

## REEF FISH BEHAVIOR DURING A TOTAL SOLAR ECLIPSE AT PINTA ISLAND

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At 10.59 hours (Ecuadorian Time) on 26 February 1998 there was a solar eclipse at Pinta Island, Galápagos (Esenak and Anderson 1997; Figure 1). The eclipse began when the sun was at an altitude of  $68^\circ$  and the period of totality (sun completely obscured by the moon) lasted 3.5 min. Light levels during totality were equivalent to those at night, and planets and stars were visible to the human eye. The eclipse provided an opportunity to observe the effects of changes in light intensity on the behavior of reef fishes.

Reef fishes can be categorised as diurnal, nocturnal, or crepuscular (Hobson 1965, 1972, McFarland 1991). In late morning, on reefs close to the equator, only diurnal fishes are active and nocturnal or crepuscular fishes are sheltering within crevices or caves. The behavior and abundance of reef fishes was recorded before, during, and after the eclipse in an area of 10 m by 2 m at a depth of 7-10 m on the reef slope north of Pinta Island (Figure 1,  $00^\circ 37.77' N$ ,  $90^\circ 45.32' W$ ). The study area consisted of a volcanic boulder slope with c. 15% massive coral and 2% branching coral cover. All fishes  $>5$  cm LT swimming in open water above the reef were

counted at 5 min intervals from 10.20 until 10.45 hours and then counted before, during, and after totality. Each census took 2-3 min. Divers also made behavioral observations at depths of 2-15 m on the same reef.

Eight diurnal species: the anthias (Serranidae) *Paranthias colonus* (Valenciennes), the wrasse (Labridae) *Bodianus diplotaenia* (Gill), the damselfish (Pomacentridae) *Stegastes beebei* (Nichols), the hawkfish (Cirrhitidae) *Cirrhitichthys oxycephalus* (Bleeker), the angelfish (Pomacanthidae) *Holocanthus passer* Valenciennes, the butterflyfish (Chaetodontidae) *Johnrandallia nigrirostris* Gill and the grunt (Haemulidae) *Anisotremus interruptus* (Gill) were observed in the 20 m<sup>2</sup> study area. The nocturnal squirrelfishes (Holocentridae) *Myripristis leiognathos* Valenciennes and *Adioryx suborbitalis* (Gill) were sheltering in crevices.

Clear changes in the behavior of diurnal fishes were observed at 10.55 hours, 4 min before totality. At this time light levels had fallen to  $< 1\%$  of those in unobstructed sunlight at the same time of day. Plankton-feeding *P. colonus* started to descend from the shallow study area towards the reef edge and other species stopped feeding and retreated to crevices between the boulders and corals. Hawkfishes sheltered within branching corals. When the area was censused during totality (Figure 2), no diurnal fishes were swimming above the reef.

All species within the study area remained in shelter during totality, with the exception of some *P. colonus* which formed tight schools on the reef edge. There was no sign of nocturnal squirrelfishes emerging from the reef and they shared crevices and caves with diurnal species. Totality ended shortly after 11.02 hours and diurnal fishes returned to areas above the reef within 3 min. At this time fishes were as abundant above the reef as they had been 14-39 min prior to the eclipse (Figure 2). Seven minutes after totality, all species in the study area had been observed feeding.

The behavior of other species was observed outside the 20 m<sup>2</sup> study area. In deeper water (12-15 m), some nocturnal species such as the glasseye *Heteropriacanthus cruentatus* (Lacepède) and *Myripristis* spp. started to leave the shelter of caves and crevices. The diurnal parrotfishes (Scaridae) *Scarus ghobban* Forsskål and *Scarus rubroviolaceus* Bleeker stopped feeding 3 min before totality and resumed feeding 4 min after totality. During totality the parrotfishes sheltered in the reef as at night. The only diurnal species which did not exhibit typical night-time behavior during the eclipse was the surgeonfish (Acanthuridae) *Prionurus laticlavus*

