



Captive pandas are at risk from environmental toxins

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1 **Captive pandas are at risk from environmental toxins**

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18

19 *Ex situ* conservation efforts are the last resort for many critically endangered
20 species and captive breeding centers are thought to provide a safe
21 environment in which to produce individuals for eventual re-introduction to the
22 wild. The giant panda (*Ailuropoda melanoleuca*) is one of the most
23 endangered animals in the world, and it is recognized worldwide as a symbol
24 for conservation. Here, we report that captive pandas of the Sichuan and
25 Qinling subspecies are exposed to high concentrations of persistent organic
26 pollutants, including polychlorinated dibenzo-p-dioxins (PCDDs),
27 dibenzofurans (PDCFs), and biphenyls (PCBs), as well as heavy metals
28 (arsenic, cadmium, chromium, and lead). Further analysis of the *ex situ*
29 environment of the Qinling subspecies demonstrated that contaminated food
30 supplies exposed captive Qinling pandas to high concentrations of PCDD,
31 PCDFs, PCBs, As, Cd, Cr, and Pb). In the short term, these endangered
32 animals should be relocated to breeding centers in less contaminated areas.
33 Their long-term survival, however, depends on reducing emissions of toxic
34 pollutants throughout China.

35

36 Key words: Endangered species, *ex situ* conservation, Giant panda, heavy
37 metals, persistent organic pollutants.

38

39 The giant panda (*Ailuropoda melanoleuca*) is one of the most endangered
40 animals in the world, and it is recognized worldwide as a symbol for
41 conservation. The panda lineage is at least 11.6 million years old (Abella *et al.*
42 2012); fossils > 2 million years old and historical records have revealed that
43 pandas once were distributed in at least 18 of China's 23 provinces (Zhu and
44 Long 1983). Until the mid-19th century, giant pandas still inhabited most of
45 eastern and southern China (Hunan, Hubei, Sichuan, Shaanxi and Gansu
46 provinces), but their range has declined in recent years as a result of hunting,
47 habitat destruction, logging, resource exploitation, and tourism (Zhang *et al.*
48 2013). Giant pandas now survive only in small, fragmented conservation
49 zones in the Qinling, Bashan and Qionglai Mountains (Zhang *et al.* 2013) and
50 in *ex situ* breeding centers including the zoos of Beijing and the breeding
51 centers of Wolong and Chengdu.

52 It is generally assumed that the conservation areas and the captive
53 breeding centers protect giant pandas from the adverse impacts of human
54 activities. However, their presumed safety may be compromised by the
55 dissemination of widespread pollutants into conservation zones or the
56 proximity of breeding centers to more heavily-polluted urban areas. For
57 example, perfluorinated compounds used in consumer and industrial products
58 as surfactants, surface protectors, and fire-fighting foams have been found in
59 serum samples taken from giant pandas in the Beijing zoo as well as from red
60 pandas (*Ailurus fulgens*) in a number of other zoos and wild animal parks in

61 China (Dai et al. 2006). However, the extent to which either wild pandas or
62 pandas in breeding centers are exposed to persistent organic pollutants (POPs)
63 and heavy metals that can accumulate in their tissues, compromise their
64 health, and potentially affect the success of ongoing conservation programs
65 remains unknown.

66 Here, we present data illustrating that giant pandas in *ex situ* breeding
67 centers are exposed to much greater concentrations of POPs and heavy
68 metals than their wild counterparts. Our data suggest that the bamboo fed to
69 the pandas is the proximate source of these compounds. Consequently, urgent
70 action is needed to safeguard these conservation icons, both in captivity and in
71 the wild.

72

73 **Materials and Methods**

74 Faecal droppings, which can be used as non-invasive indicators of pollutant
75 exposure (Christensen *et al.* 2013), were collected from wild pandas in the
76 Wolong and Foping National Nature Reserves, and from captive pandas
77 housed in China Conservation and Research Center for the Giant panda
78 (CCRCGP) and the Shaanxi Wild Animal Research Center (SWARC) (Fig.1).
79 The CCRCGP is the largest captive panda breeding center for the Sichuan
80 subspecies of giant panda, and SWARC is the only breeding center for the
81 Qinling subspecies. Samples of bamboo, the primary food for giant pandas,
82 were collected in the wild from Foping and from plants grown at SWARC.

83 Mixed feedstuff, fed to pandas as a nutrient supplement, was also sampled
84 from SWARC. Additional details on sample collection are provided in the
85 Supplemental Online Material.

86 The faecal droppings, plant tissue, and feedstock samples all were dried
87 to constant mass, digested, and analyzed using standard methods.
88 Determination of concentrations of POPs in the samples was done using
89 (high-resolution mass spectrometry (Liu *et al.*2006; Li *et al.* 2008) at the
90 Research Center for Eco-environmental Sciences of the Chinese Academy of
91 Sciences. Concentrations of heavy metals were determined using atomic
92 absorption or fluorescence spectrometry at the Institute of Earth Environment
93 of the Chinese Academy of Sciences. Complete details on analytical methods,
94 including QA/QC protocols, can be found in the Supplemental Online Material).

95 Data were analyzed using the SPSS software, version 19.0 (IBM SPSS
96 Inc.). Contaminant concentrations in droppings from wild and captive giant
97 pandas among and between the two subspecies were compared using *t*-tests.

98

99 **Results and discussion**

100 It is generally thought that pandas in captive breeding centers are better
101 protected from human activities than are wild pandas in nature conservation
102 zones, primarily because *in situ* conservation zones have become more
103 fragmented and less suitable for giant pandas (Liu *et al.* 2001). However, *ex*
104 *situ* breeding centers usually are close to urban areas and there is an

105 increasing concern that *ex situ* conservation efforts may be being
106 compromised due to environmental pollution associated with urbanization.
107 With China's rapid industrialization and urbanization, environmental pollution is
108 increasing in seriousness and following as it follows a trajectory similar to that
109 previously traversed by developed countries (Seinfeld 2004). This pollution
110 trajectory is having major impacts on public health, as seen in, for example,
111 the > 200 "cancer villages" in China (Yang 2013).

