Submarine Beetles

When the tide comes in, they button down the hatches

by Tristan Wyatt

One summer evening, I watched the tide as it flowed gently up the creek like a river in reverse, creeping slowly over the salt-marsh shore in Norfolk, England. Out of the corner of my eye I saw a flash of red. A small, shiny black-and-red beetle had run in and out of the burrows. Then, momentary, the burrow was no larger than a small tea cup. After a moment of stillness, I discovered a hundred or more red and black beetles among the Salicornia—stubby little plants with water-swollen stems—that followed a contour around the salt-marsh creek. The burrows had a characteristic little heap of tailings above an entrance. The beetle I saw had emerged to scrape algae from around the burrow entrance; then it carried the moribund down below to be stored and later eaten in safety.

The intertidal zone is a difficult habitat for few animals can exploit it. It is between land and sea, and a creature adapted to one is often poorly adapted to the other. Most intertidal animals are essentially marine species, such as crabs, that colonize the land. Their major risk is dying out on a sandy beach or rocky shore. By contrast, muddy salt-marsh shores in northern Europe, with their wetland acres of mud and quiet creeks can support such land animals as spiders and birds; others simply develop behaviors to avoid getting drowned. Insects’ cuticles are already impermeable to water. The box is land, but their main challenge has been to adjust to the tides. Those that have adapted to life in this difficult environment can explain a rich habitat. The only serious competitor of Bledius is the gray mottle, a fish that comes in at high tide and also feeds on shoreline algae, leaving its tracks in the mud.

Colonies of salt-marsh beetles may occupy hundreds of square yards in the intertidal zone, with densities of a thousand adults per square yard. Colony perimeters are abrupt; no beetles dig burrows outside its boundaries. Sometimes the intertidal beach is covered with beetles; on a given shore, they can number in the millions.

How does this hard beetle survive the twice daily tides without any special bodily adaptations? It lacks, for example, scoop-like tubes that might allow it to breathe under water. The answer lies in its behavior: the salt-marsh beetle builds and maintains a snug, water-tight burrow. And the females are good parents, protecting their eggs and larvae from predators as well as from the tides.

When I first dug up some burrows, I could see that they were made with care and were perhaps the key to understanding the beetle’s adaptation. The mud is firm and will hold any shape into which it is sculpted; a pencil hole made in the surface will last for many weeks. To study the burrows’ shapes and preserve the eggs in place, I filled a few burrows with clear silicone resin. When the clear, hardened resin cast was removed from the mud, the egg chambers, each containing an egg, resembled miniature table-tennis balls stuck to the burrow’s characteristic “wane-bottom” shape. The burrow is about two and one-half inches long, with a living chamber one-quarter of an inch in diameter; a narrow neck three-quarters of an inch long opens out at the surface. The individual egg chambers extend from the living space.

I saw no evidence that burrows ever become flooded, even at high tide. To find out why, I sculpted an artificial burrow in clear agar (the kids of gel used for bacterial plates) and then submerged it. At first the narrow neck seemed effective in keeping the water out, while artificial burrows with wider openings quickly became flooded. Eventually, however, even narrow-necked burrows took on water. Since this didn’t happen in the field, I introduced a female beetle into one of my transparent burrows to observe her during my artificial “high tide.” A few minutes after the “tide” began, the beetle suddenly ran up to the burrow neck and sealed the entrance with a neat plug of agar mud, taken in mouthfuls from the wall. When I tested for the same behavior in the salt marsh, burrows from which I removed the female did indeed flood, while those with a female inside remained dry. Rather than anticipate the tide and block their burrows in advance, females can continue to feed until the very last moment, when the water reaches their doorstep.

A dry, sealed burrow poses other dangers, however. Salt-marsh beetles usually burrow into “blue” mud, which is so tightly compacted that it allows no oxygen into the burrows. (This mud is unlike the surrounding, looser, aerobic “brown” mud, which is saturated by iron oxides.) During low tide, when the burrows must be re-
...opened to allow oxygen replenishment, each beetle pushes up a new heap of tailings as it clears the entrance of washed-in debris. Only by plugging and unplugging her home in sync with the tides can a female salt-marsh beetle rear eggs and larvae in the airless mud—a life style very much like that of hidden crabs.

For most of the year, male *Glaucus* dig burrows very similar to those of females, but without the egg chambers. During the spring tides, they walk the mudflats in search of mates, pausing at burrow entrances. If caught by the tide during their search, males grip the mud and flip their abdomens over their heads to create an air bubble. After the tide subsides, those that remain continue their search, but many have been washed away. When he finds a female that allows him access, the male stays with her for some hours underground, where copulation takes place. Right after mating, the male larvae and goes in search of another female.

After fertilization, the female lays an egg every other day in an individual chamber off the main burrow. After about twenty-seven days, the first instar larva hatches, crawls into the main living chamber and begins to feed on its mother's algae collection. Eight days later, it leaves its own burrow. After six more days, it molts into a second instar, then into a third, thirteen days later. It remains in its third and final instar stage for twenty-eight days. Finally, it spends about fifteen days as a pupa. A beetle's development from egg to adult takes about a hundred days during a British summer.

