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Behavioural assessment of dental pain in captive Malayan sun bears (Helarctos malayanus)

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Abstract

*Captive bears are prone to developing dental pathology for reasons including longevity in captivity, inappropriate diet, trauma, and stereotypical bar biting. If not detected, this can cause pain and suffering, with negative welfare consequences. As animals cannot verbally express feelings, objective methods are required to detect pain. Some methods of pain assessment can be invasive and impractical but behavioural observations offer a non-invasive alternative. Behavioural assessment for the detection of pain has been described in some domestic species but little published research has applied this to wild animal species. Eight Malayan sun bears (*Helarctos malayanus*) required dental extractions under anaesthesia. Their behaviour was observed, alongside a control cohort with no visible disease, pre-operatively and at one, two and four weeks post-operatively, when it was assumed the pain had resolved from the original pathology and surgery performed. Behavioural indices measured included general activity, social behaviours, stereotypies, eating-related behaviours and oro-facial behaviours hypothesised to be affected by dental pain. Bears that had received treatment took significantly longer to eat hard sugarcane pre-operatively compared to four weeks post-operatively, and took longer to eat soft porridge one week post-operatively compared to four weeks post-operatively. Untreated bears tended to be more active outdoors one week post-operatively compared to the treatment cohort. Results suggest that using hard foods and assessing the duration of eating behaviours could be useful to indicate dental pain in sun bears. General behavioural assessment of dental pain in sun bears is unlikely to be effective as a single diagnostic tool, but may be combined with other methods of assessment, and further research into this area is warranted.*

Keywords: *animal welfare, behaviour, dental pain, pain assessment, sun bears, wild animal*

Introduction

Captive bears have a high prevalence of dental pathology (Bourne *et al* 2010). One study found that in a population of captive brown bears (*Ursus arctos*), all bears over ten years had at least one canine with an exposed pulp cavity and at least one carious tooth (Wenker *et al* 1999). In another study of five captive brown bears it was shown that all of them had severe dental attrition and pulp exposure of their canine teeth (Wenker *et al* 1998). Kitchener and MacDonald (2002) suggested the incidence of broken lower and upper canines, and mandibular fistulae to be over 50% in zoo bears of various species over 15 years old. Free-ranging bears also suffer from dental pathology but the prevalence is thought to be lower (Stromquist *et al* 2009).

International Species Information System (ISIS) estimates that over 2,000 bears reside in member zoos worldwide (ISIS 2011). Numbers in non-ISIS registered zoos and rescue centres are unknown, and overall this equates to a large global captive bear population, and potentially a large number of bears for which dental pathology may be an issue.

Bears can be long-lived in captivity, and sun bears (*Helarctos malayanus*) reaching 35 years of age have been documented (Kitchener & Asa 2010). With advancing age, dental disease naturally becomes more prevalent (Kitchener & MacDonald 2002; Glatt *et al* 2008), and secondary factors such as inadequate diet and trauma caused by other bears or cage fixtures can be predisposing factors (Robinson 1987).

When sun bears, which are naturally solitary, come into close contact with conspecifics, episodes of aggression increase the likelihood of fractured teeth (Stromquist *et al* 2009). Some bears also have their teeth deliberately broken by humans who believe this will make them more manageable as pets or farmed animals (Maas 2000; Milella 2007; Loeffler *et al* 2009). A natural diet can be difficult to appropriate in captivity. Soft diets are associated with increased plaque formation, while very coarse diets can cause excessive wearing of teeth (Fagan 1980; Vosburgh *et al* 1982). Captive diets can be high in sugars due to the use of domesticated fruits (Schmidt *et al* 2005; Clauss *et al* 2009) and sweet items used for enrichment.

'Bar biting', a common manifestation of abnormal behaviour in captive bears (Vickery & Mason 2004), is another cause of erosion of dental enamel, predisposing the teeth to fracture (Maas 2000).

Regardless of the aetiology of dental pathology, if associated with broken or loose teeth it can potentially cause severe and chronic pain to the animal through the exposure of the sensitive pulp cavity and recurrent dental infections. Such infections can have systemic effects such as sepsis, organ damage, and reduced reproductive potential (Robinson 1987). Pain can lead to long-term distress, anxiety, and maladaptive behaviour (Carstens & Moberg 2000). Chronic pain can cause immunosuppression, predisposing the animal to other diseases (Seksel 2007). External signs of dental pain have been suggested to be subtle and difficult to detect in bears (Bourne *et al* 2010), and in many instances it is not practical to closely examine the oral cavity of captive wild animals while they are conscious, unless they have been specifically trained to accept this (Wiggs & Lobprise 1997; Laule 2003). Dental pain is therefore a significant welfare issue for captive bears that can easily be overlooked.

