Philosophical Background of Attitudes toward and Treatment of Invertebrates

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Abstract

People who interact with or make decisions about invertebrate animals have an attitude toward them, although they may not have consciously worked it out. Three philosophical approaches underlie this attitude. The first is the contractarian, which basically contends that animals are only automata and that we humans need not concern ourselves with their welfare except for our own good, because cruelty and neglect demean us. A second approach is the utilitarian, which focuses on gains versus losses in interactions between animals, including humans. Given the sheer numbers of invertebrates—they constitute 99% of the animals on the planet—this attitude implicitly requires concern for them and consideration in particular of whether they can feel pain. Third is the rights-based approach, which focuses on humans' treatment of animals by calling for an assessment of their quality of life in each human-animal interaction. Here scholars debate to what extent different animals have self-awareness or even consciousness, which may dictate our treatment of them. Regardless of the philosophical approach to invertebrates, information and education about their lives are critical to an understanding of how humans ought to treat them.

Key Words: cephalopod; consciousness; contractarian; ethics; invertebrate; nociception; pain; rights; utilitarian

It is probably not surprising that people's attitudes toward invertebrates, and indeed all animals, are human-centered. After all, as infants we are first aware only of ourselves, truly egocentric (Berk 2000). Gradually we learn that there is a world separate from us, and by age 3 or 4 a child is busy exploring and cataloguing it. Later, in adolescence we go through another stage of egocentrism where we focus tightly on our place in this burgeoning universe. So anthropocentrism, the attitude that we are the measure of everything and the universe revolves around us, is predominant in human thinking.

This attitude is fostered by Western science (see Balcombe 2010). Western society is individual rather than communally focused, emphasizing competition instead of cooperation and thus reinforcing an individual focus and increasing the egocentrism. Furthermore, there is a strong belief in the objectivity of this view, so that it is not critically evaluated but assumed to be correct. This is supported by the Judeo-Christian view of humans as having dominion over the earth and all things in it. Some have pointed out that this dominion should mean protection and care, but in practice the industrial complex has used it as an excuse for exploitation.

This attitude goes hand in hand with the arrangement of animals on a *scala naturae*, a sort of tree of life with "lower" organisms at the base, rising through simpler vertebrates to the peak—primates and, of course, humans. This hierarchical approach originated with Aristotle as a way of logically organizing all life, and was taken up by the Christian church. God was at the top of the chain of life, indicating perfection, and humans were the next step down, working toward it (Balcombe 2010).

Surprisingly, there are modern versions, now with three peaks, showing insects, molluscs, and vertebrates increasing in neural complexity toward the apex of intelligence. Even now, people talk of "highly evolved animals" at these peaks. Of course this is untrue—simpler animals like nematode parasites and blind cave fishes are very highly evolved for their demanding environment. And horseshoe crabs, whose fossils can be found in rocks from the late Ordovician, are an enduring model that may survive when recent "generalists" like octopuses and humans have passed on.

No animal is better than any other, yet studies (Bekoff 1994; Eddy et al. 1993) show that humans value intelligent animals and those similar to us over all others. For example, although invertebrates comprise 99% of the animals on the planet, Eddy and colleagues (1993) proved the vertebrate-centered view by choosing only 3 invertebrates for their sample of 30 animals.

Whatever the particular bias, attitudes toward animals have a philosophical and ethical basis, even though those who hold them may not realize or explore the meaning of their attitudes toward animals in general and invertebrates in particular. There is a lot of variation, but the attitudes can be roughly categorized as contractarian, utilitarian, and rights based (Nussbaum 2001).

The Contractarian Approach

This philosophy presumes the complete separation of humans and nonhuman animals. Writing long ago, Descartes

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proclaimed that humans merited consideration in terms of pain and suffering because we have souls; all other animals did not have souls and thus were no better than automata (Balcombe 2010). He was supported in this by the Christian church, which sanctioned much cruelty to animals.

Disconcerting as it is to those who care for animals, this approach has one advantage: it asks us to evaluate the effects of our interactions with animals *for our own good*. Rollin (1985), talking about treatment of animals for research, places the responsibility for and benefit of ethical behavior on our shoulders and argues that we must act fairly toward animals. As people who control animals' lives, we must treat them well not because they "deserve" it but because it demeans us not to. For example, he asks undergraduate students using shock as a deterrent in their animal studies to first try the shocks on themselves, so that they are aware of what they are doing. He calls on all humans to be moral actors.

