

Tasmanian devil facial tumour disease: lessons for conservation biology

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Tasmanian devil facial tumour disease is an infectious cancer that threatens the largest surviving marsupial carnivore with extinction. After emerging in 1996, it has spread across most of the range of the species, leading to a population decline of more than 60%. This bizarre disease, in which the cancer cells themselves are the infective agent, illustrates some important general principles about disease and conservation biology, including the threat posed by loss of genetic diversity and the potential of pathogens with frequency-dependent transmission to cause extinction.

Introduction: host-specific pathogens and extinction

Since Anderson and May [1,2] first drew ecologists' attention to the significance of parasites and pathogens in the population dynamics of their hosts, the importance of infectious disease in conservation biology has been widely discussed [3–7]. In only one case to date [8] (the Polynesian snail *Partula turgida*) can extinction be unequivocally attributed to a parasite, although there is very strong evidence that the fungal pathogen *Batrachochytrium dendrobatidis*, the causative agent of chytridiomycosis, has been responsible for the extinction of several frog species in both Australia [9,10] and Central America [11] and that avian malaria and bird pox caused the extinction of up to 13 species of Hawaiian land birds [4,12,13]. It seems that the Tasmanian devil *Sarcophilus harrisii*, the largest surviving marsupial carnivore, might be added to this list in the near future. An infectious cancer, devil facial tumour disease (hereafter DFTD), has spread throughout most of the range of the species, leading to a population decline of at least 60% [14]. As a consequence of this disease, the species was formally listed as endangered by the Australian state of Tasmania in May 2008.

In the cases of frog and Hawaiian land bird extinctions, the pathogens thought to be responsible have a range of host species. Extinction was able to occur because one or more of the host species was relatively unaffected by the pathogen and therefore functioned as a reservoir, maintaining a high force of infection on the species threatened by extinction [6]. However, DFTD is entirely host specific. The tumour has never been detected in the other five members of the Tasmanian devil's family (Dasyuridae) present in Tasmania, and its biological nature (discussed below) makes it almost inconceivable that it could infect any other species.

In this review, I show that this unusual disease provides some important lessons for conservation biologists con-

cerning detecting and managing threats posed by emerging disease. This case cautions that species-specific infectious diseases can pose an extinction risk, provided their transmission is frequency dependent. DFTD is an excellent example of how loss of genetic diversity within populations increases threats from pathogens. Finally, it is an ideal case study with which to evaluate the management options available to conservation biologists faced by an emerging disease threat.

The Tasmanian devil and its tumour

With the extinction of the thylacine or Tasmanian tiger *Thylacinus cynocephalus* in the 1930s, the Tasmanian devil became the largest extant marsupial carnivore. Male devils can be up to 13 kg in weight, with females being somewhat smaller [15]. Until the appearance of Tasmanian devil facial tumour disease in 1996, devils were common and widespread across most of Tasmania, with estimates of the population size ranging up to 150 000 [16].

Since European settlement, there is anecdotal evidence that Tasmanian devil populations might have been through a series of substantial fluctuations [17]. It has been proposed that these fluctuations might have been related to the influence of density-dependent infectious disease [18]. In particular, it was suggested that an increase in devil numbers between the mid-1900s and 1990 might have been a recovery following a disease epidemic. However, there is no concrete evidence of any epidemic of infectious disease being observed in devil populations before the appearance of Tasmanian DFTD in 1996, and the external signs of the disease are so gross (see Figure 1) that it is inconceivable that this disease could have been present at high prevalence much before it was first observed. As predators of lambs and domestic poultry, devils were extensively persecuted until at least the middle of the 20th century [15], and the apparent increase in population size since the 1960s until the appearance of Tasmanian devil facial tumour disease might have been related to a reduction in this persecution.

In 1996, a devil with an unusual facial tumour was photographed at Mt William (Figure 2) in the northeast of Tasmania [15]. Although this attracted some interest, the marsupial carnivore family Dasyuridae to which the devil belongs is well known in zoos to be prone to development of tumours [19,20], so the threat that the tumour would prove to pose to Tasmanian devil populations was not immediately apparent. However, over the next five or so years, more individuals were observed with the cancer, with records spreading south and west from the original point

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