CEPHALOPODS AND DECAPOD CRUSTACEANS

Their Capacity to Experience Pain and Suffering

ADVOCATES FOR ANIMALS

Giving voice, taking action

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2005

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Executive Summary

1. THE SCOPE OF ANIMAL PROTECTION LAW

Animal protection legislation has tended to include only vertebrates (such as mammals, birds, reptiles, amphibians and fish) and exclude cephalopods and decapod crustaceans on the grounds that they are non-sentient and, therefore, incapable of suffering. However, the belief that these animals are non-sentient is very questionable. In view of current scientific understanding of the nervous systems and behaviour of cephalopods (octopus, squid, cuttlefish and nautilus) and decapod crustaceans (lobster, crab and crayfish), there is now an urgent need to amend and update all relevant legislation.

Octopus, squid, cuttlefish, lobster, crab and crayfish especially need legal protection from possible suffering because they are widely used by humans for food, as fishing bait, and, in some cases, in scientific research.

Some jurisdictions have already taken the view, on the basis of the scientific evidence, that cephalopods and decapod crustaceans are likely to experience pain and suffering and hence have included all or some of them within animal protection legislation.

2. THE NEED FOR PROTECTION

Catching, trapping, handling, holding, storing and killing can cause injury, stress and suffering to cephalopods and decapod crustaceans.

Crabs and lobsters in particular are used widely as human food. They can be severely stressed by catching and handling, exposure to air, storage and transport. During these processes they suffer infections, open wounds and other lesions. Many may die from starvation, dehydration, overheating, or from injuries sustained from fighting whilst in unattended storage pots or lost traps.

Restaurant and domestic methods of storage and killing are not yet regulated. The current practice of killing lobsters by cooking them alive in boiling water without the use of anaesthesia or pre-stunning is of particular concern. During this cooking process they struggle violently and shed limbs and, on the scientific evidence, it is no longer acceptable to assume that this behaviour is reflex and involves no pain.

3. THE ASSESSMENT OF CAPACITY FOR SUFFERING

The typical route for the assessment of pain or suffering in non-human animals is to use the method that scientists refer to as ‘argument by analogy’. It is assumed that an event that is painful or distressing to humans is likely to have the same or similar effect on animals that have a similar physiological organisation and behaviour to humans[1–4].

This method becomes harder to apply to animals that have a body and brain structure and behaviour that are very different from that of mammals, such as invertebrates. However, existing scientific research on decapod crustaceans and cephalopods suggests that they do indeed possess the capacity to experience pain and should be given the benefit of the doubt in all human activities that have the potential to cause them suffering.

4. WHAT TYPES OF EVIDENCE CAN SHOW THE CAPACITY FOR PAIN AND SUFFERING?

Nociception is the ability to detect and respond to potentially painful, harmful or noxious stimuli, and has been described as a basic characteristic of all animals. The capacity for nociception does not necessarily imply that the animal is consciously aware of the harm or injury, and hence does not tell us directly whether the animal experiences pain and suffering. Since pain and suffering are private, internal experiences, they are difficult to prove beyond doubt even in animals we know well, or in other humans. Therefore scientists normally want to be able to show that the animal:

- is in principle capable of feeling pain, because it has a nervous system and related physiological and neurochemical mechanisms
- gives some indication in its behaviour that it feels pain or distress, for example by avoidance or escape behaviour and
- can behave in ways that show some mental capacity, for example an ability to learn, remember, discriminate, and respond flexibly to new situations.

Cephalopods and decapod crustaceans possess a nervous system and a nociceptive system. Invertebrates also share some features of the neurochemical systems that are involved in pain perception in vertebrates. In particular, opioid molecules have been found in these animals and they appear to function in similar ways as in vertebrates. There is evidence for considerable continuity and similarity between the pain and stress systems that are found in vertebrates and in invertebrates.[1,2,5]

5. EVIDENCE REGARDING DECAPOD CRUSTACEANS

Decapod crustaceans have a nervous system consisting of ganglia (concentrations of nerve cells) connected by nerve cords, and a brain consisting of fused ganglia at the front of the body. They have a large number of internal and external mechanical and chemical receptor cells (for the detection of pressure, odour, etc.) and they have compound eyes that cover a wide field and are connected by nerves to the brain. They thus have the potential to be well informed about their surroundings.

The likelihood that decapod crustaceans can feel pain is supported by the fact that they have been shown to have opioid receptors and to respond to opioids (analgesics such as morphine) in a similar way to vertebrates. For example, morphine is found to reduce a crab's reaction to an electric shock or to being presented with a pseudo-'predator'. Natural opiates are found in crustaceans as they are in vertebrates. These findings strongly suggest that opioids have a role in mediating pain in crustaceans in the same way as is known to occur in vertebrates. A recent Opinion of the Scientific Panel for Food Safety of the Norwegian Food Safety Authority commented that opioids in some invertebrate species might be involved in pain perception and relief in much the same manner as in vertebrate species.

In addition, the behaviour of decapod crustaceans shows that they can recognise and remember painful or threatening objects or situations and try to avoid them. The animals also have the ability to learn and to make discriminations. They show some understanding and memory both of places and of other individuals, for example by forming social hierarchies when a number of animals are kept confined together.

When crabs and lobsters are caught, taken out of water and handled, they make vigorous efforts to escape. Physiological studies of lobsters show that they are very stressed by the process of catching, handling, transport and being kept out of water. Many crabs and lobsters arrive at factories very weak, dying or dead. Lobsters make vigorous attempts to escape when they are put alive into boiling water to be cooked. They also often shed limbs, an escape response known as autotomy, which is likely also to be a response to pain.

6. EVIDENCE REGARDING CEPHALOPODS

Scientists who work with octopuses typically assume that these are intelligent animals that experience pain. Cephalopods have a well-developed nervous system and a complex brain, which is relatively larger than the brains of some fishes and reptiles. They have numerous sense organs that rival those found in vertebrates in their complexity. They have good eyesight and an excellent sense of touch, and they can use both of these senses to make fine discriminations between objects. Aspects of their brain functioning have been found to be similar to that of vertebrates.

There is good evidence from their behaviour that cephalopods can feel pain; for example, electric shocks have been used in experiments to train octopuses to discriminate between objects (and they show signs of fear when subjected to such shocks). Cuttlefish quickly learn not to attack 'prey' enclosed in a glass tube, because hitting the glass hurts their tentacles. Octopuses try to avoid being stung by sea anemones and try vigorously to escape when they are anaesthetized using urethane, which they find aversive.

The environment and lifestyle of cephalopods means that they need to be capable of complex and flexible behaviour. As active predators they need to explore, understand and remember their environment and the behaviour of other animals. A number of the abilities of octopuses have been studies by scientists. Octopuses learn easily, including learning by observation of another octopus that has been previously trained to perform a task. They can solve problems, as when they remove a plug or unscrew a lid to get prey from a container. They use rocks and jets of water in a way that could be classified as tool use. They have been found to play with a 'toy' and to have individual responses and individual temperaments.