112 Among the many pollutants, POPs and heavy metals are of significant
113 environmental concern because they may be transported over long distances
114 in air and water (Lohmann *et al.* 2007), are very persistent in the environment,
115 accumulate readily in fatty tissues, and are highly toxic to humans and other
116 mammals (*e.g.*, Qiu 2013; Adriano *et al.* 2014; Fernandez-Rodriguez *et al.*
117 2015; Syed Ali *et al.* 2015). Three classes of POPs – PCDDs (polychlorinated
118 dibenzo-p-dioxins), PCDFs (polychlorinated dibenzofurans), and PCBs
119 (polychlorinated biphenyls) were found in much higher concentrations in faecal
120 droppings of captive giant pandas than in wild pandas (Fig. 2, WebTables1, 2).
121 POPs were also found at elevated levels in the bamboo fed to captive pandas
122 and their nutrient-supplement feedstock (WebFigures 1, 2). A variety of forms
123 ("congeners") of PCDDs and PCDFs are generated as by-products from
124 various combustion and chemical processes, whereas polychlorinated
125 biphenyls (PCBs) were widely used as dielectric fluids in transformers and
126 capacitors, heat exchange fluids, and as additives in pesticides, adhesives,

127 plastics, and paints because of their insulating and nonflammable properties
128 (Fiedler 2007). Although production of PCBs ceased in 1974, they are still
129 released from old capacitors and transformers and can still be found in various
130 environmental components and in human tissues (Mai *et al.* 2005; Imamura *et*
131 *al.* 2007).

132 Because PCDDs, PCDFs, and PCBs occur as congeners that differ in
133 toxicity and toxic equivalency factors, the World Health Organization has
134 defined a single toxic equivalent (WHO-TEQ) that can be calculated to
135 determine total POP exposure (Van den Berg *et al.* 2006). Both total
136 concentrations and the WHO-TEQ for PCDDs, PCDFs, and POPs were higher
137 in droppings collected from captive pandas than they were in wild pandas (Fig.
138 3). These results are paralleled by total concentrations and WHO-TEQs for the
139 bamboo fed to the pandas and their nutrient-supplement feedstock
140 (WebFigure 2).

141 Four heavy metals with known toxicity – arsenic (As), cadmium (Cd),
142 chromium (Cr), and lead (Pb) (Brahmia *et al.* 2013; Neal and Guilarte 2013;
143 Uddh-Soderberg *et al.* 2015) – also were found at elevated levels in droppings
144 of captive pandas relative to wild ones (Fig. 3), as well as in their food and their
145 nutrient-supplement feedstock (WebFigure 3). Unlike POPs, these heavy
146 metals occur in the natural environment, but they are readily mobilized by
147 human activities such as mining, automobile use, and overuse of chemical
148 fertilizer.

149 Our results provide direct evidence that giant pandas are exposed to
150 PCDDs, PCDFs, PCBs, and heavy metals in both *ex situ* captive breeding
151 centers and *in situ* conservation areas, but concentrations of these toxins in
152 pandas are far greater for pandas in captivity. Previous studies have shown
153 that PCDDs and PCDFs are associated with developmental toxicity,
154 immunotoxicity, and reproductive toxicity. PCBs and their breakdown products
155 are known endocrine disrupters, cause the loss of renal cell viability, and are
156 associated with increased risk of chloracne, goiter, anemia, and cancer
157 (Lohmann *et al.* 2007; Qiu 2013; Adriano *et al.* 2014; Fernandez-Rodriguez *et*
158 *al.* 2015; Gustavson *et al.* 2015; Syed Ali *et al.* 2015). Heavy metal exposure
159 has been associated with increased incidence of cancer (Cr and As),
160 nephrotoxicity and bone damage (Cd), and reduced reproductive function (Pb)
161 (Neal and Guilarte 2013; Brahmia *et al.* 2013; Uddh-Soderberg *et al.* 2015).
162 We conclude that our results belie the notion that captive breeding centers and
163 zoos provide a safe haven from human impacts.

164 Our results also illustrate that dietary exposure is the dominant, proximal
165 pathway through which giant pandas are exposed to POPs and heavy metals
166 (WebFigures 1-3). Although the food of both captive and wild pandas was
167 enriched in POPs (WebFigures 1, 2) and heavy metals (WebFigure 3), the
168 concentrations of both POPs and metals, and WHO-TEQs of POPs were
169 significantly greater in bamboo eaten by captive pandas (WebFigures 1–3).
170 We note that the nutrient-supplemented feedstock (baked into steamed bread

171 for the pandas) was enriched only in Cd, Cr, and Pb, but not in As, relative to
172 fresh bamboo.

173 In sum, our data provide clear evidence that giant pandas both in the wild
174 and in captivity are exposed to PCDDs, PCDFs, PCBs, and heavy metals
175 through their diet, and that exposure to these environmental toxins is greater in
176 *ex situ* breeding centers than in *in situ* nature reserves. Because exposure to
177 these environmental toxins is likely to impact negatively the health of these
178 animals, we suggest that urgent action is needed to safeguard these
179 conservation icons. In the short-term, captive breeding centers should be
180 relocated to areas less impacted or contaminated by environmental toxins, and
181 the food provided to captive pandas should be strictly monitored to ensure that
182 it lacks POPs and heavy metals, and is of consistent high quality. In the long
183 term, however, a more sustainable solution will rely on improving air quality
184 through reducing emissions of toxic pollutants.

185

186 **Acknowledgments**

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188 Conservation and Research Center for Giant panda (CCRCGP) for helping
189 with this research. Here we also thank Professor An for valuable advice during
190 the course of this study.

191

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- 259

260 **Figure legends**

261 Figure 1. Sites of sample collection (a); typical dropping of wild pandas (b); and
262 captive pandas (c) at the Shaanxi Wild Animal Research Center (SWARC).

263

264 Figure 2. Concentrations of 12 PCB congeners (top) and 17 CDD/F congeners
265 (bottom) in the droppings of wild and captive pandas of the Sichuan and
266 Qinling subspecies of giant pandas. In each of these star plots, the radius is
267 equal to the maximum observed concentration, and concentrations of each
268 individual congeners are scaled to the maximum. The conclusion from these
269 plots is that captive pandas have both more congeners and higher
270 concentrations of them in their faecal samples than wild pandas. Tabular data
271 (actual mean concentrations and the standard errors of the means) are given
272 in WebTables 1 and 2.

273

274 Figure 3. Concentrations of (a) all (summed) PCDDs and PCDFs; (b) all
275 (summed) PCBs; (c) WHO-TEQs of PCDDs and PCDFs; and (d) WHO-TEQ of
276 PCBs in faecal samples collected from two subspecies of wild (blue) and
277 captive (red) giant pandas. Bars (means \pm 1 SE of the mean from $N = 4$
278 independent replicates comprising three or four pooled samples) with different
279 letters between the wild and captive pandas for the same subspecies (A or B),
280 or between Sichuan and Qinling subspecies (X or Y) are significantly different
281 ($P < 0.05$, t -test).

