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SHORT COMMUNICATION

Taxonomic status and conservation strategy of the endangered red wolf: a response to Kyle et al. (2006)

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Kyle et al. (2006) evaluated hypotheses related to the origin and taxonomic status of eastern wolves (*Canis lycaon*) and suggested that *C. lycaon* is conspecific with *C. rufus*. They maintain that the *C. lycaon/C. rufus* taxon likely was endemic to North America even prior to colonization by *C. lupus*. We consider that the putative origin of *C. lycaon* proposed by Kyle et al. (2006) is plausible, as is their suggestion that *C. lycaon* and *C. rufus* are closely related and possibly conspecific. However, their conclusions regarding ongoing *C. rufus* restoration efforts in the U.S. are problematic from the perspective of conservation and management for this endangered species.

Kyle et al. (2006) imply that management efforts reducing hybridization between *C. rufus* and *C. latrans* for the experimental endangered *C. rufus* population in eastern North Carolina (see Stoskopf et al. 2005) are ''likely not practical, or desirable''. Their argument centers on the premise that *C. rufus* does not deserve special conservation attention because *C. lycaon* subsumes *C. rufus* and populations of the former taxon are not imperilled over much of their range in eastern Canada. However, uncertainty over taxonomic status of *C. lycaon* and *C. rufus* is substantive and ongoing, with other researchers suggesting that: i) *C. rufus* is a hybrid between *C. lupus* and *C. latrans* (Wayne and Jenks 1991; Roy et al. 1996), ii) *C. lycaon* is a *C. rufus–C. lupus* hybrid (Nowak 2002), iii) *C. lycaon* is subspecific to *C. lupus* whereas *C. rufus* is a distinct species (Nowak 2003), iv) *C. rufus* is a distinct species but not taking a position on the status of *C. lycaon* (Sillero-Zubiri et al. 2004), and v) *C. lycaon* and *C. rufus* are subspecies of *C. lupus* (Wilson and Reeder 2005). Kyle et al. (2006) propose to merge *C. lycaon* and *C. rufus* based on phylogenetic analysis derived from an mtDNA control region fragment and nDNA microsatellites from samples of *C. latrans*, *C. lycaon*, and *C. rufus* (see Wilson et al. 2000). However, there are small differences in published mtDNA control region sequences of these two taxa. More importantly, a different conclusion on taxonomy might be reached if other species concepts are used that include adaptive differences in morphology, behavior, or ecological function (e.g., cohesion species concept, see Templeton 1989). Given the importance of maintaining genetic and ecological integrity in any recovering population, it is premature to assume that the *C. rufus* gene pool need not be preserved as distinct, at least until genetic comparisons with *C. lycaon* go beyond neutral markers and include loci important for fitness and under selection.

Even if *C. lycaon* and *C. rufus* ultimately are classified as conspecific, Canadian populations of *C. lycaon* should not have direct conservation bearing on legal protection of the U.S. population of *C. rufus.* By comparison, gray wolves, Canada lynx (*Lynx canadensis*), and grizzly bears (*Ursus arctos*) receive protection under the Endangered Species Act (ESA) despite occurrence of viable populations throughout Canada and Alaska (U.S. Fish and Wildlife Service 2006). Because the red wolf recovery area in North Carolina is > 1000 km from Canadian populations

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of *C. lycaon*, any natural rescue of *C. rufus* by Canadian wolves is unlikely. Furthermore, the site of origin of red wolves transplanted to North Carolina is 1900 km southwest, meaning that extant populations of *C. lycaon*/*C. rufus* represent gene pools drawn from habitats at extreme ends of the historic range. Recent work on coyotes (Sacks et al. 2004), North American wolves (Geffen et al. 2004), European wolves (Pilot et al. 2006), and red fox (Swanson et al. 2005) shows population genetic structuring in relation to habitat and environmental gradients. Thus, Canadian populations of *C. lycaon* and *C. rufus* likely have accumulated adaptive differences, and any discussion of managing them as a single species should consider time and degree of divergence between the two.

Kyle et al. (2006) suggest that protection for North American *Canis* should not emphasize maintaining phenotypes but rather involve conserving evolutionary processes through preserving genetic diversity that is not recoverable once it is lost. Yet, Kyle et al. (2006) also state that *C. rufus* should not receive specific protection because ''adaptive phenotypes can be recovered through recurrent selection (Moritz 2002)''. By inference, they propose that *C. rufus* should be allowed to hybridize freely with *C. latrans* because hybrids may be better adapted to human-altered landscapes that prevail throughout the *C. rufus* recovery area. Although hybridization can be a natural evolutionary process and may have contributed to *Canis* evolution in North America, hybridization between *C. rufus* and *C. latrans* has been, and continues to be, exacerbated by anthropogenic factors. Prior to European settlement, historic ranges of *C. rufus* and *C. latrans* apparently had limited overlap and the hybrid zone probably was small (Nowak 2002); *C. latrans* was not documented in North Carolina until the 1980s (Moore and Parker 1992). Anthropogenic habitat change probably favored disproportionately high human-caused mortality of *C. rufus* and consequent range expansion by *C. latrans* (Nowak 2002; Phillips et al. 2003). These points imply that evolutionary novelty occurring from *C. rufus*–*C. latrans* hybridization is not natural and thus should be considered undesirable from a conservation standpoint (Jenks and Wayne 1992; Allendorf et al. 2001; Wayne and Brown 2001).

The mandate of the red wolf program is to restore a remnant of the wild red wolf population to select areas in the historic range. Currently, the captive *C. rufus* population numbers > 175 animals across 38 facilities (A. Beyer, U.S. Fish and Wildlife Service, personal communication), so the gene pool is healthy and secure. By minimizing hybridization between *C. rufus* and *C. latrans* in North Carolina, the only population of free-ranging *C. rufus* is actively being protected. Although Kyle et al. (2006) are correct in pointing out that adaptive phenotypes may be recovered through selection, in small populations such as *C. rufus* the relative adaptive force of selection tends to be greatly diminished compared to random forces of drift (Kimura 1962; Frankham et al. 2002). Accordingly, Kyle et al.'s (2006) argument does not hold for the case of recolonizing *C. rufus*, where unmanaged introgression of coyote genes likely would swamp the *C. rufus* gene pool within a few generations (Fredrickson and Hedrick 2006). Thus, introgression of genetic material from *C. lycaon* (through active transplant) or *C. latrans* (through benign neglect) should only be considered following i) evidence of inbreeding depression and the need for genetic rescue in *C. rufus*, and ii) clear understanding of potential ecological differences between canid species and their hybrids (see Storfer 1999).

Efforts to restore *C. rufus* in the wild have faced setbacks primarily due to hybridization with *C. latrans* (Phillips et al. 2003; Stoskopf et al. 2005). Current management involves minimizing hybridization and increasing red wolf habitat through removal and sterilization of non-wolves (Stoskopf et al. 2005). Because asymmetry in population size between expanding *C. latrans* and declining *C. rufus* likely prompted disequilibrium and hybrid zone expansion, in theory *C. rufus* may be recovered if hybridization is reduced at least until *C. latrans* can be excluded naturally by an established *C. rufus* population. Currently, efficacy of this particular strategy is uncertain (Stoskopf et al. 2005), but its broader merits lie in helping elucidate the feasibility of restoring populations under threat of hybridization. Because invasive species will continue to shape ecological communities and conservation biology efforts, the red wolf program serves as a valuable model for future species restoration. Notwithstanding ESA legislative mandates, this contribution should justify ongoing efforts to re-establish *C. rufus* in areas where it has been extirpated.

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