COMMENTARY

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ON THE EVIDENCE NEEDED FOR LISTING NORTHERN GOSHAWKS (*ACCIPITER GENTILIS*) UNDER THE ENDANGERED SPECIES ACT: A REPLY TO KENNEDY

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Kennedy (1997) assessed whether the available scientific evidence supports the claims of declining Northern Goshawk (*Accipiter gentilis*) abundance, which were made in recent petitions (Anonymous 1997) to list the Northern Goshawk as a Threatened Species under the Endangered Species Act (ESA). She analyzed scientific data from published research reports for evidence of a decline in goshawk abundance across North America, including declines in geographic range, population density, nest occupancy, fecundity and survival, and rates of population change. Based on analyses of these variables, she concluded that the available evidence did not support the listing petitioners' claims of declining goshawk abundance across North America.

Congress intended for ESA listings to be based on the best scientific and commercial data available, although the types of data and those qualifying as the best were left up to environmental scientists (Bogert 1994). Lacking internal statutory guidance as to what are the best scientific and commercial data applicable to listing decisions, Carroll et al. (1996) proposed the following standards for prioritizing listing of candidate species: (1) the number of additional species that can benefit from the listing; (2) the species' ecological role; (3) the species' recovery potential; and (4) the species' taxonomic or evolutionary distinctiveness. However, these standards appear to be intended for increasing collateral benefits to the ecosystem and for balancing costs, although the latter would be contrary to the intent of the ESA. None of these standards bear directly on reducing the species' jeopardy of extinction and increasing its chances for survival and recovery in the wild (i.e., conserving the species). Kennedy chose declining abundance of the taxon as her standard, which was a decision warranted by the intent of the ESA. The purpose of my reply to Kennedy is to question both the appropriateness of her choice of variables and her analyses of them when testing for evidence of declining Northern Goshawk abundance.

GEOGRAPHIC RANGE CONTRACTION

A contracting geographic range would indeed signal a likely decline in goshawk abundance. However, the sequence of range maps used for concluding such a trend need to be examined carefully for possible biases due to several influential factors. First, as Kennedy speculated, an apparent range expansion in the eastern U.S. could be due to greater efforts at locating goshawks during modern times. A temporal trend in the size of the geographic range cannot be justified as an indicator of goshawk abundance without considering trends in the level of search effort within this range. Second, natural, multiannual shifts in geographic range due to climate or other factors (MacArthur 1972) can appear as unidirectional contractions or expansions when examined over too few years. Third, habitat typically grows more patchy and sparse near a species' range boundary, as does species' abundance (MacArthur 1972, Taylor 1993, Krebs 1994). Accordingly, a number of methods have been used for deciding where to delineate range boundaries (Krebs 1994). Should the range boundary circumvent all breeding populations? All individuals? All habitat patches? Or, should it include only high-quality habitat patches? Perceived temporal trends in range boundary could be due to inconsistent application of multiple range delineation methods. Kennedy (1997) provided no rigorous accounting of these aforementioned methodological problems in comparing geographic range maps through time.

Probably the most useful indicator variable for detecting range contraction is the fraction of area used by the species, which can be measured as the cumulative area either of all occupied habitat patches or of all occupied grid cells overlaid on a distribution map (Gaston 1991, Hanski et al. 1993). However, because species abundance patterns tend to consist of population clusters that shift locations every generation or so (Taylor and Taylor 1977, 1979, den Boer 1981, Hanski 1994), as well as large areas with little or no ecological value to the species (Gaston 1991, Hanski et al. 1993), the fraction of area providing environmental conditions known to serve as high-quality habitat also would be useful for assessing range contraction of Northern Goshawk (Ward et al. 1992, Iverson et al. 1996). Maguire (1993) found that habitat loss contrib-

Table 1. Published estimates of nesting density for Northern Goshawks in North America.

