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COMPARISON OF BALD EAGLE (*HALIAEETUS LEUCOCEPHALUS*) NESTING AND PRODUCTIVITY AT KODIAK NATIONAL WILDLIFE REFUGE, ALASKA, 1963–2002

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ABSTRACT.—In 1963, 158 (48%) of 326 Bald Eagle *(Haliaeetus leucocephalus)* nests surveyed on Kodiak National Wildlife Refuge (KNWR) were occupied. Nesting success was 66%. Production rates of young per occupied nest and young per successful nest were 1.10 and 1.66, respectively. In 2002, 538 (55%) of 979 Bald Eagle nests were occupied. Nesting success was 52% and production of young per occupied nest was 0.87; however, production of young per successful nest remained at 1.66. Since 1963, the number of Bald Eagle nests on KNWR increased 241% and the total production of young increased 425%. The factors that have influenced this increase are not known. Despite decreased nest success and lower productivity per occupied nest, the KNWR nesting Bald Eagle population continues to increase.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *Kodiak Island*; *nesting*; *productivity.*

COMPARACIÓN DE LA NIDIFICACIÓN Y PRODUCTIVIDAD DE *HALIAEETUS LEUCOCEPHALUS* EN EL REFUGIO DE VIDA SILVESTRE KODIAK, ALASKA, 1963–2002.

RESUMEN.—En 1963, 158 (48%) de 326 nidos del águila *Haliaeetus leucocephalus* muestreados en el Refugio de Vida Silvestre Kodiak (RVSK) estuvieron ocupados. El éxito de nidificación fue del 66%. Las tasas de producción de juveniles por nido ocupado y el número de juveniles por nido exitoso fueron de 1.10 y 1.66, respectivamente. En el año 2002, 538 (55%) de 979 nidos de *H. leucocephalus* fueron ocupados. El éxito de nidificación fue del 52% y la producción de juveniles por nido exitoso permaneció en 1.66. Desde 1963, el número de nidos de estas águilas aumentó en un 241% en el RVSK y la producción total de juveniles aumentó en un 425%. Los factores que han influenciado este aumento no son conocidos. A pesar de la disminución del éxito de nidificación y la menor productividad por nido ocupado, la población de *H. leucocephalus* en el RVSK continúa aumentando.

[Traducción del equipo editorial]

Bald Eagles (*Haliaeetus leucocephalus*) nest along the Alaskan coastline from the dense old-growth forests of southeastern Alaska, to the treeless Aleutian Islands, and north to the Bering Sea (Bent 1961, Robards and Taylor 1973, Buehler 2000). Early studies of nesting biology of Bald Eagles in Alaska were described by Dixon (1909), Murie (1940) and Imler (1941). Reports of diminished numbers of Bald Eagles across their range in the 1950s prompted initiation of Bald Eagle nesting surveys in many states (Sprunt and Cunningham 1961). The Kodiak National Wildlife Refuge (KNWR, Fig. 1) has had one of the longest ongoing and earliest published Bald Eagle monitoring programs in Alaska. This program began in the 1950s with boat surveys along the shores of Karluk Lake (Chrest 1964, Hensel and Troyer 1964). An aerial survey of all KNWR lands was first completed in 1963 (Troyer and Hensel 1965), and Sprunt et al. (1973) used these data to evaluate relative productivity of Bald Eagle populations in North America. No KNWR Bald Eagle breeding data have been published since 1965. This account updates the nesting and productivity status of the KNWR Bald Eagle population through the 2002 breeding season.

STUDY AREA

Located in the northwestern Gulf of Alaska, the Kodiak Archipelago is separated from the Alaska mainland by Shelikof Strait. KNWR occupies approximately 757 000 ha on Kodiak and Afognak Islands (Fig. 1) and includes over 2000 km of coastline. The archipelago is influenced by a maritime climate with an annual mean temperature of about 4°C.

