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ABSTRACT

Scientists are increasingly taking advantage of a variety of technological advances to study animal behavior. Unfortunately, small animals, like insects, remain a challenge because even the smallest spatiotemporal tracking devices are too heavy to be carried by anything but the largest insects. However, extremely small Radio-Frequency Identification (RFID) tags allow researchers to record movement of insects that travel past a sensor. This technology is particularly advantageous for understanding behavior in social insects such as bees and ants that return to a single nest location. Regrettably, current RFID systems are often costly, proprietary, and difficult to reproduce. Therefore, we present the Arduino-based RFID Monitoring System (ARMS), an open-source, low-cost platform for tracking the movement and foraging behavior of social insects. ARMS integrates ultra-high frequency (UHF) RFID tags, an Arduino microcontroller, datalogging shield, and modular sensors to record time-stamped passage events at colony entrances. In laboratory trials with a captive bumble bee colony, tags (weighing ~5–16% of worker body mass) were affixed to bumble bees (*Bombus huntii*) using fast-curing UV glue. ARMS recorded 12,625 detections from 16 bees across 57 days, revealing striking individual variation in foraging frequency, timing, and career length. Some bees foraged consistently over weeks with predictable daily schedules, while others made few or irregular trips. Compared to traditional mark–recapture or video monitoring, ARMS provides continuous, high-fidelity behavioral data with minimal disturbance. Its affordability, reproducibility, and modular design make ARMS a powerful tool for studying pollinator ecology, colony dynamics, and the impacts of environmental stressors.

Keywords: RFID, social insects, behavior, tracking, Arduino, bumble bees

INTRODUCTION

The marriage of ecology and technology has allowed scientists to ask increasingly complex questions about animal movement and behavior. 100 years ago, scientists only had one kind of mark-recapture technique available to them, which involved leaving a physical identifier on a captured animal, such as a colored band or scar and attempting to recapture the animal [1,2]. These mark-recapture techniques allow for estimation of population size and structure, of movement patterns, and of birth and death rates [1,2], all of which provide important information about the ecology of diverse organisms. However, this approach requires recapturing marked animals and the behavior of those animals between capture remains a mystery. In the mid-1980s, passive integrated transponder (PIT) tags revolutionized mark-recapture techniques [3]. PIT tags consist of an 8-14 mm long microchip encased in glass that is inserted subcutaneously on an animal [3]. Tags have individual identifying numbers that can be read by a scanner placed in close range to the animal. This revealed food web dynamics when tagged animals were consumed by others and solved some of the problems that plagued traditional mark-recapture techniques such as animals removing physical tags [3,4]. However, PIT tags are still too large to be carried by small invertebrates, and the majority of animal

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