voiceless
the animal protection institute

THE WATERY WORLD OF FISHES

This booklet provides teachers with the information they need to teach students about the sentience and capabilities of fishes.

FACT SHEET: FACTS AND FISHES

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ABOUT VOICELESS

Voiceless, the animal protection institute, is an independent non-profit think tank working to promote respect and compassion for animals. By encouraging critical-thinking on animal protection issues and growing the field of animal law, Voiceless is equipping today's youth to become tomorrow's decision-makers.

CONTACT

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Thank you to Professor Culum Brown, Dr Cat Dorey and Dr Dinesh Wadiwel for their assistance in reviewing this booklet.

Want to keep reading on this topic? This information and more can be found in Jonathan Balcombe's book, *What a Fish Knows* (Scientific American / Farrar, Straus and Giroux, 2016).

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The watery world of fishes

Oceans cover more than 70% of the Earth's surface, so it's no surprise that we share this planet with a staggering number of fishy individuals. In fact, fishes make up 60% of all vertebrate species on the planet (and that's just the fishes we know about).

So far, at least 33,230 species of fishes have been identified,[2] but some scientists estimate that this figure may be only half of the fish species that actually exist.

Did you know that humans have only explored 5% of the ocean? That means a majority of the ocean and its inhabitants remain undiscovered.[1]

WHAT'S A VERTEBRATE?

Vertebrates are animals with a backbone. There are five major groups: mammals (including humans), birds, reptiles, amphibians, and fishes.

What do we mean when we talk about fishes?

When we use the term 'fish', we clump together a huge range of diverse aquatic individuals from thousands of species. Salmons, goldfish, eels, manta rays, and sharks are all different kinds of fishes.

Ethologist Jonathan Balcombe says this kind of grouping can be misleading, "because it fails to represent the profound distinctions among fishes."[3] Consider, for example, that a tuna is more closely related to a human than to a shark… yet both are simply called 'fish'.

To put this in perspective, Professor Victoria Braithwaite reminds us that "there are approximately 30,000 described species of fish, but only 5416 mammals."[4]

The term 'fishes' is used to refer to multiple species.

Note: words that are orange and in bold are defined in the glossary on page 20.

Why is it important to learn about the sentience and capabilities of fishes?

Though very few of us encounter them in their natural habitat, fishes are the most consumed type of animal in the world and also the most popular 'pet'. A huge number of fishes are used in scientific research (second only to mice), while around one in every ten people engages in recreational fishing.[5]

This ratio is even higher in Australia, where it has been found that young people (aged 5 – 14) participate in recreational fishing more than any other age group.[6]

Yet some people don't think of fishes as 'animals'.

This might be because fishes seem alien at first glance. They live in a vastly different, unfamiliar environment and don't have recognisable facial expressions.

As a result, many people treat fishes differently to the way they would treat other animals.[7]

Some animal welfare laws in Australia even exclude fishes from the definition of animal, leaving them entirely unprotected. Fishing is also often exempted from welfare laws.[8] As fish experts Professor Culum Brown and Dr Catarina Vila Pouca point out, fishing is "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."[9]

In recent years, scientific evidence has accumulated to show that fishes are highly intelligent, socially sophisticated and, most importantly, capable of suffering.

SO, WHAT DO WE KNOW ABOUT FISHES?

The following pages showcase some of the latest findings about sentience and capabilities of fishes. This research busts common myths about fishes being unsophisticated, unfeeling, unintelligent and unsocial.

MYTH 1

FISHES AREN'T SOPHISTICATED

Are fishes primitive?

Many people are quick to dismiss fishes because they first came into existence such a long time before modern humans (530 million years ago, compared to 2 million years ago for humans).[10]

Instead of existing in a primitive form for millions of years, fishes have been constantly evolving. As a result, fishes have extraordinarily sophisticated senses and abilities.

Moreover, all humans evolved from a fish-like ancestor, which in simple terms means that "[w]e are essentially fish with a few tweaks."[11]

So, what capabilities do fishes have?

Smell, sight and taste

Fishes have highly developed sensory systems that often outperform humans.[12]

For example, the smelling ability of sharks is about 10,000 times more sensitive than our own. Salmon also have a remarkable sense of smell, which has been likened to detecting the smell of less than a single drop of chemicals in an Olympic-sized swimming pool.[13]

Many fishes can also better differentiate between colours and see them far more vividly than we do.[14]

They also have a more refined ability to taste, as they hold the animal record for the most number of taste buds. Their taste buds can be almost anywhere on their bodies, not just in their mouths.[15]

THE SMELLING ABILITY OF SHARKS IS ABOUT 10,000 TIMES MORE SENSITIVE THAN OUR OWN.

Communication

Many people mistakenly think that fishes are silent.

