# FINAL REPORT

# A SURVEY OF CADMIUM IN BROWN CRABMEAT AND BROWN CRABMEAT PRODUCTS: FOLLOW-ON STUDY ON CADMIUM IN CRAB HEPATOPANCREAS AND OTHER EDIBLE ORGANS

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| **Submitted to:** | Richard Burden, The Food Standards Agency |
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| **Project Manager:** | Thi Bolam |
| **Report compiled by:** | Thi Bolam and Philippe Bersuder |
| **Quality control by:** | Robin Law |
| **Approved by & date:** | Steve Millward, 04th April 2013 |
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**Final Report**

# Cefas Project C5700B –A Survey of Cadmium in Brown Crabmeat and Brown Crabmeat Products: Follow-on Study on Cadmium in Hepatopancreas and Other Edible Organs.

**Authors: Thi Bolam and Philippe Bersuder**

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Commissioned by: The Food Standards Agency
Area 3B Aviation House,
125 Kingsway,
London,
WC2B6NH

Contact person: Richard Burden

e-mail: Richard.Burden@foodstandards.gsi.gov.uk

**Head office**
Centre for Environment, Fisheries & Aquaculture Science
Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK
Tel +44 (0) 1502 56 2244 Fax +44 (0) 1502 51 3865
www.cefas.co.uk

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# Executive Summary

The European Commission has recommended that Member States should provide advice on brown crabmeat consumption to their consumers as the brown meat from crabs (brown crabmeat) has the potential to contain elevated levels of cadmium (Cd). Following a recent survey on Cd levels in brown crabmeat and its products on sale in the United Kingdom (UK) commissioned by the Food Standards Agency (FSA) in 2012, additional information with regards to Cd levels in the hepatopancreas and other edible tissues from the crab's cephalothorax was required to provide this advice.

A total of fifty six live brown crab (*Cancer pagurus*), representing four geographical locations (Fraserburgh, Aberdeen, Dorset, Newlyn) were procured by the FSA from Billingsgate. The crabs were transported to the Cefas Lowestoft laboratory where they were tagged for traceability and stored under appropriate conditions. The crabs were subsequently killed humanely and immediately dissected, all hepatopancreases being homogenised and bulked into one sample, the remaining edible tissues from the cephalothorax making up a second bulked sample.

The analysis of Cd and a suite of other trace metals were carried out on six replicates of each sample using a fully validated and accredited methodology based on the acid digestion of crab tissues using an enclosed vessel microwave. The determination of Cd was performed by Inductively Coupled Plasma-Mass Spectrometry.

For the hepatopancreas sample, the mean Cd concentration [±standard deviation] was found to be 4.0 [±0.18] mg/kg wet weight (w.w.), while the mean Cd concentration in other edible tissues from the cephalothorax was found to be 0.27 [±0.02] mg/kg w.w. The concentration data reported here will support the FSA's risk assessment and management processes regarding the safety of consuming brown crab meat products that are available for purchase in the UK.

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# Glossary

| | |
|---|---|
| Cd | Cadmium |
| CRM | Certified Reference Material |
| EC | European Commission |
| FSA | United Kingdom's Food Standards Agency |
| ICP-MS | Inductively Coupled Plasma-Mass Spectrometry |
| LIMS | Laboratory Information Management System |
| LSN | Laboratory Sample Number |
| RSPCA | The Royal Society for the Prevention of Cruelty to Animals |
| SOP | Standard Operating Procedure |
| w.w. | Wet weight |

# 1 Introduction

In 2011, the EC released an information note to raise awareness of national authorities regarding the consumption of brown crabmeat as it has the potential to contain elevated levels of cadmium (Cd) (EC, 2011), with the anticipation that individual Member States would produce consumption advice relevant to their consumers. However, the available information on Cd concentration in brown crabmeat and its products on sale in the United Kingdom (UK) has not been sufficient to allow the Food Standards Agency (FSA) to provide this advice. Consequently, the FSA commissioned a survey to provide a data base which describes the range of Cd concentrations in brown crabmeat and food products containing brown crabmeat sold in UK retail outlets that were readily available to the UK consumer (Bolam and Bersuder, 2013). As a result of this initial survey, additional information with regards to Cd levels in various edible tissues present in the cephalothorax of freshly killed crab is required. This survey provides quality assured evidence with regards to mean levels of Cd in the hepatopancreas and other edible tissues composing the brown crabmeat. The concentration data reported here will support the FSA's risk assessment and management processes regarding the safety of consuming brown crab meat products that are available for purchase in the UK

# 2 Methods

The study was based on two distinct phases. The first phase involved the collection of fifty six live crabs from at least four different landing locations and their delivery to the Cefas Lowestoft laboratory, their tagging and storage. Subsequently, crabs were killed humanely, dissected for their hepatopancreases and other edible organs, bulked into two distinct samples and analysed for cadmium and other trace elements using reliable, quality assured analytical methodologies.

