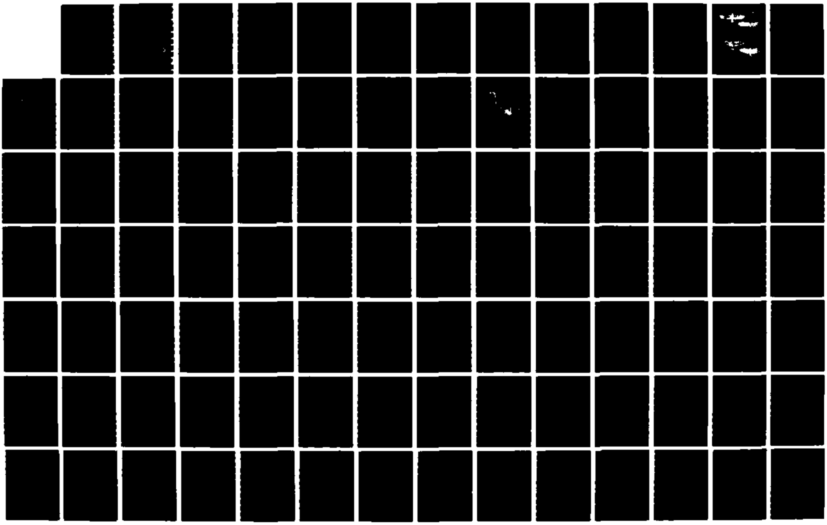
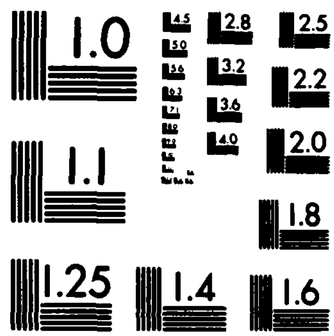
AD-A171 451 THE NORTHERN BALD EAGLE (HALIAEETUS LEUCOCEPHALUS ALASCANUS)(U) CORPS OF ENGINEERS SEATTLE WA SEATTLE DISTRICT JAN 79 1/1

UNCLASSIFIED F/G 6/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A171 451

THE NORTHERN BALD EAGLE

(Haliaeetus leucocephalus alascanus)

A Literature Survey

Prepared by Environmental Resources Section
Seattle District, U.S. Army Corps of Engineers

January 1979

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. A171 451	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The northern bald eagle		5. TYPE OF REPORT & PERIOD COVERED Final, 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Environmental Resources Section		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Seattle District, U.S. Army Corps of Engineers P.O. Box C-3755 Seattle, Wa 98124-2255		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS same		12. REPORT DATE January, 1979
		13. NUMBER OF PAGES 86
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) unlimited
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Eagles
Bald Eagles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Compiles and presents information on the northern bald eagle to provide a resource tool for understanding the bird and its interrelationship with the environment. Report gives special consideration to management techniques being employed to conserve the species which has "endangered" status throughout most of the US.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

A

PREFACE

This report has been prepared under the assumption that, although they are considered separate subspecies, much of the biological and behavioral research on the southern race is probably applicable to the northern bald eagle as well. Conversely, some of the information in this paper may also pertain to the southern bald eagle.

TABLE OF CONTENTS

INTRODUCTION

The objective of this report is to compile and integrate the most recent information available on the northern bald eagle (Haliaeetus leucocephalus alascanus Townsend) in order to provide a resource tool for a better understanding of this bird and its interrelationship with its environment. Such knowledge is essential in determining the impact of various human activities on this eagle and is particularly pertinent in consideration of the recent extension of the protective provisions of the Endangered Species Act of 1973 to all bald eagles in the conterminous United States (U.S. Department of Interior, 1978). Some of man's projects, such as water and power management systems, can possibly be manipulated to benefit the bald eagle. If adverse impacts are identified, ameliorative actions can be taken to insure the protection of this eagle and the habitat upon which it depends. To further facilitate this goal, this report gives special consideration to management techniques being employed to help conserve populations.

The bald eagle (Haliaeetus leucocephalus) was chosen to officially represent the United States in 1782. To the members of the Continental Congress, the striking bird probably seemed to embody the spirit they wished to instill in their new country. Symbolizing the noble ideals of liberty and independence, the powerful eagle commanded respect. Although the attribution of such anthropomorphic characteristics may not be valid, the choice of the bald eagle as the national symbol was appropriate in that the bird is native only to North America and is widely distributed across the United States.

Two subspecies of the bald eagle are recognized: the northern bald eagle and the southern bald eagle (H. l. leucocephalus Linnaeus) (American Ornithologist's Union (A.O.U.), 1957). The separation is based on a geographic variation in size, as the northern race is generally larger than the southern race. The northern bald eagle breeds across the northern half of the conterminous United States, northward through Canada to the Alaska peninsula, and west through the Aleutian Islands to Bering Island on the Arctic coast, the only place outside of the North American continent where the species is found. The southern race generally ranges across the United States south of this region, with the major breeding concentrations located in the southeastern states (A.O.U., 1957).

Until recent years, appreciably more information had been amassed regarding the southern bald eagle than its northern counterpart. This was due in part to the relatively restricted breeding range of the southern race, which facilitated research, and partially because its major breeding populations were located near areas of high human concentrations and were therefore more conspicuous. These eagles were the first in which the adverse effects of some human activities were discerned (Broley, 1950, 1958; Cunningham, 1960).

Spurred by such reports, the National Audubon Society initiated and sponsored the Continental Bald Eagle Project, which began in 1961. Among its objectives was the determination of the status, numbers, and distribution of nesting and wintering bald eagles. The study's results indicated that the species still occupies most of its historic range. However, its numbers appear to have been reduced, with an accelerated decline evident since World War II (Sprunt, 1969). This decline was attributed to loss of nesting habitat due to human activities, general human disturbance, shooting, and contamination of the environment with pollutants which reduce reproductive ability (Sprunt and Ligas, 1966, cited by Corr, 1974).

The reduction of bald eagle populations in the southeastern United States appeared so extensive that in March of 1967 the U.S. Fish and Wildlife Service placed the southern bald eagle on the List of Endangered Wildlife and Plants. The northern bald eagle was not listed primarily because the Alaskan population was not considered endangered, even though some populations in the northern United States were believed to be in comparable, if not worse condition than populations of the southern race. These populations were not afforded the same protection under the law because it was not legally possible to list only a portion of a subspecies at that time. The status of "threatened" was nonexistent. The listing of only the southern subspecies as "endangered" presented some problems. Foremost was the difficulty in distinction between the two races through an extensive area of the central United States where there is a gradual cline between the two size extremes. Any range delineation is arbitrary, as there is considerable post-breeding movement of both subspecies into each other's breeding ranges. The extent of such intermingling is largely unknown (A.O.U., 1957; Department of Interior, 1978).

The enactment of the Endangered Species Act of 1973 allowed listing of individual populations of a species as "endangered" or "threatened." The law defines an "endangered species" as any species or subspecies which is in danger of extinction throughout all or a significant portion of its range; the term "threatened" refers to any species which is likely to become "endangered" within the forseeable future. The Endangered Species Act makes it unlawful to kill, capture, collect, possess, buy, sell, trade, transport, import, or export any such species or any parts thereof. Perhaps most importantly, Section 7 insures that actions which are federally funded, authorized, or administered do not jeopardize the continued existence of any endangered or threatened species or result in the modification or destruction of habitat critical to such species. This special legal status can be extended to a species because of any of the following five factors:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;

(2) overutilization for commercial, sporting, scientific, or educational purposes;

(3) disease or predation;

(4) the inadequacy of existing regulatory mechanisms; and

(5) other natural or manmade factors affecting its continued existence.

The status of the northern bald eagle was reviewed by the Fish and Wildlife Service in consideration of the above criteria, and it was determined that many populations qualified for "endangered" status under all categories except the fourth (Department of Interior, 1978). As of 16 March 1978, "endangered" status was extended to the bald eagle throughout the conterminous United States except in the states of Washington, Oregon, Minnesota, Wisconsin, and Michigan, where it is listed as "threatened." Alaska was not considered because of the relatively large, stable population in that state. All subspecific references were deleted from the List of Endangered and Threatened Wildlife and Plants.

The bald eagle has a larger regularly inhabited range than any other species now listed or being considered for listing. Until recently, relatively little has been known about this eagle throughout the northern part of its range. Although increased studies during the past decade have rapidly yielded information on the ecology of the northern bald eagle, many data gaps still exist. Some particularly vital gaps concern age-specific mortality, the origins and movements of migratory eagles, and long-range population trends. These information voids must be filled in order to facilitate enlightened management of this eagle.

GENERAL BIOLOGY

Description. As is the case of most birds of prey, the female northern bald eagle is significantly larger and heavier than the male. Adult females may reach 107 centimeters (cm) in length with a wingspread of 2.4 meters (m) and may weigh over 6.4 kilograms (kg). Their smaller mates are perhaps 18 cm shorter and 1 to 1.5 kg lighter, with a wingspread upwards of 2.1 m (Herrick, 1933; Chura et al., 1967). Sexual dimorphism in the bald eagle is limited to this difference in size. Brown and Amadon (1968) maintain that reversed sizes of the sexes is an adaptation to facilitate pairing in birds that are aggressive, predatory, and normally of solitary habit.

Size is also the only distinction between the two races of bald eagles, with the largest of the species coming from the northern part of the range, gradually decreasing in size southward so that the eagles of Alaska are noticeably larger than those of Florida.

Bent (1937) gives average wing measurements of bald eagles from several localities. The average wing length for 10 Alaskan adult males was 61.14 cm, while the average of nine males from Florida and Georgia was 52.91 cm. The comparable measurement of six Alaskan females was 64.87 cm and for five females from the southern states 57.53 cm. Similar differences in size also exist in the measurements of the tail, bill, and other features of the two subspecies (Friedman, 1950). The greater size of the northern race is even reflected in the eggs, with the average size of eggs increasing gradually northward through the bald eagle's range (Bent, 1937). Several authors attribute the difference in size to clinal variation (Bent, 1937; Grewe, 1966; Maestrelli and Wiemeyer, 1975).

Immature bald eagles tend to have greater length and wingspan measurements than adults. Kalmbach et al. (1964) recorded the dimensions and weights of 108 bald eagles from Alaska, including juveniles and adults of both sexes. The average measurements of immature eagles, except that of the beak, were greater than those of adult birds of the same sex. Yet the average weight of juveniles was less than adults, indicating the greater dimensions of juveniles are attributable to greater length of wing and tail feathers, rather than greater body size. Thus, it appears that young eagles require a molt or more to acquire adult proportions as well as coloration. This is also true of many other Falconiformes; in some species of hawks, the feathers of immatures may be long enough to affect flight, and thus feeding habits (Brown and Amadon, 1968).

An adult bald eagle cannot be confused with any other bird of prey. The body is a dark chocolate brown except for the distinctive white head and tail. The bill and cere are yellow. The cere is the basal part of the upper mandible, which is softer and more skin-like than the remainder of the bill. The feet are also yellow, with black talons. Servheen

(1975) reports the iris of the adult to be cream white in color, although other sources describe the eye as bright yellow (Grossman et al., 1964; Brown and Amadon, 1968; Beebe, 1974).

Attainment of the adult plumage is a gradual transition occurring over a period of several years. Many inconsistencies exist in literature regarding the sequence of molts and plumage characteristics, as well as the length of time the bald eagle retains its subadult plumage. According to a detailed age classification system developed by Servheen (1975), full adult plumage is not attained until the bald eagle is 6 years old. Shea (1973) and Southern (1967) consider eagles to be immature until the seventh year, although Southern admits the possibility that adult plumage begins as early as the fifth year. Crandall (1941) reports that a captive bald eagle did not acquire a completely white tail until its eleventh year. Such differing reports may indicate individual variation in young eagles (Brown and Amadon, 1968).

A newly hatched bald eagle chick is covered with a thick, silky down which is gray above and paler gray to white on the head, chin, and underparts. The bill and eyes, which do not open until several hours after hatching, are a contrasting dark color. The down is of two sorts: a thick inner coat plentifully supplied with barbs, and a thin outer layer of long, hairlike filoplumes. The lower third of the bald eagle's shank is naked in both the adult and juvenile stages, but in the early down stage, the shank is feathered all the way down, except on the underside. This first natal down lasts about 3 weeks, after which it is replaced by a short, dense down coat of a uniformly dark gray (Herrick, 1934).

At the age of 6 and 7 weeks, transition to the juvenile plumage occurs. This plumage is largely dark brown to black with a few light brown feathers on the breast, back, and upper wing coverts (Servheen, 1975) and is retained until the first annual molt. The time of year which molting occurs is not clear. Observation of plumage changes of captive bald eagles indicates that molting takes place during the summer months (Crandall, 1941), while Southern's (1967) data suggests late winter through spring. Through subsequent annual molts, juveniles acquire new feathers which have increasing amounts of white, particularly around the shaft, until the deep chocolate brown adult plumage is attained. The head and tail gradually become completely white (Snow, 1973; Servheen, 1975). Southern (1967) gives a detailed description of annual and transitional plumages.

The beak, cere, and iris of the first-year juvenile are dark brown. The legs are a pale yellow. The second year the iris is a light brown, becoming noticeably more golden by the fourth year and only slightly darker than the adult iris by the fifth year. The beak and cere also become gradually lighter until the yellow color of the adult is attained (Servheen, 1975).

While the distinctive plumage of adult bald eagles makes them unmistakable, immatures are often confused with golden eagles (Aquila chrysaetos). The bald eagle can be distinguished by its heavier bill, lack of golden head feathers, and incompletely feathered tarsi, which are feathered in the golden eagle. Immature golden eagles have white wing patches and a broad white band at the base of the tail which is dark-tipped. This band gradually disappears as the adult plumage is acquired, becoming marked with narrow, irregular brown bars. The tails of juvenile bald eagles are variably mottled with white and are not so distinctly dark-tipped as in immature goldens. In flight, golden eagles soar more frequently than the bald eagles. The head and neck of the bald eagle is stretched out longer in flight than in the golden eagle (see Figure 1) (Bent, 1937; Shea, 1973; Snow, 1973).

Population Estimates, Distribution, and Trends. Accurate census data on the bald eagle is fragmentary and virtually nonexistent throughout extensive parts of its northern range. Increased studies during the past 15 years indicate that the present continental population of the species is much larger than first suspected (see Figure 2). A recent estimate places the population between 35,000 to 60,000 eagles, most of which occur in Alaska and Canada (Brown et al., 1975). Surveys conducted by the Fish and Wildlife Service in 1973 and 1974 indicate that approximately 1,000 pairs of bald eagles nest in the conterminous United States (Department of Interior, 1974); nonbreeding adults and immatures probably account for another 500 to 1,000 birds (Marshall and Nickerson, 1976). The determination of subspecific populations is complicated by the fact that the winter ranges of the northern and southern bald eagle overlap. Data indicates that the population of the southern subspecies is less than 300 nesting pairs (U.S. Congress 1971:96). Thus, the northern subspecies constitutes most of the continental bald eagle population.

Alaska supports the largest known population of northern bald eagles, estimated between 30,000 to 55,000 birds (Department of Interior, 1974). The relatively mild, southeast portion alone supports about 8,000 eagles (King et al., 1972). Significant numbers of breeding eagles occur southward along the Pacific Coast to the Olympic Peninsula in Washington. An estimated 1,000 nesting territories exist on Vancouver Island and adjacent islands off the British Columbia-Washington coast (Hancock, 1965). Substantial populations nest throughout Canada's Northwest Territories, Alberta, Saskatchewan, Ontario, Manitoba, and the maritime provinces, where only scattered attempts have been made to assess populations. One study in the boreal forest region of central Saskatchewan estimates a breeding population of 1,592 to 7,970 bald eagles (Whitfield et al., 1974).

In the United States, the Pacific Coast states support significant breeding populations. An intensive study conducted in 1974 and 1975 found 114 active nests in western Washington, ranking the population of that state among the largest in the contiguous United States (Grubb,

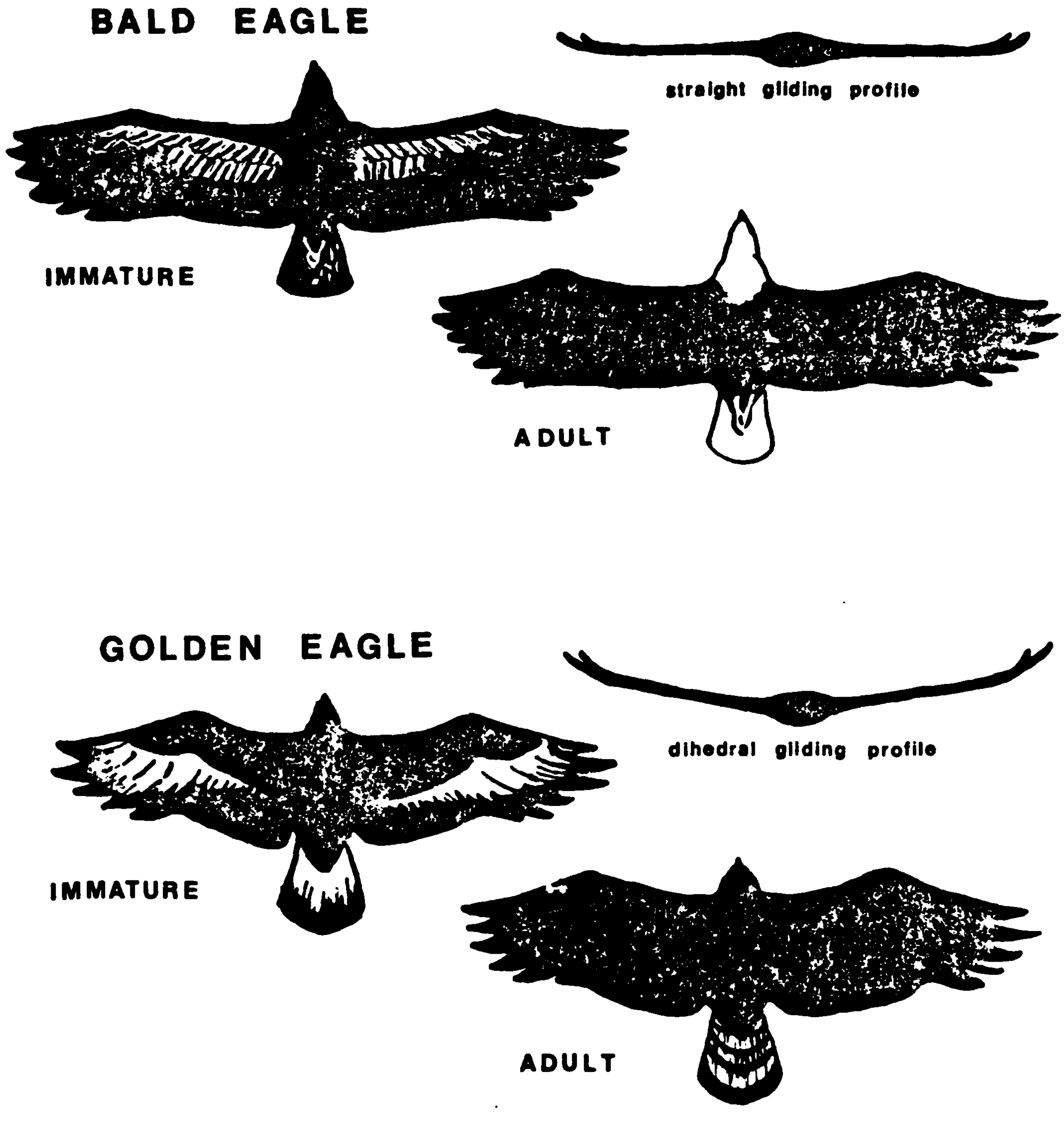


Figure 1. Flight silhouettes of the Bald Eagle and the Golden Eagle.

Figure 2. The shaded areas represent the three main breeding regions of the Northern Bald Eagle: 1) the Pacific coast from the Aleutian Islands south to Washington's Olympic Peninsula; 2) scattered across Canada's boreal forests; and 3) the Great Lakes area (adapted from Hancock 1970).

1976a). Bald eagles nest inland on major reservoirs and lakes in Oregon, and an extension of this population occurs in northern California (Marshall and Nickerson, 1976). The latter state is estimated to support from 25 to 50 pairs of bald eagles. Although the A.O.U. checklist (1957:113) includes California within the range of the southern race, Bent (1937:339) suggests that the large dimensions of 16 eggs from southern California and northern Lower California indicate that the northern race breeds that far south along the Pacific Coast.

Eagles breed throughout the Rocky Mountain states. Idaho and Montana were known to contain about 30 nests in 1973, and estimates range up to 75 nests (Nickerson, 1973). Significant bald eagle populations occur in the western Great Lakes states. The 1974 Fish and Wildlife Service survey found the states of Minnesota, Wisconsin, and Michigan to support the highest concentrations of breeding eagles in the lower United States, with 127, 109, and 82 active nests, respectively (Nickerson, 1974, cited by Grubb, 1976a). In the eastern states, notable eagle populations are located in Maine and in the Chesapeake Bay area, which in 1975 had 31 and 75 active nests, respectively (Marshall and Nickerson, 1976).

Although the northern race of the bald eagle still occupies most of its historic range, breeding populations in some localities south of the United States-Canadian border have declined or virtually vanished. As of 1973, numbers of breeding pairs in Maine, Michigan, and the Great Lakes states were declining annually. New York State once supported a breeding population linking the Maine population with the Great Lakes eagles. Since World War II, however, nesting eagles through interior New York have disappeared. By 1975, only one nesting pair remained in that state (Marshall and Nickerson, 1976). Only a remnant population still nests in Maine's interior (Sprunt et al., 1973). The Chesapeake Bay area is estimated to have supported 200 pairs of bald eagles in 1936 (Sprunt and Ligas, 1966, cited by Snow, 1973); 30 years later the population had declined to about 75 pairs (Marshall and Nickerson, 1976). The Great Lakes area has undergone a definite population loss, especially from the lakeshores and islands (Sprunt, 1969). Nesting eagles are virtually gone from several states along the Mississippi River drainage (Department of Interior, 1974).

The overall population of the bald eagle is generally believed to have declined slowly for a long time, but documentation is difficult, as accurate figures for historical populations are nonexistent. Claims that populations have declined are primarily based on information regarding reproductive success. However, such data alone, without information on age-specific mortality and age of first breeding, is not sufficient to determine long-range population trends. Yet the lack of definitive data in the latter two areas precludes the modeling of bald eagle population dynamics and, at least for now, necessitates reliance on data regarding reproductive rates and changes in numbers of individuals comprising populations (Grier, 1977). Although adequate census data is also lacking, the information which is available indicates an accelerated rate of decline in portions of the eagle's range since World War II (Sprunt, 1969; Marshall and Nickerson, 1976). An analysis of Audubon-sponsored Christmas Bird Counts from 1955 to 1975 indicates the United States bald eagle population has steadily diminished in most of the states where censusing was consistent (Brown, 1975). However, Grier (1977) notes that winter counts are of limited value in determining population status because they reflect annual variations in weather and food availability.

Determination of the "normal" reproductive rate of the northern bald eagle is impossible due to the lack of definitive studies dating back far enough. The large, relatively undisturbed breeding population on the Kodiak National Wildlife Refuge in Alaska is believed to represent as close to a normal situation as presently exists (Sprunt et al., 1973). This population has a comparatively higher productivity than most others: 66 percent nesting success, with an average of 1.1 young produced per nest and 1.6 young per successful nest (Troyer and Hensel, 1965). Study of this population and of others in British Columbia lend evidence that, in a given population, at least 50 percent of breeding pairs must be productive, and the population as a whole must produce at least 0.7 young per active nest in order to maintain stability (Sprunt, 1973).

Evidence acquired through the 1960's indicated that the United States bald eagle population was not reproducing at a rate high enough to maintain a stable population. In 1963, a National Audubon Society survey identified 417 active bald eagle nests in the lower 48 states which produced only .59 young per nest (Marshall and Nickerson, 1976). Decreased productivity appeared to be reflected in a decline in the percentage of immature birds comprising United States populations. Comparison of immature to mature ratios, as determined by Audubon counts during the winters of 1961 to 1963, to the ratio of the population on the British Columbian coast, considered to be a stable one, indicated that the United States population was indeed declining (Hancock, 1964). Sprunt and Ligas (1966, cited by Corr, 1974) gave four reasons for the evident decline:

(1) an increase in human disturbance due to greater populations, greater amounts of leisure time, and growing popularity of outdoor recreation;

(2) loss of nesting habitat through the human activities of timber harvest and land development;

(3) illegal shooting; and

(4) strong evidence of the adverse effects of environmental pollutants on eagle populations.

