1–10 individuals for 2-hectare canyons and 1–100 individuals for 20-hectare canyons. A few decades of isolation eliminated about half these small populations, and 70 or more years of isolation eliminated almost all populations.

It seemed paradoxical at first that survival of birds should be promoted by coyotes, which are large predators that eat birds on occasion. But coyotes prey more heavily on medium-sized predators such as foxes, cats, raccoons, opossums and skunks, which in turn prey more heavily on birds than do coyotes. Hence local extinction of coyotes leads to population explosions of medium-sized predators and thence to bird extinctions. This phenomenon, which Soulé *et al.* term "mesopredator release", is likely to be of widespread importance.

Some chaparral species are much more prone to extinction than others. The characteristic sequence in which species tend to disappear after a canyon is isolated begins with black-tailed gnatcatcher and proceeds through roadrunner, California quail, California thrasher, rufous-sided towhee and Bewick's wren to wren tit as the last holdout (see figure). This sequence is close to that of the species' abundances in undisturbed chaparral (0.25, 0.02, 0.96, 1.10, 1.29, 1.75 and 2.5 pairs per hectare, respectively), as populations consisting of fewer individuals are likely to become extinct sooner. A second factor affecting this sequence is body size: big species (such as the large but rare roadrunner) can better survive short crises in availability of resources and in weather conditions. These two predictors, abundance and body size, account for almost all the variation in canyon occupancy.

Another surprising result of Soulé *et al.* is that species survival was not affected by distance from colonization sources, the biogeographical variable usually second in importance only to area. However, most of the canyons now lie 100–2,900 metres from the nearest canyon containing the common chaparral bird species, but those species are notoriously sedentary and refuse to cross strips of non-chaparral habitat wider than 50–100 metres. Thus, once development isolates a canyon by more than 100 metres, chaparral birds cannot immigrate, so Soulé *et al.* suggest that the simplest way to reverse extinctions in canyons would be to connect them to other chaparral areas. Because chaparral birds are observed in strips as narrow as 1–10 metres, even strips left along the edges of roads and under power lines could prevent extinctions. Reintroductions of chaparral species into those canyons that have already lost them could reanimate the San Diego landscape. □

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Planetary satellites

Taking a dim view of Nereid

J. Veverka

NEPTUNE has two known satellites. One, Triton, gets all the attention because of its retrograde and probably unstable orbit, its atmosphere of nitrogen and methane, and the possibility that it has an ocean of frigid liquid nitrogen[1]. The other is neglected Nereid, a faint satellite discovered in 1949 by G. P. Kuiper, about which little is known. Nereid orbits Neptune once every 360 days in an inclined, highly eccentric path[2] which takes it from 54 R_N out to 400 R_N (R_N is Neptune's radius, about 25,000 km). The unusual orbit fostered the belief that the satellite is a captured object, although some suggest[3] that Nereid was once a normal moon that was perturbed into its current elongated path by a passing body. If Nereid is a captured object, it is almost certainly not a comet. Its diameter must exceed 200 km, too large for a comet, but comparable to that of the unusual object 2060 Charon, which orbits between Saturn and Uranus[4]. Whatever Nereid's origin, it has seemed unlikely that its spin period has been synchronized by tides to its orbital period of 360 days[5]. Now, careful photometric observations by Schaefer and Schaefer, reported on page 436 of this issue[6], show that the spin period is less than 1 day, and also suggest that Nereid must be a very odd satellite that deserves considerable attention.

Schaefer and Schaefer find that Nereid could have an unusual colour and definitely displays large light variations of about 1.5 mag (a factor of 4 in brightness) with a probable period of between 8 and 24 hours. Clearly, it is not in a synchronous spin state, but more observations are needed to refine the period and obtain data on the position of the pole. The data reported in this issue contain no direct information on Nereid's albedo; hence the satellite's size remains undetermined. Because of its faintness, Nereid's infrared colours remain to be measured; it has not been possible to apply the powerful 'JHK technique' (using the J-, H- and K-bands of the infrared spectrum) developed by Cruikshank and Hartmann[7,8] to distinguish icy objects from rocky ones and obtain useful estimates of albedos for distant bodies.

Whatever its size, Nereid must be an unusual object. If the large light variation arises from an irregular shape, the satellite's longest axis must be four times bigger than the shortest dimension — making it much more elongated than any other satellite. Otherwise, some of the light variation must be caused by spots on the surface: Saturn's satellite Iapetus is spherical, for example, but still has an intensity variation of 1.8 mag. But this explanation also makes Nereid, like Iapetus, a bizarre object with highly contrasting albedo markings, indicating large-scale surface exposures of segregated and very distinct materials (such as ice and carbonaceous rock).

As already noted, Nereid's albedo is still unknown. Average diameters of known objects span the wide range from about 210 km for an albedo of 1.0 (Enceladus) to about 1,500 km for an albedo of 0.02 (darkest asteroids). If Nereid is much larger than 300 km, then it is unlikely to be very irregular. All satellites larger than Saturn's Hyperion (average diameter about 250 km) have been found to be almost spherical[9].

So what is weird about Nereid: a very irregular shape or highly contrasting markings? Fortunately, the answer will not be long in coming. Voyager 2 is on its way to Neptune and in late August 1989 will approach Nereid within 4.7 million km, close enough for the high-resolution camera to resolve details of about 50 km. Even if Nereid is only 300 km across, the data will be adequate to reveal its size, shape and albedo. If it is bigger, so much the better. The Voyager cameras will also monitor Nereid's light variation. The combined data set should give a better determination of its spin period and a clue to the orientation of the spin axis.

Spectral coverage of Nereid from Voyager will be limited, but sufficient to test whether the satellite has the peculiar colour characteristics suggested by the data reported in this issue[6]. Future JHK and higher-resolution infrared spectral measurements will be needed to begin sorting out Nereid's surface composition. Because the Voyager encounter with Nereid will be a distant one, no mass determination can be made. Nereid's mean density and internal make-up will remain unknown, as will, almost certainly, the satellite's origin. □

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