In considering which animals need legal protection, a scientific submission from the University of British Columbia to the Canadian Federal Government has stated that 'the cephalopods, including octopus and squid, have a remarkably well developed nervous system and may well be capable of experiencing pain and suffering.'

7. PUBLIC POLICY AND LEGISLATION CONCERNING DECAPOD CRUSTACEANS AND CEPHALOPODS

Public opinion and public policy are now changing in relation to these groups of animals, and a precautionary approach is needed to protect them from possible pain and suffering. Certain encouraging steps in this direction have already been taken

Because of the growing realisation that crustaceans are capable of suffering, the traditional methods by which these animals are killed for food are now increasingly seen as inhumane, if the animal is not either stunned before being killed or else killed instantaneously. Internationally, crabs and lobsters are killed by a variety of methods, including pithing, boiling, freezing, or during the process of cutting them up to remove their meat. Some crabs are killed on the deck of vessels. Crayfish are sometimes killed by cutting away the tailmeat when the cray has not been chilled and is still active. Lobsters are often cooked while still alive and conscious.

The New South Wales Government agriculture department has issued guidelines for the humane killing of crustaceans, which include stunning/killing either by cooling or by rapid destruction of nerve centres with a sharp instrument (pithing). While these methods may not be guaranteed to avoid pain, they are an example of progress in public policy and recognition that decapod crustaceans can experience pain.

A preferable stunning method is an electrical stunner that can be used by an unskilled operator. An electrical stunner (Crustastun) is available in Britain, which produces immediate unconsciousness lasting 30 minutes. The device is in operation at a commercial seafood company in England and is also to undergo restaurant tests in Scotland.

Humane euthanasia methods applicable to research laboratories are also being developed, with the aim of avoiding causing pain to the animals. One possible method is injection of potassium chloride solution into the region of the animal's central nervous system. This method is believed to cause immediate depolarization of the neurons and unconsciousness. As with the development of humane killing for food, this illustrates a growing professional and public concern with the humane treatment of crabs, lobsters and crayfish.

Certain jurisdictions have already made the decision, on scientific evidence, to include some or all of the decapod crustaceans and cephalopods within animal protection law. These jurisdictions include New Zealand, Norway, the Australian Capital Territory and Queensland. The UK has decided that the common octopus *(Octopus vulgaris)* should be included in the scope of the Animals (Scientific Procedures) Act 1986, which previously applied only to vertebrates.

8. CONCLUSIONS

In light of the scientific evidence which strongly suggests that there is a potential for decapod crustaceans and cephalopods to experience pain and suffering, it is now necessary to adopt the precautionary principle in dealing with these animals by giving them the benefit of the doubt in the regulation of all activities that could cause them suffering. We believe that this potential for experiencing pain and suffering should be recognised in law in Scotland and in England and Wales - and indeed in all other jurisdictions - by including cephalopods and decapod crustaceans within the scope of all animal welfare legislation.

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1. THE SCOPE OF ANIMAL PROTECTION LAW

Animal protection legislation in general has tended to include only vertebrates (such as mammals, birds, reptiles, amphibians and fish) and to exclude all or most invertebrates on the grounds that they are non-sentient and, therefore, incapable of suffering. In view of current scientific understanding of the nervous systems and behaviour of invertebrates, in particular of cephalopods (octopus, squid, cuttlefish and nautilus) and decapod crustaceans (lobster, crab and crayfish), there is an urgent need to amend and update all relevant legislation.

Octopus, squid, cuttlefish, lobster, crab and crayfish especially need legal protection from possible suffering because they are widely used by humans for food, as fishing bait, and, in some cases, in scientific research. One reason they are used for research (besides convenience, cost and lower regulation) is that they are assumed to be less sentient than vertebrates and, therefore, less likely to suffer from laboratory use. However, the common octopus *Octopus vulgaris* has been included in the scope of the UK's Animals (Scientific Procedures) Act 1986, on the grounds that this species is capable of experiencing pain and distress. Similarly some jurisdictions, such as that of New Zealand and the Australian Capital Territory, include some or all cephalopods and decapod crustaceans in the scope of their animal protection laws.

2. THE NEED FOR PROTECTION

Catching, trapping, handling, holding, storing and killing can cause injury and suffering to cephalopods and decapod crustaceans.

Crabs and lobsters in particular are used widely as human food. The handling of lobsters is of particular concern, since they are typically cooked alive in boiling water without anaesthesia or pre-stunning. During this process, the animals struggle violently and shed limbs, which is their normal stress behaviour in order to escape capture or to prevent injury to a limb from affecting the rest of the body. Astonishingly, this escape behaviour is still often assumed to be reflex and totally without conscious sensation.

Lobster being boiled alive

Trapping is also a potential cause of suffering. Traps left in the sea often go missing and the lobsters caught in them may be left to die from starvation, dehydration or heat if the traps are washed up on the shore and abandoned. Since more than one animal can be caught in the same trap, they may fight and kill each other when the trap is left unattended.

Crabs and lobsters can also suffer during transportation and when in storage - in over-crowded conditions, with lobsters often having their claws bound together with plastic bands. A review of lobster health by the Atlantic Veterinary College has detailed how the animals' health and welfare can suffer from a number of causes during handling, transportation and storage in holding pots or tanks. These include dehydration, the fatal bacterial disease red-tail (Gaffkemia), shell disease and 'bumper car' disease, all spread by crowded conditions. Combined with rough handling, including the practice of throwing them, a significant proportion of lobsters suffer open wounds and other lesions between the time of catching and killing. Mortality before processing (killing for food) can be up to 10-15%.[1] There are no regulations governing their subsequent treatment during storage and killing for those live lobsters and crabs sold to the public or for the restaurant trade.

DECAPOD CRUSTACEANS: CRABS, LOBSTERS AND CRAYFISH

Crabs, lobsters and crayfish are animals of the class Crustacea (subclass Malocostraca), members of the animal phylum Arthropoda which includes invertebrate animals with jointed limbs and an external skeleton. Being crustaceans, they have tough, crust-like shells. Within the crustaceans, they are classified as the Decapoda because they have five pairs of limbs (the front pair having claws or pincers).

Crabs are 10-legged animals that walk sideways and most species of crab live in the sea. The crab's shell (known as an exoskeleton or carapace) both protects it and provides support. Their two front legs have large, grasping claws (known as pincers or chelipeds). They have two feelers (antennae) and two eyes located at the end of stalks. Aquatic crabs breathe underwater using their gills to extract oxygen from the water, much like a fish. But crabs can survive for periods out of water, and to some extent can also use their gills to extract oxygen from air. Some species have adaptations that allow them to live mainly on land. The edible crab *(Cancer pagurus),* found in North West Europe and common on British coasts, matures at over 10 years old and can live for 20-100 years.