Fishes actually have more ways of producing sounds than any other vertebrate group. To make noise, they can rapidly vibrate their swim bladders, grate their teeth, rub their bones or gills together, expel bubbles, and more.

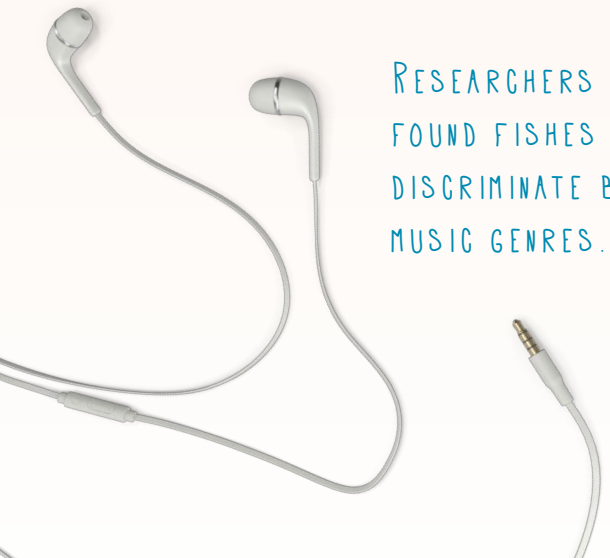
Human technology has only recently caught up with fish communication, allowing us to hear underwater conversations (and discover that there are dawn and dusk choruses!). They make various sounds, including hums, whistles, grunts, croaks, purrs, clicks, chirps, growls, and snaps.[16]

Female cod and haddock even choose males based on their drumming ability (a muscle that vibrates on their swim bladder), while minnows may shout at each other during aggressive exchanges.[17]

It's been found that some fishes have developed such refined hearing abilities that they can eavesdrop on the ultrasonic sounds made by dolphins (who may be hunting nearby), while other researchers have found fishes who can discriminate between music genres.

Such sensitive hearing abilities mean that fishes are vulnerable to human-made noise, like the sounds emitted by ships or in underwater mining and exploration.[18]

MINNOWS MAY SHOUT AT EACH OTHER DURING AGGRESSIVE EXCHANGES.



RESEARCHERS HAVE FOUND FISHES WHO CAN DISCRIMINATE BETWEEN MUSIC GENRES.

Navigation

Fishes are champion navigators, which is necessary in vast watery environments.

Some fishes detect the turbulence reflected off underwater obstacles or distant land formations to navigate their way through the water (hydrodynamic imaging). Others use the angle of the sun (sun compassing) or tune into the Earth's magnetic fields (electromagnetic navigation).[19]

Many fishes also have keen **electroreception abilities,** which is the fastest form of communication in the animal kingdom. This sensitivity, which is particularly effective in water, is so refined that a shark may be able to sense the heartbeat of a fish hiding six inches under the sand.[20]

MYTH 2 FISHES AREN'T SENTIENT

"Since, to us, they appear devoid of expression, people often assume they are incapable of feeling."
- Vicky Bond [21]

