DIFFERENTIAL DIURNAL DISTRIBUTION OF *PROCAMBARUS CLARKII* (GIRARD) JUVENILES AND ADULTS AND POSSIBLE ADAPTIVE VALUE OF COLOR DIFFERENCES BETWEEN THEM (DECAPODA, ASTACIDEA)

BY

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INTRODUCTION

Cryptic coloration frequently comprises the first line of an animal’s defense against predators (Edmunds, 1974). This is dramatically demonstrated by animals such as the flatfish, various cephalopods, and a variety of shrimp (e.g., Brown, 1935; Portmann, 1959) capable of rapid physiological color change to match their backgrounds. Slower, more permanent color changes may also function in crypsis if the animal is seen against a suitably colored background (e.g., Brown, 1934). Crayfish exhibit both types of color change at different life cycle stages. Individuals of the crayfish *Procambarus clarkii* (Girard, 1852) for example, can approximate background colors with physiological color changes when the crayfish are very young, but as older juveniles their color becomes morphologically fixed typically to a mottled brown-green, and later still as adults to a dark red. The color differences between juvenile (green) and adult (red) specimens of *P. clarkii* may reflect age- or size-related differences in selection pressure for crypsis. Individuals of *P. clarkii* typically inhabit streams with silt bottoms covered in leaf litter (Penn, 1943); a background against which juveniles but not adults are quite cryptic to a human observer in daytime. The crayfish is nocturnal, however, and the green coloration of juveniles would be cryptic only if juveniles suffer predation by diurnal, visually hunting animals. Indeed, various diurnal vertebrates are included among the predators of crayfish, and anecdotal evidence suggests that juvenile crayfish remain more exposed than adults during the day (Pennak, 1953). If the latter observation is true, then juvenile crayfish are more likely than adults to be predated during the day, and selection would favor green juveniles that appear cryptic to diurnal predators. For similar reasons, many other nocturnal organisms appear cryptic by day (Cott, 1940).

We measured the diurnal distribution of juvenile and adult specimens of *P. clarkii* relative to sheltered and exposed areas in a stream, and we examined several of the possible causes for a differential distribution. To our knowledge,
no quantitative confirmation of such a distribution has been published previously. This information will indicate whether *P. clarkii* juveniles are indeed more likely than adults to be exposed to diurnal predators, and thus whether crypsis may be a reasonable explanation for juveniles' green color.

**MATERIALS AND METHODS**

The relative distribution of juvenile and adult specimens of *P. clarkii* in exposed and sheltered areas of a stream was monitored at seven observation sites along a single stream in Riverside County, California, U.S.A. We selected this stream because it flows year round, it supports a long established and very large population of crayfish, and its narrow width, shallow depth, and clear water make it ideal for visual surveys of crayfish. The observation sites were separated from each other by about 40 m, and they averaged about 30 m in length for a total length of over 200 m of stream sampled. Stream depth at the observation sites ranged from 15 cm to 1 m in the middle, and width ranged from 1.7 m to 4.6 m. Each observation site consisted of sheltered banks on either side of an open channel with a silt bottom strewn with leaf litter and green algae. Grasses and shrubs, many with foliage extending into the stream, provided dense cover over the banks. Once a day for five days, an observation team of two or three people visited each observation site and counted the number of juvenile and adult crayfish in the middle and along the banks of the stream. For each region (middle and bank), the number of juveniles and adults in exposed and sheltered areas was also noted. Juveniles were observationally defined as individuals with predominately green bodies and chelae, and with a total body length (rostrum to telson) of less than 6 cm, i.e., less than the average lower limit on the body size of reproductively mature individuals (Penn, 1943). Adults were recognized by their larger body size, larger chelae, and red color. The stream banks were defined as the regions of stream bed that continuously sloped up to the water's edge. Shelter was defined as any covering over the entire animal as viewed from above.

Because the most important point of this survey was to determine the relative distribution of juveniles and adults in the exposed areas of the stream, we sampled the exposed areas first in all cases. To determine the number of crayfish in the exposed areas of the middle and bank regions of the stream at a particular site, the observers counted from the stream's edge all of the observable individual crayfish and scored them as either juveniles or adults. Care was taken to minimize disturbance of the crayfish. One observer then entered the stream at the downstream end of the site being sampled and flushed out crayfish in the middle that were sheltered, i.e. covered by leaf litter or algae. Meanwhile, the other observer monitored the site from the shore and noted any crayfish that entered or left the bank as a result of the disturbance and generally controlled for double-counting of individual specimens. The site was