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People often judge animal intelligence by how much their behaviour resembles ours. The lack of expression on fish faces and their very different lifestyles make it easy for people to denigrate them as unfeeling, simple creatures. But recent studies imply that fish intelligence and sentience is comparable to that of other vertebrate groups. This Australian blenny (*Ecsenius australianus*) is a denizen of the Great Barrier Reef and Coral Sea. *Photo: Robin Jeffries*

HOW FISH THINK AND FEEL

AND WHY WE SHOULD CARE ABOUT THEIR WELFARE

Don't be fooled by their lack of expression. Behavioural ecologists **Culum Brown** and **Catarina Vila Pouca** reveal fish to be thinking, feeling animals that deserve a better deal.

Watching fish swim around a home aquarium is soothing and said to be good for human health. Although pretty, they seem to be rather dull, simple creatures. But consider this – if you feed them daily at the same time and same place, they soon learn the routine and wait for you there. And if you feed them at one end in the morning and the opposite end in the evening, they also learn this routine. There may be more going on in their brains than you think.

One group popular in aquariums are the rainbowfish (genus *Melanotaenia*), which are native to Australia and New Guinea. They are definitely smarter than they look and lead complex social lives. They recognise each other, and females prefer to shoal with individuals they know rather than strangers. The males have a social hierarchy, and court females by displaying to them and chasing them. One of us (Culum) has spent many hours in the laboratory and the field putting them through their intellectual paces. When taught to swim through a hole to avoid getting trapped in a net, they proved to be quick learners, needing no more than five attempts (about an hour's training). Those in groups of five did better than those in pairs, showing they learned from each other. And even though rainbowfish live only two or so years in the wild, they still remembered the escape route a year later, without having seen the apparatus in the meantime. They also learned, like Pavlov's famous dogs, to associate a signal (a light) with food – outshining rats by learning the association within 14 trials compared to about 40 for rats (aided by a tone) – and to avoid particular locations or microhabitats associated with a predator.

Rainbowfish clearly have brain power – but they are not at all exceptional for fish. Since Culum started that research 20 years ago, evidence has piled up to overturn the reputation of fish as dull, unfeeling creatures with simple behaviours.

No one could fail to be impressed by the Machiavellian social intelligence of cleaner wrasses, for example, which rivals that of many primates. They maintain 'cleaning stations' on coral outcrops, where they remove parasites and dead skin for a wide range of clients.

Studies by Redouan ▸

They are definitely smarter than they look and lead complex social lives.

It might not be obvious in an aquarium but rainbowfish have good memories, a capacity for social learning, and many other mental capacities. They also lead complex social lives. This crimson-spotted rainbowfish (*Melanotaenia duboulayi*) is native to streams in eastern Australia. *Photo: Culum Brown*

Bshary have revealed that cleaners recognise each of their regular clients, sometimes numbering more than 100, and treat customers differently according to categories. For example, they give priority to visitors (the locals have nowhere else to go, so will wait), and they only cheat on non-predators (by nipping some skin for its nutritious mucous). Reputation and public relations are important to cleaner wrasses. They cheat less when being watched by potential clients or when they face competition for their services, and if a client leaves in a huff after being bitten, they seek to reconcile by chasing after and giving it a 'back rub'. In fish a back rub can reduce stress hormone levels just as it does in humans.

What we are learning about fish conflicts with widely held beliefs that justify public disinterest in how they are treated. A major reconciliation is needed – of the moral status of fish with the evidence of their intelligence and capacity to suffer.

Fish and animal welfare laws

Animal welfare laws are shaped by public perceptions of animals' intelligence and consciousness. The greatest concern is felt for great apes, and primates in general, because they are considered smarter than other animals, and most like us in their capacity to suffer. But as research continues to reveal that the mental capacities of animals of many types are much greater than realised, the compassion has spread, particularly to other mammals. Animal welfare laws are now much less biased to certain species, and generally recognise that all vertebrates warrant welfare concern – except fish. Fish are mostly either excluded from welfare laws (Western and South Australia for example exclude fish from the definition of 'animal') or fishing is exempted from welfare laws. Every major commercial animal production system nowadays has some animal welfare requirements – inadequate though they are – except those involving fish. Only under laws for scientific institutions are fish treated like other vertebrates in requiring welfare assessments and certain levels of care.