Even industries that inflict suffering on animals can minimize it in the name of moral action. A vertebrate-centered example of this approach is that of Temple Grandin (1995), who has described her understanding of the worldview of cattle and has developed a career in designing holding facilities and slaughterhouses for them. She has designed places that minimize their daily stress and the trauma of death and notes her satisfaction in knowing that they are as well cared for as possible.

Grandin also discusses the effect of working in such facilities on people. The Jewish man who conducts ritual slaughter of kosher beef considers this a calling and an act of religious piety; and Grandin (1995) sees his attitude as reflecting a need for ritual and respect at the death of animals, a need that is present in many cultures. Even so, routine killing can't help but affect those who do it, and may engender internalized pain or repudiation as a means of emotional or psychological protection from the reality of large-scale animal slaughter. Grandin advises slaughterhouse managers to rotate the actual job of killing to enable workers to retain a moral stance—so that the act of killing never becomes commonplace and no one gets callous about life because of it.

A further challenge is that the modern, urbanized, technical world removes humans farther and farther from organisms of all kinds. In addition, Balcombe (2010) suggests that media coverage deliberately distances us from animals and distorts the understanding of their lives by focusing on the "excitement" of the chase and the drama of death. But octopuses, for example, are predators that actually spend three-quarters of their daytime lives resting or sleeping, which doesn't make "good press" (Mather 1988). Balcombe (2010) also points out that, in order to make ourselves seem more important, we use demeaning and uncomplimentary words not only to describe animals but also to insult humans—think of "beastly," "brutish," "savage," or even simply calling someone "an animal."

How much more true this uncaring attitude is toward invertebrates! It is not just that their importance is seen as much less than their numbers indicate, but also either that they are simply not considered (Bekoff 1995) or, in the case of insects, that we are uneasy and even fearful around them (Hardy 1988).

The most positive of human attitudes toward animals is Wilson's (1984) "biophilia." He writes that humans should gain an "inherent human affinity for life and lifelike processes" and that we will act ethically if we appreciate the living inhabitants of the planet in all their diversity. Again, the point is not the type of animal but that all animals benefit when we care. Wilson (1984) has a long way to go to persuade us to love *all* animals.

The Utilitarian Approach

A Gain-Loss Approach to Animal Ecology

The utilitarian approach to the importance of animals is objective: humans should assess gains and losses when making any decisions and judgments about animals. According to this practical view, the dominance of invertebrates in terms of number of animals means that they are critical to the survival of life on the planet and should therefore be respected and protected (New 1993).

Kellert (1993) makes the point by emphasizing the value of invertebrates in waste decomposition, as food for humans and for the organisms that humans eat, as sources of chemicals and drugs of immense benefit to humans, and as indicators of the health of ecosystems. Recent prominent developments illustrate this close-knit relationship between invertebrate and human welfare. Observing the decimation of bee colonies by disease, experts pointed out that bees' pollination enables the production of many human food crops. And coral reef animals, which form the backbone of one of the most productive marine ecosystems (Ponder et al. 2002), are threatened by a number of human actions.

Assessing Pain as a Cost

The gain-loss equation applies to evaluation of the impact of human actions in particular situations and on specific animals or populations. For example, what are the impacts of fishing, keeping animals in aquariums, and using them as experimental subjects? Unfortunately, it is often the human gains that are the major consideration and the losses to animals secondary.

Debate has focused especially on the possibility that humans inflict pain and suffering on animals and on how these conditions can be assessed in nonhuman animals. Evaluation of emotions in animals is fraught with subjectivity; indeed, many Western scientists refused until quite recently to even speculate that animals had emotions at all because it was not possible to properly prove their existence. Griffin's (2001) efforts over many years have helped but the problem of evaluating animal emotions is a huge one still.