AUTHORS	LOCATION	YEAR	STUDY AREA (km^2)	NO. OF PRS OF ACTIVE NESTS	NESTING DENSITY (Pairs/km^2)
McGowan (1975)	near Fairbanks, AK	1971	372.0	7.0	0.0188
McGowan (1975)	near Fairbanks, AK	1971	372.0	9.0	0.0242
McGowan (1975)	near Fairbanks, AK	1973	372.0	8.0	0.0215
McGowan (1975)	near Fairbanks, AK	1974	372.0	1.0	0.0027
Shuster (1976)	northern CO, Rocky Mts.	1974	81.0	6.0	0.0741
Shuster (1976)	northern CO, Rocky Mts.	1975	81.0	6.0	0.0741
Bartelt (1977)[a]	Black Hills, SD	1975	448.5	8.0	0.0178
Reynolds and Wight (1978)	western OR	1970	92.8	0.0	0.0000
Reynolds and Wight (1978)	western OR	1971	92.8	0.0	0.0000
Reynolds and Wight (1978)	western OR	1974	117.4	4.0	0.0341
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	8.5	0.9	0.1059
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	12.0	1.2	0.1000
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	22.0	3.0	0.1364
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	27.5	4.0	0.1455
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	29.0	2.1	0.0724
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	36.0	2.4	0.0667
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	44.5	3.3	0.0742
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	50.5	5.1	0.1010
Crocker-Bedford and Chaney (1988)	Kaibab Plateau, AZ	1985	230.0	24.0	0.1043
Kennedy (1989)	Jemez Mts., NM	1986	121.0	7.7	0.0636
Kennedy (1989)	Jemez Mts., NM	1986	273.5	7.7	0.0282
Austin (1993)	Cascades of CA	1989	473.7	9.0	0.0190
DeStefano et al. (1994)	Paisley, east OR	1992	87.8	4.0	0.0456
DeStefano et al. (1994)	Paisley, east OR	1993	129.6	8.0	0.0617
DeStefano et al. (1994)	east Bear Valley, east OR	1992	90.5	8.0	0.0884
DeStefano et al. (1994)	east Bear Valley, east OR	1993	90.5	6.0	0.0663
DeStefano et al. (1994)	west Bear Valley, east OR	1993	105.2	9.0	0.0856
DeStefano et al. (1994)	Spring Creek, east OR	1992	114.0	8.0	0.0702
DeStefano et al. (1994)	Spring Creek, east OR	1993	114.0	3.0	0.0263
DeStefano et al. (1994)	Bly, east OR	1993	106.3	4.0	0.0376
Doyle and Smith (1994)[b]	southwest Yukon	1990	100.0	10.0	0.1000
Woodbridge and Detrich (1994)	Sierran Montane, CA	1989	102.3	11.0	0.1075
Woodbridge and Detrich (1994)	Upper Montane, CA	1989	104.4	6.0	0.0575

[a] Reported density estimates from two immediately adjacent areas, which I combined into one area and one estimate.
[b] Assumed that the 5 pr they observed comprised only half the population.

uted substantially to a decline in goshawk population viability on the Kaibab Plateau, Arizona. Maguire's population viability analysis (PVA) simulated a declining trend in habitat carrying capacity of 1%/yr and produced certain extinction in goshawk populations, even those with stable or increasing growth rates. Concluding whether the fraction of area used or potentially used by goshawks has changed through time must include knowledge of goshawk habitat and habitat fragmentation, which I will discuss further.

NESTING DENSITY

To evaluate the appropriateness of nesting density for detecting a range-wide abundance trend, I compared 33 nesting density estimates made from 24 study sites spanning the years 1970–93 (Table 1). Estimates of nesting density averaged 0.062 pair per km^2 (range = 0–0.145, SD = 0.039). The nesting populations studied averaged only 6 pairs of nesting goshawks (range = 0–24, SD = 4.4) on study areas that averaged 148 km^2 in size (range = 8.5–474, SD = 134).