282

283 Figure 4. Concentrations of heavy metals in faecal samples collected from two
284 subspecies of wild (blue) and captive (red) giant pandas. (a) Arsenic (As); (b)
285 Cadmium (Cd); (c) Chromium (Cr); (d) Lead (Pb). Bars (means \pm 1 SE of the
286 mean from N = 4 independent replicates comprising three or four pooled
287 samples) with different letters between the wild and captive pandas for the
288 same subspecies (A or B), or between Sichuan and Qinling subspecies (X or Y)
289 are significantly different ($P < 0.05$, *t*-test).

290

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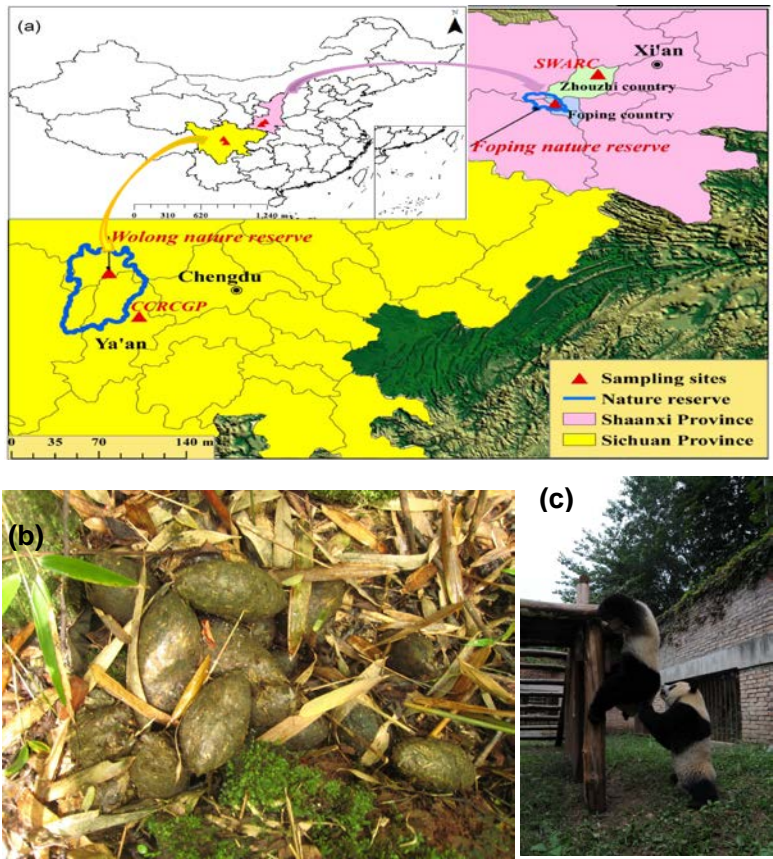
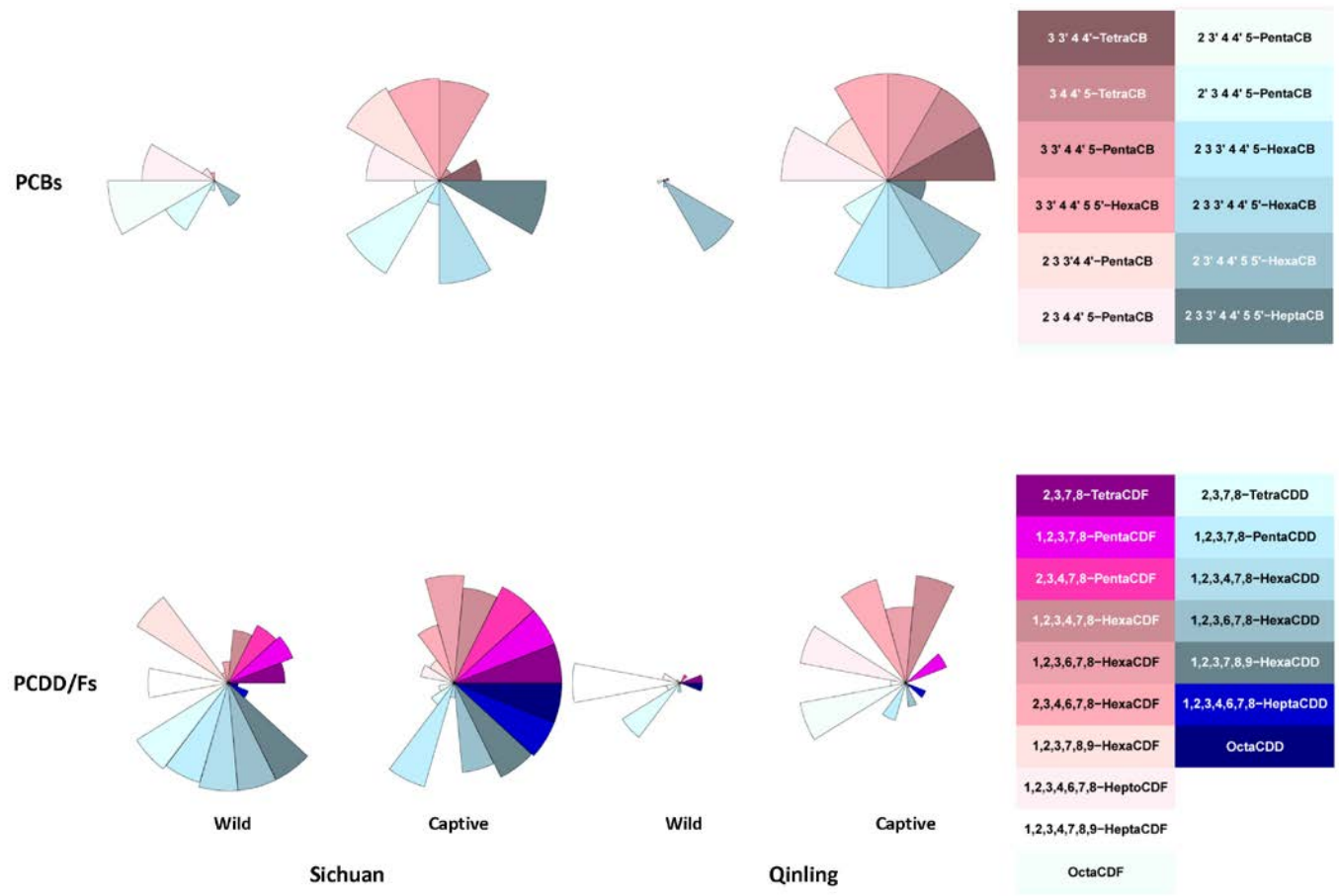