The Significance of Pain versus Nociception

Pain is valuable from an ecological perspective as it allows an organism to be aware of danger and to avoid situations in which damage might occur or recur. Yet it is not a simple sensory modality. Even in humans, who can describe their physical sensations, it is not easy to understand (see Matlin and Foley 1997 for a textbook description). Merskey's (1986) definition of pain as "information about actual or potential tissue damage, or interpreted in terms of such damage" conveys the variability of the sensation.

The experience of humans shows that receptor signals of damage are not automatically processed and passed undistorted to the central nervous system and brain. There are many examples of rituals, sports, and wartime experiences in which humans are not aware of painful major tissue damage for minutes or even hours (Matlin and Foley 1997); clinically diagnosed pain disorder (American Psychiatric Association 2000) is not tightly associated with actual damage, only triggered or even unaccompanied by actual damage; and phantom pain, the sensation from a lost limb, is the result of a central representation that endures after the periphery is no longer sending signals. Because of all these variations in pain, it is obvious that it has sensory, emotional, and cognitive aspects in humans, and these make it difficult to identify in nonhuman animals, whose ways of communicating discomfort are often less well understood by humans.

One way to separate these different aspects of pain experiences is to define and evaluate nociception, the purely sensory experience of the damage signal (Kavaliers 1988; also see Elwood 2011, in this issue). It is too simple to suggest that nonhuman animals have only nociception, especially if they exhibit learning and expectation of future stimuli—and many invertebrates do demonstrate at least simple learning.

Evidence of Pain in Vertebrates (Fish)

Braithwaite's (2010) study of whether fish feel pain shows how such an investigation could be carried out for invertebrates. She notes that fish, as vertebrates, should have structural and brain similarities with mammals that experience pain, and her assessment of the anatomy of receptor systems similar to those of other vertebrates does show a clear parallel. She looks at data about brain regions and finds that, although the specific brain arrangement is different among the vertebrate classes, similarly functioning regions are present (this is harder to show in invertebrates). She then measures responses to stimulus situations that would be considered painful for mammals and demonstrates clearly comparable results, though of course not in brain location.

In light of her observations, Braithwaite asks whether pain-inducing stimuli trigger differences in responses that matter to the animals' daily lives, such as whether a fish is willing to tolerate the possibility of electric shock so that it can school with conspecifics (the answer is different for two fish species). The evidence indicates that it is important to look at interference with nonreflex (i.e., "planned") behaviors and evaluate investigation of novelty as an example of such behavior.

Given the positive answers for these studies, Braithwaite concludes that yes, fish do feel something like pain.

Assessing Pain versus Nociception in Invertebrates

This structural parallel between fish and other vertebrates makes it easier to prove pain in those species than in invertebrates, but an examination of nociception across different invertebrate phyla is a good starting point.

Cnidarian sea anemones, for example, have stinging cells that they use on each other and that are also painful to humans and repellent to animals of many species (Braithwaite 2010; Mather 2001). The anemones live in clones (groups of identical individuals), holding fast to the rocks of the seashore and catching drifting small animals and detritus. Clones that encounter each other have "wars," stinging each other and inflicting considerable damage. They flinch from these attacks and eventually one clone retreats from the other and is the loser in the encounter. These animals have no centralized brain and only a nerve net, yet they clearly exhibit nociception in this situation.

The anemones' weapons are also used by other animals, in situations that *seem* to demonstrate learning. Hermit crabs pull anemones off the substrate and place them on their borrowed gastropod shells where they repel both crabs and octopuses, which learn to avoid the crabs as prey (Maclean 1983). One study showed that chemical stimuli in water that contained an octopus stimulate hermit crabs to put anemones on their shells (Ross and von Boletzky 1979), presumably to repel predators. However, there is no evidence that the hermit crab learned this behavior.

The physiology of stress responses is clearly similar across many phyla. Stefano and colleagues (2002) point out that the immediate rise in immunocytes and a later increase in opiates in mussels and leeches subject to cold water shock are not only normal stress responses but the same as found in humans after coronary artery bypass surgery. These animals also show adrenocorticotropic hormone (ACTH) downregulation of immunocyte activation, again similar to that of mammals. Even more interesting is the heart rate increase of juvenile queen scallops (*Aequipecten opercularis*) under predation threat when on a substrate that offered no refuge (Kamenos et al. 2006). And the heart rate of mussels increases in response to a chemical cue in the effluent of their predator, the dog whelk (*Nucella lapillus*; Rovero et al. 1999). While these observations are scattered, they make it clear that the physiological systems are very similar across widely diverse vertebrate and invertebrate animals.