The problem is that most people think of fish as 'lower' species, more primitive than other vertebrates, and good mainly for eating or as low maintenance pets. More fish are eaten and more are kept as pets than any other type of animal. Because they lack recognisable facial expressions and we don't hear them vocalise, they don't generate much empathy, and few of us get to see them behaving or interacting in their natural environment. As a result, they are mostly excluded from our 'moral circle'. We don't consider their needs and wants, and fail to understand the cruelty inflicted on them. Billions of fish are caught each year in huge trawling nets. Most are crushed to death when the net is pulled up, and others suffer trauma from the pressure changes. If they survive that, they suffocate on the deck.

The other problem is that the fishing industry has powerful lobbyists and the commercial value of these practices is high. Fishing is also a popular recreation – and not regarded in the same way as other forms of hunting. It is even permitted in many national parks, where it is illegal to pick flowers.

The problem is that most people think of fish as 'lower' species.

Primitive?

The fallacy that ancient forms of life are primitive underpins the ill-treatment of fish. Scientists used to understand evolution as a linear progression from inferior to superior forms, with humans at the top of the evolutionary 'ladder'. This idea comes from the time of Aristotle but remains popular today and is still taught in some schools. Fish have an ancient lineage – they have existed for over 500 million years and all other vertebrates can be traced to a fish ancestor that lived around 360 million years ago – but ancient does not equate to primitive. With more than 32,000 species, more than all other vertebrate species combined, fish are a very successful and highly diverse group of animals. They have continued to evolve, and most fish species alive today emerged around the same time as humans. Evolution tends to be highly conservative, preserving important traits through time, so it is not surprising that fish and humans have many features in common, including in our brains and behaviour, due to our shared ancestry. We are essentially fish with a few tweaks.

Intelligent?

Fish have a sensory system as good as or better than our own – the smelling ability of sharks, for example, is about 10,000 times more sensitive than ours, and with four or more cones in their eyes, compared to three in humans, fish see more colours than we do. But how do they process and act on all the sensory information they obtain? Understanding the cognitive capacities of animals is important for animal welfare, for intelligent animals are more likely to suffer from mistreatment because they can remember and anticipate stressful and painful events. Here are just a smattering of examples showing that fish intelligence has been vastly underestimated.

Frillfin gobies (*Bathygobius soporator*) live in shallow intertidal rocky areas on both sides of the Atlantic Ocean. By roaming over their neighbourhood at high tide, they build up a mental map of their surroundings that allows them to escape predators at low tide by jumping into neighbouring pools without being able to see their destination. *Photo: Kevin Bryant*

French grunts (*Haemulon flavolineatum*) rely on cultural knowledge of pathways to their feeding sites. *Photo: Rob Atherton (bbmexplorer.com)*

Social traditions are thought to be responsible for the migration routes of many species.

Memory: Contrary to the myth that fish can remember things only for three seconds, like Dory from the film *Finding Nemo*, they actually have exceptional memories. Some fish avoid hooks for as long as a year after being caught once. Rock-dwelling gobies are champions of spatial memory. They roam in rock pools at high tide and build a mental map of their surroundings that allows them to jump into another pool if they are disturbed at low tide. Even after being moved 30 metres they can return home, and they retain their mental map for weeks after being moved. Port Jackson sharks, native to Australian waters, quickly learn to associate air bubbles with a food reward and remember this association for longer than a month.

Recognition of self and others: Most fish live in social groups, so it is not surprising they can recognise individuals. Guppies easily learn the identities of up to 15 others. Fish prefer to shoal with familiar individuals, and are better able to learn from each other and avoid predators than when they are with strangers. There is recent evidence that some fish are capable of self-recognition, regarded as one of the key criteria of consciousness. Timo Thünken and others showed that male cichlids recognise their own odour, which they preferred to the odours of brothers or unrelated males. Most fish can also determine how closely related they are to other individuals.

