Baseline Study of Metals in Selected Local Market Fishes and Invertebrates from the Western Huon Gulf, PNG

Final Report

Prepared for Wafi-Golpu Joint Venture (WGJV)

Neira Marine Sciences Consulting (Marscco)
December 2020

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by

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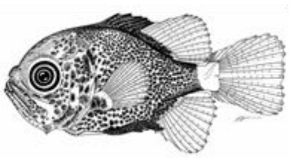

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Baseline Study of Metals in Selected Local Market Fishes and Invertebrates from the Western Huon Gulf, PNG

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EXECUTIVE SUMMARY

Background

Wafi-Golpu Joint Venture (hereafter "WGJV") proposes to implement a deep-sea tailings placement (DSTP) system to manage tailings generated from an underground copper-gold mine at Mt Golpu. The mine is located approximately 65 kilometres (km) south-west of Lae in the Morobe Province in Papua New Guinea (PNG), with a deep seabed area of the Markham Canyon in the western Huon Gulf being identified as the most suitable area for the DSTP outfall and tailings placement. The Environmental Impact Statement (EIS) commissioned by WGJV was submitted to the Conservation and Environment Protection Agency (CEPA) of Papua New Guinea on 25 June 2018.

The EIS included a comprehensive baseline study of metal concentrations in fishes of the western Huon Gulf as a first step toward assembling a scientifically robust database to compare against future monitoring of fishes and other fauna. The EIS baseline study was carried out in November 2016 and May 2017 by Neira Marine Sciences Consulting ("Marscco") for Coffey Environments (a Tetra Tech Company) as part of a deep-slope and pelagic fish characterisation study to inform the EIS. The EIS baseline study included fishes directly caught in both the predicted DSTP deep water canyon receiving environment and in the western Huon Gulf coastal reference area (see Figure 1 for locations), as well as a small number of fishes (n = 12) caught by the local artisanal fishery in the western costal Huon Gulf and sold in local fish markets in Lae for human consumption.

The WGJV has conducted extensive consultation with coastal communities regarding the scientific studies presented in the EIS to support DSTP as the safest and most environmentally and socially responsible tailings management solution for the Wafi-Golpu Project. Ongoing WGJV oceanographic studies conducted since October 2016 continue to validate the conservative (50% safety factor) design of the DSTP outfall at a depth of approximately 200 m and confirm the continued absence of ocean upwelling in the intended DSTP area. The EIS studies have since predicted that there would be no effect on the coastal environment, productivity of upper surface waters or community health, or fisheries activities which typically occur at depths of less than 100 m.

Despite the extensive consultation carried out by the WGJV, local coastal communities have expressed their concern over potential impacts on their artisanal fishery and have requested that the WGJV demonstrate that fish species typically captured for human consumption remain safe to eat in the long term. Accordingly, the WGJV has responded to this community feedback by expanding the artisanal fishery studies to extend the baseline dataset to continue to demonstrate the EIS prediction that coastal fishery resources will not be negatively impacted and that there is no risk to public health from the consumption of coastal fishes.

In March 2019, the WGJV commissioned Marscco to undertake a second baseline study focused on metal levels in representative species of fishes and invertebrates caught by the local coastal artisanal fishery and sold at the local fish markets in Lae for human consumption. This report describes findings of this baseline study based on the market fish survey carried out by Marscco during the period between 6 and 11 May 2019.

Objectives

The primary objective of this study was to further describe the baseline levels of selected metals in fish and invertebrate species caught by the local coastal artisanal fishery in the western Huon Gulf outside the predicted DSTP outfall and tailings placement area, and which are sold for human consumption by the local community at markets in Lae. Main objectives of this study were to:

(a) assess natural variability in baseline levels of metal concentrations in fishes and invertebrates typically consumed by the local coastal communities;

(b) examine how baseline metal levels in fishes and invertebrates tested compare with general food quality guidelines recommended by Food Standards Australia New Zealand (FSANZ), noting that PNG does not have such guidelines; and

(c) further validate findings from the initial market fish baseline study undertaken in November 2016 for the WGJV EIS.

Methodology

Source of fish samples

Fish samples for this baseline study originated from coastal waters <100 m deep between Labu Tale and Lae in the western Huon Gulf, including Labu Lakes, and were sourced directly from the local coastal artisanal fishers at the DCA Point fish market in Lae. This region of the western Huon Gulf is located well outside the predicted tailings footprint and corresponds to the "reference" area where both market and actively caught fishes originated for the initial DSTP baseline study completed in November 2016 and reported in the EIS (Coffey/Marscco, 2018). No fish samples were sourced from the area predicted for the DSTP outfall and tailing placement since no artisanal fishing takes place in that area due to depth of the water column (>100 m) and lack of seabed rocky reef structures that support fish species typically targeted for human consumption.

Selection criteria and sampling of selected fish species

Criteria for selection of fish species comprised (1) frequency of occurrence, i.e., most common species caught by the local coastal artisanal fishing fleet in the western Huon Gulf and sold for human consumption in local markets; and (2) adequate coverage of a range of habitats and distribution, i.e., samples of reef-associated and/or sand-associated, demersal and/or benthic species that can considered as representatives of the western Huon Gulf area. No pelagic migratory species were examined during this study as these species move significant distances between oceanic and PNG coastal regions, and hence cannot be regarded as true representatives of the present baseline study area for the purpose of metal analysis. However, future baseline metal studies will include selected apex predator species such as mackerel tuna and Spanish mackerel (Family Scombridae) which may be sold at the Lae fish markets.

A total of 56 specimens of 14 bony fish species from seven families were examined for this study; 46 fish specimens came from the western Huon Gulf offshore of Labu Lakes and the remaining 9 came from Labu Lakes, an open coastal estuary-like system that supports an important local fishery. Fish tissue samples were collected from four species of threadfin breams (Family Nemipteridae), three species of tropical snappers (Family Lutjanidae), three species of trevallies (Family Carangidae), and one species each from four families comprising a grouper (Family Serranidae), a conger eel (Family Muraenesocidae), a gudgeon (Family Eleotridae) and a mullet (Family Mugilidae). The six most abundant species tested were saddletail snapper (n = 11), teardrop threadfin bream (n = 9), Malabar trevally (n = 6), yellowbelly threadfin bream (n = 6), mangrove jack from Labu Lakes (n = 5), and common pike conger (n = 4). Of these, two species tested during this study were also tested for metals in the November 2016 EIS study, i.e., saddletail snapper (n = 5) and mangrove jack (n = 2) (Coffey/Marscco, 2018).

Metal analysis of fish tissue samples

A total of 108 samples of muscle and liver tissues were removed from the 56 fish specimens dissected for subsequent metal testing. Liver samples could not be collected in a few fish specimens as these had either already been gutted prior to being sold or there was insufficient liver tissue available for metal analysis.

Metal analyses were carried out by Australian Laboratory Services Pty Ltd, NSW (ALS Sydney-Environmental), and comprised the following nine metals and respective Limits of Reporting (LOR; mg kg^{-1} wet weight; ww): Arsenic (As, 0.05); Cadmium (Cd, 0.01); Chromium (0.05); Copper (Cu, 0.10); Mercury (Hg, 0.01); Lead (Pb, 0.05); Nickel (Ni, 0.05); Selenium (Se, 0.05); and Zinc (Zn, 0.5). The accuracy of tissue metal analysis was tested with blanks and a certified reference material (fish protein).

Invertebrates

In addition to fishes, this baseline study included 13 giant mud crabs (Family Portunidae) and 12 mangrove mud clams (Family Lucinidae), which were sourced from the nearby Labu Lakes and tested for the same suite of metals as in fishes. In all, 26 samples were obtained from all mud crabs examined consisting of muscle from the left cheliped (propodus, carpus and merus) and hepatopancreas (digestive gland), while each mangrove mud clam was tested whole, i.e., soft tissues, after removal from respective individual shells.

Comparison with FSANZ standards and guidelines

In the absence of human health standards or guidelines for metal concentrations in marine produce in PNG (fish, crustaceans, molluscs), metal concentrations in fish and invertebrate samples reported in this study were compared against the recommended guidelines of the joint Food Standard Australian and New Zealand (FSANZ) in order to place baseline metal concentration results in context. The FSANZ guidelines include maximum limits and means under the FSANZ Standard 1.4.1 (FSANZ, 2016), and 90th percentile concentrations under the FSANZ Generally Expected Levels (GELs) for metal contaminants (FSANZ, 2001). These guidelines are considered the most suitable for marine produce in PNG and were applied during the initial WGJV EIS as well as other metal fish surveys elsewhere in PNG (Coffey/Marscco, 2018).