Elwood (2011) and his associates are the only researchers that have explicitly studied whether the nociception that an invertebrate shows to noxious stimuli could be extended to pain. The first study (Barr et al. 2007) was on prawns' antennal grooming. Prawn antennae are crowded with tactile and chemical receptors and are a major area for evaluation of waterborne sensory stimuli. Application of chemicals or gentle pinching caused grooming of the specific antenna and rubbing against the substrate, which was reduced by application of the local anesthetic benzocaine (which did not reduce general arousal, only antennal grooming). Because the grooming is a targeted and not a generalized response, the authors suggested that it parallels the responses of fish and other vertebrates in similar situations and can be considered evidence of pain.

Elwood (2011) argues that separating immediate nociceptive responses from longer-term cognitively guided pain responses will always be difficult because pain is such an imperative system that response is usually immediate. According to the utilitarian approach, the solution is simply to accept the importance of minimizing the effect (i.e., "costs") of these stimuli on animals, whatever their perception of the stimulus might be.

The Rights-Based Approach

According to the rights-based approach both the agent and the receiver in any interaction have value and thus deserve consideration and respectful treatment (Regan 2003). This is the only one of the three viewpoints that focuses on the individual and accords animals the right to bodily integrity and physical liberty. The spotlight is thus on the experience of the animals themselves.

Nussbaum (2001) suggests taking into account an animal's life, health, physical integrity, and emotional well-being. Such a perspective raises some difficult questions, such as whether it is defensible to exhibit animals (including invertebrates) in aquariums and zoos, thus depriving them of liberty. And one of my colleagues asked whether this approach requires consideration of the potentially conflicting welfare of a parasite or its host.

Furthermore, it is necessary to understand the basic physiology of the animal itself, whereas such knowledge is missing for most invertebrates. How can humans protect the right of the clam, the luna moth (*Actias luna*), or the nereid worm without understanding how the animal lives? Davis and colleagues (1999) make this point about the ascidians, a primitive chordate that is common but whose ecology is very poorly known: we might like or need to protect them if we knew how.

The rights-based approach demands close study of the experiences and awareness of animals and evaluation of the situations to which humans subject them. Does the animal have the learning capacity to recognize and respond to a stimulus that signals an event? Does it have the self-awareness to know how trouble will affect it and the mobility to avoid trouble? The animal's capacity to learn is important; Bekoff (1994) points out that suffering might be less bearable without cognition, which remembers the past and plans for the future, only dealing more effectively with an unpleasant present. Many people say that invertebrates do not have consciousness or self-awareness, so it is important to examine their capacity in this area to evaluate what humans' treatment of them might mean.

According to Broom (2007, 99), a sentient animal is "one that has some ability to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings, and to have some degree of awareness." This account of cognition and awareness certainly applies to cephalopod molluscs, which studies have shown are heavily dependent on learning (Alves et al. 2008; Wells 1978) and may have consciousness (Mather 2008). The following sections therefore focus largely, but not exclusively, on these invertebrate species.

Self-Referencing, Self-Awareness, and Self-Consciousness

Bekoff and Sherman (2004) propose three levels of understanding of self: self-referencing, self-awareness, and self-consciousness. They believe that an animal's fit in these categories is dictated more by its behavioral ecology (e.g., whether it is social) than its brain size (within limits) or phylogenetic derivation. And presumably the animal's place in these categories should dictate the treatment it receives from humans. For instance, a Korean-style restaurant in New York City cooks mixed shellfish and octopuses alive in a frying pan at the table. Do some of these animals or none of them deserve this treatment?

Self-Referencing

Self-referencing is the matching of a target individual to oneself and does not usually involve learning or cognition. Courtship of hetero- or homosexual individuals entails the identification of species, sex, and readiness to reproduce before mating actually takes place.[1] Dual-sexed hermaphrodites may compete with one another to see which will be which sex in the reproductive act (Anthes 2010). Simple awareness of self and of the identity of the target animal is necessary.