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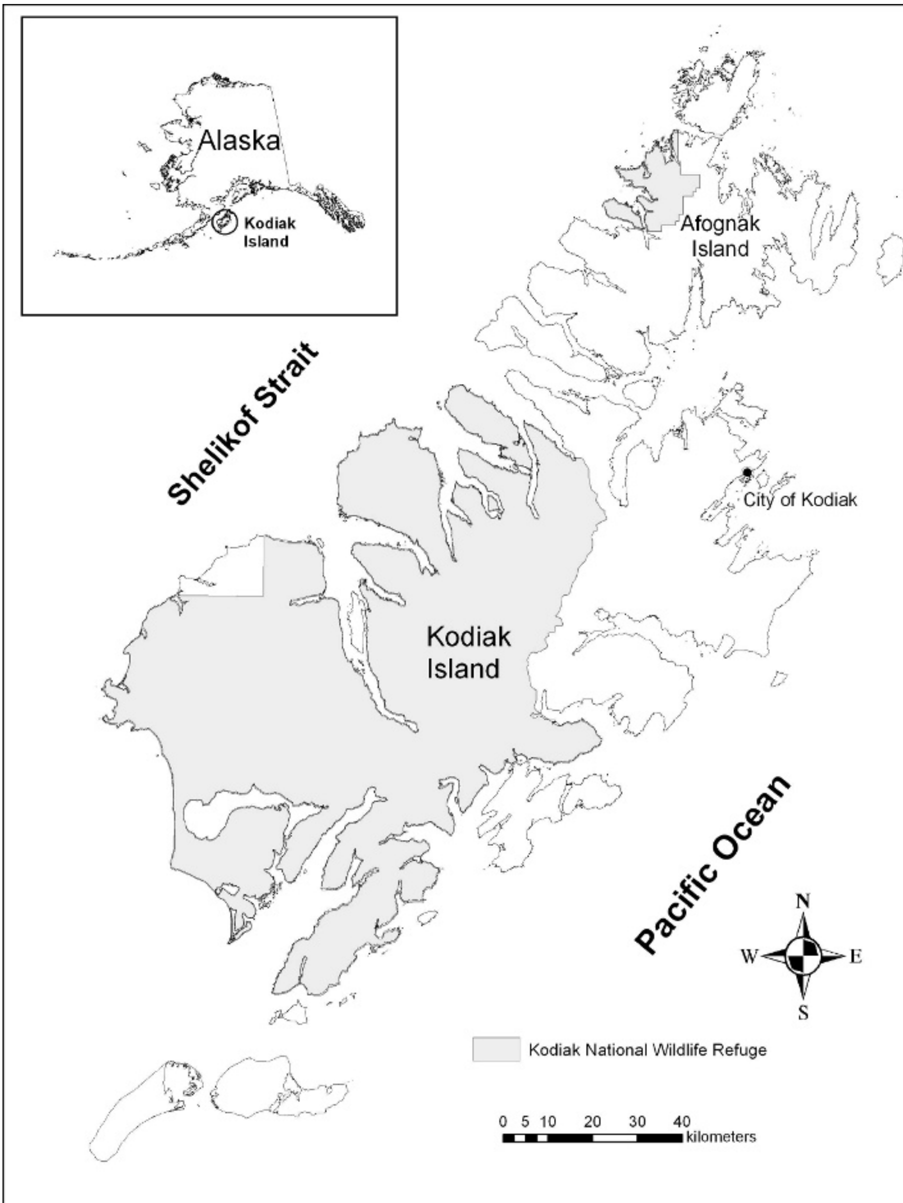

Figure 1. Location and boundaries of the Kodiak National Wildlife Refuge, Kodiak Archipelago, Alaska, with locations mentioned in the text.

