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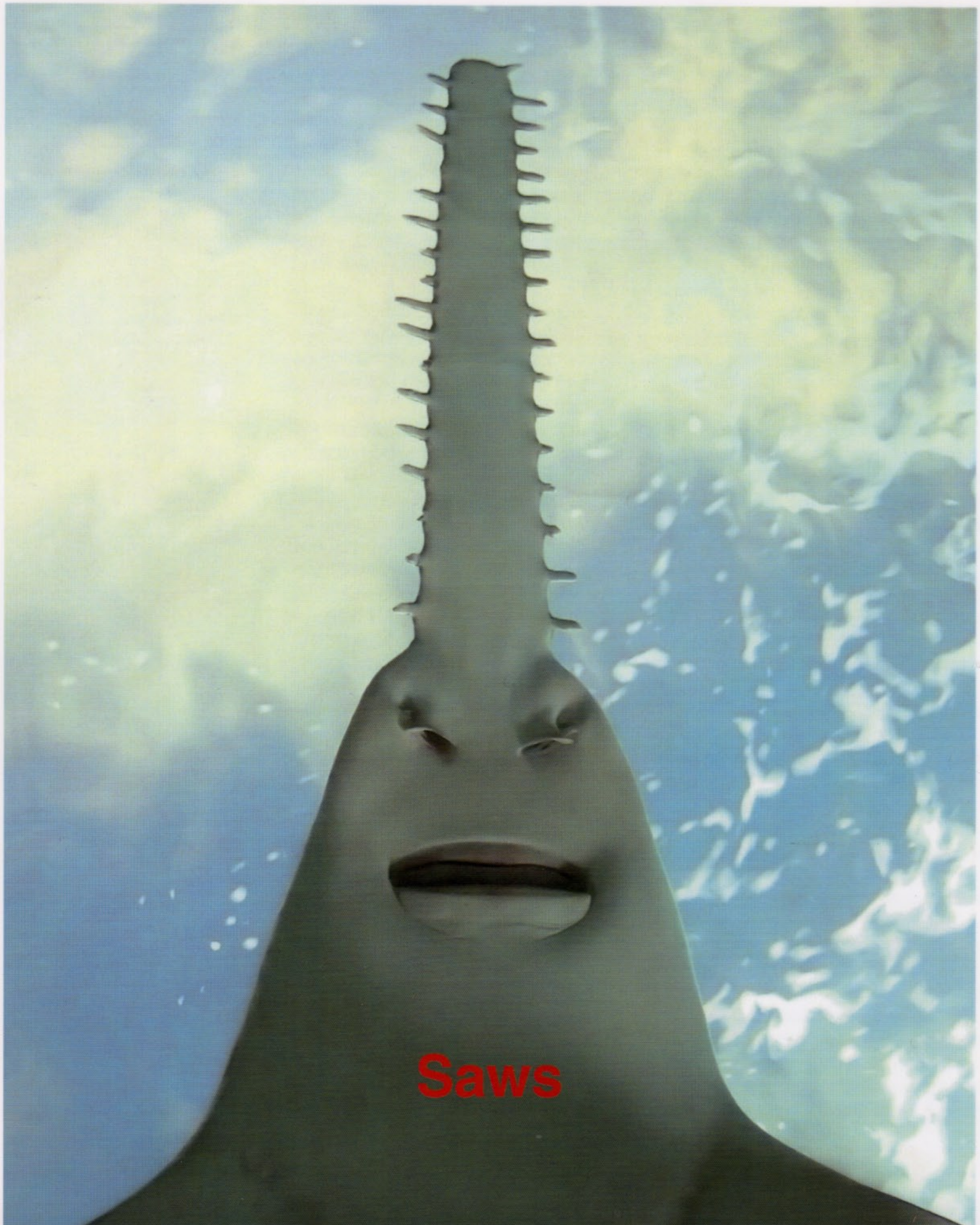

that are associated with life-span determination and initiation of age-related degenerative diseases, such as those involving AMP-activated protein kinase, TOR, and SIRT1 (sirtuin 1). A more recent suggestion is that anthocyanins may stimulate the synthesis of long chain omega-3 polyunsaturated fatty acids (PUFAs), so increasing the production of anti-inflammatory eicosanoids, compared to pro-inflammatory eicosanoids produced from omega-6 PUFAs.