Figure 1



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Figure 2

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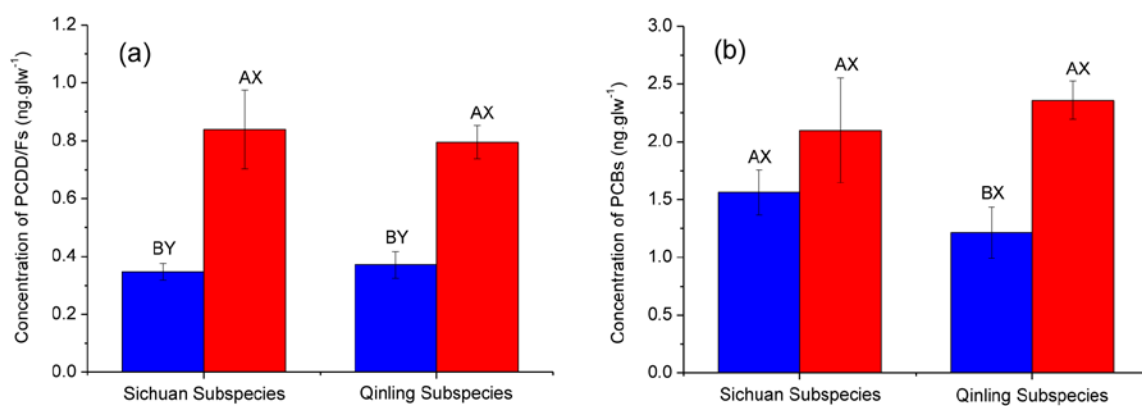
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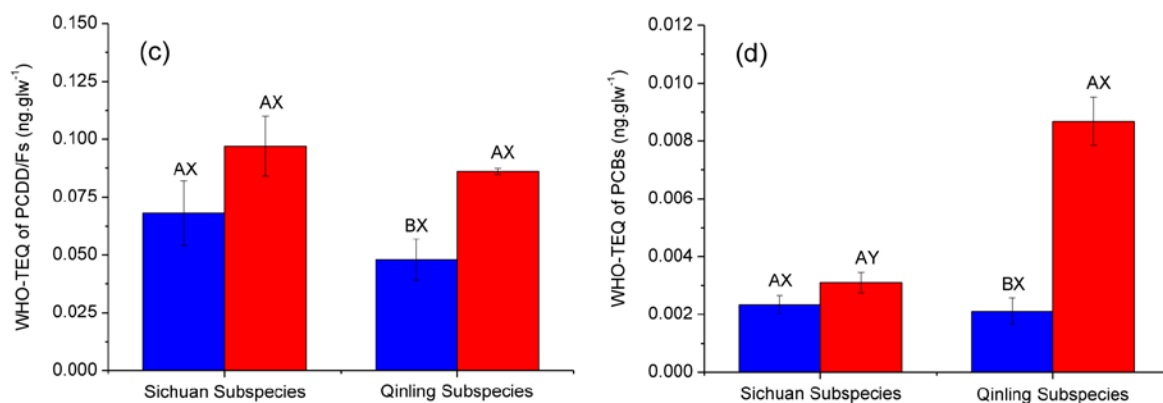
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Figure 3

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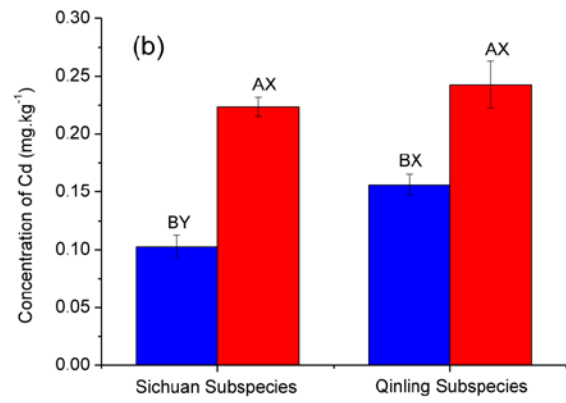
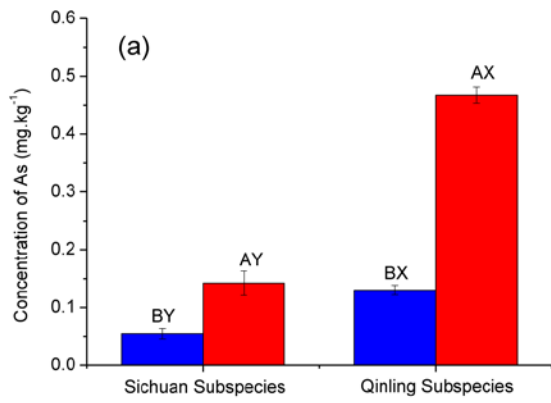
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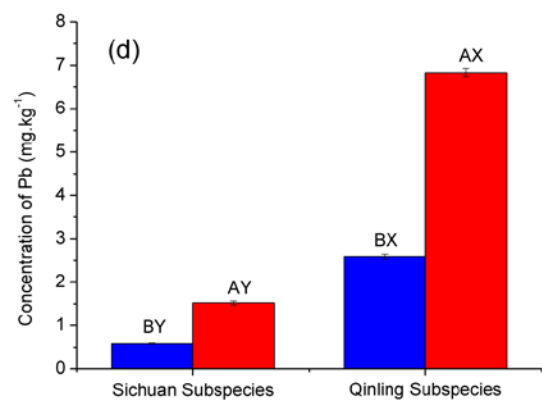
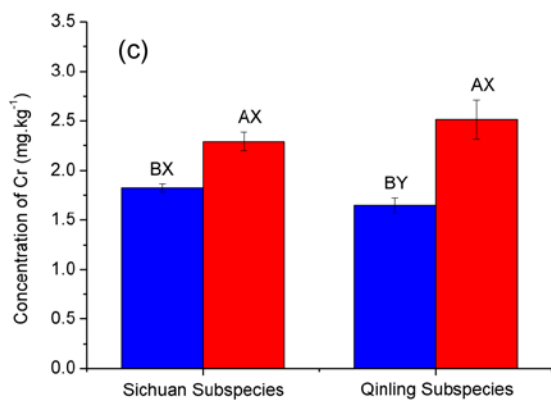
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Figure 4

1 **Captive pandas are at risk from environmental toxins**

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4

5 **Supplemental Online Material**

6 **Additional Materials and Methods**

7 **Additional References**

8 **WebTables 1, 2**

9 **WebFigures 1 – 3**

10

11

12 **Additional Materials and Methods**

13

14 ***Sample collection***

15 All faecal, plant, and feedstock samples were collected from the Wolong National

16 Nature Reserve in the Qionglai Mountains (“Wolong NNR”: 30°45’-31°25’N,

17 102°52’-103°25’E), the Foping National Nature Reserve in the Qinling Mountains

18 (“Foping NNR”: 33°33’-33°46’N, 107°40’-55’E), the China Conservation and

19 Research Center for Giant Panda (“CCRCGP”: 30°04’N, 102°59’E) and the Shaanxi

20 Wild Animal Research Center (“SWARC”: 34°06’N, 108°32’ E). The CCRCGP is the

21 largest captive breeding center for the Sichuan subspecies of the giant panda. It was
22 relocated to its current location in Bifengxia Ya'an city from Wolong after the 2008
23 Wenchuan earthquake. SWARC is located in Louguantai, Zhouzhi County, Xi'an city.
24 It was established in 1987 and is the only center for conservation of the Qinling
25 subspecies of the giant panda.