### *2.1 Sampling strategy and plan*

Live brown crabs (*Cancer pagurus*) were purchased by the FSA from Billingsgate Fish Market. A total of fifty six crabs were required, with the objective of obtaining as even a distribution as possible between the geographical areas that are sold at Billingsgate and the sex of crab e.g. if crabs were able to be purchased from four geographical areas, the ideal split for the fifty six crabs would be as follows:

- **Area 1**: fourteen live brown crabs (seven male and seven female)
- **Area 2**: fourteen live brown crabs (seven male and seven female)

- **Area 3**: fourteen live brown crabs (seven male and seven female)
- **Area 4**: fourteen live brown crabs (seven male and seven female)

Additionally, the sampling plan also stipulated the following:

- no more than fifteen crabs were to be purchased from a single geographical area;
- the minimum number of geographical areas to be covered was to be four;
- crabs were to be packaged by catch area for transport and information (i.e. location, sex, sample number) was to be clearly recorded and handed over to Cefas staff;
- all crabs were to be nicked prior to delivery at the Cefas laboratory as they were to be kept alive in tanks at the Cefas aquarium facilities before dissection.

### *2.2 Sample receipt and storage*

#### *2.2.1 Sample receipt*

Upon sample receipt, Cefas checked for sample numbers, recorded any mortality or other observations (e.g. claw shedding). All dead crab were stored separately from live crab and, depending on the conditions of the dissected organs from the dead crabs, a decision on whether these should be bulked with the remaining samples was taken. Subsequently, crab sex and length were recorded and an identification tag was fixed to each animal (both dead and alive).

Crabs were tagged using Super Heavy Duty monofilament Double T anchor tags (SHD FD-94 anchor tags) manufactured by Floy Tag and Manufacturing inc. (Seattle, USA). The tag had two 10mm long T-bars that were 10mm apart. The external monofilament of the tag was 55mm long surrounded by coloured polyolefin tubing which contained the numbering and legend, protected by a shrink lock covering. Each tag was serially inscribed with the tag batch and series numbers, e.g. :

E04 0001 WWW.CEFAS.CO.UK PLEASE RECORD

TAG NO, DATE, LAT & LONG, WIDTH, SEX

The last 4 digits of the tag number being sequentially incremented.

Avery Dennison Mark II SHD tagging guns, with a 2.3mm external diameter needle, were used to insert the tags. The guns were modified to reduce possible damage to the crabs' internal organs when tagged. The long point of the needle was ground off and a guard attached, limiting the maximum penetration of the needle to around 1cm. The needle was inserted into the branchial

chamber through a hole made in the epimeral line at the back of the carapace of the crab and, when triggered, the head of the tag was driven inside the carapace and anchored by the terminal T-bar. The second T-bar remained outside the carapace, preventing the trailing tag section from being drawn inside the crab.

#### *2.2.2 Live crab storage*

Live crabs were transferred into three storage tanks (volume 1.35 $m^3$) containing saline water (31 ppt salinity) refreshed at a rate of 3 L/min. The water was aerated with compressed air through a medium pore air stone, and the water temperature was maintained at 4.5°C. Crab mortality was checked daily and recorded.

#### *2.2.3 Killing of crabs:*

Cefas followed the guidelines of handling and storage of live crabs provided in the RSPCA protocol for the humane stunning/killing of Crustacea (RSPCA, 2012). Electrical stun/killing is the most humane and effective method for killing crabs, as it renders them immediately insensible with death ensuing (whilst insensible) within seconds, and this method was therefore applied in this study. For this, a CrustaStun™ single stunner device (Crustastun, Studham, Beds, UK), designed to administer a lethal shock (230 volt, 1-8 amp electrical charge) to crab was used to kill the live crab humanely.

The CrustaStun™ device was operated by initially dissolving 60g of Analar grade sodium chloride (VWR, Leicestershire, UK) in purified water (reverse osmosis) to fill the base of the device. The electrode sponge located in the lid was dampened with the saline solution, and one crab at a time was placed abdomen down onto the sprung tray in the unit. The lid was closed and secured before the stun button specific to “crab” was depressed. Within half a second, the nerve functions of the crab are interrupted and the animal cannot feel pain, the animal being killed within ten seconds of application.

### *2.3 Sample preparation*

Each dead crab was dissected following Cefas Standard Operating Procedure 2150: “*Whole crab handling, storage (for pre-killing), killing and dissection*” (provided as Supplementary Information separately to this report). The hepatopancreas and other edible tissues from the cephalothorax (including the reproductive organs, soft skin tissue etc.) were manually separated from the whole crab. The hepatopancreas of fifty six crabs were combined in batches of 5-6, homogenised and bulked into one single sample. The same bulking method was applied to the remaining edible tissues, producing a second bulked sample. Additionally, the sex, weight and size of the whole crab,

as well as the weight of the hepatopancreases and other edible organs of each crab, were also recorded during the sample preparation stage.