Behavioural, physiological and hormonal parameters have been suggested as tools to assist in the detection and assessment of pain, alongside other more invasive methods such as nociceptive threshold testing and electroencephalographic response testing (Dobromylskyj *et al* 2000; Rutherford 2002; Ashley *et al* 2005; Johnson 2008). However, pain studies commonly concentrate on acute, severe or obvious pain, and analgesia research is often central to their aim (Liles & Flecknell 1994; Weary *et al* 2006; Morton *et al* 2011).

Pain will often cause behavioural changes such as avoidance of associated stimuli, guarding of the painful area, reduced aggression threshold, altered social behaviour, and changes in species-specific behaviour (Anil *et al* 2002; Rutherford 2002). Behavioural assessment could be a beneficial method to use in captive bears, as it is non-invasive and minimally stressful for the animals (Dawkins 2004), and other techniques such as assessing physiological changes and nociceptive threshold testing, can be impractical in captive wild animals.

Behaviour-based pain assessment methods have been developed for use in some laboratory and domestic animals (Molony 1995; Holton *et al* 2001; Molony *et al* 2002; Sutherland *et al* 2008; Farnworth *et al* 2011), but for many wild animal species they have not been well researched or validated. Even in more commonly studied species there is often disagreement on what objective measurements should be used, and anthropomorphic judgements can confound evaluation of pain-related behaviour (Flecknell 2000; Rutherford 2002; Leach *et al* 2011).

Suggested behavioural signs of dental pain in particular include rubbing the mouth and face, frequent lip licking, general lethargy, hiding, aggression, reduced appetite, dropping food when eating, vocalising when eating, and preference for soft food items (Kertesz 1993; Wiggs & Lobprise 1997; Ashley *et al* 2005). There is also anecdotal evidence of behavioural changes following treatment for dental pathology in six captive lions (*Panthera leo*) (Fagan 1983): after treatment, lions appeared less aggressive, took less time to eat and were more responsive to training.

This study aimed to identify specific behaviours of sun bears with visible signs of dental disease that changed after treatment and presumed alleviation of dental pain, to determine if any of these behaviours could be used for the non-invasive, non-intrusive detection of dental pain in captive sun bears. It was hypothesised that, before and one week after surgical treatment (ie before the surgical wounds had completely healed), bears with dental pathology would take longer to eat, show preference for a soft food item over a hard food item, exhibit more lip licking and head rubbing, and be involved in more episodes of aggression when compared to: (i) four weeks after treatment; and (ii) bears in a control cohort.

Materials and methods

Study animals

The study was carried out on two cohorts (n = 8 per cohort) of Malayan sun bears (Table 1). One cohort was suspected of having dental pain on the basis of careful visual inspection of broken or discoloured teeth during manual feeding of morsels of food to the bears through cage bars, and the other cohort served as a control. Bears in the control cohort had received dental treatment recently or had no signs of broken or discoloured teeth on visual examination. They varied in age from six to 19 years, and seven females and nine males were included. All were resident at Phnom Tamao Wildlife Rescue Centre in Cambodia, a national facility for the placement of rescued wild animals, owned and managed by the Cambodian Forestry Administration. The bear facilities are supported by Free the Bears, a non-governmental organisation dedicated to the rescue and protection of bear species in Asia and India. All bears apart from one had been poached from the wild as cubs to supply the illegal wildlife trade and then confiscated or donated to the centre. One male had been rescued from a snare in the forest as an adult.

Environment and daily routine

The study bears were housed in seven different forested outdoor enclosures that were connected to four indoor houses with individual dens. Enclosures varied in size but contained the same basic furniture and contents, including a pool, climbing platforms, hammocks and toys. At 0830h each day, all bears were brought inside and held in dens which measured approximately 2.5 × 2.5 × 2.5 m (length × width × height), and contained one or two ledges to sit on. Bears were offered a breakfast of rice porridge mixed with egg and complete dog biscuits (Pedigree, Mars, Thailand) while their outdoor enclosures were cleaned and dog biscuits were scattered around to encourage foraging behaviour. After feeding, bears were locked outdoors so the dens could be cleaned, after which they had access to the indoor dens again. They were also locked indoors for up to 30 min in the afternoon so fruits and vegetables could be hidden around the outdoor enclosures. Water was available *ad libitum* from drinking nozzles in indoor dens and from outdoor pools and drinking nozzles. Enrichment was given to all bears in one of the houses each afternoon; the type of enrichment was rotated and included scents, stuff-balls, stuffed bamboo, grass piles and novel toys.

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Table 1 Bears used in the study.

