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Evidence-based practice

Behavioural indicators of welfare exhibited by the common European cuttlefish (*Sepia officinalis*)

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Abstract

The common European cuttlefish (*Sepia officinalis*) is frequently found in public aquaria in Europe. These remarkable creatures make fantastic display animals due to their rapid colour/texture/behaviour changes associated with feeding or camouflage. They possess extremely fragile bodies and soft tissues, adaptations thought to have evolved to evade predators, and in captivity cuttlefish can damage easily when startled or fleeing perceived threats and these injuries rarely heal, can cause permanent damage and even death. Knowing the signals which typically occur before damaging behaviours can reduce such incidents and therefore dramatically improve their welfare. Another aspect of captive animal welfare is providing suitable enrichment. Cuttlefish are adept at revealing how they feel about their present circumstances through deimatic displays, threat signals and defensive behaviours. Here, based on approximately two thousand hours of observations a very detailed welfare-focused behaviour table, a table summarising tank requirements/enrichment in cephalopods and an example care sheet derived from the observations are presented. This paper provides the resources to determine and prevent behaviours likely to precede damaging behaviours. Collating behaviours and sharing them with aquarists can be a valuable tool in preventing injuries and assessing wellbeing in captive animals.

Background

Cephalopods are frequently seen in public aquaria (e.g. the common European cuttlefish, *Sepia officinalis*) and are often star attractions, impressing visitors with their unrivalled ability to change shape, colour and texture. This ability of many cephalopods to instantaneously match their background or exhibit conspicuous displays has evolved under significant selection pressure to reduce the great predation threat many species face (Hanlon and Messenger 1996), and these adaptations are likely in lieu of significant physical protection (Hanlon and Messenger 1996). All cephalopods (bar Nautili) are extremely fragile, lacking external protection commonly associated with other molluscs, and have a limited and soft epidermis. As such they are more likely to become damaged than other aquatic animals commonly kept in public aquaria and aquaculture or research facilities.

In the wild cephalopods demonstrate a wide repertoire of behaviour when threatened (Hanlon and Messenger 1996), which frequently have negative consequences when performed in captivity. Some cephalopods (and especially cuttlefish) emit a dark, viscous, melanin-based liquid known as "ink" (see Derby et al. 2007), which may divert a predator's attention away from the individual cuttlefish or significantly reduce visibility for the predator (Hanlon and Messenger 1996; Sykes et al. 2012) whilst potentially acting as a chemical deterrent (Wood et al. 2008). In aquaria this substance may completely black out tanks (Cooke pers. obs.), which can also be an issue for off-show animals that are part of closed recirculating systems. Although not immediately toxic to con- and heterospecifics, cephalopod ink can put increased pressure on the filtration features of life support systems. It may also be an alarm substance (Wood et al. 2008; Gilly and Lucero 1992; Lucero et al. 1994), potentially increasing stress or fear in other cephalopods in connected systems. Unrelated taxa may also become stressed if visibility is reduced. When a tank is blacked out through inking, welfare can be compromised via accidental or panic-driven collisions with other animals, substrates, sides of displays and other features. Furthermore, if injury occurs during a time of reduced visibility, care staff cannot act immediately, having to wait until the tank clears before seeing what damage has occurred.

Another anti-predator strategy some cephalopods possess is to jet backwards erratically (Hanlon and Messenger 1996). In the wild this has few consequences, but in enclosed captive conditions animals may damage themselves. Indeed, in cuttlefish, one of the most common captive cephalopods,

Table 1. Summary of cephalopod environment considerations, with references where available. Data collected from research, aquaculture and zoo (including public aquaria) literature. Listed are potential advantages and disadvantages and are not certain outcomes. Abbreviations: ST = Stimulation; ES = Eustress; RA = Reduced aggression; RF = Reduced fear/threat behaviours; RI = Reduced injury; IG = Increased growth rates; EB = Exploratory behaviour; HC = Reduced ability to health check individuals; PE = Pollutes local captive environment; IH = Increased husbandry; IT = Increased territoriality; BB = Breeding behaviour; EC Excessive cost/time for husbandry; II = Increased injury; RM = Reduced mortality; HS = Hastened senescence; NB = Natural behaviour. See also Moltschaniwskyj et al. 2007 for a review of cephalopod welfare and ethics.