### *2.4 Sample analysis*

Six sub-samples of each bulked tissue (hepatopancreases and other edible organs) underwent an acid digestion using an enclosed vessel microwave (Multiwave 3000, Anton Paar, Hertford, UK). Typically, approximately 3 g of homogenised sample was weighed out and pre-digested overnight in 6mL of nitric acid (Aristar grade 69%, VWR, Leicestershire, UK). The digestion was performed using a temperature-controlled microwave programme specific for the sample matrix. The digest was then further diluted prior to analysis by inductively coupled plasma-mass spectrometry (ICP-MS) using an Agilent 7500ce (Agilent Technologies, Waldbronn, Germany). Quantification of Cd was performed by external calibration, using eight levels (0, 0.5, 1, 5, 10, 20, 100 and 500µg/L) of working standard solutions, which were prepared from a customised mixed metal standard solution of 100mg/L (SPEX Certiprep Ltd, Middlesex, UK).

A reagent blank and a certified reference material (CRM TORT-2-Lobster hepatopancreas; National Research Council Canada, Halifax, Nova Scotia, Canada) were included with the batch of 12 samples. Concentration data derived from the analysis of the CRM were then added to existing quality control Shewhart charts (using North West Analytical Quality Analyst™, Northwest Analytical Inc., USA) for the assessment of the day-to-day method performance and validity of Cd concentration data from the batch analysis of real samples. The validity of results was established using the warning and control limits of the Shewhart chart, which are defined as 2σ and 3σ, respectively.

# 3 Results

### *3.1 Sampling survey*

A retailer from Billingsgate was commissioned by the FSA to source the live crabs for this study. A total of fifty six live crabs, all of the *Cancer pagurus* species, were delivered at the Cefas laboratory in Lowestoft. Six crabs were found to be dead, probably as a result of longer distance transport as all six originated from Scotland. The crabs were from four different landing locations:

- Fraserburgh: 2x12 samples;
- Aberdeen: 10 samples;
- Dorset: 10 samples;
- Newlyn: 12 samples.

All crabs, whether alive or dead, were tagged with a unique number to cross-reference their landing location (See Figure 1). Details of the crab landing information and condition upon receipt are tabulated in Appendix 1.


**Figure 1: Example of crab tagging**

All six dead crabs were put aside for dissection on the same day. The remaining crabs were put into three tanks filled with aerated seawater (Figure 2), with tank 3 containing only one crab from Fraserburgh (tag number EO04 2630) as it was not nicked. The crabs were not fed whilst they were waiting to be killed.


**Figure 2: Tank facilities used for storing live crab**

Regular monitoring was carried out to check for any mortality: during the whole study, only one crab died at the end of day 1 (tag number EO04 2636), it was removed, frozen and dissected the following day.

### *3.3 Crab humane killing method*

The RSPCA believes that electrical stun/killing is the most humane and effective method for killing crabs, lobsters, crayfish and langoustines. The electical stun/killing method renders them immediately insensible with death ensuing (whilst insensible) within seconds. Figure 3 shows the CrustaStun™ single stunner device, in use with a live crab.

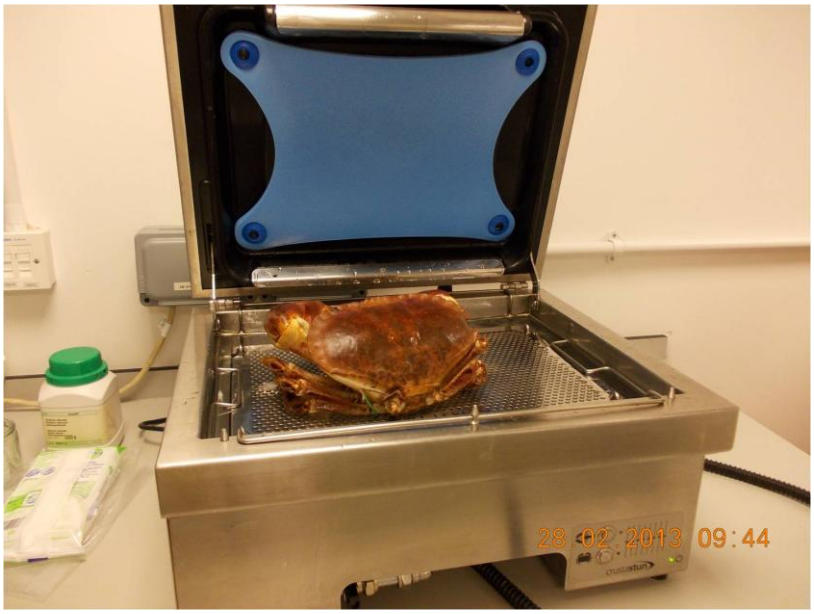


**Figure 3: The Crustastun™ single stunner device**

### *3.4 Sample preparation*

The crabs were dissected as per SOP 2015 to remove the hepatopancreas and other edible organs in batches of five or six samples (Figures 4 and 5). The tissues were bulked and homogenised respectively for hepatopancreases and other edible organs. As the dissection was carried out over 2 days, the bulked and homogenised samples were stored frozen at the end of each day and were combined on the last day of dissection into a final container (one for hepatopancreas, one for the other edible organs) and homogenised once more.