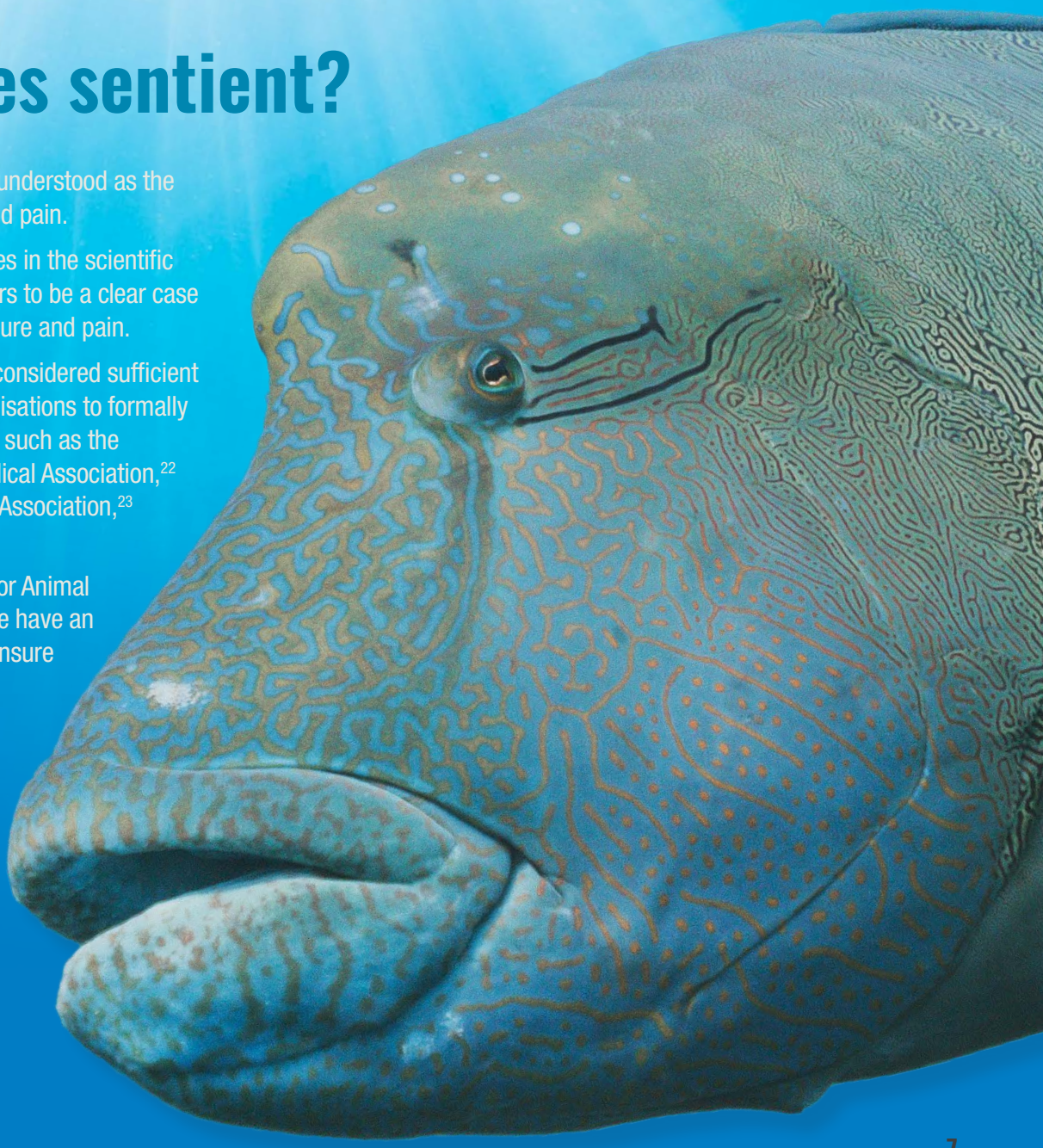
Are fishes sentient?

Sentience is commonly understood as the ability to feel pleasure and pain.

Although debate continues in the scientific community, there appears to be a clear case that fishes can feel pleasure and pain.

This evidence has been considered sufficient enough for various organisations to formally recognise fish sentience, such as the American Veterinary Medical Association,[22] the Australian Veterinary Association,[23] and RSPCA Australia.[24]

The World Organisation for Animal Health also states that we have an ethical responsibility to ensure the welfare of fishes.[25]



Biology of fishes

The main argument against fish sentience is based on a particular interpretation of fish biology. In 2012, a paper was published concluding that fishes cannot feel pain or have other feelings, because they are **unconscious.**

The basis of this conclusion was that fishes lack a part of the brain called the **neocortex**, which only **mammals** have, and that a neocortex is necessary in order to feel pain.[26]

Numerous scientists have since produced a large body of evidence to dispute this.

These scientists explain that different anatomy can still achieve the same results, and fishes have all the hardware they need to have the same experiences as mammals with a neocortex.[27]

In fact, they explain that the neocortex takes over functions that may also exist in other parts of the brain.

For example, consciousness in birds has been widely accepted even though they too lack a neocortex.[28]

Instead of a neocortex, birds have a paleocortex and fishes have a pallium, both of which are sufficient to suggest that these animals are conscious and able to feel pain.

A group of scientists held a forum at Cambridge University to discuss the current scientific understanding of animal consciousness. As a result, they drafted and signed a Declaration on Consciousness, which concludes that consciousness isn't limited to vertebrates; that emotions can derive from parts of the brain other than the cortex; and that pain can still be felt without a neocortex.[29]

In simple terms, the case in favour of fish sentience is that fishes have all the biological and physiological systems necessary for **pain perception.**

Moreover, many scientists draw attention to how similar these systems are to those of mammals, including humans. They explain that this shouldn't be surprising, as humans inherited our pain receptors from fish-like ancestors.[30]

Behaviour

In addition to having similar or equivalent bodily functions, fishes show all of the **behavioural markers** of feeling pain. They learn to detect and avoid painful **stimuli**, which is a fundamental indicator of pain perception.[31]

More so, fishes get distracted from simple tasks or everyday behaviour when in pain, which suggests they are **cognitively affected.**

They also respond positively to pain relief, and studies show they are willing to pay a cost to get it. For example, certain fishes chose an otherwise less desirable tank because it had pain killers in the water.[32]

Purpose

Finally, many scientists point out the necessity and usefulness of pain perception for survival.

AS PROFESSOR CULUM BROWN EXPLAINS,

"...it would be impossible for fish to survive as the cognitively and behaviourally complex animals they are without a capacity to feel pain."[33]

Are fishes conscious?

