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INDIRECT ESTIMATES OF ABUNDANCE OF BIRDS

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ABSTRACT.—Relative density can answer many questions regarding bird populations, precluding the necessity of taking the additional time and expense to determine absolute density. Indirect indices of relative density include auditory signals, feeding and dusting sites, and track, roost, fecal, and nest counts. Their use assumes these indicators are related to the population size.

Population censusing is a methodological problem in ecology, particularly for inconspicuous, mobile animals which are distributed over a large area (Marten 1972). Knowledge of the number in a population is a prerequisite for effective wildlife resource management (Andrewartha 1971). All management techniques require information about the total or relative number so the effects of the management effort can be assessed. This information is essential to establish the relationship of a population to its habitat and to determine the changes in the population level over time (Talbot 1970).

Two abundance estimates include numbers per unit area (absolute density) and population densities relative to one another (relative density). Some studies such as sustained-yield harvesting, and those relating density to behavior, reproduction, survival, emigration, and immigration require estimates of absolute density, while studies concerning habitat use, rate of increase, dispersal, and population reaction to manipulation can be considered using relative density (Caughley 1977). The estimate selected depends on study purpose, species, season, and habitat.

ABSOLUTE DENSITY

Counting birds yields an accurate measure of absolute density if area size is known. Disadvantages of using absolute density include (1) high cost, (2) disturbance to the population, (3) difficulty in counting secretive or nocturnal species, and (4) high time requirements in counting birds with large home ranges (Scattergood 1954). In populations too large to count, a sample of the entire population is taken. Sampling is less costly and disturbing, but representative samples are sometimes difficult to obtain.

RELATIVE DENSITY

Relative density is an index to population size and is used when the actual size of a population is not needed. Indices are derived based on the assumption that the sample represents a constant but unknown proportion of the population. When appropriate conversion factors are used, such indices can be converted to absolute density. This relationship can be variable, however, and estimates of that variability difficult to determine.

There are two types of indices: direct and indirect. Direct indices are derived from counts of birds in a sampling scheme. A direct population estimate is not obtained. Examples include migrating birds seen flying between observer and the moon per hour and birds seen per kilometer of transect walked. Accuracy depends on standard census conditions (e.g., weather, time) and the observer's skill.

Counts of variables associated with animal presence produce indirect indices. Examples include tracks, calls, and fecal counts. Advantages are: (1) less skilled observers are required, (2) it is easier to develop standard techniques, (3) results are affected less by viewing conditions, (4) less disturbance is created, and (5) effectiveness in studying secretive species is increased (Caughley 1977). There is a time lag between creation of the sign and its observation. Signs, then, provide indices to density over time and are not indices of current density (Caughley 1977). As a result, there may be a less direct relationship to density than in the case of direct counts. I present a variety of indirect indices in the remainder of this paper.

AUDITORY SIGNALS

The use of auditory signals (e.g., singing or calling males) to estimate bird numbers is suited to territorial, noncolonial species. This technique assumes each singing male is mated and that the count reflects the number of breeding pairs in the area (Davis 1965). Because these assumptions are not always valid, this index is best suited to make comparisons in bird use between areas or for the same area between years. Correction factors used in deriving density estimates may be gained by simultaneously counting birds for comparison to the call counts.

Variables to be considered include: weather, effects of terrain and vegetation on sound, time of day, season, territoriality, breeding condition, duplication of counts, and variation between ob-

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servers (Davis 1965). Variability should be minimized and identified, and counts adjusted to increase reliability.

Using auditory signals to obtain population estimates has several advantages. Birds are disturbed less. Relatively few observers can cover a large area and obtain a large number of observations rather inexpensively even when the density of a species is low (Gates and Smith 1972). Some species like the Greater Prairie Chicken (*Tympanuchus cupido*) (Silvy and Robel 1967) and White-tailed Ptarmigan (*Lagopus leucurus*) (Braun et al. 1976) respond readily to recorded calls making it easier to locate the bird.

Auditory signals that are hard to hear yield poor population estimates, and distances from the observer to the bird are difficult to calculate. This hinders density calculations. Counts must be made under standard conditions, because wind, temperature, season, time of day, and precipitation influence singing and some affect audibility. Territorial diurnal birds sing most profusely shortly before and after sunrise throughout the breeding season. The intensity depends on the stage of the breeding period. Kendeigh (1944) and Lack (1937) reported unmated males singing more prior to acquiring a mate.

Auditory signals include: crowing, hoots, songs, calls, and drumming. I present examples of surveys using these signals below.