Bear	Age (years)	Sex	Bears in enclosure (n)	Time resident at rescue centre (years)	Study cohort
Aural	19	M	3	8	Treatment
Franklin	8	F	3	4	Treatment
Ralph	10	M	3	4	Treatment
Tong Tong	14	F	16	10	Treatment
Kiem	15	M	16	12	Treatment
Bondol	15	F	16	9	Treatment
Go You	6	M	7	5	Treatment
Lux	14	M	3	10	Treatment
Mom	17	M	3	11	Control
Bobo	14	M	3	11	Control
Romdool	9	M	1*	9	Control
Dim Roi	6	F	3	3	Control
Pete	7	M	7	7	Control
Sara	17	F	16	15	Control
Kong Kong	12	F	16	10	Control
San	17	F	16	8	Control

* One bear lived alone in an enclosure but had visual access to other bears and physical contact was possible between indoor dens.

Behavioural observations and data collection

A repeated measure design was used, and for each bear observations were carried out over four time-points: one week pre-operatively, and one, two and four weeks post-operatively. For four days of each week three bears were observed, and for one day four bears were observed. Each day was divided into four sessions of general behaviour observations and two sessions of eating behaviour observations for each bear. Before any data were collected, preliminary observations were carried out for five days to refine which behaviours should be measured and to aid in the identification of individual bears. During the pre-operative time phase the observer did not know which cohort each bear belonged to.

General behaviour observations

Behaviour was observed individually, and four continuous focal observation periods of 15-min duration were carried out for each bear, two in the morning after feeding, between 0830 and 1300h and two in the afternoon between 1330 and 1600h to cover different parts of the daily routine. Therefore, bears observed each day were sampled one after the other until they had all been observed for 15 min each and this sequence was repeated four times. When time permitted (ie if the observer was able to stay late), an extra recording session was completed on all bears under observation that day. This gave a total mean (± SD) observation time per bear per time-point of 63.95 (± 16.87) min. The mean (± SD) indoor observation time was 40.90 (± 14.26) min, and mean (± SD) outdoor observation time was 22.80 (± 11.73) min. These values do not include times when bears were out of sight.

Behaviours measured were defined in an ethogram (Table 2). State behaviours were measured by instantaneous sampling, and event behaviours by one-zero sampling (Martin & Bateson 2007). A 1-min sample interval was used, measured using an interval timer (Gymboss, USA). All data were entered manually onto a recording sheet.

Bears were observed both indoors and outdoors. During the first and fourth observation periods in a day, (early morning and late afternoon, respectively), the bears were indoors, and during the second they were outdoors (late morning). During the third session (early afternoon), the bears had access to both their outdoor enclosure and their indoor den, and observations were therefore carried out wherever the bear chose to be. This methodology allowed data to be collected for all bears, with the exception of one individual of the treatment group, which consistently refused to come indoors and spent most of his time out of sight in the outdoor enclosure. This meant that general behaviour observations for this bear were not possible.

Eating behaviour observations

The following data were collected when bears were given breakfast on each observation day: time taken to eat; number of mouthfuls taken; and an estimate of the proportion of time the bears licked rather than took mouthfuls. As the bears were fed different amounts, time to eat and number of mouthfuls were corrected for 1 kg of food. In the afternoon on each observation day, a food preference test was performed indoors, with each bear being offered hard sugarcane and soft banana simultaneously. Their choice of sugarcane or banana, measured as shortest latency to start to eat, was noted and the time taken to eat the sugarcane, which was pre-cut into 25-cm long sticks, was recorded.

Table 2 Sun bear ethogram used in the study of both cohorts of bears.

Behaviour category	Individual behaviour	Definition	Status
Activity	Walk	Movement on all four feet from one part of the outdoor enclosure to another	State
	Climb	Movement up or down a tree or to or from a platform	State
	Stand†	Standing with either two or four feet on the ground and remaining stationary, alert	State
Inactivity	Rest	Lying, sitting down, or apparent sleeping, and not moving around or looking around	State
	Sit	Sitting on the hindquarters with the upper body off the ground, alert	State
Stereotypical behaviour	Stereotype	Repetitive movement or action, fixed in form with no obvious function, eg pacing, repeated at least three times without a break	State
Social behaviour	Social play	Contact with another bear involving scampering, rotating the body or wrestling, with an open-mouthed grin, and not associated with threat or aggression	Event
	Aggression (received or delivered)	Charging or attacking another bear and bellowing, with teeth bared and ears flattened back, causing avoidance or injury in the recipient. Can be associated with pushing, scratching or biting	Event
Behaviours hypothesised to be amplified by orofacial pain	Lip lick	A sweeping movement of the tongue outside of the mouth and then back in again and not associated with eating or drinking	Event
	Head rub	Applying pressure from external surfaces or the paws to the head or face, including the mouth, cheeks, forehead and muzzle	Event
Eating behaviour‡	Eating	The consumption of edible food items offered as part of the daily routine or as a choice test	State
	Hard vs soft food preference	When offered a hard and soft item of food simultaneously, the item which had the shortest latency to eating	Event
	Licking	Placing the tongue into food, forming a scoop with the tongue and thus lifting food into the mouth	State