Social learning and traditions: Social traditions are thought to be responsible for the migration routes of many species. Gene Helfman and Eric Schultz showed this was the case for the daily feeding routes of French grunts. These inhabitants of tropical reefs in the Western Atlantic and Caribbean Sea hide by day among sea urchins and migrate together along the same route each night to their feeding grounds. When the researchers moved some to new empty sites, they headed off in the same direction as if they were at home and failed to find food. But if they were transplanted into sites with resident grunts, they followed the locals to their traditional foraging ground. Commercial fishing that targets older fish may deplete such cultural knowledge, and could explain recent shifts in fish movements like the location of cod spawning grounds.

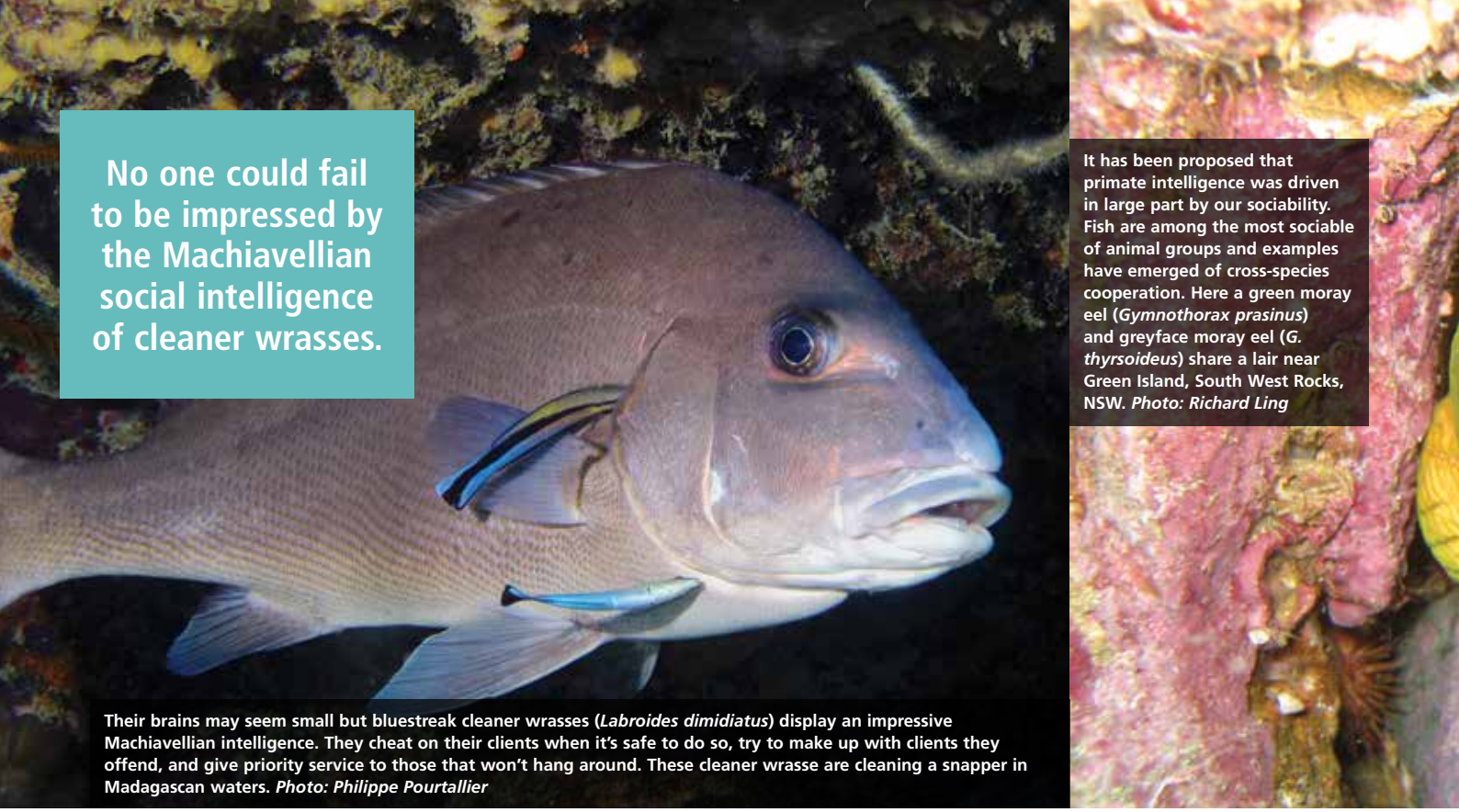
Social intelligence: The complexity of some fish interactions – including cooperation, deception and reconciliation – implies a sophisticated social intelligence in some species. One fascinating example of cooperation is team hunting by groupers and giant moray eels, reported by Redouan Bshary. It is initiated by a grouper rapidly shaking its head at an eel at rest in its rock cavity. Although normally a night hunter, the eel more often than not follows the grouper and they hunt together, the moray fossicking among the coral and the grouper cruising over the surface. The combination is so efficient that groupers catch five times as many prey than when foraging alone. Fish also tend to cooperate with each other in more dangerous deeds. When approached by a predator, sticklebacks and guppies usually form pairs to inspect the predator and obtain information about its identity and intentions, advancing towards the predator in turns. If one partner chickens out and hangs back, the other fish remembers that and refuses to cooperate in future inspections. This shows that fish punish others when they break social rules.