Correlation of reproductive success to the status of various bald eagle populations shows regional variation. In Alaska, British Columbia, and western Washington, populations appear stable. These are among the most productive populations known, with nesting success rates of 66 percent, 73 percent, and 63 percent, respectively (Hensel and Troyer, 1964; Hancock, 1973; Grubb, 1976a). Studies conducted through the 1960's indicate that the major populations throughout the remainder of the United States are declining. Eagles nesting in New Jersey had a success rate of 25 percent in 1965, those in the Chesapeake Bay region only 13 percent, and those in Maine 18 percent. Bald eagles nesting on the shores of the Great Lakes had a low success rate of 4 percent in 1965, while interior nests in the Lakes states exhibited a relatively higher rate of 45 percent (Sprunt, 1969). In an analysis of the comparative productivity of six bald eagle populations, Sprunt et al. (1973) emphasize this surprising discovery that adjacent or even contiguous populations were reproducing at significantly different rates. The principle factor producing such differences appears to be the relative contamination of various environments with hydrocarbon pesticides, particularly DDT and its metabolites.

Relatively recent reports suggest an encouraging improvement in the reproductive success of bald eagles in the contiguous United States. Nesting surveys conducted in 1973 and 1974 by the Fish and Wildlife Service, similar to one by the Audubon Society a decade earlier, determined productivity rates of .83 and .78 young per active nest, respectively. In 1963, active nests produced only .59 young per nest (Marshall and Nickerson, 1976). Increased productivity in some threatened populations lends optimism about their future. In the Chesapeake Bay area, the success rate of nesting bald eagles inexplicably increased from about 10 percent in 1962 to approximately 40 percent a decade later (Nickerson, 1973). Although that rate is still not sufficient to sustain the population, the increase is significant. From a mere success rate of 4 percent in 1965, about 10 percent of breeding pairs on the shores of the Great Lakes currently produce young, and pairs nesting on inland lakes, reservoirs, and marshes exhibit a nesting success of 37 to 66 percent (Postupalsky, 1978a; Sprunt, 1969). Although the recent increase in bald eagle reproductive success appears to follow the 1972 ban on the use of DDT in the United States, proof is not yet available. Residues in dead bald eagles had not yet decreased through 1974, and eggs collected in Maine in 1974 and 1975 contained the highest residues yet recorded from that locality (Marshall and Nickerson, 1976; Prouty et al., 1977). Still, pesticide residues have been declining in other birds and fish of the Great Lakes area (Postupalsky, 1978a).

An ease in the pressures which have contributed to the decline of bald eagle populations may be hoped for in the future. A decline of pesticide levels in the environment should be accompanied by increased reproductive success and perhaps even the return of nesting pairs to areas from which they were extirpated. As the human population continues to grow, alteration of the environment is inevitable. However, with increasing public awareness and the recent extension of the protective stipulations of the Endangered Species Act to the entire species, critical bald eagle habitat is more likely to be identified and preserved. Increased studies of the habits and requirements of bald eagles have led to the continuing development of management guidelines on many Federal lands to protect both habitat and the birds themselves from disruptive human activities. In addition, new research into techniques which manipulate bald eagle breeding biology, habits, and habitat have potential to help secure the future of threatened populations.

Breeding Habits. In most birds, attainment of the adult plumage serves to indicate sexual maturity to a potential mate. However, Kalmbach et al. (1964) maintains that bald eagles become sexually mature even before they acquire full adult plumage. Indeed, several observers report bald eagles nesting in the immature plumage (Hoxie, 1910; Bent, 1937; Murie, 1959; Sherrod et al., 1976). Although Sherrod et al. (1976) observed an immature female mated with an adult male, they noted that nesting was unsuccessful. Records of bald eagles breeding in captivity show that no fertile eggs were produced until both eagles were at least 5 years old and in the distinct adult plumage (Hancock, 1973).

Bald eagles are generally believed to mate for life. If one of a pair is killed, however, the other usually acquires a new mate if one is available and may continue to nest at the former site. Herrick (1932) tells of a female which in this manner was known to have four different mates while occupying the same territory. Such an instance perhaps indicates that lifetime mating reflects attachment to the nest site, rather than the mate (Brown and Amadon, 1968).

It is not known to what extent, if any, mated pairs remain together during migration and the winter months, although it would seem reasonable for a pair that migrates to travel together. There has been scant observation of pair relationships among eagles on wintering grounds, perhaps indicating that the pair reunites only when reproductive drives bring them back to the nest. Grewe (1966) noted two birds, possibly a mated pair, which remained dissociated from other eagles wintering below Gavins Point Dam in Nebraska.

The timing of breeding and egg deposition varies throughout the range of the northern bald eagle according to latitude and climate. In coastal zones where climate is moderated by oceanic influences, eagles may begin breeding as early as mid-February in the more southerly latitudes, and young may fledge as early as June (Retfalvi, 1965, cited by Snow, 1973; Beebe, 1974). Northward along the Pacific coast, the egg-laying period in southeast Alaska extends from mid-April to the end of May, reaching a peak in the second week of May (Hensel and Troyer, 1964). In midcontinental areas of the conterminous United States, eggs may be laid from as early as February to as late as mid-April (Herrick, 1932; Shea, 1973; Murphy, 1965). In the northern extremities of interior Canada, where spring thaws occur later, eagles may not arrive on their breeding territories until late April; eggs are sometimes not laid until well into May, and the young do not fledge until mid- to late August (Brown and Amadon, 1968; Beebe 1974). The severity of the preceding winter influences the timing of breeding activities. Herrick (1932) reports that bald eagles in Ohio began rebuilding their nests in March of 192[illegible], although in milder seasons they would begin such activities in the first days of February.

Sexual union of bald eagles has been observed before, during, and after nest-building. Herrick (1932, 1934) even observed what he termed "redundant" mating of a pair after their eggs had hatched.

The clutch of the northern bald eagle may vary from one to, rarely, four eggs, with two being the most common number (Herrick, 1932; Brown and Amadon, 1968; Sprunt, 1973). The eggs are approximately the size of a goose egg, measuring about 74 by 57 millimeters (mm) and weighing 130 grams (g) after deposition (Brown and Amadon, 1968; Chrest, 1964). Externally they are a dull white, but the shells are light blue on the inside. The eggs are not always laid in daily succession, and intervals between eggs may extend from 3 to 4 days and perhaps even longer. As incubation begins with the appearance of the first egg, there may be a significant difference in size between hatchlings, which may give the oldest a chance to mature more rapidly and thus play a part in eaglet mortality through dominance over nestmates.

The period of incubation usually lasts 34 to 35 days (Herrick, 1932). The task is performed by both the male and the female, as in the care of the young after hatching. A chittering note is used as a signal in making cooperative shifts during incubation and brooding. Once incubation begins, the adults are off the nest for less than 2 percent of the time, and even then remain in the vicinity (Whitfield et al., 1974). There are several reports of bald eagles covering the eggs when leaving the nest, a habit considered unique to the species (Herrick, 1934; Brown and Amadon, 1968; Sherrod et al., 1976).

If the eggs are destroyed or removed during the early part of egg-laying or incubation, another set may be laid by the northern bald eagle. In three such instances observed by Herrick (1934), the second clutch was laid in the same nest as the first, but, according to Kalmbach et al. (1964), there is usually a shift to an alternate nest.

Breeding Success and Productivity. Studies indicate that the nesting success of bald eagle populations varies from year to year and further suggest that productivity patterns differ among populations (Chrest, 1964; Hensel and Troyer, 1964). Potential breeding success and productivity may be reduced by a combination of factors, often to an actual productivity of only half the potential or less (Brown and Amadon, 1968). In some populations, particularly those nesting in the contiguous United States, the main factors contributing to reduction are related to the activities of humans. General human disturbance and, particularly, widespread environmental pollutants have been blamed for reduced productivity and the resultant decline of continental bald eagle populations. These factors are discussed in detail in the section titled "Human-Related Factors Affecting Populations" (p. 48).

Intermittent breeding is common among large eagles and has been observed in both races of bald eagles (Broley, 1947; Chrest, 1964; Brown and Amadon, 1968). Mated pairs may frequent and even defend a nesting territory, but not lay eggs that season. The cause of intermittent breeding is not known. Speculations include some sort of physiological upset, production of fewer eggs with increasing age of the birds, or an increase in eagle density with resulting decline in food supply (Chrest, 1964; Lockie and Ratcliffe, 1964, cited by Chrest, 1964). Evidence indicates that the response of golden eagles to a lower prey base is nonbreeding of adults (White, 1974).

Predation of eggs and young may reduce productivity to a slight extent. Raccoons (Procyon sp.), magpies (Pica pica), gulls (Larus sp.), ravens (Corvus sp.), and crows (Corvus sp.) are suspected of egg predation (Chrest, 1964; Hensel and Troyer, 1964; Sprunt and Ligas, 1964). If the eggs are destroyed or removed from the nest during an early phase of egg-laying or incubation, a replacement clutch is often laid by the southern bald eagle. This phenomenon has also been observed in the northern race by Herrick (1934). However, the relatively short breeding season throughout much of the range of the northern bald eagle may prevent the deposition of second clutches (Kalmbach et al., 1964). At Karluk Lake in Alaska, Chrest (1964) reports that no pair which had nesting failures renested that same season.

A proportion of all eggs laid are infertile, and the incidence is higher in larger raptors (Brown and Amadon, 1968). Infertility of single-egg clutches may result in prolonged incubation, preventing the possible deposition of a second clutch.

A relationship is apparent between the severity of the weather during the preceding breeding season and the overall success of that season (Postupalsky, 1967, cited by Sprunt, 1973). High winter winds frequently destroy many nests, forcing returning pairs to construct new ones. Chrest (1964) reports that of 10 pairs which built new nests and deposited eggs one season, four pairs were unsuccessful in hatching their eggs. Five pairs which built a new nest did not deposit any eggs that season. Broley (1947) suggests that the time involved in rebuilding may interfere with the synchronization of the endocrine system and photoperiod, thus impairing the reproductive cycle. Later into the breeding season, wind-thrown nests may result in destruction of eggs or mortality of nestlings.

The extent to which fratricide affects productivity of bald eagles is not known. Sherrod et al. (1976) observed greater nestling mortality in nests with more than one young, but whether competition among siblings or parental inefficiency in feeding more than one young resulted in the higher mortality was not clear. Antagonism between bald eagle nestlings hatched in captivity has been observed (Maestrelli and Wiemeyer, 1975). Several observers have noted that fratricide is not uncommon among nestlings in situ and report that frequently only one nestling fledges (Dixon, 1909; Herrick, 1934; Bent, 1937; Brown and Amadon, 1968). Productivity data from Alaska conflicts with such reports, however, where as many as 35 percent of successful nests produce two young (Sprunt, 1973). Antagonism may be restricted to the first 2 to 3 weeks immediately following hatching; after this critical period, it is believed that eaglets dwell together peaceably (Herrick, 1934; Brown and Amadon, 1968; Maestrelli and Wiemeyer, 1975).

Young eagles sometimes fall from their nests to the ground below. Birds younger than 7 to 8 weeks probably won't survive if they land in dense growth where the adults cannot reach them (Dunston, 1978). Sherrod et al. (1976) note the first flights of fledglings may also prove treacherous if their lack of skill lands them in water far from land.

Migration and Winter Distribution. Winter arrives first on the breeding grounds of northern Alaska and Canada, bringing deep snows and below-freezing temperatures. Waterways in these areas become ice-locked, resulting in a severe reduction of food resources for the bald eagle, whose preferred dietary component is fish. This annual paucity of food results in the migration of eagles south to milder climates and more accessible food sources. The northern bald eagle appears to have a highly developed migratory pattern in which the most northerly breeding populations tend to overfly and winter well south of midcontinental resident or slightly migratory populations (Brown and Amadon, 1968). In coastal areas, where the climate is moderated by oceanic influences, breeding populations may make only local movements in search of food (Sherrod et al., 1976). Nearby interior birds may simply move to the coast during winter, although it is probable that many also wander southward (Corr, 1974). Thus, as far as is now known, populations in the Aleutian Islands, Canada's Maritime Provinces, Maine, and the Chesapeake Bay area are essentially nonmigratory (Sherrod et al., 1976; Spencer, 1977).

Eagles winter as far north as open water and food are available. Their winter range extends from Alaska, northern MacKenzie, southern portions of Quebec, Ontario, and Nova Scotia south through and even beyond the breeding range (A.O.U., 1957) (see Figure 3). Some northern eagles spend portions of the winter as far south as the Gulf of Mexico in Texas and as far southwest as Mormon Lake, just south of Los Angeles (Snow, 1973; Spencer, 1976). Recoveries of birds banded in the northern states and provinces indicate that some northern bald eagles migrate as far southeast as Florida, Georgia, and Arkansas (Postupalsky, 1976).

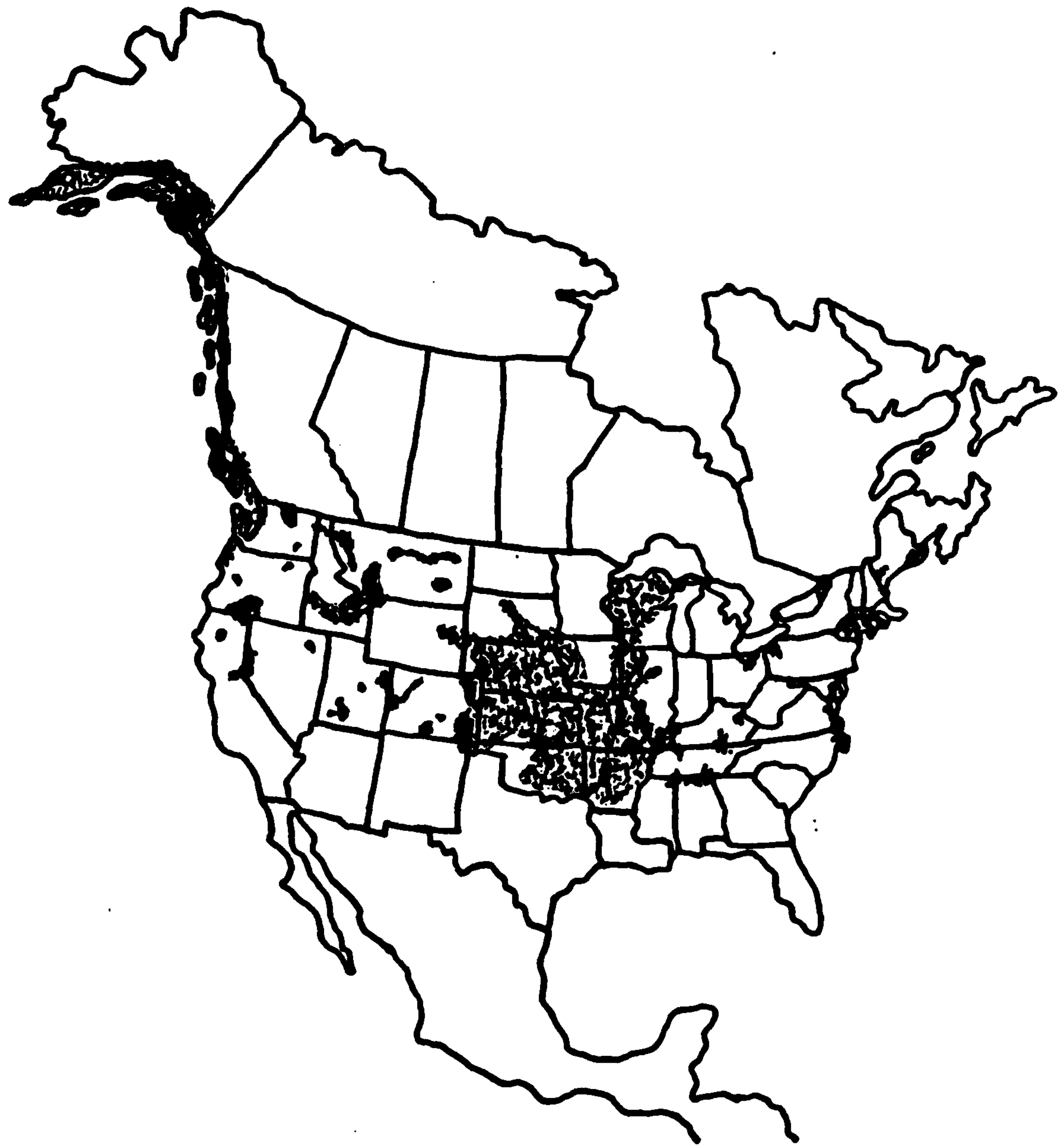


Figure 3. Distribution of winter concentrations of the Northern Bald Eagle (from Steenhof 1976).

The southward movement of migrant bald eagles generally occurs from September to late December, and the reciprocal northward migration from late January to April. Movement of migrant populations may be continuous except for a short period during the first 3 weeks of January (Sprunt, 1961). Bald eagles make extensive use of favorable winds and thermals created by the sun to fly, so migratory movement probably takes place by day. With the aid of these conditions, the migrating birds use primarily a soaring flight. Depending upon the wind, eagles may average as few as one or two wingbeats per mile, thus requiring a minimum of energy to travel long distances (Ingram, 1965). Raptors which migrate primarily by soaring can be slowed or grounded by bad weather, but can travel 400 to 500 miles in a day of favorable weather (Brown and Amadon, 1968). Eagles migrate singly, but may be seen in groups due to physical factors such as waterways and mountain ridges which create favorable flight conditions (Ingram, 1965; Brown and Amadon, 1968).

With migration, the solitary habit of nesting eagles changes to one of group living, as the birds concentrate where quantities of food are available. Such aggregations allow efficient utilization of large food sources. Servheen (1975) suggests the possible evolution of a social system among wintering eagles which minimizes intraspecific competition over food, thereby maximizing food utilization and conservation of energy.

Most eagle concentrations occur in association with open water along rivers, lakes, and coastal areas where food is readily available. National wildlife refuges throughout the United States harbor numbers of wintering eagles attracted by concentrations of waterfowl (Ligas, 1968). The greatest known concentration of wintering bald eagles occurs in the Chilkat Valley of southeast Alaska, where as many as 3,000 to 3,500 eagles spend the period from October to January, attracted by large runs of spawning chum salmon (Robards, 1967; Snow, 1973). Other eagle concentrations occur throughout the Aleutian Islands and southward along the Pacific Coast from southeast Alaska to Puget Sound. Over 600 bald eagles are estimated to spend the winter in the Gulf-San Juan Islands archipelago off the coasts of British Columbia and Washington (Hancock, 1964).

Few concentrations of wintering bald eagles occur across Canada's interior. Limited, essentially nonmigratory populations occur in the Maritime Provinces (Spencer, 1977). The majority of Canada's breeding population migrate south in winter to milder climates in the United States.

Estimates of numbers of wintering eagles in the conterminous United States are variable. The Fish and Wildlife Service coordinates annual midwinter waterfowl inventories, which in recent years have included a census of bald eagles. The 1976 inventory recorded 4,478 bald eagles (Steenhof, 1976). Spencer (1976) estimates a more reasonable figure to be 8,000 to 9,000 birds. He points out that bald eagles are not exclusively associated with waterfowl and that more intensive surveys have revealed much higher numbers of eagles. In the 1973 inventory, the Fish and Wildlife Service counted 37 bald eagles in Wyoming, yet a more intensive survey conducted that same season gave an estimate of 687 bald eagles within the confines of the state (Wrakestraw, 1973).

The construction of numerous dams and reservoirs in this century has altered the distribution of wintering eagles in the United States. Man's alteration of habitat has unintentionally increased potential wintering areas, attracting population to areas where eagles were previously only casual visitors. Concentrations of wintering bald eagles below locks and dams on the Mississippi and Missouri Rivers are recent phenomena (Musselman, 1949; Grewe, 1966; Steenhof, 1976). These man-made structures create areas of relatively warm, open water which provide feeding areas throughout the winter. Particularly in the southwest, water management programs have created permanent sources of water where it was previously only seasonally available. Reservoirs throughout Oklahoma have thus become important bald eagle wintering habitat (Steenhof, 1976).

The midwestern states support approximately half of the wintering bald eagles in the contiguous United States (Sprunt and Ligas, 1966, cited by Steenhof, 1976). Major concentrations occur in the Mississippi River Valley, where a high of 485 eagles was counted along the river bordering Illinois and interior Illinois (Fawks, 1965, cited by McClelland, 1973). Southern (1965) reported 268 bald eagles just along a 23 km stretch of the river in Illinois. Concentrations also occur in the Missouri River Valley (Grewe, 1966; Steenhof, 1976) and along the Platte and Arkansas Rivers (Steenhof, 1976).

The second most important region for wintering eagles is the Northwest, encompassing Washington, Oregon, Idaho, and Montana. In the mid-1960's, the National Audubon Society estimated that this area sustained 20 percent of the total continental United States population (Snow, 1973), but that figure is undoubtedly higher because concentrations, previously uncounted, have since been inventoried (Servheen, 1975; Stalmaster, 1976; Anonymous, 1978a). Runs of spawning salmon, which provide a regularly occurring and readily available source of food, attract significant concentrations to the Skagit and Nooksack Rivers in western Washington. Introduction of the land-locked kokanee salmon in the interior brings eagles to Lakes Coeur d'Alene and Pend Oreille in Idaho (Lint, 1975). Kokanee runs also bring eagles to the waterways of Glacier National Park, where a 1977 census counted a high of 444 eagles along an 11.2 km stretch of McDonald Creek and the Middle Fork of the Flathead River (McClelland and Shea, 1978). The largest concentration of wintering bald eagles outside Alaska occurs in the Klamath Basin area of Oregon and northern California, where great concentrations of waterfowl - possibly a food source - also occur. An interagency survey in 1977 located three night roosts serving 498 eagles (Spencer, 1977; Anonymous, 1978).

Numbers of wintering bald eagles are scattered throughout the western states where suitable habitat is available and even in some areas which would seem inhospitable. Bald eagles were first observed wintering in desert valleys of Utah in 1960, an unusual wintering area in that the eagles are not associated with water. Mountainous areas in Colorado and northern New Mexico host wintering eagles at surprisingly high altitudes. A recent survey revealed some 250 eagles in Colorado's San Luis Valley at an elevation of 7,000 feet (Spencer, 1976). Such widespread dispersal of bald eagles across the United States probably facilitates the location and utilization of new sources of food, enabling survival of more individuals.

The middle Atlantic states, particularly the Chesapeake Bay area, host the remaining concentrations of wintering bald eagles. This region accounted for about 5 percent of the total United States population counted in the early 1960's (Sprunt and Cunningham, 1961, 1962, cited by Snow, 1973).

The specific breeding locations and migratory pathways of wintering concentrations of bald eagles have not yet been determined and are largely conjecture at present (Steenhof, 1976; McClelland and Shea, 1978). Recoveries of bald eagles banded on their nesting grounds suggest that the large numbers of eagles wintering in the midwest come from breeding populations of western Ontario, Manitoba, Saskatchewan, and Alberta, as well as the states of Michigan, Wisconsin, and Minnesota (see figure 4) (Whitfield et al., 1974; Spencer, 1976, 1977). Many of the migrant eagles in the northwest probably nest in western Canadian provinces and the Northwest Territories (Spencer, 1976). Sprunt and Cunningham (1961, cited by Steenhof, 1976) suggest three general migration routes from breeding grounds to wintering areas: the Mississippi River Valley, the Great Plains, and the Great Basin.

The correlation between numbers of bald eagles and food availability demonstrates the importance of food supply on formation of winter aggregations (Southern, 1963; Hancock, 1964; Servheen, 1975). Even in resident populations, this is a major factor regulating local movements (Sherrod et al., 1976). High concentrations of eagles may rapidly deplete a food source, resulting in dispersal. In this manner, where the food supply is not adequate to sustain numbers of eagles through the winter, an aggregation-dispersal-aggregation system may occur. For example, in Glacier National Park, eagles first begin to arrive in early October, and the population disperses in the last week of November when the kokanee salmon run is depleted (Servheen, 1975). East of the park, significant increases in numbers of eagles at Lake Coeur d'Alene in Idaho begin in early to mid-December (Lint, 1975). The Glacier Park dispersal also occurs just 1 week prior to the arrival of eagle aggregations in Utah, approximately 950 km to the south. Many of the same eagles may comprise these populations (Servheen, 1975; Lint, 1975).