The behaviours chosen aimed to measure general activity of bears, social behaviours, behaviours which were hypothesised to be affected by oro-facial pain, stereotyping and eating-related behaviours. † Standing was included in the 'activity' category as during preliminary observations it was noted that bears moved quite slowly and tended to stand in between steps when walking but they were still active. When inactive they usually sat rather than stood. ‡ Eating behaviours were observed separately.

Dental procedures

In the week following the pre-operative observations, bears in the treatment cohort were anaesthetised by blowdart (Telinject, USA) with a combination of tiletamine and zolazepam (Zoletil, Virbac, France) at a dose of 1.7 mg kg^{-1}, and medetomidine (Dormilan, Genitrix, UK) at a dose of 0.04 mg kg^{-1}. They were then transferred to the surgery, where they were intubated and maintained on isoflurane gaseous anaesthesia (Forane, Abbott, India). Meloxicam (Metacam, Boehringer Ingelheim, UK) was administered at a dose of 0.2 mg kg^{-1} subcutaneously and tramadol (Amadol, Union Korea Pharm Co Ltd, Korea) at 1 mg kg^{-1} intravenously. The oral cavity was examined and dental surgery performed as required. Dental status of all bears was recorded on a dental chart.

Most of the bears required extraction of the canine teeth (Table 3). This was done using an open non-standard technique (Bourne 2014). Post-surgery bears were medicated orally with meloxicam at 0.1 mg kg^{-1} once daily for seven days (Meibic, Mihika, India), and clindamycin at 5 mg kg^{-1} twice daily for ten days (Dacin, Mersi, Indonesia).

Data analysis

Non-parametric tests were performed because of the small sample size and the violation of the assumption of a normal distribution. Mann-Whitney *U* tests were used to compare the behaviours at each time-point between the Treatment and Control cohorts, and Friedman tests were used to compare within both cohorts over the time-points of the study. Wilcoxon signed rank tests were used *post hoc* for any variables showing significant within-cohort differences, to show where specific differences lay. All analyses were carried out using PASW Statistics 18, Release Version 18.0.0 (SPSS Inc, Chicago, IL, USA, www.spss.com). Because 14 behaviours were tested for each cohort/time-point comparison, the significance level was adjusted for multiple testing using the False Discovery Rate (Benjamini *et al* 2001; Garcia 2004). Results for which the *P*-value fell below 0.05 but above the adjusted significance level will be reported as non-significant trends.

Ethical approval

The project received ethical approval from the Zoological Society of London Ethics Committee, and permission to carry it out was granted by the Ministry of Agriculture, Forestry and Fisheries, Cambodia, and Free the Bears.

Table 3 Dental pathology present and surgery performed in the Treatment cohort.

Bear	Dental pathology present	Surgery performed
Aural	Fracture and pulp exposure of all four canines with severe osteolysis of the surrounding bone. Apical infection present and bilateral mandibular sinus formation	Four canine and one mandibular incisor extractions (left side)[†]
Franklin	Erosion of the enamel of one canine with pulp exposure and mild apical infection	One mandibular canine, one incisor and one premolar extraction (left side)[†]
Ralph	Fracture and pulp exposure of all four canines, with moderate osteolysis of the surrounding alveolar bone, and apical infection	Four canine extractions
Tong Tong	Fracture of the tip of the canine with pulp exposure and mild apical infection	One maxillary canine and two premolar extractions (left side)[†]
Kiem	Fracture of the tip of the canine with pulp exposure	One maxillary canine extraction (left side)
Bondol	Fracture of the tip of one canine with pulp exposure and mild apical infection	One maxillary canine extraction (left side)
Go You	Fracture of two canines with pulp exposure and mild apical infection	One maxillary (right side) and one mandibular (left side) canine extraction
Lux	Moderate calculus of the mandibular incisors with sulcus formation and loosening of the teeth	Five mandibular incisor extractions

Seven of the bears had one or multiple canine tooth extractions. All bears had differing degrees of calculus formation. [†] Although pathology mainly affected the canine teeth, in some cases the surrounding teeth required extraction either to allow successful extraction of the canine or because they were also diseased.