26 Faecal droppings of wild pandas were collected from 12 sites within the Wolong
27 NNR and 16 sites within the Foping NNR. Sampling locations were 10 km apart and
28 samples were pooled to give three samples/replicate from the Wolong NNR and four
29 samples/replicate from the Foping NNR. Droppings of captive pandas of the Sichuan
30 subspecies were collected at CCRCGP whereas droppings of captive pandas of the
31 Qinling pandas were collected at SWARC. Droppings from either 12 individuals
32 (CCRCGP) or 16 (SWARC) individuals were sampled and pooled into four replicates
33 each comprising of three or four independent samples.

34

35 ***Source of the Environmental Toxins***

36 To investigate the source of the pollutants detected in panda droppings, the Qinling
37 subspecies was studied in more detail. This subspecies was selected because there
38 are about 350 individuals left (State Forestry Administration of the People's Republic
39 of China.2015), so its conservation is much more urgent than that of the Sichuan
40 subspecies. Further, as noted in the Results, the faecal droppings of the Qinling
41 pandas contained significantly higher concentrations of As, Cd and Pb than droppings
42 of the Sichuan subspecies.

43 Fresh leaves of the primary bamboo fed to these pandas (*Fargesia qinlingensis*,
44 *Bashania fargesii*) and mixed feedstock used to make nutrient-supplements for the
45 Qingling subspecies were collected from the Foping NNR, from plants cultivated at
46 SWARC, and from feedstock at SWARC. Twelve samples of each food type were
47 collected per location and pooled to produce four replicates each consisting of three
48 samples.

49

50 **Heavy metal analysis**

51 All samples were dried to constant mass at 60°C before being homogenized using a
52 ball mill. Dried samples (500 mg) were placed into Teflon bombs to which were added
53 5 ml of HNO₃ for digestion with a microwave system (CEM, Mars 6, CEM, USA). After
54 digestion, samples were diluted to 50 mL with deionized water. Concentrations of
55 cadmium (Cd), chromium (Cr), and lead (Pb) were measured using a graphite
56 furnace atomic absorption spectrometer (220-FS; Varian Company, USA.) with a
57 hollow cathode lamp (Vigorous Instruments Co., Ltd., Beijing, China) (Yu *et al.* 2001).
58 Concentrations of arsenic (As) were measured using an Atomic Fluorescence
59 Spectrometer (AF-7500; Beijing Dongxi Instruments Co., Ltd., China) with a hollow
60 cathode lamp (Vigorous Instruments Co., Ltd., Beijing, China) (Rahman *et al.* 2000).

61

62 **Analysis of PCDDs, PCDFs, and PCBs**

63 Samples (dropping, bamboo and feedstuff) were freeze-dried before being spiked
64 with ¹³C-labeled surrogate standards (Environmental Protection Agency [EPA]

65 method 1613B and 1668A) and underwent accelerated solvent extraction with
66 dichlorinmethene: hexane (1:1). After determining the lipid content of each sample,
67 the extract was adjusted to 50 ml with hexane; 15 g of acid silica (30% w/w) was
68 added to remove lipids. The acid silica was stirred for 2 h and the extract was poured
69 through 5 g of anhydrous sodium sulfite. All of the extracts were concentrated to 2 ml
70 by rotary evaporation.

71 All solvents were purchased from Fisher (Fairlawn, NJ, USA). Silica gel was
72 obtained from Merck (silica gel 60; Darmstadt, Germany). Basic alumina was
73 obtained from Aldrich (Brockmann I, standard grade; Milwaukee, USA). Florisil was
74 obtained from Riedel-de Haën (60–100 mesh ASTM; Seelze, Germany). Calibration
75 standard solutions, $^{13}\text{C}_{12}$ -labeled surrogate standards, and $^{13}\text{C}_{12}$ -labeled injection
76 standards were purchased from Wellington Laboratories (Guelph, Canada).

77 PCBs, PCDDs, and PCDFs were analyzed at the POP laboratory of the Research
78 Center for Eco-environmental Sciences, Chinese Academy of Sciences; all
79 concentrations were corrected for lipid weight. Sample extraction, cleanup, and
80 chemical analysis followed established methods with some modifications (Liu *et*
81 *al.* 2006; Li *et al.* 2008). Twenty-five PCB congeners, including 12 dioxin-like
82 congeners, were quantified by an isotope dilution method using high-resolution gas
83 chromatography coupled with high-resolution mass spectrometry (HRGC/HRMS).
84 Total organic carbon (TOC) concentration was analyzed on a TOC Analyzer (O.I
85 Analyzer; College Station, TX, USA). A 0.1-g sample was weighed and loaded into
86 the combustion cup, which was packed with quartz wool. Prior to combustion, the

87 samples were wetted with 5% phosphoric acid and heated to 250°C for 1 min to
88 purge inorganic carbon. The signal was detected by non-dispersed infrared (NDIR)
89 detection when flashed at 900 °C for 6 min in the combustion house.

90 The quantification of 17 PCDD/PCDF homologues was done using
91 HRGC/HRMS on an Agilent 6890 gas chromatograph coupled with an Autospec
92 Ultima mass spectrometer (Waters Micromass, Manchester, UK) operating in the EI
93 mode at 35 eV with the trap current was 600 IA. The GC was equipped with a CTC
94 PAL autosampler. One or two µL samples were injected in splitless mode (splitless
95 time, 2 min for PCDD/Fs) in a DB-5MS fused silica capillary column (60 m for
96 PCDD/Fs and PCBs) with helium as carrier gas at a constant flow rate of 1.2 ml/min.
97 The oven temperature programs were as follows: for PCDD/Fs, start 150°C held for 3
98 min, 150-230°C at 20°C min⁻¹ held for 18 min, 230-235°C at 5°C min⁻¹ held for 10 min,
99 235-320°C at 4°C min⁻¹ held for 3 min; for PCBs, start 120°C held for 1 min,
100 120-150°C at 30 °C min⁻¹, 150-300°C at 2.5°C min⁻¹ held for 1 min.