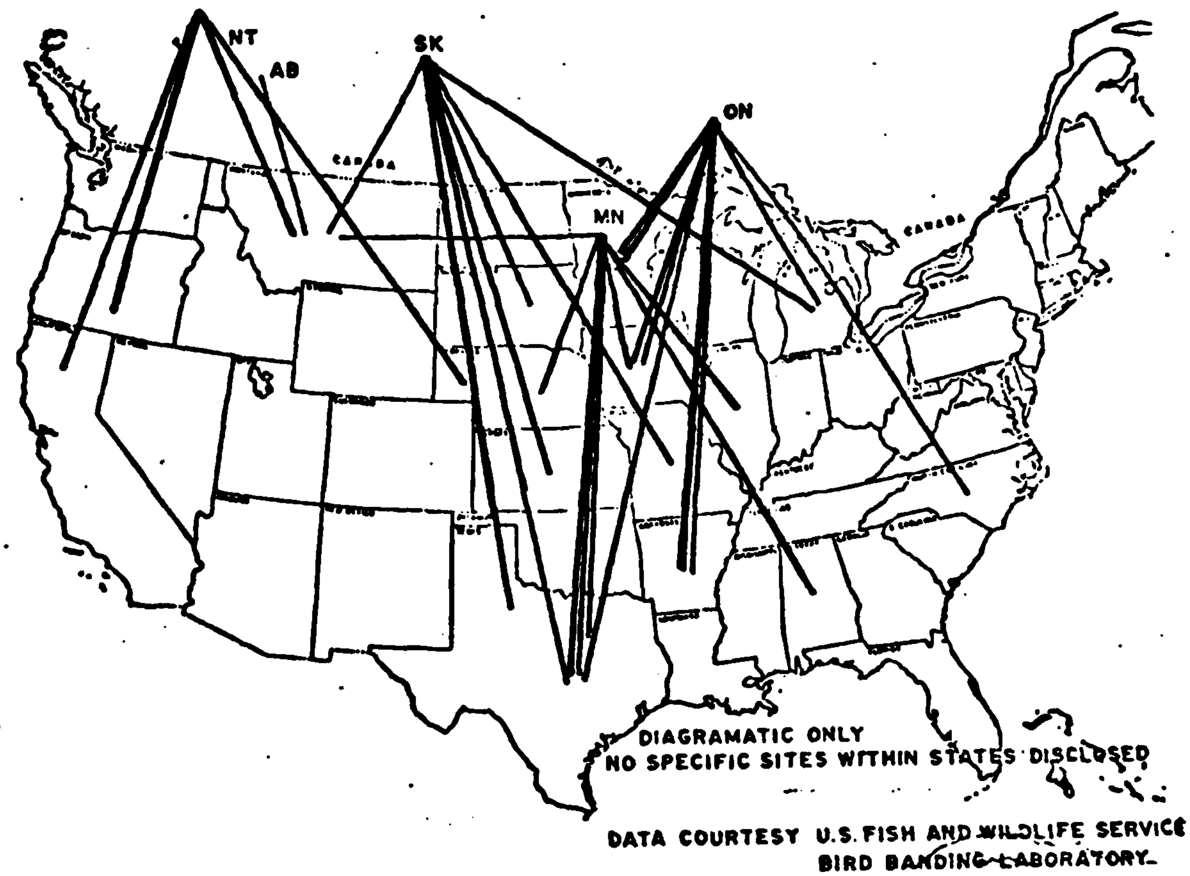


Figure 4. Recoveries of Bald Eagles banded on their nesting grounds (from Spencer 1976).

Servheen (1975) suggests that this aggregation-dispersal-aggregation system may also occur along the coast of southeast Alaska, British Columbia, and Washington. Seasonal movements there are coordinated with spawning runs of salmon in the coastal rivers which peak in August on the Alaskan Peninsula and move gradually southward to occur in November and December in the Puget Sound area. It appears that many of the adults and young depart northward soon after fledging from nests on the Washington and British Columbia coasts in order to take advantage of the salmon runs (Hancock, 1965; Beebe, 1974). Hancock (1965) notes the virtual absence of eagles from the Gulf Islands between early September and the end of October. After this brief postnesting migration, the breeding adults of the area return to their nesting grounds to winter, accompanied by numbers of migrant bald eagles.

Adult and immature eagles appear to have differential migratory patterns which vary according to geographic locale. Studies of bald eagles in the Pacific Northwest and Utah noted a pattern of early adult arrival on the wintering grounds (Hancock, 1964; Edwards, 1969; Servheen, 1975; Stalmaster, 1976). However, researchers in the midwestern states and Montana observed the opposite pattern of early arrival of subadults (Southern, 1963; Sprunt and Ligas, 1966, cited by Stalmaster, 1976; McClelland, 1973; Shea, 1973; Steenhof, 1976). The time of departure was similar for both adult and subadult bald eagles in the Pacific Northwest, although subadults comprise a smaller percentage of populations toward the end of the winter (Shea, 1973; Servheen, 1975; Stalmaster, 1976). Southern (1964) and Edwards (1969) recorded an earlier northward migration of adults from Utah and at Savannah, Illinois.

Servheen (1975) attributes control of spring movements to proximate factors, perhaps photoperiod. He suggests that nonbreeding subadults would be less sensitive to these factors and more responsive to local factors determining time of dispersal, such as food supply and weather conditions.

In the midwest, immature eagles apparently tend to winter further south than adults (Sprunt and Ligas, 1966, cited by Steenhof, 1976). The more northern populations have relatively high proportions of adults (Southern, 1964; Ingram, 1965; Grewe, 1966), while immatures outnumber adults in eagle populations wintering in Missouri and Oklahoma (Halloran, 1959; Southern, 1974, cited by Steenhof, 1976).

Sherrod et al. (1976) reports that resident adults in the vicinity of Amchitka Island are less prone to move between islands in winter than juveniles because of attachment to the nest sites. He suggests that wanderings of subadults permit a larger percentage of individuals to reach adulthood by allowing use of large sources of carrion. Further movement also increases the dispersal potential of a population.

Food Habits. Throughout its range, the northern bald eagle exhibits an amazing adaptability in food habits. The birds are generalized predators, capable of utilizing a wide variety of prey items including fish, other birds, mammals, and invertebrates - any of which may be consumed both as live prey and carrion. Few other raptors are as capable of exploiting so many food resources. Proportions of prey types utilized varies with the time of year, geographic location, particular habitat, and even the age of an eagle. Previous experience or preference, which can be variable with individual eagles, also influence what is eaten (Hancock, 1964).

Fish is the staple food item of most bald eagles, in some areas and seasons comprising virtually the entire diet. Fish also appears to be the food item preferred by eagles. Wright (1953) conducted food preference tests during the summer months in which at least one species of fish, bird, and mammal were offered at each test site. The eagles always took the fish. A definite preference for fish by nestlings was observed by Retfalvi (1965, cited by Snow, 1973). Other prey brought to the nest was abandoned when fish was brought by the parents.

Studies of the food habits of bald eagles inhabiting various shoreline habitats reveal the importance of fish in the diet. On San Juan Island in Washington, Retfalvi (1970) determined through pellet analysis that fish comprised 50.8 percent of the year-round diet of bald eagles. Birds composed 27.9 percent and mammals 21.3 percent of the fare of these eagles. Along the coast of southeastern Alaska, 65.7 percent of the diet of bald eagles consists of fish and 18.8 percent of birds (Kalmbach, 1964). In the maritime province of New Brunswick, Wright (1953) reported the diet of bald eagles to consist of 90 percent fish, 9 percent birds, and 1 percent mammals. In two consecutive years of bald eagle study near the Ohio shore of Lake Erie, Herrick (1934) observed 70 percent and 96 percent of food delivered to the nest to be fish. Dunstan and Borth (1975) determined that 90.1 percent of the diet of nesting eagles in Chippewa National Forest was fish, apparently obtained from small lakes. In wintering areas located on rivers and creeks, the food source attracting eagles is most often great numbers of spawning fish. During these periods of abundance, fish may constitute virtually the only food eaten (McClelland, 1973; Shea, 1973; Servheen, 1975; Stalmaster, 1976).

Many quantitative studies on the food habits of bald eagles rely on the analysis of regurgitated pellets containing the indigestible portions of their food. It is important to note that pellet analysis alone tends to minimize the proportions of fish eaten by bald eagles due to the fact that eagles feeding exclusively on fish seldom form compact pellets. Many of the small fish bones are completely digested, and, without a binding material, the larger bones are likely to be scattered when regurgitated. When mammals are eaten, and to a lesser extent birds, pellets are usually formed (Kalmbach et al., 1964). Direct observation of food habits presents a more accurate picture of prey types in the diet of bald eagles (Hancock, 1964; Offelt, 1975).

Bald eagles eat a wide variety of fish species, varying according to geographic locality, specific habitat, and seasonal availability. Whether a particular species is utilized depends on its characteristic habits and, to some extent, its size. Fish species common in shallow waters of tidal areas and streams and those which feed or school at the water's surface are particularly vulnerable to the hunting methods of bald eagles. Although bottom fish are generally unavailable to eagles, deep-dwelling fishes often become stranded in tidal pools or pools created by fluctuating water levels below dams and thus become easy prey (Kalmbach et al., 1964; Steenhof, 1976). The spawning habits of several salmon species allow heavy eagle utilization, but the timing and spawning habitat selection of other species largely precludes their availability (Stalmaster, 1976). Throughout the midwest, gizzard shad (Dorosoma cepedianum) may constitute the primary prey species of wintering eagles (Dunstan, 1974, cited by Steenhof, 1976). Shad are a readily available food source because of large annual die-offs during winter months (Steenhof, 1976). Some fish species are probably not used because they are too large for eagles to carry from the surface of the water, but the birds will readily feed on large dead fish which wash ashore.

Fish species significantly utilized by bald eagles include gizzard shad, carp (Cyprinus carpio), buffalo (Ictiobus sp.), catfish (Ictalurus sp.), white bass (Roccus chrysops), walleye (Stizostedion vitreum), goldeye (Hiodon alosoides), bullheads (Ictalurus spp.), chain pickerel (Esox niger), suckers (Catostomus sp., Moxostoma sp.), northern pike (Esox lucius), ciscos (Coregonus artedii), whitefish (Coregonus sp.), perch (Percidae), alewife (Alosa pseudo harengus), crappie (Pomoxis sp.), bowfin (Amia calva), Pacific sandlance (Ammodytes hexapterus), herring (Clupea sp.), pollack (Theragra chalcogramma), Pacific cod (Gadus macrocephalus), rockfish (Sebastodes spp.), Irish lord (Hemilepidotus hemilepidotus), Dolly Varden (Salvelinus malma), chum salmon (Oncorhynchus keta), pink salmon (O. gorbuscha), kokanee salmon (O. nerka), chinook salmon (O. tshawytscha), and coho salmon (O. kisutch) (Wright, 1953; Southern, 1963, 1964; Kalmbach et al., 1964; Hancock, 1965; Retfalvi, 1965; Hehnke, 1973; Shea, 1973; Snow, 1973; Dunstan and Borth, 1975; Sherrod et al., 1976; Stalmaster, 1976; Steenhof, 1976).

Whether bald eagles prefer to capture live fish or utilize carrion is debatable. During the spawning runs of salmon which occur during fall and winter, it seems that the highly opportunistic birds would primarily utilize the more easily accessible dead or dying fish. Indeed, Servheen observed bald eagles wintering on the Skagit River to eat salmon only after they had spawned and died. He observed eagles capture live fish only twice, both times when salmon carcasses were unavailable. Kalmbach et al. (1964) believe that bald eagles in southeast Alaska primarily consume fish as carrion, with less than 10 percent of salmon captured alive.

In the Fraser Valley of British Columbia, however, Brooks (1922) observed that salmon were taken largely before they had spawned and were eaten alive. In Glacier National Park, McClelland (1973) noted that although wintering adults and immatures both took dead salmon, the adults preferred to dive upon floating or weakly swimming salmon. Lint (1975) suggests that eagles may discriminate between the sexes in their selection of salmon, preying predominately on the more lively, less deteriorated males. Southern (1963) observed that eagles wintering in Illinois preferred live fish, even when quantities of dead ones were available.

Quantities of dead and dying fish, as found during spawning seasons, are usually not available during the summer months. Fish consumed by bald eagles during this period are likely to have been captured alive. Through dedicated observation of eagle nests in Ohio, Herrick (1933) calculated that one-half or more of the fish delivered to the nest were still alive upon arrival.

While it appears that bald eagles are primarily fisheaters, they are highly opportunistic and take prey other than fish if it is more readily available. Among nesting eagles on the Alaska Peninsula, Hehnke (1973) recorded a shift from a predominately fish diet in 1968 to a predominately bird diet in 1970. He correlates the change to a die-off of common murres (Uria aalge) in the summer of 1970.

In the Aleutian Islands, Murie (1940) reported that 80.7 percent of the diet was comprised of sea birds, which are locally abundant. His results were determined through examination of pellets; therefore, the importance of fish may have been underestimated (Kalmbach et al., 1964). Throughout most of the southern Gulf Islands in British Columbia, fish is the major dietary component; but on several of the islands where extensive sheep ranching is practiced, the most prominent food of bald eagles is dead sheep (Hancock, 1964). Further south in the same archipelago, Retfalvi (1970) studied the food habits of eagles on San Juan Island. He determined the most abundant food source to be feral domestic rabbit carrion, which also proved to be the most prominent in the diet of nesting bald eagles and their young. Retfalvi points out that the ability of a primarily fish-eating bird to feed on a less preferred, but more abundant food item shows the beneficial role that predators and scavengers play in reduction of carrion and the adaptability of the bald eagle to the most abundant food supply.

Retfalvi (1970) observed an interesting shift in the relative quantities of fish and mammals brought to the nest to feed young as the season progressed. Fish predominated until about mid-May, after which the young were fed primarily on rabbit carrion, which is the most common food item available on the island. Retfalvi asserts that the switch cannot be attributed to seasonal changes in food availability. Observations suggest that young eagles on San Juan Island feed almost entirely on carrion after the parental-offspring relationship ends. As recently fledged birds possess limited flying ability, the task of securing a fish out of the water might be too difficult for their limited level of hunting skills. The seasonal change in diet may be of survival value, aquainting the young with the food item they are most likely to obtain successfully.

The composition of the diet of bald eagles undergoes seasonal variation as the availability of prey species changes. During the winter, eagles utilize a wider variety of prey items, particularly during early and late winter when food becomes relatively scarce. Carrion appears to play a more prominent role in the diet during the winter than in the summer. Thus, the eagle makes its living in the easiest way possible, as carrion requires no effort in capture and may often be found in substantial quantities. Carrion utilized by eagles is usually essentially fresh meat, rarely in an advanced state of decay (Kalmbach, 1964).

Much of the avian prey captured is taken under conditions of adversity which the eagles capitalize upon. Dead and wounded waterfowl resulting from hunting activities are often utilized (Southern, 1964; Hancock, 1974). One study found that 50 percent of bald eagle pellets containing the remains of waterfowl also contained lead shot (Dunstan, 1974, cited by Steenhof, 1976). Southern (1964) reports that so long as dead waterfowl were available, eagles showed no interest in live birds.

During the winter months, avian prey, particularly waterfowl, becomes a more prominent part of the diet, partially due to increased difficulty in obtaining fish and partly because waterfowl may be concentrated and readily available. Swisher (1964) observed ducks to be the principal food of bald eagles wintering near the Bear River Migratory Bird Refuge in Utah. Canada geese (Branta canadensis) were the main food of wintering eagles in Oklahoma (Lish and Lewis, 1975, cited by Steenhof, 1976). Wright (1953) observed seasonal eagle predation of waterfowl in New Brunswick. As winter progressed, bald eagles concentrated around flocks of wintering waterfowl and became predators of primary importance on a local basis. However, at the first signs of open water in the spring, bald eagles resumed their fish diet as soon as possible. A few eagles persisted in taking ducks occasionally during the summer, but they were the exceptions.

Bald eagles have been known to eat most species of North American waterfowl, particularly surface-feeding ducks (subfamily Anatinae), bay ducks (Aythyinae), sea ducks (Aythyinae), mergansers (Merginae). and Canada and emperor geese (Philacte canagica). Numerous other avian species are also utilized, including American coots (Fulica americana). fulmars and shearwaters (family Procellariidae), alcids (Alcidae), loons (Gavia spp.), grebes (Podicipedidae), and gulls (Larus spp.). Some Gallinaceous birds, such as ring-necked pheasant (Phasianus colchicus) and ptarmigans (Lagopus sp.), and various perching birds (order

Passeriformes) are sometimes preyed upon by bald eagles (Murie, 1940; Kalmbach et al., 1964; Sherrod et al., 1976; Steenhof, 1976).

Among some bald eagle populations, mammalian prey, primarily eaten as carrion, constitutes an important dietary component. On some islands in the Gulf-San Juan Islands archipelago off the Pacific coast, eagles primarily subsist on dead sheep or feral domestic rabbit carrion (Hancock, 1964; Retfalvi, 1970). In some instances, the presence of quantities of mammalian carrion allows overwintering of eagles which otherwise would not be possible. A group of 10 to 12 bald eagles overwinter near Massachusett's ice-locked Quabbin Reservoir, subsisting entirely on big game carrion. In 1960, a concentration of wintering bald eagles was first observed in the desert valleys of Utah County, west of Provo. This wintering area is unique in that the eagles are not associated with a body of water. The situation presented the puzzling question of how a large population of eagles sustains itself without the usual fish resources, or even suitable habitat for waterfowl resources. Observations by Platt (1976) indicate that the population relies heavily on an "artificial" food source - road- and hunter-killed blacktailed jackrabbits (Lepus californicus).

Other mammalian species known to be utilized by bald eagles are deer (Odocoileus spp.), elk (Cervus canaclensis), coyote (Canis latrans), various species of whales (order Cetacea), sea otter (Enhydra lutris), harbor seal (family Otariidae), walrus (Odobenus rosmarus), steller sea lion (Eumetopias jerbata), Norway rat (Rattus norvegicus), cottontail rabbit (Sylvilagus floridanus), fox squirrel (Sciurus niger), black-tailed prairie dog (Cynomys ludovicianus), ground squirrel (Citellus sp.), voles (Microtus sp.), domestic pig (Sus scrofa), and domestic cattle (Bos taurus) (Kalmbach et al., 1964; Hehnke, 1973; Sherrod et al., 1976; Steenhof, 1976). Probably any type of mammalian carrion would be eaten by eagles in times of scarcity.

Retfalvi (1970) observed that food items other than fish, birds, and mammals are seldom eaten by bald eagles. Kalmbach (1964) found that aquatic invertebrates comprised 2 percent of the diet, apparently reflecting the beachcombing habits of bald eagles in coastal Alaska.

The extreme opportunism of bald eagles is demonstrated where wintering concentrations are formed around steady sources of wastes discarded by man. Refuse dumps provide an important source of food on Amchitka Island, particularly during the winter months. After a bad snowstorm in January 1970, approximately 85 percent of the island's bald eagle population was seen to visit the dump. The birds frequented the dumps at almost any time of the day, but reached peak numbers after the daily garbage runs. There have been numerous reports of eagles eating bread and similar foods at the dumps during the winter (Sherrod, 1976). Eagles sometimes utilized rough fish discarded by fishermen (Southern, 1963; Grewe, 1966). In addition, they have been known to congregate and feed on offal from slaughterhouses and fish processing plants

(Musselman, 1949; Hehnke, 1973). Eagles have also been seen to feed on the afterbirth and dung of sea lions and sheep (Hancock, 1964; Sherrod et al., 1976).

Hunting Methods. Bald eagles have acquired notoriety for stealing and scavenging their food. The latter may indeed constitute the main foraging technique in some parts of the eagle's range, particularly during the winter months. However, bald eagles have often been observed to display a degree of skill at capturing live prey as well (Bent, 1937; Southern, 1963, 1964; Edwards, 1969; Sherrod et al., 1976).

The hunting methods used by some bald eagles undergo an interesting change with the seasons. The techniques are basically the same, but from the status of independent provider during the summer months, wintering concentrations often facilitate as well as necessitate a degree of cooperative hunting. Such methods have been reported by several observers (Bent, 1937; Hancock, 1964; Southern, 1964; Edwards, 1969; Sherrod et al., 1976).

Southern (1963) discerned four basic methods of capturing fish used by bald eagles wintering in Illinois. Each method seemed to be particularly suited for, although not restricted to, certain feeding conditions, such as depth of water and size of the open area. Each was apparently successful enough to encourage repetition. Other observers report much the same techniques used by eagles year round to obtain both live and dead fish.

(1) Bald eagles often locate a fish from a conspicuous perch, then swoop down and pluck it from the water. This is the method most frequently used by nesting eagles on San Juan Island (Retfalvi, 1965, cited by Snow, 1973) and by wintering eagles in Glacier National Park (Shea, 1973). In Alaska, Hehnke (1973) found that eagles hunting from a perch had a success rate of 78 percent, the highest of all fishing methods. In Illinois, however, Southern (1963) calculated a much lower success rate of 25 percent.

(2) Bald eagles may locate fish while flying over the water, then swoop and strike. Southern found that birds using this method were successful about 25 percent of the time.

(3) Southern observed eagles to obtain fish by standing on the edge of the ice and reaching into the water with talons or beak. This method was used infrequently.

(4) Eagles also fish by wading into shallow water and catching fish with the beak, characteristically submerging their heads. Southern determined this to be the most successful method; he once watched an adult eagle capture and eat at least ten shad within 2 minutes.

Although not generally noted, Offelt (1975) asserts that eagles can take fish by diving completely into the water. If the captured prey proves too heavy to fly away with, an eagle can paddle ashore with the aid of its wings, dragging the prey in its talons (Campbell, 1969; Hehnke, 1973; Hatler, 1974; Offelt, 1975).

The particular method used to obtain fish may depend somewhat upon the age of an individual eagle. Shea (1973) observed that wintering immatures did not attempt to capture fish by swooping as often as the adults. When they did, they were not as skillful, obtaining fish 63.6 percent of the time as compared to an 83.9 percent success rate by adults. Instead, immatures were more prone to obtain fish from the shore, and often attempted to steal fish.

Hehnke (1973) calculated an overall fishing success of 28 percent by bald eagles in southeast Alaska, although some particular methods had a much higher success rate. Shea (1973) observed a fishing success of 83.9 percent among adult bald eagles feeding on spawning kokanee salmon; the higher rate probably reflects the greater availability of salmon. The osprey (*Pandion haliaetus*), noted for its specialized fishing methods, was reported to have a success rate of 83 percent in Montana and 77 percent in California. This raptor is a specialized predator, depending upon fish for its livelihood, while the bald eagle is a more opportunistic, generalized predator, feeding on a wide variety of prey types. Consequently, it has not been essential for the eagle to develop great skill at capturing fish.

The bald eagle is known to take advantage of the activities of other fish-eating animals. The most classical example of the eagle's exploitive opportunism is that associated with the osprey. The eagle will watch for the osprey, a more adept fisher, to capture a fish. Then persistent attacks may force the osprey to release its prey, which the eagle often retrieves by a swift dive. The eagle has been seen to fly up beneath an osprey, flip upside down, and actually snatch the prey from its legitimate owner. Bald eagles have also been observed to steal the prey of other birds including the marsh hawk (*Circus cyaneus*) peregrine falcon (*Falco perogrinus*), common merganser (*Mergus merganser*), black-backed gulls (*Larus marinus*), and even other bald eagles (Southern, 1963; Kalmbach, 1964; Erskine, 1968; Grubb, 1971; Sherrod et al., 1976). Eagles on Amchitka Island frequently rob sea otters as they lie on their backs feeding in the water (Sherrod et al., 1976). Observers have reported eagles to capture fish driven to the surface by the fishing activities of loons, seals, and killer whales (*Orcinus rectipinna*) (Dixon, 1909; Offelt, 1975, 1976). Bald eagles even take advantage of man's fishing activities during the scarce winter months. Southern (1964) reports that the activities of fishermen attract groups of eagles which feed on discarded rough fish, and Sherrod et al. (1976) writes of the boldness exhibited by hungry eagles in chasing fishermen as they carried away their day's catch.

Bald eagles are believed to primarily capitalize upon crippled and dying birds as prey, and it has been suggested that they may be inefficient predators even on debilitated birds. Hancock (1964) observed 85 unsuccessful attempts by eagles to capture crippled waterfowl; no passes were made at healthy birds. Yet other observers report that eagles are efficient hunters, capable of obtaining even healthy prey (Bent, 1937; Sherrod et al., 1976).