What's the best way to get adequate amounts of anthocyanin every day? Anthocyanin consumption comprises an important part of campaigns to promote consumption of 5 servings of fruit and vegetables per day for a healthy life (5-a-day campaigns). Of course, many other constituents of plant-based foods such as vitamins (A, B1, B6, C and E), carotenoids and fibre contribute to the beneficial effects of 5-a-day. Anthocyanin-rich foods are easily recognised by their strong red or purple colours, and should be included in a 5-a-day diet to protect against chronic diseases such as cardio-vascular disease, neuro-degeneration and certain cancers. Because of their relative prevalence in fruit and vegetables, it should be quite easy for most people to consume adequate amounts, choosing from soft fruits such as strawberries, raspberries, blackcurrants, red grapes, cranberries, blueberries, blackberries, cherries, plums or from high-anthocyanin vegetables such as red cabbage, red onion, aubergine, purple corn, purple sweet potato, purple broccoli, red or purple potatoes, and purple cauliflower.

How do I find out more?

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The function of the sawfish's saw

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Jawed fishes that possess an elongated rostrum use it to either sense prey or to manipulate it, but not for both. The billfish rostrum, for instance, lacks any sensory function and is used to stun prey [1], while paddlefishes use their rostrum to detect and orient towards electric fields of plankton [2]. Sturgeons search through the substrate with their electroreceptive rostrum, and engulf prey by oral suction [2]. Here, we show that juvenile freshwater sawfish *Pristis microdon* are active predators that use their toothed rostrum — the saw — to both sense prey-simulating electric fields and capture prey. Prey encountered in the water column is attacked with lateral swipes of the saw that can stun and/or impale it. We compare sawfish to shovelnose rays, which share a common shovelnose ray-like ancestor [3] and lack a saw.

The sawfish's saw comprises an elongated cranial cartilage with teeth protruding from its lateral edges and is covered in a dense array of electroreceptors [3,4]. The predatory behaviour of sawfish and the function(s) of the saw have been widely speculated upon, but only one specimen of the smalltooth sawfish, *Pristis pectinata,* has been observed attacking pieces of fish floating in the water [3,5]. It has also been suggested that the saw may facilitate raking through the sand in search of buried prey, cutting tissue out of whales and slashing at schooling fish [5,6].

Here, we analysed the predatory behaviour of recently captured juvenile freshwater sawfish fed with mullet or tuna pieces (Supplemental Information). Sawfish are active predators that employ two different feeding strategies depending on whether a prey item is first encountered in the water column ($n = 62$) or on the substrate ($n = 430$) (Figure 1; Supplemental Information). Three of the 17 described behaviours involve the use of the saw, namely 'saw on substrate', 'saw in water' and 'pin'. 'Saw in water' behaviour is only produced in response to prey located in the water column and consists of rapid lateral swipes of the saw aimed at the prey. The movement can split a fish in half, impale it on the rostral teeth or sweep it onto the substrate. During 'pin' behaviour*,* a sawfish uses the underside of its saw to pin the prey on the substrate. Feeding events end with the prey being ingested. 'Ingest' behaviour was sub-divided based on prey orientation: headfirst, tail-first, or not visible. When feeding on mullet, sawfish prefer to ingest their prey headfirst (one-tailed z-approximation test; $p < 0.001$, $z = -12.33$).

Sharks and rays can detect the bioelectric dipole fields of aquatic animals. These fields elicit an innate feeding response [7]. In the present study, weak electric dipole fields (induced by currents of 18–80 μA) were presented either on the substrate or 20–30 cm above the substrate. One dipole was active during trials, while the others served as controls. Freshwater sawfish oriented towards electric dipoles located on both the substrate ($n = 146$) and suspended in the water column ($n = 57$) at a median field strength of $13.0\ \text{nVcm}^{-1}$, most commonly with a 'single turn' behaviour*.* Dipoles located on the substrate evoked predominately a biting response ($p = 0.9$) and sometimes 'wiggle' ($p = 0.1$; a slight lateral movement of the head). Dipoles suspended in the water column evoked repositioning behaviours and 'saw in water' and 'wiggle', but never a biting response (Supplemental movie S2).

Reactions of giant and eastern shovelnose rays (*Glaucostegus typus* and *Aptychotrema rostrata)* towards dipoles presented on the substrate closely resembled those of sawfish, both during approach and manipulation (Supplemental Information). Both shovelnose ray species always bit the dipole centre ($p = 1.0$). Giant shovelnose rays repeatedly bumped into and spiralled around dipoles suspended in the water column, in an uncoordinated fashion.