101

102 ***Quality control and quality assurance***

103 All data were subject to quality control and quality assurance. All glassware was
104 washed two times with distilled water, and then with dichloromethane after use. After
105 washing, glassware was dried for 6 hours at 400 °C in a muffle furnace.

106 All performance criteria required for the analysis of PCBs and PCDD/PCDFs
107 followed US EPA methods (1668A and 1613B).¹³C-labeled surrogated standards

108 (1668A-LCS and 1613-LCS) were spiked in the sample for qualification and
109 quantification, and ¹³C-labeled injection standards (EPA 68A-IS and 1613-IS) were
110 added for recovery calculation. The recoveries of the surrogate standards ranged
111 from 76.7±25.2% and 49.2±13.6% for PCB and PCDD/PCDFs, respectively, which
112 met the requirements of US EPA methods 1668 A and 1613 B. Limit of detection (LOD)
113 in the sample was defined as a signal to noise (S/N) ratio = 3. The LOD values were
114 in the range of 0.01–0.82 pg g⁻¹ for PCBs and 0.04–8.40 pg g⁻¹ for PCDD/PCDFs.
115 Laboratory blanks were analyzed with samples quality control at set intervals, and
116 there was no detection of target compounds in the blanks.

117

118 **Additional References**

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127

128 WebTable 1. Concentrations of PCDD and PCDF congeners in faecal droppings from
 129 wild and captive pandas of both Sichuan (SS) and Qinling (QS) subspecies. Values
 130 are means \pm 1 standard error of the mean for $N = 4$ independent replicates each
 131 comprising three or four pooled subsamples.
 132

Congeners (pg.glw ⁻¹)	Wild SS	Captive SS	Wild QS	Captive QS
2,3,7,8-TetraCDF	7.802 \pm 2.509	14.278 \pm 4.946	3.402 \pm 1.244	0.536 \pm 0.473
1,2,3,7,8-PentaCDF;	10.098 \pm 2.402	14.536 \pm 5.413	2.074 \pm 1.278	7.117 \pm 7.117
2,3,4,7,8-PentaCDF;	11.585 \pm 2.027	18.100 \pm 3.694	3.214 \pm 1.565	1.816 \pm 1.816
1,2,3,4,7,8-HexaCDF	11.002 \pm 1.477	15.934 \pm 6.152	4.868 \pm 2.764	17.300 \pm 9.700
1,2,3,6,7,8-HexaCDF	8.900 \pm 3.097	19.125 \pm 5.736	6.352 \pm 3.043	15.397 \pm 8.576
2,3,4,6,7,8-HexaCDF;	6.568 \pm 3.119	15.621 \pm 5.895	4.507 \pm 2.000	24.320 \pm 8.676
1,2,3,7,8,9-HexaCDF	6.582 \pm 4.347	2.186 \pm 2.001	0.800 \pm 0.289	0.579 \pm 0.579
1,2,3,4,6,7,8-HeptaCDF	42.796 \pm 14.568	65.054 \pm 13.461	54.471 \pm 17.196	113.048 \pm 37.687
1,2,3,4,7,8,9-HeptaCDF	4.365 \pm 2.732	0.566 \pm 0.382	5.661 \pm 3.843	1.283 \pm 1.222
OctaCDF	34.857 \pm 5.274	72.098 \pm 31.329	67.689 \pm 19.035	291.502 \pm 165.188
2,3,7,8-TetraCDD	2.521 \pm 1.456	0.631 \pm 0.494	1.591 \pm 1.334	☆
1,2,3,7,8-PentaCDD;	2.846 \pm 1.582	2.952 \pm 1.450	0.356 \pm 0.235	1.289 \pm 1.289
1,2,3,4,7,8-HexaCDD	7.514 \pm 3.456	1.051 \pm 0.698	0.680 \pm 0.324	0.053 \pm 0.053
1,2,3,6,7,8-HexaCDD	5.676 \pm 2.729	4.926 \pm 2.046	1.247 \pm 0.428	2.216 \pm 2.174
1,2,3,7,8,9-HexaCDD	6.654 \pm 4.893	6.483 \pm 3.772	☆	0.288 \pm 0.288
1,2,3,4,6,7,8-HeptaCDD	37.442 \pm 5.204	87.879 \pm 24.617	24.736 \pm 8.696	37.214 \pm 22.064
OctaCDD	148.753 \pm 8.656	469.836 \pm 97.490	189.186 \pm 29.664	115.741 \pm 92.914

133 ☆ less than the limit of determination.