Total annual precipitation varies from >250 cm along the eastern coast of the archipelago to <60 cm over the western areas adjacent to Shelikof Strait. Mountains, several over 1220 m with permanent glaciers, traverse more than half the length of Kodiak Island. Vegetation ranges from Sitka spruce (*Picea sitchensis*) forest on the northern end of the archipelago to treeless tundra on the southern end of the archipelago (Karlstrom and Ball 1969, USFWS 1987, Barnes and Smith 1998).

METHODS

Bald Eagle habitats were surveyed aerially using a Piper PA-18 Supercub (1963–97) or an Aviat Husky (2002) fixed wing aircraft during seven breeding seasons from 1963 to 2002. The aircraft was flown ca. 60 m above ground level with the passenger as the primary observer and the pilot as a secondary observer. Survey coverage remained constant through the years with all known and potential coastal, lacustrine, and riparian Bald Eagle nesting habitat within KNWR searched for nests. Two surveys were conducted during each survey year. The first survey, for occupation, was conducted in early May. Nest sites were classified as occupied using one or more of the following criteria: (1) presence of an adult in an incubating position; (2) eggs or young in the nest with an adult standing in the nest; (3) fresh nesting materials present; (4) two adults defending the nest, or (5) one or two adults standing in the nest but no eggs or young visible. Unoccupied nests contained no evidence of bird use, no indication of added nest material, and no recent construction activity (Stalmaster 1987, Bowman 1990). By early May, the majority of nesting pairs on Kodiak have completed their clutches. A second survey, for productivity, was conducted in late July or August to determine the status of occupied nests and count number of young present (Bowman 1990). The determination of nest success was based on the observation of young in or adjacent to an occupied nest during production surveys. Typical age of young observed at this time ranged from 6 to 11 wk old.

Six nest substrate classifications were used in all survey years, except in 1972 when only tree or ground substrate classifications were used. Tree nest substrate classes were cottonwood (*Populus trichocarpa*), Sitka spruce, black birch (*Betula kenaica*), and willow (*Salix* sp.). Ground nest classes included rock pinnacles, rocky cliffs, and alder (*Alnus sinuata*) cliff nests. Classification of alder cliff nests may have varied between 1963 and later years. Field observers were different in 1963 and 1972, although the author served as the observer for all other surveys.

Productivity surveys from 1963–1982 were not representative of the total nest population as only selected high-quality habitats were sampled. Only 51, 15, and 8% of all nests occupied during the occupancy surveys were revisited during the productivity surveys in 1963, 1972, and 1982, respectively. Production surveys after 1982 attempted to revisit all occupied nests but weather and time constraints resulted in 75–99% of all occupied nests sampled. Nest and production surveys covering all KNWR lands have been conducted at 5-yr intervals since 1982 and are scheduled to continue under the refuge's Long Term Inventory and Monitoring Program. All observations were recorded on U.S. Geological Survey 1:63 360 scale topographic maps. Plotted nest locations were then transferred to a Geographical Information System database for mapping and archiving.

RESULTS

The number of occupied nests located during surveys increased 241% since 1963 (Fig. 2). In the first year of the survey (1963), 158 (48%) of 326 Bald Eagle nests located on KNWR were occupied (Troyer and Hensel 1965). During 2002, 538 (55%) of 979 nests located in the same KNWR survey area were occupied (Table 1). Of the 538 occupied nests in 2002, 526 (98%) were revisited for production and 275 (52%) of these produced a total of 457 young (Table 2). During 2002, 0.87 young were produced per occupied nest and 1.66 young were produced per successful nest.

The composition of nest substrates was similar between 1963 and 2002, with two-thirds of the occupied nests in trees and one-third of the occupied nests on the ground (Table 1). Substrates of occupied and successful nests varied slightly among years although the number of tree species utilized by nesting Bald Eagles increased as the number of nests increased (Fig. 3, 4). Cottonwoods represented 100% of occupied and successful tree nests in 1963. Sitka spruce, black birch, and willow comprised 1–5% of occupied and successful tree nests in subsequent survey years (Fig. 3, 4). Of the occupied ground nests, rocky cliffs, including rock pinnacles and other treeless nests encompassed 67–99%, while alder cliff nests comprised the remaining 1–33% (Fig. 3). Nests on rocky cliffs were 88–98% successful and alder cliff nests were 2–12% successful. The highest rates of nest failure for all substrate classes were seen in 1997 and 2002 (Table 2).

