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TONGUE REPLACEMENT IN A MARINE FISH (*LUTJANUS GUTTATUS*) BY A PARASITIC ISOPOD (CRUSTACEA: ISOPODA).—In the Gulf of California, Mexico, the isopod crustacean *Cymothoa exigua* Schioedte and Meinert causes the degeneration of most of the tongue of its host fish, the snapper *Lutjanus guttatus* (Steindachner), and attaches to the remaining tongue stub and floor of the fish's mouth by hook-like pereopods. In this position the isopod superficially resembles the tongue of its host fish. There is no indication of reduced feeding or respiratory ability in infested hosts. We herein hypothesize that these isopods serve as mechanical replacement for the fish's tongue,

Fig. 1. *Lutjanus guttatus*, the spotted rose snapper, from the Gulf of California, with the parasitic isopod *Cymothoa exigua* attached in the mouth where it has destroyed the tongue (left), and a non-infested individual with a normal tongue (right).

Fig. 2. Preserved specimen of *Lutjanus guttatus* showing relative size of the isopod in the mouth. The gill cover and jaws have been partly removed to show how far posterior to the tongue base the isopod has attached.

and represent the first known case (in animals) of functional replacement of a host structure by a parasite.

Isopod crustaceans in the Cymothoidae are ectoparasites on hundreds of species of marine and freshwater fishes throughout the world's tropical and temperate regions. They parasitize most commercial fish species but probably do not cause significant rates of mortality among their hosts. Brusca (1981) has pointed out that genera infesting buccal and gill chambers probably represent a more advanced phyletic lineage within the family than do genera attaching on the outer epidermis. Probably all species of Cymothoidae are protandrous hermaphrodites. Buccal-gill infesting species enter the gills of the host as males after a short, free-living juvenile stage, to later become functional females in the host's gills or mouth. In some species, copulation occurs within the gill chamber while in others it may occur in the buccal region. The source of nutritional energy for the large, mouth-inhabiting females is unknown, and it has been suggested that individuals in at least some of these species are actually non-feeding commensals, rather than parasites (reviewed in Brusca, 1981). Romestand and Trilles (1977a, b) described the histological alterations associated with the isopod-induced degeneration of the tongue in the sparid fish *Boop boops* (L.). They conclude that the disorganization and regression of the connective tissue and cartilage of the tongue is a result of 'hématophagie' ("blood feeding") by the parasite and that decreased blood circulation at the site of attachment is a proximate cause of the degeneration. Vu-Tân-Tuê (1973) reported on the increased likelihood of *Boop boops* to grow vomerine teeth when parasitized by the buccal cymothoid parasite *Meinertia oestroides*.

In Nov. 1979, one of us (MRG) examined 37 specimens of the spotted rose snapper *Lutjanus guttatus* caught on hook and line by fishermen near Guaymas, Sonora, Mexico. Of these, two had parasitic isopods *(Cymothoa exigua)* attached in the mouth and in both cases more than 90% of the fish's tongue was absent. Fig. 1 shows the mouth of a freshly caught specimen containing an isopod, compared with a noninfested individual. The relative size of the isopod in the mouth cavity is seen in a preserved and dissected specimen (Fig. 2), which shows it to be somewhat larger than the tongue. In life, the isopods were firmly attached to the floor of the fish's mouth by their seven pairs of hooklike pereopods. Both parasitized fish appeared to be in good condition, with full intestines and adipose deposits in the visceral cavity; one had a 20 × 50 mm piece of fish in its stomach. The two host fish were young adults (165 mm and 270 mm standard length) of a species that grows to a length of 80 cm (Thomson et al., 1979).

Recent migration of these isopods to the mouths of their hosts from the gill chambers is unlikely; there is no space in the fish's buccal cavities or gill chambers that could accommo-

date parasites approaching this size. There was very close fit between the dorsal curvatures of the isopods' exoskeletons and the shapes of the fishes' palates (convex anteriorly; more V-shaped posteriorly). Minor abrasion by the medial process of the vomerine tooth patch of the fish was evident on the first two thoracic segments of both isopods. It is clear that: 1) excepting a small proximal stub, tongues were absent in the host fish, 2) the isopods were firmly attached to the floor of the mouth in a position that superficially resembled a tongue and 3) the isopods fit well enough in the mouth to allow the hosts' vomerine tooth patch to score the anterior thoracic somites of the parasites, presumably during feeding by the hosts, during which the isopod might serve the same function as the missing tongue.

In fishes, unlike most other vertebrates, the tongue is a non-protrusible extension of the underlying branchial skeleton (and a covering for the basibranchials and basihyal) and has no skeletal muscle components of its own. It is primarily a mechanical device to hold prey in the mouth against the vomerine and palatine teeth in the roof of the mouth while being processed. There is no evidence that the teleost tongue is essential to respiration (Hughes and Shelton, 1958; Harder, 1958). Its replacement by a parasite would not appear to be a complex phenomenon.

The central question is whether the fitness of the fish, in evolutionary terms, is reduced more by the total absence of a tongue, with no isopod taking its place, or by having the isopod attached in its place. From the evidence presented we propose the hypothesis that a fish with an "isopod tongue," while perhaps not feeding as efficiently as a non-parasitized fish, feeds more efficiently than a fish with no tongue at all and no isopod in its place. It seems evident that, in isopods of this size, any displacement of host body volume that would create more space for them in the mouth must involve host tissue that the fish can somehow afford to lose. In gill-inhabiting isopods, for example, the size of the eroded cavity within the gill filaments of the host is usually identical in size with the isopod itself (Comeaux, 1942; Bowman, 1960; Bowman and Mariscal, 1968; Brusca, 1978). Naturally, there must be a limit to the amount of gill erosion that a fish can tolerate without respiratory impairment. Several workers have noted apparent decreased health in host fish sustaining multiple gill infestations of cymothoid isopods, particularly when hosts were placed in stressful environments (Keys, 1928; Westman and Nigrelli, 1955; Lewis and Hettler, 1968; Turner et al., 1969; Lanzing and O'Conner, 1975). However, it is apparent that almost the entire tongue can be replaced in the spotted rose snapper with little, if any, effect on the fish's health. That these parasitized fish were healthy and apparently feeding well supports this contention.

Mimicry of host body functions by parasites is not unknown. A classic example in animals is the induction of supernumerary larval molts in the flour beetle *Tribolium* by the microsporan parasite *Nosema*. *Nosema* produces a juvenile hormone-like substance which stimulates growth and larval molts in the host but deters adult development, resulting in giant larvae (Fisher and Sanborn, 1964). "Replacement" of host organs is also known but usually involves emasculation and replacement of host gonad body volume by the parasites (Cheng, 1964). In these cases, however, normal host organ function is naturally lost. We know of no case in animals of what could be interpreted as both structural and functional replacement of a host organ or body part by a parasite (T. C. Cheng and G. L. Hoffman, pers. comm.).

If tongue replacement is an adaptive strategy by the isopod, that is, a behavioral adaptation permitting growth of the isopod to a large (brooding) size in the host's mouth while maintaining the host's feeding function, then we might expect to see greater host-specificity in this species, since this suggests a more intimate association than seen in most other cymothoid species. However, *Cymothoa exigua* has a fairly low host specificity and has been reported from eight species of fish (in 6 families) in the eastern Pacific, including two other species of *Lutjanus* (Brusca, 1981). In all cases females attach in the host's mouth while males are found attached to the gills. This suggests that tongue replacement may not be a highly evolved or obligate evolutionary strategy, but rather that functional replacement of the tongue by this isopod is an evolutionary consequence of preadaptation to having a body plan which is well suited to this function.

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