Eagles use the advantages of height, surprise, or working in pairs to hunt avian prey. Methods of obtaining are similar to fishing techniques; hunting may be done from a perch or from aerial height, as well as in direct flight over land and water. On Amchitka Island, Sherrod et al. (1976) watched eagles fly out over the ocean, dropping down into the dips between each swell in sometimes successful attempts to surprise alcids. They also observed eagles to hunt ptarmigan on land in a similar manner, dipping over the tundra mounds. Waterfowl often dive underwater at the swoop of an eagle, but if the hunter is persistent, the prey may yet be attained. When the bird surfaces for air, the awaiting eagle merely attacks again, forcing its prey to make repeated dives until, exhausted, it is easily secured by the eagle. From two to as many as four bald eagles have been observed to cooperate in this hunting method, making sequential stoops at the prey (Bent, 1937; Hancock, 1963; Southern, 1964; Sherrod et al., 1976).

Apparently, bald eagles are capable of considerable speed and agility when in pursuit of flying prey. One observer (Bent, 1937) witnessed inflight attacks on geese and brant (Branta sp.) in which the eagle quickly flew beneath its prey, and, turning upside down, thrust its talons into the victim's breast. Sherrod et al. (1976) observed the inflight capture of a gull by an eagle, as well as alcids caught in the air at nesting colonies.

Gulls concentrated in breeding colonies were observed by Hayward et al. (1976) to effect a form of colony-wide defense against preying bald eagles. If an eagle approached too close, large numbers of gulls would fly up to mob it, eventually driving the predator away. Coots have also adapted a group defense against eagle predation (Munro, 1938). Apparently, as long as the birds remain in massed concentrations they are safe, but any straggler is vulnerable to pursuit and capture.

There are several areas, particularly on eagle wintering grounds, where mammals constitute a significant portion of the diet. Where an abundance of mammalian carrion exists, actual capture of live prey by eagles may not occur (Hancock, 1964; Retfalvi, 1965; Platt, 1976). Where carrion is not so readily available, bald eagles are known to resort to more energetic methods of obtaining food. Reports exist in literature of bald eagle attacks on deer, antelope (Antilocarpa americana), sheep, sea otters, and mountain goats (Oreamnas americanus), but few are substantiated. One report from late in the last century cited a "gang attack" by five bald eagles on a doe fawn struggling through the snow on the shore of Lake Huron (Kalmbach et al., 1964). Sherrod et al. (1976) never observed eagles to prey upon live adult sea otters, but believes that nesting birds probably regularly prey upon the pups. They suggest that eagles quickly become conditioned to associate the screams emitted by pups, left alone while their mothers hunt, with food. These researchers observed eagles to hunt rats.

The best known occurrence of predation on mammals is exhibited by wintering bald eagles in Utah, where Edwards (1969) observed regular hunting of live jackrabbits. The eagles tended to hunt in small groups and cooperate in flushing and killing, as well as eating prey. The basic technique consisted of low, coursing flights over vegetation concealing prey. Perching was also used as a flushing technique, with more time spent perching than flying while hunting. Edwards also observed eagles to land in and walk about low brush in apparent attempts to flush prey, which were subsequently killed by other flying eagles.

Longevity and Mortality. Large species of raptors are particularly long-lived and may attain great ages in captivity. Captive golden eagles are recorded to have lived 60 years. Although records of bald eagle longevity are few, they should have a comparable life expectancy. A female bald eagle at the San Diego Zoo lived to an age of 25 years and a male was still living in 1967 at the age of 34 years (Hancock, 1973).

While birds of prey may live to considerable age in captivity, they seldom attain such ages in nature due to environmental hazards and stresses. Mortality data on wild bald eagles is scanty. Ringing records of 107 bald eagles found that almost 100 percent died before sexual maturity; 78.5 percent died within their first year of life. The survival rate increases after this critical period, and eagles which attain sexual maturity have a fair life expectancy (Brown and Amadon, 1968). Sherrod et al. (1976) determined that 90 percent of young bald eagles on Amchitka Island died within their first year. Approximately 5.4 percent of adults there suffer mortality each year.

Autopsies performed on 276 bald eagles during the period 1964 to 1974 found illegal shooting to be the most common cause of death. Immatures are more likely than adults to be mistaken for golden eagles and wantonly shot by man. Accumulation of pesticide and heavy metal residues to toxic levels also have been determined to result in eagle mortality. Other unnatural causes of death include trapping, poisoning, electrocution on high-tension wires, and other accidents (Reichel et al., 1969; Anonymous, 1970, cited by Snow, 1973; Coon et al., 1970; Belisle et al., 1972; Cromartie et al., 1975; Prouty et al., 1977). These mortality factors are discussed in greater detail in the section titled "Human-Related Factors Affecting Populations" (page 48).

After man and his activities, starvation is probably the greatest cause of death, particularly for eagles in their first year (Brown and Amadon, 1968; Sherrod et al., 1976). Recently fledged birds are less skillful at procuring food than adults, and thus more susceptible to starvation. Adverse weather conditions encountered during winter months contribute to this mortality factor, as high wind speeds and blowing snow reduce visibility, maneuverability, and prey availability for eagles (Sherrod et al., 1976).

Often fatal mishaps may befall fledglings on their first flights from the nest. Their ineptitude at maneuvering and landing may result in crash landings to the ground or water below where survival may depend on whether the parents can reach the young to deliver food.

Few records exist of disease as a cause of mortality in bald eagles. Coccidiosis was apparently responsible for the death of six eagles, or about 5 percent of all eagles examined by the Fish and Wildlife Service from 1971 to 1974 (Cromartie et al., 1975; Prouty et al., 1977). *Pasturella multocida*, the causative organism of avian cholera, was isolated from five of 203 bald eagles examined during the period 1960-1974, although the disease was given as the cause of death in only two cases (Coon et al., 1970; Mulhern et al., 1970; Cromartie et al., 1975).

In many wintering areas, a significant portion of the diet of bald eagles is comprised of dead, sick, or hunter-crippled waterfowl. Eagles likely contract avian cholera through scavenging of carcasses of waterfowl which have died of the disease. Loss of waterfowl from avian cholera outbreaks have numbered as high as 70,000 birds in California alone during the 1965-1966 winter season (Rosen, 1972). If such extensive outbreaks occurred in major flyways and wintering areas, the disease could pose a serious threat to bald eagles (Locke et al., 1972).

REPRODUCTIVE BEHAVIOR

Territoriality. Bald eagles maintain two general types of territories during the breeding season. The first is the actual breeding territory of a nesting pair, which Hensel and Troyer (1964) define as an area defended against competing members of the same species from the time of mating until the young are independent. Bald eagles continue to maintain these territories after departure of the young, but they are not as clearly defined or vigorously defended as during nesting periods. Nesting territories may be established and defended even though the mated pair do not produce eggs that season (Chrest, 1964; Robards and Hodges, undated). Bald eagles exhibit a high degree of tenacity for a particular nesting territory over a period of years (Sprunt et al., 1973), and may even stop nesting if they are displaced (Snow, 1973).

The second type of territory is the home range, defined as the entire area used by the breeding pair for hunting and soaring, and is usually a good deal larger than the actual nesting territory (Chrest, 1964; Brown and Amadon, 1968). This hunting territory increases in size as the nesting season progresses. Early in the season, when the young require constant attention, the adults remain close to the nest; as the eaglets grow and their food requirements increase, the adults roam farther afield in search of food (Robards and Hodges, undated).

Under favorable breeding conditions when food is abundant, bald eagles share feeding territories (Hancock, 1973). This is probably an adaptation to allow efficient utilization of abundant food supplies with little energy wasted on territorial strife.

Robards and Hodges (undated) state that the distance between active bald eagles nests, size of the nesting territory, and density of breeding pairs are all closely related and mutually dependent upon the available food supply. In Ontario and Manitoba, Grier (1973) reports a minimum average distance between active nests of about 1.7 km. Small groups of nesting eagles in western Washington exhibit similar proximities and may be remnant of an earlier population of greater density (Grubb, 1976). Observations of 2,760 bald eagle nests in southern Alaska indicate that breeding pairs avoid selecting nests closer than 1 km from another active nest. The more dense breeding population perhaps indicates a more optimum habitat. The average distance between nests in southeast Alaska is 4 miles, although this does not mean that the eagles defend a territory of that size (Robards and Hodges, undated).

At the Kodiak National Wildlife Refuge in southwest Alaska, Hensel and Troyer (1964) observed that most nesting territories of bald eagles had relatively uniform physical characteristics. Territories ranged from 11.3 hectares (ha) to 45.4 ha in size, with an average of 23.1 ha, and were delineated by perching or loafing areas. Establishment and maintenance of territories is accomplished through habitual use of such perches. Chrest (1964) found that territories along the shoreline of Karluk Lake in the Kodiak NWR were linear to oval in shape. On the coast of British Columbia, the area defended is cone-shaped, expanding upward above the nest (Hancock, 1970, 1973). The vegetative pattern was the most influential factor determining size of territories at Karluk Lake; most territories were distinctly separated by open areas (Chrest, 1964).

Also in southeast Alaska, Corr (1974) found average territory sizes in the Petersburg area to be much larger than previously reported in literature. He attributed the greater spatial distribution to three factors:

(1) a comparatively smaller resident breeding population;

(2) fewer available nest sites due to logged beach frontage; and

(3) a relatively large human population resulting in increased eagle-human interaction.

A recent study found comparable territories in the San Juan Islands and Olympic Peninsula of Washington where similar factors may be affecting population densities (Grubb, 1976a).

The extent of territorial defense against other bald eagles is somewhat variable, but doesn't appear to be great. On Amchitka Island, where the density of breeding pairs is high, Sherrod et al. (1976) noted that scant attention is given to other eagles flying through nesting territories. The nesting birds sometimes gave shrill screams, but rarely left the nest in pursuit of the intruder. Usually, however, a passing eagle flew at some distance out to sea beyond the nest of another eagle. Sherrod et al. also report the tolerance of many breeding pairs to immature eagles, which often sat just 9 to 12 m away from the nest. In southeast Alaska, where the density of nesting pairs is not so high, Robards and Hodges (undated) report that an intruding eagle is certain to provoke angry screams from a nesting pair, and occasionally the interloper is pursued. Hancock (1970, 1973), studying bald eagles in British Columbia, determined that nesting pairs actually defend only a cone-shaped air space extending up and out from the nest. Immature and adult eagles unable to secure nesting sites probably concentrate where food is plentiful away from nesting areas in order to avoid territorial strife.

Throughout most of the year, bald eagles tend to ignore many annoyances from other species of birds. However, during the critical period of incubation and while the eaglets are small, the presence of such heckling intruders upon the eagles' territory is not tolerated, and the intruders are promptly driven away from the vicinity of the nest (Herrick, 1932). After this critical period, the bald eagle is rarely disturbed by the intrusion of other species. Hancock (1973) states that any other raptor is tolerated even in the nest tree as long as it remains below nest level. It is usually the smaller avian species which feel threatened and become aggressive toward the larger eagles. Peregrine falcons and kingbirds (Tyrannus spp) are among the species which have been observed to give chase to eagles which impinge too closely upon their territories (Herrick, 1934; Sherrod, 1976).

Most nesting bald eagles are not aggressive toward human intruders, and, when watched from a distance, little attention is usually paid to observers. When nest trees are climbed by researchers, the adults generally circle overhead, calling intermittently, and may eventually leave the area (Grier, 1969). Occasionally, however, the adults may dive at and even strike intruders (Murphy, 1965; Grubb, 1976b).

Mating Display. Few descriptions of courtship behavior of bald eagles occur in literature. Flight displays mainly consist of swooping at each other accompanied by vocalizations (Nature Conservancy, 1976). In one spectacular display, the mated pair locks talons high in midair, then descends for several hundred feet in a series of somersaults or cartwheels. The nuptial display sometimes ends in the more orthodox pursuit of the female by the male (Snow, 1973; Brown and Amadon, 1968; Beebe, 1974). Similar aerial displays thought to be associated with mating or pair formation have been observed during the last few weeks prior to the northward migration and during migration itself (Ingram, 1965; Grewe, 1966).

Nest Site Selection. The optimum nesting environment of the northern bald eagle is probably a shoreline habitat which provides ample food; tall trees for nesting, hunting, and loafing perches; and open flight paths on updrafts in an area which is sparsely populated by humans (Whitfield et al., 1974). Where such optimum conditions are not available, bald eagles can utilize a less preferred habitat. Still, certain elements seem to be consistent nest site requirements, regardless of specific habitat.

Proximity to open water is the prime factor determining the selection of a nest site. Food availability is the reason for this preference, as fish comprise a major portion of the diet of nesting bald eagles and their young. Particularly during the first few weeks following hatching, food must be obtained in a minimum time away from the nest. Although there is regional variation, most nests are built within .8 km of a sea coast, lake, or river, and many are considerably closer (Snow, 1973). Robards and Hodges (undated) note an apparent reluctance to nest within 9 m of a beach and suggest that increased exposure to the weather and human disturbance may be the reason. If nests are situated away from a shoreline, there is always an unobstructed flight path to the water (Robards and King, 1966, cited by Corr, 1974).

A noted exception to this preference occurs in the Bena District of Chippewa National Forest in northern Minnesota. Only eight nests of 25 were within .4 km of open water, and nine nests were farther than .8 km (Juenemann, 1973, cited by Whitfield et al., 1974). In Wisconsin, the inland relocation of eagles once found on the shores of lakes has been noted (Gerrard, 1973). It has been suggested that increased human presence along the shorelines of these areas may have resulted in eagles choosing nest sites farther inland.

In southeast Alaska, King et al. (1972) found that clusters of islets or broken shorelines tend to support greater nest densities than areas with a uniform shoreline. Gerrard (1973) also observed a preference for island habitat, which comprised only 20 percent of the total shoreline surveyed but contained about 40 percent of the nests found. Small islets are ideal nesting sites as they are surrounded by water, providing isolation and a nearby source of food for eagles (Robards and Hodges, undated).

Robards and Hodges (undated) found two timber types to be preferred by breeding eagles in southeast Alaska: dense, old growth stands which provide trees, and islands with little timber, which provide isolation and unobstructed perching sites. Of 2,760 bald eagle nests located in that area, none were found in second-growth timber.

Growth form is a significant factor determining the selection of a nest tree. Preferred trees are the tallest in the immediate vicinity with sturdy branching at considerable height. Bald eagle nests in live conifers usually occur in trees with normal bushy tops, broken live tops, or deformed tops, as these types provide the strong branching necessary to support the large, heavy nests (Robards and Hodges, undated; Grubb, 1976a). Robards and Hodges (undated) found that the percentage of active nests increases significantly with increasing height. Thus, it seems important that the nest overlook the surrounding area and provide a degree of isolation and an open flight path (Frenzel et al., 1973; Gerrard, 1973; Grubb, 1976a; Robards and Hodges, undated).

The actual height of the nest depends on the species of tree utilized and growth factors determined by the particular environment. Robards and Hodges (undated) determined that most bald eagle nests in southeast Alaska ranged from 15.2 m to 31.1 m above the ground. Hensel et al. (1964) found that the average height of cottonwoods (Populus trichocarpa) used as nest trees was 23 m and that the range in height from the nest to the ground was 12.8 m to 19.8 m.

A strong preference of bald eagles for live nest trees has been repeatedly documented (Grewe, 1966; Murphy, 1965; Troyer and Hensel. 1965; Mathisen, 1968; Grubb, 1976a), although Herrick (1934) and Retfalvi (1965, cited by Snow, 1973) report that dead and dying trees are often utilized. Grubb (1976a) determined that the preference exhibited by eagles for overhead foliage provided by live trees results in increased nesting success. Hancock (1973) concurs, and further states that when the overhead foliage of a nest tree dies, the nest will usually be deserted if suitable alternate trees are available.

The particular species utilized as a nest tree varies, depending on what is available as determined by the habitat. In the mixed forests of western hemlock and Sitka spruce which occur along the coastal shorelines and islands of southeastern Alaska, a preference for Sitka spruce, which provides greater height, is exhibited by bald eagles. Along riparian systems in southeastern Alaska, cottonwoods constitute the tallest species and are preferred for nesting (Troyer and Hensel, 1965; Corr, 1974). Tall poplar trees constitute about 60 percent of nest trees in mixed forests of Saskatchewan and Manitoba (Gerrard, 1973). On San Juan Island in Washington, Retfalvi (1965, cited by Snow, 1973) found all bald eagle nests in Douglas firs. In Yellowstone National Park, eagles build nests in Engelmann spruce (Picea engelmannii), lodgepole pine (Pinus contorta), whitebark pine (P. albicaylis), and Douglas fir (Murphy, 1965).

Along the shores of Lake Erie, once covered by deciduous woodlands, Herrick (1934) found the chosen species to include hickory (Carya sp.), sycamore (Platanus sp.), oak (Quercus sp.), ash (Fraxinus sp.), maple (Acer sp.), elm (Ulmus sp.), and honey locust (Gleditsia triacanthos).

In the Chippewa National Forest, the usual nest trees selected by bald eagles are "super-canopy" red pine and white pine (Frenzel et al., 1973). These large pines are present because of the 1902 Morris Act, which requires that 5 percent of pines with a diameter-breast-height greater than 25.4 cm be left as seed trees after harvesting. Many of these protected trees now are aged between 84 and 184 years (Snow, 1973).

Where tall trees are not available for nesting, bald eagles may utilize low vegetation or even nest on the ground. On Amchitka Island, where such a condition prevails, nest ground sites are still chosen which provide height and isolation, usually on sea stacks or ridges (Sherrod et al., 1976). When tall trees are not available on Kodiak Island, eagles build nests on rock cliffs or the bases of alder (Alnus sp.) trees protruding from cliffs. Such nests were usually found from 12.2 m to 61 m above sea level. Areas devoid of both trees and cliffs contain no nests (Troyer and Hensel, 1965).

Presence of suitable perch sites in the vicinity influences selection of a nesting site (Sprunt et al., 1973). Gerrard (1973) suspects that selection of territories may be influenced by the prevailing winds, as they provide updrafts that are used in flight. Robards and King (1966, cited by Corr, 1974), however, found that prevailing winds, as well as exposure to sun, did not influence nest site selection in Alaska. Freedom from human disturbance is one of the most variable factors influencing nest site selection.

Studies on the influence of human activities on nesting by Jueneman and Frenzel (1972, cited by Snow, 1973) showed an indirect relationship between nesting activity and degree of human-related disturbance. However, several studies indicate that some individual breeding pairs and populations appear to be more tolerant to human activities than others, depending on the degree of disturbance to which they are accustomed (Retfalvi, 1965, cited by Newman et al., 1977; Grier, 1969; Jueneman, 1973, cited by Newman et al., 1977; Radtke, 1973).

A study of bald eagle nesting in western Washington, conducted by Grubb (1976a), found that only 11 percent of known nests had no human disturbance within 1.6 km, while 74 percent were located with some human activity within .8 km. Several successful nests were found in or very near housing areas, while, on the other hand, inactive nests were located in areas with no sign of human activity within miles. On San Juan Island. also in Washington, Newman et al. (1977) found that although there has been a significant increase in human activity in the 12 years elapsed since a previous survey there (Retfalvi. 1965), the number of active bald eagle nests has increased 100 percent. They found most nests located much closer to human interference than in 1963. However, as Postupalsky (1974, cited by Grubb, 1976) stressed, human presence should not necessarily be equated with disturbance.

Nest Building. Throughout most of its range, the bald eagle is inclined to use the same nest year after year. It is a progressive structure; each year the breeding pair refits the old nest, virtually building a new one on top of the old. Both the male and female share in this labor, which can be completed within a few hours or as long as a few days. Because the nests are progressive structures, they can acquire great dimensions over the years. One bald eagle nest in the vicinity of Vermillion, Ohio, was ultimately destroyed during a storm in the 36th year of its occupancy. By that time it was 3.7 m high and 2.6 m across the top. The upper surface had an area of nearly 4.6 m^2, and its total weight was computed to be about 1.8 metric tons (Herrick, 1932). Another nest in Maine was reported to be 6.7 m in height (Grewe, 1966). Not all nests reach such great proportions, however. Kalmbach (1964) computed bald eagle nests in Alaska to average about 1.7 m high and 2.1 m in diameter.

Nesting habits of bald eagles on Amchitka Island differ from those just described. The ground nests are virtually rebuilt every year, as the young and adults soon trample and scatter the nest materials. Average nests vary in size from 1.2 to 2.1 m in diameter and rarely exceed .3 m in height. The actual size of a nest depends on the nesting substrate; a sea stack may limit the size to 1 m in diameter, whereas a ridge may provide room for a larger nest (Sherrod et al., 1976).

Herrick (1924a) purports that the size and shape of a nest is largely determined by the supporting branches and is thereby correlated with the species of tree used. The branching growth of conifers would only allow construction of shallow, disc-shaped nests, while more deeply branched deciduous species provide space for a deeper, more conical nest.

A new nest may be completed within 4 days (Herrick, 1932) and measure about 1.5 m in diameter as well as depth (Corr, 1974). The mass of the nest is made up of sticks, most of which are picked up off the ground by the eagles and carried to the nest site in the talons. Sometimes a branch is snapped off a tree by an eagle while in flight. Grewe (1966) observed eagles using sticks up to 1.2 m long and 5.1 cm in diameter. Robards (1966, cited by Snow, 1973) estimated that the weight of the sticks used as nesting material never exceeded 1.4 kg. The branches are laid with the aid of the beak and the interstices filled with dried grasses and other various materials which are then trod down. The nest cavity is lined with a thick layer of dead grass or straw, mosses, seaweed, and other debris depending on locality, including even manmade items such as cork, cellophane, and plastic (Sherrod et al., 1976). As is the habit of most birds of prey, greenery of some kind is often brought to the nest at its completion and may be periodically replaced throughout the nesting season (Herrick, 1932). Brown and Amadon (1968) suggest that the main reason for this habit is emotional, as its occurrence seems to be primarily connected with the heightened excitement of courtship, incubation, and brooding. Any other effects which have been suggested, such as shading of the young and nest sanitation or lining, are probably incidental.

The building fever is apt to break out again, although with diminishing fervor, during the first weeks after the young are hatched. Herrick (1932) maintains that throughout this period, the building instinct may still be stronger than that of either brooding or feeding the young. The mere sight of building materials may be the only stimulus needed to arouse it.

Grubb (1976a) found that eagle nests in western Washington ranged from the very top of broken trees to nearly halfway down and essentially below the tree crown in a few cases. Ninety-three percent of nests were in the top 6.1 m of the nest tree. Corr (1974) observed a similar range in Alaska, with most nests in the upper fifth of the tree. Grubb (1976) suggests that less-exposed nests placed within the tree crown require less repair at the start of the nesting season, requiring less energy of the breeding pair.

It appears to be common for a breeding pair of eagles to have more than one nest within their territory and use them alternately year to year (Hensel and Troyer, 1964; Murphy, 1965; Frenzel, 1973; Grubb, 1976a). Thirty-eight percent of bald eagle territories in western Washington contained alternate nests (Grubb, 1976a).

In the Chippewa National Forest, Frenzel et al. (1973) found that there are usually two nests within a breeding territory, sometimes one nest, and occasionally three nests. One nest is used to rear the young, while the others are used for perching and feeding. Supernumerary nests may be adaptive in that if a preferred nest is destroyed by a winter storm, a breeding pair can turn to a spare nest and quickly recondition it for occupancy.

Several observers have noted the use of alternate nests by bald eagles previously disturbed by human activity (Retfalvi, 1965, cited by Newman et al., 1977; Mathisen, 1968; Grier, 1969; Dunstan and Harper, 1975). In Washington, Grubb (1976a) observed a higher percentage of alternate nests on the San Juan Islands than on the less developed Olympic Peninsula. On San Juan Island itself, Newman et al. (1977) interpret an increased incidence of alternate nests as a recent change in nesting patterns which appears to have developed in conjunction with increased human activity.

Eagle nests are often confused with those of osprey by the inexperienced. The critical distinguishing characteristics are size and shape of the nest, condition of the nest tree, and position of the nest in the tree. Eagle nests tend to be flat-topped, cone-shaped, and located below the tree crown. Nest trees are generally live trees located in upland timber. Osprey nests tend to be smaller, ball-shaped, and placed at the very top of a dead tree with little or no overhead cover. Osprey nest trees are often adjacent to streams entering larger bodies of water (Corr, 1974; Grier, 1977; Kichura and Ruediger, 1978).