DISCUSSION

Over 128 000 Bald Eagles were killed for bounty in Alaska between 1917 and 1952 (Bounty Acts of 1917 and 1949), although it is unknown how many of these were taken on Kodiak (Robards and King 1966). Hansen and Hodges (1985) indicated the southeast Alaska Bald Eagle population had likely rebounded from the reduced population the bounty had created. While this increase may have set the stage for future Bald Eagle population growth on Kodiak, other factors also played a role.

A number of studies have indicated Bald Eagle reproduction and productivity is controlled by prey composition and abundance during early spring (Hansen et al. 1984, Hansen and Hodges 1985, Gende and Wilson 1997, Hansen 1987, Elliott et al. 1998, Anthony 2001). It is unknown whether changes in the timing, quantity, or types of prey available to Kodiak nesting Bald Eagles (Grubb and Hensel 1978) account for the observed variation in productivity. While the factors limiting population growth in KNWR were unknown, the Bald Eagle population in southeast Alaska increased 92% between 1967 and 1992 and stabilized thereafter (Jacobson and Hodges 1999). Also, the past changes and current density of Bald Eagles nesting on KNWR (Fig. 2) suggest that the habitat may be close to saturated. Higher nesting densities would ulti-

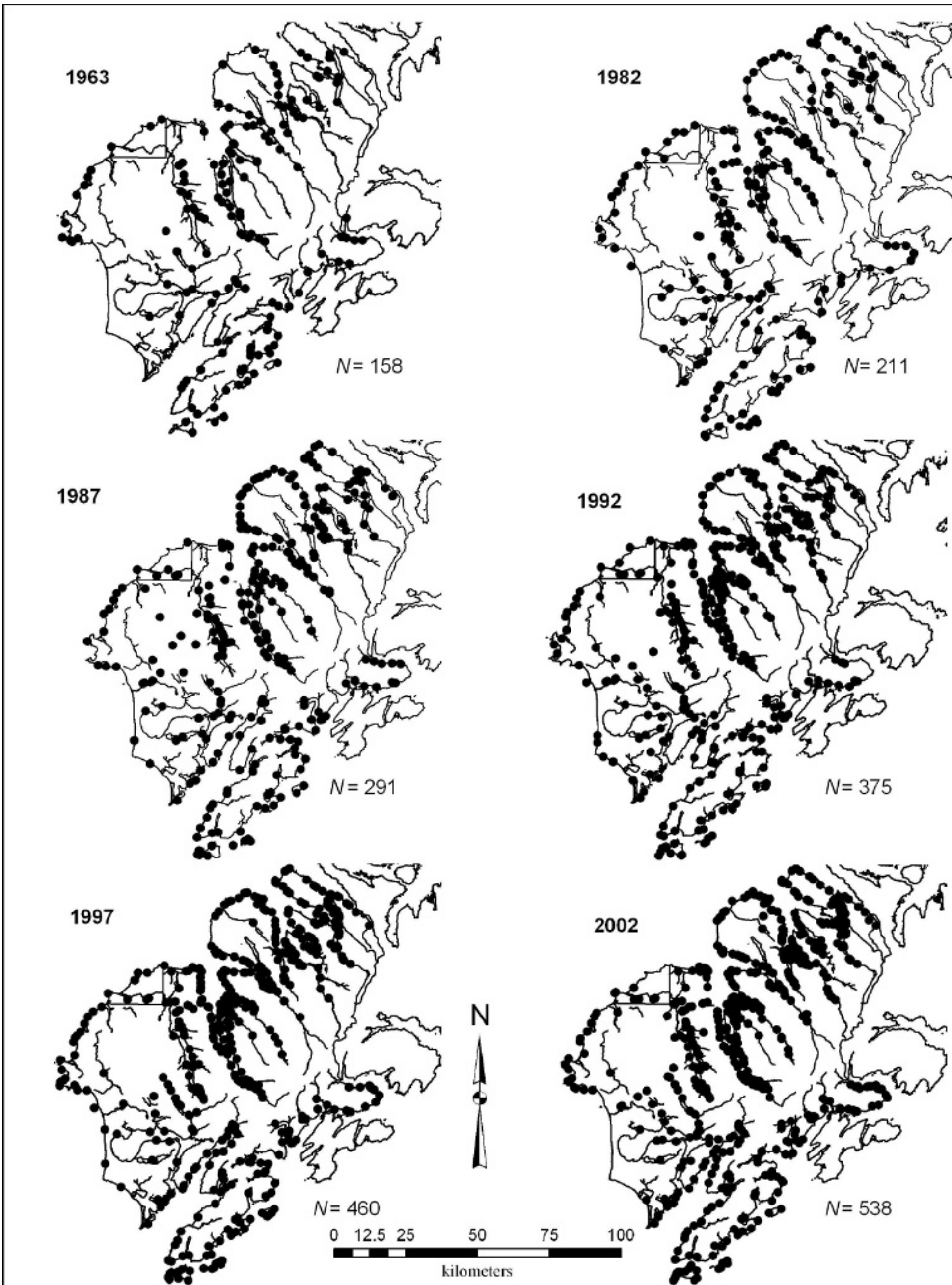

Figure 2. Number (*N*) and distribution of occupied Bald Eagle nests (•) on the Kodiak National Wildlife Refuge in 1963, 1982, 1987, 1992, 1997, and 2002.

Table 1. Comparison of the percentage of different substrates, occupied and unoccupied Bald Eagle nests on Kodiak National Wildlife Refuge, 1963 and 2002.

Year	Nest Type	Occupied (%)	Unoccupied (%)	Total Nests (%)
1963[a]	Tree	106 (67)	158 (94)	264 (81)
	Ground	52 (33)	10 (6)	62 (19)
	Total	158 (48)	168 (51)	326
2002	Tree	367 (68)	253 (74)	620 (63)