All fifty six crabs were dissected and their hepatopancreas and other edible organs (including the tissues from the dead crabs) were bulked and homogenised respectively.

The information on sex, weight (hepatopancreas, other edible organs and total weight of whole crab) and size of each individual crab is summarised in Appendix 2.

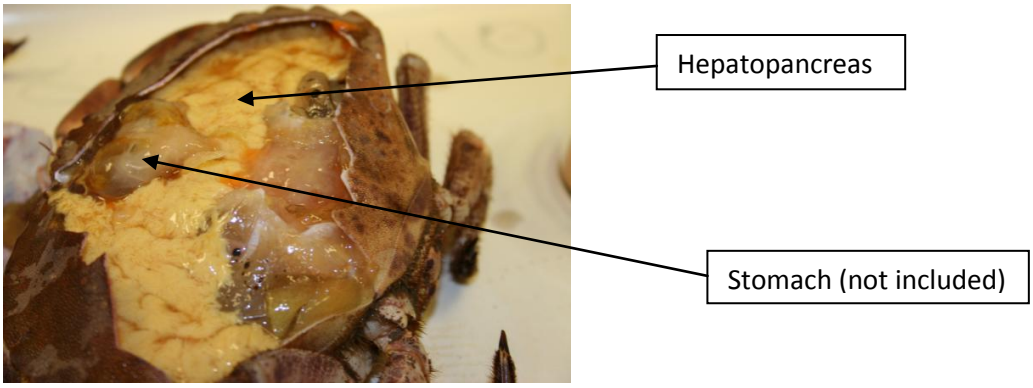


**Figure 4: Hepatopancreas (and stomach)**

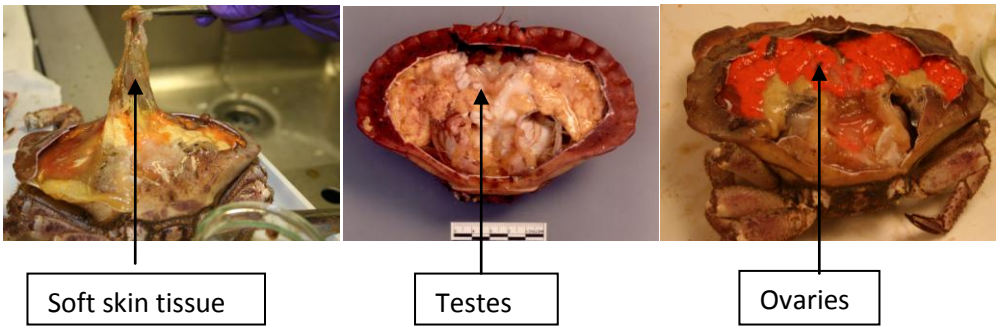


**Figure 5: Other edible organs: including the soft skin tissue (left) and reproductive organs: testes in male crab (middle) or ovaries in female crab (right)**

### *3.5 Internal quality assurance and control*

The mean recovery of Cd from the extraction and analysis of certified reference material (CRM Tort-2, certified Cd value of 26.7mg/kg) was 93.4% (*n*=64; RSD of 4.2%). The inter-batch variations of Cd concentrations from the CRM are presented in Figure 6.

The method limit of detection and limit of quantification for Cd are 8 µg/kg w.w. and 27 µg/kg w.w. respectively.

