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Entrapment, escape, and diffusion of swimming bodies in complex environments

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We will begin by addressing the hydrodynamic entrapment of a self-propelled body near a stationary spherical obstacle. Simulations of model equations show that the swimmer can be trapped by a spherical colloid larger than a critical size, that sub-critical interactions tend to result in short residence times on the surface, and that the basin of attraction around the colloid is set by a power-law dependence on the colloid size and dipole strength. With the introduction of Brownian fluctuations, swimmers otherwise trapped in the deterministic setting can escape from the colloid at randomly distributed times. The distribution of trapping times is governed by an Ornstein-Uhlenbeck process, resulting in nearly inverse-Gaussian or exponential distributions. Analytical predictions are found to match very favorably with the numerical simulations. We also explore the billiard-like motion of such a body inside a regular polygon and in a patterned environment, and show that the dynamics can settle towards a stable periodic orbit or can be chaotic depending on the nature of the scattering dynamics. We envision applications in bioremediation, sorting techniques, and the study of motile suspensions in heterogeneous or porous environments.