Lobsters have a segmented body, a tough shell, four pairs of walking legs and a pair of front limbs that may have strong pincer and crusher claws. Like crabs, they have antennae and compound eyes on stalks. Lobsters have gills to extract oxygen from water, and to a limited extent they can also use their gills to extract water from air, when out of water. The lobster grows in size by shedding its shell several times a year. *Homarus Americanus,* the American lobster, is caught for food when it is about 5-7 years old, but some lobsters can live for tens of years and travel large distances in their lifetimes.

Crayfish are also known as freshwater lobsters and live in streams, rivers, ponds and swamps.

THE CEPHALOPODS: OCTOPUS, SQUID, CUTTLEFISH AND NAUTILUS [35,36]

The animal class Cephalopoda belongs to the phylum Mollusca that includes molluscs such as snails and clams. The word cephalopod means 'headfoot', indicating that the animals' limbs (arms and tentacles) appear to be attached to their heads. The octopus, squid and cuttlefish belong to the subclass known as Coleoidea, whereas the various species of nautilus are in the subclass Nautiloidea, and have an external protective shell. The Coleoidea have no shells, but their internal organs and gills are enclosed in a muscular mantle and they use changes in the colour and texture of their skin for camouflage. They rely on speed to escape, and squirt ink into the water to distract pursuers. The octopus has a globular body shape, whereas the bodies of the cuttlefish and squid are more elongated, and some species have fins along the mantle. All cephalopods move by a form of jet propulsion, rapidly expelling water from the mantle cavity through a funnel. The funnel can be turned backwards and sideways, giving considerable manoeuvrability and enabling the animals to move at up to 37 km/hr.

Octopus (Order Octopoda) have eight limbs (arms). The very strong arms have two rows of suction cups on the undersides. The animal has large eyes, with lenses similar to the human eye, a large brain and a tough beak, used for attack. The various species range in size from a centimetre to several metres and from 30 gms to 50 kg for the large Octopus dofleini. Octopus tend to have a short lifespan of a year to 20 months. The animals live alone on the sea floor in dens under rocks and live by hunting fish, crabs and other sea animals. They swim mainly when they need to escape or attack and normally walk on the sea floor by a fast relaxed scrambling or a slower exploratory walking, using arms and suckers. They swim by propelling themselves backwards by spewing a jet of water from a funnel (or siphon), which is also used to pump water into the gills to obtain oxygen.

Cuttlefish (Order Sepiida) have many similarities in appearance and behaviour to the octopus, but their body is elongated and they have eight short arms and two tentacles. The cuttlebone is a gas-filled shell within the mantle that is used to make the animal buoyant in the water, which means that cuttlefish can 'hover' without swimming. Cuttlefish are about 30 cm in length and live up to 2 years.

Squid (Order Teuthida) are closely related to octopus and have 8 suckered arms, two longer feeding tentacles, a parrot-like beak and large eyes and brain. Species range in size from a third of a metre to the Giant Squid, which can be 18 metres in length and 450 kg in weight. Because squid are not buoyant in water, they need to swim almost continuously.

Nautilus (Order Nautilida): the pearly nautilus, unlike the other cephalopods, has its own external shell and many small suckerless tentacles. When the animal is withdrawn into the shell, the opening is covered with a tough hood. The shell is pearly and spiral and is extended as the animal grows. Like the octopus, the nautilus swims by jet propulsion, but more slowly.

3. THE ASSESSMENT OF CAPACITY FOR SUFFERING

How do we know if an animal has the capacity for suffering? The typical route is to use the method that scientists refer to as 'argument by analogy', that is, to assume that an event that is painful or distressing to humans is likely to have the same or similar effect on animals with a similar physiological organisation and behaviour to humans. In the case of a dog, cat or monkey, both these conditions are relatively easy to fulfil. Other animals, for example prey species such as sheep, or poultry, may be harder to assess because they have evolved to avoid showing pain or injury in their overt behaviour. However, experiments can show changes that we can recognise as indicating that the animals feel pain. Lame chickens have been shown to select food laced with carprofen, an analgesic[2], and fish injected with bee venom in their lips showed behavioural and physiological signs of pain relief when given morphine[3].

But identifying with the animal's behaviour and assessing its capacity for suffering by the method of analogy becomes more difficult at greater evolutionary distances from humans, as discussed by Kavaliers[4], Sherwin[5], Smith[6], Fiorito[7], Mather[8] and others. The evolutionary distance between mammals and cephalopods or crustaceans is very large.[9]

How consciousness arises is still poorly understood, but in humans and mammals both consciousness and the experience of pain are associated with the cerebral cortex and particularly the neocortex. It becomes more difficult to assess the potential for suffering of animals that do not have the mammalian brain structure. In principle, it is possible for an animal to be capable of making a physical response to a noxious stimulus that would be painful or harmful to humans without actually experiencing the sensation of pain or related fear and distress (for example, this can be true of mammals or humans whose cortex has been damaged or removed).

But it is very likely that non-mammalian and some invertebrate species have evolved the capacity to experience pain, as an essential survival mechanism, through other brain and nervous system mechanisms. It is known that different animal species can evolve similar functions through different mechanisms. For example, it is known that crows and other corvids, and parrots, have evolved certain learning and problem-solving abilities comparable to those of great apes, although the birds' brains are very small, with a different structure to mammalian brains, and have little cerebral cortex.[10,11] Therefore, scientists normally require both physiological and behavioural evidence to back up the argument by analogy, especially for those animals whose central nervous systems are very different from those of, say, primates. As a result, as noted above, some jurisdictions have already assessed that some cephalopods and crustaceans can experience suffering.

In the case of the invertebrate species we are concerned with here, little research has been done compared to that on vertebrates, possibly reflecting a long-held prejudice that these animals are self-evidently non-sentient. The results of this research are certainly not sufficient to dismiss the potential for pain in these animals. On the contrary, the results suggest that they do possess the potential for experiencing pain and should therefore be given the benefit of the doubt in all human activities that could cause pain or distress.

Evidence that the same or very similar mechanisms of stress and potential for pain perception exist in both vertebrates and invertebrates is supported by detailed research on the neurophysiology and neurochemistry of invertebrates over the last 15 years.

4. WHAT TYPES OF EVIDENCE CAN SHOW THE CAPACITY FOR PAIN AND SUFFERING?

Evidence from scientific research, both long-standing and very recent, strongly suggests that some invertebrate animals are capable of feeling pain and distress. Linked to the scientific evidence, there is a growing public consensus that some animals that are widely used by humans, such as cephalopods, lobsters and crabs, need protection from possible pain, through legislation and through the development of 'humane killing' methods.

