AN UNUSUAL PULSE IN RECRUITMENT OF TWO REEF FISHES IN THE GALÁPAGOS ISLANDS COINCIDENT WITH THE 1997–1998 EL NIÑO

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Recruitment pulses of reef fishes can result in significant changes in both population and community structure of fishes on reefs (reviewed by Sale, 1991). These pulses can occur because of increased reproduction (Danilowicz, 1997), increased larval or juvenile survivorship (Gutierrez, 1998; Jones, 1997), or increased larval supply to an area (Caselle and Warner, 1996; Masterson et al., 1997). Pulses of commercially valuable species can also be significant factors to consider for fishery management, as a pulse may be fished down over the following years or seasons (see Sissenwine, 1984 and references therein). Environmental factors can also have a substantial impact on recruitment pulses, and while pulses are frequently observed, they can be attributed only occasionally to a specific environmental event (e.g., Cowen, 1985; Doherty, 1991; Lenarz et al., 1995; Masterson et al., 1997; Danilowicz, 1997). This paper presents evidence of pulses in recruitment of two reef fishes in the Galápagos Islands that occurred coincident with a large-scale environmental perturbation, the 1997–1998 El Niño.

The El Niño/Southern Oscillation (ENSO) phenomenon is the largest recurring global climatic perturbation, generally occurring every 3 to 7 yrs (Hansen, 1989). The Galápagos Islands are heavily affected by this phenomenon, where average sea surface temperatures can rise by more than 4°C throughout the archipelago and current patterns can change dramatically (Wyrtki et al., 1976; Glynn and Wellington, 1983; Houvenaghel, 1984; Wellington et al., in press). In normal years, the warm season in Galápagos (January–May) is dominated by the Panama Current from the north, while the cold season (June–December) is dominated by upwelling from the equatorial undercurrent from the west and the Humboldt Current from the south (Glynn and Wellington, 1983; Houvenaghel, 1984). During ENSO events, the influence of the Humboldt Current weakens drastically, upwelling ceases, the Panama Current penetrates further south for longer duration, and unusually warm water accumulates in the entire tropical eastern Pacific as the trade winds slacken (Wyrtki et al., 1976; Glynn and Wellington, 1983). Strong ENSO events can be devastating to marine ecosystems in the Galápagos as productivity drops in the warmer water (Chavez et al., 1999). Many organisms dependent on marine productivity suffer greatly increased mortality and reproductive failure, including corals, pinnipeds, marine iguanas, and sea birds (Glynn, 1984; Limberger, 1989; Laurie, 1989; Duffy, 1989; R. Bustamante, unpub. data). Abundances of fishes also change during ENSO events (McCosker and Rosenblatt, 1984), and juvenile growth of some species declines (Meekan et al., 1999), but the magnitude of these changes is unknown.

Recruitment failure in eastern Pacific fishes may be associated with ENSO events (Wellington and Victor, 1985; Lenarz et al. 1995). In contrast, in this study I document a dramatic increase in the abundance of subadult bumphead parrotfish (Scarus perrico) and adult Mexican goatfish (Mulloidichthys dentatus) following the 1997–1998 ENSO event that began in March and ended in June (Wolter and Timlin, 1998; R. Bustamante, unpubl. data). This increase may be the result of a number of factors, including increased reproduction, increased recruitment, increased juvenile survivorship or movement of in-
individuals that settled before ENSO began. To evaluate these hypotheses, I examined survey data for both species and analyzed otolith daily increment rings from subadult \textit{S. perrico} to determine if these fish settled before or after the onset of the ENSO phenomenon.

**METHODS**

**CENSUS OF DENSITIES OF \textit{S. perrico} AND \textit{M. dentatus}.—**As part of a larger monitoring study, I surveyed communities of fishes, including \textit{S. perrico} and \textit{M. dentatus}, in Galápagos at the beginning of the ENSO event from March through June 1997 and after the ENSO event from June through August 1998 and again in December 1998. Subadult \textit{S. perrico} are easily distinguished from mature fish. They are smaller (25–40 cm vs 60–80 cm for adults), distinctly colored, and lack the characteristic cranial hump of mature individuals (Rosenblatt and Hobson, 1969). Only adult \textit{M. dentatus} were seen during the study. I made repeated quantitative abundance estimates of all subadult \textit{S. perrico} and all adult \textit{M. dentatus} using a point count method modified from Samoilys (1997) in a circle of area 150 m$^2$ (radius of 6.9 m) at a variety of sites in the central islands (Fig. 1). Data from each replicate were combined to give one category value for number of individuals seen per dive.

