

Weston, F. M. 1966. Bird casualties on the Pensacola Bay Bridge (1938-1949). Florida Naturalist 39(2): 53-54.

Wiese, J. H. 1979. A study of the reproductive biology of herons, egrets and ibis nesting on Pea Patch Island, Delaware; final interpretive report. Delmarva Power and Light Co., Wilmington, Del.

Willard, D. E. 1978. The impact of transmission lines on birds (and vice versa). Pages 3-7 in M. L. Avery (ed.) Impacts of transmission lines on birds in flight. U. S. fish Wildlife Service FWS/OBS-78/48.

Wong, F. K. O. 1991. Habitat utilisation by Little Egrets breeding at Mai Po Egretry. *Hong Kong Bird Report* 1990: 185-190.

WWF Canada. 1997. Time to turn out the office lights at night: migratory bird season has begun. Canada News Wire.

Wylie, B. 1977. Bird kill at Chestnut Ridge. Redstart 44: 65.