Table 4 Comparisons of pre-operative behaviour between the Treatment and Control cohorts.

Variable	Treatment			Control			*P*-value
	n	Median	Q1–Q3	n	Median	Q1–Q3	
Activity indoors	7	0.25	0.11–0.26	8	0.22	0.13–0.36	0.69
Activity outdoors	5	0.71	0.21–0.97	8	0.62	0.18–0.67	0.44
Inactivity indoors	7	0.58	0.56–0.83	8	0.56	0.31–0.86	0.69
Inactivity outdoors	5	0.21	0.21–0.79	8	0.38	0.18–0.82	0.52
Stereotypical behaviour	7	0.16	0.00–0.25	8	0.17	0.01–0.30	0.87
Aggression episodes	7	0.01	0.00–0.02	8	0.00	0.00–0.01	0.23
Social play	7	0.00	0.00–0.00	8	0.00	0.00–0.17	0.69
Social interactions	7	0.00	0.00–0.09	8	0.02	0.00–0.07	0.87
Lip licking indoors	7	0.31	0.01–0.59	8	0.27	0.12–0.40	0.78
Lip licking outdoors	5	0.00	0.00–0.30	8	0.07	0.00–0.25	0.62
Head rubbing	7	0.00	0.00–0.07	8	0.00	0.00–0.00	0.34
Time to eat 1 kg of porridge (s)	8	97.55	56.50–118.14	8	107.75	91.67–148.45	0.65
Number of mouthfuls	8	27.35	18.10–32.65	8	33.0	17.50–49.50	0.23
Estimated proportion licked	8	0.38	0.30–0.64	8	0.50	0.50–0.88	0.16
Time to eat 25 cm sugarcane (s)	7	320	236–339	8	255	206–337	0.62

Results from the Mann-Whitney *U* test displaying median, the values from the first to third quartiles, and *P*-value.
There were no significant differences in any of the behaviour categories between the two groups.

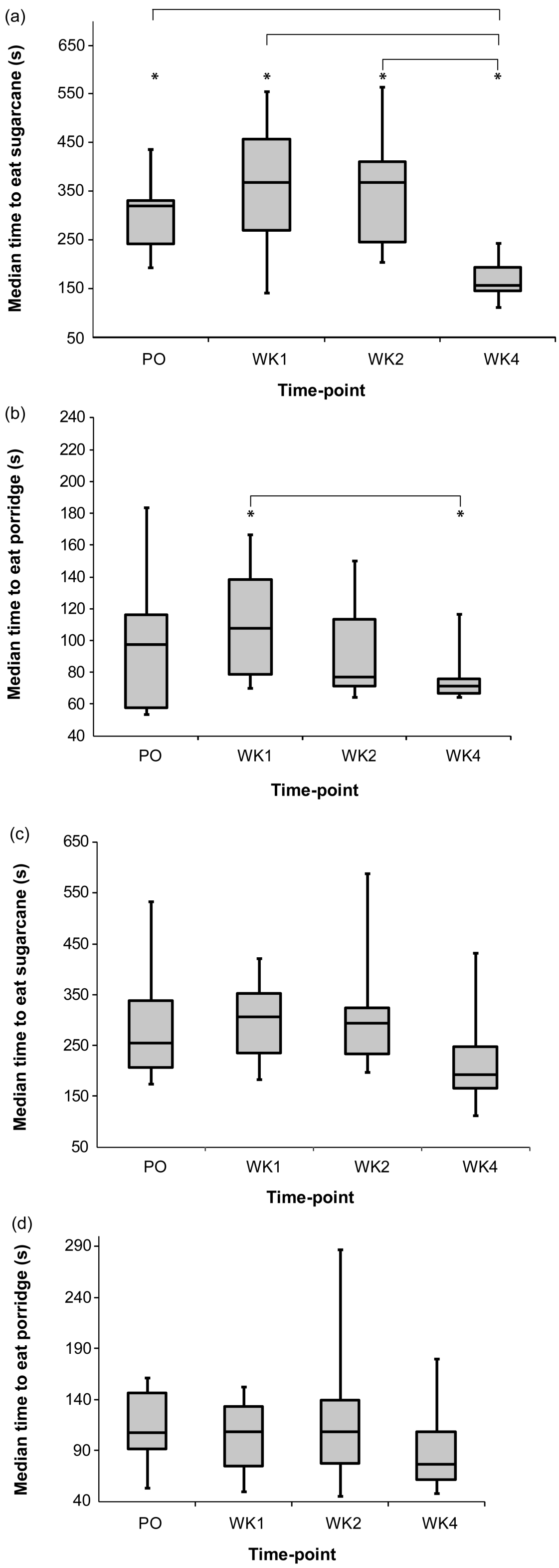
Results

Pre-operative comparisons between the Treatment and Control cohort

Overall, there was no significant difference in behaviours between the two cohorts during the pre-operative time phase (Table 4). Social behaviours were relatively infrequent and were therefore difficult to analyse statistically. Three bears played socially during pre-operative observations: two of these were bears in the control cohort. Four individuals of the treatment cohort were involved in at least one episode of aggression, compared to two bears of the control cohort.