Since pain and suffering are private, internal experiences, they are difficult to prove beyond doubt even in animals we know well, or in other humans. Therefore, scientists normally want to be able to show that the animal:- (1) is in principle capable of feeling pain, (2) gives some indication in its behaviour that it feels pain, and (3) can behave in ways that show some mental capacity. In particular, scientists look for evidence that:

- the animal has a nervous system and physiological mechanisms that make it in principle capable of experiencing pain or distress, and
- the animal behaves in a way that we would interpret as a response to experiencing pain or distress; for example, by trying to guard itself, by trying to escape, by learning to avoid the situation that caused pain, or by paying attention to the site of the pain, for example, an injured limb.
- Related to this, it is thought to be more likely that an animal can experience pain if its brain and nervous system allow it to have more understanding about its environment and what is happening to it. Evidence for this comes from proof of capacity for learning, remembering, generalising, making choices and modifying behaviour to the appropriate circumstances.


Kevin Shafer/NHPA

Chambered Nautilus

Compared to vertebrate animals, there is relatively little scientific research on invertebrates and the future will certainly reveal far more about their behaviour and physiology than is yet known. However, scientists can already show that the cephalopods and decapod crustaceans can be considered to fulfil the three criteria given above.

The detailed evidence that these animals can experience pain is given in separate sections below. It includes the following important aspects, which we spell out in advance:

4.1 Nociception

Nociception refers to the ability of animals to respond, either by reflexes or by voluntary actions, to what are called 'aversive' or 'noxious' stimuli - things that cause pain, harm or pose a threat. Nociception has been described as a 'basic characteristic of animals'[4,6], without which they could not survive. In vertebrates animals, including fish, there are specialised cells called nociceptors, associated with the nervous system, that detect harm from chemicals, heat, cold, mechanical force, etc. Nociception exists in invertebrates, as it does in vertebrates and in humans[4,7]. It does not in itself mean that the animal has a subjective experience, rather than being enabled to make a reflex response, such as withdrawing. In humans and, we assume, in other vertebrates, nociception creates nerve impulses that are transmitted to the brain (in particular the thalamus and the cerebral cortex) that give rise to the relevant unpleasant sensations such as stinging, burning, aching and pinching of the body's tissues, and associated fear and distress.

4.2 The role of opioid molecules in the regulation of pain

It has been found that some invertebrates have very similar physiological and neurochemical responses to stimuli that would be expected to cause pain to those of vertebrates. Opioids are substances that mimic the effects of opium in the brain, and include peptide molecules such as enkephalins and endorphins. In humans and vertebrates, opioids that are produced in the body can modify the nervous transmission of nociception and reduce pain[4-7], in the same way as an injection of morphine relieves the unpleasant experience of pain. Naloxone is a substance that counteracts the analgesic effect of opiods. Opioids have been found in cephalopods and decapod crustaceans, and appear to have a similar role as in vertebrates, strongly suggesting that they mediate pain in the same way. The antibacterial enkelytin peptide found in invertebrate proenkephalin (an enkephalin precursor) has 98% sequence identity with mammalian enkelytin.[12] Opiate receptors have been found in some invertebrates that are very similar to those in mammals.[12] It is unreasonable to dismiss these similarities purely because we have traditionally assumed that the invertebrate nervous system could not be capable of producing the experience of pain. The recent Opinion of the Scientific Panel for Food Safety of the Norwegian Food Safety Authority commented that although 'the significance of the presence of opioids in the circulation of some invertebrate species is not known, ...these substances might be involved in pain perception and relief much in the same manner as in vertebrate species'.[13]

4.3 Similarities between stress systems in vertebrates and invertebrates

There are strong similarities and signs of continuity between vertebrate and invertebrate stress systems. In many invertebrates, molecules similar to adrenocorticotropin, one of the major stress-signalling molecules in vertebrates, have been found to be present.[12] Endogenous morphine in invertebrates appears to be involved in the immune and nervous system's response to injury[14], in a similar manner to mammals. A review comparing vertebrate and invertebrate stress systems has concluded that they are closely related and that the invertebrate system should not be seen as 'simple' or 'primitive'. On the contrary, the 'commonalities of signal molecules, activities and regulatory mechanisms must be viewed as demonstrating a continuity of information during the development of various response systems throughout evolution, rather than the appearance of "chance" similarities. One is therefore left to conclude that the invertebrate perturbation-stress system developed many of the strategies for mammalian stress phenomena'.[12]

5. DETAILED EVIDENCE REGARDING DECAPOD CRUSTACEANS

5.1 Nervous and sensory systems of decapod crustaceans

The nervous system of these animals consists of nerve cords running along their bodies connecting ganglia, or concentrations of nerve cells that are almost like small brains[9]. There is also a brain made up of fused ganglia at the front of the animal. But, in general, the central nervous system is not entirely concentrated in the brain but is divided between different ganglia. These can be relatively large compared to the brain at the front of the body, and also function as centres for reception of sensory inputs. The animals have a large number of receptor cells for detecting chemical and mechanical inputs and have compound eyes (on stalks) that cover a wide field and are connected by nerves to the brain. Decapod crustaceans are thus considered to be well equipped to be kept informed about their surroundings and internal state of their bodies[9]. According to evidence given to a review conducted in 2002 of the French animal experimentation laws with regard to invertebrates, the presence of both internal and external receptors makes it plausible that the decapod crustaceans can also feel pain[15].

Some of the behaviour of crustaceans appears to be caused by reflexes, such as tail-flip escape response of the crayfish. But this does not, of course, imply that the stimulus that caused the reflex did not also cause pain. There is evidence from 1975 that the crayfish escape response can also be delayed until a good time to try to escape, and thus can be in effect voluntary[16,17]. Recent evidence suggests that the animals' brains are capable of more than has been assumed; by measuring brain activity ('evoked potentials'), it has been shown that crayfish brains respond differently to interesting, highly relevant or irrelevant objects either seen or smelled. The researchers commented, 'the relatively simple brain...of the crayfish is capable of evoked activity similar to that recorded from the brain of vertebrates', suggesting that 'other functions, labelled "high" because of their presence in mammals, could also be present in crayfish'[18]. It was further found that crayfish brains are capable of a cognitive task known as 'expectation' by demonstrating the 'omitted stimulus potential'. This is a form of brain activity mainly known from studies on humans, where it is considered to be a sign of higher mental processing and associated with conscious experiences[18].

5.2 Experience of pain and fear in decapod crustaceans

NHPA

Squid

Many of the experiments on the neurophysiology and neurochemistry of these animals appear to assume that they do feel pain, since electric shocks are used as an aversive stimulus. The likelihood that they are capable of feeling pain is supported by the fact that they appear to have opioid receptors which function in the same way as in vertebrates. It has been known for many years now that the defensive reaction of crabs to electric shocks is reduced by morphine, an analgesic, and that this effect can be counteracted by naloxone, an opioid antagonist. A relatively early experiment (1988) showed that morphine reduced crabs' sensitivity to electric shocks by 50% and that the effects were dose-dependent. The effects of both morphine and naloxone were highly statistically significant ($P<0.001$). In addition, the strength of the crabs' reactions correlated with the strength of the electric shock (4 to 10 volts)[19].