As noted by Kennedy, estimates of goshawk density have been highly variable. However, her comparison of these density estimates was unlikely to reveal any temporal trends because half the variation in goshawk nesting densities can be explained by the size of the study areas used to make the density estimates (Fig. 1). Similar

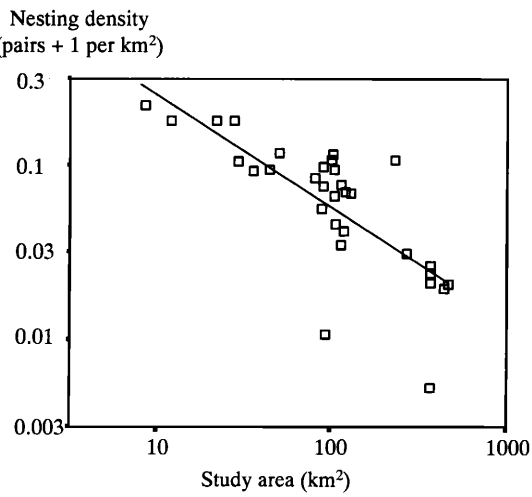

Figure 1. Relationship between nesting density (log of nesting pairs per km^2) and study area size (log km^2 of study area) for Northern Goshawks across North America (see Table 1).

to other species, such as Swainson's Hawks (*Buteo swainsoni*; Smallwood 1995), European Kestrels (*Falco tinnunculus*; Village 1984, Kostrzewa 1988), mammalian primary consumers (Blackburn and Gaston 1996) and mammalian carnivores (Smallwood and Schonewald 1996), published estimates of goshawk nesting density were inversely proportional to the study area (r^2 = 0.53, Root MSE = 0.27, $P < 0.0001$):

$$\log Density = 0.072 - 0.658 \log km^2\ study\ area,$$

where density was calculated as the number of nesting pairs plus one, so as to avoid log-transforming 0-values.

The *y*-intercept of the regression slope predicted 0.18 pair of Northern Goshawks on the average 1 km^2 of habitat area included within the collective study boundaries. This predicted density is about three times as large as the average of reported densities, which is already higher than will be found on the majority of North American forest land units the size of 1 km^2. My model prediction was absurd. After all, nesting home ranges of 73 adult goshawks averaged 59 km^2 in size and ranged up to 879 km^2 (Bartelt 1977, Kennedy 1989, Austin 1993, Doyle and Smith 1994, Hargis et al. 1994, Keane and Morrison 1994, Iverson et al. 1996). Foraging areas of 50 goshawks averaged 894 km^2 in size and were as large as 2321 km^2 (Hargis et al. 1994, Keane and Morrison 1994, Iverson et al. 1996). The most likely explanation for the excessive density predicted both by the regression model at 1 km^2 (see Smallwood and Schonewald 1996) and by the average among reported estimates was that most investigators selected study sites known in advance to support breeding populations of Northern Goshawk. In fact, the locations of four of the 10 studies summarized in Table 1 were reportedly selected based on historical records of goshawk nesting or on the distribution of high-quality habitat. At least most of the remaining sites were likely also chosen in one of these ways, rather than randomly Therefore, estimates of nesting density were made for only one aspect of the population: the high-density cluster. Without long-term sampling across large geographic areas, including the majority of the forest landscapes where goshawks are much rarer, comparisons of nesting density are unlikely to reveal any temporal trend in goshawk abundance across North America.