Consideration	Group	Potential advantages	Potential disadvantages	Notes	Reference (Context)
Substrate	Cuttlefish Octopus	NB, RA, RF NB, RA, RF	HC, PE, IH HC, PE, IH	Facsimile of substrates may remove issues	Tonkins et al. 2015, Sykes et al. 2003; Boal 2011; Mather and Anderson 1999 (Research)
Pipes/caves	Octopus Cuttlefish	NB RA	HC, IT HC, IT	In the wild, an octopus may spend 88% of daylight hours in dens	Mather and O'Dor, 1991 (Natural observation); Tonkins et al. 2015, Sykes et al. 2003 (Research)
Fake/real plants	Cuttlefish	NB, RA	if real PE, EC, IH	Fake plants can have many uses	Boal 2011; Tonkins et al. 2015
General environmental heterogeneity	Octopus Cuttlefish	RA, RF, NB RM	HC, IT, II	Not appropriate for squid or nautilus	Fagen, 1982 (Zoo); Tonkins et al. 2015 (Research)
Learning/novel objects/ problem solving	Octopus Cuttlefish	ST, IG ST, IG	HS	Reduces longevity	Rehling 2000; Anderson and Wood 2001 (Zoo); Boal 2011 (Research)
Conspecifics	Octopus Cuttlefish Squid	NB, ES, RA	IT, BB, II	Required for breeding but at least one squid species shoals	Fagen 1982 (Zoo); Boal et al. 1999 (Research)
Live food/varied diet	All	NB, IG, RM	EC, EI, PE, IH	Bar reproductive opportunities, best enrichment	Octopus: Anderson and Wood 2001; Mather and O'Dor, 1991; Wood and Wood, 1999 (Zoo) Cuttlefish: Sykes et al. 2012, 2014 (Aquaculture)
Bespoke tank design	Nautilus – tall tank Cuttlefish – rounded and soft sided tank Squid – raceway	NB RI NB	EC EC EC	Large systems may be required to ensure tolerable levels of nitrogen compounds	For all groups, Sykes et al. 2012, 2014 (Aquaculture), Hanley et al. 1999 (Research)

the most frequent ailment is perhaps a condition known as "butt burn" (or "bubble butt"), where an individual has damaged the posterior end of its mantle after a collision. These injuries rarely if ever heal, are susceptible to bacterial infection (Smith et al. 2013) and can retard growth (Oestmann et al. 1997). Impact damage can be (though is not always) lethal if the cuttlebone is broken (von Boletzky and Overath 1989; see also Sherrill et al. 2000). Posterior mantle damage can be very unsightly and clearly visible to visitors.

Cuttlefish possess brains comparatively larger than some fish and reptiles (Sykes et al. 2012), are thought to possess high cognitive function (Hanlon and Messenger 1996), are perhaps even emotionally aware and conscious (Mather and Anderson 2007) and also appear to have personalities (Carere et al. 2015). Furthermore, cuttlefish have many open nerve endings in the outer dermis as well as a well-developed nervous system, which suggests that they are able to feel pain (Andrews et al. 2013). Given these remarkable abilities they deserve stimulating and appropriate care in captivity, yet there is still relatively little information available regarding their welfare.

Many welfare issues may be prevented by appropriate tank sizes, tank mates and other established techniques (e.g. see Slater et al. 2014), but in addition to common reactive measures, cuttlefish allow us to proactively avoid issues by warning us they may occur. In addition to camouflage, many cuttlefish use conspicuous colour, texture and behavioural changes to warn or deter receivers within visual proximity (Hanlon and Messenger 1996; and see Langridge et al. 2007 for evidence that some deimatic displays are threat specific). Learning these signals, and determining what they mean in a variety of contexts, can help in understanding whether or not a cuttlefish is stressed and likely to commit potentially damaging behaviours (see Tonkins et al. 2015, for use of these signals in welfare assessment experiments). Furthermore, cuttlefish signals may reveal the beginning of episodes of ill health before other more problematic symptoms manifest themselves; for example, posture and colour changes in cuttlefish may reveal if the animal is sick (Sherrill et al. 2000).

