Inside JEB highlights the key developments in *The Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

HOW CORALLINE SEAWEEDS WITHSTAND THE WAVES

Picture by Patrick Martone

Life in the intertidal zone is pretty tough. Taking a constant battering from the waves, most creatures either hunker down, or move to a more sheltered spot. But relocation isn't an option for seaweed. They simply have to make the most of the situation where their spores took hold. Mark Denny and Patrick Martone from Stanford University's Hopkins Marine Station are fascinated by the ways that seaweeds withstand the waves. Martone explains that fleshy seaweeds 'go with the flow', but calcified seaweeds, such as *Calliarthron* are relatively inflexible compared with kelp. Curious to know how *Calliarthron* withstands the constant pounding and how the sea may have shaped this coralline seaweed, Martone and Denny set about developing a mathematical model of the organism (p. 3421).

Martone admits that developing the model coralline was challenging. According to Martone, *Calliarthron* fronds are built from calcified segments linked by flexible joints consisting of thousands of elongated cable-like cells; so the duo modelled the seaweed as short rigid beads joined by linkers made of thousands of independent flexible cables. Building the model in MatLab, Martone was able to calculate how stresses exerted on the articulated seaweed by the waves altered as he varied the seaweed's physical characteristics. Lengthening the joints, shortening the calcified segments, and shortening the calcified lips (which are found at either end of the calcified segments and are ground down, deform and break when the seaweed is under stress) made fronds more flexible and reduced the stress on the seaweed. Which ties in well with the duo's observation that joints near the base of the fronds are longer to tolerate being tugged by the sea.

Ultimately the team's mathematical seaweed looked very much like the real thing, but Martone and Denny wanted to find exactly how much wave force *Calliarthron* fronds can take before being smashed to smithereens (p. 3433). Sticking with the seaweed simulation, Martone allowed individual articulation cables in the articulated joints to fail as he increased the force on the frond and found that an individual *Calliarthron* frond can withstand wave forces as great as 10 N, rising to 20 N when neighbours in a clump supported the frond.

But how much stress does a real *Calliarthron* frond experience when at the tide's mercy? Martone had to go gathering the seaweed fronds from deep in the intertidal zone adjacent to the Hopkins Marine Station to find out. 'I had about 6 seconds between waves to jump down onto a rock, find a frond, cut it and get back up before being washed away,' says Martone. 'It's a real testament to the habitat, and a dangerous place to live,' he adds.

Having survived gathering the seaweed, Martone first tested the seaweed's resilience by attaching weights to the fronds until they snapped and found that when the frond's joints were bent through 90 deg. they could support masses over 1 kg before failing. Martone admits that 'the fact that the joints could bend through 90 deg. is impressive,' and adds that the 9.8 N force supported by the seaweed 'agreed nicely with the model prediction'. But these were static tests. Martone and Denny needed to see how the seaweed performed in more realistic circumstances.

Knowing that conventional flow tanks only produce flows of 3 m s^{-1}, well below the 25–30 m s^{-1} experienced at the shore during a storm, Denny and Martone built a wave simulator. Attaching a long pipe to the side of the laboratory building, the duo filled the top portion of the tube with water before releasing the 'wave' and sending it crashing at 10 m s^{-1} into the parking lot. 'These experiments attract a lot of attention when we run them,' laughs Martone. Attaching a *Calliarthron* frond to a force transducer in the bottom of the simulator, Martone released the wave and measured the force exerted on the frond by the rushing water. Amazingly the force on a typical large frond was only 5 N, well below the 9.8 N that individual fronds had survived in the lab, and the 20 N predicted by simulations of clumps.

But what does all this mean for a cluster of *Calliarthron* fronds clinging to the Californian coast? Although the seaweed can tolerate average waves with ease, Martone suspects that large fronds may not survive larger storms. He explains that large wave impacts probably limit the seaweed's ultimate size by tearing out larger fronds. 'Water velocity probably sets an upper limit to how large intertidal fronds grow,' explains Martone, and adds that this probably explains why seaweeds never grow as large as Californian redwoods.

10.1242/jeb.025676

Martone, P. T. and Denny, M. W. (2008). To bend a coralline: effect of joint morphology on flexibility and stress amplification in an articulated calcified seaweed. *J. Exp. Biol.* **211**, 3421-3432.
Martone, P. T. and Denny, M. W. (2008). To break a coralline: mechanical constraints on the size and survival of a wave-swept seaweed. *J. Exp. Biol.* **211**, 3433-3441.

