Ebola Outbreak Killed 5000 Gorillas

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Over the past decade, the Zaire strain of Ebola virus (ZEBOV) has emerged repeatedly in Gabon and Congo. During each human outbreak, carcasses of western gorillas (*Gorilla gorilla*) and chimpanzees (*Pan troglodytes*) have been found in neighboring forests (*1*). Opinions have differed as to the conservation implications. Were these isolated mortality events of limited impact (*2*)? Was ZEBOV even the cause (*3*)? Or, were they part of a massive die-off that threatens the very survival of these species (*4*)? Here, we report observations made at the Lossi Sanctuary in northwest Republic of Congo, where ZEBOV was the confirmed cause of ape die-offs in 2002 and 2003 (*5*). Our results strongly support the massive die-off scenario, with gorilla mortality rates of 90 to 95% indicated both by observations on 238 gorillas in known social groups and by nest surveys covering almost 5000 km^2. ZEBOV killed about 5000 gorillas in our study area alone.

Starting in 1995, we habituated gorillas to our presence, and by 2002 we had identified 10 social groups with 143 individuals (fig. S1). In late 2001 and early 2002, human outbreaks of ZEBOV had flared up along the Gabon-Congo border (*1*). In June 2002, a gorilla carcass was found 15 km west of the sanctuary. By October, gorilla and chimpanzee carcasses began appearing inside the sanctuary. In the next 4 months, we found 32 carcasses. Twelve of the carcasses were assayed for ZEBOV, and 9 tested positive (*5*). From October 2002 to January 2003, 91% (130/143) of the individually known gorillas in our study groups had disappeared.

In June 2003, one fresh carcass appeared south of the sanctuary. In September, we identified seven new social groups with home ranges straddling and to the east of the two rivers and monitored their sleeping nests on a biweekly basis. Then in October carcasses again appeared within the sanctuary. Ten carcasses were found in the following 3 months. From October 2003 to January 2004, Ebola spread sequentially from north to south, killing 91 of the 95 individuals (95.8%) in the newly monitored groups. One remarkable feature of this spread was that the onset of ZEBOV deaths in each group was predicted by the number of home ranges separating it from the first group to experience deaths (Fig. 1A). In particular, the estimated time lag between deaths in successive groups (11.2 days) was very similar to the typical length of the ZEBOV disease cycle of about 12 days (*6*). Assuming deaths were caused by spillover from a north-south reservoir epizootic did not fit the mortality pattern well (Fig. 1B). This implies that recent ape die-offs may not have been caused only by massive spillover from a reservoir host (*1*, *5*). Rather, group-to-group transmission may have also played a role in amplifying outbreaks, as transmission within gorilla groups apparently has (*7*).

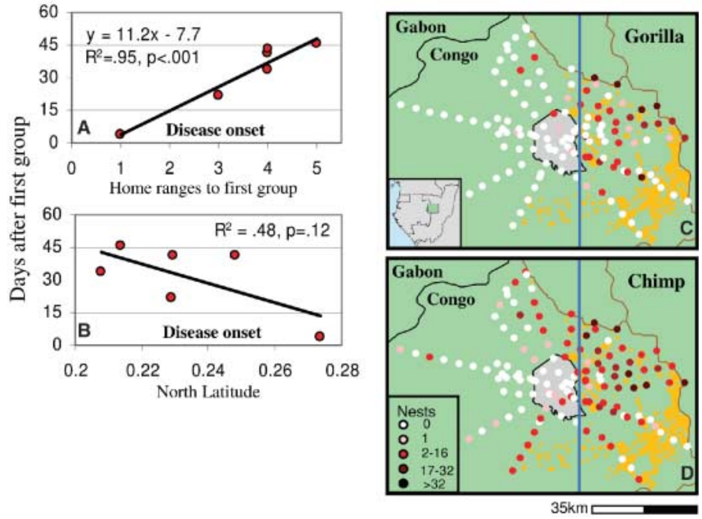

Fig. 1. (**A**) Last day at which each group was at full size plotted against number of home ranges separating that group from the first group to suffer deaths. (**B**) Day of last full group size was not well predicted by latitude, as might be expected with spillover from a north-to-south reservoir epizootic. Assuming other reservoir epizootic trajectories did not improve fit. (**C**) Gorilla nest distribution during 2004 to 2005 surveys (after ZEBOV die-offs). Shading of each dot proportional to number of gorilla nests found on a 5-km survey segment. Blue line at 14.55°E longitude separates eastern from western sampling zone. Lossi Sanctuary in gray, savannas in yellow, and roads in brown. (**D**) Chimpanzee nest distribution in 2004 to 2005 surveys.

The location of carcasses at the end of 2002 suggested a sharp mortality frontier running north to south at about longitude 14.55°E. The late-2003 outbreak reemerged along this frontier, but nest surveys conducted in 2004 and 2005 suggest that it affected only a limited enclave centered on our study site. High gorilla densities still persist in much of the region to the east of the 14.55°E frontier, but to the west a zone covering at least 2700 km^2 was largely emptied of gorillas, with nest encounter rates 96% lower than in the east (Fig. 1C). This encounter rate difference is not explained well by hunting, because the western zone experienced substantially lower hunting pressure than that in the eastern zone (table S1).

If we conservatively assume that the western zone held pre-Ebola ape densities only half as high as the 4.4 gorillas/km^2 typical of the sanctuary, then the east-west difference in nest encounter rate implies that ZEBOV killed about 5500 [minimum 3500 (Materials and Methods)]. We lack the density data necessary to make a similar estimate for chimpanzees, but east-west differences in nest encounter rate (Fig. 1D) imply a ZEBOV-induced decline of about 83% (table S1).

We hope this study dispels any lingering doubts that ZEBOV has caused massive gorilla die-offs. The Lossi outbreaks killed about as many gorillas as survive in the entire eastern gorilla species (*Gorilla beringei*). Yet Lossi represents only a small fraction of the western gorillas killed by ZEBOV in the past decade or indeed of the number at high risk in the next 5 years. Add commercial hunting to the mix, and we have a recipe for rapid ecological extinction. Ape species that were abundant and widely distributed a decade ago are rapidly being reduced to tiny remnant populations.

References and Notes

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Supporting Online Material

www.sciencemag.org/cgi/content/full/314/5805/1564/DC1
Materials and Methods
Fig. S1
Table S1
References
Movie S1

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