No FSANZ Standard or FSANZ GELs are available for Cd, Cr or Ni for fishes. While guidelines for various metals in marine produce are available for various regions and/or countries elsewhere in the world (e.g., MFR, 1985 in Hossen *et al*., 2015; EC, 2006; FAO/WHO, 1984, 2011a, b; PCR, 2012; US Environmental Protection Agency), these were not consulted during this baseline study in order to maintain consistency with the EIS approach and other metal fish surveys carried out elsewhere in PNG (Coffey/Marscco, 2018). Therefore, comparisons of metal concentrations in fish and invertebrate samples with food standards and guidelines in this baseline study were limited to FSANZ Standard maximum limits and means and FSANZ GELs 90th percentile concentrations.

The FSANZ Standard and FSANZ GELs are only applicable to metal concentrations in muscle tissue of fishes as the limits apply to the portion of food that is typically consumed by the local community, i.e., fish flesh. Therefore, no comparisons of metal concentrations in fish livers with FSANZ standards or guidelines are reported herein since fish livers are not consumed by the local community. However, testing of metal concentrations in livers of fishes was included during this baseline study given the key function of the liver as a major metal bioaccumulation organ and therefore useful to identify long-term changes in metal concentrations over time.

Key findings

The main findings of this second local artisanal fishery baseline study on metals in selected coastal market fish species and invertebrates from the western Huon Gulf are outlined below.

Market fish species tested

- The 14 species of bony fishes tested for metals during this baseline study are typically caught by the local artisanal fishery in waters of the western Huon Gulf, including Labu Lakes, outside the predicted DSTP deep water canyon receiving environment. All fish species tested are regarded as representatives of the Huon Gulf and therefore suitable for future metal biomonitoring surveys in the region.

Metal concentrations in fish tissues

- Nine metals were tested in muscle tissue samples and livers of 56 specimens from 14 bony fish species sourced for this baseline study. These comprised Arsenic (As); Cadmium (Cd); Chromium (Cr); Copper (Cu); Lead (Pb); Mercury (Hg); Nickel (Ni); Selenium (Se); and Zinc (Zn).
- Metal concentrations in muscle tissues and livers of all 14 fish species tested varied between individuals of the same species (intraspecific variability) as well as across species of the same genus and species from different families (interspecific variability). Variability was significant in some cases, based on large standard deviations (SDs) of means.
- Intraspecific and interspecific variability in metal bioaccumulation is typical of marine fishes occurring in coastal environments elsewhere in PNG, and has been well described in literature pertaining to metals in fishes as highly species-specific, age-and-size specific, and tissue-specific.
- The variability in metal levels observed during this study can be attributed to a range of factors including natural local sources (e.g., continuous sediment loading from rivers discharging into the western Huon Gulf), anthropogenic activities (e.g., port shipping, existing wastewater discharges from Lae), and contaminated sediment from existing mines and small-scale mining operations in the Markham river catchment.
- Overall, higher metal concentrations were detected in livers than in muscle tissues of almost all fish species tested during this baseline study, particularly for essential metals Cu and Zn.
- Higher concentrations of metals in fish livers compared to muscle tissues were also described in the initial baseline survey of market fishes from the western Huon Gulf tested to inform the EIS, and have been reported in baseline surveys of wild-caught fishes elsewhere in PNG and other localities worldwide.
- Fish livers are not consumed by the local community. However, testing of metal concentrations in fish livers is being included in baseline monitoring surveys for comparison with future post-DSTP surveys as the liver is a major site of metal bioaccumulation and hence useful in biomonitoring metal changes over time.

- Of the nine metals tested, Cr, Cd, Ni and Pb in muscle tissues of most fish species tested were detected in exceptionally low concentrations or were undetectable, i.e., below the Limit of Reporting (<LOR). Similarly, Cu, Se and Hg were present in low concentrations in muscle tissues of most fish species tested.
- Arsenic (measured as total As) and Zn were detected in much higher concentrations than all other metals in muscle tissue of all fish species tested, with highest As and Zn levels recorded in muscle tissues of a sunbeam snapper (Family Lutjanidae) and a common pike conger (Family Muraenesocidae), respectively.

Comparisons with FSANZ Standard and FSANZ GELs

- Concentrations of metals in muscle tissues from all fish species tested were checked against the recommended guidelines for metal contaminants in marine produce listed by the FSANZ Standard and the FSANZ GELs.
- No FSANZ Standard or FSANZ GELs are available for Cd, Cr or Ni for fishes.
- Comparisons of metal concentration against FSANZ Standard and FSANZ GELs were restricted to muscle tissues as limits and guidelines only apply to the edible portion of food that is typically consumed by the local community., i.e., fish flesh. No comparisons of metal concentrations in fish livers with FSANZ standards or guidelines are reported herein since fish livers are not consumed by the local community.
- The FSANZ Standard for As pertains to inorganic As, and not to total As as measured in metal analysis. Therefore, to compare As levels with the FSANZ Standard, total As concentrations detected in fish species during this baseline study were converted to inorganic As using a conservative ratio of 0.042 (i.e., 4.2% of total As) derived from published laboratory work on several marine fish species independent to this study.
- Mean concentrations of inorganic As in muscle tissues of all fish species did not exceed the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for fishes.
- The maximum estimated inorganic As concentration of 3.79 mg kg^{-1} in muscle tissue of a common pike conger, corresponding to a total As of 90.20 mg kg^{-1}, slightly exceeded the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for fishes.
- Arsenic in fish muscles is mostly present as the non-toxic compound arsenobetaine. Therefore, based on the low levels of inorganic As estimated in muscle tissues during this baseline study, no adverse health issues would be expected to manifest in the local community from the consumption of muscle (flesh) from fish species tested.
- Concentrations of Pb in muscle tissues of almost all fish species were undetectable (<LOR of 0.05 mg kg^{-1}) and did not exceed the FSANZ Standard of 0.5 mg kg^{-1} for Pb listed for fishes. Therefore, Pb concentrations detected during this study are not expected to pose a risk to public health from the consumption of muscle (flesh) from fish species tested.
- Mean Hg concentrations in muscle tissues in all fish species did not exceed either the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum limit of 1.0 mg kg^{-1} for Hg listed for fish. Therefore, Hg

concentrations detected during this study are not expected to pose a risk to public health from the consumption of muscle (flesh) from fish species tested.

- Maximum Hg concentrations detected in muscle tissues did not exceed the recommended FSANZ GELs 90th percentile concentration of 2.0 mg kg^{-1} listed for fish and were therefore within the range of generally expected levels.
- Mean and maximum Cu concentrations in muscle tissues of all fish species did not exceed the FSANZ GELs 90th percentile concentration of 2.0 mg kg^{-1} for Cu listed for fishes and were therefore within the range of generally expected levels.
- Concentrations of Se detected in muscle tissues of all fish species did not exceed the FSANZ GELs 90th percentile concentration of 2.0 mg kg^{-1} for Se listed for fishes and were therefore within the range of generally expected levels.
- Maximum Zn concentrations detected in muscle tissues of eight of the 14 fish species tested exceeded the FSANZ GELs 90th percentile concentration of 15.0 mg kg^{-1} and were therefore outside the range of generally expected levels. Exceedances in maximum Zn concentrations were found in teardrop threadfin bream (16.0 mg kg^{-1}), yellowbelly threadfin bream (17.8 mg kg^{-1}), common pike conger (17.9 mg kg^{-1}), saddletail snapper (20.0 mg kg^{-1}) and sunbeam snapper (26.20 mg kg^{-1}).
- Zinc is an essential metal required for various biochemical and physiological functions, including as a component of metalloenzymes and as a catalyst for regulating activity of many zinc-dependent enzymes. Given the key role of Zn in diverse metabolic body functions, the elevated maximum Zn concentrations detected in some fish species during this study are not expected to pose a risk to local community health from the consumption of muscle (flesh) from the species tested.
- Concentrations of Cd (LOR of 0.01 mg kg^{-1}) and Ni (LOR of 0.05 mg kg^{-1}) were undetectable in muscle tissues of almost all fish species tested, while Cr was detected at very low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1}) in muscle tissues of all species except Malabar trevally, which returned a maximum muscle concentration of 4.77 mg kg^{-1}.