Alternatively, cuttlefish signals can also reveal when they are enriched, or suffering from a lack of stimulation. Counting the frequency and type of signals that are given may allow staff to monitor long term psychological wellbeing. This paper provides a comprehensive list of both negative and positive behaviours which either frequently lead to damaging behaviour (such as inking or jetting) or are a signal that an individual is enriched.

Action

During the past four years (August 2011 – June 2015) we have worked with over 100 adult *Sepia officinalis* and between 150 and 200 juvenile/sub-adults in a wide variety of contexts, e.g. feeding on dead or live prey; groups and individuals, enriched and impoverished environments; breeding groups with varying sex ratios; and observed behaviour including agonistic interactions; mating; post-copulatory defence and many more. In addition to our own observations, we have consulted the literature, in particular research by Hanlon and Messenger (1988; 1996). We also collated information on enrichment in other cephalopds, e.g. octopus, squid and nautilus, summarised in Table 1. This table provides a source of information for those wishing to keep cephalopods for the first time.

Table 2. Negative and positive behaviours in *Sepia officinalis* observed in our experience, found in the literature and gathered from conversations with cephalopod experts and keepers. Some behaviours cross contexts so can be positive and negative. Some natural behaviours (e.g. Intense Zebra Patterning), especially those during breeding, might initially be encouraged as they show the animal is enriched in captivity; however, they may also lead to negative behaviours for others in close proximity.

Behaviour type	Definition	Interpretation/context	Implications for captive welfare
Locomotor			
Thigmotaxis	Touching sides of tank with any part of fin but facing away from the touching side	Felt under threat	Welfare compromised
Avoidance movement	Movement that is due to human disturbance	Aversion to stimulus	May precede damaging behaviour
Jetting	Sudden and quick movement away from stimulus that can lead to mantle damage in confined spaces	Escape from perceived threat	Welfare compromised
Pushing	Pressing of the side of the tank, pushing using top of tentacles that are facing down; stereotypic behaviour, mostly seen in adults prevented from breeding	Stereotypic attempt to leave present environment	Welfare compromised
Pacing	Swimming from one end of the tank to the other with no clear purpose. Documented in many aquatic captive animals and seen mostly in adult individuals prevented from breeding, especially individuals who have just become sexually mature	Stereotypic behaviour of distressed individual	Welfare compromised
Head bobbing	Surface breaking with head, repeatedly. Seen in gregarious individuals who have been well fed, called "begging" by public aquaria staff	Attempt to gain attention for feeding	Gregarious individual
Head bobbing	Seen in under-fed individuals	Attempt to gain attention for feeding	Welfare compromised
Water spitting	Use of siphon to "spit" water from tank at staff. Seen in gregarious individuals who have been well fed, called "begging" by public aquaria staff	Attempt gain attention	Gregarious individual
Arm waving	Front two arms wave or sway	Attempt to distract prey	Animal is enriched
Arm waving	Front two arms wave or sway	Attempt to warn off threat	Welfare compromised
Postural			
Flattened body	Flattening of the body	Threat signal/bluff	Welfare compromised
Fin oscillation	Oscillation of the mantle fin. Not seen in resting non-stimulated cuttlefish. Seen when disturbed during husbandry	Agitation/preparing for rapid movement	May precede damaging behaviour
Fin oscillation	Oscillation of the mantle fin. Not seen in resting non-stimulated cuttlefish. Seen when live prey are provided	Preparing to hunt prey/ feed	Animal is enriched
Raised arms	Always middle pair of arms, raised in response to stimulus	Threat signal/bluff	May precede damaging behaviour
Raised arms	First step in hunting live prey	Predatory behaviour	Animal is enriched
Burying	Achieved only in gravel and sand tanks, however frequent attempts in other tanks which is possibly a stereotyped behaviour	Concealment	Possibly skittish individual
Drooped arms	Typically seen with "Blanche" colour. Often seen after agonistic interaction by loser. Often seen just before death after prolonged senescence	Sub-ordinate/sick/distressed	Welfare compromised
Defence			
Ink pseudomorph	Small release of ink, possibly alarm substance to conspecifics	Attempt to distract threat	May precede damaging behaviour
Ink fully	Large amount of ink that blacks out the tank, possibly alarm substance to conspecifics	Significantly reduces visibility to threat	Welfare compromised
Texture			
Papillated skin	Rough texture to skin, sudden appearance used out of camouflage context	Threat signal/confuse perceived threat	May precede damaging behaviour

Cont...