134

135

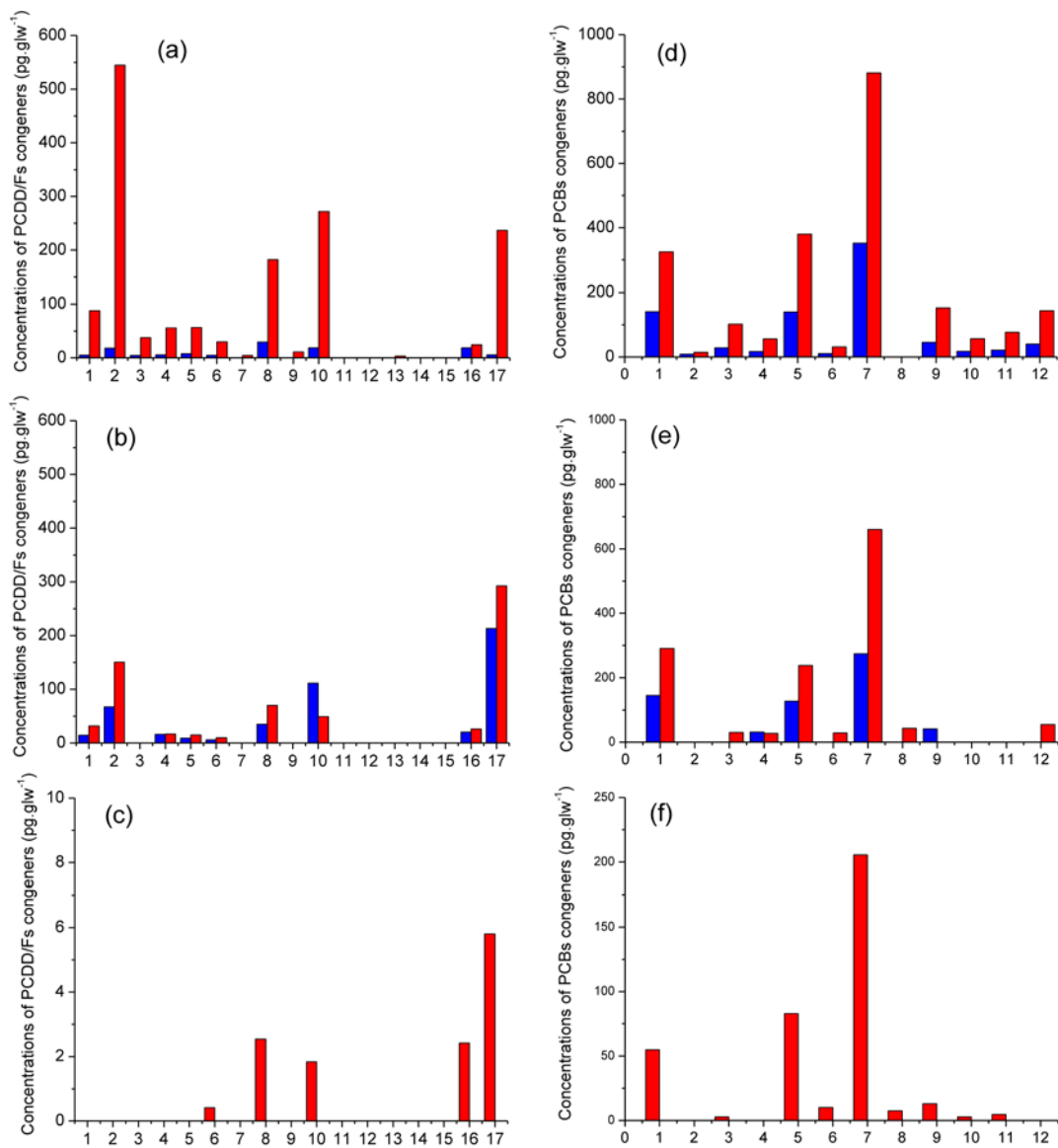
136 WebTable 2. Concentrations of PCB congeners in faecal droppings from wild and
 137 captive pandas of both Sichuan (SS) and Qinling (QS) subspecies. Values are means
 138 \pm 1 standard error of the mean for $N = 4$ independent replicates each comprising
 139 three or four pooled subsamples.

140

Congeners(pg.glw ⁻¹)	Wild of SS	Captive of SS	Wild of QS	Captive of QS
3,3',4,4'-TetraCB	72.745 \pm 10.721	151.170 \pm 22.013	82.564 \pm 32.295	270.217 \pm 44.520
3,4,4',5'-TetraCB	☆	5.768 \pm 4.476	☆	45.409 \pm 19.320
3,3',4,4',5-PentaCB	7.910 \pm 3.856	155.379 \pm 101.403	9.495 \pm 5.967	165.775 \pm 99.209
3,3',4,4',5,5'-HexaCB	1.721 \pm 1.629	21.159 \pm 14.862	☆	22.145 \pm 22.145
2,3,3',4,4'-PentaCB	295.723 \pm 31.734	716.133 \pm 246.199	230.065 \pm 57.408	556.994 \pm 204.311
2,3,4,4',5-PentaCB	54.729 \pm 6.431	54.830 \pm 15.421	21.003 \pm 8.061	70.455 \pm 9.945
2,3',4,4',5-PentaCB	976.121 \pm 57.739	788.122 \pm 446.010	744.270 \pm 135.106	731.055 \pm 238.280
2',3,4,4',5-PentaCB	54.104 \pm 5.305	79.313 \pm 19.382	25.294 \pm 3.305	51.228 \pm 12.658
2,3,3',4,4',5-HexaCB	64.191 \pm 4.816	68.530 \pm 25.965	61.105 \pm 4.694	94.781 \pm 24.436
2,3,3',4,4',5'-HexaCB	11.179 \pm 2.846	35.653 \pm 13.606	12.693 \pm 9.960	36.634 \pm 6.900
2,3',4,4',5,5'-HexaCB	24.245 \pm 7.676	18.822 \pm 10.687	33.975 \pm 5.332	38.804 \pm 13.105
2,3,3',4,4',5,5'-HeptaCB	☆	4.982 \pm 4.860	☆	1.763 \pm 1.763

141 ☆ less than the limit of determination.