Comparisons with previous baseline market fish survey reported in the WGJV EIS

- Concentrations of Zn detected in muscle tissues from mangrove jack (Family Lutjanidae) were significantly higher in this study than those obtained in muscle tissues of this species during the initial baseline survey carried out in November 2016 to inform the EIS, i.e., 14.0-17.30 mg kg^{-1} in May 2019 (this study) vs. 2.60-2.80 mg kg^{-1} in 2016 (EIS survey).
- The higher Zn concentrations detected in mangrove jack during this study can be attributed to natural between-year variability from bioaccumulation and/or biomagnification. However, sampling location is likely a major contributing factor since all mangrove jack tested during this study (n=5) originated from Labu Lakes, where food prey and exposure to enriched, suspended sediment-bound metals in brackish habitats could account for the higher Zn levels, whereas the mangrove jack tested in 2016 (n=2) were fished from coastal marine waters in the western Huon Gulf well outside Labu Lakes.

Metal concentrations in giant mud crab tissues

- Metal testing of the left cheliped muscle and hepatopancreas (digestive gland) was carried out on a single species of giant mud crab sourced from Labu Lakes. Key findings below focus only on muscle tissue as the edible part of boiled mud crabs consumed by the local coastal community.
- No FSANZ Standard or FSANZ GELs are available for Cd, Cr, Pb or Ni for crustaceans.
- The maximum estimated inorganic As concentration of 0.05 mg kg^{-1} in the left cheliped muscle of mud crabs, corresponding to a total As of 1.28 mg kg^{-1}, did not exceed the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for crustaceans. Therefore, inorganic As concentrations estimated in cheliped muscle of mud crabs during this study are not expected to pose a risk to public health from consumption of meat from Labu Lakes mud crabs.
- Concentrations of Hg detected in cheliped muscle of mud crabs did not exceed either the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum limit of 1.0 mg kg^{-1} for Hg listed for crustaceans. Therefore, Hg concentrations detected in cheliped muscle of mud crabs during this study are not expected to pose a risk to public health from consumption of meat from Labu Lakes mud crabs.
- Concentrations of Cu detected in cheliped muscle of all mud crabs (maximum of 13.70 mg kg^{-1}) did not exceed the FSANZ GELs 90^{th} percentile concentration of 20.0 mg kg^{-1} for Cu listed for crustaceans, and were therefore within the range of generally expected levels.
- Concentrations of Se detected in cheliped muscle of all mud crabs (maximum of 0.75 mg kg^{-1}) did not exceed the FSANZ GELs 90^{th} percentile concentration of 1.0 mg kg^{-1} for Se listed for crustaceans, and were therefore within the range of generally expected levels.
- Concentrations of Zn detected in cheliped muscle of all mud crabs (maximum of 121.00 mg kg^{-1}) greatly exceeded the FSANZ GELs 90^{th} percentile concentration of 40.0 mg kg^{-1} for Zn listed for crustaceans, and were therefore well outside the range of generally expected levels.
- The elevated Zn concentrations in cheliped muscle (and hepatopancreas) can be associated to the burrowing behavior of mud crabs in muddy sediments typical of mangrove areas within Labu Lakes, as well as ingestion of enriched particulate matter while mobilising sediments during feeding.
- Elevated Zn concentrations have been found in the same species of edible giant mud crab (*Scylla serrata*) from other estuarine/coastal environments worldwide and have reported to cause no adverse health risks to shellfish consumers in those locations. Given the key role of Zn in diverse metabolic body functions, the elevated concentrations of Zn detected during this study are not expected to pose a risk to public health from consumption of meat from Labu Lakes mud crabs.
- Lead (Pb) in cheliped muscle was undetectable (<LOR of 0.05 mg kg^{-1}) in all mud crabs tested.
- Concentrations of Cd in cheliped muscle of mud crabs were largely undetectable (<LOR of 0.01 mg kg^{-1} in 11 of 13 samples).
- Overall Cr and Ni concentrations detected in cheliped muscle of mud crabs were very low, and were undetectable (<LOR of 0.05 mg kg^{-1}) in most of the 13 samples, i.e., five for Cr and 11 for Ni; maximum concentrations of Cr and Ni were 0.44 mg kg^{-1} and 0.39 mg kg^{-1}, respectively.

Metal concentrations in mangrove mud clams

- Metal testing of soft tissues was carried out on a single species of mangrove mud clam (whole animal) sourced from Labu Lakes.
- No FSANZ Standard or FSANZ GELs are available for Cr, Ni or Zn for molluscs.
- The maximum estimated concentration of inorganic As of 0.04 mg kg^{-1} in mud clams, corresponding to a total As of 0.99 mg kg^{-1}, did not exceed the FSANZ Standard maximum limit of 1.0 mg kg^{-1} for inorganic As listed for molluscs. Therefore, inorganic As concentrations are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
- The maximum Cd concentration of 0.07 mg kg^{-1} detected in mud clams did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Cd listed for molluscs. Therefore, Cd concentrations are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
- Concentrations of Hg detected in mud clams did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum limit of 1.0 mg kg^{-1} for Hg listed for molluscs. Therefore, Hg concentrations are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
- The maximum Pb concentration of 0.24 mg kg^{-1} detected in mud clams did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Pb listed for molluscs. Therefore, Pb concentrations are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
- Concentrations of Cu detected in mud clams (maximum of 13.8 mg kg^{-1}) did not exceed the FSANZ GEL 90th percentile concentration of 30.0 mg kg^{-1} for Cu listed for molluscs, and were therefore within the range of generally expected levels.
- Concentrations of Se detected in mud crabs (maximum of 0.65 mg kg^{-1}) did not exceed the FSANZ GEL 90th percentile concentration of 1.0 mg kg^{-1} for Se listed for molluscs, and were therefore within the range of generally expected levels.
- Chromium (Cr) in mud clams was detected at low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1}; the maximum Cr concentration detected was 1.16 mg kg^{-1}.
- Nickel (Ni) and Zn were detected in all 13 mud clams, with concentrations of 0.16-1.18 mg kg^{-1} for Ni (mean of 0.51 mg kg^{-1}), and 16.30-68.90 mg kg^{-1} for Zn (mean of 41.57 mg kg^{-1}).

1 INTRODUCTION

1.1 Background

Wafi-Golpu Joint Venture (hereafter "WGJV") proposes to implement a deep-sea tailings placement (DSTP) system to manage tailings generated from an underground copper-gold mine at Mt Golpu. The mine is located approximately 65 kilometres (km) south-west of Lae in the Morobe Province in Papua New Guinea (PNG), with a deep seabed area of the Markham Canyon in the western Huon Gulf being identified as the most suitable area for the DSTP outfall and tailings placement. The Environmental Impact Statement (EIS) commissioned by WGJV was submitted to the Conservation and Environment Protection Agency (CEPA) of Papua New Guinea on 25 June 2018.

The EIS included a comprehensive baseline study of metal concentrations in fishes of the western Huon Gulf as a first step toward assembling a scientifically robust database to compare against future monitoring of fishes and other fauna. The EIS baseline study was carried out in November 2016 and May 2017 by Neira Marine Sciences Consulting ("Marscco") for Coffey Environments (a Tetra Tech Company) as part of a deep-slope and pelagic fish characterisation study to inform the EIS. The EIS baseline study included fishes directly caught in both the predicted DSTP deep water canyon receiving environment and in the western Huon Gulf coastal reference areas (see Figure 1 for locations), as well as a small number of fishes (n = 12) caught by the local artisanal fishery in the western costal Huon Gulf and sold in local fish markets in Lae for human consumption.

The WGJV has conducted extensive consultation with coastal communities regarding the scientific studies presented in the EIS to support DSTP as the safest and most environmentally and socially responsible tailings management solution for the Wafi-Golpu Project. Ongoing WGJV oceanographic studies conducted since October 2016 continue to validate the conservative (50% safety factor) design of the DSTP outfall at a depth of approximately 200 m and confirm the continued absence of ocean upwelling in the intended DSTP area. The EIS studies have since predicted that there would be no effect on the coastal environment, productivity of surface waters or community health, or fisheries activities which typically occur at depths of less than 100 m.