Head rubbing was also an infrequent behaviour with one untreated and three treated bears showing it. Six bears in the control cohort and five bears in the treatment cohort

Figure 1



Eating behaviour in the Treatment and Control cohorts over time showing (a) median time to eat 25 cm sugarcane and (b) median time to eat 1 kg of porridge in the Treatment cohort (n = 7) and (c) median time to eat 25 cm sugarcane and d) median time to eat 1 kg porridge in the Control cohort (n = 8). PO = pre-operative time-point, W1 = week one, W2 = week two and W4 = week four, post-operatively. * Indicates statistical significance in a Friedman test with *post hoc* Wilcoxon signed ranks tests.

showed stereotypical behaviour indoors, with pacing being the most common stereotypy performed (n = 9), followed by swaying (n = 2) and paw sucking (n = 1). Bar biting was not observed. In the food preference test two bears from each cohort selected the hard sugarcane first, and the rest chose the soft banana first, but all bears ate both food items offered to them.

Comparison within the cohorts between pre- and post-operative behaviour

In the treatment cohort the median time to eat 25 cm sugarcane was significantly shorter at four weeks post-surgery (157 s [IQR 63]) compared to pre-operatively (320 s [IQR 103], Wilcoxon $Z = -2.366$; $P = 0.018$), one week post-operatively (368 s [IQR 280], Wilcoxon $Z = -2.366$; $P = 0.018$) and two weeks post-operatively (368 s [IQR 182], Wilcoxon $Z = -2.366$; $P = 0.018$, n = 7; Figure 1[a]).

Similarly, the bears in the treatment cohort spent significantly more time eating the soft porridge one week post-surgery (median 127 s [IQR 72]) compared to four weeks post-surgery (71 s [IQR 20], Wilcoxon $Z = -2.197$; $P = 0.028$, n = 7; Figure 1[b]). These differences were not significant for bears in the control cohort (Figures 1[c] and [d]). There were no other significant differences in either cohort (Table 5).

Post-operative comparisons between the treatment and control cohorts

The median proportion of time engaged in active behaviour outdoors showed a non-significant trend towards being higher in bears in the control cohort (median proportion of time = 0.46, IQR 0.24) compared to the treatment cohort (0.33, IQR 0.23) one week post-surgery (Mann-Whitney $Z = -2.047$; $P = 0.038$; Figure 2). There were no other trends or significant differences between the cohorts at this time phase and there were no significant differences between the cohorts for any of the measured variables at weeks two and four post-surgery (data not shown for reasons of space, but see Table 4 for equivalent tests carried out pre-operatively).

Discussion

The aim of the study was to detect potential behavioural changes in sun bears after the alleviation of dental pain, and to establish if any of those behaviours could be used for the early detection of dental pain in captive bears.

Bears that had received treatment took significantly less time to eat hard food four weeks post-surgery compared to pre-operatively, one and two weeks post-surgery. Similarly, they took less time to eat even soft porridge at four weeks compared with one week post-surgery. It is unlikely that analgesics administered for seven days post-surgery would alleviate all pain (Flecknell 2000), and the surgical trauma associated with canine extraction potentially could have caused more severe and acute pain than that felt pre-operatively. As bears moved the sugarcane stick around their mouth it would have contacted the canines and surrounding gingival structures, and therefore it is logical to conclude that they would take longer to eat this hard item before alleviation of dental pain. These results suggest that eating time

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could be related to dental pain and it may be wise for keepers to monitor bears that are particularly slow eaters (eg, taking > 300 s to eat 25 cm of sugarcane; Table 4, Figure 1[a]) or become slower over time to detect those with dental pain. Interestingly, all bears in the study readily consumed both the hard and soft foods offered in the preference test and there was no relationship between cohort and which item was selected first. The utilisation of hard food to assay dental pain in bears therefore seems promising. It would be useful to discover if results are repeatable with other bears or other hard foods. Foods lower in sugar than the sugarcane used here should be considered for this though if they are to be given on a regular basis, to prevent simultaneously exacerbating any dental decay.