At least since 1939 (McClure 1939), Mourning Dove (*Zenaida macroura*) call counts have been used to provide an index to spring population levels (Sayre et al. 1978). Calling doves are counted for 4 minutes at 20 plots at 1.6 km (1 mile) intervals along predetermined routes (Cohen et al. 1960). The radius of the audible plot varies with terrain and vegetation. Foote et al. (1958) reported a plot radius of 0.6 km (⅜ mile). Nonrandom selection of route was biased toward higher populations compared to those selected through stratified random sampling (Foote et al. 1958).

This survey is used primarily as an index of population density showing shifts in the density rather than estimating absolute density (Gates and Smith 1972). However, Petraborg et al. (1953) presented a quantitative approach to estimating density, and Lowe (1956) found 1.74 breeding pairs for each calling bird heard.

This species is a good example of a large scale survey with a large sample size and standard techniques and analytic procedures. Recent findings, however, suggest that factors influencing the calling activity may affect validity. Sayre et al. (1978) identified pairing as the primary influence on cooing rates. Unmated males called more than mated males. Laperriere and Haugen (1972) reported higher levels of cooing when more than one bird called and different levels of calling activity associated with weather conditions.

Calls have been used to survey male Ring-necked Pheasants (*Phasianus colchicus*). Kozicky (1952) recorded crowing along a 10 mile circular route and found temperature, cloud cover, and presence of dew to have little effect on crowing behavior, although wind greater than 8 mph and time past sunrise decreased the counts.

Brown et al. (1978) counted calling Scaled Quail (*Callipepla squamata*) along 28-km routes stopping at 1.6 km intervals for 3 minutes. He recorded the number of single calls, the number of birds calling, and calculated a call-count index from the mean of the highest count.

Robel et al. (1969) investigated factors affecting the number of Bobwhite (*Colinus virginianus*) whistles heard. They found time of year, time of day, wind velocity, temperature, and relative humidity influenced calling rate.

Woodcocks (*Philohela minor*) occupy singing grounds in the spring where their vocalizations can be reported by stopping at points along routes for a predetermined amount of time (Stroll 1980).

Bergerud and Mercer (1966) found a becking census of Willow Ptarmigan (*Lagopus lagopus alleni*) was the only technique other than aerial surveillance suitable for extensive surveys. They assumed a 0.8 km (½ mile) audibility radius and calculated cocks per square mile. They cautioned that phenological, meteorological, and density factors affect the calling behavior.

Drumming counts have been used to determine population trends and relative abundance of Ruffed Grouse (*Bonasa umbellus*) (Petraborg et al. 1953, Dorney et al. 1958, Stroll 1980). Observers record number of drummings heard at plots 1.6 km (1 mile) apart along a 16.1–24.1 km (10 to 15 mile) route. These counts start before sunrise and last several hours. Routes are duplicated at least three times, and the highest count is used. Gullion (1966) concluded that the amount of drumming heard on roadside counts may have little relation to the actual size of the breeding population. The frequency and persistence of the drumming activity varies from bird to bird and between years and is influenced by date of snowmelt, temperature, and precipitation. He thinks the total census of drumming activity centers provides the best population estimate but cautions that any estimate based on drumming behavior has the problems of an unknown sex ratio and an unknown number of nondrumming males. Woodpeckers and sapsuckers (Picidae) drum on trees as part of their territorial display. These auditory signals can be used in the same manner as grouse drumming, dove call, and pheasant crowing counts to calculate relative abundance. Sapsucker drummings are distinct from those of woodpeckers, but distinguishing among the woodpecker species is difficult (Rushmore 1973, Jackman 1974). Rushmore (1973) surveyed forests for Yellow-bellied Sapsuckers (*Sphyrapicus varius*) by imitating their drumming and feeding sounds along transects.

Owls, being nocturnal and secretive, are difficult to locate. Yet, many species can be surveyed aurally because they respond readily to taped calls (Forsman 1976).

Nest Count

Relative densities are often calculated from nest tallies (Robbins 1978a). This technique works best with species that have conspicuous nests, colonial nesters, and species nesting in open country (Kendeigh 1944, Oetting and Dixon 1975). Problems include: finding enough nests, individuals within species do not nest at the same time (Lowe 1956), some pairs have more than one brood (Kendeigh 1944), and nests are often abandoned or unsuccessful. So, all individuals that actually breed during the season may not be counted.