Table 2 cont.

Behaviour type	Definition	Interpretation/context	Implications for captive welfare
Chromatic			
Blanche	All white in appearance. Seen in subordinate and sick individuals, also first stage of senescence	Confuse perceived threat/ distressed/sick; may also be concealment in very light tanks	Welfare compromised
Blanche	All white in appearance and little/no movement	Tank temperatures are very low	Welfare compromised
Colour oscillation "passing cloud"	Quick pattern and colour changes display as seen just before attacking prey	Confuse prey	Animal is enriched
Dark eyes	Intense dark bands around each eye	Threat signal/bluff	May precede damaging behaviour
Dark stripes	Dark stripes either side of the middle of the body	Threat signal/bluff	May precede damaging behaviour
Dark ring	Dark ring around mantle edge	Threat signal/bluff	May precede damaging behaviour
Deimatic spots	One to four dark spots on the body	Threat signal/bluff	May precede damaging behaviour
Disruptive	Disruptive pattern used out of camouflage context	Threat signal/bluff	May precede damaging behaviour
Mottle	As above, pattern used out of camouflage context	Threat signal/bluff	May precede damaging behaviour
Courtship/breeding			
Intense zebra pattern	Black and white striped signal used by mature males and occasionally by females. Constantly used by dominant males, particular during courtship, mate guarding and agonistic interactions. In captivity frequently leads to direct injuries (male–male fights) or indirect posterior mantle damage (males/females fleeing dominant male)	Sexually mature male/ courtship signal/territorial signal	Animal is enriched/ potential negative welfare implications
Mate guarding	Arguably showing animal is enriched, yet if other males are present frequently leads to agonistic and potentially damaging interactions. Females appear harassed by it. Guarding male will also forgo food whilst guarding the female.	Guarding of female by male immediately after mating	Animal is enriched/ potential negative welfare implications
Arm waving (1st or 8th arm)	Warning signal by dominant male to subordinates. Frequently leads to circling/chasing/jetting/inking	Protrusion of arms to warn off rival males	Animal is enriched/ potential negative welfare implications
Circling	Male –male competition during breeding, frequently leads to chasing/ jetting/inking	Circling of two males	Animal is enriched/ potential negative welfare implications

There was also consultation with experts from an EU funded cephalopod welfare organisation (Cephs*In*Action – http://www.cephsinaction.org), UK/EU regulators of cephalopods used in a scientific context (who have written codes of best practice for keeping cephalopods), aquarists from SeaLife (UK public aquaria), and members of the British and Irish Association of Zoos and Aquariums.

The collation of behaviours associated with stress and enriched lives is presented in Table 2. It is possible that some of these behaviours/signals/techniques are known to aquarists yet presently have not been formally published; here a summary of cuttlefish signals is presented with proposed context-dependent explanations, serving as a guide to aquarists responsible for cuttlefish welfare. In addition to this a summary table for cephalopod environmental requirements, enrichment and other factors affecting wellbeing is provided. Lastly, an example table that is used daily to ensure long term well-being information is collected is provided, aiding future husbandry practices.

Consequences

Table 1 allowed care staff to quickly access information when setting up new cephalopod tanks and determining best husbandry and enrichment techniques. Using Table 2 allowed care staff to score daily responses to husbandry, providing a quantitative index of welfare – Table 3. It also led to a research project investigating welfare in captivity (Tonkins et al. 2015), which could not have been achieved without a thorough understanding of cuttlefish signalling. Some of this knowledge of cuttlefish behaviour and their warning signals was included in the BIAZA *Management Guidelines for the Welfare of Zoo and Aquarium Animals; Cuttlefish* (Slater et al. 2014).