Bears in the treatment cohort tended to be less active outdoors than bears in the control cohort when observed one week post-surgery, and if this trend is repeatable, it could be due to an increase in pain during this time-phase for the reasons mentioned above. This trend is in agreement with other authors who propose that pain can cause a reduction in activity (Anil *et al* 2002; Weary *et al* 2006; Gregory 2008). However, this difference was not evident during any other time phase, and arguably it should also have been evident pre-operatively. Alternatively, medications administered during and after the surgery, including analgesics, could have resulted in general lethargy in the treatment cohort. However, meloxicam, a non-steroidal anti-inflammatory drug (NSAID), was used, and there is little evidence that NSAIDs significantly affect normal behaviour of animals in which they have been studied (Roughan & Flecknell 2003). Even if the reduced activity was indeed due to oral pain, inactivity is likely to be too non-specific as an indicator that a bear requires dental attention, as it can indicate diverse health and welfare problems, for example sickness behaviour, depression, or chronic pain (Weary *et al* 2006; Burn *et al* 2010). Low activity levels, especially within individuals, may warrant a more detailed assessment to identify the precise cause of lethargy, but they do not necessarily imply dental pain *per se*.

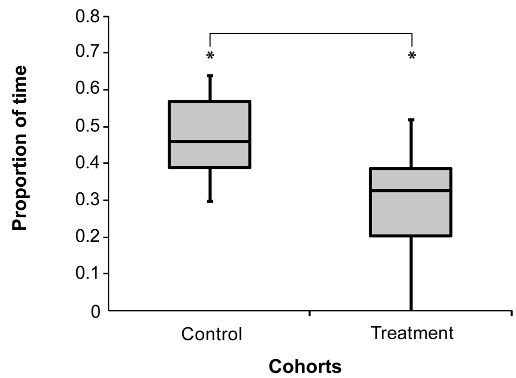
Surprisingly, no significant differences in behaviour were detected between the two cohorts pre-operatively. Two non-significant trends that were consistent with the hypotheses were observed, namely that slightly more individuals of the treatment cohort were involved in aggression and displayed head rubbing than untreated bears. It is possible that these would reach significance with a larger sample size, but the sample size here means that the trends remain inconclusive and could be due to chance or other factors such as a differing sex ratio between the cohorts. In the light of intra-species variation in behaviour, it has been suggested that the most sensitive assessment of pain in a single animal would use that animal as its own control (Rutherford 2002). This may account for why there were more significant results within the treatment cohort than between cohorts. It is feasible that varying degrees of pain were felt by the bears that had received treatment, but this did not notably affect behaviour. When teeth are fractured and the sensitive pulp is exposed it can become non-vital over time. In cases of irreversible pulpitis in humans, pre-operative pain can be

Table 5 Comparisons of behaviour across time-periods within the Treatment and Control cohorts.

Behaviour	Treatment cohort (Friedman χ^2; df; *P*-value	Control cohort (Friedman χ^2; df; *P*-value
Activity indoors	0.565; 3; 0.904	3.684; 3; 0.298
Inactivity indoors	0.043; 3; 0.998	1.329; 3; 0.722
Activity outdoors	1.531; 3; 0.675	1.174; 3; 0.759
Inactivity outdoors	2.265; 3; 0.519	1.087; 3; 0.780
Stereotypical behaviour	1.114; 3; 0.774	1.481; 3; 0.687
Social play	5.735; 3; 0.125	0.086; 3; 0.993
Aggression	1.188; 3; 0.756	5.605; 3; 0.132
Other social interactions	3.0; 3; 0.392	5.014; 3; 0.171
Lip licking indoors	1.522; 3; 0.677	6.423; 3; 0.093
Lip licking outdoors	2.114; 3; 0.549	0.466; 3; 0.926
Head rubbing	3.866; 3; 0.274	3.971; 3; 0.265
Time to eat 1 kg of porridge	12.739; 3; 0.005†	2.848; 3; 0.416
Estimated proportion of porridge licked	2.857; 3; 0.414	5.952; 3; 0.114
Time to eat 25 cm sugarcane	14.829; 3; 0.002†	5.914; 3; 0.116

Results of the Friedman test carried out on both the Treatment and Control cohorts. † Statistically significant result at $P < 0.05$.

Figure 2



Proportion of time Treatment and Control cohorts engaged in active behaviours outdoors (n = 7 per cohort) one week post-surgery. * Indicates statistical significance in a Mann-Whitney test.

intermittent (Nusstein & Beck 2003). If this occurs in other mammals, this could account for a reduction in pain sensation in some bears in the treatment cohort when observed during the pre-operative time phase.