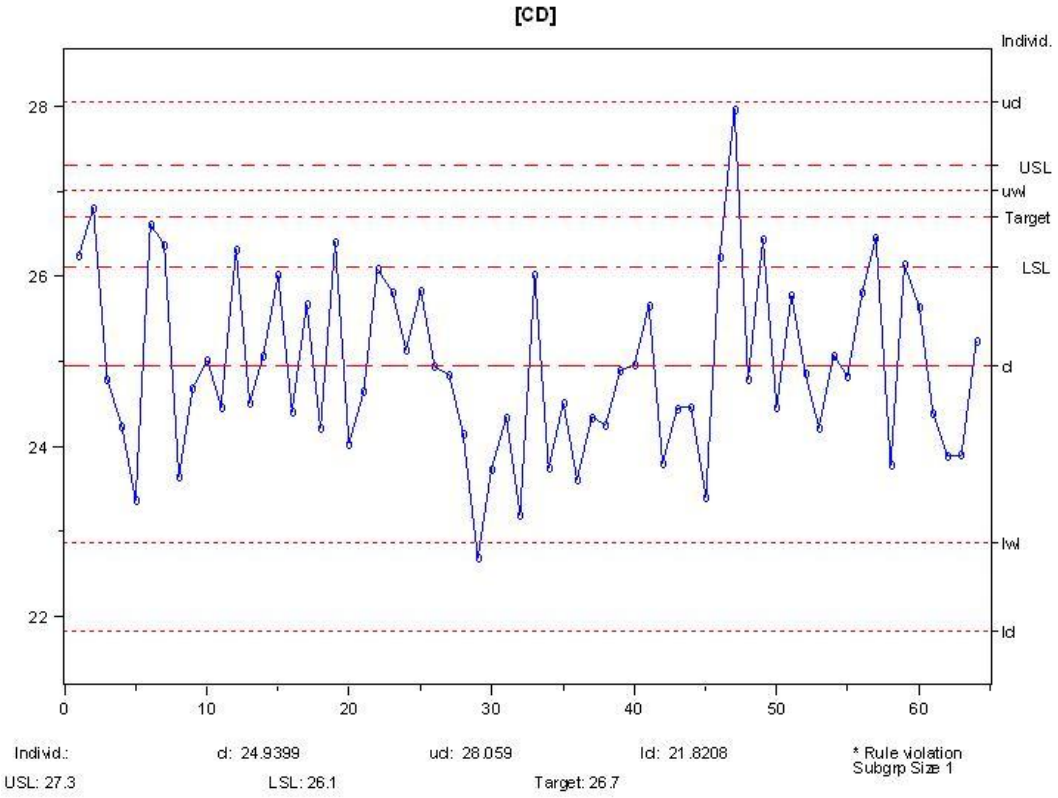


**Figure 6: Shewhart Chart showing the inter-batch variation of determined Cd from the TORT-2 (Lobster hepatopancreas) certified reference material. Where: Target = certified value in mg/kg; cl = control limit (average of all CRM results for Cd); lwl/uwl = lower/upper warning limit (defined as ± 2 standard deviations); lcl/ucl = lower/upper control limit (defined as ± 3 standard deviations).**

### *3.6 Cadmium levels hepatopancreas and other edible organs tissues*

Six sub-samples from each bulked tissue were analysed for Cd and other trace elements (arsenic, chromium, copper, iron, lead, manganese, mercury, nickel, selenium and zinc). The individual results and summary statistics are tabulated in Table 1.

**Table 1: Cadmium concentrations in bulked crab hepatopancreas**

| Laboratory Sample Number | Sample Description | Trace and heavy metal concentration (mg/kg w.w.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cr | Ni | Cu | Zn | As | Cd | Pb | Se | Mn | Fe | Hg |
| 2013/00475/01 | Heppatopancreas 1 | 0.10 | 0.46 | 46 | 17 | 15 | 4.2 | 0.02 | 2.2 | 4.6 | 47 | 0.10 |
| 2013/00475/02 | Heppatopancreas 2 | 0.10 | 0.46 | 46 | 19 | 15 | 4.1 | 0.02 | 2.2 | 5.0 | 51 | 0.10 |
| 2013/00475/03 | Heppatopancreas 3 | 0.11 | 0.46 | 45 | 18 | 15 | 4.1 | 0.02 | 2.1 | 4.8 | 48 | 0.11 |
| 2013/00475/04 | Heppatopancreas 4 | 0.09 | 0.41 | 41 | 17 | 13 | 3.7 | 0.02 | 1.9 | 4.5 | 45 | 0.09 |
| 2013/00475/05 | Heppatopancreas 5 | 0.10 | 0.43 | 42 | 19 | 14 | 3.9 | 0.02 | 2.0 | 5.0 | 51 | 0.10 |
| 2013/00475/06 | Heppatopancreas 6 | 0.12 | 0.45 | 44 | 18 | 14 | 4.0 | 0.02 | 2.1 | 4.8 | 49 | 0.10 |
| | Mean | 0.10 | 0.44 | 44 | 18 | 14 | 4.0 | 0.02 | 2.1 | 4.8 | 48.4 | 0.10 |
| | SD | 0.01 | 0.02 | 2.16 | 0.73 | 0.76 | 0.18 | 0.002 | 0.11 | 0.22 | 2.30 | 0.00 |
| | %RSD | 7.8 | 4.9 | 4.9 | 4.1 | 5.3 | 4.5 | 6.7 | 5.4 | 4.5 | 4.8 | 4.4 |