**OTOLITH PROCESSING.—**Between December 1998 and January 1999, 6 mo after the end of the 1997–1998 ENSO event, I collected eight \textit{S. perrico} specimens from shallow waters (<7 m) using a speargun. Of these, only five had readable otoliths. Logistic constraints prevented me from collecting any specimens of \textit{M. dentatus}. To determine the age of the fish (see Victor, 1991 for a review), I mounted otoliths on slides using thermoplastic glue, then ground and polished them using abrasive paper until daily increment rings were readable under 400× magnification. I counted increment rings and measured increment widths using a microscope camera and Optimas image analysis software (Media Cybernetics Corp., Silver Spring, Maryland). It was impossible to validate counts because collections were made opportunistically after the subadults were present.
I estimated the center of the otolith using the nearest rings for two of five readable samples because no precise center mark was clearly visible. Three of the otoliths had sets of rings near the core that I presumed were pre-settlement rings. These rings generally changed beyond 100 μm from the center, which I assumed to be time of settlement, so I arbitrarily set 100 μm as the point at which settlement occurred for all specimens. The sections of each otolith nearest to the center and the edge were unreadable, so I estimated the number of increments in each of these sections using analyses of the mean increment widths in the adjacent readable sections. Settlement date was computed by subtracting age, calculated as the sum of the number of rings counted plus the estimates from unreadable sections, from the date of collection.

**RESULTS AND DISCUSSION**

Both subadult *S. perrico* and adult *M. dentatus* were absent from all sites surveyed in 1997, while in 1998 subadult *S. perrico* were present at six of the nine sites and adult *M. dentatus* were present at all sites (Table 1). Qualitative data from long-time naturalists and scientists in the Galápagos indicate that neither subadult *S. perrico* nor adult *M. dentatus* have been seen in high densities in the central islands of the Galápagos for at least the past few years, and possibly much longer (Grove and Lavenberg, 1997; J. McCosker, R. Bustamante, G. Merlen, D. Day and S. Henderson, pers. comm.).

Goatfish and parrotfish are fairly long-lived, non-migratory permanent residents of reefs (Munro, 1976; Choat et al., 1996; van Rooij and Videler, 1997; Kaya et al., 1999). Goatfishes settle at large sizes (McCormick, 1994), and could grow to roughly adult size within one year (Munro, 1976; Kaya et al., 1999). For these reasons, it is most likely that the dramatic appearance of subadult *S. perrico* and adult *M. dentatus* is the result of an uncommon recruitment pulse or increase in juvenile survivorship, and not due to movement of previously settled individuals. Results of the otolith daily increment counts support the hypothesis that subadult *S. perrico* recruited during the 1997–1998 ENSO event. All five specimens for which I obtained age estimates appear to have settled after May 1997 (nearly 2 mo after the onset of ENSO in March 1997); settlement dates range from May 1997 to May 1998 (Fig. 2).

Both *S. perrico* and *M. dentatus* are restricted to the eastern Pacific, and while waters in the eastern Pacific tend to be relatively cool for the tropics, sea surface temperatures are higher throughout most of their range than they are in Galápagos (Grove and Lavenberg,
Both parrotfishes and goatfishes are primarily warm water species, and despite the loss of primary productivity in the eastern Pacific (Chavez et al., 1999), it may be that these two species are well adapted to intense warm water events such as ENSO.

The sources and causes of recruitment pulses in fishes can be complex and difficult to identify (Doherty, 1991). Although these data do not conclusively show that ENSO was responsible for the observed increases of both *S. perrico* and *M. dentatus*, other species in the eastern Pacific have experienced notable recruitment during ENSO events in areas where adults were not common (Cowen, 1985; Lenarz et al., 1995). These studies, along with evidence presented here, suggest that ENSO can facilitate recruitment of marine species. While some species may be devastated by ENSO events, others may be adapted to survive and thrive in its extreme conditions.

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