Eagle populations are frequently assessed by locating nest sites. Grier (1974, 1977) surveyed nesting Bald Eagles (*Haliaeetus leucocephalus*) with aerial searches as nest trees were conspicuous from the air. McGahan (1968) and Boeker (1971) located nests of Golden Eagles (*Aquila chrysaetos.*). Supernumerary nests could complicate calculating a nesting density as McGahan (1968) found an average of 1.8 supernumerary nests per pair ranging from a few meters to 6.1 km (3.8 miles) apart.

Nest counts of colonial nesting birds serve as an index showing changes in the population over time or between areas. Great Blue Herons (*Ardea herodias*) (Williams 1957), Rooks (*Corvus frugilegus*) (Birkhead 1974), Cliff Swallows (*Petrochelidon pyrrhonota*) (Emlen 1941), and albatrosses (*Diomedea immutabilis, D. nigripes*) (Rice and Kenyon 1962) have been surveyed in this manner. Nettleship (1976) presented methods of surveying seabirds of Arctic and eastern Canada. Most techniques included counting the number of nests for species like gulls (*Larus* spp.), cormorants (*Phalacrocorax* spp.), and terns (*Sterna* spp.); although counting burrows in the ground or rock scree worked for the Leach's Storm-Petrel (*Oceanodroma leucorhoa*) and Common Puffin (*Fratercula arctica*).

Nest counts are well suited to cavity nesters, because the number of cavities is correlated with the number of cavity nesters (Haartman 1957, Beebe 1974, Jackman 1974, Balda 1975b, Thomas et al. 1979a). During the breeding season, nest sites of cavity dwellers are readily located by checking available cavities. Activity around a cavity can be used to verify it as a nest. During the postbreeding season and up to one year later, active nest sites of excavators can be identified by the presence, abundance, and coloration of the chips on the ground and the coloration of the wood at the cavity entrance. After one year, aging cavities is difficult.

Evaluating old cavities can give an index to cavity nester populations if several factors are considered. Cavities of most woodpecker species can be distinguished on the basis of size. Because it is difficult to distinguish among the sapsuckers (*Sphyrapicus* spp.) and species in the genus *Picoides,* they should be combined. Only a certain percentage of apparent cavities actually are completed so a correction factor can be developed by climbing some of the trees to verify completed cavities. Between 40 and 60 percent of nests excavated by Pileated Woodpeckers (*Dryocopus pileatus*) in northeastern Oregon are not completed the same year (Bull, unpubl. data). Jackson (1977) reported inflated estimates of Red-cockaded Woodpecker (*Picoides borealis*) abundance based on the presence of cavity trees.

Roost Count

Roost sites can be used as an abundance index assuming that number of roosts correlates with abundance. This technique applies particularly to species with conspicuous roost sites or communal roosts.

Conspicuous roosts are left by a variety of species. White-tailed Ptarmigan roost in burrows below the surface of the snow (Braun et al. 1976). Some grouse burrow in the snow to roost (Glover 1948). Barwick et al. (1970) reported roosts of young wild Turkey (*Meleagris gallopavo*) broods to consist of a depression in the grass with numerous poult droppings in the vicinity. Generally adult wild Turkeys roost in trees and are identified by the droppings underneath (Boeker and Scott 1969). Many cavity nesters roost in holes (Jackman 1974), so number of roost cavities indicates abundance.

Communal roosting species lend themselves well to censusing. Sometimes thousands of birds congregate at roosts which are used repeatedly. Emlen (1938, 1940) estimated the mid-winter distribution of Common Crows (*Corvus brachyrhynchos*) in New York and California by locating all the roosts. Stewart (1973) calculated numbers of Starlings (*Sturnus vulgaris*), Redwinged Blackbirds (*Agelaius phoeniceus*), Common Grackles (*Quiscalus quiscula*), and Brown-headed Cowbirds (*Molothrus ater*) using a roost based on the amount of fecal material present.

Owl (Strigiformes) roosts are often scattered with pellets of undigested food which has been regurgitated (Welty 1975). These pellets help locate birds, indicate number of birds using a particular roost, and suggest species distribution in an area. I will discuss this topic in greater detail in the section on feeding sites.

Track Count

Track counts of birds, particularly gallinaceous birds (Overton 1971), serve as indices assuming the number of tracks correlates with the number of birds. Tracks, however, are remote from the animal in time; and it is difficult to determine how many birds made the tracks (Stearns 1970). Soil and weather conditions affect the visibility of tracks. During the winter, some types of snow conditions make track counts readily visible. In areas of high concentrations, track counts on kymograph paper may be feasible (Seber 1973).

Flocks of wild Turkeys (Glover 1948, Eaton et al. 1970) and White-tailed Ptarmigan (Braun et al. 1976) have been located by following tracks. The tracks indicate approximate numbers in the flocks.

