Shantou University Medical College,
Shantou 515031, China

e-mail: yguan@hkucc.hku.hk

†Department of Microbiology, The University of
Hong Kong, Pokfulam, Hong Kong SAR, China

‡Institute of Zoology, Chinese Academy of
Sciences, Beijing 100080, China

§Virology Division, Department of Infectious
Diseases, St Jude Children's Research Hospital,
Memphis, Tennessee 38105, USA

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CONSERVATION

Top predators and biodiversity

The charisma of top vertebrate predators is often used by conservationists as a lever for financial support^{1,2}, to raise environmental awareness^{3,4} and in planning protected areas^{5,6} — a strategy that has been criticized^{3,5,7}. Here we use information collected from five raptor species that differ widely in their diet and habitat associations to show that sites occupied by these predators are consistently associated with high biodiversity. The biodiversity at these sites is more extensive than it is at sites selected at random, or at sites occupied by species from lower down the trophic pyramid (insectivorous or herbivorous species, for example). Our results indicate that

conservation focusing on top predators can be ecologically justified because it delivers broader biodiversity benefits.

We surveyed five species of diurnal and nocturnal raptors in the Italian Alps during the breeding season: the goshawk (*Accipiter gentilis*), pygmy owl (*Glaucidium passerinum*), Tengmalm's owl (*Aegolius funereus*), tawny owl (*Strix aluco*) and scops owl (*Otus scops*) (for site locations, see supplementary information). The diversity of birds, trees and butterflies was used as a surrogate measure of biodiversity. For each raptor species, we compared the biodiversity recorded at 25 sites occupied for breeding with that at three other types of site: 25 sites randomly chosen in comparable habitat (spatial-control sites); 25 breeding sites of a randomly selected species from a lower trophic level (taxonomic-control sites A); and 25 breeding sites of a species from a lower trophic level that has specialized ecological requirements (taxonomic-control sites B). (For methods, see supplementary information.)

Compared with the three types of control site, locations occupied by top predators had greater numbers and more diversity of avian species, vulnerable avian species, butterfly species and tree species (for all raptor species and for all comparisons, $t \geq 3.14$, $P < 0.05$, except for one comparison, for which $t = 2.96$, $P < 0.07$; Fig. 1a–c). By contrast, none of the biodiversity estimates collected at sites occupied by species from lower trophic levels was higher than those collected at their associated

spatial-control sites (for all species, $t \leq 2.45$, $P \geq 0.16$; Fig. 1a–c).

We also did a simulation exercise (gap analysis^{7,8}; see supplementary information) that selects a network of protected areas by maximizing the overall level of biodiversity representation while minimizing the number of protected areas included in the network. This showed that the number of sites required to include all avian species, or all vulnerable avian species, in a hypothetical protected system was lower when using sites occupied by top predators than when using any type of control site ($t \geq 2.89$, $P \leq 0.05$). The difference between sites occupied by species from lower trophic levels and their associated spatial-control sites was not significant ($t \leq 1.64$, $P \geq 0.14$).

Furthermore, the efficiency of each protected-area system (expressed as the percentage of maximum attainable biodiversity) was higher for top-predator sites than for any type of control site ($t \geq 3.97$, $P < 0.01$; Fig. 1d), whereas it did not differ between sites that were occupied by lower-trophic-level species and their associated spatial-control sites ($t \leq 1.36$, $P \geq 0.21$; Fig. 1d). On average, networks planned using lower-trophic-level species represented 72% of the maximum species richness and 76% of the maximum richness of vulnerable species in each sample, compared with 94% and 93% for networks based on the presence of top predators.

Our results are evidence of a tight association, at least in some biological systems, between apex predators and high biodiversity, which may justify the strategic economic exploitation of top-predator species on ecological grounds. More information from other systems will be needed before the powerful top predators can be dismissed from the conservation arena as unscientific tools.

Fabrizio Sergio*, Ian Newton†, Luigi Marchesi‡

*Department of Conservation Biology, Estación
Biológica de Doñana, CSIC, 41013 Seville, Spain

e-mail: fsergio@ebd.csic.es

†Raptor Conservation Research Unit, Trento
Museum of Natural Sciences, 38100 Trento, Italy

‡Centre for Ecology and Hydrology,
Monks Wood, Abbots Ripton, Huntingdon,
Cambridgeshire PE28 2LS, UK

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Figure 1 | Biodiversity estimates are higher at sites occupied by five top predators than at randomly selected sites or at sites occupied by species from lower trophic levels (taxonomic controls). Red bars, breeding sites; blue bars, randomly selected spatial-control sites. Values represent averages $\pm$ 1 s.e. a, Numbers of all avian species. b, Numbers of avian species classified as vulnerable. c, Numbers of tree species. d, Percentage of maximum attainable avian-species richness in a hypothetical system of protected areas, as estimated by gap analysis^{7,8}.