Tool use: Not so long ago, tool use was one in a long list of skills thought to be unique to primates. In 2006, while diving on the Great Barrier Reef, Scott Gardner heard a loud crack. He found a black-spotted tuskfish with a cockle shell in its mouth that it whacked against a rock from alternate sides until the shell broke, releasing its contents. Gardner's photos were among the first documented evidence for tool use in fish. The broken shells scattered around the rock suggested a habit, and similar middens can be found all over the Great Barrier Reef. It turns out that tool use in the wrasse family is common – a number of species crush sea urchins against corals and rocks to break off spines and access soft body parts. Cichlids and catfish often glue their eggs to leaves and small rocks and carry them around when their nest is threatened. The archerfish's remarkable ability to hunt insects on land by squirting water at them – taking account of the difference in light refraction between air and water – is also akin to tool use. They have to learn to do this and benefit from watching others.

Sentience and pain perception

Despite fish displaying all sorts of intelligent behaviours, there is still controversy about the question crucial to animal welfare – do fish feel pain? Although definitions are constantly debated by scientists and philosophers, it is generally accepted that 'sentient' animals experience pleasure and pain, while 'consciousness' includes being intelligent, sentient and self-aware. But, unlike intelligence, they are virtually impossible to measure. We cannot know what is going on inside another person's mind let alone another animal. Instead, we rely on various physiological responses and behaviours that are assumed to imply sentience and consciousness – such as changes in stress hormones with painful events and recognition of self in a mirror.

There is no doubt that fish have all the hardware for pain perception. Their pain receptors resemble ours, which is not surprising since we inherited them from a fish-like ancestor.



No one could fail to be impressed by the Machiavellian social intelligence of cleaner wrasses.

Their brains may seem small but bluestreak cleaner wrasses (*Labroides dimidiatus*) display an impressive Machiavellian intelligence. They cheat on their clients when it's safe to do so, try to make up with clients they offend, and give priority service to those that won't hang around. These cleaner wrasse are cleaning a snapper in Madagascan waters. *Photo: Philippe Pourtallier*

It has been proposed that primate intelligence was driven in large part by our sociability. Fish are among the most sociable of animal groups and examples have emerged of cross-species cooperation. Here a green moray eel (*Gymnothorax prasinus*) and greyface moray eel (*G. thyrsoideus*) share a lair near Green Island, South West Rocks, NSW. *Photo: Richard Ling*

But do fish respond to pain in an emotional, cognitive sense? When we experience pain, there is both a reflex response to stop or avoid the painful stimulus and a conscious component of feeling and remembering, which motivates us to avoid painful stimuli in future. Some biologists say the physical and emotional experiences are separate, and that fish lack the latter. But if the point of pain is to reduce the chances of injury, it is more likely that pain detection and emotional and cognitive responses have evolved as an integrated system. Fish have brain structures with functions similar to other vertebrates, including areas thought to have emotional and cognitive functions, so we strongly suspect they respond emotionally to pain.

