FIG. 1.
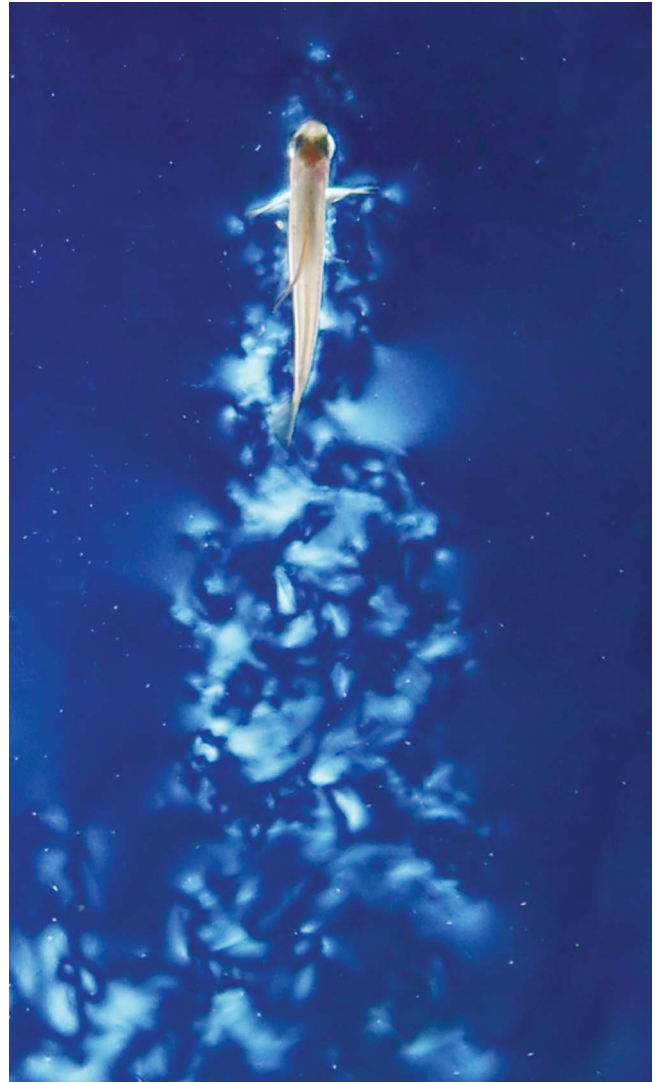

FIG. 3.
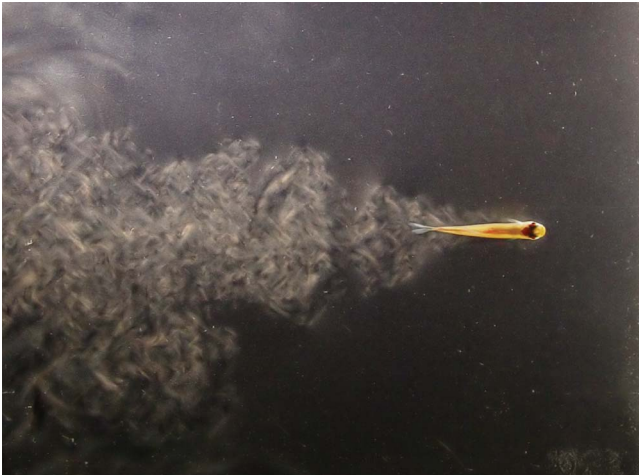

FIG. 2.

Visualization of a fish wake using tobacco mosaic virus

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We have redeveloped a flow visualization technique pioneered by Fritz Goro,[1] Time–Life science photographer from 1937–1978, but never described in print. Linearly polarized light is transmitted through a dilute aqueous suspension of tobacco mosaic virus[2] (TMV) and viewed through a crossed polarizer. Flow disturbances cause the rod-shaped TMV to orient along flow lines and so differentially refract incoming light to produce bright spots in regions of strong shear. The viral solution is invisible to the naked eye and only becomes apparent under examination through a polarizer. An attractive feature of this technique is that it is harmless to fish, providing a safe alternative for visualizing their wakes.

The black neon tetra (Fig. 1) of body length 3.6 cm maintains a steady position by flicking its fins and creating vortices. The fish's breathing is marked by a glowing white region created by the suction into its mouth. In Fig. 2, the fish swims upward generating a conical wake whose breadth and turbulent interior is made evident by the TMV. The fish brakes by extending its pectoral fins and blowing a vortex ring from its mouth.

Polarized light can also be used to illuminate a sufficiently low dilution of Kalliroscope (Fig. 3) that it is invisible to the naked eye and benign to fish.

[1] T. Goreau, P. Goreau, and S. Goreau, *On the Nature of Things: The Scientific Photography of Fritz Goro* (Aperture, New York, 1993).
[2] F. C. Bawden, N. W. Pirie, J. D. Bernal, and I. Fankuchen, "Liquid crystalline substances from virus-infected plants," Nature (London) **38**, 1051 (1936).