Development and Care of Young. A period of intensive parental care accompanies the first 3 to 4 weeks following hatching of the young. One or both parents are at the nest most of the day performing activities of brooding, feeding, and guarding. The young are most closely attended during the first downy stage when they are particularly vulnerable to the elements. Once the second down is attained, the young are often left exposed. Brooding is performed by both sexes, although more constantly by the female. Night brooding lasts 3 to 4 weeks, and sometimes even longer (Herrick, 1934).

As the young grow larger, brooding shifts to a shielding attitude in which the parent merely stands over the young with drooping, half-spread wings to protect them from excessive heat and rain showers. After about 4 weeks, such protection is only afforded when necessary, and most guarding is accomplished from nearby perches. During the late stages of juvenile development, inspection flights into the vicinity of the nest, which Herrick (1924) termed "reconnoitering," take the place of visits to the nest itself. At this time contact is seldom made with the nest except in the purveyance of food.

The period of time the young remain in the nest prior to fledging is somewhat variable, possibly depending upon weather conditions and food supply. Nestling periods have been observed to last from 10 to 13 weeks (Herrick, 1934; Gerrard et al., 1974).

Movements of the young eagles are relatively sluggish at first, but increase in activity as they become more acute to their surroundings. During the last month in the nest, their major activities center around feeding, preening, reactions to the parents and any nestmates present, and the more striking behavior of flying exercises and play (Herrick, 1934).

The eaglets begin crawling about the nest with the aid of their wings soon after hatching. The wings are used extensively in this manner during the first few weeks of nest life. As early as the second week, eaglets may begin the wing flapping which soon develops into a daily routine of exercise. Although the actions are undoubtedly instinctive, such exercise helps to develop the flight muscles, insuring their strength before the critical tests away from the nest. Herrick (1934) postulates that the large surface area of the eagle's nest is correlated with its function as a training gymnasium. He also suggests that the long nest life of young bald eagles may be related to their need to master flight before leaving.

Herrick (1934) noticed that the adults brought food to the nest most frequently before 9 a.m. and after 3 p.m., a task in which the female was twice as active as the male. Retfalvi (1965, cited by Snow, 1973) and Offelt (1975) observed both sexes to bring food equally, although Retfalvi reports that most of the feeding of the young was done by the female.

Young eaglets instinctively peck at objects which arrest their attention, thus learning to peck at the food brought by the parents long before they can actually feed themselves. That state of self-sufficiency is not attained until the eaglets are around 7 weeks old (Snow, 1973). During early nest life, the parents feed the young by a bill-to-bill method which utilizes their pecking instinct. The food is torn into pieces by the adult's bill and held up to the bill of the eaglet, but never placed directly in an open mouth. This practice continues to some extent up to the end of nest life, even after the young are capable of tearing the prey themselves. Herrick (1934) postulates this continuing behavior to be a safety factor insuring that the young get sufficient food. Retfalvi (1965, cited by Snow, 1973) calculated the average food consumption of newly hatched eaglets to be 21.3 g a day, while, just prior to fledging, consumption is 1.7 kg per day.

Whenever hungry, the young manifest their desires by emitting cries, heads extended in the direction of an approaching parent. When not hungry, they exhibit little excitement at a parent's approach. A hungry eaglet crouches before the food-bearing adult with upheld bill and, squealing, seems to beg for food. Once an eaglet has learned to tear up food, its behavior changes. Food is snatched at the first opportunity, whereupon the squealing eaglet spreads over it with feathers erected, thus claiming the food as its own. When more than one eaglet hatches, the larger, usually the oldest, often gets the food first. The nestmate patiently awaits its turn unless the degree of hunger is too great.

Herrick (1924c) relates a number of incidents illustrating play activities in eaglets which actually serve as practice of later methods of dealing with prey. Such play with mock-prey includes tossing objects about and clutching a stick in the talons and dragging it around the nest or attempting to rise with it into the air. Herrick terms other activities "fighting plays," in which nestmates carry on a friendly rivalry. In the event of a single eaglet occupying a nest, sham fighting with a parent may substitute (Weekes, 1975).

Preening is a major daily activity of eaglets, particularly during molting periods. The young sleep intermittently throughout the day, dozing while standing on the edge of the nest or lying flat (Herrick, 1924c).

Flight exercises often culminate in short practice flights before the young actually leave the nest. Usually the leave-taking is voluntary, but Herrick (1934) tells of an instance when the last bird in the nest had to be forced out by the parents. The young eagle was starved, then finally lured out of the nest with a show of food.

Kussman (1976, cited in Diss. Abst. Intern. 38(3):1033-B) studied postfledging behavior of eagles in the Chippewa National Forest. Of 23 eagles observed immediately following fledging, 11 could free-fly, while 12 fledged to or near the ground prior to free flight. Kussman distinguished three postfledging activity periods. The early period, lasting 1 to 5 days, was characterized by uncoordinated or no free flight. An intermediate period varied from 97 to 98 days. During this stage, juveniles accomplished free flight and soaring, but were still dependent upon adults for food. A late postfledging stage involved long-range movements and independent movement preceding emigration.

A study of the postfledging movements of young eagles in Saskatchewan found that nonmigratory movements away from the nest are not random, but are correlated with wind movement over 17 km per hour (10 m.p.h.). The birds gradually distribute downwind from their nest sites, following the path of least resistance. The orientation of shorelines also influences the direction of dispersal, as the young eagles tend to follow shorelines rather than travel overland (Gerrard et al., 1974).

Observations suggest that the nest-site bond of young eagles is strong immediately following fledging, but gradually weakens as they mature. Juveniles may associate with the parents and return to the nest for up to 3 months, using it as a perch, feeding station, and roosting site (Herrick, 1934; Gerrard et al., 1974).

In British Columbia, Beebe (1974) noted a definite tendency for immature eagles to socialize exclusively by about October, making it reasonably certain that most familial associations were dissolved by that time. On Amchitka Island, however, Sherrod (1976) reports that in a great many of the active nests, not only was the adult pair present with the young of the current year, but a 1-year-old, or in some cases a 2-year-old, eagle remained in the immediate vicinity. He speculated that they may have been the young of the previous year, citing the fact that immature golden eagles have been known to remain near the nest from which they were fledged for up to 2 years.

WINTER BEHAVIOR

Night Roosting. Bald eagles tend to congregate at communal night roosts throughout their winter range (Steenhof, 1976). Edwards (1969) reported a maximum of 82 eagles using one roost on a particular night. As many as 61 bald eagles have been seen perched in a single tree (Spencer, 1976). Smaller groups of roosting eagles are probably more common where suitable roost sites are abundant (Southern, 1963, 1964; Shea, 1973; Servheen, 1975; Stalmaster, 1976). Group roosting is not the rule, however, as bald eagles have also been observed to roost singly (Southern, 1964; Edwards, 1969; Stalmaster, 1976).

Servheen (1975) suggests that communal roosting is an aspect of the social structure of wintering bald eagles which evolved partially in response to irregular distribution of food. According to Ward and Zahavi (1973), communal roosts function as information centers where the location of food sources can be communicated among individual birds. In this manner communal roosting may be of significant adaptive value, promoting efficient location and utilization of limited food resources (Steenhof, 1976) and thus survival of large numbers of eagles through the winter months. Group roosting also allows maximum number of eagles to utilize an optimum roosting site (Steenhof, 1976). In some wintering areas, bald eagles exhibit consistent use of traditional roost sites over the years (Lint, 1975; Steenhof, 1976). Steenhof (1976) theorizes that this habit allows more efficient exchanges of information about food, as less time and energy is wasted by an individual searching for food or other eagles.

Unlike selection of diurnal perches, proximity to feeding areas is not an essential factor in the selection of roosting sites. Swisher (1964) found that if proper roosting habitat is not available near feeding grounds, eagles will commute considerable distances to seek it. He observed bald eagles in Utah fly over 25 km from feeding to roosting areas. Ligas (1968) and Steenhof (1976) found that roosting sites are typically protected from prevailing winds, a practice which would reduce the energy demand of eagles during cold periods. A concentration of wintering eagles may use several roosting sites, and the population may alternate between sites on different nights. Selection of a particular site may be determined by atmospheric conditions which influence the dynamics of flight to and from the roost (Spencer, 1976).

Freedom from human disturbance is apparently a variable factor in selection of a roosting site. Some bald eagle roosts are located near rural communities where landowners disturb the birds almost daily. In two such roosts studied by Platt (1976), the eagles seemed to become habituated to individual humans and their actions. Southern (1963) reports that eagles disturbed by humans walking into a roost site failed to return to that particular site. Steenhof (1976) reports a similar incident in which the disturbed eagles resumed roosting 2 days later.

The specific perching site at the night roost is typically a tall tree with stout, horizontal branches extending over an open area, thus facilitating unobstructed takeoff and landing (Ligas, 1968; Spencer, 1976; Steenhof, 1976). Both live and dead trees are utilized by roosting eagles, but when they are available, dead ones seem to be preferred, perhaps due to a relative absence of obstructing branches and twigs (Servheen, 1975; Spencer, 1976). Stalmaster (1976) observed that bald eagles on the Nooksack River in Washington seem to prefer conifers as roost trees. He suggests that they provide a more sheltered microhabitat against chilling winds and rains than do snags or deciduous trees. However, he also noted that such a preference might be related to their greater availability. Where trees are not readily available, bald eagles have occasionally been observed to roost on other tall structures, such as windmills and buildings (Spencer, 1976).

The time of day that eagles move into the roost apparently varies according to the weather and feeding success (Steenhof, 1976). In Utah, Edwards (1969) reports that eagles return to the roost in early afternoon, while Platt (1976) observed birds to arrive throughout the afternoon. Eagles in Montana and Idaho generally leave feeding areas just before sunset (Shea, 1973; Lint, 1975). The birds converge upon the roost singly or in loose groups of three or four. Edwards (1969) found that the first eagles to arrive perched in a preferred tree until it was filled; only then were surrounding trees used. Eagles would often land on a branch occupied by other birds, then sidestep along until individuals were almost touching.

Platt (1976) reports that eagles usually leave the roosts for feeding areas singly or in pairs just before sunrise. Age was not found to determine early or late departure time. Timing is probably determined by feeding the prior day; a bird which fed late in the day would probably be more likely to remain in the roost longer the following day. Ingram (1965) observed that bald eagles remain on roosting sites longer if inclement weather prevails.

Platt (1976) found that the morning behavior of immature eagles differed from that of adults. Immatures invariably left roost trees early, only to return in less than a minute. As many as three birds would spend this time chasing each other around the trees. When an adult leaves its perch, it flies directly out of sight.

Flight used for travel from night roosts to feeding areas and perching sites is usually at an altitude of 100 m or less. It is characterized by deep wingbeats enroute, with gliding and slow circling around the feeding or perching destination before landing. Servheen (1975) clocked such flight at speeds of 50 and 63 km per hour (30 and 38 m.p.h.) on calm days.

Feeding. The hunting behavior of bald eagles undergoes some seasonal change. They appear to use the same basic techniques year round, but a particular method may be utilized more often. Scavenging of carrion may become the dominant foraging behavior. A particularly interesting seasonal change in behavior occurs in many areas where aggregations of eagles occur. From the status of an independent provider during the summer months, wintering concentrations seem to facilitate and perhaps necessitate a degree of cooperative hunting. The specific hunting techniques and food habits of bald eagles are discussed in detail in separate sections (pages 18 through 26).

Most behavioral studies of wintering bald eagles have been conducted in areas where fish constitute the major dietary component; consequently, the more obvious feeding behavior associated with fishing activities is best known.

Bald eagles generally arrive at feeding areas around dawn. This is the most vocal part of the day, as eagles converge upon favored areas (Shea, 1973). Some birds may remain perched for about 1/2 hour, while others commence feeding immediately (Southern, 1964; Steenhof, 1976). In some wintering areas, the early morning hours constitute the period of most intensive feeding (Ingram, 1965; Edwards, 1969; Steenhof, 1976).

Servheen (1975) found that when food was abundant on the Skagit River in western Washington, feeding periods occurred twice daily. Eagles fed intensively from early morning to about 1000 hours. Feeding activities would begin again about 2 hours before sunset and continue until the eagles departed for night roosts. Early and late in the season, when food was more scarce, feeding activities were not limited to these periods, but occurred throughout the day. Researchers in Illinois, Maine, and South Dakota also noted similar bimodal feeding patterns (Grewe, 1966; Dunstan, 1974; Cammack, 1975, cited by Steenhof, 1976; Steenhof, 1976).

Feeding and fishing activities of adults and immatures appear to differ. Stalmaster (1976) observed subadults to congregate in areas where food was abundant and easily accessible, whereas adults were more dispersed over the wintering area. He suggests that subadults may be less efficient at locating food sources, which would account for their presence at high-yielding feeding areas. Indeed, Shea (1973) found juveniles do not attempt to capture prey by swooping as often as adults, and, when they do, they are not as successful. He calculated a success rate of 63.6 percent for subadults, as compared to 83.9 percent for adults. The less-skillful immatures are more prone to obtain fish which have been washed ashore or by wading. They often attempt to steal fish rather than capture their own prey.

Bald eagles often swallow small fish while in flight, but carry larger 900 to 1,200 g fish to a nearby perch, where a vocal period lasting up to a minute typically precedes eating (Ingram, 1965; McClelland, 1973; Shea, 1973; Lint, 1975). Larger salmon are usually dragged onto shore to be eaten, although they are sometimes consumed in shallow water when part of the carcass is exposed (Servheen, 1975).

<u>Diurnal Perching</u>. Bald eagles use daytime perches as loafing and feeding sites, as well as vantage points for sighting prey. Periods of perching usually follow feeding and may last several hours. Servheen (1975) found it not uncommon to observe an eagle perched in the same spot for 6 to 8 hours. Stalmaster (1976) calculated that 83 percent of daytime activity is devoted to perching by eagles wintering on the Nooksack River in Washington, illustrating the importance of perching requirements and behavior to wintering bald eagles.

Proximity to a readily available food source is the most important factor in selection of a perch site. As fish constitutes the major food item at most wintering areas, eagles select perches which are located close to the shorelines of feeding areas. Steenhof (1976) calculated that most perch sites chosen by bald eagles wintering below Fort Randall Dam in South Dakota were within 30 m of the river, and that 58 percent of perched eagles were within 5 m of the bank. In the desert valleys of Utah, a wintering area not associated with water, Platt (1976) found that selection of a perch site is still generally influenced by the proximity of food sources, as eagles there also hunt from perches.

Visibility is critical factor determining selection of a perch site, as bald eagles depend primarily on vision to locate food. High, relatively conspicuous perches affording an unobstructed view are preferred. Tall trees with strong, open branching and minimal visual obstructions or with branches extending over the water fulfill these requirements and are favored eagle perches. The availability of trees suitable as perches is important to eagles and influences local distribution. Areas where trees are a distance from the shore and areas with uniform stands of trees may not be utilized by bald eagles, even though food is readily available (Servheen, 1975; Steenhof, 1976).

The absence of foliage in favored perch trees may indicate that eagles prefer perches exposed to direct sunlight, perhaps because heat loss would be reduced (Dunstan, 1974, cited by Steenhof, 1976). Stalmaster (1976) tabulated perch tree preferences of bald eagles on the Nooksack River in western Washington. He determined a "perch preference index" for each tree type, calculated as the ratio of perch utilization to perch availability. Dead trees had by far the greatest preference index. Dead trees have fewer twigs to interfere with an open flight pathway, provide unobstructed views, and are often higher than the surrounding vegetation. Live deciduous species received high preference indexes, a perch type also noted by Servheen (1975) to be favored by bald eagles. Conifers appeared to be avoided by eagles, perhaps because of their relatively dense foliage which obstructs both vision and flight. Sitka spruce was an exception, probably due to its large size and common occurrence near water.

Bald eagles display affinities to certain trees and even to particular branches which they use throughout the winter (Grewe, 1966; Edwards, 1969). They usually perch near the highest point on the tree at which branches can support their weight (Stalmaster, 1976). Selection of a perch height in a tree is due to visibility afforded by the perch in addition to the availability of suitable, usually horizontal, branches. The latter factor is primarily determined by the morphological characteristics of the perch species. Servheen (1975) found that crop condition significantly influences the height that an eagle perches within a tree. Birds which have just eaten choose lower perches than those with an empty crop. He speculates that this is related to the energetics of flight, with up to 10 percent of body weight contained in the crop. A social factor may also be involved, as eagles which have just eaten have no need to observe the movements of other eagles to possible food sources.

Throughout their range, bald eagles use various species as perch trees. Geographic location and perch species availability are important in determining preferred perch species (Stalmaster, 1976). Eagles wintering on the Nooksack River in Washington prefer big leaf maple (*Acer macrophyllum*), black cottonwood, and Sitka spruce for perch trees. Shea (1973), working in Glacier National Park, found that eagles chose western larch (*Larix occidentalis*), western red cedar (*Thuja plicata*), black cottonwood, and Englemann spruce. Robards (1966) found that eagles wintering in the Chilkat Valley of Alaska favored black cottonwood for perching. Eagles wintering below Fort Randall Dam in South Dakota exhibited a definite perch preference for cottonwoods (*Populus deltoides*) (Steenhof, 1976).

Other structures utilized for perching include ice on the water, gravel bars, submerged logs, driftwood, cliff faces, and rock outcrops overlooking the water (Southern, 1963, 1964; Shea, 1973; Servheen, 1975; Steenhof, 1976). Bald eagles wintering in areas where trees are not available use a variety of objects as perches, including telephone poles, fenceposts, sagebrush, open hillsides, soil hummocks, and even level ground. A series of 35 power poles was once observed to have 24 eagles perched on them (Edwards, 1969; Platt, 1976).

Servheen (1975) emphasizes the importance of gravel bars in eagle habitat preferences along the Skagit River. Visibility while obtaining fish from the shoreline may be the major reason, as eagles are reluctant to land on the ground where visibility is poor. This preference for open areas may preclude the utilization of thickly vegetated shorelines for feeding.

Steenhof (1976) studied bald eagles wintering below Fort Randall Dam on the Missouri River in South Dakota. The study included an analysis of diurnal habitat use. The results of 6,919 eagle sightings indicate that the following factors, listed in order of decreasing importance, influence selction of habitat:

(1) Proximity to a food source.

(2) Protection from wind.

(3) Proximity to the river.

(4) Protection from human disturbance.

(5) Proximity to edge.*

(6) Type of branches available.

(7) Height, diameter, and species of tree.

Intraspecific Behavior. The large concentrations characteristic of wintering bald eagles inevitably involve a great deal of intraspecific actions. Stalmaster (1976) observed an evident social hierarchial system, based predominantly on age, when wintering eagles were in close proximity. Older birds were dominant on the feeding grounds, exhibiting greater success at driving younger birds away. He found this order also reflected in selection of perching sites; adults perched more frequently in the optimal, higher perch sites. Servheen (1975) believes the social structure of wintering bald eagles to be similar to that of crows, a species also present at wintering areas in large numbers.

Observations of interactions among bald eagles indicate that individuals compete for preferred perch sites at the feeding grounds and at night roosts. At feeding areas, individuals claim and defend a particular place from intrusion by other eagles and will sometimes fly considerable distances in order to supplant an interloper (Grewe, 1966; Edwards, 1969). If several eagles are perched in the same tree, a distance of about 1 m is generally maintained between individuals (Shea, 1973; Platt, 1976). If a perched bird is approached too closely while feeding, it may protest by vocalizing, striking out with its talons or beak, and beating its wings. At night roosts, the supplanting of one eagle by another is particularly common in the evening as additional birds arrive and jostle for position. This behavior is accompanied by raised neck hackles, an open gape, and a characteristic vocalization (Edwards, 1969).

*Meaning an unobstructed visual and flight pathway. Steenhof lists various types of edges; i.e., riverbank, rangeland, road, etc.

In late winter, when food was probably scarce, Erskine (1968) observed frequent quarrels over food with adults largely supplanting subadults. He suggests that, when food is abundant, eagles may tolerate much closer proximity to each other. Yet Southern (1963) reports that conflicts are common among large concentrations of eagles even when food is plentiful. Attempts to steal food from other bald eagles are most common when food is scarce. The most frequently used tactic is persistent diving until an eagle is forced to drop its catch. A perched bird is sometimes actually knocked off its perch in this manner. At other times, although the perched eagle may be driven off, it retains its prey, simply transfering it from talons to bill while in flight. Mature eagles have been seen to exhibit a more skillful method of robbery - flying beneath another eagle, then flipping over upside down and plucking the prey from the other's talons (Shea, 1973). Although adult birds may be more successful at attempts to steal food from other eagles, immatures exhibit such aggressiveness more frequently (Southern, 1963; Shea, 1973). Spencer (1977) suggests that this behavior appears to be carried over from the fledging period in that immatures continue to expect adults to turn over their prey.

Soaring is an important group activity of wintering bald eagles. Perched eagles often respond to the sight of soaring eagles by flying to the area and ascending to join the group (Servheen, 1975). Sherrod et al. (1976) note that the presence of numbers of eagles soaring in the same area appears to act as a signaling mechanism, attracting other eagles from considerable distances to a food source. Soaring is often accompanied by chases and dives, while the participants emit loud cries. Ingram (1965) estimated chase speeds to reach 65 to 70 miles per hour. During the last few weeks before eagles depart northward, soaring activities include aerial displays thought to be associated with pair formation (Ingram, 1965).

Bathing is reported by Shea (1973) to be a social activity of bald eagles. If one bird initiated bathing, it would often be joined by others. He reports that it was not unusual to see four to five eagles in the water together engaged in this activity.

Interspecific Behavior. The concentrations of food which attracts bald eagles also draw many other animals into the area, increasing the likelihood of interspecific contacts. When food is plentiful, serious competition and conflicts between eagles and other animals on the feeding grounds is rare. Edwards (1969) observed bald eagles and golden eagles hunting together and even sharing prey; such congeniality was exhibited more often by immature than adult golden eagles. Common crows (*Corvus brachyrhynchus*) often attend feeding eagles, but wait their turn and are generally ignored by the larger birds (Erskine, 1968). When fish are easily available, waterfowl are usually not bothered by eagles and may be seen to swim within a few feet of them. Although grizzly bears and otters may also feed on spawning fish, no direct conflicts between bald eagles and mammals have been observed (Shea, 1973).

When food is more scarce, particularly in late winter, contacts with other species of birds increases (Erskine, 1968). Bald eagles may then drive ravens and crows from their food and force other avian species to turn over their prey.

Platt (1976) observed bald eagles to occasionally share night roosts with other birds. Ravens were the most common. Rough-legged hawks (Buteo lagopus) and golden eagles were also seen, with subadult golden eagles more common than adults. Edwards (1969) also reports bald and golden eagles sharing roosts. The two species were largely tolerant of each other and were even seen perched side by side on the same limb. Juvenile golden eagles were more aggressive and would harass perched bald eagles, often causing them to leave their perches.

Factors Affecting Activities. The daily activities and, consequently, distribution of bald eagles within a wintering area are affected by a variety of factors. Food availability is the most influential variable. When food is plentiful, feeding activities decrease, and more time is devoted to loafing. Reduced availability of a primary food source forces eagles to utilize other sources and probably hunt over a larger territory in the process. Servheen (1975) found that scarcity of food, usually occurring early and late in the season, results in increased quarrels over food between eagles. Interspecific contacts also increase as eagles drive other animals from food and increase predation of more prey types (Erskine, 1968).

Weather conditions have an indirect influence on eagle activities and distribution as they affect the availability of food, but weather exerts direct influences as well. Fewer eagles are present on feeding grounds on fair and windy days and on days of inclement weather. Windy conditions and clear days which produce thermal columns of air stimulate soaring. On such days, feeding and perching periods are shortened, and most of the day is devoted to flight. Soaring activities increase as wind speed increases (Servheen, 1975; Steenhof, 1976).

On days with high winds, winds accompanied by severe chill conditions, heavy cloud cover or precipitation, eagles generally remain perched and may tend to group together (Southern, 1964; Servheen, 1975; Steenhof, 1976). Chosen perches are lower and may be further from the shoreline in more protected areas (Southern, 1964; Grewe, 1966; Steenhof, 1976). Steenhof (1976) observed increased feeding activity below Fort Randall Dam as air temperatures decreased from 20° C to -5° C. This is probably due to increasing consumption requirements to maintain a steady metabolic rate at colder temperatures (Brown and Amadon, 1968; Steenhof, 1976). Feeding activity on the river decreased at temperatures below -5° C. Steenhof attributes this pattern to a decrease in the amount of net energy gained by increased feeding, a shift of activity to upland areas, or a combination of both. Inclement weather may cause eagles to stay in night roosts longer or even remain all day (Ingram, 1965).