Despite the extensive consultation carried out by the WGJV, local coastal communities have expressed their concern over potential impacts on their artisanal fishery and have requested that the WGJV demonstrate that fish species typically targeted for human consumption remain safe to eat in the long term. Accordingly, the WGJV has responded to this community feedback by expanding the artisanal fishery studies to extend the baseline dataset to continue to demonstrate the EIS prediction that coastal fishery resources will not be negatively impacted and that there is no risk to public health from the consumption of coastal fishes.

In March 2019, the WGJV commissioned Marscco to undertake a second baseline study focused on metal levels in representative species of fishes and invertebrates caught by the local coastal artisanal fishery and sold at the local fish markets in Lae for human consumption. This report describes findings of this second baseline study based on the market fish survey carried out by Marscco during the period between 6 and 11 May 2019. Results of this study complement findings from the previous metal study of local fishes sold at the DCA Point fish market that were submitted in June 2018 as part of the WGJV Project Feasibility Study and EIS (Coffey/Marscco, 2018; Section 1.2 below).

1.2 Previous market fish studies

The earliest study of metal concentrations in local fishes from the western Huon Gulf was carried out in November 2016 and comprised 14 specimens from five species of bony fishes caught by local artisanal fishers and purchased at the DCA Point fish street market. The survey was undertaken to complement information on species diversity both in the intended DSTP and reference study areas required for the Wafi-Golpu Project Feasibility Study and EIS (Coffey/Marscco, 2018; Appendix P). Species that were examined in November 2016 comprised sharptooth jobfish (*Pristipomoides typus*), saddletail snapper (*Lutjanus malabaricus*) and mangrove jack (*L. argentimaculatus*) from the Family Lutjanidae; and bigeye trevally (*Caranx sexfasciatus*) and pennantfish (*Alectis ciliaris*) from the Family Carangidae. Muscle and liver tissue samples obtained from each of the 14 fishes were analysed by Advanced Analytical Australia (AAA) for total concentrations of 12 metals (mg kg^{-1}) including arsenic (As), cadmium (Cd) and copper (Cu). Results of muscle and liver metal analyses in these species are provided in Table 19 of Section 4.2 (Discussion).

1.3 Scope of work

The primary objective of this study was to further describe the baseline levels of selected metals in fish and invertebrate species caught by the local coastal artisanal fishery in the western Huon Gulf outside the predicted DSTP outfall and tailings placement area, and which are sold for human consumption by the local community at markets in Lae. Specific objectives of this study were to:

1. Identify the main fish species caught by the local artisanal fishery and sold at the DCA Point market in Lae during the survey period, along with information on approximate location of capture and depth where practicable.
2. Assemble a detailed photographic registry of most common fish species sold at the DCA Point market to be used as an identification reference guide to compare with future market surveys.
3. Compare fish species diversity with that described during earlier baseline fish surveys undertaken to inform the WGJV EIS.
4. Record morphological and biological characteristics of fish specimens sourced from the DCA Point market, including length and weight, sex, and reproductive condition.

5. Collect muscle tissue and liver samples from each fish specimen sourced at the DCA Point market, as well as samples from selected invertebrate species from Labu Lakes, and ship samples to a NATA-accredited laboratory in Australia to determine concentrations of selected metals.
6. Analyse pre-DSTP concentrations of metals using appropriate statistical metrics and compare results with data available from previous fish baseline characterisation studies completed in the western Huon Gulf and reported in the EIS, and with the Food Standards Australia and New Zealand guidelines (FSANZ Code).

2 METHODOLOGY

2.1 Fish sample collection

2.1.1 Source of fish samples

All fishes examined for this baseline study originated from coastal waters of the western Huon Gulf between Labu Tale and Lae, including Labu Lakes, and were purchased from artisanal fishers at the DCA Point fish market in Lae (Figure 1; Table 1). Fishes are caught by the local artisanal fishery daily at depths of approximately 100 m or less while sailing their outriggers between the Labu Tale and Lae; a few fish samples also originated from the brackish waters of the shallow Labu Lakes (average depth of 2 m). Exact positions of fishing locations (latitude and longitude coordinates) are unavailable as artisanal fishers lack access to GPS units onboard their outriggers.

No fishing takes place within the predicted DSTP outfall and tailings placement area (see Figure 1) due to the depth of the water column depth (>100 m), lack of deep-water fishing gear and the absence of seabed slope features (i.e., deep rocky reefs) that would support fish species typically targeted for human consumption. The existing fishing practices of the artisanal fleet in the western Huon Gulf are described in Appendix P of the EIS (Coffey/Marscco, 2018).

2.1.2 Selected market fish species

Fifty-six specimens representing 14 species of bony fishes from seven families were examined during the study period, 6 to 11 May 2019 (Table 1). Specimens were sourced from the DCA Point fish market in Lae and directly from Labu Lakes. Information on the locations where fishes were caught in the western Huon Gulf, as well as approximate depth and fishing gear used, was freely provided by individual fishers during the purchasing process and it is regarded as reliable.

2.1.3 Fish identifications

Fishes examined during the study were identified to family and species level using a combination of specific published information on respective families, regional atlases, and the websites Fish Base (www.fishbase.org) and Fishes of Australia (www.fishesofaustralia.net.au). Specific publications consulted included snappers of the Family Lutjanidae (Allen, 1985; Anderson and Allen, 2001), threadfin breams of the Family Nemipteridae (Russell, 1990, 2001), and trevallies of the Family Carangidae (Smith-Vaniz, 1999). Fish regional atlases encompassing PNG in the Indo-Pacific region included those published by Gloerfelt-Tarp and Kailola (1984), Randall *et al*. (1990), Harrison *et al*. (1999) and Allen (2018).

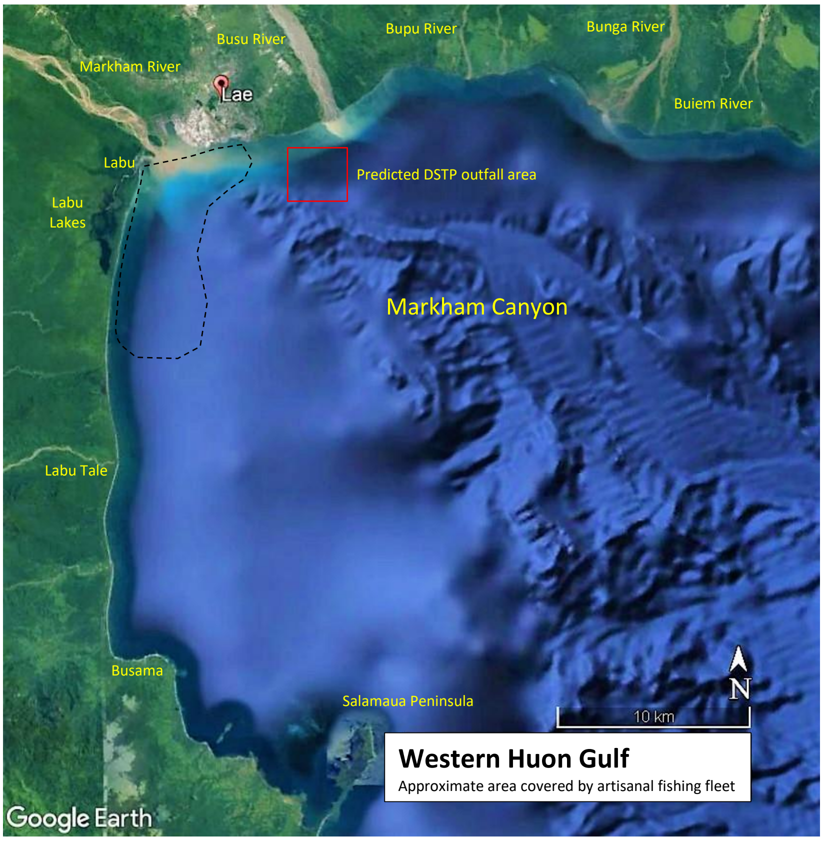

Figure 1. Main area of the western Huon Gulf to the west of Lae fished by the local coastal artisanal fishery, and from where most fishes examined for this study originated (dashed line). Some fish samples and all specimens of giant mud crabs and mangrove mud clams (invertebrates) came from within Labu Lakes.

Short descriptive summaries are provided in Section 3.1 for every fish species examined for this study along with photographs of fresh specimens prior to dissections. Where appropriate, common names employed in descriptions correspond to main English names adopted by the Food and Agriculture Organisation (FAO).