Since older larvae were found alone in their own burrows, I wondered at what stage they venture above ground. William Foster, of Cambridge University, and I went to the salt marsh about midnight with red flashlights to observe the very first instars. They come out only at night and walk over the beach exploring eery crevices and dimples in the mud. (They were very interested in a hole I made with a pencil point.) If a larva ventures into an occupied burrow, the owner chases off the intruder, which continues to search for a home. Within dense colonies, the young larvae roam in tight circles during their search, but run quickly in straight lines through areas without burrow entrances. These movement patterns (also used by parasitized wasps hunting for hosts) tend to keep the larvae within the colony.

For the dispersing larvae, survival is a race against two clocks. They have to find or dig a burrow before the next tide washes them away or before the sun rises, which ever comes first. At night most predatory shorebirds are asleep. The mud is cool and damp, making capturing easy. The air is relatively humid, so the larvae (accustomed to high humidity below ground) do not risk drying out. On a summer day, the salt-marsh surface is a baking desert covered with salt crystals.

By emerging at night, the instar larvae are protected from hazards, but are exposed to others. During our nocturnal forays, we noticed a number of crab beetles, whose numbers on the muddy beach peaked about midnight. Before long, we saw one bump into a first instar salt-marsh beetle and eat it. Soon we realized that all over the marsh, *Euplia* larvae were being gobbled up. As though in a game of "blindman's bluff," the predators lunged in the direction of larvae as soon as their antennae touched one. Sometimes larvae are running back toward or forward (they can move just as fast in either direction) or by jerking their heads. With such tactics they were able to escape about half the encounters with crabs. But when we glued newly hatched first instars from maternal burrows and placed them on the beach, they were always caught. And when we removed females, we found that the burrows were soon invaded by crabbed adults that fed on newly hatched larvae.

Once a larva has successfully emerged, it runs the midnight gauntlet on the beach, and when it finds a home, it may be safe. Most predators are too large to descend into a larva's burrow, which is very similar to that of an adult. For the rest of its life, the larva does not travel again, coming up to the burrow's entrance only to collect algae as adults do, and enlarging its burrows as it grows. Unlike adults, the larva leave their faces nearly at the side of the burrow, instead of at the bottom. One summer, we were fascinated to see a female parasitoid wasp walking along the flat mud, stopping at each heap of beetle tailings. We marked each one she visited with a little numbered flag. Within ninety-nine minutes she had visited sixty-two heaps, walking a total of fifty-nine feet, but there was more to the story. After investigating some heaps with her antennae, she quickly moved on. At others she patted the little mound with her antennae and then vigorously probed with her ovipositor to find the hole hidden below. If successful, she lifted up her wings and, ovipositor first, disappeared down the burrow for up to six minutes. Underground, we learned later, the wasp had attempted to parallelize the resident larva with its sting in order to lay a pearly white egg inside its body. Why did she behave so differently that of an adult? To find out, we dug up the burrows beneath each heap she had touched. When a burrow contained a lone larva, the wasp had usually entered, but if an adult female was present, in thirteen out of fourteen cases the wasp did not enter. When the female beetle is with her...
young, she defends them vigorously. Her
good-sized jaws can nip, and she also lifts
her poison-tipped abdomen over her head
to jab as an intruder. Glands in the tip emit
noxious chemicals, some of which smell
strong even to humans. Perhaps the pur-
gest odor of adult females alerts the wasps
to stay away from guarded burrows.

A parasitic wasp that hatches out of a
beetle larva must emerge from its pupa,
and find salt-marsh beetle larvae to
parasitize, all between tides. Once inside
the unfortunate beetle larva, the wasp's
egg is protected from saltwater and preda-
tors. After depositing her eggs, a female
wasp is swept up in the next tide and ends
as lifeless flotsam. When mature, the wasp
larva bursts out of its living larva and
spins a cocoon. It will overwinter in the
chamber its host dug as its last act, emerg-
ing as an adult wasp the next summer.

Parental care appears to have evolved
independently in several groups of beetles
in similar environments. Ecologist Ellen
Larsen, working in Danish salt marshes in
the 1930s, found two other species in
which the mother digs narrow-necked bur-
rows and remains with her eggs. (The
three species belong to unrelated beetle
families: the Staphylinidae, Carabidae,
and Histeridae.)

When she compared close relatives of
the salt-marsh beetles, Larsen found one
species that lives a few yards below them
on the shore and also cares for its eggs and
larvae. However, other closely related spe-
cies that inhabit the high marsh or sand
dunes, rarely covered by tides, do not
show any parental care at all. Apparently,
species that burrow in fast-draining, aer-
ated, sandy beaches can also safely leave
their eggs. So parental care seems to be an
adaptation to the combined dangers of
tidal flooding and outright burrows. Addi-
tional advantages, such as pollinating pra-
tions and reducing larval parasitism, were
secondary gains.

After some years, beetle burrows hon-
ecomb the muddy shore, increasing aera-
tion and drainage. Now the soil is just right
for bushy salt-marsh plants that move in
and proliferate, shading and killing the
algae on which beetles feed. Soon, only
abandoned burrows remain under these
bushes, and the beetles must find a new
young marsh to colonize. Neither time nor
tide waits for these beetles.

Trevor Bland is a research associate in
the Department of Zoology and a univer-
sity lecturer in the Department of Conti-
uing Education, University of Oxford.