The sawfish's saw is unique in its use for both detecting and manipulating prey. The behaviours displayed by *P. microdon* during feeding closely resemble the reactions towards electric dipoles, as localized dipole fields in the aquatic environment indicate the presence of living organisms. The different strategies displayed towards prey located on the substrate or within

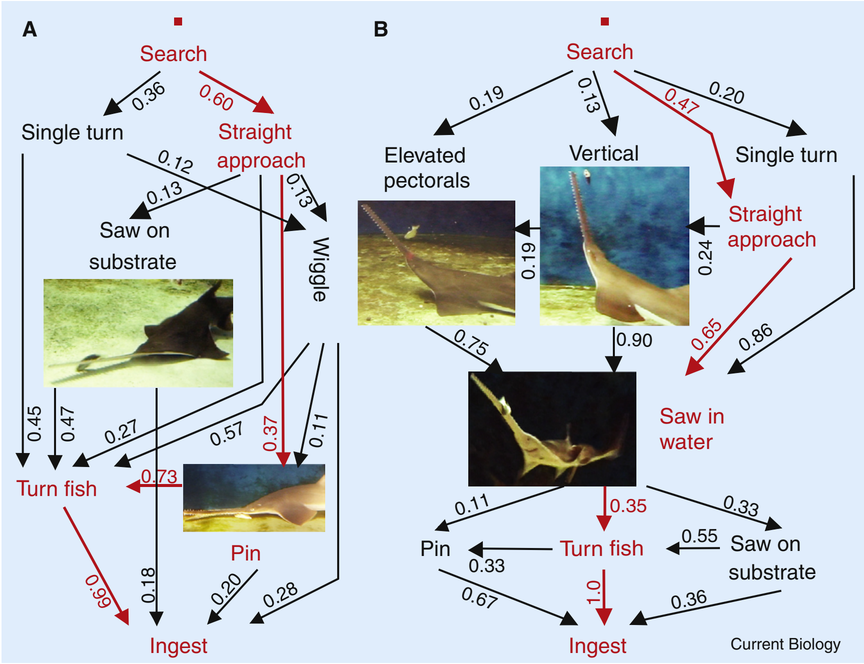

Figure 1. Kinematic graphs of feeding sequences of juvenile freshwater sawfish.
The most probable feeding sequence is highlighted in red. Only transitional probabilities >0.10 are presented. Contact with the prey item is initiated (A) on the substrate (B) in the water column. When 'searching' for food, sawfish swim close to the bottom and make rapid turns with their saw held 14.6° ± 5.5° (n = 18) above the substrate. The most likely approach patterns are 'straight approach' and 'single turn'. During prey manipulation on the substrate (A), the approach is most likely followed by 'pin' or 'turn fish', but also rarely by 'saw on substrate'. A fish is 'pinned' down with the ventral side of the saw, while 'saw on substrate' consists of lateral swipes aimed at the prey and the substrate. 'Pin' and 'saw on substrate' are most likely followed by 'turn fish', after which the fish is ingested. (B) The repositioning behaviours 'elevated pectorals' and 'vertical in water' only occur in feeding events commencing in the water column. The saw is lifted while the pectoral fins remain in contact with the substrate during 'elevated pectorals' but not during 'vertical'. Both approach and repositioning behaviours are predominately followed by 'saw in water', during which lateral swipes of the saw are aimed at the prey suspended in the water column. 'Saw in water' can be followed by 'saw on substrate', which can result in the fish being wiped off the saw. Prey is then 'ingested', or further manipulated during 'turn fish'.

the water column may be used by wild sawfish for capturing benthic and free-swimming prey. Their prey spectrum comprises catfish, mullet, and freshwater prawns [8], all of which occupy different parts of the water column. 'Turn fish' behaviour is central to any feeding event and helps headfirst ingestion, which is particularly important when ingesting catfish that possess poisonous, caudally-directed spines. Our data do not support the common belief that sawfish use their saw to rake through the substrate in search of benthic prey [5], as the saw is elevated off the substrate during search, wiggle and dipole manipulation. However, sawfish were observed to randomly scrape their teeth on the substrate, which may sharpen them (Supplemental movie S2).

Prey manipulation on the substrate by sawfish is very similar to that observed for shovelnose rays, i.e. *Rhinobatus lentiginosus* [9], *G. typus* and *A. rostrata*, and may have evolved before the elongation of the sawfish's saw. Shovelnose rays pin prey onto the substrate using their pectoral fins, head and short rostrum, while repositioning themselves before ingestion [9]. In sawfish, even the highly efficient 'saw on substrate' behaviour is more likely to occur after 'saw in water' than during manipulation of prey on the substrate. This hypothesis is strengthened by the fact that sawfish and shovelnose rays (and many other elasmobranchs) bite substrate dipoles, but only sawfish use their saw to manipulate dipoles in the water column. Therefore, the behaviours 'repeated bumps' and 'spiral' displayed by benthic shovelnose rays may be evolutionary predecessors of 'saw in water' behaviour.

Sawfish are skilled predators but, ironically, the saw is partly to blame for their global decline: the saw is easily entangled in fishing gear [3,10], perhaps as a result of targeting prey caught in the net. We hope that a better understanding of foraging behaviours in these critically endangered predators will eventually lead to by-catch mitigation strategies.

Supplemental Information

Supplemental Information includes supplemental data, experimental procedures, a table and two movies and can be found with this article online at doi: 10.1016/j.cub.2012.01.055.

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