Buller (1967) and Guthery (1975) demonstrated that the larger race of the Sandhill Crane (*Grus canadensis*) can be distinguished from the lesser race by footprint measurements. The track measurements taken in the central flyway revealed the race composition during different periods of the fall migration.

Fecal Count

The fecal-count method of estimating relative numbers of animals is used most extensively with ungulates (Neff 1968) but has been used occasionally in the study of gallinaceous birds (McClure 1945). Although presence or absence of feces is commonly recorded, the number of droppings can be counted on plots along transects. The number of droppings correlates with the number of birds present if the durability of scat and resistance to weather, diet, behavior, and time are considered. McClure (1945) thought this method was best for determining relative pheasant populations, particularly during the winter when the fecal pellets freeze and remain intact longer than in the summer when they are readily attacked by insects or dissolved by rain. Diet also affects longevity of pellets. For these reasons, it is difficult to calculate absolute density from pellet counts even though the defecation rate is known.

The presence of fecal material is used to identify roost sites of species including the Turkey (Hoffman 1968, Boeker and Scott 1969, Barwick et al. 1970, Eaton et al. 1970) and Pileated Woodpecker (Bull 1978). A Pileated Woodpecker had been using a roost cavity for at least four months based on the accumulation of fecal material at the base of the tree (Bull 1978). Gullion (1966) determined the active status of Ruffed Grouse drumming logs by the fresh accumulation of droppings at the drumming stages. Stewart (1973) calculated that 2,294,713 blackbirds and Starlings used a roost by determing the amount of fecal material deposited overnight by individual birds and by all birds in the congregation.

Czekala and Lasley (1977) developed a technique to determine the sex of birds by comparing the amount of sex steroid excreted in the fecal material. They found females had higher values of estrogen/testosterone than males. Some of the species they investigated included American Kestrel (*Falco sparverius*), Bobwhite Quail, and Rock Dove (*Columba livia*).

Feeding Sites

Indices of abundance can be derived for species that leave conspicuous evidence of feeding activities. Examples include scratch marks, plucking posts, excavations, and pellets.

Brown (1976a) used the scratch marks of Montezuma Quail (*Cyrtonyx montezumae*) to obtain population estimates. He searched along transects for scratching. It was difficult to distinguish other soil disturbances from scratch marks particularly in areas covered by litter and where there was rodent activity.

Wild Turkeys leave evidence of their feeding activities particularly during the winter by scratching through the snow to obtain food (e.g., beechnuts, old acorns, dried fruit) (Glover 1948, Eaton et al. 1970).

Goshawks (*Accipiter gentilis*) perch on logs or stumps to pluck prey (Reynolds 1978). These "plucking posts" can be used as an index to relative abundance over large areas.

Hook-billed Kites (*Chondrohierax uncinatus*) extract and feed on snails at an extracting perch and leave characteristically damaged snail shells. The presence and density of these sites are an index to occurrence and relative abundance of this kite in the area within the previous year or two (S. A. Temple, pers. commun.).

Some woodpeckers, particularly Pileated and sapsuckers, leave characteristic excavations at foraging sites. Pileated Woodpeckers make large rectangular holes into the interior of dead and down woody material (Jackman 1974). Sapsuckers drill rows of small holes in the bark of living trees (Rushmore 1973). The relative abundance of each species can be determined by observing feeding sites along transects in different areas. It is difficult, however, to accurately age the excavations other than distinguishing between a current year's activity and older feedings.

At least eight families of birds form pellets (Rea 1973). Pellets have been analyzed to identify prey remains for food habitat studies of some birds, particularly owls (Forsman 1976). Hawks generally eat less roughage than owls and digest bones more thoroughly making their pellets less useful in determining food habits (Welty 1975). Birds regurgitate distinct pellets, so pellet numbers indicate presence or absence of a species and numbers using a particular area.

Dusting Sites

Dustbathing behavior is characteristic of several taxa of birds. Originally this behavior was thought to aid in removing parasites, but recent work indicates that dustbathing reduces excess lipid substances on the bird's plumage and prevents the feathers from becoming matted (Borchelt and Duncan 1974, Borchelt 1975).

Bailey and Rinell (1968) reported wild Turkeys dusting frequently in the summer in the dry residue of rotten logs, anthills, and newly tilled soil. Bobwhite Quail dust regularly (Borchelt 1975). Dusting leaves telltale soil disturbances which can be used as an abundance index. Because dustbathing regulates the amount of lipid substance on the feathers, however, the amount of dusting may be in response to environmental factors (e.g., diet), so caution should be used in comparison between populations.