2.1.4 Fish morphological and biological data

Each fish examined was weighed whole (i.e., not gutted) to the nearest gram (g) and measured to the nearest centimetre (cm). Length measured corresponds to total length (TL), i.e., anterior margin of head to end of the tail. Information on total length, weight as well as common name, location of capture and sex of each fish examined during this study is provided in Appendix 1.

Table 1. Summary of fish families and species sampled during this baseline study to determine tissue metal concentrations.

Family	*N*	Common name	Species	Origin	Numbers sampled (n)	Total length (cm)	Total weight (g)
1. Nemipteridae	1	Teardrop threadfin bream	*Nemipterus isacanthus*	Huon Gulf - DCA	9	23.0 – 32.0	113 – 308
	2	Yellowbelly threadfin bream	*Nemipterus bathybius*	Huon Gulf - DCA	6	20.0 – 29.5	79 – 203
	3	Doublewhip threadfin bream	*Nemipterus nematophorus*	Huon Gulf - DCA	2	21.6 – 25.0	85 – 100
	4	Fivelined threadfin bream	*Nemipterus tambuloides*	Huon Gulf - DCA	2	24.7 – 26.0	151 – 172
2. Lutjanidae	5	Saddletail snapper	*Lutjanus malabaricus*	Huon Gulf - DCA	11	25.0 – 67.0	231 – 4,100
	6	Mangrove jack	*Lutjanus argentimaculatus*	Labu Lakes	5	20.4 – 36.0	150 – 770
	7	Sunbeam snapper	*Lutjanus dodecacanthoides*	Huon Gulf - DCA	3	15.1 – 18.0	51 – 91
3. Carangidae	8	Malabar trevally	*Carangoides malabaricus*	Huon Gulf - DCA	6	28.0 – 39.8	318 – 500
	9	Tille trevally	*Caranx tille*	Huon Gulf - DCA	2	29.3 – 32.5	337 – 440
	10	Coastal trevally	*Carangoides coeruleopinnatus*	Huon Gulf - DCA	2	19.5 – 21.0	108 – 150
4. Muraenesocidae	11	Common pike conger	*Muraenesox bagio*	Huon Gulf - DCA	4	87.0 – 101.2	763 – 1,800
5. Serranidae	12	White-dotted grouper	*Epinephelus polystigma*	Labu Lakes	2	31.1 – 37.4	387 – 683
6. Eleotridae	13	Spangled gudgeon	*Ophiocara porocephala*	Labu Lakes	1	29.0	262
7. Mugilidae	14	Squaretail mullet	*Ellochelon vaigiensis*	Labu Lakes	1	25.0	159
				TOTAL	**56**		

Table 2. Summary of invertebrate families and species sampled during this baseline study to determine tissue metal concentrations.

Family	*N*	Common name	Species	Origin	Total Sampled (n)	Carapace width (cm)	Total weight (g)
Portunidae	1	Giant mud crab	*Scylla serrata*	Labu Lakes	13	95 – 128	110.7 – 213.5
Lucinidae	2	Mangrove mud clam (= *kina*)	*Anodontia edentula*	Labu Lakes	12	N/A	N/A
				TOTAL	**25**		

All spines and soft rays of the dorsal (D) and anal (A) fins were counted in each fish examined to aid in taxonomic identifications. Counts provided in species descriptive accounts are based on standard fish taxonomy nomenclature (Cailliet *et al*., 1986), where D and A represent dorsal and anal fins, respectively, and spines and rays are denoted with Roman and Arabic numerals, respectively, e.g., D = X, 11 describes a dorsal fin with 10 spines and 11 soft rays. For species with two separate dorsal fins, counts are given for the first (spiny) dorsal fin plus second dorsal fin, e.g., D = X + I, 9 denotes a first dorsal fin with 10 spines followed by a separate second dorsal fin with one spine (I) and 9 rays.

The sex of each fish examined was determined visually from the body cavity as either females (ovaries) or males (testes). Fishes that could not be sexed were assigned as indeterminate and comprised mostly immature individuals where gonadal development has not yet commenced.

2.1.5 Sampling of fish tissues

Fish dissections were performed at a laboratory-adapted room facilitated by WGJV at the 11 Mile Camp in Lae while maintaining the highest possible hygiene conditions to avoid cross-contamination. Measures of quality assurance to maintain a sterile environment included (a) use of powder-free latex gloves when handling specimens and equipment; (b) carrying out dissections over a clean surface; (c) discarding stainless steel surgical scalpel blades immediately after use on one fish, i.e., single-use only; and (d) using 98% ethanol to sterilize scalpel handles, as well as stainless steel forceps and scissors between dissections.

Samples of muscle tissues (flesh) and whole livers were obtained from all fish specimens examined during the present study, and subsequently tested for selected metals as part of a major ongoing pre-DSTP implementation baseline study to assess natural variability of metal concentrations in fishes and other fauna (Section 2.3). Muscle comprises the edible part of fishes consumed by the local population. In contrast, fish livers are not consumed though the liver is considered as the main organ for metabolic and detoxification functions and hence a site of metal bioaccumulation, e.g., for metals such copper, lead and zinc. The monitoring of metals in liver is thus relevant as it provides information as to what prey fishes consume and what is available in the environment (Agusa *et al*., 2005; Etesin and Benson, 2007; El-Moselhy *et al*., 2014; Alijani *et al*., 2017; Bawuro *et al*., 2018).

Muscle tissue samples between 4.1 g and 54.4 g depending on fish size were removed from the top left side of the anterior trunk region, i.e., above the pectoral fin base. Whole livers from all specimens examined were removed whole for analysis except in specimens which had previously been cleaned to be sold at markets (n = 4), and ranged between 0.2 g and 20.3 g in weight (Appendix 1). All dissections were carried out using sterilised carbon steel surgical blades size 23.

Muscle and liver samples were each weighed to the nearest 0.01 g using a high-precision analytical balance, and then immediately placed individually inside zip-lock plastic bags labelled with specimen number, tissue type and weight, as well as date and site fished, and subsequently stored in a freezer

Fish tissue samples collected during the study were flown frozen on 13 May 2019 from Lae to Brisbane International Airport via Port Moresby. The samples were picked up by a representative from the Australian Laboratory Services Pty Ltd (ALS Global; 'ALS') in Brisbane along with respective Chain of Custody forms, and subsequently posted frozen to the ALS Sydney-Environmental facility, NSW, for metal analysis.

2.1.6 Sampling of fish otoliths

Otoliths (ear bones) were extracted from the otic cavity at the base of the skull of most fishes examined. Otoliths are calcium carbonate structures used to estimate age in fishes, a process which relies on interpreting otoliths' growth structures and counting the annual growth bands which are laid down at different rates throughout the fish's life (Cailliet *et al*., 1986).

Of the three paired otoliths present in fishes, the saggitae are often the largest and therefore the easiest to extract. Each saggitae pair removed from dissected fish species was stored dry in an envelope labelled with sample number, species, location of capture and total length (Appendix 1). Fish ageing was outside the scope of this study; however, fish ageing has been planned for a later stage in the WGJV baseline program as it is relevant to understand age-related changes in metal bioaccumulation[1] and biomagnification[2].

2.2 Sampling of invertebrate species

The two invertebrate species examined for this baseline study originated from within Labu Lakes and were purchased for the study directly from local fishers who confirmed the location source. These comprised 13 freshly caught giant mud crabs (*Scylla serrata*, Family Portunidae) and 12 mangrove mud clams (*Anodontia edentula*, Family Lucinidae) (Table 2). The crabs (Subphylum Crustacea, Class Malacostraca, Oder Decapoda) and clams (Phylum Mollusca, Class Bivalvia) were identified to family and species level following the taxonomic keys of Ng (1998) and Poutiers (1998), respectively. Short descriptions of the crabs and clam species are provided in Section 3.2 and Section 3.3, respectively.

Tissue samples from crabs and clams during this study were handled following the same approach applied to fishes (Section 2.1.5) and subsequently tested for the same 9 metals. Tissues from crabs included the entire muscle from the left cheliped (propodus, carpus and merus), and most of the

[1] Bioaccumulation: Process by which metals are naturally accumulated by aquatic organisms from water directly or through consumption of food containing the metals.
[2] Biomagnification: Process by which tissue concentrations of bioaccumulated metals increase as the metal passes up the food chain or web.

hepatopancreas (digestive gland) (Pinheiro *et al*., 2012). In the case of clams, the whole animal was removed for testing after opening the two valves, i.e., it included digestive and reproductive organs. Cheliped muscle samples and hepatopancreas removed from crabs weighed 0.9-11.7 g and 1.1-6.6 g, respectively (Appendix 2); whole clams (shell and soft tissues) weighed 1.4-10.0 g (Appendix 3).