	Ground	171 (32)	188 (26)	359 (37)
	Total	538 (55)	341 (45)	979

[a] Data from Troyer and Hensel 1965.

mately increase competition for available food resources (Anthony 2001) and result in lower productivity, as seen in classic models of density dependent compensation (Sinclair and Krebs 2002).

Kodiak's 52% nest success rate is only 2% greater than the 50% needed to maintain a stable Bald Eagle nesting population (Sprunt et al. 1973). The 2002 nest production rate, however, is approximately 24% higher than the estimated maintenance value of 0.7 young per occupied nest (Sprunt et al. 1973). While production per occupied nest and nest success were lower in 2002 than in 1963, the number of young per successful nest (1.66) was the same for both 1963 and 2002 (Table 2). As higher-quality habitats are filled, newly nesting eagles are likely forced into nesting in poorer-quality habitats with higher frequencies of nest failure, thereby lowering overall nesting success. The 1.10 young per occupied nest recorded in 1963 may be inflated, because the proportion of nests checked for production were located in high-density nesting areas and probably biased toward higher-quality habitats.

The increase in KNWR's nesting population of Bald Eagles corresponds with similar patterns of growth in other Alaskan Bald Eagle populations, such as Prince William Sound (Bowman et al. 1997), southeastern Alaska (Jacobson and Hodges 1999), and interior Alaska (Ritchie and Ambrose 1996). Factors contributing to increasing Bald Eagle populations on Kodiak Island, Prince William Sound, and southeastern Alaska were unknown (Bowman et al. 1997). However, Swenson (1983) surmised that the growth of interior North American Bald Eagle population was promoted by warmer climatic conditions supporting increased food availability that may have influenced overall survival.