**Table 2: Cadmium concentrations in bulked edible organs from the cephalothorax, not including the hepatopancreas**

| Laboratory Sample Number | Sample Description | Trace and heavy metal concentration (mg/kg w.w.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cr | Ni | Cu | Zn | As | Cd | Pb | Se | Mn | Fe | Hg |
| 2013/00476/01 | Other Edible Organs 1 | 0.03 | 0.05 | 16 | 30 | 12 | 0.28 | 0.02 | 1.4 | 1.0 | 8.2 | 0.03 |
| 2013/00476/02 | Other Edible Organs 2 | 0.03 | 0.06 | 17 | 31 | 13 | 0.29 | 0.02 | 1.5 | 1.1 | 8.8 | 0.03 |
| 2013/00476/03 | Other Edible Organs 3 | 0.02 | 0.05 | 16 | 30 | 12 | 0.28 | 0.02 | 1.4 | 1.0 | 8.4 | 0.02 |
| 2013/00476/04 | Other Edible Organs 4 | 0.10 | 0.05 | 16 | 29 | 12 | 0.27 | 0.02 | 1.4 | 1.0 | 8.5 | 0.02 |
| 2013/00476/05 | Other Edible Organs 5 | 0.02 | 0.05 | 16 | 29 | 12 | 0.27 | 0.02 | 1.4 | 1.0 | 8.1 | 0.02 |
| 2013/00476/06 | Other Edible Organs 6 | 0.03 | 0.05 | 14 | 27 | 11 | 0.24 | 0.02 | 1.2 | 1.0 | 7.6 | 0.02 |
| | Mean | 0.03* | 0.05 | 15.7 | 29.4 | 11.9 | 0.27 | 0.02 | 1.37 | 1.02 | 8.27 | 0.03 |
| | SD | 0.005* | 0.002 | 0.90 | 1.35 | 0.77 | 0.02 | 0.001 | 0.07 | 0.04 | 0.43 | 0.004 |
| | %RSD | 16* | 4.1 | 5.7 | 4.6 | 6.5 | 6.3 | 4.5 | 5.4 | 3.8 | 5.1 | 16.9 |

*Key =*not including outlier of 2013/00476/04 due to possible Cr contamination*

# 4 Conclusions

A total of fifty six crabs were successfully dissected for the extraction of the hepatopancreas and all other edible organs from the cephalothorax. The respective tissue groups from the fifty six crabs were bulked and homogenised. Six sub-samples from each bulked tissue group were analysed for cadmium and a suite of other trace elements.

Levels of Cd were found to be significantly higher in the crab hepatopancreas than in other edible organs, with a Cd mean concentrations of 4.0mg/kg w.w. and 0.27mg/kg w.w., respectively.

# 5 Acknowledgments

The authors would like to thank Andy Lawler and Derek Eaton for their helpful contributions towards the dissection and tagging of the crabs, Calum Hurley and Matthew Eade for providing the tank facilities, Simon Buckhavens for the rental of the Crustastun™ single stunner, Boby Thomas, Lee Warford and Malgorzata Wilczynska for the analytical work.

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# 7 Appendices

Appendix 1 Crab details as receipted at the Cefas Lowestoft laboratory

Appendix 2 Crab individual measurements

# Appendix 1. Crab details as receipted at the Cefas Lowestoft laboratory

| Crab number | Tag Number | Location | Date in Tank | Date of removal for dissection | Observation on receipt | Tank Number | Sex | Length (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | EO04 2583 | Fraserburgh | 27/02/2013 | 28/02/2013 | 2 legs missing | 2 | F | 167 |
| 2 | EO04 2584 | Fraserburgh | n/a | 27/02/2013 | recently deceased | n/a | M | 162 |
| 3 | EO04 2586 | Fraserburgh | n/a | 27/02/2013 | recently deceased | n/a | M | 156 |
| 4 | EO04 2588 | Fraserburgh | n/a | 27/02/2013 | recently deceased | n/a | F | 170 |
| 5 | EO04 2589 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 177 |
| 6 | EO04 2590 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 175 |
| 7 | EO04 2591 | Fraserburgh | 27/02/2013 | 27/02/2013 | reactive | 2 | M | 159 |
| 8 | EO04 2592 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | M | 167 |
| 9 | EO04 2593 | Fraserburgh | n/a | 27/02/2013 | recently deceased, 4 legs missing | n/a | M | 150 |
| 10 | EO04 2594 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive, 1 leg missing | 2 | F | 168 |
| 11 | EO04 2595 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive, 1 leg missing | 2 | M | 185 |
| 12 | EO04 2596 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 204 |
| 13 | EO04 2597 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 147 |
| 14 | EO04 2598 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | M | 140 |
| 15 | EO04 2599 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 153 |
| 16 | EO04 2600 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | M | 145 |
| 17 | EO04 2601 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | M | 156 |
| 18 | EO04 2602 | Dorset | 27/02/2013 | 27/02/2013 | reactive | 2 | M | 156 |
| 19 | EO04 2603 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 157 |
| 20 | EO04 2604 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 147 |
| 21 | EO04 2605 | Dorset | 27/02/2013 | 27/02/2013 | reactive | 2 | M | 148 |
| 22 | EO04 2606 | Dorset | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 144 |
| 23 | EO04 2607 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 179 |
| 24 | EO04 2608 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 168 |
| 25 | EO04 2609 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 166 |
| 26 | EO04 2610 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive, 2 legs missing | 3 | F | 153 |
| 27 | EO04 2611 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 164 |
| 28 | EO04 2612 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 161 |
| 29 | EO04 2613 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 152 |
| 30 | EO04 2614 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 168 |
| 31 | EO04 2615 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 150 |
| 32 | EO04 2616 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 161 |
| 33 | EO04 2617 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 168 |
| 34 | EO04 2618 | Cornwall Newlyn | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 159 |
| 35 | EO04 2619 | Aberdeen | n/a | 27/02/2013 | recently deceased | n/a | M | 170 |