BATS TAKE TURNS BY BANKING AND CRABBING


Picture by José Iriarte-Díaz

Manoeuvring accurately through a complex environment can be a matter of life or death. Take a wrong turn and a crash could be fatal. José Iriarte-Díaz explains that quite a lot is known about the mechanisms that birds and insects use to negotiate turns, but virtually nothing was known about the mechanics of bat turns. Filming four *Cynopterus brachyotis* fruit bats as they flew along a corridor with a 90 deg. bend in the middle, Iriarte-Díaz and Sharon Swartz from Brown University found that the animals use a combination of banking and crabbing to make it round a bend (p. 3478).

According to Iriarte-Díaz and Swartz, it took between six and seven wing beats for the bats to take the 90 deg. turn. Analysing the animal's flight path and orientation, they found that as well as banking to generate corner-turning centripetal forces, the bats reoriented their bodies in the direction of the bend during each upstroke; they were crabbing too. The bats were using the net aerodynamic force to negotiate the turn during the upstroke by reorienting their bodies to direct the force around the corner, while using the forward component of the net aerodynamic force to move in the direction of travel during the down stroke.

Having found that *C. brachyotis* bats rely on two mechanisms to turn a corner, the team compared the mammal's manoeuvrability with bird and insect data from the literature and found that the bats are much more manoeuvrable than banking cockatiels, probably due to the bat's smaller size. However, they are not as manoeuvrable as microchiropteran bats, which H. Aldridge found could turn through 180 deg. in the 1980s. The team also compared their results with David Alexander's 1986 dragonfly data, where he found that crabbing insects were significantly more manoeuvrable than banking insects, and they suggest that combining crabbing with banking gives bats the edge when taking a turn.

10.1242/jeb.025668

Iriarte-Díaz, J. and Swartz, S. M. (2008). Kinematics of slow turn maneuvering in the fruit bat *Cynopterus brachyotis*. *J. Exp. Biol.* **211**, 3478-3489.

PREPARATORY STAGE OF C-START IS PROPULSIVE


Picture by George Lauder

Startle a fish, and it'll turn tail and flee. However, repeat the exercise a few more times and you'll see that far from being uncontrolled, the fish's departure is a highly choreographed manoeuvre. Bending its body into a tight C shape, the fish then beats its tail to make its escape in less than 0.06 s. According to Eric Tytell, from the University of Maryland, scientists have studied the movements and neural circuits that control the regulated departure for more than 30 years. But there was a hole in our understanding of the fish's escape routine. No one had measured the way the fish interact with their environment. Curious to find out more about the hydrodynamics of the escape response, Tytell and George Lauder from Harvard University teamed up to film bluegill sunfish as the fish fled a threat (p. 3359).

Filming fish as they swam in a flow tunnel, the pair tracked the jets and eddies generated by the fish's bodies with a thin plane of laser light reflected off microscopic spheres suspended in the water. Keen not to disturb the water's flow as they startled the fish, Tytell rigged up a flat plate to generate a pressure wave in the water and trigger an escape response. Having spooked the fish, he filmed its reactions with the plane of laser light situated at three different levels on the fish's body to reveal the resulting fluid movements. Tytell admits that the experiments ran surprisingly smoothly, and he had collected all of the escape sequences that he needed to analyse within a week. Returning to Maryland, Tytell spent months analysing the fluid flows around the fish's bodies before building a model of the complex hydrodynamics generated as the fish turned.

The first thing that struck Tytell was the jet of water generated by the fish's tail as it curled its body into a tight C. This was closely followed by a second jet of water generated at the centre of the C shape, but directed in the opposite direction from the first jet, that continued to develop through to the end of the escape sequence. According to Tytell the first stage of the escape response, as the fish curled up into a C, was thought to be preparatory and not to contribute to the propulsion; but the second jet was clearly generating thrust as the startled fish fled. In the final stages of the escape, as the fish's tail swept to the side at the end of the first tail beat, the fish generated a third jet pulling water in towards its body, which the team suspects counteracts the fish's momentum as it turns.

Tytell admits that he and Lauder were surprised that the early stages of the escape were propulsive, although there had been theoretical studies that had predicted that the first phase was more than preparatory. What is more, it suggests that the Mauthner cells (which trigger the fish's sharp bend into a C) directly contribute to thrust generation, rather than just preparing the fish to make a speedy get away.

10.1242/jeb.025650

Tytell, E. D. and. Lauder, G. V. (2008). Hydrodynamics of the escape response in bluegill sunfish, *Lepomis macrochirus*. *J. Exp. Biol.* **211**, 3359-3369.

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