While sentience is generally understood as feeling pain and pleasure, 'consciousness' refers to **intelligence** and **self-awareness.**[34]

The two main elements of pain perception are a **reflex** to stop or avoid a stimulus that causes pain, and the conscious act of feeling and remembering that in the future.

Some scientists argue that fish only have reflexes to pain. Others argue that these two elements have evolved as an integrated system, because they are both necessary for animals to survive and prosper.[35]

Additionally, research points to a strong connection between pain or discomfort and an emotional state.

For example, studies have shown how fishes learn to avoid places where they encountered a predator or a hook, with scientists noting that "it is difficult to explain the results of these studies without assuming that the fish feel fear."[36]

Research has also found that farmed fishes display the same behaviours and brain chemistry as those of severely depressed and stressed humans.[37]

FISHES HAVE FUN

Fishes have also been documented playing either alone or with other fishes (or even other species of animals). Some fishes have been seen riding bubbles, playing with objects or inventing games with each other.

The actions have been labelled 'play' because they don't serve any necessary purpose and occur spontaneously.[40]

Can fishes experience pleasure?

At the other end of the emotional scale, there is growing evidence of fishes actively seeking out pleasure or **positive cognitive states.**[38]

Many divers have reported instances of fishes seeking physical affection, such as moray eels or groupers who approach familiar humans to receive pats and chin rubs.

In one such anecdote, a human reported that a particular grouper called Larry "even rolls side to side to be petted properly, as a dog or a pig will do."[39]

MYTH 3 FISHES AREN'T SMART

Fishes are commonly regarded as unintelligent, encouraged by popular myths such as the '3-second memory'. As a result, many people may be surprised to find out that fishes have passed self-recognition tests, actually have excellent memories and are even known to use tools.

Are fishes smart?

If an animal has a large brain in ratio to their body, they are generally considered to be intelligent. Fish often have a small brain-to-body ratio, which means they don't fare well when brain-size is used as a marker of intelligence.

This test, however, does not take environmental factors into consideration.

Fish benefit from having large muscles to propel them through water, which is 800 times denser than air. As they are almost weightless underwater, they don't need to limit the size of their body in ratio to their brain. [41]

In fact, fishes can perform almost any feat of learning displayed by a mammal or bird, and have even outperformed primates in successfully solving certain puzzles.[42]

> **"When fishes outperform primates on a mental task, it is another reminder of how brain size, body size, presence of fur or scales, and evolutionary proximity to humans are wobbly criteria for gauging intelligence."**
> - Jonathan Balcombe[43]

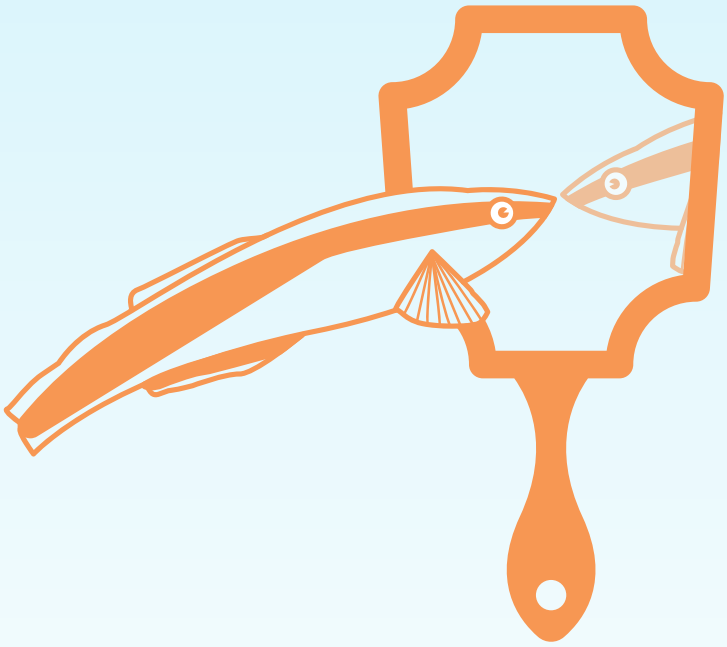
That said, just like humans, some individual fish may be more intelligent than others of their species!

Are fishes self aware?

The classic test for self-awareness is the 'mirror self-recognition test'.

If an animal recognises him or herself in a mirror, the species is celebrated as having complex cognitive abilities.

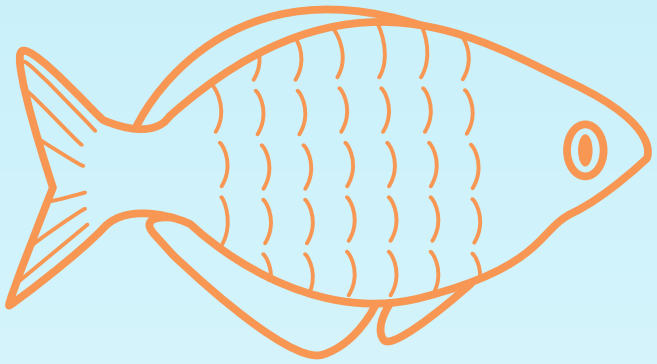
In the past, only a narrow selection of species has been thought to be self-aware, including humans, elephants, dolphins, crows, and ravens.