Table 2. Number of nests located during surveys, number of occupied nests (% of total), number of occupied nests checked for production, number of successful nests (% successful), young per occupied nest, and young per successful nest found on the Kodiak National Wildlife Refuge in 1963–2002.

Year	Nests Located During Surveys	Occupied Nests (%)	Occupied Nests Checked for Production	Successful Nests (%)	Young per Occupied Nest	Young per Successful Nest
1963[a]	326	158 (48)	80	53 (66)	1.10	1.66
1972[b]	300	159 (53)	24	16 (67)	1.00	1.50
1982	323	211 (65)	17	15 (88)	1.50	1.73
1987	501	291 (58)	198	122 (62)	0.90	1.49
1992	645	375 (58)	321	220 (69)	0.90	1.58
1997	771	460 (60)	448	229 (51)	0.80	1.52
2002	979	538 (55)	526	275 (52)	0.87	1.66

[a] Data from Troyer and Hensel 1965.
[b] Data from G. Atwell (pers. comm.).

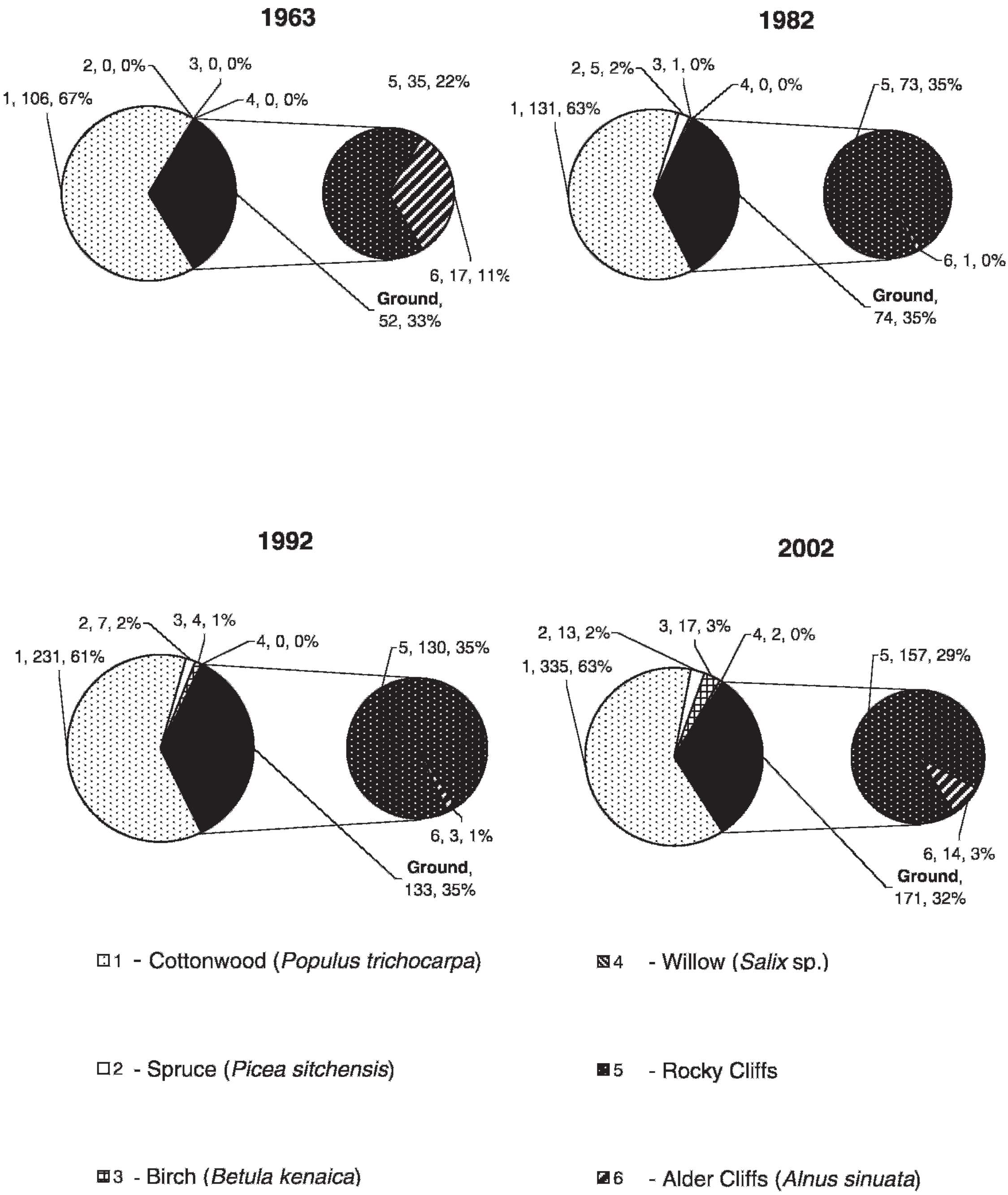

Figure 3. The category number, number, and percent of occupied Bald Eagle nests located in six habitat substrates on the Kodiak National Wildlife Refuge during 1963, 1982, 1992, and 2002. Data from 1963 taken from Troyer and Hensel 1965.