A 1992 experiment found similar results by striking the crab between the eyestalks. Injection of morphine produced a dose-dependent reduction in the crabs' reactions and this was blocked by naloxone injections. The researchers concluded: 'It is worthwhile to stress that the inhibitory effect of morphine, naloxone reversible, on the invertebrate behaviour was reported the first time in 1982. Later studies confirmed this effect and ...indicated the existence of enkephalin analogs and native peptides with opioid-like activity'[20]. Experimenters assume explicitly that an electric shock is a 'painful stimulus' to a crab and studies have concluded that the fact that crabs show a reduction in reaction to shocks could be due to an analgesic effect produced by endogenous opiates[21].

Both the pain and stress systems of decapod crustaceans show striking similarities to those of vertebrates. Enkephalins from the thoracic ganglia of the shore crab have a primary structure identical to that of enkephalins from vertebrates and act to inhibit release of the crustacean hyperglycaemic hormone and blood sugar levels, the latter antagonised by naloxone[22]. Opiate binding sites have also been identified in crabs by electron microscopy[23]. Experiments have shown that enkephalin and naloxone act on the crab's escape reaction to a visual danger stimulus such as a shadow[24,25]. Opioids and their antagonists have also been shown to act on other aspects of the crab's behaviour and physiology, such as its level of locomotor activity and changes in pigmentation, again emphasising that the role of opioids as signalling molecules has been maintained throughout evolution.[26]

In addition, the 'aversive' stimuli (such an electric shock or a pseudo-predator) that are used experimentally may in fact be experienced as painful, unpleasant or frightening by the animals. In spite of the relatively simple repertoire of the observed behaviour of lobsters, crabs and crayfish, it seems arbitrary to assume that opiate receptors exist in these invertebrate animals without having any relation to pain perception. There is arguably also an inconsistency (at least) in the assumption that electric shocks used experimentally are 'aversive' but are not experienced as painful or distressing.

An additional important indicator of pain may be 'limb autotomy'. Crabs, like spiders and other arthropods, shed a limb that is injured, and crabs put on a hot plate do likewise[5,7] (as do crabs that are placed, without pre-stunning, in boiling water for cooking). Experiments on spiders appear to confirm the interpretation that autotomy may well be related to the experience of pain. Spiders are found to shed a leg when they are injected with a venomous substance that would cause pain to humans, but not when they are injected with venom components that do not cause pain to humans.[5,27] Venoms are effective as a defence mechanism just because they cause pain (but not necessarily death), since they deter would-be attackers. Researchers have concluded that 'The sensing mechanism by which spiders detect injected harmful chemicals such as venoms therefore may be fundamentally similar to the one in humans that is coupled with the perception of pain'[27]. It thus seems very likely that autotomy, or limb shedding, by crabs and lobsters is a response to pain.

5.3 Learning and behaviour of decapod crustaceans

Crabs and lobsters have the ability to learn[9], to make discriminations about their environment and to make associations and generalisations. Lobsters have a 'highly complex' olfactory system[28], which can be used to test their discrimination and learning. They are tested on their response to the odour of individual chemicals, or combinations of these chemicals, that are related to food that is attractive to lobsters. This is usually done by the use of some aversive stimulus such as a pseudo-predator (for example, a black plastic square that is rushed towards the animal or a passing shadow). The experiments show that lobsters are capable of associative learning, i.e. learning to associate one odour with the aversive stimulus, and that they can attain a 'high degree' of associative learning[29]. Further, they can generalise from an individual odorant to a mixture containing it[30,31]. It has been suggested that crabs may be using some kind of higher order processing, such as 'configural discrimination', in their response to mixtures of 2 compounds, as is known to occur in mammals (i.e., they regard the mixture as different from the sum of its parts).[31] For crabs, experiments on the neurological mechanism of reactivation and reconsolidation of long-term memory give results that are consistent with those reported for vertebrates, leading the researchers to suggest that 'evolution may have adopted a given molecular cascade as the preferred means of encoding experiences in the nervous system'[32]. These results emphasize the point that the similarities between the functioning of the central nervous systems of vertebrates and invertebrates seem to be much greater than we have, hitherto, been inclined to accept.

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Cuttlefish

Lobsters, crayfish and crabs show some understanding and memory both of places and of other individuals. Crabs appear to understand when they are in a novel environment. Experimenters found that crabs put in an experimental chamber explore it very actively for a few minutes, but they do not do this if they are put back in the chamber shortly after their first experience of it, suggesting that they had 'acquired a degree of "knowledge" and did not need to "explore" the familiar surroundings'[26]. Like many vertebrate animals, both lobsters and crayfish form stable social hierarchies when they are kept together in captivity, thus reducing the number of confrontations between animals. They initially challenge each other, including threat displays, restrained use of claws, and brief periods of combat. Lobsters can remember individuals they have fought with for up to 1 - 2 weeks. Researchers found that subordinates immediately backed away from animals who had defeated them, but were willing to fight other dominant animals they did not know, suggesting that lobsters are capable of individual recognition.[33,34]

5.4 Evidence of physiological stress in catching, handling and transport

In international fisheries, lobsters and crabs are caught in trap pots, by spearing, handheld scoop nets or by hand and lantern. If not killed immediately, they are often stored alive in tanks irrigated with sea water. Research in New Zealand and Australia on product quality and animal welfare in the crustacean fishing industry has documented the animals' physiological reactions to the various stressors they are exposed to during catching, handling, storing and transport.[35,36,37]

The types of stressors that the animals are subject to have been detailed by lobster scientists. Stressors include capture and landing, post-capture transfers and their vigorous attempts to escape (tail-flips) when they are taken out of water and handled. They are also stressed by physical damage (such as loss of limbs and blood), conflict between individual animals, sudden temperature changes, low water quality and exposure to air.[36]

It is known that aquatic 'lobsters generally cannot breathe properly in air'[37] and that they are stressed by handling[36]. Their demand for oxygen is higher when they are disturbed because they have a higher respiration rate[37], but their gills work very much less efficiently in air than in water. According to scientists, the diffusion of gases in the gills is 'severely impaired in air', and 'air exposure is an entirely artificial situation' for lobsters.[36] Research suggests that the usual commercial practice of keeping lobsters' and crabs' gills moist when out of water may actually make it harder, rather than easier, for them to obtain oxygen from the air. It seems likely that water on the gills causes the filaments to clump and creates a barrier to oxygen diffusion.[36]

Inefficient gas exchange by the gills in air is 'a primary cause of stress', according to lobster scientists.[36] When they are short of oxygen due to air exposure or vigorous exercise, crustaceans switch to anaerobic respiration (i.e. metabolic energy creation without using oxygen, in a similar way to the processes in a human athlete's muscles). Anaerobic respiration leads to a build-up of lactate in the animals' haemolymph (blood) and to acidosis (abnormally high acidity in the body). According to scientists, 'It is clear that significant changes in oxygen, pH [acidity], glucose and lactate in the haemolymph occur when lobsters are subjected to air exposure or exercise.'[36]

In addition, because their gills are much less effective in air, lobsters may not be able to excrete two of their waste products, carbon dioxide and ammonia gas, leading to accumulation of CO_2 and ammonia in their bodies. CO_2 contributes to acidosis and ammonia is believed to be toxic to lobsters.