Further adding to the unsuitability of available density estimates for detecting temporal trends in range-wide goshawk abundance, high-density clusters typically shift locations every generation or so (Taylor and Taylor 1977, 1979, den Boer 1981). A study originally designed around a high density cluster might detect a sudden drop in abundance after a few years. Such a reduction in local density would likely be misinterpreted as a population decline rather than a spatial shift, unless the sampling was of sufficient duration and spatial extent to detect the shift. All but two density estimates included <11 nesting pairs, which in my opinion is barely enough to qualify as a population cluster. The studies generating these estimates have lasted ≤9 yr, which is less than a goshawk lifespan and therefore is insufficient for judging persistence (Connell and Sousa 1983). The studies designed to estimate density were not intended to detect population trends across large areas, let alone North America

REPRODUCTIVE PATTERNS

Fecundity and survival, estimated from local, autonomous studies, also have no necessary relationship with goshawk abundance at the scale of North America. Such estimates represent populations, and have no documented relationship with geographic range size (Gaston 1990) or range-wide abundance. Habitat fragmentation has been proposed as the most likely cause for declines in Northern Goshawk abundance across North America (Crocker-Bedford 1990, Keane and Morrison 1994). However, habitat fragmentation might reduce nest-site occupancy and availability (Crocker-Bedford 1990, Ward et al. 1992, Woodbridge and Detrich 1994), and not fecundity (Woodbridge and Detrich 1994) and survival. Extrapolating Crocker-Bedford's (1990) observed rates of timber harvest and impacts on goshawk nesting on the Kaibab Plateau, habitat loss could conceivably reduce goshawk abundance across North America by 75% during the 75-yr lifetime of a scientific investigator. However, the remaining 25% might reproduce and survive at levels comparable to pre-harvest conditions (Woodbridge and Detrich 1994). The relationships between habitat fragmentation and reproductive success remain unknown except for what has been learned from the stand-thinning studies of Crocker-Bedford (1990) and Ward et al (1992). Like geographic range contraction, widespread reductions in fecundity or survival across North America would be of concern, but local, autonomous estimates are inappropriate for extrapolation to range-wide estimates of productivity.

TEMPORAL ABUNDANCE TREND

Kirk and Hyslop (1998) recently assessed the status of Canadian raptors by analyzing data from migratory hawk counts, Christmas Bird Counts (CBC), and the Breeding Bird Surveys (BBS) across North America. They found significant declines in the annual number of migrating Northern Goshawks at the majority of migratory hawk count sites in the U.S., although the CBC and BBS showed no such declines. Kirk and Hyslop (1998) acknowledged the hazards of relying on counts of migrating raptors, such as possibly misinterpreting change over several counting years as a trend rather than just as part of a multiannual population cycle. However, changing counts of migrating Northern Goshawks are more likely to be indicative of continent-scale change in abundance through time than would be the rate of population change assessed by Kennedy, because populations are local and may shift locations through time as described previously (Taylor and Taylor 1977, 1979, den Boer 1981).

Kennedy dismissed counts of migrating goshawks because no direct relationship has been established between counts of migrants and the abundance of goshawks across North America. This rationale was not applied to geographic range, population density estimates, nor fecundity and survival, although there was every reason to do so. Her (1997) use of these variables for assessing evidence of a goshawk decline in North America lacks scientific foundation, but serves as a first step in the needed scientific debate on the evidence needed to conclude whether a species is declining across its geographic range.

HABITAT FRAGMENTATION

The relationships between goshawk nesting patterns and forest landscape conditions were not assessed by Kennedy. These relationships also bear on critical habitat designation, which is one of the major steps called for in the ESA listing process, and was originally intended to precede listing decisions (National Research Council 1995). Critical habitat was not defined explicitly in the ESA, but Hall et al. (1997) defined this habitat as the geographic areas providing the resources necessary for breeding and population persistence, consistent with the concept of high-quality habitat. Although critical habitat has yet to be designated for the Northern Goshawk, the available research reports indicate that "mature," "closed-canopy," or "old-growth" forest will likely comprise a good part of the critical habitat designation (Crocker-Bedford and Chaney 1988, Ward et al. 1992, Graham et al. 1994, Iverson et al. 1996, Beier and Drennan 1997).