Population management can be improved by housing compatible individuals (Watters and Powell 2011). Understanding behaviours allows staff to recognise shy/bold individuals (see Carere et al. 2015); this helps identify individuals that may cause problems for a population, e.g. skittish individuals may trigger others whilst bold individuals are frequently aggressive. This paper includes many behaviours that may only be seen in some individuals of *Sepia* spp. and not others. For example, during normal husbandry a cuttlefish may display the deimatic eye spot warning signal; staff can use this signal as an indicator to stop what they are doing or perform the task more slowly. Skittish individuals often do nothing before jetting erratically, so for these individuals staff may need to work more slowly and carefully from the start.

Since 1 January 2013 all cephalopods have been protected under EU law (European Directive 2010/63/EU) in the context of scientific research, following Australia, Canada and New Zealand.

Table 3. A hypothetical example of the implementation of Table 2. The table shows data collected for one individual cuttlefish known to be problematic. The table can equally be used for individuals of any kind as it can highlight deviations from any norm. We prescribed a score for different responses e.g. +1 for natural behaviour during feeding, -1 for deimatic displays, -2 for inking and so. These scores are arbitrary and can be changed to suit different individual cuttlefish or facilities. The weekly summary score can be compared to other weeks to elucidate long term changes in behaviour.

Cuttlefish ID:	"Inky" #5/12	Age: ~ 5 months		Notes	Week trial in group tank on busy section of aquarium. Prone to inking, please monitor carefully, especially for triggering tank mates
Date (day)	Time	Context	Behaviour	Score (Σ for week)	Action/notes
20 January 2013 (Mon)	0745	AM check	Pseudo-morph ink (-1), no jet, no warning signal, no damage	-2 (-2)	Make note to avoid sudden movements first thing. This time tank mates not set off
20 January 2013	1100	AM feeding (live shrimp)	Raised middle arms (+1), passing cloud display (+1), pounce on prey	+2 (0)	Nice hunting behaviours, looked enriched, excitable when prey provided
21 January 2013 (Tues)	1000	Husbandry (uneaten food removal)	Deimatic eyespots, flattening with dark ring around mantle fin (-1)	-1 (-1)	When threat signal seen by aquarist slowed behaviour, warning signal ended with no further negative behaviour
21 January 2013	1100	AM feeding (dead sand eel)	Slow swim up to food and gathered with feeding tentacles	0 (-1)	Looked lacklustre compared to previous day
21 January 2013	1535	Visit by stakeholders	Inked fully (-3), jetted backwards (-2), caused tank mate to Pseudo-morph ink (-1)	-6 (-7)	Beginning to think this individual may not be suitable for showing off
22 January 2013 (Wed)	1100	AM feeding	Raised middle arms (+1), passing cloud display (+1), pounce on prey	+1 (-6)	Loves its shrimp!
23 January 2013 (Thurs)	1000	Husbandry (algae wiping)	Very relaxed, slight bury in substrate when net came near	+1 (-5)	Encouraging
24 January 2013 (Fri)	0945	Husbandry (algae wiping)	Deimatic eyespots (-1)	-1 (-5)	Aquarist backed off at sign of threat
25 January 2013 (Sat)	1100	AM feeding (dead sand eel)	Slow swim up to food and gathered with feeding tentacles	0 (-5)	Took a couple of attempts to get it to take the food
26 January 2013 (Sun)	0900	AM check	Pseudo-morph ink (-1), no jet, no warning signal, no damage	-1 (-6)	Weekend feeder not aware, need to inform all staff of problematic individuals
		Weekly summary	Erratic responses, can cause problems with visibility, damage to itself and triggering tank mates	-6	Rehouse to tank with less thoroughfare, label as individual of concern and make all staff aware

Whilst this legislation does not apply to commercial zoos and public aquaria, it does apply to aquaculture-related research or research carried out within zoos and public aquaria. Although it has now been determined they are worthy of legal protection, captive cephalopod welfare is still in its infancy compared to other commonly kept aquarium animals (see Moltschaniwskyj et al. 2007 for a review of cephalopod welfare and ethics). The tables we have produced have allowed us to improve the lives of our cuttlefish by preventing damaging behaviour and collecting daily information on their responses to husbandry, and should be of use to cuttlefish keepers in many types of institution.

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