Selection of a roosting site for a particular night may be determined by atmospheric conditions which influence the dynamics of flight to and from the roost (Spencer, 1976). On clear or windy days which facilitate soaring at great altitudes, eagles' roosts at high elevations may be utilized. During inclement weather, however, more protected roosts at lower elevations are used (Edwards, 1969; Lint, 1975). In Utah, however, Platt (1976) found that mountain roosts were used by eagles during stormy weather because available valley roosts did not provide sufficient protection.

Evidence indicates that at preferred sites, where habitat is optimal, wintering bald eagles will tolerate a high level of human activity. At less optimal sites, however, human activities are more disruptive to eagles and can cause a shift in habitat use patterns (Steenhof, 1976). Shea (1973) believes that when food is relatively scarce, undue human disturbance could cause dispersal of eagles from a wintering ground.

In some wintering areas, the distribution of eagles reflects the extent of human activity. In western Washington, perching and feeding areas of least human activity are preferred; more disturbed areas are utilized only as food becomes depleted in the favored areas (Servheen, 1975; Stalmaster, 1976). Birds disturbed while on the feeding grounds usually fly to nearby perches and do not resume feeding for long periods, if at all, that particular day (Stalmaster, 1976). Adults are more sensitive to disturbance than immatures. This higher tolerance would be expected to result in higher proportions of young eagles at feeding areas where disturbance is prevalent, a behavior which may enhance their feeding success (Stalmaster, 1976). Steenhof (1976) feels that roosting eagles in South Dakota may tolerate less human disturbance than when loafing or feeding. A disturbed roosting site may be deserted by eagles (Southern, 1964; Steenhof, 1976). However, Edwards (1969) reports that eagles in Utah seem to be more tolerant of human interference at their accustomed roosts than at other areas.

HUMAN-RELATED FACTORS AFFECTING POPULATIONS

As with other species of great longevity, the bald eagle's attainment of sexual maturity takes several years, and reproductive rates are relatively low. Consequently, factors which reduce productivity and cause excessive mortality have a much more serious impact than on species with high fecundity (Snow, 1973). In their position as top carnivores in food chains, bald eagles are exposed to higher degrees of environmental contaminants than species at other ecological levels. And because they are predators, eagles must cope with the biases of man.

The evident decline in populations has been attributed to a number of factors, including loss of habitat due to human activities, general human disturbance, release of pesticides into the environment which cause reduction in reproductive ability, and shooting of bald eagles for sport or alleged depredations on livestock (Sprunt and Ligas, 1966, cited by Snow, 1973). All are caused by human activities.

Fatality. Shooting has been the most common cause of bald eagle mortality throughout at least this century. The main reason for killing the birds has been supposed direct competition with man's interests. Although the bald eagle has officially represented the United States since 1782, legislation protecting the species in this country did not exist until the enactment of the Bald Eagle Act of 1940. This law prohibits shooting, as well as other methods of hunting, capture, or exploitation of the bald eagle except by permit for scientific purposes. The Territory of Alaska was not held subject to these provisions, primarily because of objections to the protection of the bald eagle in an area where the species was abundant and was thought to have potential to harm fishing and fur industries (Kalmbach et al., 1964). In fact, in 1917, the Territorial Legislature placed a bounty on the bald eagle. By the time that the bounty was repealed in 1953, it is estimated that as many as 150,000 bald eagles, from two to three times the present continental population, may have been killed (King et al., 1972). The effects of such decimation cannot be determined because the original population is not known, but even in areas of great concentrations of eagles, the decrease was observable (Kalmbach et al., 1964).

Possibly up to 500 bald eagles are illegally shot each year (Braun et al., 1975). Coon (1970) performed autopsies on 64 bald eagles from 21 of the contiguous states plus nine from Alaska and three from Canadian provinces. Trauma was found to be the most frequent cause of death, of which 62 percent of mortalities were attributed to gunshot injury. Continued studies at the Patuxent Wildlife Research Center for the periods 1966-1968, 1969-1970, and 1971-1972 found shooting mortality rates of 40 percent, 46 percent, and 35 percent, respectively (Mulhern, et al., 1968, 1970; Belisle et al., 1972; Cromartie et al., 1975). Shooting was still the most common cause of death for the period 1973 to 1974, but accounted for a reduced proportion of 25 percent of mortalities, hopefully indicating a downward trend (Prouty et al., 1977).

Immature bald eagles are most susceptible to shooting because of their close resemblance to golden eagles, which have many charges of livestock depredation against them. Coon (1970) found twice as many immatures shot as white-headed adults. Differences in behavior between immatures and adults may be involved. Immatures tend to remain perched longer at the approach of humans, thus making easier targets (Snow, 1973; Stalmaster, 1976).

Another of man's efforts to control other predators resulted in the unintentional mortality of a number of bald eagles in at least one incident near Casper, Wyoming, in 1971. Autopsies performed at the Patuxent Center revealed that nine bald eagles died of thallium poisoning as a result of ingestion of poisoned bait intended for coyotes.

On a local basis, direct killing of bald eagles by humans may be a limiting factor. On San Juan Island, shooting is a significant limiting factor with at least 75 percent of the population gain from annual production being lost (Retfalvi. 1965; cited by Snow, 1973). A small, isolated population of approximately ten breeding pairs at the western end of Lake Erie has undergone attrition of breeding-age birds recently. Three adults are known to have been electrocuted on power transmission lines, and at least three more have been shot in recent years. Such losses pose a great threat to the population, as dead mates are almost impossible to replace (Postupalsky, 1978a).

Electrocution of eagles on power transmission lines is now recognized as a frequent problem in the west. This mortality factor is most severe to golden eagles; the numbers killed annually may exceed several hundred eagles. On Amchitka Island, as many as five dead bald eagles have been found under one power pole (Sherrod et al., 1976). Of 194 bald eagle carcasses examined at the Patuxent Center from 1969 to 1974, 11 birds, or 5.7 percent, died by electrocution (Belisle et al., 1972; Mulhern et al., 1970; Prouty et al., 1977).

Evidence suggests that lead shot ingested along with hunter-killed or crippled waterfowl and rabbits is lethal to bald eagles. Lead poisoning was determined to be the cause of death in two eagles examined at the Patuxent Center since 1964 (Mulhern et al., 1970). Some 75 lead shot were found in the gizzard of an eagle found dead in Maryland; lead concentrations were 22.9 parts per million (ppm) in the liver and 11.3 ppm in the gizzard, concentrations considered to be consistent with lead toxicosis (Jacobson et al., 1977). Approximately two to three percent of the U.S. waterfowl population die annually from lead posioning, and 20 to 25 percent have body shot in skeletal muscle (Jacobson et al., 1977). Platt (1976) found lead shot in 71 percent of bald eagle pellets gathered beneath winter roost sites in Utah, where the primary food is hunter- and road-killed rabbits.

Although the Fish and Wildlife Service has banned the use of lead shot for waterfowl hunting along sections of the Atlantic, Mississippi, Central, and Pacific flyways, lead is relatively inert and may remain in the environment where it is inadvertently consumed by foraging waterfowl indefinitely (Jacobsen et al., 1977; Anon., 1978b).

Alteration of Habitat. The Bald Eagle Protection Act afforded protection to the bird itself but not its habitat. The migratory habits of bald eagles require the sustained integrity of both breeding and wintering habitats. Each is vital to preservation of the species, the first for continued production of replacement generations and the latter for sustaining the bald eagle populations through the relative scarcity of the winter months. Yet it wasn't until March of 1978, with the reclassification of the bald eagle under the Endangered Species Act of 1973, that habitat of the northern race was protected by law. As an "endangered" or "threatened" species, depending on the state, critical bald eagle habitat is protected from modification or destruction resulting from actions funded or authorized by the United States Government. But the law still does not protect habitat from private actions.

Many areas which once provided optimum habitat for eagles have been greatly modified and, in some cases, virtually destroyed by human endeavors. Bald eagles prefer to nest and winter near water, but humans prefer shorelines, too. Particularly in the United States, extensive river, lake, and coastal habitats have been altered by construction of housing developments as well as industrial complexes which require large amounts of water.

Timber harvesting activities have modified vast expanses of land, reducing the quality of these areas as eagle habitat. Harvesting of timber along shorelines is especially critical. Unless a substantial shoreline fringe is left, the breeding eagle population will be forced from the area for lack of suitable habitat (Corr 1974). Large, mature trees are preferred by logging companies as well as by nesting bald eagles. Removal of such trees forces utilization of substandard nesting sites. The practice of clearcutting, which is the most common harvesting method used in coniferous forests in the west, results in replacement stands of even-aged timber. These forests are harvested again as soon as possible, and do not contain the crown-dominant trees preferred by eagles for nesting. By 1976, a total of 2,760 bald eagle nests had been recorded in southeast Alaska, and not one of them was located in second-growth timber (Robards and Hodges, undated). Trenholme et al. (1975) state that if bald eagle populations are to be maintained in the future, the limiting factor may well be the presence of large trees.

Nest trees left in fringe timber are extremely vulnerable to wind-throw or damage (Corr, 1974). Thus, not only is the utilization period of such nests shortened, but fallen nest trees may result in mortality of nestlings. Logging practices also increase siltation in nearby waterways. High siltation which often results from clearcutting may adversely impact fish, which nesting eagles largely depend upon. Apparently, the response of some eagles to a lower prey base is nonbreeding of adults (White, 1974).

Wintering bald eagles exhibit preference for the same roosts year after year (Lint, 1975; Steenhof, 1976). However, loss of a favored roosting site may not be disastrous, provided other suitable roosting habitat and a plentiful food source exists. Eagles wintering on Salt Plains National Wildlife Refuge in Oklahoma have been forced, through loss of roosting trees, to change roosting sites twice in recent years. Yet the population keeps returning, drawn by a continuing source of food (Spencer, 1976).

Some of the habitat modifications caused by man have proved to be beneficial to bald eagles. In recent years, a large concentration of wintering eagles has gathered in Glacier State Park, attracted by runs of spawning kokanee salmon. Kokanee is not native to the area, having been introduced into the Flathead drainage in 1916. Records of eagles were few until 1939, when 37 eagles were seen along McDonald Creek (Shea, 1973). Maximum eagle counts since 1947 show a general upward trend, with a high of 444 eagles in 1977 (McClelland, 1973; McClelland and Shea, 1978).

Water-management systems inplemented during this century have drastically altered the distribution of water, particularly throughout the western United States. The construction of dams, locks, and reservoirs has created permanent impoundments where water may have only been seasonally available before. In areas where lakes and rivers normally freeze over during winter, turbulence caused by locks and dams provides open water through the season. Not only are numbers of wintering waterfowl attracted to these areas, but also concentrations of eagles, often in areas where they were previously only occasional visitors. Robbins (1960) discerned an increase in numbers of bald eagles wintering in the Midwest and southern Great Plains states. Other researchers have noted recent phenomenon of eagle concentrations throughout these areas (Musselman, 1949; Cooksey, 1962, cited by Steenhof, 1976; Grewe, 1966). Apparently, man has inadvertantly expanded winter habitat for bald eagles.

A prime factor suspected to attract eagles below dams is a readily available source of fish in the open waters. Southern (1963), however, asserts that fish were not readily available to eagles below Lock and Dam 12 on the Mississippi River. Spencer (1976) claims that fish passing through the turbines of hydroelectric plants are usually stunned or killed, providing food for eagles in the open water of the tailrace.

Steenhof (1976) conducted as yet the most definitive study of the aspect of fish availability below a dam. She found the tailwater fishery to be an important food source for wintering eagles at Fort Randall Dam in South Dakota. The reservoir fishery was also determined to contribute significantly to the eagles' diet; there were long periods when eagles fed intensively on fish passing through the turbines. Young-of-the-year fish were particularly susceptible to being drawn through the turbines, as declining water temperatures apparently caused them to seek deeper water. Steenhof also found that fluctuating water release rates at the dam created a food source that attracted eagles in early winter; fish were often stranded by receding waters, becoming easily available to eagles.

Heated effluent from industrial and power plants also maintains open water and readily available sources of food for eagles during winter. The warm water attracts numbers of fish in stressed condition, and periodic plant shutdowns with accompanying rapid temperature changes result in fish kills (Ingram, 1965; Spencer, 1976).

General Human Disturbance. The encroachment of civilization upon lands used by bald eagles has rapidly accelerated during this century. A growing human population has resulted in the development of many of these areas. Increased amounts of leisure time have led to greater interest in outdoor recreation, introducing numbers of people and off-road vehicles into areas which were virtually isolated a few years ago.

Researchers generally agree that human activities in the vicinity of bald eagle nesting sites have a negative effect on populations (Snow, 1973). An intensive study conducted by Juenemann (1973, cited by Grubb, 1976) found that although there was little correlation between human disturbance and nesting success on an individual territory basis, when the population as a whole was considered, increased disturbance resulted in reduced activity and productivity.

Numerous studies indicate that the type of human activity and time of occurrence during the breeding chronology may be the critical factors affecting the occupation and production of nests (Herrick, 1934; Chrest, 1964; Retfalvi, 1965, cited by Newman et al., 1977; Mathisen, 1968; Grier, 1969; Juenemann and Frenzel, 1972, cited by Snow, 1973). Hancock (1966) expressed concern that some research methods, particularly climbing nests, might seriously interfere with productivity in subsequent years. However, Grier (1969) reported that censusing eaglets between 2 to 11 weeks in age, either by climbing to the nest or from a distance, caused no significant reduction in the productivity of Ontario eagles. Grier suggests that other types of human activities in the vicinity of the nest might influence the degree of disturbance caused by climbing to nests. Eagles accustomed to activities might be less disturbed than eagles having little contact with people. On the other hand, a great deal of activity near nests might be sufficient additional disturbance to cause desertion.

Only recently have researchers attempted to analytically quantify the degree of disruption caused by various human activities. Juenemann and Frenzel (1972, cited by Snow, 1973) evaluated human-related activities occurring within 1.7 km (1 mile) of eagle nests in Chippewa National Forest and categorized them according to disruptive intensity. They determined that the most disturbing factors included medium-to-heavy recreational use (e.g. seasonal activity around resorts and campsites), active construction of rice paddies, tree plantations, and the blasting of potholes. Timber industry activities, particularly plantation preparation during the months when eagles are on their nest sites, were considered to be especially critical disturbance factors.

Mathisen (1968) conducted an earlier study in the same area. He reported that productivity of bald eagles did not appear to be affected by existing recreational and timber harvesting activities. He did point out, however, the importance of the timing of such activities in relation to breeding chronology. In the Chippewa National Forest, most activities around nest sites occurs during the latter part of the nesting cycle when vulnerability to disturbance is less than during the earlier stages of nesting.

Disturbance during egg laying, incubation, and when the eaglets are small may not be tolerated. Chrest (1964) indicates that early disturbance of breeding eagles may cause mated pairs to not lay eggs, fail to incubate those that are deposited, or result in failure of eggs to hatch. He found that abandonment of eggs is the main factor contributing to nesting failure at Karluk Lake in Alaska. Hensel and Troyer (1964) suggest that frequent human visitation of nests during incubation may cause abandonment or destruction of eggs as adults shuffle excitedly about the nest. The cause of abandonment is further complicated by the fact that some nests are deserted despite no human interference (Chrest, 1964). Herrick (1934) thought that incubating adults deliberately destroyed their eggs when disturbed frequently.

Chrest (1964) reports that when nests are disturbed, several hours may sometimes elapse before the adults return to the nest. If the disruption occurs during inclement weather, the young are exposed to the elements for periods of time. During the early down stages, such extended exposure may result in mortality. Chrest attributes the death of two eaglets at Karluk Lake to this cause.

Weekes (1975) cites instances suggesting that where a nest tree is fairly exposed, there is a regular tendency for the parents to move with their young to areas providing better cover after the young are able to fly. He theorizes that human disturbance and lack of adequate cover may be important factors influencing the timing of fledging and, in some instances, may lead to a crucial shortening of time needed for the young to learn survival techniques.

Several studies suggest the possibility of variable tolerance of nesting eagles to human activities according to the level of activity to which the birds have become accustomed (Retfalvi, 1965, cited by Newman et al., 1977; Grier, 1969; Juenemann, 1973, cited by Newman et al., 1977). Beebe (1974) states that eagles exhibit a high degree of tolerance and adaptability to human disturbance if the activity is not directed toward them. The consensus of several researchers is that bald eagles do not require the isolation of pristine wilderness for successful reproduction, but do need a noninterfering attitude (Grewe, 1964; Hancock, 1965; Beebe, 1974).

Studies of wintering bald eagles also indicate a variable tolerance to human activities by different populations. Evidence suggests that in wintering areas where the habitat is optimal, bald eagles will tolerate a high level of activity. At less preferred sites, however, human activities are more disruptive to eagles and can cause a shift in habitat use patterns (Steenhof, 1976) or even dispersal from the area (Shea, 1973).

Stalmaster (1976) conducted studies on the effects of various human activities on bald eagles wintering on the Nooksack River in western Washington. The activities most disruptive to eagles were both drift and motorboating along the river. Close-range viewing of the birds, fishing within their sight, and hunting - largely due to the adverse reaction of eagles to gunshots - were also disruptive. The study found that normally disturbing activities such as general foot traffic on the river were better tolerated by eagles if the activity was partially concealed from view by vegetative buffers. Stalmaster also determined that eagles become habituated to routine human activities on the riverbank, but disturbances on river bars or the river itself continued to be highly disruptive.

Stalmaster states that ". . . human activity on the feeding grounds is beyond the limits of tolerance for most bald eagles and threatens the wellbeing of the population." Shea (1973) also contends that human disturbance is the major threat to wintering bald eagles in Glacier National Park.

Environmental Pollutants. In their position as top carnivores in food chains, bald eagles are exposed to many environmental pollutants which have lesser effects on species at other trophic levels. They are the final recipients, through the process of biological magnification, of relatively large accumulations of such pollutants. The presence of pesticides and their metabolites, PCB's (polychlorinated biphenyls), and heavy metals in bald eagles from throughout the conterminous United States, Alaska, and Canadian provinces reflect the widespread contamination by these compounds.

In 1960, the Patuxent Wildlife Research Center initiated analyses of pesticide residues in bald eagles which have continued to date. Eagles found dead or moribund are collected by Federal, state, and private cooperators, packed in dry ice, and shipped air express to the laboratory for analysis. All 276 eagle carcasses analyzed from the period 1964 to 1974 were found to contain residues of DDE, a metabolite of DDT. Dieldrin was found in 235 and DDD residues in 177 eagle carcasses. Unknown compounds found in eagles analyzed from 1964 and 1965 were later identified as PCB's. The presence of PCB's was detected in all eagles except two thereafter (Reichel et al., 1969; Mulhern et al., 1970; Belisle et al., 1972; Cromartie et al., 1975). Median carcass residues of dieldrin, TDE, DDE, and PCB's have shown no decrease from 1969 to 1974 (Prouty et al., 1977).

Studies conducted on the effects of pesticides on captive bald eagles found little reason to suspect any unusual susceptibility to DDT mortality. Consequently, a hazard zone of about 30 ppm in the brain, as found in other birds and mammals, might also apply to eagles. Indeed, experimental and field studies have shown that 30 parts ppm of DDT plus DDD in the brain of a bald eagle is lethal (Mulhern et al., 1970). Captive eagles fed 160 ppm DDT exhibited tremors at 55 days and died at 71 days. Eagles fed 10 ppm showed no evidence of poisoning. DDT content of the tissues was discovered to increase slowly for many months before a metabolic balance was maintained. When intake of DDT was discontinued, concentrations slowly declined (Stickel et al., 1966; Chura et al., 1967).

PCB's are widely used industrial compounds sold in the United States under *the trade name* Aroclor. Their toxicity is similar to that of DDE, and the two substances are also present in similar quantities in the environment. The toxicity of dieldrin and DDT is enhanced beyond an additive effect by the addition of PCB's containing fewer numbers of chlorine atoms. Toxic effects of DDE and Aroclor 1254 are additive, not synergistic (Snow, 1973). Significant correlations have been found between levels of PCB's and DDE in the brains of bald eagles (Snow, 1973). The effects, besides toxicity, of PCB's on bald eagles are not known. Experiments have demonstrated the capability of PCB's to induce microsomal enzyme activity in domestic pigeons and kestrels. Ten-day-old ducklings fed a diet containing 50, 25, or 100 ppm Aroclor 1254 showed 35 percent to 44 percent mortality on exposure to duck hepatitis virus, whereas mortality among ducklings not receiving Aroclor was 14 percent (Dustman et al., 1971, cited by Snow, 1973).

Composition of diet may be important in determining the concentration of pesticides ingested. The highest residues of PCB's have been found in birds that feed on other birds or mammals (Snow, 1973). Reichel et al. (1969) found that pesticide residues in bald eagles were considerably higher than in golden eagles. Bald eagle residues averaged 8.90 ppm DDE in the carcass, 4.91 ppm in the liver, and 1.37 ppm in the brain; DDE residues in golden eagles averaged 0.49 ppm in the carcass, 0.33 ppm in the liver, and 0.10 ppm in the brain. They suggested this may reflect the difference in the food habits of the two species of eagles. The diet of the bald eagle is primarily comprised of fish, while that of the golden eagle consists of mammals.

Widespread use of mercury compounds, primarily as fungicides, has resulted in high accumulations in fish (Wagner, 1974). It wasn't until 1969 that the Patuxent Center included determination of the mercury content in dead bald eagles. The equivalent ppm mercury present as methyl mercury, the more biologically reactive form, ranged from 0.38 to 44.56 ppm Hg (Belisle et al., 1972). Two eagles recovered in Minnesota in 1969 were apparent victims of mercury poisoning. The birds were suspected to have accumulated lethal residues through ingestion of fish from mercury-polluted waters (Anon., 1970, cited by Snow, 1973).

The compounds just discussed, along with others discovered in the tissues of bald eagles but not yet found to be of significance, are contaminants which probably add to the physiological stress of bald eagles. Of 276 dead eagles examined at the Patuxent Center from 1964 to 1974, 23 birds or 8.3 percent were suspected to have died of dieldrin poisoning; four ppm dieldrin has been determined to be the lower lethal range. However, the real threat to bald eagle populations posed by environmental contaminants is not accumulation resulting in mortality, as most eagles die of other causes, but significantly reduced productivity resulting from sublethal doses of DDE, dieldrin, and perhaps other compounds also.

Researchers have long suspected that the primary factor producing reproductive failure among bald eagles was the contamination of the environment with persistent chlorinated hydrocarbon pesticides. The onset of reproductive failures coincided with the introduction of DDT after World War II. Its unrestricted dispersal led to accumulations of the pesticide and its metabolites throughout the world's ecosystems, particularly aquatic ones.

In a study of the comparative productivity of six bald eagle populations, Sprunt et al. (1973) found widely varying rates of reproductive success. They concluded the principle factor in such large differences to be the relative contamination of various populations with hydrocarbon pesticides, principally DDT and its metabolites. Productivity was lowest in bald eagle populations nesting close to the shores of the Great Lakes, where breeding populations presumably draw a large proportion of their food from the highly contaminated lakes. Analysis of bald eagle eggs has shown a direct relationship between reproductive rates and the amounts of DDE and dieldrin present; the higher the residues, the lower the rate (Krantz et al., 1970).

The exact physiological cause of reproductive failure was not known until the late 1960's. Research revealed that DDE in the liver induces enzymes which hydroxylate certain steroid hormones, primarily by estrogen, causing abnormal calcium metabolism in eagles. The females are not able to store or utilize calcium, resulting in thin-shelled eggs, which are usually cracked or crushed during incubation attempts (Wiemeyer et al., 1972; Snow, 1973).

Studies have determined that average declines in eggshell thickness greater than 17 percent have been accompanied by severe declines in populations and/or reproductive success. Analysis of southern bald eagle eggs from two Florida counties revealed declines in eggshell weights of 18.0 and 19.8 percent since organochlorine pesticides were initially used (Hickey and Anderson, 1968). Northern bald eagle eggs collected in 1968 to 1970 from Kodiak, Alaska, exhibited a 14.1 percent decrease in shell thickness, and eggs from the Great Lakes states averaged 12 percent thinner than pre-1946 norms (Wiemeyer et al., 1972).

Locke et al. (1966) studied spermatogenesis in bald eagles experimentally fed a diet containing DDT. They concluded that DDT does not interfere with this process except at toxic levels. However, they were unable to determine whether DDT caused production of abnormal or reduced levels of sperm. The latter incident has been shown to occur in white leghorn cockerels fed a diet containing DDT (Albert, 1962).