In 2018, a particular species of fish (the cleaner wrasse) passed the mirror self-recognition test, indicating that fishes may be self-aware too.[44]

Do fishes have good memories?

Fish have been found to have exceptional memories. They can recognise and remember individual humans even after several months, something which many humans would find tricky in reverse.[45]



Case study: Rainbowfish

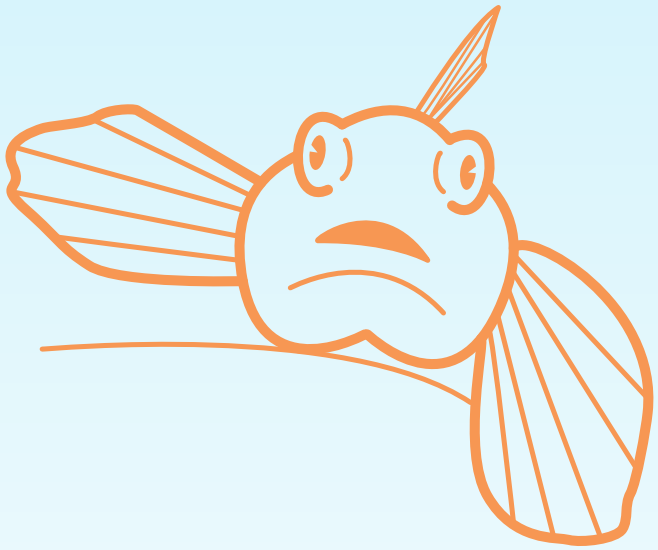
In one experiment, captive rainbowfish were exposed to an unusual contraption with a complicated escape route. They required a few attempts to successfully work out how to escape. The fish did not see the contraption again until one year later, when they showed on their first go that they still remembered the safe way out! This is especially impressive when you consider that rainbowfish only live for about two years in the wild.[46]

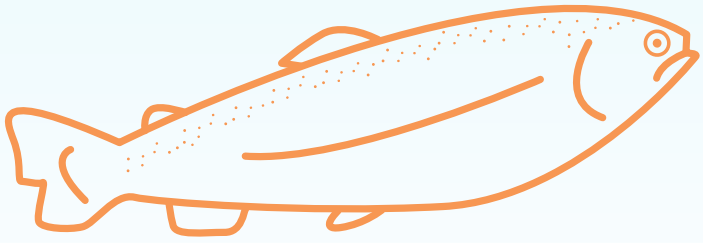
Case study: Frillfin Goby

The frillfin goby is a master mapmaker. An excellent spatial memory allows the goby to escape predators by jumping through the air to neighbouring rockpools, without being able to see the destination.

To do this, the goby creates a mental map of an intertidal zone by swimming over it at high tide, memorizing the topography and calculating which rocky depressions will form future pools at low tide.

They can also find their way back to their home pool after being displaced by 30 metres, and remember the topography for at least 40 days without revisiting the pools. From this, it's clear that gobies (alongside other species) have a remarkable memory for spatial detail.[47]





Case study: salmonids

Salmonids (salmons, trouts, greylings, and more) are another group of fishes with an amazing long-term memory. When young salmonids hatch inland, they imprint the chemical signature of their home stream. Years later, after living in the open ocean, mature salmonids are able to find their home streams by remembering and following subtle chemical cues.[48]

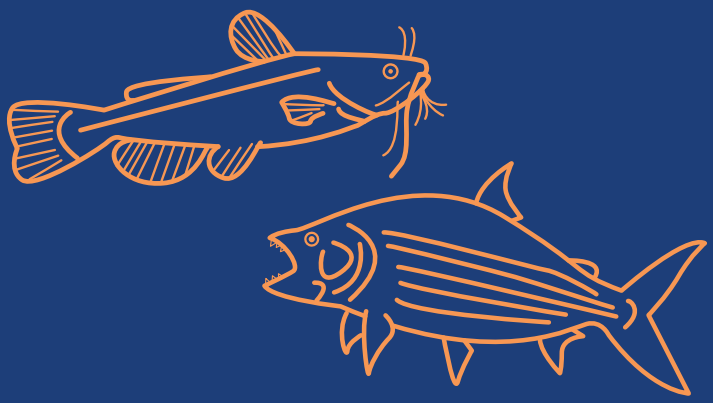
Do fish use tools?