2.3 Laboratory analysis

Tissue samples obtained from fishes and crabs, along with whole clams, were analysed by the ALS Sydney-Environmental facility, NSW. ALS is a global company regarded as the leading provider of laboratory testing, certification and verification solutions (https://www.alsglobal.com/). Frozen samples were received by ALS Sydney-Environmental on 15 May 2019, and the results of the metal analysis emailed to Marscco on 31 May and 3 June 2019.

2.3.1 Chain of custody

Sample Receipt Notification (SRN) reports provided by ALS Sydney-Environmental are included as Appendices 4 and 5 at the end of this report. These consist of separate outputs corresponding to two sample lots, namely Work Order (WO) # ES1914646 (Appendix 4), which includes fish samples from the western Huon Gulf labelled HG-1-M/L to HG-42-M/L (M – muscle; L – liver); and WO # ES1914661 (Appendix 5), corresponding to fish samples from the western Huon Gulf (HG-43-M/L to HG-47-M/L); fish samples from Labu Lakes (LL-1-M/L to LL-9-M/L); crab samples from Labu Lakes (LL-C-1-M/H to LL-C-13-M/H; M – m muscle; H – hepatopancreas); and clam samples from Labu Lakes (LL-K-1 to LL-K-12; whole animals).

2.3.2 Metal analysis

Muscle tissue and liver samples were analysed for total concentrations (mg kg^{-1} wet weight; ww) of the following metals and metalloids (Table 3): Arsenic (As); Cadmium (Cd); Chromium (Cr); Copper (Cu); Lead (Pb); Mercury (Hg); Nickel (Ni); Selenium (Se); and Zinc (Zn). For convenience, both metals and the two metalloids (i.e., As and Se) are subsequently referred to as 'metals' throughout this report, and all metals concentrations (mg kg^{-1}) refer to wet weight (ww) unless stated otherwise.

Limits of Reporting (LOR in mg kg^{-1} ww) for each metal were: 0.01 for Cd and Hg; 0.05 for As, Cr, Pb, Ni and Se; 0.1 for Cu; and 0.5 for Zn. Results with a *less than* symbol (<) that are higher than a specific LOR may be due to primary sample extract/dilution and/or insufficient sample for analysis (ALS Sydney-Environmental, 2019).

Tissue analysis for all metals except Hg was carried out using inductively coupled plasma mass spectrometry (ICP-MS); Hg analysis was performed using method EG035-LL via Flow Injection Mercury System (FIMS) in order to achieve a LOR of 0.01 mg kg^{-1}. The analytical procedures used by

ALS Sydney-Environmental have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM (ALS Sydney-Environmental Certificate of Analysis emailed to Marscco, May 2019).

2.3.3 Quality assurance and quality control

The quality assurance/quality control (QA/QC) protocol implemented by ALS Sydney-Environmental for metals in fish tissues included certified reference materials (CRM) published by the National Research Council (NRC) of Canada, specifically CRM-DORM – 4: Fish protein certified reference material for trace metals. This rigorous test of the analytical method for determining metals in a fish tissue matrix compares metal analysis results against the CRM-DORM certified values. Results obtained during this study (Appendix 8) fell well within the expected CRM-DORM means and standard deviation ranges for a given metal and are provided in Table 3. Listed CRM-DORM certified values for all metals tested in this study including information on instrumental method used for quantitation, can be found in:

https://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/dorm_4.html

Table 3. CRM-DORM certified quantity values used as reference against analytical results reported by ALS Sydney-Environmental for each of the seven metals and two metalloids analysed during this study.

Metal	Type*	CRM-DORM certified quantity value and range (mass fraction; mg kg^{-1})	ALS analytical result – spike concentration (mg kg^{-1})	Spike recovery (%)
Arsenic (As)	Non-essential metalloid	6.87 ± 0.44	6.80	92.3 - 104.0
Cadmium (Cd)	Non-essential metal	0.29 ± 0.018	0.306	94.0 - 108.0
Chromium (Cr)	Essential metal	1.87 ± 0.18	1.87	74.9 - 85.6
Copper (Cu)	Essential metal	15.7 ± 0.46	15.9	87.8 - 103.0
Lead (Pb)	Non-essential metal	0.40 ± 0.062	-	-
Mercury (Hg)	Non-essential metal	0.41 ± 0.036	0.41	70.6 - 82.9
Nickel (Ni)	Non-essential metal	1.34 ± 0.14	1.36	90.4 - 114.0
Selenium (Se)	Essential metalloid	3.45 ± 0.40	3.56	81.9 - 117.0
Zinc (Zn)	Essential metal	51.6 ± 2.8	52.2	88.8 - 107.0

*Essential" refers to "nutrients required for various specific metabolic (biochemical) and physiological functions, even in minute trace amounts (list based on Tchounwou *et al*., 2012); dash (-) denotes no data.

Results of the rigorous QA/QC applied by ALS Sydney-Environmental in the metal analyses undertaken for this study are included in Appendices 6 through 9 of this report. These comprise QA/QC Compliance Assessment to Assist with Quality Review (Appendices 6 and 7; include Summary of Outliers; Analysis Holding Time Compliance; Quality Control Parameter Frequency Compliance; and Brief Method Summaries); and Quality Control Report (Appendices 8 and 9; include General

Comments; Laboratory Duplicate (DUP) Report; Method Blank (MB) and Laboratory Control Spike (LCS) Report; and Matrix Spike (MS) Report).

As with the SNR reports (Appendices 4-5), Appendices 6-7 and 8-9 correspond to sample lots WO # ES1914646 and WO # ES1914661, respectively (refer to Section 2.3.1 for details of samples included under each WO).

2.4 Statistical metrics

Concentration data obtained for each metal (mg kg^{-1}) are tabled in Section 3.4 (fishes) and Section 3.5 (invertebrates) for each species tested. Summary tables for each metal provide Limit of Reporting (LOR), average (mean), minimum and maximum concentrations, total number of muscle and liver tissues tested in each species (n), standard deviation, and number of tissues which resulted in concentrations below the LOR for the corresponding metal (n<LOR). In addition, median concentrations and 90th percentile values are provided for Cu (fishes, crabs, clams), Hg (fishes), Se (fishes, crabs, clams) and Zn (fishes, crabs) for comparisons against FSANZ GELs (Section 2.5).

2.5 Metals recommended standards/generally expected levels

2.5.1 Food Standards Australia New Zealand (FSANZ)

Concentrations of metals obtained in muscle samples from all fish species analysed during this study, along with tissue samples from the single species of crab (cheliped muscle and hepatopancreas) and clam (whole animal), were compared to the standards specified by the joint Australia New Zealand Food Standards Code under Food Standards Australia New Zealand (FSANZ) Act 1991 (FSANZ Act) for fish, Crustacea (giant mud crabs) and Molluscs (mangrove mud clams). The Standards comprise legislative instruments under the *Legislation Act 2003* while the FSANZ is an independent statutory agency established by the FSANZ Act (https://www.foodstandards.gov.au/code/Pages/default.aspx).

Comparisons of metal concentration in fish livers against the FSANZ Standards were omitted as the guidelines specify that maximum concentration levels only apply to the "*portion of food that is ordinarily consumed*" (FSANZ, 2001, 2016), and hence pertain only to fish muscle tissue (flesh).

The standards include FSANZ Standard 1.4.1: Contaminants and Natural Toxicants: **Schedule 19**: maximum levels of contaminants and natural toxins (FSANZ, 2016), and the *Generally Expected Levels* (GELs) for Metal Contaminants (FSANZ, 2001). **Schedule 19** of the FSANZ Standard 1.4.1 states: (1) The limits prescribed by this Standard apply to the portion of foods that is ordinarily consumed; and (2) In this Standard and Schedule 19, a reference to a particular food is to the food or classes of food as described in **Schedule 22** (https://www.legislation.gov.au/Details/F2016C00167). **Schedule 22** states that the portion of the commodity to which the Maximum Residue Limits (MRLs) apply, and which is analysed, is the whole commodity, including bones and head (generally after removing the digestive tract) in fishes, and the whole commodity after removal of the outer shell of crabs and molluscs, i.e., clams, squid, etc. (https://www.legislation.gov.au/Details/F2015L00433). The MRL is defined as the amount identified in **Schedule 20** of the FSANZ Standard 1.4.2 – Agvet chemicals for the permitted residue of a specific 'agvet chemical' in that food, where 'agvet chemical' means an agricultural chemical product or a veterinary chemical product, within the meaning of the Agvet Code (https://www.legislation.gov.au/Details/F2016C00168).