Lobsters can recover most of their normal physiological functioning within a period that can be between 1 and 14 hours, depending on species of lobster, if they are left undisturbed in well-oxygenated seawater.[37] However, experiments with one species of lobster found that 48 hours' recovery time was needed for cardio-respiratory functioning to return to normal following 50 tail-flips and 8 hours out of water.[36] Crabs stressed by capture, handling and transport also have increased levels of bacterial infection in their blood, which may


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Signal Crayfish

contribute to the risk of food poisoning when they are eaten.[35,37] If the stress has been too severe, it may be irreversible, due to damage to the animals' cells caused by acidosis, ammonia, nitrite, temperature or blood loss.[36]

Many crabs and lobster arrive at factories and packing stations in a poor or even moribund condition, almost unable to move their limbs. The freshness of crabs that are to be sold alive is assessed by whether they appear lively, weak, critically weak or dead.[35] In the western rock lobster fishery of Australia, on average 20% of the lobsters arriving at the factory are too weak to be considered fit for live export.[37] A Canadian study found that 19% of lobsters had a missing claw. [35]

Crabs and lobsters are killed by a variety of methods, including pithing (destroying nerve centres with a sharp instrument), boiling, freezing, or during the process of cutting them up to remove their meat. Some crabs are killed on the deck of vessels. Crayfish are sometimes killed by cutting away the tailmeat when the cray has not been chilled and is still active. There has been quite inadequate consideration of the possible suffering caused by these methods. According to a review carried out for the New Zealand Ministry of Agriculture and Forestry, 'The stage at which an animal loses sentience during these killing procedures has not been examined in any detail'.[35]

6. DETAILED EVIDENCE REGARDING CEPHALOPODS

6.1 Nervous and sensory systems of cephalopods

Cephalopods are fast-moving, active predators and have to compete with fish, involving the need to process much information. All modern cephalopods have a well-developed nervous system and central brain, which is 'relatively enormous when compared to that of other molluscs, other invertebrates, and even some fish and reptiles', according to the assessment of one of the major British zoologists of the 20th century[38]. Their brain to body ratio is greater than that of most fish and reptiles. The cephalopod brain is complex and has numerous lobes (25 major, nearly 40 in total) carrying out different functions[38]. In addition to the central brain, there are ganglionic masses in its arms and other organs, with functions restricted to those organs. The 8-armed octopus has the most complex central nervous system of the group, but the general description applies also to the 10-limbed species (squid and cuttlefish) and nautilus. Unlike vertebrates, their nervous system is somewhat decentralised, so that the adult octopus brain has up to 200 million cells and an additional 300 million cells in the nerve cords of the arms[39], giving the arms practical autonomy.

In addition, the animals have numerous sense organs that, in their complexity, rival those found in vertebrates[38]. Octopuses have good eyesight, with eyes superficially similar to those of vertebrates, and a very good sense of touch. Their arms contain chemoreceptors (which are used for smell and taste) as well as mechanoreceptors (which are used for detecting by touch). The cephalopod sense organs, although structured and organised differently from those of vertebrates, have been described as some of the most advanced in the animal kingdom[9].

6.2 Experience of pain and suffering in cephalopods

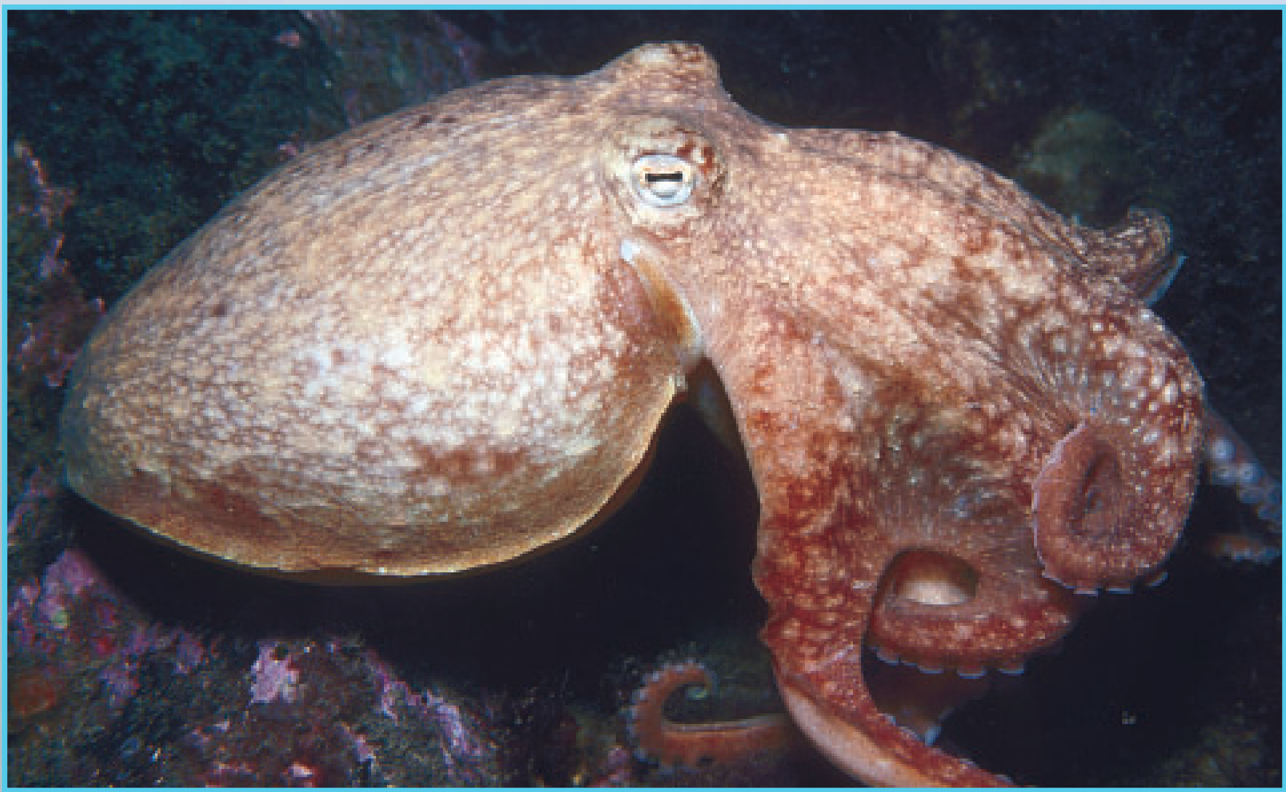
It is clear that scientists who work extensively with octopuses often assume that they feel pain and experience emotional states. The models of learning used by two of the best known octopus zoologists include a 'pain' pathway leading to the 'highest' centre of the brain[6]. A scientific submission from the University of British Columbia to the Justice department of the Canadian federal government, on revisions to animal protection law, stated that 'the cephalopods, including octopus and squid, have a remarkably well developed nervous system and may well be capable of experiencing pain and suffering'[40]. Cuttlefish learn fast not to attack prey enclosed in a glass tube, because 'Tentacular clubs striking against the glass produce pain', according to the researchers[41,42]. Cephalopods can show vigorous attempts to escape when anaesthetised by urethane, rather than with alcohol, which appears to be less aversive to them[39]. Electric shocks are used as negative reinforcement in discrimination and learning experiments.