Organochlorine compounds other than DDE are suspected to depress productivity of eagles. Following the ban on the use of dieldrin in sheep dips in Scotland, researchers observed that the proportion of golden eagles successfully reproducing young doubled. Average dieldrin residues in the eagles dropped by more than half, from .87 to .38 ppm (Lockie, Ratcliff, and Balharry, cited in 1964, cited in Wiemeyer et al., 1972). An earlier study of these golden eagles revealed a correlation between reproductive failure and amounts of dieldrin exceeding one ppm in the eggs (Lockie and Ratcliffe, 1964.). One-half of the bald eagle eggs collected from 1968 to 1972 from Maine and a few from Minnesota, Michigan, Wisconsin, and Florida have contained more than one ppm. If the effects of dieldrin on the bald eagle are the same as on the golden eagle, then dieldrin could be a factor in the reduced productivity of these areas (Wiemeyer et al., 1972).

Transmission of pesticide residues from parent to offspring via the eggs of birds is well known (Stickel et al., 1966). Residues may have an adverse effect on hatching and survival. Pheasants fed 50 milligrams of Aroclor daily for 17 weeks produced fewer eggs, and a higher percentage of chicks pipped the shell but did not succeed in hatching. Eggshell thickness was not affected (Dustman et al., 1971, cited by Snow, 1973).

The use of DDT in the United States was finally banned in 1972. Although several studies show that residues of DDT and its metabolites have been declining in some birds and fish, studies conducted at the

Patuxent Center report no decrease in levels of residues in dead bald eagles through 1974 (Prouty et al., 1977). DDT is the most persistent biocide; the half-life of the compound is around 15 years, the exact time depending on decomposition rates of different environments. DDT is readily absorbed by the bottom sediments of aquatic systems. As DDT in the water is degraded or assimilated by organisms, fresh supplies from the bottom mud are released. Because of its relatively long half-life, DDT can be released in this manner into an aquatic system for years (Wagner, 1974).

The decreased use of chlorinated hydrocarbon pesticides can be expected to be accompanied by increased reproductive success in bald eagles. As well as the 1972 ban on DDT, a voluntary halt was called on the manufacture of PCB's in 1977. A recently proposed regulation would prohibit resumption of manufacturing, as well as the import of these compounds into the United States (Anon., 1978c). However, the use of DDT may not be halted altogether despite laws prohibiting it. In certain parts of the Pacific Northwest, applications have been made for special permission to use DDT to control the outbreak of the tussock moth. Its use would almost certainly have adverse effects on bald eagle populations there, which are currently among the most productive in the United States.

MANIPULATIVE MANAGEMENT TECHNIQUES

Bald eagle management guidelines emphasize preservation of habitat integrity, and are primarily aimed at minimizing human disturbance to eagles. In addition, however, intentional manipulation of the habits and habitats of bald eagles may not only be desirable, but necessary to maintain required environmental conditions and secure threatened populations. Recent research indicates that this eagle does lend itself to manipulative management (Postupalsky, 1978b). Various techniques are currently being researched and employed to enhance the status of raptor populations in general, most of which are probably applicable to bald eagles. Methods of increasing populations seem to lie mainly in enhancement of existing nesting and feeding habitats, provision of additional habitats, or through manipulation of breeding biology to produce more young.

Food availability, which is particularly critical during the winter, may be the main factor limiting bald eagle populations. Management of food resources to provide food for eagles could increase the carrying capacity of both nesting and wintering grounds. When recreation fishing conflicts with eagle management, fisheries could be converted to species not as appealing to recreation but which provide food for eagles (Radtke, 1973). Fisheries management should be directed toward maintenance of natural spawning populations; efforts toward increased numbers of artifically spawned fish are of no benefit to wintering bald eagles (Servheen, 1975; Stalmaster, 1976). At dams where reservoir and tailwater fisheries have been determined to be important to wintering eagles, efforts should be directed toward maintenance and enhancement of these food sources (Steenhof, 1976).

Steenhof (1976) found fluctuating water release at Fort Randall Dam often left fish stranded, effectively creating a food source which attracted eagles. However, she emphasizes that this practice is of limited value as a management technique, as fluctuations in water level did not cause stranding when water temperatures were below 7° C. In fact, she points out that it may be detrimental to eagles in that significant fish kills may occur during the summer months when eagles are not present to utilize the food. Where avian prey constitutes a significant portion of the diet of wintering bald eagles, populations of waterfowl and upland species may be encouraged by provision of grain supplies and roosting sites (Steenhof, 1976).

Artificial feeding may attract wintering bald eagles and carry them through the periods when other food sources are scarce. This technique was successfully used during the 1975-1976 season on the Skagit River when high-water levels made salmon unavailable to eagles (Nature Conservancy, 1976). Supplementation could create new wintering areas as well as increase utilization of existing ones. Experimentation has proven that bald eagles will eat food, primarily fish, set out by man (Wright, 1953; Southern, 1963, 1964; Ingram, 1965; Robards, 1967; Ligas, 1968; McClelland and Shea, 1978). Provision of food which can be readily obtained by young eagles, relatively unskilled in procurement of food, may help to offset juvenile mortality.

Lack of suitable perch sites may preclude utilization of high-yielding stretches of wintering habitat as feeding grounds and thus limit its carrying capacity for bald eagles. Erection of raptor poles, perhaps in conjunction with planting trees to provide future sites, may allow utilization of food resources thus far essentially untapped by eagles. Such experimentation proved successful with golden eagles in Utah where sagebrush flats contain high densities of jackrabbits but essentially no hunting perches. In 1972, the Bureau of Land Management erected eight 16-foot towers with platforms in this area. All were used as feeding and hunting perches by numerous eagles that same year, and what may have been nesting attempts were observed (White, 1974). Where natural perch sites exist, however, artificial ones may not be used by bald eagles (Steenhof, 1976).

In some breeding areas, the availability of suitable nesting structures may be an important factor limiting population density. Research with ospreys has demonstrated the effectiveness of artificial nesting platforms in eliminating this limiting factor and allowing populations to increase to the level that a particular habitat is capable of supporting (Postupalsky, 1978b). Bald eagles have used artificial nesting structures for several years in Michigan, Wisconsin, Arizona, and Idaho, but were not successful until 1977, when a total of five eagles fledged from two manmade nests in Michigan (Postupalsky, 1978a). This success assures the viability of nest-site manipulation with bald eagles and opens up the possibilities for its use. Provision of appropriate nest supports might help attract new breeding pairs to otherwise suitable habitats which lack natural nesting structures. Where nests are exposed to excessive human activity, nesting success might be increased by relocating them to more secluded sites within the same home range. Replacement of old, structurally weak nests with manmade ones could prevent windthrow and allow continued occupation of a favorable habitat (Postupalsky 1978a, 1978b). Successful reconstruction of fallen, active bald eagle nests has been reported by Dunstan and Borth (1970) and Postupalsky (1978b). Nest-site manipulation has potential for maximizing bald eagle productivity, which may not have occurred otherwise, by attracting breeding pairs to good habitat. Nesting success may also be increased by reduced nestling mortality due to windthrown nests, shown to be a benefit accompanying use of artificial nests by ospreys (Postupalsky, 1978b). Artificial nesting structures also facilitate research methods, such as banding, upon which the development of sound management programs depends (Postupalsky, 1978b).

Buffer zones are currently used to minimize disturbance to eagles at nesting sites on national wildlife refuges and national forests. Vegetative buffers which obscure human activities from sight and lessen noise have been demonstrated to be effective in reducing disturbance to wintering bald eagles as well (Stalmaster, 1976). Establishment of obscuring vegetation where natural buffers are nonexistant may be desirable. Propagative species could be selected to include rapid-growing tree species known to be preferred by bald eagles so as to provide future perch, roost, and nest trees (Stalmaster, 1976; Sprunt and Cunningham, 1962, cited by Chrest, 1964). The distribution of eagles on wintering grounds could possibly be manipulated through the establishment of stands of preferred trees, perhaps facilitating management. Selective thinning of shoreline trees could stimulate growth of remaining trees, provide improved flight access and visibility, and thus attract eagles (Steenhof, 1976). On rivers where waterflow is controllable, levels should be maintained which minimize shoreline erosion and consequent loss of perch and roost trees.

Researchers are just beginning to explore the possibilities of manipulating the breeding biology of bald eagles. Egg substitution has potential to increase productivity of populations experiencing reproductive failure due to environmental contamination. Eggs taken from nests of healthy eagles in Minnesota and Wisconsin have been successfully used to replace eggs laid by nonproductive pairs in Maine. Transplants made in 1974 and 1975 produced one and two fledglings, respectively. Research in Maine and Michigan has demonstrated that eagle pairs will accept and successfully foster nestlings. This technique could be used to induce pairs which continue to incubate addled eggs well past normal periods to adopt nestlings (Marshall and Nickerson, 1976). The eventual goal of these methods is the replacement of contaminated adults in the breeding population by healthy foster young. Success depends on the as yet unproven assumption that young bald eagles return to nest near the places where they fledged. Reduction or stabilization of contamination levels so that recontamination does not occur is also requisite for success.

Most wild raptors will lay two or even three clutches of eggs if the first is immediately removed (White, 1969). This phenomenon has been observed in both the northern (Herrick, 1934) and the southern bald eagle (Hoxie, 1910; Bent, 1937), suggesting the possibility of removal of first clutches to be transplanted or reared in captivity. leaving second clutches to be raised by the legitimate parents. Artificial incubation of bald eagle eggs placed under a bantam hen has proved successful, but attempts to hatch eggs in incubators have failed (Herrick, 1934; Hancock, 1973).

Manipulative techniques could artificially increase survival rates of bald eagle nestlings in threatened populations. Research conducted by

Gargett (1971, cited by White, 1974) on the Black Eagle (Aquila verreauxii) of Africa suggests the possibility of offsetting nestling mortality due to sibling conflict. This "Cain and Abel" conflict, documented in young nestlings, is not exhibited at a more advanced stage of development, leading to the assumption that the young are compatible once past a critical period. The study involved the removal of one of two young shortly after hatching. The young were exchanged at regular intervals, giving each a turn both in the nest and being raised by hand. Once past the critical stage, both young were left in the nest to complete development. In this manner, two young, rather than one, were successfully raised (Spofford, pers. comm. with White, 1974).

The survival prospects of the bald eagle may be enhanced by captive breeding. The aims of this technique are to obtain birds for reintroduction into the wild to boost threatened populations and to provide stock for captive situations, thus reducing exploitation of wild populations. Although seldom intentionally attempted historically, breeding of bald eagles in captivity has proved very successful. Hancock (1973) analyzed known captive breeding attempts. He calculated an average clutch size of 2.13 eggs, a hatching success of 87 percent, and a fledging success of 87 percent with an average of 1.9 young per successful nest. These rates are higher than those found in the wild eagle population of British Columbia, considered to be a stable one. That population was determined to have an average clutch size of 1.88, or 60 percent hatching success, and a 57 percent fledging success, with 1.38 young per succssful nest. Longevity records suggest that captive bald eagles should have a productive lifespan of 20 to 30 years. Fecundity of captive pairs might be stimulated through removal of the first clutch, which could then be artificially incubated or transplanted into nests of wild pairs (Maestrelli and Wiemeyer, 1975).

The Patuxent Wildlife Center has been successful in recent attempts to breed captive bald eagles (Maestrelli and Wiemeyer, 1975). Young eagles hatched and raised at the center have been introduced into the wild in several states. In one case, young eaglets were successfully placed in a New York nest where a pair was incubating an inviable egg (M. Pramstaller, pers. comm.). Captive breeding techniques may eventually be perfected through experimentation with artificial insemination. This method was first successful with the golden eagle in 1972 (Grier, 1972). Of nine eggs which were produced by two females, seven were fertile. One egg was incubated by the mother, and three were successfully hatched in an incubator. The remaining three eggs failed to hatch.

Another, albeit costly, method to reestablish bald eagles in their former range is being attempted by researchers at Cornell University. Adopting the hacking techniques of falconers, a pair of 9-week-old bald eagle chicks were imported from a nest in Wisconsin to New York in 1976, where they were placed in an artificial nesting structure. A human "babysitter" cared for the young eagles through the summer months, feeding them regular meals, protecting them from possible predators, and retrieving them from the first unsuccessful attempts at flight. The eagles soon became proficient hunters and departed with the approach of winter. Now, researchers can only wait and hope that the eagles will eventually return to New York to breed (Wolff, 1977).

INFORMATION ORGANIZATIONS

Federal Agencies:

1. United States Fish and Wildlife Service
   Washington, D.C. 20240

Lynn A. Greenwalt, Director
Telephone: (202) 343-4717

Keith M. Schreiner, Associate Director
and Endangered Species Program Manager
Telephone: (202) 343-4646

John Spinks, Chief
Office of Endangered Species
Telephone: (202) 343-5687

a. Patuxent Wildlife Research Center
   Laurel, Maryland 20810

   Lucille F. Stickel, Director
   Telephone: (301) 776-4880, ext. 211

b. Migratory Bird Research Laboratory
   Laurel, Maryland 20810

   Fant W. Martin, Director
   Telephone: (301) 776-4880, ext. 223

c. U.S. Fish and Wildlife Service - Alaska Area
   Eagle Management Studies
   Juneau, Alaska 99801
   Telephone: (907) 586-7243

   Fred C. Robards, Game Management Agent

Formerly named the Bureau of Sport Fisheries and Wildlife, the Service enforces laws protecting the bald eagle, including the Endangered Species Act and the Migratory Bird Act. The Office of Endangered Species is responsible for scientific study and application of research findings to the preservation of threatened wildlife species. The Patuxent Center conducts analyses of dead eagles to determine cause of death and levels of pesticide residues contained in the tissues. The Center also maintains captive bald eagles for study and for the production of stock for reintroduction into the wild to boost threatened populations.

Federal Agencies (con.):

2. United States Forest Service
   Division of Wildlife Management
   Washington, D.C. 20250

   Dale A. Jones, Director
   Wildlife Management
   Telephone: (703) 235-8015

The Forest Service cooperates with Federal and state officials in the enforcement of wildlife laws and execution of management programs on National Forests. The Service was the first Federal agency to provide for bald eagle management on public lands.

3. Canadian Wildlife Service
   Ottawa, Ontario KIA OE7

   A. G. Loughrey, Director General
   Telephone: (819) 997-1307

   H. J. Boyd, Director
   Migratory Birds Conservation Branch
   Telephone: (819) 997-2957

   J. A. Keith, Director
   Wildlife Research and Interpretation Branch
   Telephone: (819) 997-1244

The Canadian Wildlife Service administers Federal laws regarding wildlife, provides management advice to National Parks and Territories, and conducts research on migratory birds.

Independent Organizations:

National Audubon Society
950 Third Avenue
New York, New York 10022
Telephone: (212) 832-3200

Alexander Sprunt, IV, Research Director
115 Indian Mound Trail
Tavernier, Florida 33070
Telephone: (305) 852-5092

The general purposes of the Audubon Society are to promote the conservation of wildlife and the environment, and to educate the public regarding man's relationship with the environment. The Society sponsored the Continental Bald Eagle Project in the early 1960's. and continues to provide funds for independent investigators conducting research on bald eagles.

Independent Organizations. (con.):

National Wildlife Federation
1412 - 16th Street NW.
Washington, D.C. 20036
Telephone: (202) 797-6800

Fred R. Scroggin, President

a. Raptor Information Center

William S. Clark, Director

Mike Pramstaller, Raptor Information Specialist

The National Wildlife Federation is a conservation education organization dedicated to arousing public awareness of the need for wise use, management, and conservation of natural resources. The Federation has been involved in the identification and acquisition of critical bald eagle habitat. The Raptor Information Center is a new service provided by this organization. Its projects include coordination of an annual midwinter bald eagle census, which will be initiated this winter, a computerized bibliography and data bank on the bald eagle, as well as public education programs. The Center also publishes a newsletter, The Eyas, which features reports on raptor projects around the nation.

3. Raptor Research Foundation

Richard R. Olendorff, President

The Raptor Research Foundation is an international organization formed to stimulate, coordinate, and conduct research on the biology and management of birds of prey. Its Raptor Rehabilitation Committee retains a list of groups nationwide that are willing to do rehabilitation. The foundation publishes a quarterly journal, Raptor Research.

4. Eagle Valley Environmentalists, Inc.
Box 155, Apple River, Illinois 61001
Telephone: (815) 594-2259

Environmental Center:
Box 37
Glen Haven, Wisconsin 53810
Telephone: (608) 794-2373

Terrence N. Ingram, President

Independent Organizations. (con.):
This conservation organization is particularly dedicated to the preservation of the bald eagle, working toward this goal by promoting research, conducting habitat preservation programs and public education through workshops, seminars, and publications. Probably the most notable is the Annual Bald Eagle Days event, when researchers gather to exchange new findings and ideas.

5. The Nature Conservancy
   Suite 800 - 1800 North Kent Street
   Arlington, Virginia 22209
   Telephone: (703) 841-5300

The Conservancy is dedicated to the preservation of unique natural areas for present and future generations. Its land acquisition program has included important bald eagle habitat, such as the Skagit River bald eagle area in Washington. Natural heritage programs in various states include compilation of data on bald eagle nesting and wintering sites.

6. Laboratory of Ornithology
   Cornell University
   159 Sapsucker Woods Road
   Ithaca, New York 14853
   Telephone: (607) 256-5056

   Douglas A. Lancaster, Director

The Laboratory of Ornithology is an international center for the study of birds. Its researchers are currently investigating the viability of using falconers' hacking techniques to reintroduce bald eagles into areas from which they were extirpated (Wolff, 1977). Recent research has also included successful artificial insemination of golden eagles (Grier, 1972). The Living Bird is one of the publications put out by the Laboratory of Ornithology.

SELECTED AUTHORITIES ON THE NORTHERN BALD EAGLE

1. John J. Craighead
   Frank C. Craighead
   5125 Orchard Lane
   Missoula, Montana 59801

The Craigheads have studied many North American birds of prey, including both the bald and golden eagles.

2. Thomas C. Dunstan
   Department of Biological Sciences
   Western Illinois University
   Macomb, Illinois 61455

Dunstan has studied wintering and nesting bald eagles throughout the United States. He has recently implemented radio-telemetry to track movements of young eagles away from their nests (Dunstan, 1978).

3. Jonathan M. Gerrard
   954 - 15th Avenue SE
   Minneapolis, Minnesota 55414

Gerrard has studied nesting bald eagles in Saskatchewan and Manitoba.

4. James W. Grier
   Zoology Department
   North Dakota State University
   Fargo, North Dakota 58102
   Telephone: (701) 237-7087

Grier has conducted field studies primarily in Ontario and Manitoba.

5. David Hancock
   3215 Island View
   Saanich, British Columbia

Also a Canadian researcher, Hancock's studies have concentrated on bald eagles in coastal British Columbia, where he is Director of the Wildlife Conservation Centre.

6. Eugene Knoder
   9250 West Fifth Avenue
   Lakewood, Colorado 80226
   Telephone: (303) 232-9493

As Director of the Audubon Western Environmental Science Program, Knoder is an authority on eagles in general and the golden eagle in particular.

7. John Mathisen
U.S. Forest Service
Chippewa National Forest
Cass Lake, Minnesota 56633

Mathisen is a wildlife manager in one of the most important bald eagle breeding areas in the conterminous United States, where he has been locating nests and banding eagles for several years.

8. Joseph R. Murphy
Department of Zoology, Room 167-WIDB
Brigham Young University
Provo, Utah 84601
Telephone: (801) 374-1211, ext. 4075

Murphy and several of his graduate students have conducted research on bald eagles in the intermountain and great basin regions. He is Vice President of the Raptor Research Foundation and Secretary of World Working Group on Birds of Prey.

9. Sergei Postupalsky
Department of Wildlife Ecology
University of Wisconsin
Madison, Wisconsin 53706

Postupalsky has been conducting bald eagle and osprey research in the Great Lakes region since 1960. His studies have included the use of artificial nesting structures by both of these species (Postupalsky, 1978b).

10. Fred C. Robards
U.S. Fish and Wildlife Service - Alaska Area
Eagle Management Studies
Post Office Box 1287
Juneau, Alaska 99801
Telephone: (907) 586-7243

Robards, an eagle management specialist, designed and supervises a continuing nest survey which identified 2,760 nests in southeast Alaska during the period 1969 to 1976 (Robards and Hodges).

11. Ronald Ryder
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523

Ryder has ongoing bald eagle research in the western states via graduate students.

12. Alexander Sprunt, IV
    115 Indian Mound Trail
    Tavernier, Florida 33070
    Telephone: (305) 852-5092

In his capacity as Director of the Audubon Research Department, Sprunt was in charge of the Continental Bald Eagle Project, and has since continued research on both races of the bald eagle.

13. Douglas W. A. Whitfield
    Department of Botany
    University of Alberta
    Edmonton, Alberta T6G 2E1

Whitfield collaborated with Gerrard and other researchers to study nesting bald eagles in Saskatchewan and Manitoba.

Northwest Researchers

Washington:

1. Teryl G. Grubb
   Research Wildlife Biologist
   U.S. Forest Service
   Hydriology Laboratory
   Tempe, Arizona

2. Laszlo Retfalvi

3. Christopher W. Servheen
   University of Montana
   Missoula, Montana 59801

4. Mark V. Stalmaster

Idaho:

5. Donald R. Johnson
   Biology Department
   University of Idaho
   Moscow, Idaho 83843

Montana:

6. Lance Craighead
   Box 361
   Libby, Montana 59923

7. B. Riley McClelland
   Assistant Professor, School of Forestry
   University of Montana
   Missoula, Montana 59801

8. David S. Shea
   Research Associate
   West Glacier, Montana 59936

ADDITIONAL AUTHORITIES ON NORTH AMERICAN FALCONIFORMES

1. Thomas J. Cade
   Laboratory of Ornithology
   Cornell University
   159 Sapsucker Woods Road
   Ithaca, New York 14853
   Telephone: (607) 256-5056

As Research Affiliate with the Laboratory of Ornithology, Cade has conducted studies on varous diurnal birds of prey. He led a recent project to reestablish the bald eagle in New York by adapting falconers' hacking techniques.

2. Joseph J. Hickey
   Department of Wildlife Ecology
   University of Wisconsin
   Madison, Wisconsin 53706

Hickey has studied various raptors, particularly the peregrine falcon

3. Walter R. Spofford
   Department of Anatomy
   State University of New York
   Medical Center
   Syracuse, New York 13062

Spofford is an authority on the golden eagle.

4. Richard R. Olendorff

Olendorff is currently President of the Raptor Research Foundation. He is coauthor of _An Extensive Bibliography on Falconry, Eagles, Hawks, Falcons, and Other Diurnal Birds of Prey_ (1967).

5. Clayton M. White
   Department of Zoology
   Brigham Young University
   Provo, Utah 84601
   Telephone: (801) 374-1211, ext. 1006

White has primarily studied the peregrine falcon, but has done research on the northern bald eagle and other raptors as well. He is the editor of _Raptor Research_, a quarterly journal published by the Raptor Research Foundation.

LITERATURE CITED

Albert, T. F.
1962 The Effect of DDT on Sperm Production of the Domestic Fowl. Auk, 79: 104-107.

American Ornithologists' Union
1957 Checklist of North American Birds, Fifth Edition. Lord Baltimore Press, Inc. Baltimore, Maryland. pp 113-114.

1970 Bald Eagles Poisoned by Mercury. Raptor Research News, 4(3): 70-71. Original publication not examined.

Anon.
1978a Forest Service Manages NWF Eagle Site. Natl. Wildl., 16(5): 24 D.

1978b Condemned to Die. Natl. Wildl., 16(6): 17.

1978c PCB Ban Proposed. Consv. News 43(18): 14.

Beebe, F. L.
1974 Field Studies of the Falconiformes of British Columbia. Occasional Papers of the British Columbia Provincial Museum No. 17, Victoria, British Columbia.

Belisle, A. A., W. L. Reichel, L. N. Locke, T. G. Lamont, B. M. Mulhern, R. M. Prouty, R.B. DeWolf, and E. Cromartie
1972 Residues of Organochlorine Pesticides, Polychlorinated Biphenyls, and Mercury and Autopsy Data for Bald Eagles, 1969 and 1970. Pestic. Monit. Jour., 6(3): 133-138.

Bent, A. C.
1937 Life Histories of North American Birds of Prey, Part 1. Dover Publications, Inc. New York. pp 321-349.

Braun, C. E., F. Hammerstrom, T. Ray, and C. M. White
1975 Conservation Committee Report on Status of Eagles. Wilson Bull., 87(1): 140-143.