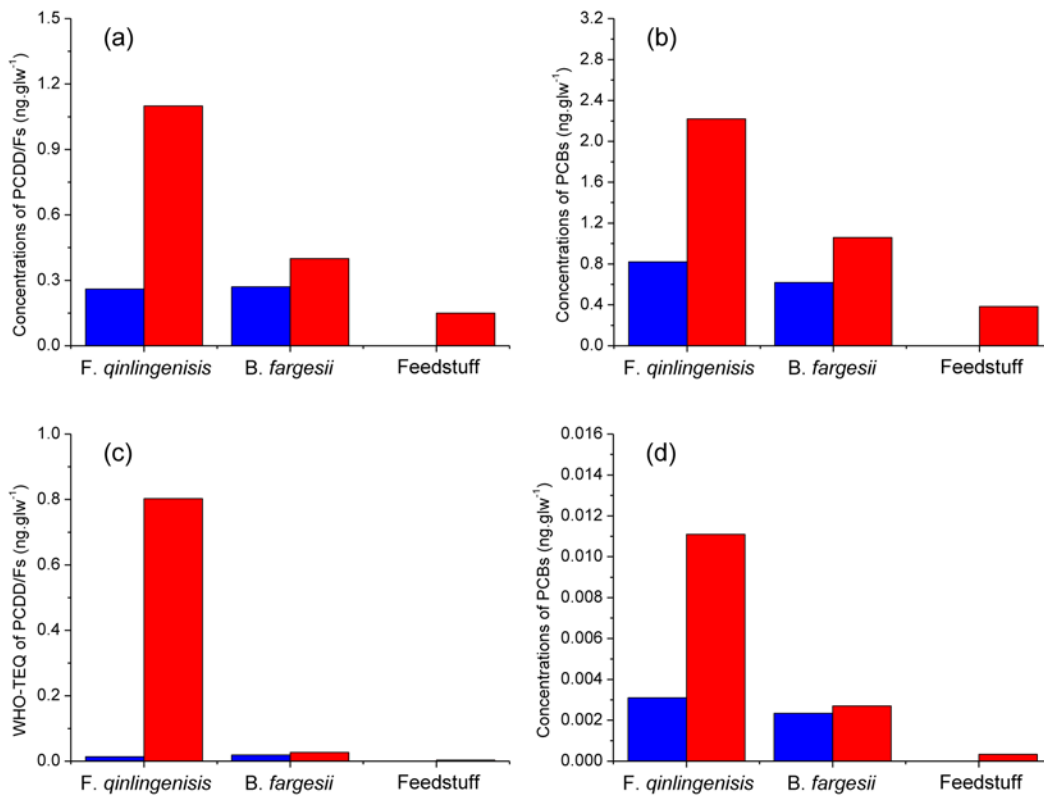
142



143

144 WebFigure 1. The concentrations of congeners of (a, b, c) PCDDs and PCDFs; and
 145 (d, e, f) PCBs in the bamboos *Fargesia qinlingensis* and *Bashania fargesii*, and
 146 feedstuff of wild (blue) and captive (red) pandas. Numbers on the x-axis of panels (a),
 147 (b) and (c) denote different congeners of PCDD/F. 1=2,3,7,8-TetraCDF;
 148 2=1,2,3,7,8-PentaCDF; 3=2,3,4,7,8-PentaCDF; 4=1,2,3,4,7,8-HexaCDF;
 149 5=1,2,3,6,7,8-HexaCDF; 6=2,3,4,6,7,8-HexaCDF; 7=1,2,3,7,8,9-HexaCDF;
 150 8=1,2,3,4,6,7,8-HeptoCDF; 9=1,2,3,4,7,8,9-HeptaCDF; 10=OctaCDF;

151 11=2,3,7,8-TetraCDD; 12=1,2,3,7,8-PentaCDD; 13=1,2,3,4,7,8-HexaCDD;
152 14=1,2,3,6,7,8-HexaCDD; 15=1,2,3,7,8,9-HexaCDD; 16=1,2,3,4,6,7,8-HeptaCDD;
153 17=OctaCDD; Numbers on the x-axis of panels (d), (e) and (f) denote different
154 congeners of PCBs. 1=3,3',4,4'-TetraCB; 2=3,4,4',5-TetraCB; 3=3,3',4,4',5-PentaCB;
155 4=3,3',4,4',5,5'-HexaCB; 5=2,3,3',4,4'-PentaCB; 6=2,3,4,4',5-PentaCB;
156 7=2,3',4,4',5-PentaCB; 8=2',3,4,4',5-PentaCB; 9=2,3,3',4,4',5-HexaCB;
157 10=2,3,3',4,4',5'-HexaCB; 11=2,3',4,4',5,5'-HexaCB; 12= 2,3,3',4,4',5,5'-HeptaCB.
158



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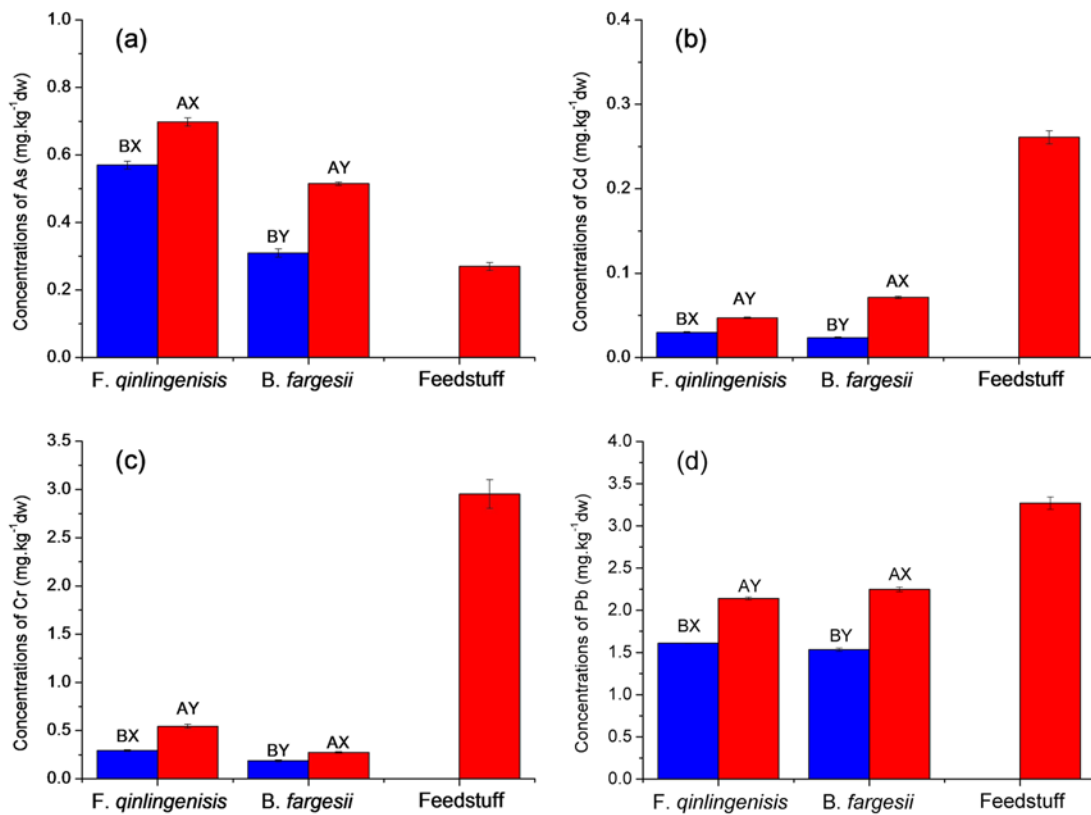
160 WebFigure 2. Concentrations of (a) Σ PCDDs and PCDFs, (b) Σ PCBs, (c) WHO-TEQ
 161 of PCDDs and PCDFs, and (d) WHO-TEQ of PCBs in the bamboos *Fargesia*
 162 *qinlingensis* and *Bashania fargesii*, and from panda feedstuff. Bars are the value from
 163 a single replicate comprising five pooled samples.

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169

170 WebFigure 3. Concentrations of heavy metals in Qinling subspecies food of wild (blue)
 171 and captive (red) from bamboo species (*Fargesia qinlingensis* and *Bashania fargesii*)
 172 and feedstuff. (a) Arsenic (As); (b) Cadmium (Cd); (c) Chromium (Cr); (d) Lead (Pb).
 173 Bars (means \pm 1 SE of the mean from N = 4 independent replicates from three pooled
 174 samples) with different letters between the two bamboo species (*Fargesia*
 175 *qinlingensis* and *Bashania fargesii*) (A and B) or between the bamboos fed to wild and
 176 captive (X or Y) are significantly different ($P < 0.05$, t-test).