The FSANZ codes applied during this study have already been used in the (a) deep-slope fish characterisation study for the WGJV EIS (Appendix P; Coffey/Marscco, 2018); (b) assessment of metal bioaccumulation and biomagnification from predicted DSTP subsurface plumes for the WGJV EIS (Appendix N; Tetra Tech Inc., 2018); and (c) several comparable past baseline fish metal studies in PNG (e.g., NSR, 1988, 1996; Coffey, 2012).

Metal concentrations published under the FSANZ Standard 1.4.1 (Schedule 19) and FSANZ GELs are presented in Table 4. The FSANZ GELs correspond to additional guidelines to maximum levels in Standard 1.4.1. However, while GELs are not legally enforceable, they provide a benchmark against which to measure contaminant levels in food and should be considered in conjunction with Standard 1.4.1. For simplicity, in this report the FSANZ Standard 1.4.1 is referred to as 'FSANZ Standard'.

Of the 9 metals analysed during this study, no FSANZ Standard or FSANZ GELs are available for Cr or Ni for crustaceans, molluscs, or fish (Table 4). For fish, however, FSANZ Standard (maximum limits and/or means) are available for As, Pb and Hg, while FSANZ GELs (90th percentiles) are available for Cu, Hg, Se and Zn. In the case of crustaceans and molluscs, FSANZ Standard are available for As and Hg (crustaceans, molluscs) and Pb (molluscs), while FSANZ GELs are available for Cu and Se (crustaceans, molluscs), and Zn (crustaceans) (Table 4).

Concentrations of As, Cu, Pb, Hg, Se and Ze detected in muscle tissues of all fish species tested during this study were compared with the FSANZ Standard and FSANZ GEL guidelines (Table 4) to determine exceedances, if any (Section 3.4.10; Table 15). For this, concentrations of As, Pb and Hg in muscle tissues were compared with maximum limits and means (FSANZ Standard), while concentrations of Cu, Hg, Se and Zn were compared with 90th percentiles (FSANZ GELs). In the case of As, maximum total As concentrations in muscle tissues of all fish species were converted to inorganic As to allow comparison with the FSANZ Standard (refer to Section 2.5.2 below for details).

Concentrations of As and Hg in the left cheliped muscle and hepatopancreas from crabs, as well as concentrations of As, Cd, Pb and Hg in whole clams, were compared against maximum limits listed for these metals under the FSANZ Standard (Table 4); maximum total As concentrations were converted to inorganic As to allow comparison with the FSANZ Standard under the assumption that the same conversion factor applied to fishes could be applied to invertebrate muscles (Section

2.5.2). Concentrations of Cu, Se and Zn in the respective tissues from crabs and whole clams were compared to 90th percentile values under FSANZ GELs (Tables 4). Results are described separately for crabs in Section 3.5.1 and Section 3.5.2, respectively.

Table 4. Summary of Food Standard Australia New Zealand (FSANZ) Standard 1.4.1 for Contaminants and Natural Toxicants, and FSANZ Generally Expected Levels for metal contaminants (FSANZ GELs). Concentrations in mg kg^{-1}.

Metal	FSANZ Standard 1.4.1[a] Maximum limit (mg kg^{-1})	FSANZ GEL[b] 90th percentile (mg kg^{-1})
Arsenic (inorganic)		
Crustacea	2.0	-
Molluscs	1.0	-
Fish	2.0	-
Cadmium		
Molluscs	2.0	-
Chromium	-	-
Copper		
Crustacea	-	20.0
Molluscs	-	30.0
Fish	-	2.0
Lead		
Molluscs	2.0	-
Fish	0.5	-
Mercury [c]		
Fish	-	2.0
Crustacea, molluscs and fish	0.5 (mean)[d] 1.5 (maximum limit)[e] 0.5 (mean)[f] 1.0 (maximum limit)[g]	
Nickel	-	-
Selenium		
Crustacea	-	1.0
Molluscs	-	1.0
Fish	-	2.0
Zinc		
Crustacea	-	40.0
Fish	-	15.0

- denotes no applicable standard or guideline.

[a] Australia New Zealand Food Standards Code - Standard 1.4.1 - Contaminants and Natural Toxicants. Canberra: Commonwealth of Australia. Standards are maximum permitted levels unless noted otherwise, where maximum level (ML) is defined as "*maximum level of a specified contaminant, or specified natural toxicant, which is permitted to be present in a nominated food expressed, unless otherwise specified, in milligrams of the contaminant or the natural toxicant per kilogram of the food (mg kg^{-1})*".

[b] Source: Food Standards Australia New Zealand 2001. Generally Expected Levels (GELs) for Metal Contaminants - Additional guidelines to Maximum levels in Standard 1.4.1 - Contaminants and Natural Toxicants. Guidelines are given for median and 90th percentile values. The guidelines recommend that exceedance of the 90th percentile value should initiate further investigation into the concentration source.

[c] Concentrations based on criteria in Schedule 19-7 (S19-7) of the Australia New Zealand Food Standards Code - Standard 1.4.1 - Contaminants and Natural Toxicants (in place from 1 March 2016). Mean and maximum concentrations levels of mercury in sample units must be no greater than those indicated under FSANZ Standard 1.4.1.

[d, e] Conditions: (i) if 10 or more sample units are available; and (ii) if concentration of mercury in any sample unit is >1.0 mg kg^{-1}.

[f] Condition: if 5 sample units are available.

[g] Condition: if there are insufficient samples to analyse in accordance with subsection S19—7(2) of FSANZ (2016).

2.5.2 Treatment of Arsenic (As) concentration data

Concentrations of As measured in tissue samples during this study correspond to 'total As' which comprises both organic and inorganic As. Organic As in bony fishes is mostly present as arsenobetaine (also known as "fish arsenic"), a compound which is non-toxic and not metabolised, whereas inorganic As comprises a combination of arsenite (As^{+3}) and arsenate (As^{+5}). Organic As predominate in fish tissues and organs while inorganic As occurs as a minor fraction (Ciardullo *et al*., 2010; Sevcikova *et al*., 2011; Taylor *et al*., 2017; Jia *et al*., 2018).

While As concentrations in this study are provided as total As, the FSANZ Standard recommended for fishes, crustaceans and molluscs refer to inorganic As (FSANZ, 2016). Therefore, to allow a direct comparison between total As detected in muscle tissues during this study and the maximum limits specified under the FSANZ Standard (Table 4), a conversion factor was applied to estimate inorganic As from total As values. Laboratory-derived factors (standard ratios) available to convert inorganic As from total As in fish muscle are provided in Table 5. For this study, the mean value of 0.042 (4.2%) reported for inorganic As in marine fishes by Uneyama *et al*. (2007) was selected as the most conservative ratio noting that such factors are however species-specific.

Table 5. Published factors to convert total arsenic to inorganic arsenic (iAs) in fish muscle

Group/species (Family)	No. samples tested	Mean iAs (ratio)	Mean iAs (%)	Reference
Marine fishes	133	0.042	4.2	Uneyama *et al*. (2007)
Marine fishes	170	0.020	2.0	EFSA (2009a)
Sargocentron spp. (Holocentridae)	10	0.0028	0.28	Peshut *et al*. (2008)
Caranx papuensis (Carangidae)	9	0.030	3.0	Peshut *et al*. (2008)
Mugil cephalus (Mugilidae)	3	0.020	2.0	Peshut *et al*. (2008)

3 RESULTS

3.1 Bony fishes (Class Actinopterygii)

A total of 14 species of bony fishes from seven families were dissected to remove muscle samples and livers during this study (Table 1). The six most abundant species tested were saddletail snapper (n = 11), teardrop threadfin bream (n = 9), Malabar trevally (n = 6), yellowbelly threadfin bream (n = 6), mangrove jack from Labu Lakes (n = 5), and common pike conger (n = 4).

