

dendritic growth than either DHT or E alone (13), but we do not know whether this is a result of additive or interactive effects of the metabolites or of specific effects of testosterone itself.

In both birds and rodents, hormonal differences in very young animals result in behavioral and neuroanatomical divergence of the sexes as adults (14, 15). In rodents, the incidence of behaviors typical of the opposite sex can frequently be increased by hormone therapy in adulthood (16). In the adult female canary, testosterone induces singing, a male-typical behavior, although female song is not as complex as that of males (6, 17). We have shown that dimorphic features of one cell class within the song system become male-like in testosterone-treated ovariectomized females. However, although the volumes of song control brain nuclei such as RA grow with androgen treatment, they do not attain male sizes (6). Possibly, a smaller number of neurons in telencephalic vocal control nuclei of females (15) sets a limit to the size of these nuclei and to the vocal virtuosity they control.

The hormone-induced changes reported here are remarkable in their magnitude and relation to a behavioral change. To our knowledge, this is the first report of dendritic growth induced by gonadal hormones in the adult brain.

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crinology **96**, 50 (1975)]. Five millimeters of packed steroid were used for E, DHT, and testosterone in the present study. V. Luine, F. Nottebohm, C. Harding, and B. S. McEwen [*Brain Res.* **192**, 89 (1980)] had previously shown that 5-mm tubes packed with testosterone would produce in ovariectomized female canaries levels of serum testosterone similar to those seen in intact, singing male canaries.

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9. For purposes of analysis, dendritic branches were ordered from the soma outward. Thus, each dendrite joining the soma is a first-order branch, the two branch segments which arise from a first-order branch are second-order branches, and so on. In our adaptation of the Sholl analysis [D. A. Sholl, *Organization of the Cerebral Cortex* (Methuen, London, 1956)] a system of regularly spaced concentric spheres is superimposed on the neuron, centered on the cell body. The number of dendrite-sphere intersections is tabulated for each 5- μ m radial increment away from the cell body, giving a plot of overall dendritic accretion and decay as a function of distance to the cell body.
10. Each hemisphere that had well-stained cells was represented by the mean values of all cells sampled from that hemisphere. Preliminary evaluation of these data revealed that no left-right differences were present. Data from cells located in the two hemispheres were therefore pooled for the statistical comparisons. For each comparison described in the present study we used *t*-tests based on animal means. Thus, for each measure, one value was obtained for each animal.
11. When viewed from several perspectives, nearly all of the cells from the intact male and female canaries proved to have spherical or spheroidal

dendritic fields. This was so even when the cell soma, because of its proximity to the RA boundary, had an eccentric position within this field. The volume of this field was estimated for each cell by averaging the distances from dendritic tips to the cell body and treating this value as the radius of a sphere.

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The Fish Connection: A Trophic Link Between Planktonic and Rocky Reef Communities?

Abstract. *The blacksmith (Chromis punctipinnis), an abundant pomacentrid fish off southern California, regularly forages on zooplankton during the day and shelters in rocky reefs at night. This behavioral pattern results in the importation of 8 grams of carbon per square meter per year, deposited as feces in the nocturnal shelter. Since blacksmiths regularly return to the same shelters, this represents a transport of extrinsic organic carbon to the reef which is predictable in time and space.*

Inshore reef communities obtain organic carbon from two major sources: algae attached to the reef and plankton and detritus transported to the reef by water currents. Oceanic zooplankton may also be a source of energy; Hamner and Carleton (1) concluded that their contribution to the reef has not been accurately assessed. We believe that the inaccuracy is due in part to the fact that an important trophic link has been overlooked. In this report we describe a pathway through which oceanic zooplankton, consumed by planktivorous fish, are made available to the benthic community of inshore rocky reefs in a manner that is predictable in time and space.

Many temperate and tropical fish regularly aggregate in the midwater and consume zooplankton (2-4). While involvement of planktivorous fish in the importation of energy to reefs has been suggested (5), the mechanism has not been investigated. The blacksmith (*Chromis punctipinnis*) is an abundant fish of in-

shore rocky reefs in southern California (3, 6). At dawn blacksmiths emerge from their shelters and migrate to specific locations in the midwater, where they forage almost exclusively on zooplankton; at dusk they return to the reef and shelter in crevices until dawn (3, 6). This diel behavior is reflected in a pattern of gut fullness: guts are generally full at dusk and empty at dawn (3, 6). The pattern, often used as evidence that planktivores feed during the day (4), also indicates that the fish defecate at night while in their shelters.

To determine whether blacksmiths ingest feces at night, we collected fish at dusk with the aid of the anesthetic quinaldine and placed them individually into 20-liter plastic buckets that had lids fitted with plankton netting (70- μ m mesh) to promote water exchange yet exclude sediments. The buckets were placed at a depth of 10 m along the rocky bottom off Santa Catalina Island, 35 km southwest of Los Angeles, and retrieved the following dawn while most fish were emerging

from their shelters. The fish in the buckets were then measured for length and damp weight (7, 8), and all fecal pellets—easily recognized by their red coloration, cylindrical shape, and mucus envelope—were removed, dried at 60°C, and weighed. We collected measurable amounts of fecal material from all 57 buckets. The largest fecal particle was approximately 3 mm in diameter and 70 mm long. The amount of feces egested in the buckets varied directly with fish size and ranged from 6.8 mg for a 8.3-g fish to 90.1 mg for a 88.4-g fish (Fig. 1).