Broley, C. L.
1947 Migration and Nesting of Florida Bald Eagles. Wilson Bull., 59(1): 3-20.

1950 The Plight of the Florida Bald Eagle. Audubon Mag., 52(1): 42-49.

1958 The Plight of the American Bald Eagle. Audubon Mag., 60(4): 162-163.

Brooks, A.
1922 Notes on the Abundance and Habits of the Bald Eagle in British Columbia. Auk, 39(4): 556-559.

Brown, L., and D. Amadon
1968 Eagles, Hawks, and Falcons of the World. McGraw-Hill Book Co., New York. 945 pp.

Brown, W. H.
1975 Winter Population Trends in the Bald Eagle. Am. Birds, 29(1): 12-14.

Cammack, E.
1975 Winter Bald Eagle (Haliaeetus Leucocephalus) Study in Maine. Unpubl. Report Colby College, New York. 8 pp mimeogr. Original publication not examined.

Chrest, H. R.
1964 Nesting of the Bald Eagle in the Karluk Lake Drainage on Kodiak Island, Alaska. M.S. thesis. Colorado State Univ., Fort Collins, Colorado. 115 pp.

Chura, N. J., and P. A. Stewart
1967 Care, Food Consumption, and Behavior of Bald Eagles Used in DDT tests. Wilson Bull., 79(4): 441-448.

Coon, N. C., L. N. Locke, E. Cromartie, and W. L. Reichel
1970 Causes of Bald Eagle Mortality, 1960-1965. Jour. of Wildl., Diseases, 6: 72-76.

Corr, P. O.
1974 Bald Eagle (Haliaeetus Leucocephalus Alaskanus) Nesting Related to Forestry in Southeastern Alaska. M.S. thesis, Univ. of Alaska. 144 pp.

Crandall, L. S.
1941 Notes on Plumage Changes on the Bald Eagle. Zoologica, 26: 7-8.

Cromartie, E., W. L. Reichel, L. N. Locke, A. A. Belisle, T. E. Kaiser, T. G. Lamont, B. M. Mulhern, R. M. Prouty, and D. M. Swineford
1975 Residues of Organochlorine Pesticides and Polychlorinated Biphenyls and Autopsy Data for Bald Eagles, 1971-1972. Pestic. Monit. Jour., 9(1): 11-14.

Cunningham, R. L.
1960 The Status of the Bald Eagle in Florida. Audubon Mag., 62(1) 24-26, 41, 43.

Dixon, J.
1909 A Life History of the Northern Bald Eagle. Condor, II: 187-193.

Dunstan, T. C.
1970 Successful Reconstruction of Active Bald Eagle Nest. Wilson Bull., 82(3): 326-327.

1974 The Status and Role of Bald Eagle Winter Studies in the Midwest. pp. 62-67 in: Our Eagle's Future: Proceedings of Bald Eagle Days. Eagle Valley Environmentalists, Apple River, Illinois. Original publication not examined.

1973 Our Bald Eagle: Freedom's Symbol Survives. Natl. Geog., 153: 186-199.

Dunstan, T. C., and M. Barth
1970 Successful Reconstruction of Active Bald Eagle Nest. Wilson Bull., 82(3): 326-327.

Dunstan, T. C., and J. F. Harper
1975 Food Habits of Bald Eagles in North-Central Minnesota. Jour. Wildl. Manage, 39(1): 140-143.

Dustman, E. H., L. F. Stickel, L. J. Blus, W. L. Reichel, and S. N. Wiemeyer
1971 The Occurrence and Significance of Polychlorinated Biphenyls in the Environment. North Am. Wildl. and Nat. Res. Conf. Trans., 36: 118-133.

Edwards, C. C.
1969 Winter Behavior and Population Dynamics of American Eagles in Utah. Ph.D. dissertation, Brigham Young University, Provo, Utah. 156 pp.

Erskine, A. J.
1968 Encounters Between Bald Eagles and Other Birds in Winter. Auk, 85: 681-683.

Frenzel, L. D., G. Juenemann, and J. Kussman
1973 Behavioral Aspects of Eagle Nest Surveys. pp 33-36 in: Bald Eagle Nest Survey Workshop, 15 Aug. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Friedman, H.
1950 Birds of Middle and North America. U.S. National Museum Bull. 50, part XI. pp 483-498.

Gargett, V.
1971 Some Observations on Black Eagles in the Matopos, Rhodesia. Ostrich Sup., 9: 91-124. Original publication not examined.

Genelly, R. E., and R. L. Rudd
1956 Effects of DDT, Toxaphene, and Dieldrin on Pheasant Reproduction. Auk, 73: 529-539.

Gerrard, J.
1973 Eagle Census Experiences in Canada. pp 21-29 in: Notes on a Bald Eagle Nest Survey Workshop, 15 Aug. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Gerrard, P., J. M. Gerrard, D. A. Whitfield, and W. J. Maher
1974 Postfledging Movement of Juvenile Bald Eagles. Blue Jay, 32(4): 218-226.

Grewe, A. H., Jr.
1966 Some Aspects in the Natural History of the Bald Eagle in Minnesota and South Dakota. Ph.D. Dissertation, Univ. of South Dakota. Vermillion. 72 pp.

Grier, J. W.
1969 Bald Eagle Behavior and Productivity Responses to Climbing to Nests. Jour. Wildl. Manage., 33(4): 961-966.

1973 Aerial Eagle Census Techniques as Experienced in Ontario and Manitoba. pp 11-20 in: Notes on a Bald Eagle Nest Survey Workshop, 15 Aug. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

1974 Reproduction, Organochlorines, and Mercury in Northwestern Ontario Bald Eagles. Can. Field-Nat. 88(4): 469-475.

1977 Quadrat Sampling of a Nesting Population of Bald Eagles. Jour. Wildl. Manage., 41(3): 438-443.

1978 Congratulations to an Absentee Father. Natl. Wildl., 10(6): 44.

Grossman, M. L., and J. Hamlet
1964 Birds of Prey of the World. Clarkson N. Potter, Inc., New York.

Grubb, T. G., Jr.
1971 Bald Eagles Stealing Fish From Common Mergansers. Auk, 88(4); 928-929.

1976a A Survey and Analysis of Bald Eagle Nesting in Western Washington. M.S. Thesis, Univ. of Washington, Seattle. 87 pp.

1976b Nesting Bald Eagles Attack Researcher. Auk, 93(4): 842-843.

Grubb, T. G., Jr., and W. M. Shields
1977 Bald Eagle Interferes With an Active Osprey Nest. Auk, 94(1): 140.

Halloran, A. F.
1959 Notes on Wintering Populations of the Bald Eagle on the Witchita Mountains Wildlife Refuge. Proc. Okla. Acad. Sci., 40: 120-121.

Hancock, D.
1964 Bald Eagles Wintering in the Southern Gulf Islands, British Columbia. Wilson Bull., 76(2): 111-120.

1965 West Coast Eagle Survey. Can. Audubon, 27(2): 37-41.

1966 David Hancock Reports on the Bald Eagle Research Project. Can. Audubon, 28(3): 88-92.

1970 Adventure with Eagles. The Wildlife Conservation Centre, Saanihton, British Columbia, Canada. 40 pp.

1973 Captive Propagation of Bald Eagles - a Review. Internat. Zoo Ybk., 18: 244-249.

Hatler, M. F.
1974 Bald Eagle Preys upon Arctic Loon. Auk, 91: 825-827.

Hayward, J. L., Jr., W. H. Gillett, C. J. Amlaner, Jr., and J. F. Stout
1977 Predation on Gulls by Bald Eagles in Washington. Auk, 94(2): 375.

Hehnke, M. F.
1973 Nesting Ecology and Feeding Behavior of Bald Eagles on the Alaska Peninsula. M.S. Thesis, California State Univ., Humboldt. 56 pp.

Hensel, R. J., and W. A. Troyer
1964 Nesting Studies of the Bald Eagle in Alaska. Condor, 66(4): 282-286.

Herrick, F. R.
1924a Nests and Nesting Habits of the American Eagle. Auk, 41(2): 213-231.

1924b The Daily Life of the American Eagle: Late Phase. Auk, 41(3): 389-422.

1924c The Daily Life of the American Eagle: Late Phase (concluded). Auk, 41(4): 517-540.

1932 Daily Life of the American Eagle: Early Phase. Auk, 49(3): 307-323.

1933 Daily life of the American Eagle: Early Phase (concluded). Auk, 50(1): 35-53.

1934 The American Eagle. D. Appleton-Century Company, Inc., New York. 267 pp.

Hickey, J. J., and D. W. Anderson
1968 Chlorinated Hydrocarbons and Eggshell Changes in Raptorial and Fish-Eating Birds. Science, 162(3850): 271-273.

Howell, J. C.
1958 Further History of Some Bald Eagle Nests in Central Florida. Auk, 75: 96-98.

Hoxie, W. J.
1910 Notes on the Bald Eagle in Georgia. Auk, 27(4): 454.

Ingram, T. N.
1965 Wintering Bald Eagle at Cassville, Wisconsin. Iowa Bird Life, 35(3): 66-78

Jacobson, E., J. W. Carpenter, and M. Novilla
1977 Suspected Lead Toxicosis in a Bald Eagle. Jour. of the Am. Vet. Med. Assoc., 171(9): 952-954.

Johnson, D. R., and W. E. Melquist
1973 Unique, Rare, and Endangered Raptorial Birds of Northern Idaho, Nesting Success and Management Recommendations. University of Idaho and USDA/Forest Service, Publication No. R1-73-021. 42 pp.

Juenemann, B. G.
1973 Habitat Evaluation of Selected Bald Eagle Nest Sites in the Chippewa National Forest. M.S. Thesis, Univ. of Minnesota, Minneapolis. Original publication not examined.

Juenemann, B. G., and L. D. Frenzel
1972 Habitat Evaluations of Selected Bald Eagle Nest Sites in the Chippewa National Forest. Unpublished. Presented at the 34th Annual Fish and Wildlife Conference, Dec. 10-13, 1972. Original publication not examined.

Kalmbach, E. R., R. H. Imler, and L. W. Arnold
1964 The American Eagles and Their Economic Status. U.S. Dept of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Washington, D. C. 86 pp.

Kichura, T., and B. Ruediger
1978 1978 Osprey/Eagle Nesting Inventory. U.S. Forest Service, Kootenai National Forest. 7 pp.

King, J. G., F. C. Robards, and C. J. Lensink
1972 Census of the Bald Eagle Breeding Population in Southeast Alaska. Jour. Wildl. Manage., 36(4): 1292-1296.

Krantz, W. C., B. M. Mulhern, G. E. Bagley, A. Sprunt, IV, F. J. Ligas, and W. B. Robertson, Jr.
1970 Organochlorine and Heavy Metal Residues in Bald Eagle Eggs. Pestic. Monit. Jour., 3(3): 136-140.

Kussman, J. V.
1976 Post-Fledging Behavior of the Northern Bald Eagle, Haliaeetus Leucocephalus Alascanus Townsend, in the Chippewa National Forest, Minnesota. Ph.D. Dissertation, Univ. of Minnesota. 455 pp. Original publication not examined.

Laycock, G.
1973 Autumn of the Eagle. Chas. Scribner Publ., New York. 239 pp.

Lien, J.
1975 Aggression Between Great Black-Backed Gulls and Bald Eagles. Auk, 92(3): 584-585.

Ligas, F. J.
1968 Studies on Wintering Bald Eagles in the Mississippi and Missouri River Valleys, 1963-1967. National Audubon Society. 30 pp.

Lint, J. B.
1975 The Bald Eagles of Wolf Lodge Bay. USDI Bureau of Land Management, Coeur d'Alene, Idaho. 13 pp.

Lish, J. W., and J. C. Lewis
1975 Status and Ecology of Bald Eagles Wintering in Oklahoma. Proc. Southeastern Assoc. Game and Fish Commissioners, St. Louis, Missouri. Original publication not examined.

Locke, L. N., N. J. Chura, and P. A. Stewart
1966 Spermatogenesis in Bald Eagles Experimentally Fed a Diet Containing DDT. Condor, 68(5): 497-502.

Locke, L. N., J. A. Newman, and B. M. Mulhern
1972 Avian Cholera in a Bald Eagle from Ohio. Ohio Jour. of Science, 72(5): 294-296.

Lockie, J. D., and D. A. Ratcliffe
1964 Insecticides and Scottish Golden Eagles. Br. Birds, 57(3): 88-102

Maestrelli, J. R., and S. N. Wiemeyer
1975 Breeding Bald Eagles. Wilson Bull., 87: 45-53.

Marshall, D. B., and P. R. Nickerson
1976 The Bald Eagle: 1776-1976. Natl. Parks Cons. Mag., 50(7): 14-19.

Mathisen, J. E.
1968 Effects of Human Disturbance on Nesting of Bald Eagles. Jour. of Wildl. Manage., 32(1): 1-6.

Mathisen, J. E., and T. C. Dunstan
1975 A Strategy for Bald Eagle Management. Unpubl. Manuscript Presented at Raptor Research Foundation Fall Meeting, Boise, Idaho. Original publication not examined.

McClelland, B. R.
1973 Autumn Concentrations of Bald Eagles in Glacier National Park. Condor, 76(1): 121-123.

McClelland, B. R., and D. S. Shea
1978 Local and Long-Range Movements of Bald Eagles Associated With Autumn Concentrations in Glacier National Park. Progress Report for 1977 and Proposed Work for 1978.

Mulhern, B. M., W. L. Reichel, L. N. Locke, T. G. Lamont, A. Belisle, E. Cromartie, G. E. Bagley, and R. M. Prouty
1970. Organochlorine Residues and Autopsy Data From Bald Eagles, 1966-1968. Pestic. Monit. Jour., 4(3): 141-144.

Munro, J. A.
1938 The Northern Bald Eagle in British Columbia. Wilson Bull., 50(1): 28-35.

Murie, O. J.
1940 Food Habits of the Northern Bald Eagle in the Aleutian Islands, Alaska. Condor, 42(4): 198-202.

1959 Fauna of the Aleutian Islands and the Alaska Peninsula. U.S. Fish & Wildl. Serv., N. Am. Fauna, No. 61.

Murphy, J. R.
1965 Nest Site Selection by the Bald Eagle in Yellowstone National Park. Utah Acad. of Sci., Arts and Lett. Proc., 42(2): 261-264.

Musselman, T. E.
1949 Concentrations of Bald Eagles on the Mississippi River at Hamilton, Illinois. Auk, 66: 83.

Nature Conservancy
1976 Skagit Eagles: A Management Program for the Skagit River Bald Eagle Natural Area. The Nature Conservancy, Portland, Oregon. 52 pp.

Newmann, J. R., W. H. Brennan, and L. M. Smith
1977 Twelve-Year Changes in Nesting Patterns of Bald Eagles on San Juan Island, Washington. Murrelet, 58: 37-39.

Nickerson, P. R.
1973 Eagle Nest Survey Objectives and Progress. pp 1-3 <u>in</u>: Notes on a Bald Eagle Nest Survey Workshop, 15 Aug. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

1974 The Bald Eagle Nesting Survey 5, 1973 and 1974. U.S. Fish and Wildl. Serv., Div. of Techn. Assistance. Unpubl. title quoted from Grubb, 1976a.

Offelt, C. H.
1975 Food Habits of Nesting Bald Eagles in Southeast Alaska. Condor, 77(3): 337-338.

1976 Unusual Feeding Behavior of Bald Eagles in British Columbia. Murrelet, 57(3): 70.

Platt, J. B.
1976 Bald Eagles Wintering in a Utah Desert. Am. Birds, 30(4): 783-788.

Postupalsky, S.
1967 Reproductive Success and Population Trends in the Bald Eagle in Michigan. M.S. Thesis, Univ. of Michigan Biological Station, Ann Arbor. Original publication not examined.

1976 Banded Northern Bald Eagles in Florida and Other Southern States. Auk, 93: 835-836.

1978a The Bald Eagles Return. Nat. Hist., 87(7): 62-63.

1978b Artificial Nesting Platforms for Ospreys and Bald Eagles. pp. 35-45 in: Endangered Birds: Management Techniques for Preserving Threatened Species, S. A. Temple, ed. Univ. of Wisconsin Press, Madison.

Prouty, R. M., W. L. Reichel, L. N. Locke, A. A. Belisle, E. C. Cromartie, T. E. Kaiser, T. G. Lamont, B. M. Mulhern, and D. M. Swineford
1977 Residues of Organochlorine Pesticides and Polychlorinated Biphenyls and Autopsy Data for Bald Eagles, 1973-74. Pest. Monit. Jour., 11(3): 134-137.

Radtke, R.
1973 Eagle Management Guidelines on National Forests. pp 37-42 in: Notes on a Bald Eagle Nest Survey Workshop, 15 Aug. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Reichel, W. L., E. Cromartie, T. G. Lamont, B. M. Mulhern, and R. M. Prouty
1969 Pesticide Residues in Eagles. Pestic. Monit. Jour., 3(3): 142-144.

Retfalvi, L. I.
1965 Breeding Behavior and Feeding Habits of the Bald Eagle on San Juan Island, Washington. M.F. Thesis, Univ. of British Columbia, Vancouver. 193 pp. Original publication not examined.

1970 Food of Nesting Bald Eagles on San Juan Island, Washington. Condor, 72(3): 358-361.

Robards, F. C.
1967 Capture, Handling, and Banding of Bald Eagles. Bur. Sport Fish and Wildl., Juneau, Alaska. 25 pp.

Robards, F. C., and J. I. Hodges
Undated Observations from 2,760 Bald Eagle Nests in Southeast Alaska: Progress Report 1969-1976. USDI Fish and Wildlife Service, Alaska Area. 27 pp

Robards, F. C., and J. G. King
1966 Nesting and Productivity of Bald Eagles, Southeast Alaska, 1966. USDI Fish and Wildlife Service, Juneau, Alaska. 28 pp. Original publication not examined.

Robbins, C. S.
1960 Status of the Bald Eagle Summer of 1959. Wildlife Leaflet 418. U.S. Fish and Wildlife Service, Washington, D.C. 8 pp.

Rosen, M. N.
1972 The 1970-71 Avian Cholera Eporitics Impact on Certain Species. Jour. Wildl. Diseases, 8(1): 75-78.

Servheen, C. W.
1975 Ecology of the Wintering Bald Eagles on the Skagit River, Washington. M.S. Thesis, Univ. of Washington, Seattle. 83 pp.

1976 Bald Eagles Soaring into Opaque Cloud. Auk, 93(2): 387.

Shea, D. S.
1973 A Management-Oriented Study of Bald Eagle Concentrations in Glacier National Park. M.S. Thesis, Univ. of Montana. 78 pp.

Sherrod, S. K., C. M. White, and F. S. L. Williamson
1976 Biology of the Bald Eagle on Amchitka Island, Alaska. Living Bird, 15: 143-182.

Siderits, K.
1974 Immature Eagle Movement. Loon, 46(4): 170.

Snow, C.
1973 Habitat Management Series for Endangered Species. Report No. 5: Southern and Northern Bald Eagle. Bureau of Land Management. 58 pp.

Southern, J. M.
1974 Ecology of Eagles Wintering in Missouri with Emphasis on Waterfowl Relationships. Miss. Coop. Wildl. Res. Unit. Progress Rep. 6pp. Original publication not examined.

Southern, W. E.
1963 Winter Populations, Behavior and Seasonal Dispersal of Bald Eagles in Northwestern Illinois. Wilson Bull., 75(1): 42-55.

1964 Additional Observations on Winter Bald Eagle Populations: Including Remarks on Biotelemetry Techniques and Immature Plumages. Wilson Bull., 76(2): 121-137.

1967 Further Comments on Subadult Bald Eagle Plumages. Jackpine Warbler, 45(3): 70-80.

Spencer, D. A.
1976 Wintering Bald Eagle. National Agricultural Chemicals Association, Washington, D.C. 170 pp.

1977 Habitats for Symbols. Water Spectrum, 10(1): 1-8.

Sprunt, A., IV
1961 An Eagle-Eyed Look at our Bald Eagle. Audubon Mag., 63(6): 324-327.

1963 Bald Eagles Aren't Producing Enough Young. Audubon Mag., 65(1): 32-35.

1969 Population Trends of the Bald Eagle in North America. pp. 347-351 <u>in</u>: Peregrine Falcon Populations: Their Biology and Decline, J. J. Hickey, ed. Univ. of Wisconsin Press, Madison.

Sprunt, A., IV, and R. L. Cunningham
1961 Continental Bald Eagle Project Report 1. Natl. Audubon Soc., Tavernier, Florida. 7 pp. mimeogr. Original publication not examined.

1962 Continental Bald Eagle Project, Progress Report No. 2. Natl. Audubon Soc. 58th Annual Conv., 10-14 Nov. 1962, Corpus Christi, Texas. 11 pp. Original manuscript not examined.

Sprunt, A., IV, and F. J. Ligas
1964 Excerpts From Convention Addresses on the 1963 Bald Eagle Count. Audubon Mag., 66: 45-47.

1966 Audubon Bald Eagle Studies, 1960-1966. Natl. Audubon Soc., New York. 6 pp. Original manuscript not examined.

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. Trans, N. Am. Wildl. and Nat. Res. Conf., 38: 96-106.

Stalmaster, M. V.
1976 Winter Ecology and Effects of Human Disturbance on Bald Eagles in the Nooksack River Valley, Washington. M.S. Thesis, Western Wash. State College, Bellingham. 100 pp.

Steenhof, K.
1976 The Ecology of Wintering Bald Eagles in Southeastern South Dakota. M.S. Thesis, University of Missouri. 147 pp.

Stickel, L. F., N. J. Chura, P. A. Stewart, C. M. Menzie, R. M. Prouty, and W. L. Reichel.
1966 Bald Eagle Pesticide Relations. Trans. N. Am. Wildl. and Nat. Res. Conf., 31: pp 190-200.

Swisher, J. F.
1964 A Roosting Area of the Bald Eagle in Northern Utah. Wilson Bull., 76(2): 186-187.

Trenholme, N. S., and R. W. Campbell
1975 Survey of Bald Eagle Populations in the Southern Gulf Islands, British Columbia. Syesis, 8: 109-111.

Troyer, W. A. and R. J. Hensel
1965 Nesting and Productivity of Bald Eagles on the Kodiak National Wildlife Refuge, Alaska. Auk, 82: 636-638.

U.S. Congress
1971 House Committee on Merchant Marine and Fisheries, Hearing on Hawks, Owls, and Eagles Before a Subcommittee on Fisheries and Wildlife Conservation, House of Representatives, Serial 92-14, 92d Congress, 1st session, 363 pp.

1973 Endangered Species Act of 1973. Public Law 93-205; 87 Stat. 884. Laws of the 93d Congress, 1st session: pp 979-1002.

U.S. Dept. of Interior
1974 United States Estimated to Have 1,000 Nesting Pairs of Bald Eagles in the Lower 48 States. Fish & Wildl. Serv. news release, 27 February.

1978 Determination of Certain Bald Eagle Populations as Endangered or Threatened. Federal Register, 43(31): 6230-6233.

Ward, P.
1965 Feeding Ecology of the Black-Faced Dioch (Quela quela) in Nigeria. Ibis, 107(2): 173-214.

Ward, P., and A. Zahvi
1973 The Importance of Certain Assemblages of Birds as Information Centres for Food-Finding. Ibis, 115(4): 517-534.

White, C. M.
1974 Current Problems and Techniques in Raptor Management and Conservation. Trans. Thirty-Ninth North Am. Wild. and Nat. Res. Conf., 301-312.

Whitfield, D. W. A., J. M. Gerrard, W. L. Maher, and D. W. Davis
1974 Bald Eagle Nesting Habitat, Density, and Reproduction in Central Saskatchewan and Manitoba. Can. Field-Nat., 88(4): 399-407.

Wiemeyer, S. N., B. M. Mulhern, F. J. Ligas, R. J. Hensel, J. E. Mathisen, F. C. Robards, and S. Postupalsky
1972 Residues of Organochlorine Pesticides, Polychlorinated Biphenyls and Mercury in Bald Eagle Eggs, and Changes in Shell Thickness. Pest. Monit. Jour., 6: 50-55.

Wolff, A.
1977 Birds in the Hand. 1977. Sat. Rev., 4: 55.

Wrakestraw, G. F.
1973 Bald and Golden Eagle Survey. Am. Birds, 27(4): 716.

Wright, B. S.
1953 The Relation of Bald Eagles to Breeding Ducks in New Brunswick. Jour. of Wild. Manage., 17(1): 55-62.

END
DTIC
9-86