There is striking evidence on the capacity for suffering from an expert in octopus zoology who described how the animals respond to the major surgery required to cut their optic nerves or disconnect the optic lobes for experiments: the animals take time to resume feeding and 'generally it is necessary to keep the animals for several days after blinding before the beginning of training. During this time they at first sit huddled up with the arms curled tightly around them. If disturbed they may roll over to present the suckered underside, as an octopus does if poked in its hole in the sea. ...Within a week they will normally be found sitting on the walls or the floor of their tanks, with their arms outstretched'[43], presumably to compensate for the loss of sight. Similarly, if the blinded octopus then receives many electric shocks because of mistakes made during training sessions, it may not sit with outstretched arms, but may 'become withdrawn' and 'the octopus may shy away from contacts'[43]. Change of pigmentation in octopuses is controlled by the nervous system rather than by hormonal changes, and may signal emotional states; when contented, as after a meal, the octopus skin turns orange, whereas, when threatened, the animal winces and its skin turns grey[6]. Similarly, when anaesthetised by urethane, octopuses may ink vigorously, another possible indicator of emotional distress.[39]

Squid are caught by a variety of methods, such as trawling, and also by 'jigging', a method where a bait is put on a hook and line. The squid strikes at the 'prey' with its tentacles and becomes hooked[35], which probably causes pain. It is known from experiments that cuttlefish can feel pain in their tentacles, and squid are also likely to feel pain when their tentacles are hooked on jigging lines.

6.3 Learning and complex behaviour of cephalopods

Octopuses are 'evidently intelligent'[43] and show a wide range of complex and flexible behaviour. Octopuses and other cephalopods have been shown to be capable of fine discrimination (by sight or touch), of generalization and of associative and even observational learning with long-term and short-term memory. Octopuses can learn quickly to discriminate between different geometrical shapes[43]. Although they will grab any small object and take it to the mouth, they quickly learn to reject objects resembling those they found by previous experience to be inedible[43]. Aspects of the brain chemistry relating to their learning, such as the involvement of nitric oxide[44], are very similar to that of vertebrates. Experiments published in 2003 found that a learning and memory area of the octopus brain shows a 'vertebrate-like long-term potentiation', suggesting that 'convergent evolution has led to the selection of similar activity-dependent synaptic processes that mediate complex forms of learning and memory in vertebrates and invertebrates'[45].



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Curled Octopus Eledone Cirrhose

There is less research available on the learning abilities of the other cephalopods. However, as mentioned above, cuttlefish learn quickly to stop attacking prey enclosed in glass tubes[41,42], suggesting that their attack response is not merely a reflex. Recent research shows they can also be trained by associative learning to attack a plastic sphere associated with food[46]. Octopuses occupy dens and forage from them, requiring an ability to find and remember the location of a den and a good spatial memory for its surroundings; laboratory experiments have shown that they explore and remember their surroundings and ignore regions where they have recently hunted[47,48]. Remarkably, they can learn by observing a previously trained octopus in a physically isolated tank choosing between 2 coloured balls, showing that observational learning can occur in invertebrates. The observational learning was actually quicker and more reliable than the training by conditioning to which the demonstrator animals were subjected. The animals followed the action patterns of the demonstrators with movements of their head and eyes; this ability increases with age and brain maturity and seems related to the vertical lobe[49,50]. Interestingly, octopuses appear to try harder, and learn faster, for a bigger reward[51].

Octopuses use rocks to reduce the size of their den entrances and squirt water from their funnels at both objects and animals, behaviours that could be classified as forms of tool use[47]. They can also solve problems, such as removing a plug from a jar to retrieve food, showing a ‘highly developed ability of “integration” of the behavioral program’, in that they remove the plug and seize the prey in one attack[52]. They can also learn to open a screw-top container and several octopuses in captivity in Germany, the UK and the USA demonstrate these skills to the public[53]. Their hunting behaviour also indicates flexibility and intentionality. When stung by a sea anemone protectively placed on the shell of a hermit crab that they are hunting as prey, they do not just retreat but circle around and attempt a less obvious approach, some even aiming jets of water at the anemone as if hoping to blow it off the crab shell[8]. Octopuses do not all behave in the same way; they have been found to have distinct temperamental traits and can be reliably classified by behavioural differences across their first nine weeks of life, suggesting that their development is ‘an idiosyncratic, individualistic process’[54]. They also engage in ‘play’ behaviour - and in experiments different animals played with the offered objects (floating pill boxes) in different ways[55].

6.4 Human understanding of cephalopods

Those who have worked closely with octopuses are led to believe that they are dealing with intelligent beings, in spite of their short lifespan of under 2 years, non-social behaviour and wide differences in the structure, organisation and evolutionary history of these animals compared to humans. The Cambridge University octopus expert, M J Wells, has compared their lifestyle to that of primates - unspecialised but highly successful exploiters of complex and dangerous environments, requiring similar survival skills. While warning against making simple assumptions in interpreting the behaviour of an animal so far distant from humans, Wells writes: ‘ The result is a mollusc that a primate can recognize as a fellow creature. It is very easy to identify with *Octopus vulgaris,* even with individuals, because they respond in a very ‘human’ way. They watch you. They come to be fed and they will run away with every appearance of fear if you are beastly to them. Individuals develop individual and sometimes very irritating habits, squirting water or climbing out of their tanks when you approach - and it is all too easy to come to treat the animal as a sort of aquatic dog or cat’[43].

7. PUBLIC POLICY AND LEGISLATION CONCERNING DECAPOD CRUSTACEANS AND CEPHALOPODS

In light of the weight of scientific evidence that decapod crustaceans and cephalopods are capable of experiencing pain and suffering, we believe that a precautionary approach should be taken with regard to these animals. Indeed, certain encouraging steps in this direction have already been taken.