Self-Awareness

Self-awareness involves recognition that one is a self and that conspecifics are others, as well as a sense of one's place in the world or possessions (e.g., shelter, territory). The animal may demonstrate learning and cognition, and the factors that influence its "decisions" may be simple or complex. Hermit crabs, for example, fight one another over the possession of shells in which to hide their vulnerable abdomen; they evaluate new shells for different durations and fight others with different intensities in different circumstances, including whether the contended shell is of a more desirable species (Elwood 1995). There may be evidence that they

[1]Although some marine animals do not even do this—sessile species such as coral and bivalves use broadcast fertilization, simply releasing gametes into the water.

assess both their ability in relation to a rival and the "value" of the shell possession to calculate whether a fight should proceed (Elwood 2011).

Further demonstrating self-awareness, cephalopods are excellent navigators for short distances (Alves et al. 2008), and some of their ability to locate themselves in the environment is learned. Field studies of octopuses (Mather 1991a) showed they forage freely across the ocean bottom, returning to a sheltering "home" from a distance and over a time that necessitates spatial memory. They can return home by detours even after they have been displaced from their foraging path (Mather 1991b). They also remember which areas they have been foraging in over the last few days and do not repeat searches in these locations where no prey is likely to be found.

Interestingly, cephalopods' "decision" of whether to consume a prey species in hiding near the capture location or whether to take it home to consume it is based on the distance to the home (Mather 1991a), clearly an indication of the awareness of oneself and one's relative location. This ability has also been proven in the laboratory for octopuses and cuttlefish, and is an interesting parallel with the spatial ability of bees and mammals (Shettleworth 2010), suggesting parallel competence across several phyla.

Self-Consciousness

What of self-consciousness, which likely involves cognition? The mirror test has become the critical evaluation of this capacity in primates (Gallup et al. 2002) and lately has been used on other vertebrates, although not without controversy (Moses 1994). A simple version of the test is to expose the animal to its image in a mirror and evaluate reaction. A more stringent test is to make an innocuous mark on a nonvisible area of the animal's body (e.g., its head), then to expose the animal to a mirror image of the area and see if it touches the mark.

Cephalopods have the best potential of self-consciousness of all the invertebrates, as they exhibit exploration and play, personalities and problem solving (Mather 2008). Octopuses exposed to mirrors show alerting and approach behavior, no different from their reactions to a view of another octopus (Mather and Anderson, submitted).

Two problems have been cited concerning the exposure of animals such as octopuses and cuttlefish to mirrors, assuming their failure at the task (Bekoff and Sherman 2004; Mather and Anderson, in press). First, although octopuses have excellent visual acuity, they may not depend on that sense in the same way that mammals do. Second, they are generally asocial and so may not have complex behavioral responses to either the image or the actual presence of another octopus.

Deception

Another way to evaluate invertebrate animals for self-awareness is to look at whether they show deception. Again the ability comes in three levels, with the simplest and most automatic being permanent deception (e.g., visual or other sensory camouflage); many invertebrates have a deceptive appearance—for example, the lemon yellow dorid nudibranch gastropod (*Tochuina tetraqueta*) is a perfect match for the yellow sponges on which it lives and feeds. Similarly, kelp crabs (*Pugettia producta*) are excellent matches for the algae on which they live, and several species of shrimp mimic their gorgonian resting places exactly. Some insects have exquisite matching to aspects of the environment such as leaves and sticks, and moths mimic the bark of trees on which they hide. But these deceptive appearances are permanent and selection is the machinery that determines them; no learning or cognition is present.

A second level is deception based on time and place. Cephalopods with their changeable skin show such ability with ease and often with a wide repertoire of displays for use in different situations. One example of such deception is the deimatic dots on the dorsal surface of cuttlefish (Langridge et al. 2007) and squid (Mather 2010). These dots appear on the skin surface in the presence of a low-level threat, as when a potential but not imperatively dangerous predator approaches. The cuttlefish shows two dots and the squid two of four on their large dorsal surfaces, presumably mimicking the eyes of a larger animal, as the dorsal surface is often turned toward the approaching fish. Indeed, there is a significant correlation of appearance of lateral dots with the direction of the approaching fish, as the animals exhibit dots on the part of their body that can be most easily seen by the potential predator. Squid do not direct such warning displays toward conspecifics but toward a chosen target (Mather 2010), thus they seem not to be automatic but chosen.