For a long time, tool-use was thought to be an ability unique to humans. This has gradually been expanded to include other mammals, birds, and now fishes. In 2009, scientists filmed a fish using tools for the first time when they noticed a tuskfish using a rock as an anvil to crack open clams.[49]

Fishes have also been observed using rocks to crush sea urchins for food, while others carry their eggs around by gluing them to leaves or small rocks.[50]

The female of one enterprising species lays her eggs inside a mussel so that her offspring are protected until they're ready for the open ocean.[51]

Are fish innovative?

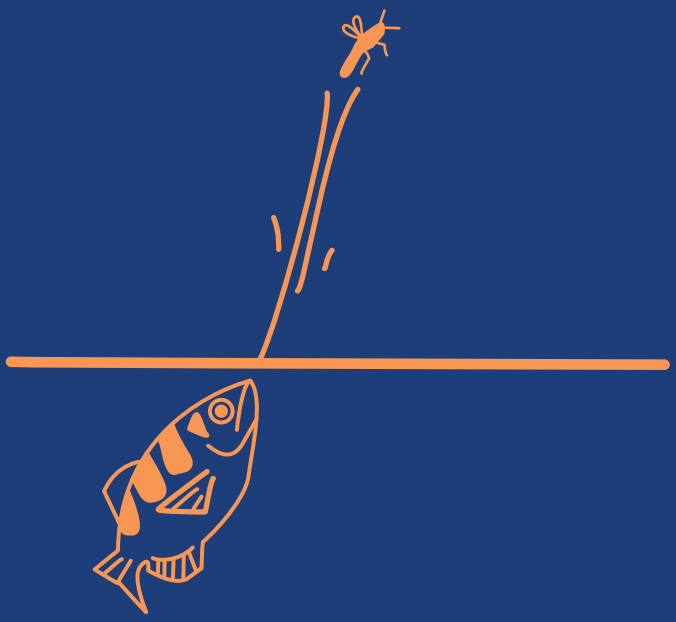


Fishes can be very flexible and creative.

When TIGERFISH were re-introduced into a dam system with little available food, they adapted by learning to leap out of the water to catch low-flying birds! CATFISH have also been seen catching doves when the birds stop for a drink. This is an example of fishes being opportunistic and practicing a new skill.[52]

The SUNFISH (who can live for 100 years) has innovated a special technique for keeping its body clean. By floating up to the surface, the sunfish swims sideways and courts sea gulls, inviting them to pick off any parasites.[53]

ARCHERFISH have another skill, which is commonly likened to tool-use. These fishes can accurately aim and spit sharp jets of water through the air to catch insects.



An archerfish can fire a single shot or repeated shots (like a machine gun) to take down insects up to 10 feet away. In order to determine target size and position, young archerfish have to learn how objects in the air are visually distorted when looking through water.

Some scientists also consider nest building to be a form of tool-use, because "it involves complex manipulation of external objects."[54] At least 9,000 species of fishes build nests, displaying a variety of architectural genius.

Some homes or nests are built from carefully pieced together rocks or coral, while others are crafted from bubbles or mucus.

A type of MINNOW collects 300 identical pebbles to act as bricks, while a type of wrasse builds a new rocky house every night.[55]

Some fishes build elaborate and decorative structures, patterns and mandalas to impress potential mates. Without hands, fishes have to use their fins and mouths to move and arrange sand or other objects.[56]

MYTH 4 FISHES AREN'T SOCIAL

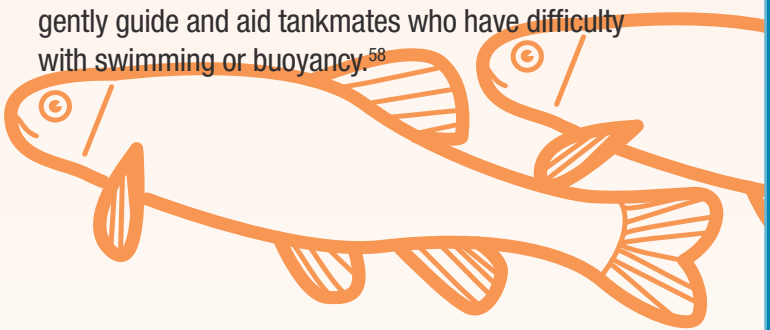
Are fishes social?

Fishes lead complex social lives. They often live in a social hierarchy, recognise individuals and are careful when choosing mates.

When protecting their territory, fishes are aggressive to strangers but tolerate familiar neighbours.[57] They can also remember individuals for a long time.

They cooperate when **shoaling** or **schooling** and in addition to complex relations within species and families, there are also many examples of **inter-species cooperation.**

There is even evidence that fishes are concerned for their friends, and numerous anecdotes of fishes displaying compassion for others who are disabled or in distress. For example, fishes have been seen to gently guide and aid tankmates who have difficulty with swimming or buoyancy.[58]



FISHES HAVE BEEN SEEN TO GENTLY GUIDE AND AID TANKMATES WHO HAVE DIFFICULTY WITH SWIMMING OR BUOYANCY.