Public opinion and public policy are now changing in relation to these groups of animals. Because of the growing realisation that crustaceans are capable of suffering, the traditional methods by which these animals are killed for food are now increasingly seen as inhumane. An example of this can be seen in the Guidelines produced by the New South Wales Government’s agriculture department for the humane killing of crustaceans. The Guidelines state that ‘Procedures causing pain or distress to crustaceans must be avoided’ and recommend stunning crustaceans either by cooling at –1°C for 20 minutes before cooking, or by rapid destruction of nerve centres, by cutting or pithing, preferably after cooling[56]. However, these procedures do not necessarily produce immediate unconsciousness without suffering and require a skilled operator. Electrical stunning using purpose-made machinery is now feasible and is the preferable method. The electric stunner known as the Crustastun[57] produces immediate unconsciousness lasting 30 minutes, and was developed from research at the Department of Food Animal Science of Bristol University and the Silsoe Institute. The stunner can be adapted for use in processing plants or for individual use by the restaurant trade or by the public at large. A commercial version is currently in use at the Blue Seafood Company in England. The stunner is also to undergo tests at a number of restaurants, including the main restaurant of Loch Fyne Seafoods, at Loch Fyne in Scotland. These changes in practice, while slow and incomplete, show that public and commercial opinion is open to including the welfare of lobsters, crabs and crayfish within the scope of animal protection law. They also demonstrate that such changes are commercially feasible.

A second example of a widening public concern about which species can suffer from pain and other causes is provided by the Government of Queensland Department of Primary Industries and Fisheries. The Department states, ‘There is ample evidence that indicates that cold-blooded animals experience pain. Fish are also capable of learning quite complex tasks and the cephalopods (such as octopus and squid) are good at complex learning tasks and, also, appear to form social bonds. So, it is quite possible that these species may experience suffering from causes other than pain.’[58]

Research has also been carried out into the humane euthanasia of crustaceans, such as those used in laboratory experiments, with the aim of avoiding pain. Some methods such as freezing (which can cause pain

Long Clawed Squat Lobster

when ice crystals form in the animal's tissues) are now being called into question as being inhumane. Canadian veterinary scientists have recommended humane euthanasia by injecting potassium chloride solution directly into the region of the central nervous system of lobsters. This is thought to induce immediate depolarization of the neurons, which prevents the transmission of sensory signals, and causes immediate loss of awareness. Death from cardiac and respiratory arrest follows within around one minute.[59]

Certain jurisdictions have already made the legal decision, on scientific evidence, that some or all of the decapod crustaceans and cephalopods should be given protection under animal welfare legislation by being included in the law's definition of 'animal'. The following are examples of such decisions that have been made. The UK has decided that the common octopus *(Octopus vulgaris)* should be included in the scope of the 1986 Animals (Scientific Procedures) Act, which had previously extended only to vertebrate animals. In Norway, the Animal Welfare Act (Code: 750.000) applies to crustaceans as well as to mammals, birds, toads, frogs, newts, reptiles and fish. In the Australian Capital Territory the Animal Welfare Act (A1992-45) includes in the definition of 'animal' a live vertebrate, a live cephalopod and a live crustacean intended for human consumption. The Queensland Government Animal Care and Protection Act 2001 includes octopi, squid, crabs, crayfish, lobster and prawns under the definition of 'animal' for the purposes of the Act. The New Zealand Animal Welfare Act of 1999 (1999 No 142) defines 'animal' as a live mammal, bird, reptile, amphibian, fish or any octopus, squid, crab, lobster or crayfish. At the time the Animal Welfare Bill was being considered, the (then) Animal Welfare Advisory Committee and the National Animal Ethics Advisory Committee (which provides advice on the use of animals in research) considered that the evidence relating to the behavioural and physiological responses of various invertebrates to painful stimuli, and the complexity of their nervous organisation, was sufficient to recommend the inclusion of cephalopods and crustacea in the Act.

The fact that these jurisdictions have included cephalopods and decapod crustaceans in the legal definition of 'animal' is extremely encouraging. Cephalopods and decapod crustaceans should be given the benefit of any doubt and included in the definition of 'animal' in the animal protection legislation of all jurisdictions.

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Edible Crab Cancer Pagurus

8. CONCLUSIONS OF THIS REVIEW

This review has addressed the issue of whether the cephalopods (octopus, squid, cuttlefish and nautilus) and the decapod crustaceans (lobster, crab and crayfish) are capable of experiencing pain and suffering. The issue is of importance because of the wide use of the animals for human food and research purposes, both of which have the potential to cause great suffering during handling, killing and scientific procedures.

Since pain and other suffering are private experiences, complete certainty on this issue is unlikely. In view of this, scientists approach the issue by considering (a) whether an animal has the nervous system and the physiological and neurochemical mechanisms to make it capable of experiencing pain, (b) whether the animal gives behavioural evidence of experiencing pain and (c) whether the animal shows other indications of mental capacity. Compared to that on vertebrates, the research effort on invertebrate sentience is still limited. However, scientists can already show that cephalopods and the decapod crustaceans meet the criteria given above that enable us to say that they have the potential to experience pain.

There is compelling scientific evidence, the implications of which have been ignored for too long, which demonstrates that there is considerable similarity and continuity between the nervous systems of vertebrates and those of cephalopods and decapod crustaceans. Apart from behavioural evidence, the opioid systems involved in analgesia and response to stress and injury appear to function in these invertebrates in the same way as they do in vertebrates. The survival of opioid processes in animals divergent in evolution by 500 million years may indicate that pain is a necessary monitoring system that requires temporary analgesia to enable the body to respond to harmful stimuli[60]. Cephalopods and decapod crustaceans also show a behavioural response to 'painful' stimuli such as electric shocks and crustaceans show a violent response to being immersed in boiling water without pre-stunning. They have the ability to learn, to remember and, especially in the case of the octopus, to respond flexibly to their environment.

This evidence taken collectively strongly suggests that there is a potential to experience pain and suffering in these animals. This is already recognised in the animal protection legislation of some jurisdictions. We believe that this potential for suffering should be recognised in law in Scotland and in England and Wales - and indeed in all other jurisdictions - by including cephalopods and decapod crustaceans within the scope of animal welfare legislation.

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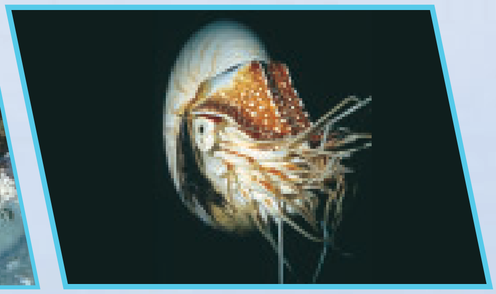
CEPHALOPODS AND DECAPOD CRUSTACEANS

Their Capacity to Experience Pain and Suffering

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