Fragmentation of mature forest may be the greatest threat to Northern Goshawks (Keane and Morrison 1994, Woodbridge and Detrich 1994, Iverson et al. 1996). Habitat fragmentation is the reduction in and increased isolation of available habitat (Wilcox and Murphy 1985). In general, habitat fragmentation has been widely acknowledged as the greatest threat to the survival of many species (Wilcox and Murphy 1985). Habitat fragmentation should be given the greatest scrutiny in making listing decisions, and its possible impact on the goshawk is measurable indirectly using historical and recent maps of mature forests (Ward et al. 1992).

However, habitat fragmentation must be defined clearly so that it can be made operational with respect to impacts on Northern Goshawks. Hansen and Urban (1992) rated goshawks as highly sensitive to old-growth forest fragmentation based on reproductive effort, nest type, and territory size, but they lacked information on goshawk responses to edge and patch size. Nest-site occupancy was later found positively related to mature forest patch size (Woodbridge and Detrich 1994) and percent canopy closure (Ward et al. 1992), and nesting areas contained less edge between forest and nonforest vegetation types (Iverson et al. 1996). Goshawk habitat must be described carefully using multiscale studies such as conducted and advocated by Keane and Morrison (1994) and Beier and Drennan (1997). Specific resource and habitat patch sizes and their configurations on the landscape must be related to abundance patterns of the species (Kotlier and Wiens 1990, Hanski 1994). The condition of goshawk habitat can then serve to indicate the abundance of goshawks in North America, although predictions of abundance based on the indicator(s) need verification with an extensive sampling and monitoring program (Green 1979).

A metaanalysis, as recommended by Kennedy, probably would not suffice for assessing goshawk abundance trends in North America in lieu of proper sampling (also see Keane and Morrison 1994). I conducted a similar type of analysis for puma (*Puma concolor californica*) density, and found that the autonomy of each population study rendered the collection of studies incapable of providing much insight (Smallwood 1997). Smallwood and Schonewald (1998) since compared all published carnivore population estimates and associated study attributes, but we found the same result: surprisingly little insight into the factors that influence carnivore density, except for the influence of study area on density. Most population studies are not sampling programs *per se,* but rather measurements of population attributes at particular sites and during brief periods of time (relative to the ecological time scale of the species). Comparison of these attributes for temporal trends is inappropriate without controlling for a variety of environmental and study conditions. Such comparison is one form of pseudoreplication (Hurlbert 1984).

An appropriate sampling program would start with a protocol for selecting multiple sampling sites from various environmental conditions, from which variation in population attributes could be effectively interpreted (Green 1979). The entire geographic range of the taxon is the appropriate spatial scale for sampling that is intended to test for abundance trends and to make taxonomically-based listing decisions. The appropriate sampling protocol for drawing inferences on trends in abundance would involve random or systematic selection of sites throughout the range. Intensive studies of resource requirements at a subset of the sampling sites would need to be linked to the more extensive sampling program so that evolutionary and ecological questions of 'why' and 'how' can be answered, and meaningful conservation strategies put to practice (Keane and Morrison 1994). Such a sampling program may seem daunting, but the case needs to be made that the Northern Goshawk and other species in the U.S. deserve allocation of the necessary funding for sampling at a scale and level of rigor sufficient to achieve the objectives of the ESA.

CONCLUSIONS

Kennedy's decision to pursue evidence of declining Northern Goshawk abundance was more appropriate to the intent of the ESA than were those of Carroll et al. (1996). However, a listing decision for the Northern Goshawk should not rely on the data and analysis she used. Population density, fecundity, survival, and rate of population change all lack scientifically defensible relationships with range-wide abundance, as does the size of the geographic range within a single species (Gaston 1990). The population parameters can be related to local population trends, but their relationships to the trend in range-wide abundance can only be inferred by multiscale study at sites chosen randomly or systematically from across the geographic range. In lieu of appropriate sampling, and in lieu of agreement among scientists for additional variables that should be analyzed, evidence for a Northern Goshawk decline across its range should be based on changes in the availability and contiguity of habitat and migratory counts.