Case study: Cleaner wrasse

The best example of a complex social system can be found at a reef's local 'cleaning station'.

Cleaner wrasses are a type of fish who provide a grooming service to other species on the reef, by picking off (and eating) parasites and dead skin.

Cleaner wrasses work solo or in pairs, and start off by using swimming postures and bright colours to advertise that they're open for business.
Other fishes will then gather to get in line.

One study found that a single cleaner wrasse in the Great Barrier Reef will have an average of 2,297 clients every day![59]

Cleaner wrasses are selective with their clients. They'll first attend to travellers visiting the cleaning station, who are less likely to wait around than the regular local residents. Cleaner wrasses show extra consideration for new clients, giving little massages to encourage them to stay longer and return to their cleaning station.

They also give massages to make amends if they 'cheat' by nipping their client's skin or mucus. However, if a regular client sees someone else being nipped, they might chase the cleaner wrasse around as a form of punishment.

Cleaner wrasses are less likely to nip their clients if there are other cleaning stations nearby or if prospective clients are watching. Wrasse are wise in the way they won't cheat on clients who are predators and instead work to develop a trusting relationship.[60]

Do fishes cooperate?

Fishes have expertly refined their cooperation skills, both with their own species and others.

When fishes sense danger, for example, they release a chemical to warn others. This alarm chemical is called 'schreckstoff' ('fright stuff'), and lets other fishes know to be alert for predators.[61]

Some fishes also pair up to inspect potential threats. If one of the pair runs off or cheats, the other will remember and refuse to cooperate with them again in the future. This has been described as a form of social punishment for breaking the rules.[62]

Fishes engage in cooperative hunting, where each individual plays a predetermined role in the hunt.

For example, groupers commonly team up with moray eels, as they are likely to catch more **prey** when working together.[63] To signal readiness to hunt, a grouper will approach a moray eel and shake his or her head. This is especially significant because it means that both the grouper and eel are imagining and planning a future event.[64]

Some groupers even signal the location of hidden prey to their hunting partners by performing a headstand over the hideout. This kind of 'referential gesture' (like pointing) is an indicator of high intelligence. It also indicates **inter-species communication,** as the hunting partner may be an eel, a wrasse, or even an octopus.

Do fishes have cultural traditions?

Most people would be surprised to learn that fishes share culture and pass traditions down generations.

'Culture' was once thought to be restricted to humans, but it has since been discovered that more species have culture, including other mammals, birds, and now, fishes.[65]

Many migration routes for fishes are likened to cultural heritage.[66] For example, some fishes maintain breeding sites according to tradition and social convention, rather than according to quality of the site itself.[67] These traditions are learned from older and more experienced individuals.

Human preference for larger fishes, however, means that many of these more knowledgeable individuals are caught and removed from their natural home.[68]

A study in 2014 found intensive fishing activities by humans have irreversibly disrupted the transmission of cultural knowledge of migration routes among fishes.

This 'loss of **group memory**' cannot simply be fixed by establishing new populations of fishes.[69]

What about industries that use fishes?

The oldest fishhook found so far dates back to between 16,000 and 23,000 years ago. The oldest fishing net dates back to 8300 BC.[70]

Fishing has clearly been around for a long time, but with the rise of technology, commercial fishing has developed to operate on a much bigger scale today.

> **"It would probably shock most people to find out that fish account for nearly 97 per cent of all animals slaughtered for food globally."**
> - Vicky Bond [71]

Commercial fishing

Aided by sonar, satellite navigation, depth sensors and maps of the ocean floor,[72] commercial fishing is responsible for killing at least 2.3 trillion individuals each year.[73]

This doesn't include the significant number of fishes who are caught but discarded or unreported.[74] It also doesn't include the unknown number of fishes who are used as bait, or the huge number of individuals caught as 'by-catch'.

By-catch refers to non-target species (such as turtles, seabirds, dolphins, living corals and seals), many of whom are caught in indiscriminate commercial fishing methods such as purse seines, longline fishing and bottom trawling.

These methods pose serious animal welfare issues, for both the trillions of targeted individuals and those caught as by-catch.

For example, some fishes may be pursued to exhaustion, suffocate or suffer from decompression when they are raised from deep water. Others may be crushed under the weight of other fishes in nets. Fishes caught on hooks, which may pierce their faces or bodies, are often left for hours, unable to escape other predators.[75]

As a result of commercial fishing (alongside pollution and habitat destruction), 80% of the biomass of fishes in the world's oceans has been lost over the last 100 years.[76]

Fish farming

With plummeting numbers of wild fish, **aquaculture** is increasingly being used to farm fishes instead. This kind of fish farming is the fastest growing animal-use industry in the world.[78]

Currently anywhere from 48 to 160 billion fishes are farmed each year.[79]

Like factory farming of land animals, aquaculture presents a number of serious animal welfare issues due to intensive confinement, artificial conditions, overcrowding, and an inability to perform basic natural behaviours.