True deception occurs when animals give misinformation about resource-holding power or their ability to win contests. Caribbean reef squid (*Sepioteuthis sepioidea*) have "honest" formalized zebra display contests, in which the intensity of the display is greater on the squid taking a position above, and that individual is the one that claims resources in terms of consortships with a nearby females (Mather 2004). There is no deception, as the animals trade places if the display of the lower animal is more intense. Juvenile squid, however, respond to the mating displays of an adult pair by engaging the male with a high-intensity zebra that does not accurately represent its ability to win a fight. Such a deceptive display intensity might mean that the juvenile later was able to mate with the female.

Similarly, male cuttlefish have alternate morphs (skin displays) when they are courting a female (Hall and Hanlon 2002). One of these displays signals dominance, and the male sets up a consortship and later mates with the female. An alternate deceptive strategy is for a male to adopt the same display as female cuttlefish and become a "sneaker," changing its body pattern to then court and mate with a female when her consort is temporarily away. Unfortunately, Hall and Hanlon (2002) did not continue to watch sneakers over time, so they did not observe whether tactics differed from one individual to the next or changed with maturity (for a discussion of alternate reproductive strategies, see Taborsky and Brockmann 2010). In reef squid, males adopt peripheral positions and sneaking strategies as subadults, then join visual display contests and hold consortships as they grow to maturity (Mather, unpublished observations).

A striking example of deception over time is the mantis shrimp fighting technique (Caldwell 1986). Individuals occupy and often successfully defend their burrows in the substrate. The meral claw strike is dangerous, so shrimp seldom actually fight but favor visual displays to indicate their size and ability to hold the burrow. When females lay eggs or when any shrimp molts, their resource holding potential is considerably reduced and fights often result in displacement from a burrow. Weakened individuals instead use a meral claw spread to indicate size and resource holding potential. They also initiate fights and are more aggressive in other ways just before they molt, enhancing their "reputation" just before it could most easily be challenged.

Scientific Evidence in Support of the Rights-Based Approach

Given this evidence that many invertebrates may have simple sentience *sensu* Broom (2007), and that the rights theorists believe that these animals have the right to a full, rich life, how should humans behave morally when interacting with them? It is helpful to look beyond simple evaluations and tap into the life history of the animal to see to what extent its natural behavior and needs are fulfilled in captivity.

Moltschaniwskyj and colleagues (2007) offer wide-ranging guidance for appropriate care of a variety of cephalopod species. They also urge use of the 3Rs (reduce numbers of animals, refine procedures, and replace animals with alternatives) for invertebrate subjects in experimentation. This advice is important because there is a trend to replace vertebrate animals in experimental work with invertebrates; but this reduces animal welfare concerns only if people believe invertebrates are not aware of the consequences of many human actions.

For example, crabs caught in commercial pot traps are declawed and then returned to the ocean (Patterson et al. 2007, 2009), a practice that seems justified by the fact that crabs sometimes autotomize a claw when threatened by a predator; declawing is thus seen as "natural" and not detrimental to the crab. The opposite turns out to be true: the effects are extensive and change several important aspects of the crabs' lives. Studies show that claw removal is a significant stressor (Patterson et al. 2007), raising the level of glucose, lactate, and glycogen in the hemolymph much higher than baseline both in handled crabs and in crabs induced to autotomize. Furthermore, glucose and lactate were higher and glycogen lower when crabs were placed with conspecifics after claw removal. Crabs are aggressive with one another and the crab with one or more claws missing, whether by autotomy or removal, is at a significant disadvantage to compete for and hold high-quality territories.

Not only do crabs without a chela move down in the hierarchy, they are at a disadvantage in feeding. Crabs with only one claw had significant difficulty consuming mussels, their common prey (normally the crab holds the mussel with one chela and crushes it with the other). In captivity they consumed a lot of alternative food (pieces of fish), but this option is likely not available in the wild. Some of the declawed animals even died from hemolymph loss and others would have starved or lost significant amounts of weight.

Thus an intervention that looks like a harmless mimic of a natural situation is instead devastating to all aspects of the crab's life. Patterson and colleagues (2009) therefore strongly recommend that this method be stopped.