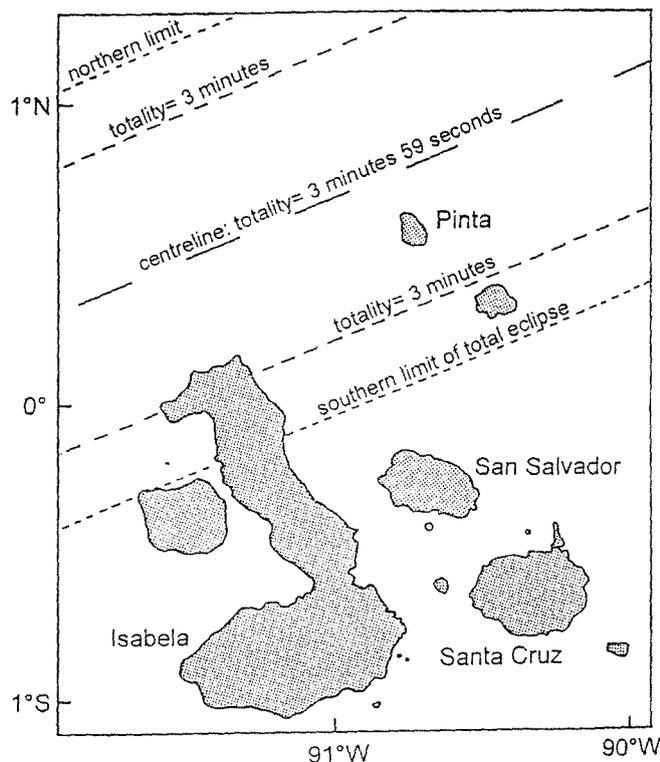


Figure 1. Map of Galápagos showing limits of total eclipse.

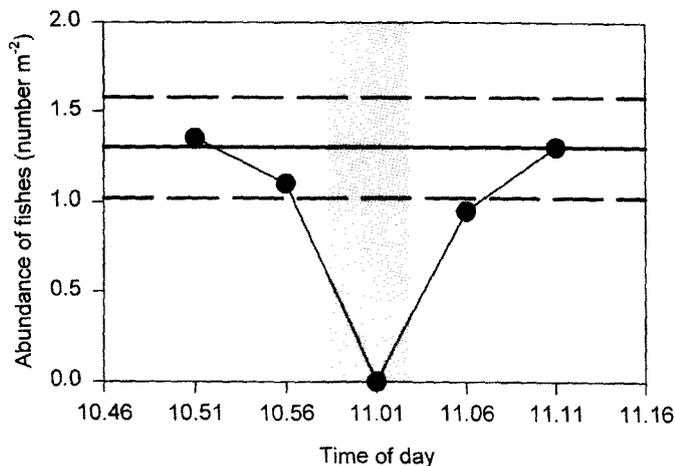


Figure 2. Abundance of fishes prior, during, and after the eclipse.

Valenciennes, which stopped grazing on algae in the surge zone approximately 4 min before totality and formed large tight schools, which swam with alarm and rapid changes in direction throughout the eclipse period. *Prionurus* continued this disturbed shoaling behaviour for 2 min after totality and did not resume grazing for another 5 min. All other species of planktivorous, herbivorous, and invertebrate-feeding fishes appeared to have adopted normal day-time behavior before this time.

The relatively slow rate of descent of fishes towards the reef at dusk is considered to be a function of the relatively slow decrease in light level (Hobson 1991, McFarland 1991). The rate of descent is governed by the trade-off between maximizing feeding rate and minimizing the risk of being attacked by predators (Hobson 1991). Our observations support the hypothesis that the behavior of diurnal reef fishes at dawn and dusk is a direct response to light level. The rapid decrease in light level during the brightest period of the day did not elicit a response noticeably different from that usually observed at dusk, but movement towards shelter provided by the reef was simply accelerated. The only species which did not respond as if subjected to a normal day-night cycle was the grazing surgeonfish *Prionurus*. Their alarmed shoaling response may have resulted from the presence of sea lions in the surge zone. The sea lions swam actively in this area throughout the eclipse, whereas they would do so rarely at night.

Studies of other animals during eclipses also demonstrate a direct response to decreased light intensity and the rapid adoption of night-time behavior. Ransome (1927) reported that brown trout *Salmo trutta* L. stopped feeding for approximately 20 min after an eclipse in the United Kingdom and Uetz *et al.* (1994) demonstrated that colonial orb-weaving spiders began to take down their webs (as they do at night) during the Mexican eclipse in 1991. Similarly, lizards reverted to

typical night time behavior during this eclipse (Ortegarubio *et al.* 1994). The next total solar eclipse will occur on 11 August 1999. The path of the moon's umbral shadow will cross marine and freshwater sites from south-west England to the Bay of Bengal.

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