Several studies imply that fish feel pain. For example, rainbow trout injected in the lips with bee venom or acid rub their lips on the tank, breathe heavily, and rock from side to side. They lose their appetite and their attention is impaired. They fail to take refuge from predators and dominant fish become less aggressive. The administration of analgesics to fish reduces the symptoms associated with pain, just as it does in mammals. Some show pain-based learning, associating certain objects or smells with harm and trying to avoid them. Their stress levels increase when anticipating painful events, and they are willing to pay a cost for pain relief. Lynne Sneddon found that zebrafish in pain choose to spend time in a barren chamber with analgesics rather than in the enriched chamber they usually prefer.

Just last year Sonia Rey and others found that fish also show 'emotional fever', an increased body temperature in response to stressful situations, that is widely regarded as indicative of sentience. The temperature of zebrafish rose by 2–4 degrees Celsius when they suffered confinement.

Mind the ethical gap

It is time to extend our empathy beyond the water's edge. Fish ought to be treated in the same way as other vertebrates, for their cognitive capacities are comparable – they have good memories, recognise other individuals, live in complex communities where they cooperate with and learn from each other, develop cultural traditions, and have abilities such as tool use. It is also clear they feel pain and have the capacity to suffer. These are all good reasons to include fish in our 'moral circle' alongside livestock, companion animals and wildlife such as dolphins.

Public concern for animal welfare has brought some changes to the treatment of livestock and pressure for much more. We hope that people will also start demanding humane treatment for fish. Achieving this is a daunting challenge, for it will require many changes in public perception, government agencies, fishing industries, and recreational angling. It may not be too hard to convince aquaculture industries to reform – for they can probably sell humanely produced fish for a premium price (like free range eggs), but it is difficult to conceive of change in industrialised commercial fishing practices. We could return to small scale, sustainable operations similar to artisanal fishing, but this will reduce catches and increase prices (which would also better reflect the true environmental cost of taking fish from the sea).

Now that we understand much better the impressive cognitive abilities of fish and their capacity for suffering, the first step is to change public opinion. Perhaps it's time to trade fishing rods for masks and snorkels. ■

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DR CULUM BROWN is an Associate Professor at Macquarie University with a fascination for Australian native fish. For years he has studied the behavioural ecology of fishes with a special interest in learning and memory. Recently, Culum has been involved in the debate about awareness and pain perception in fish, and has been trying to change public perception of fish intelligence and increase empathy towards them.

CATARINA VILA POUCA is a PhD student in Culum's lab. She is interested in the cognition and behaviour of sharks and rays. She has worked with blue sharks in Portugal and is now studying the spatial and social behaviour of Australia's Port Jackson shark.

Once thought to be unique to humans, tool use is regarded as a sure sign of intelligence. Diver Scott Gardner photographed this black spot tuskfish (*Choerodon schoenleinii*) on the Great Barrier Reef using a rock as an anvil to open a cockleshell. *Photo: Scott Gardner*

A revelation of recent years has been that giant moray eels (*Gymnothorax javanicus*) and groupers (*Plectropomus pessuliferus*) hunt cooperatively, with the grouper summonsing the eel with a specific head signal. There are likely to be many more such examples of inter-species cooperation. Here, a moray eel defends a morsel of food from a young potato cod. The eel then allowed another cod – known by local divers as its 'buddy' – to eat the food. We are a long way from being able to interpret such behaviours. *Photo: Robin Jeffries*