

COMMENTARY

Commentary on “Pandemic Human Viruses Cause Decline of Endangered Great Apes,” by Köndgen et al., 2008, *Current Biology* 18: 260–264

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In the late 19th century, Robert Koch published his now-famous postulates for attributing microbial causation to disease [Koch, 1884]. Koch's postulates define four criteria that justify attributing a causal relationship between a particular microbe and a particular disease: identification of the microbe in diseased individuals, isolation of that microbe in pure culture from a diseased individual, production of the same disease when the microbe is inoculated into a healthy individual, and, finally, re-isolation of the same microbe from the experimental individual. Although they helped guide over a century of microbiologists and medical professionals, Koch's postulates are now seen as overly rigid and somewhat anachronistic. Although they work adequately for bacteria such as those that cause anthrax and tuberculosis (Koch's own diseases of interest), they are less useful for multifactorial diseases or for agents such as viruses that can be difficult to isolate. More flexible and inclusive criteria for establishing etiology have therefore emerged that allow for the consideration of observational evidence, statistical associations, molecular diagnostics, and biological plausibility, to name a few [Inglis, 2007].

It is therefore both ironic and encouraging for those of us concerned with the health of apes (but unwilling to inoculate them experimentally) that a research group from the institute named for Dr. Koch himself has so convincingly demonstrated a causal link between respiratory disease in wild chimpanzees and emerging human viruses without needing to invoke Koch's postulates. Köndgen et al. [2008] present a strong body of molecular, observational, and epidemiological evidence that human paramyxoviruses have infected chimps from Tai National Park on at least three occasions. Their core evidence is the recovery of metapneumovirus and respiratory syncytial virus nucleic acids from chimpanzees that had died of respiratory disease, combined with phylogenetic analyses placing these viruses comfortably within clades containing globally circulating human strains. Moreover, the group examines long-term demographic trends to argue persuasively that these or similar viruses are likely

culprits in multiple ape mortality events going back to the mid-1980s. Disturbingly, Köndgen et al. demonstrate that increasing intensity of human observation by researchers tracks the severity of mortality events in the chimpanzees over time, thereby implicating researchers and tourists as likely sources of infection. Given the study's strong data and careful analyses, it is difficult to find fault with the conclusions of the article. It is equally difficult to avoid a sinking feeling that these findings represent yet another dire and previously overlooked disease-related threat to the conservation of wild apes, and that we ourselves may be to blame.

Human metapneumovirus and human respiratory syncytial virus will likely be early entries in a long list of human viral pathogens that threaten wild ape populations. These “reverse zoonoses” or “anthroponoses” have received less general attention than have their counterparts that threaten human health—the “zoonoses,” those often-emerging infections that reside in animal reservoirs and jump with ever-increasing frequency into humans as our contact with animals accelerates [Jones et al., 2008]. Ebola virus and primate immunodeficiency viruses are probably the most notorious of the ape zoonoses, the former having caused both regional ape declines and linked human epidemics and the latter having sparked the global AIDS pandemic [Gao et al., 1999; Leroy et al., 2004]. Never before, however, has a decidedly human virus been so clearly implicated in the decline of a wild ape population. Respiratory diseases of human origin have long been suspected as actual and potential threats to wild apes, and other human viruses, such as poliomyelitis virus, have been suspected in ape disease epidemics [Wallis, 2000], but the evidence

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has usually been indirect, circumstantial, and unconfirmed by laboratory testing.

Given our long-held suspicions, what we now know about the physiological similarities between humans and chimps, and the ever-growing litany of emerging diseases that have come to light for their ability to infect both us and the other primates, the most surprising thing about the Köndgen et al. findings may be that anyone does, in fact, find them surprising. The Köndgen et al. findings are, however, if not a paradigm-shifting discovery, an epidemiological “smoking gun.” Smoking guns are uniquely useful in epidemiology because they stand alone as powerful examples and therefore serve as ammunition in their own right for justifying action. More important than the science of the Köndgen et al. study may therefore ultimately be the justification that it provides in support of increased vigilance and the implementation of new disease prevention programs.

Divergent opinions have already begun to form about what the new findings mean for conservation. Some will treat the Köndgen et al. study as a call to arms, arguing that immediate and substantive changes are required to protect wild apes from this new, emerging disease threat. Others will counter that the risks of long-term and sporadic mortality from respiratory infections pale in comparison with the more pervasive dangers of habitat loss and hunting. Some may even go so far as to suggest that disproportionate attention to the comparatively minor issue of disease could actually divert resources away from these graver problems. The first camp will respond that infectious disease risks to apes, even if small in comparison with other threats, are manageable, and because we can manage them we should.

These arguments all have merit, and the actions of individual ape researchers and groups of researchers will (and should) be based on case-by-case assessments of resource availability and risks to particular ape populations. Nevertheless, the Köndgen et al. findings do hint at a more generalized picture that should give us pause. Respiratory epidemics in apes can no longer be seen as random, independent events. Rather, repeated respiratory outbreaks in Tai now appear to be linked by a common epidemic source (and one uncomfortably close to home). The dramatic and sudden decline of Central African apes owing to Ebola [Bermejo et al., 2006] now has a more insidious companion, more protracted in course, and veiled by its innocuousness in humans: the prolonged epidemic.