A potential confounding factor was the unanticipated presence of an inflammatory lip disease that affected seven of the treated bears and five of the untreated bears. Most affected bears had discrete, mild inflammatory lesions of the oral mucosa and, in a few more unusual cases, discrete areas of ulceration. Although slightly more of the Treatment than Control bears had these lesions, it is unclear if they were related to or affected by dental problems. Aetiology was unknown but biopsies were taken from affected bears and were pending CITES permission to be exported and analysed at the time of writing. It is possible that the presence of these lesions influenced behaviours such as lip licking, head rubbing and eating, resulting in less variation between the two cohorts.

Another possibility is that the bears with dental pain were exhibiting self-coping mechanisms of pain suppression when being observed, such as stress-induced analgesia, a phenomenon whereby mammals suppress signs of pain upon stressful stimuli (Gregory 2008; Butler & Finn 2009), or predator-induced analgesia, if the bears perceive humans as predators (Rutherford 2002). Most bears suffered maternal separation at an early age and spent most of their lives in captivity, often under poor conditions, before being rescued. Therefore, it is not unreasonable to assume that they may have lasting anxiety and some may be fearful of humans. Normal behaviours and reaction to pain can vary greatly both between and within species (Dobromylskyj *et al* 2000), and it has been suggested that wild animal species may hide signs of pain until very severe in order to maintain their social status or avoid predation (Kitchener & MacDonald 2002).

As is the case all too often in studies of this nature, the sample size was small, meaning limited statistical power and a higher chance of false negative results (Taborsky 2010), and so we should be wary of concluding that general behavioural assessment is an insensitive way of detecting dental pain in sun bears. Johnson (2008) suggested that a large number of animals are required for behavioural assessment of pain due to intrinsic behavioural variability. A standardised protocol of behavioural assessment could be drawn up and researched in other institutions that hold captive bear species, particularly rescue centres that tend to hold larger numbers of animals. This kind of collaboration could potentially increase sample size over time and give a better idea of which behaviours may be important.

Anecdotal evidence exists for behavioural changes following dental treatment in animals (Fagan 1983; Wiggs & Lobprise 1997; Bourne *et al* 2010), and behavioural alterations are considered to be some of the first signs of pain and sickness in animals (Seksel 2007). Therefore, it would still be wise for keepers who work closely with animals and know their normal behaviour well to be alert to any such changes. The results here suggest general behavioural assessment as a single tool is likely to overlook many cases of dental disease in bears, and until this method and others aforementioned obtain more interest and validation, they cannot be used as a substitute for attentive husbandry and good clinical practice. Bourne *et al* (2010) suggested that dental disease in captive bears is 'almost ubiquitous'. If this is the case then those responsible for their care must prudently consider using a combination of methods to detect it.

As well as appropriate behavioural assays, consideration should be given to periodic immobilisation of bears, particularly those over ten years old, to perform a full health check and oral examination. The risks of immobilisation, however, must be carefully considered and balanced with the risks of undetected dental disease (Kertesz 1993). If dental pathology is suspected, a full dental examination under anaesthesia should be carefully planned. If an animal is immobilised for other reasons, opportunistic dental examination and preventative work could be considered, including severe calculus removal where safe and appropriate to do so. Training of bears to open their mouth for examination may be a practical option in institutes holding smaller collections, and has proved successful in other species (Weiss & Wilson 2003; Prescott *et al* 2005). This can reduce the need for repeated immobilisation and acts as a form of enrichment for the animals (Laule 2003; Pomerantz &Terkel 2009). Prophylactic dental care such as formulating a balanced diet that promotes natural teeth-cleaning mechanisms, and the provision of tough enrichment items that require chewing, eg bones, can also aid in maintaining the oral health of captive bears (Glatt *et al* 2008; Bourne *et al* 2010).

Animal welfare implications and conclusion

The results of this study suggest that observing eating behaviour may be useful in the assessment of dental pain in sun bears, particularly increased duration of feeding time of harder foods. These methods could prove to be useful as eating behaviour can be induced at the convenience of the observer, and there is no reliance on lengthy observations of spontaneous behaviour. While results also suggest general behavioural assessment alone appears to be ineffective at indicating dental pain, this should be interpreted with caution because of the small sample size and confounding factors discussed. Knowledge of pain behaviour in wild animal species is deficient and more research on the subject would be welcome. It would be particularly useful to determine if these results are repeatable in sun bears, or other bear species. To the authors' knowledge, no other behavioural studies into dental pain in sun bears have been documented, and this research can hopefully serve as a base for future studies of a similar nature in bears and other wild animal species in which dental disease is a significant issue in captivity. By undertaking such studies our understanding of pain behaviour in wild animal species can be improved, allowing us to detect pain more efficiently and non-invasively, thus improving the welfare of animals under our care.

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