| Crab number | Tag Number | Location | Date in Tank | Date of removal for dissection | Observation on receipt | Tank Number | Sex | Length (mm) |
|---|---|---|---|---|---|---|---|---|
| 36 | EO04 2620 | Aberdeen | 27/02/2013 | 27/02/2013 | reactive | 3 | M | 161 |
| 37 | EO04 2621 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 168 |
| 38 | EO04 2622 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive, black hole= disease ? | 3 | M | 144 |
| 39 | EO04 2623 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 148 |
| 40 | EO04 2624 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive, 1 leg missing | 3 | F | 170 |
| 41 | EO04 2625 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive | 3 | F | 177 |
| 42 | EO04 2626 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 170 |
| 43 | EO04 2627 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive, 2 legs missing | 3 | M | 169 |
| 44 | EO04 2628 | Aberdeen | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 174 |
| 45 | EO04 2629 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 159 |
| 46 | EO04 2630 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive, not nicked | 7 | F | 153 |
| 47 | EO04 2631 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive, 1 leg missing | 3 | F | 154 |
| 48 | EO04 2632 | Fraserburgh | n/a | 27/02/2013 | recently deceased, 3 legs missing | n/a | M | 150 |
| 49 | EO04 2633 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 137 |
| 50 | EO04 2634 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 151 |
| 51 | EO04 2635 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive, 1 leg missing | 2 | F | 154 |
| 52 | EO04 2636 | Fraserburgh | 27/02/2013 | 27/02/2013 | reactive but dead at 16h30, frozen | 2 | F | 144 |
| 53 | EO04 2637 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 154 |
| 54 | EO04 2638 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 3 | M | 157 |
| 55 | EO04 2639 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 138 |
| 56 | EO04 2640 | Fraserburgh | 27/02/2013 | 28/02/2013 | reactive | 2 | F | 153 |

# Appendix 2. Crab individual measurements

| Crab number | Tag Number | Location | Sex | Length (mm) | Whole Weight (g) | Hepatopancreas Weight (g) | Other Edible Organs Weight (g) | % brown meat |
|---|---|---|---|---|---|---|---|---|
| 1 | EO04 2583 | Fraserburgh | F | 167 | 661.5 | 70.7 | 29.7 | 15.2 |
| 2 | EO04 2584 | Fraserburgh | M | 162 | 589.1 | 50.8 | 17.6 | 11.6 |
| 3 | EO04 2586 | Fraserburgh | M | 156 | 723 | 40.1 | 24.1 | 8.9 |
| 4 | EO04 2588 | Fraserburgh | F | 170 | 619.8 | 63.8 | 25.3 | 14.4 |
| 5 | EO04 2589 | Fraserburgh | F | 177 | 753 | 81.5 | 35 | 15.5 |
| 6 | EO04 2590 | Fraserburgh | F | 175 | 806.5 | 99.4 | 43.5 | 17.7 |
| 7 | EO04 2591 | Fraserburgh | M | 159 | 725.9 | 47.4 | 24.9 | 10.0 |
| 8 | EO04 2592 | Fraserburgh | M | 167 | 778.4 | 33.1 | 31.9 | 8.4 |
| 9 | EO04 2593 | Fraserburgh | M | 150 | 617.7 | 48.5 | 18.6 | 10.9 |
| 10 | EO04 2594 | Fraserburgh | F | 168 | 644.5 | 76.3 | 38.1 | 17.8 |
| 11 | EO04 2595 | Fraserburgh | M | 185 | 1280.9 | 97.2 | 29 | 9.9 |
| 12 | EO04 2596 | Fraserburgh | F | 204 | 1225 | 124.2 | 60.1 | 15.0 |
| 13 | EO04 2597 | Dorset | F | 147 | 493.9 | 55.8 | 27.4 | 16.8 |
| 14 | EO04 2598 | Dorset | M | 140 | 470 | 46.1 | 20.4 | 14.1 |
| 15 | EO04 2599 | Dorset | F | 153 | 549.2 | 65.1 | 32.3 | 17.7 |
| 16 | EO04 2600 | Dorset | M | 145 | 483.4 | 59.7 | 25.3 | 17.6 |
| 17 | EO04 2601 | Dorset | M | 156 | 614.8 | 71.3 | 30.3 | 16.5 |
| 18 | EO04 2602 | Dorset | M | 156 | 684.6 | 78.7 | 35.2 | 16.6 |
| 19 | EO04 2603 | Dorset | F | 157 | 603.7 | 70.2 | 42.1 | 18.6 |
| 20 | EO04 2604 | Dorset | F | 147 | 515.5 | 93.4 | 54.1 | 28.6 |
| 21 | EO04 2605 | Dorset | M | 148 | 500.8 | 48.7 | 22 | 14.1 |
| 22 | EO04 2606 | Dorset | F | 144 | 465.9 | 49.5 | 33.3 | 17.8 |
| 23 | EO04 2607 | Cornwall Newlyn | F | 179 | 921.1 | 72.2 | 160.7 | 25.3 |
| 24 | EO04 2608 | Cornwall Newlyn | F | 168 | 755.8 | 68.3 | 58.8 | 16.8 |
| 25 | EO04 2609 | Cornwall Newlyn | M | 166 | 858.9 | 47 | 45.5 | 10.8 |
| 26 | EO04 2610 | Cornwall Newlyn | F | 153 | 498.8 | 58.6 | 29.3 | 17.6 |
| 27 | EO04 2611 | Cornwall Newlyn | F | 164 | 675.6 | 75.7 | 46 | 18.0 |
| 28 | EO04 2612 | Cornwall Newlyn | M | 161 | 761.2 | 91.3 | 35.9 | 16.7 |
| 29 | EO04 2613 | Cornwall Newlyn | F | 152 | 506.3 | 66.5 | 29 | 18.9 |
| 30 | EO04 2614 | Cornwall Newlyn | M | 168 | 861.5 | 59.5 | 54.7 | 13.3 |
| 31 | EO04 2615 | Cornwall Newlyn | F | 150 | 575.2 | 45 | 74.5 | 20.8 |
| 32 | EO04 2616 | Cornwall Newlyn | M | 161 | 730 | 87.2 | 38.4 | 17.2 |
| 33 | EO04 2617 | Cornwall Newlyn | M | 168 | 833.8 | 76.9 | 42.3 | 14.3 |
| 34 | EO04 2618 | Cornwall Newlyn | M | 159 | 668.1 | 84.5 | 31.6 | 17.4 |
| 35 | EO04 2619 | Aberdeen | M | 170 | 711.2 | 37.8 | 25 | 8.8 |
| 36 | EO04 2620 | Aberdeen | M | 161 | 725.9 | 54 | 17.3 | 9.8 |