As most discoveries do, the Köndgen et al. findings also raise more questions than they answer, and these have already become topics of much discussion. Chief among them is “why Tai?” Although the Tai chimpanzees are biologically and culturally unique, the external pressures of habitat loss, poaching, encroachment, and accelerating hu-

man contact that threaten them are not. Why, then, are the Tai chimps losing a protracted battle with repeated respiratory epidemics whereas other, similarly vulnerable communities appear not to be? In Kibale National Park, for example, Kanyanchu community inhabits the park edge, has been intensively visited by tourists since the early 1990s, and its chimps are known to harbor bacteria of human origin [Goldberg et al., 2007]. Nevertheless, this highly impacted “edge” population has remained one of the largest and most robust communities on record. Are stochastic processes operating, in which such highly impacted communities have remained seemingly healthy and demographically stable just because they have been lucky? Alternatively, do chimpanzee communities differ in their inherent susceptibility to respiratory infection, either as a result of innate resistance, immunity, or the ecological settings in which they live?

Given our imperfect knowledge, it would be unwise to assume that today’s apparently healthy chimpanzee communities are safe from the threat of human respiratory infection. Moreover, even if differences are ultimately discovered in the susceptibility of different chimp populations to infection with human metapneumoviruses and human respiratory syncytial viruses, we would be shortsighted to assume that these first examples are the most widespread, most important, or most harmful human respiratory pathogens that wild apes can contract. Smoking guns can sometime focus attention so narrowly that they obscure the broader picture. What, for example, of those notorious relatives of the paramyxoviruses, the orthomyxoviruses, which include the influenza viruses that caused 40 million human deaths in the early part of the 20th century? One shudders to think of the potential consequences of an ape epidemic of highly pathogenic influenza. We should appreciate the Köndgen et al. findings not so much for drawing our attention to a specific viral family, but more perhaps for their illustration that even mildly pathogenic human respiratory pathogens are capable of causing severe population declines in wild apes.

It may take years of careful research to discover whether human paramyxoviruses threaten all chimpanzee populations equally, or to discover which other human respiratory pathogens may also be contributing to ape population declines. In the meantime, we should invoke the precautionary principle. There is little justifiable excuse for chimpanzee researchers and research staff not to wear aerosol-blocking facemasks. Whether or not we ourselves are, in fact, major contributors to the threat of respiratory infection in wild apes, wearing masks demonstrates our acknowledgment of disease as a critical conservation problem, as well as our willingness to modify our own behavior for the sake of the apes. Following this logic, other simple

preventive measures should be taken with respect to clothing and equipment; for example, boots should be dipped in 10% bleach baths before being worn in the forest. Tourists should not be exempt. We should adopt a “zero tolerance” policy toward the lax enforcement of minimum observation distances/times and other rules crafted to safeguard apes. Tourists should also take the same personal precautions that we do. Although many worry about the willingness of tourists to “mask up,” I suspect that the majority of these eco-minded individuals would embrace the practice. It could become a ritualized and educational part of the ape tourism experience (“Ok, everyone, we are now approaching the apes, so please don your masks!”). Such visible practices would promote a culture of disease awareness among tourists that, in this age of eco-tourism and globalization, would have benefits well beyond apes. Cost would be a minor issue; inexpensive but effective masks could be sold at tourism sites and could even turn a small local profit.

More generally, we need to abandon the paradigm of the “pristine ape” and the noninterventionist philosophy that goes with it. The apes we study are impacted, if only because we are there to study them and because our pathogens are along for the ride. Although disease may be part of the natural ecology of apes, exotic human respiratory infections are not. “Natural exposure” to such pathogens might induce protective immunity, but the negative consequences of disease are clearly too grave to justify relying on this method of protection. The Köndgen et al. findings and the growing body of evidence that they represent suggest that we should be administering vaccines to wild apes to protect them against the most significant human viral disease threats. Many vaccines might be formulated for oral administration, even if “oral baiting” invites criticism about provisioning our study populations. There would be other positive externalities to such an endeavor; research on vaccines for wild apes would entail answering interesting questions not only about effective delivery systems and the timing and frequency of vaccine administration, but also about the ecological and epidemiological relationships among disease transmission rates, demographics, social behavior, and “herd immunity.” Fortunately, little if any research would be required to determine the efficacy of some vaccines that are already available, as we can rely on medical knowledge gleaned from that most appropriate animal model for chimpanzee disease: the human.

In light of the sobering implications of the Köndgen et al. virological findings, it is much appreciated that they also describe a protective effect of research and tourism on the distribution of poaching effort within Tai. Not only will this information help us counter the inevitable external criticisms, but it also highlights the importance of considering both the direct and indirect influences of local human communities, including communities of researchers, on ape conservation in the context of disease. As we continue to learn more about pathogens, people, primates, and the dynamic environments they inhabit, we should bear in mind that the interactions among these factors often mean more for ape health and conservation than do their individual effects. How we interact with apes is every bit as important as how local people do, or how apes interact with their environment and the pathogens circulating therein. We are all, in other words, active players in the ecology of wild apes, whether or not we fully appreciate the benefits and consequences of our activities.

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