Studies have shown that animals in aquaculture suffer from systemic injuries, deformities, diarrhea, and stunted brain development.[80]

Aquaculture currently has no regulations for animal welfare in most jurisdictions.[81]

Aquaculture still impacts wild populations of fishes, because it relies on wild caught prey fishes as the main food source for farmed fish. Fish farms also contribute to the spread of diseases and parasites, such as sea lice, which can severely impact wild populations.[82]

"Today, how many we take is no longer limited by how many we can catch, but by how many there are left to be taken."
- Jonathan Balcombe [77]

As the science shows, fishes are social, sophisticated and smart.
Most importantly, there is overwhelming evidence that fishes are sentient.

Did you find any of this information surprising or new?

If so, how should this information affect our relationship with fishes?

QUESTION, CONSIDER AND DISCUSS.

QUESTION whether our treatment of fishes reflects what we know about them.

CONSIDER the different views on this issue, and decide for yourself where you stand.

DISCUSS with your friends, family, classmates and teachers. Debating complex issues is healthy and helpful.

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Let us know your thoughts on this subject and share your students' responses and class work. Email us at **education@voiceless.org.au** and share your work on social media using **#VoicelessAPE**

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Glossary

Aquaculture: the growing or farming of aquatic animals and plants, including fish farming.

Biomass: the mass of living organisms in an ecosystem at a particular point in time.

By-catch: animals unintentionally caught in commercial fishing, such as dolphins, turtles, sea birds and non-target fishes.

Cognitively affected: a mental state where usual thought patterns and brain activity may be interrupted, disturbed or unusual.

Conscious: to be aware and able to respond to one's surroundings.

Culture: non-biological information or traditions transferred across generations.

Electroreception abilities: the ability to detect and emit electric signals, sometimes as a form of communication.

Ethologist: a scientist who studies animal behaviour.

Group memory: the shared knowledge and information held by a social group of animals, often passed on between generations.

Intelligence: an ability to learn, acquire knowledge and process information.

Inter-species communication: when animals of different species exchange information.

Inter-species cooperation: when animals of different species work together to achieve a common goal.

Mammals: a class of vertebrate animals that give birth to live young and produce milk for their young, including humans.

Mirror self-recognition test: a method of determining whether an animal is self-aware, by observing whether or not the animal recognises themselves in a mirror.

Neocortex: a part of the brain in mammals that is responsible for various functions, including pain perception.

Pain perception: the ability to feel and process painful experiences.

Paleocortex: a part of the brain in birds that is responsible for various functions, including pain perception.

Pallium: a part of the brain in fishes that is responsible for various functions, including pain perception.

Positive cognitive states: a desirable mental state, such as contentment or happiness.

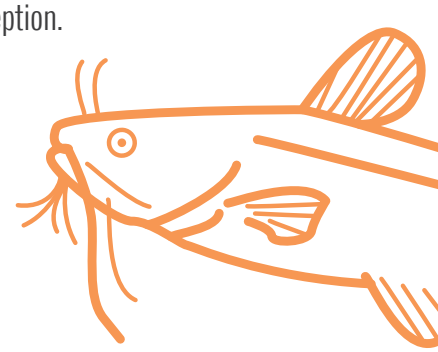
Predator: an animal that hunts and eats other animals.

Prey: an animal that is hunted and eaten by other animals.

Primates: an order of mammals that includes chimpanzees, gorillas, monkeys and humans.

Reflex: an automatic response that is performed unconsciously.

Schooling: the action of fishes swimming together in a coordinated way.



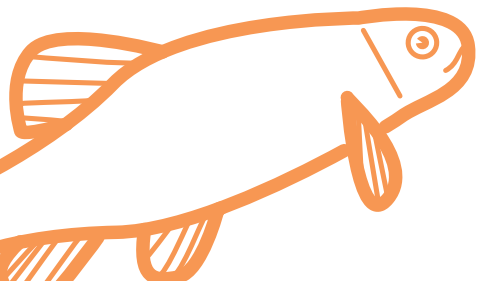
Self-awareness: the ability to identify a separate sense of self, distinct from other entities; an understanding of one's individual character.

Sentience: the ability to perceive and feel things, such as pleasure and pain.

Shoaling: the action of fishes staying in a specific group for social reasons.

Stimuli: things that cause a reaction (for example, spikey objects are stimuli that may cause pain when touched).

Unconscious: to not be awake, lacking awareness and responsiveness to one's surroundings.



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Note: this factsheet draws heavily on texts published by fish experts Jonathan Balcombe and Professor Culum Brown. In the course of their work, these scientists have collated and reviewed hundreds of scientific papers on fish sentience, cognition and ability.

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