The Importance of Supporting Species-Specific Normal Behavior

For rights theorists, even benign captivity can deprive an animal of its rights, and acting morally means ensuring all animals a full and complete life, including the rights to appropriate housing, stimulation, reproduction, and feeding opportunities (see Broom 2001 for an extensive discussion of these topics mostly in mammals).

The need to carefully choose appropriate species for captivity was recently highlighted by Mason (2010; although she ignored the invertebrates, as pointed out by Carere et al., in press). Again a good example is the cephalopods, for which Moltschaniwskyj and colleagues (2007) note clear limits in knowledge of their biology. They point out that ommastrephid squid suffer 100% mortality in rearing and are therefore not suitable for captivity.

Octopuses, for example, explore and learn well, play, have personalities, and solve problems (Mather 2008). Is it right to keep these intelligent animals in a barren, restrictive aquarium tank? Studies clearly show that enrichment makes a difference to their biology: captive young cuttlefish in an enriched environment grew faster and ended up larger than those in a barren one (Dickel et al. 2000).[2] Enrichment for these (and many other) animals helps to maintain healthy activity levels, alleviate the effects of confinement, and enable animals to pursue species-specific normal activities.

A particular risk for intelligent and social animals is boredom (Wemelsfelder 1993). Common symptoms of boredom are repetitive route retracing, constant attempts to break out of confinement, and abnormal sleep and resting patterns. Octopuses in captivity are well known for their ability to escape from the confinement of their tank, taking advantage of the manipulative ability of their arms. Aquarium owners use a wide variety of techniques to confine them, not always successfully. The first recorded event was in the Brighton Aquarium over 100 years ago, when the captive octopus visited a neighboring tank and dined on a lumpfish each night for several nights before returning to its home. But bored octopuses

[2]Wells (1978), however, has argued that octopuses are used to hiding in a protective home and moving out for food, and that their solitary lifestyle makes them preadapted to thrive in captivity.

can also be destructive; Anderson (2005) describes an octopus that attacked her tank by repeatedly moving rocks around and scratching the glass, blowing gravel up from the bottom, and finally biting through the ties holding the undergravel filter in place, pulling it up, and tearing it into pieces, which were found floating at the water surface the next morning.

One way to provide enrichment for octopuses in an aquarium is to provide substrate that is comparable to the animal's natural environment, with rocks to make a sheltering home and gravel (cuttlefish bury in gravel and should never be deprived of it; Mather 1986). Enrichment for octopuses also includes the provision of novel objects for manipulation and play (Anderson and Wood 2001). Octopuses will take apart any complex many-pieces object, and the children's Mr. Potato Head toy is a favorite at several aquaria.

If appropriate and at all possible, enrichment should also prepare the animal for release into its natural environment; for instance, hatchery-reared salmon are notoriously unaware of predators and are easily picked off (Brown and Day 2002). Cephalopods should receive live prey so that they can exercise their natural predatory response.

Anderson (2000), for example, describes the release of the giant Pacific octopus (*Enteroctopus dofleini*) Ursula, who had come to the Seattle Aquarium by donation when she was very small. She was growing too large for her aquarium tank, so her keepers fed her live crabs for several days before her release to give her the opportunity to catch appropriate prey. When she was released (to a huge blast of publicity), divers followed her progress down to the seafloor below the waterfront aquarium. The divers checked on her for the next 40 days and noted the remains of three species of local crabs piling up in front of her den, so she was hunting successfully. When she was last seen, three males were also observed near her, so it is likely that she also fulfilled the rights criterion of being able to reproduce.

Thus it is clearly possible with captive octopuses to accommodate the special needs of an intelligent invertebrate.

Conclusion

Although theorists have not necessarily thought specifically of invertebrates in postulating humans' attitudes toward animals, human attitudes are important to the welfare of these (and all) animals. Contractarian theorists value our humanness in caring about animals, utilitarians consider the importance of the 99% of animals that invertebrates represent, and rights theorists' concentration on animals' essential needs is useful for enriching the everyday lives of invertebrates.

Education is key (Meehan 1995): as invertebrates are better understood, people—whatever their value system—will come to appreciate and take better care of them.

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