| Crab number | Tag Number | Location | Sex | Length (mm) | Whole Weight (g) | Hepatopancreas Weight (g) | Other Edible Organs Weight (g) | Brown Meat (%) |
|---|---|---|---|---|---|---|---|---|
| 37 | EO04 2621 | Aberdeen | F | 168 | 708.4 | 56.7 | 96.4 | 21.6 |
| 38 | EO04 2622 | Aberdeen | M | 144 | 492.3 | 49.7 | 16.8 | 13.5 |
| 39 | EO04 2623 | Aberdeen | M | 148 | 487.1 | 30.2 | 17 | 9.7 |
| 40 | EO04 2624 | Aberdeen | F | 170 | 616.4 | 58.1 | 31 | 14.5 |
| 41 | EO04 2625 | Aberdeen | F | 177 | 776.4 | 68.5 | 38.4 | 13.8 |
| 42 | EO04 2626 | Aberdeen | M | 170 | 819 | 60.6 | 35.9 | 11.8 |
| 43 | EO04 2627 | Aberdeen | M | 169 | 792.9 | 33.2 | 30.5 | 8.0 |
| 44 | EO04 2628 | Aberdeen | M | 174 | 925.4 | 67.3 | 32.4 | 10.8 |
| 45 | EO04 2629 | Fraserburgh | M | 159 | 730 | 62.4 | 26.7 | 12.2 |
| 46 | EO04 2630 | Fraserburgh | F | 153 | 554.1 | 57.5 | 34.5 | 16.6 |
| 47 | EO04 2631 | Fraserburgh | F | 154 | 498.2 | 54.7 | 35.6 | 18.1 |
| 48 | EO04 2632 | Fraserburgh | M | 150 | 498.6 | 43 | 16 | 11.8 |
| 49 | EO04 2633 | Fraserburgh | M | 137 | 500.5 | 39.2 | 17.6 | 11.3 |
| 50 | EO04 2634 | Fraserburgh | M | 151 | 556.5 | 35.6 | 17.8 | 9.6 |
| 51 | EO04 2635 | Fraserburgh | F | 154 | 549.4 | 61.7 | 28.9 | 16.5 |
| 52 | EO04 2636 | Fraserburgh | F | 144 | 450.2 | 49.7 | 24.2 | 16.4 |
| 53 | EO04 2637 | Fraserburgh | M | 154 | 695.8 | 66.4 | 37 | 14.9 |
| 54 | EO04 2638 | Fraserburgh | M | 157 | 668.2 | 45.6 | 24.1 | 10.4 |
| 55 | EO04 2639 | Fraserburgh | F | 138 | 412.9 | 55.5 | 22.3 | 18.8 |
| 56 | EO04 2640 | Fraserburgh | F | 153 | 572.8 | 69.4 | 25.8 | 16.6 |

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**Head office**
**Centre for Environment,**
**Fisheries & Aquaculture Science**
**Pakefield Road, Lowestoft,**
**Suffolk NR33 0HT UK**

**Tel** **+44 (0) 1502 56 2244**
**Fax** **+44 (0) 1502 51 3865**
**Web** **www.cefas.co.uk**

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