According to Kennedy, the petitioners for the goshawk listing were motivated by their concern for over-harvest of old-growth forest. Regardless of the motivation behind the listing petitions, the listing decision should be based on analysis of the variables that most likely represent a threat to the survival of Northern Goshawks in the wild: the extent of its critical habitat and level of recent habitat fragmentation. Kennedy did not rigorously assess habitat fragmentation as a possible indicator of declining goshawk abundance.

Assessing inappropriate variables for making a listing decision threatens the credibility of the ESA more so than does an ulterior motivation for a listing petition, because the former is an action that can reduce the likelihood of survival and recovery of the species in the wild, whereas the latter is a request that poses no threat to the goshawk population. That is, applying less than the best scientific data to a listing decision risks committing a Type II error which can have severe conservation ramifications and would be the less ethical choice (Shrader-Frechette and McCoy 1992). Committing a Type I error and inappropriately listing a species as threatened will not reduce the likelihood of its survival, although a delisting in the future can also be time-consuming and damaging to the integrity of the ESA (if listing was unwarranted in the first place). Of course, using the best available scientific data (appropriate variables) would also reduce the chance of committing a Type I error.

Environmental scientists need to develop standards for qualifying scientific data as the best available when making listing decisions, as called for in the ESA. Perhaps Kennedy's paper and my reply can help initiate the needed scientific debate on the methods and variables that are most appropriate for assessing whether a species has declined significantly enough across its range to warrant listing under the ESA.

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THE VALUE OF DEMOGRAPHIC AND HABITAT STUDIES IN DETERMINING THE STATUS OF NORTHERN GOSHAWKS (*ACCIPITER GENTILIS ATRICAPILLUS*) WITH SPECIAL REFERENCE TO CROCKER-BEDFORD (1990) AND KENNEDY (1997)

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Northern Goshawks (*Accipiter gentilis atricapillus*) have long been associated with mature forests, an attribute that has brought them into recent debates over forest management practices. Bent (1937) associated goshawks with extensive forests and large stands of big trees, and more recent research on their nesting habitat found an association with relatively large trees and relatively dense canopies (Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Hayward and Escano 1989). Reynolds (1989) described the foraging habitat during the breeding season as older, tall forest where goshawks can maneuver in and below the canopy while foraging. Most of the investigators cited above deduced that timber harvesting could impact goshawks, while others concluded that timber harvest actually had reduced goshawk abundance in portions of some states (Reynolds and Meslow 1984, Mannan and Meslow 1984, Bloom et al. 1985, Kennedy 1988).

I (Crocker-Bedford 1990) reported that the rate of nest reoccupancy in logged areas was 20–25% the reoccupancy rate in areas not logged, despite nest buffers having been left intact in the logged areas. This finding, along with deductions on the effects of timber harvest on the size of the local population, catalyzed additional research (Squires and Reynolds 1997) and debate. Many scientists (seemingly including Kennedy 1997) and forest managers were left confused over the methods and results of my research. Herein, I assess the strengths and weaknesses of my 1990 paper in order to move the debate on methodologies toward implementation of more productive resource management practices.

Kennedy (1997) emphasized the use of demographic studies in determining whether goshawks warrant Threatened or Endangered status under the United States Endangered Species Act (ESA; United States Government 1988); however, I assert that demographic statistics are unlikely to ever provide sufficient information to determine goshawk status under the ESA. In light of limitations in technology, funding and other problems, this paper suggests an alternative approach to status assessment Finally, hypotheses are presented on landscape-level habitat needs of goshawks, for use in goshawk status assessment, and as suggestions for further study.

REVIEW OF CROCKER-BEDFORD (1990)

My study area was the North Kaibab Ranger District of northern Arizona. I started nest monitoring in 1982 under a study plan having the objective of comparing the efficacy of different-sized no-cut nest buffers for goshawk