Egestion by the captive fish was not simply a response to anesthetics or confinement. We placed 20 polyvinyl chloride pipes (50 and 100 mm in diameter and roughly 40 cm long) into crevices along the reef to simulate natural blacksmith shelters. Each afternoon we removed accumulated sediments in the pipes with a hand pump. Blacksmiths began sheltering in some of the pipes within 48 hours. Just before dawn we removed the fish, plugged the pipes, and brought the fish and pipes separately to the surface. Nine fish (31.4 to 130 g) were removed from the pipes; six pipes contained from 3.7 to 52.7 mg of feces (15.8 ± 7.6 mg, mean \pm standard error), while the other three were empty. Although these results confirm that blacksmiths defecate in shelters, this information could not be used to check the egestion data in Fig. 1 because individual fish did not always remain in the same pipe throughout the night. Some pipes that were vacant after dusk contained fish before dawn, while others contained fish after dusk but were vacant before dawn; four pipes that were vacant when checked at dusk and dawn contained 7.6 to 35.9 mg of blacksmith feces.

We estimated the total amount of fecal material egested at night by blacksmiths. Quadrats (1 m²) were randomly placed along the reef at night and blacksmiths that sheltered within the quadrats were collected with quinaldine. Each fish was weighed and its nocturnal egestion estimated with the regression equation given in Fig. 1; total egestion per square meter was the sum of the estimated egestion of each fish within the quadrat. Based on data obtained in November 1980 from 18 quadrats at depths of 6 to 11 m, we estimate that blacksmiths egested an average of 181.5 ± 34.4 mg of feces (dry weight) per square meter per night. Variation in estimated egestion among quadrats was due to differences in fish density and body size. Density varied with bottom relief—from 0 blacksmith per square meter over a mixture of sand and flat rock to 18 in a boulder pile (mean densi-

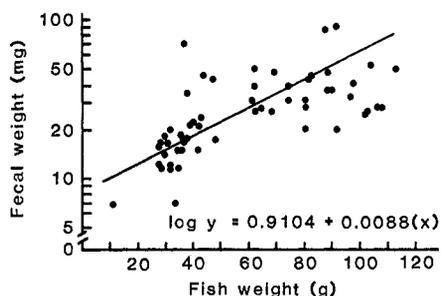


Fig. 1. Relationship between fish size (damp weight) and amount of fecal matter (dry weight) egested at night by 57 blacksmiths placed in plastic buckets along the reef. The regression formula was computed by geometric mean regression (8).

ty, 6.4 ± 1.06). Fish collected in the quadrats had a mean weight of 53.7 ± 2.5 g; maximum total fish weight per quadrat was 931.9 g.

Blacksmiths tend to return to the same shelter area over long periods of time. We tagged 13 individuals at night in a cave 4 m long by 2 m high by 1 m deep with color-coded monofilament line looped through the dorsal musculature. The cave was searched for tagged individuals 12, 13, 33, 34, 35, 47, 48, and 71 nights thereafter. Although homing behavior varied among individuals, ten of the fish were seen in the cave 12 nights after tagging, seven were seen after 35 nights, and five were seen after 71 nights (9).

We do not know the fate of the fecal material. Although we regularly find blacksmith feces on the bottom, they do not accumulate over time. Some are probably resuspended and exported, especially in heavy surge and currents. However, since many blacksmiths shelter in deep crevices, and since their feces sink rapidly (10), a portion is undoubtedly retained in the reef (11). In view of this consideration we determined the amount of organic carbon transported to the reef as blacksmith feces (12). Five analyses yielded a mean value of 12.7 percent as the carbon content (by weight) of dry feces and a mean carbon-to-nitrogen ratio of 8.0. From our quadrat counts we estimate that blacksmiths contribute a mean of 23 and a maximum of 60 mg of carbon per square meter per night as feces. While this amount may be small compared to the estimated amounts of other kinds of detritus reaching the bottom of shallow southern California waters (13), the contribution per unit area is much greater in crevices where blacksmiths concentrate. Furthermore, whereas most detritus enters benthic communities through passive, stochastic processes that vary widely on a temporal

basis, the importation of organic carbon as blacksmith feces represents an accrual of energy that is predictable in time and space.

The blacksmith is probably the only abundant fish off southern California that imports organic carbon in this way. However, many fish on tropical coral reefs forage during the day on zooplankton and shelter at night in the coral. For example, 12 species of fish off Kona, Hawaii, are diurnal planktivores and seven of these have full guts during the day and almost empty guts at night (4). Finally, this pathway of carbon import is probably not restricted to fish, but may involve other reef residents, such as demersal zooplankton (14).

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10. Sinking rates of 13 fresh fecal particles averaged 3.05 ± 0.14 cm/sec. Feces (2 to 3 mm in diameter and 10 to 40 mm long) were placed in a cylinder (10 cm in diameter) filled with seawater (15.4°C) and allowed to sink 10 cm before timing of a 20-cm descent began.
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