Defensive tool use in a coconut-carrying octopus

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The use of tools has become a benchmark for cognitive sophistication. Originally regarded as a defining feature of our species, tool-use behaviours have subsequently been revealed in other primates and a growing spectrum of mammals and birds [1]. Among invertebrates, however, the acquisition of items that are deployed later has not previously been reported. We repeatedly observed soft-sediment dwelling octopuses carrying around coconut shell halves, assembling them as a shelter only when needed. Whilst being carried, the shells offer no protection and place a requirement on the carrier to use a novel and cumbersome form of locomotion — 'stilt-walking'.

To date, invertebrates have generally been regarded as lacking the cognitive abilities to engage in such sophisticated behaviours. Putative examples of tool use do exist among invertebrates — perhaps most convincingly in the form of the use of leaves or pellets of sand to collect and transport food in various ant species — but these behaviours have been regarded as distinct from tool use in higher animals on the grounds that they only occur in response to very specific stimuli [2]. This highlights a key feature of widely used functional definitions of tool use [3] — simple behaviours, such as the use of an object (or objects) as shelter, are not generally regarded as tool use, because the shelter is effectively in use all the time, whereas a tool provides no benefit until it is used for a specific purpose. This rules out examples such as the use of gastropod shells by hermit crabs, but includes situations where there is an immediate cost, but a deferred benefit, such as dolphins carrying sponges to protect against abrasion during foraging [4] and where an object is carried around in a non-functional form to be deployed when required [5].

The dramatic and complex colour and shape change abilities

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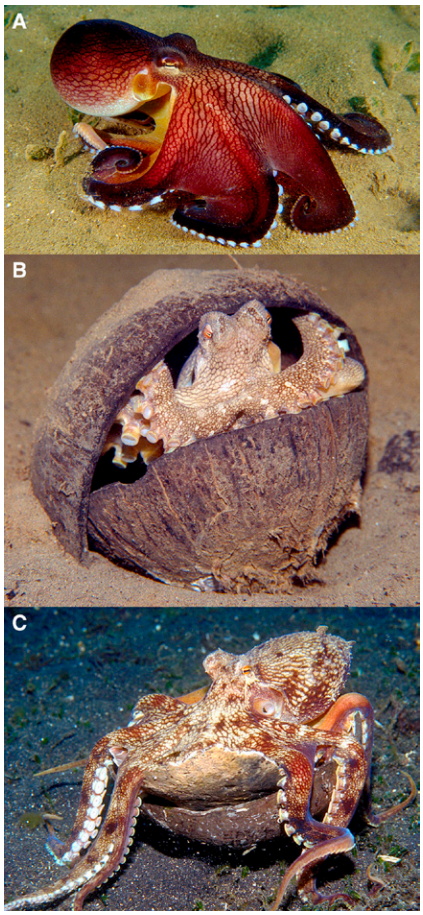

Figure 1. Veined octopus, *Amphioctopus marginatus*.

(A) Emerged on sand. (B) Using coconut shell halves assembled as shelter. (C) 'Stilt-walking' while carrying two stacked coconut shell halves (see Movie S1). Photos: M. Norman (A), R. Steene (B,C).

of cephalopods are well known [6]. However, recent observations of unexpected behavioural flexibility [7,8] and the capacity of these molluscs to physically manipulate their environment — prey manipulation, burying and den excavation [6]; arm dexterity [9]; den barricading with rocks/coral [10] — suggest that member species, particularly octopuses, could have the capacity to wield tools.

Between 1999 and 2008, we undertook more than 500 diver hours (day and night) on subtidal soft-sediment substrates to 18 metres deep off the coasts of Northern Sulawesi and Bali in Indonesia. Over this period, we studied more than 20 individuals of the Veined Octopus, *Amphioctopus marginatus* (Figure 1). Octopuses were encountered in a range of behavioral states — emerged and active on the seafloor (Figure 1A); occupying empty gastropod shells, discarded coconut shell halves (Figure 1B) or other human refuse; or buried within the substrate (with or without accompanying shells; see Supplemental Movie S1 in the Supplemental Data available on-line with this issue). When flushed from shells by the observer, individuals quickly reoccupied the shells. On four occasions (three in Northern Sulawesi, one in Gilimanuk, Bali), individuals were observed to travel over considerable distances (up to 20 m) while carrying stacked coconut shell halves below their body (Figure 1C; Movie S1). For all instances of this behaviour, observing divers (JF, MN) remained static for up to 20 minutes at 1–2 metres from stationary octopuses, which emerged from the cover of one or two shells halves, arranged the shell(s) under the arm crown, and departed. Two shell-less octopuses were also observed to extract previously un-encountered coconut shells buried in the substrate, aided by jets of water to flush mud from shells (Movie S1).

To carry one or more shells, this octopus manipulates and arranges the shells so that the concave surfaces are uppermost, then extends its arms around the outside and walks using the arms as rigid limbs. We describe this lumbering octopedal gait as 'stilt walking' (see Movie S1). This unique and previously undescribed form of locomotion is ungainly and clearly less efficient than unencumbered locomotion (i.e. costly in terms of energy and increased predator risk compared with normal walking or the faster jet swimming escape; see Movie S2). While 'stilt-walking' the octopus gains no protective benefits from the shell(s) it is carrying as the head and body are fully exposed to potential predators. The only benefit is the potential future deployment of the shell(s) as a surface shelter (Figure 1B) or as a buried encapsulating lair (Movie S1).

The fact that the shell is carried for future use rather than as part of a specific task differentiates this behaviour from other examples of object manipulation by octopuses, such as rocks being used to barricade lair entrances [10]. Further evidence that this shell-carrying behaviour is an example of tool use comes from the requirement of the octopus to correctly assemble the separate parts (when transporting two shells) in order to create a single functioning tool.

The behaviour reported here is likely to have evolved using large empty bivalve shells prior to the relatively recent supply of the clean and light coconut shell halves discarded by the coastal human communities adjacent to the marine habitat of this species.

Ultimately, the collection and use of objects by animals is likely to form a continuum stretching from insects to primates, with the definition of tools providing a perpetual opportunity for debate. However the discovery of this octopus tiptoeing across the sea floor with its prized coconut shells suggests that even marine invertebrates engage in behaviours that we once thought the preserve of humans.

Supplemental Data

Supplemental data are available at http://www.cell.com/current-biology/supplemental/S0960-9822(09)01914-9.

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