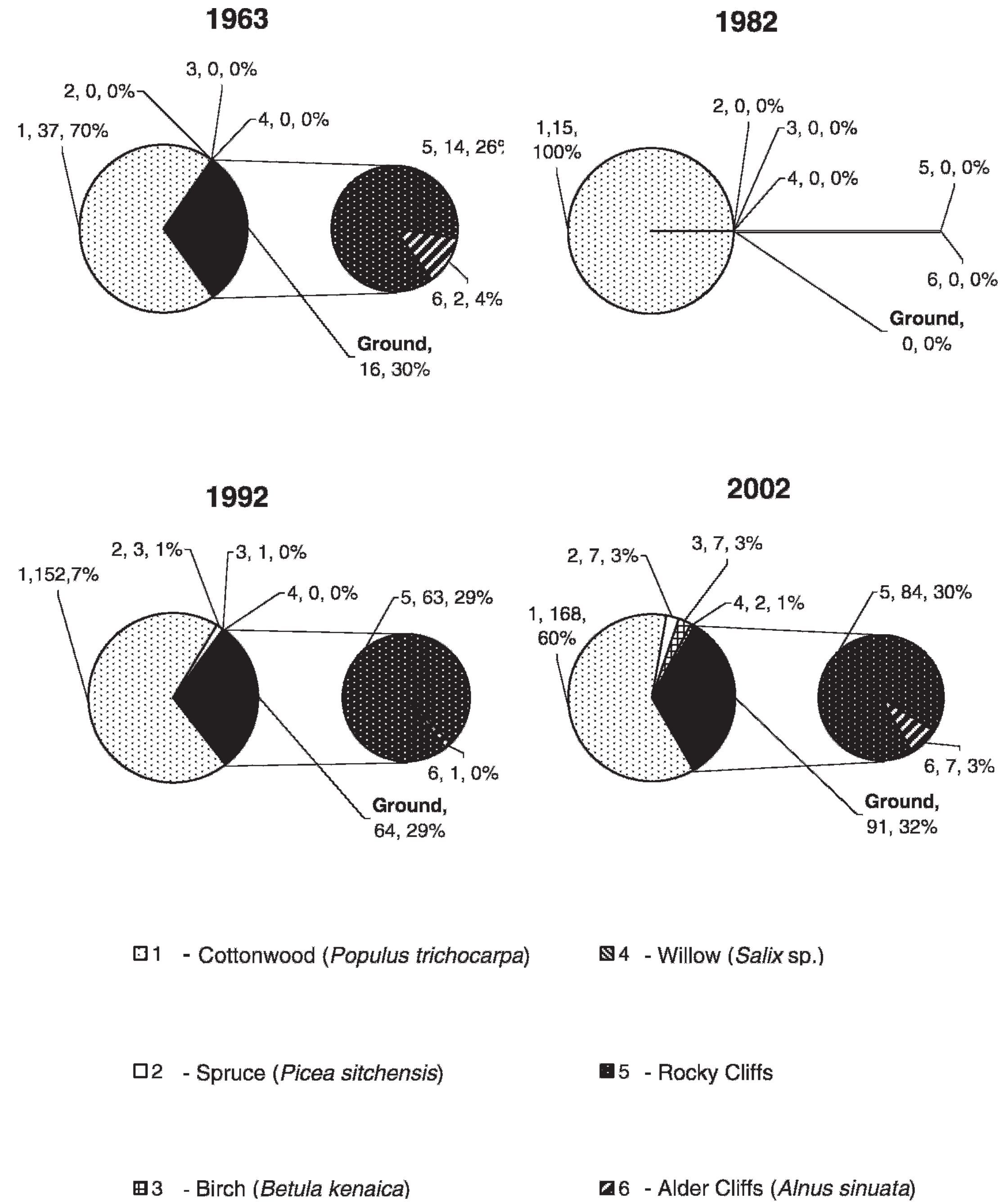

Figure 4. The category number, number, and percent of successful Bald Eagle nests located in six habitat substrates on the Kodiak National Wildlife Refuge during 1963, 1982, 1992, and 2002. The only nest substrate checked for productivity in 1982 was a limited number (8%) of occupied cottonwood tree nests. Data from 1963 taken from Troyer and Hensel 1965.

Ritchie and Ambrose (1996) also suggested warmer climatic conditions played a role in the continued growth of interior Alaska Bald Eagle nesting populations. A significant environmental shift in the early 1980s caused by above-average seawater temperatures may have extensively changed the marine forage fish communities and associated food chains in the northern Gulf of Alaska (Anderson and Piatt 1999).

KNWR has incurred substantial growth and range expansion of an introduced black-tailed deer (*Odocoileus hemionus sitkensis*) herd (L. Van Daele pers. comm.). Deer and other ungulate carrion have been reported as an important food source for wintering Bald Eagles and can increase population survival rates (Harmata et al. 1999, Lang et al. 1999, Grubb and Lopez 2000, Stocek 2000). Indeed, Kodiak Bald Eagles regularly scavenge remains of hunter-killed deer as well as carcasses from natural mortality (D. Zwiefelhofer pers. obs.). While either of these events may have influenced survival of Kodiak Bald Eagles to some degree, no direct evidence exists to test this hypothesis.

The number of Bald Eagle nests located on KNWR increased 240% since 1963 resulting in a 425% increase in the total production of young. As the interest in development of coastal facilities and recreational activities continues to increase, monitoring and mapping of Kodiak Bald Eagle nests is crucial for protecting habitat. Delineating and describing the characteristics of habitats surrounding Kodiak Bald Eagle nests also may aid in understanding the mechanisms responsible for the population's growth and continued productivity. Bowman et al. (1997) pointed out the importance of monitoring to assess population trend and provide baseline data in Bald Eagle populations at risk to human activities. The *Exxon Valdez* oil spill illustrated how oil tanker traffic accidents in the surrounding waters can impact Bald Eagles and associated prey species in the Kodiak Archipelago (Bowman et al. 1993, Ford et al. 1996, Piatt et al. 1990, Peterson et al. 2004). In summary, I suggest that the KNWR's Bald Eagle nesting population will likely stabilize in the future. As of 2002, the Bald Eagle nesting population on KNWR was apparently still increasing.

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