Sections 3.1.1 through to 3.1.7 below provide a general description of each of the fish species examined by family, along with notes on their main distinguishing morphological features and geographical distribution.

3.1.1 Family Nemipteridae – Threadfin breams

Nemipterus isacanthus – Teardrop threadfin bream

Figure 2. Teardrop threadfin bream, *Nemipterus isacanthus* (Family Nemipteridae) from Huon Gulf (male 30.5 cm TL; 308 g; top); close-up of tear-shaped yellow patch below eye (bottom).

Nine specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (23.0 cm to 32.0 cm TL, 113 g to 308 g; Figure 2). Diagnostic characters: yellow teardrop-shaped bar below eye, extending obliquely forwards; yellow upper lip; two broad yellow stripes along the lateral surface of the body; two distinct thin yellow lines along the dorsal fin membrane; and bright yellow tip of upper caudal-fin lobe. Fin counts: D = X, 9; A = III, 7. Marine demersal species widely distributed in the Indo-Australian Archipelago at depths of 50-200 m (Russell, 1990, 2001; Allen, 2018).

Nemipterus bathybius – Yellowbelly threadfin bream

Figure 3. Yellowbelly threadfin bream, *Nemipterus bathybius* (Family Nemipteridae) from Huon Gulf (29.5 cm TL; 203 g; top); close-up of wide band of undulating yellow lines along dorsal-fin membrane (bottom).

Six specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (20.0 cm to 29.5 cm TL, 79 g to 203 g; Figure 3). Diagnostic characters: two yellow stripes along the side the body, top stripe under later line and reaching upper caudal-fin base; long pectoral fins reaching almost to level of origin of anal fin; translucent anal fin without yellow stripe; ventral body surface bright yellow from under head to end of caudal peduncle ("yellowbelly"); wide band of undulating yellow lines along dorsal fin membrane; and bright yellow filamentous tip running from upper caudal-fin lobe. Fin counts: D = X, 9; A = III, 7. Tropical marine demersal species in Indo-West Pacific region, recorded in sandy and muddy bottoms to depths of 35-300 m, mostly to 45-90 m (Russell, 1990, 2001; Allen, 2018).

Nemipterus nematophorus – Doublewhip threadfin bream (Family Nemipteridae)

Figure 4. Doublewhip threadfin bream, *Nemipterus nematophorus* (Family Nemipteridae) from Huon Gulf (21.6 cm TL; 85 g).

Two specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (21.6 cm to 25.0 cm TL, 85 g to 100 g; Figure 4). Diagnostic characters: long, bright yellow filament trailing from the first two dorsal-fin spines (these are almost fused); four to five yellow stripes along body sides, under lateral line; long pelvic and pectoral fins reaching to anal-fin origin; single yellow stripe along anal fin membrane; and a long yellow filament trailing from the upper caudal-fin lobe (not always present due to damage). Fin counts: D = X, 9; A = III, 7. Previously known in the Indo-West Pacific region, including the Philippines, South China Sea, Gulf of Thailand and Indonesia; this appears to be the first record of this species in Huon Gulf. Tropical marine demersal species recorded on sand and muddy bottoms to a maximum depth of 75 m (Gloerfelt-Tarp and Kailola, 1984; Russell, 1990, 2001; Allen, 2018).

Nemipterus tambuloides – Fivelined threadfin bream (Family Nemipteridae)

Figure 5. Fivelined threadfin bream, *Nemipterus tambuloides* (Family Nemipteridae) from Huon Gulf (26.0 cm TL; 172 g).

Two specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (24.7 cm to 26.0 cm TL, 151 g to 172 g; Figure 5). Diagnostic characters: five well-defined yellow "sulphur" strips along the side of the body, the top first over the lateral line, the second under and running from the snout through the eye posteriorly to the upper caudal fin; single yellow stripes along membranes of dorsal- and anal-fin bases, one along anal fin bends downwards towards tip of last ray; and a yellow upper caudal-fin lobe that is noticeably longer than the lower lobe (no filament present). Fin counts: D = X, 9; A = III, 7. Previously known in the Indo-West Pacific region, including South China Sea, Gulf of Thailand and Indonesia; this appears to be the first record of this species in the Huon Gulf. Tropical marine demersal species recorded over sandy and muddy bottoms to depths of 50-70 m (Gloerfelt-Tarp and Kailola, 1984; Russell, 1990, 2001).

3.1.2 Family Lutjanidae – Tropical snappers

Lutjanus malabaricus – Saddletail snapper

Figure 6. Saddletail snapper, *Lutjanus malabaricus* (Family Lutjanidae) from Huon Gulf (male 36.0 cm TL; 734 g).

Eleven specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (25.0 cm to 67.0 cm TL, 231 g to 4,100 g; Figure 6). Diagnostic characters: red to orange body, truncate (squarish) caudal fin, and scale rows on back rising obliquely above the lateral line. Fin counts: D = XI, 12-4 (13); A = III, 8-9 (8). Widely distributed throughout the Indo-West-Pacific region; juveniles are usually found in shallow inshore waters while adults inhabit coastal and offshore reefs to depths of 100 m. Maximum recorded size 100 cm TL and 7 kg. Also commonly known as "Malabar blood snapper" (Allen, 1985, 2018; Anderson and Allen, 2001; Bray, 2019).

Lutjanus argentimaculatus – Mangrove jack

Figure 7. Mangrove jack, *Lutjanus argentimaculatus* (Family Lutjanidae) from Labu Lakes (male 36.0 cm TL; 770 g).

Five specimens sourced whole from Labu Lakes (20.4 cm to 36.0 cm TL, 150 g to 770 g; Figure 7). Diagnostic characters: greenish-brown to reddish body; slightly concave caudal fin; and scale rows on back roughly parallel to the lateral line. Fin counts: D = X, 13-14; A = III, 8. Widespread in the Indo-West Pacific region, in estuaries and inshore waters as well as offshore reefs to a depth of 120 m; young and sub-adults are known to occur in estuarine mangrove areas. Maximum recorded size 150 cm TL and 12 kg (Allen, 1985, 2018; Anderson and Allen, 2001; Gomon and Bray, 2019).

Lutjanus dodecacanthoides – Sunbeam snapper

Figure 8. Sunbeam snapper, *Lutjanus dodecacanthoides* (Family Lutjanidae) from Huon Gulf (female 18.0 cm TL; 91 g).

Three specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (15.1 cm to 18.0 cm TL, 51 g to 91 g; Figure 8). Diagnostic characters: reddish upper body with six yellow to orange strips along the sides, the top four sloping posteriorly towards the dorsal-fin base; and a brown patch at the base of the top pectoral-fin rays. Fin counts: D = XII, 12-13; A = III, 8. Previously only known from Indonesia and the Philippines in the Western Pacific; this appears to be the first record of this species in Huon Gulf. Tropical marine reef-associated species recorded to a maximum depth of 30 m (Allen, 1985; Anderson and Allen, 2001).

3.1.3 Family Carangidae – Trevallies

Carangoides malabaricus – Malabar trevally

Figure 9. Malabar trevally, *Carangoides malabaricus* (Family Carangidae) from Huon Gulf (male 33.0 cm TL; 500 g).

Six specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (28.0 cm to 39.8 cm TL, 318 g to 500 g; Figure 9). Diagnostic characters: strongly compressed, ovate body, bluish-grey above and silvery white below; lower head profile gently notched; anterior lateral line arched anteriorly, followed by straight section with 19-36 weak scutes (sharp scales) along tail and caudal peduncle. Fin counts: D = VIII + I, 20-23 (21-22); A = II + I, 17-19 (18). Maximum length 60 cm TL, most around 30 cm. Tropical marine species widely distributed in the Indo-West Pacific region, common in coastal and offshore reefs to depths of 20-140 m (Smith-Vaniz, 1999; Gloerfelt-Tarp and Kailola, 1984; Randall *et al*., 1990; Allen, 2018).

Caranx tille – Tille trevally

Figure 10. Tille trevally, *Caranx tille* (Family Carangidae) from Huon Gulf (32.5 cm TL; 440 g; top); close-up of convex, blunt head profile (bottom).

Two specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (29.3 cm to 32.5 cm TL, 337 g to 440 g; Figure 10). Diagnostic characters: oblong, elongate body; and blunt head with a strongly anterior convex profile. Differs from the co-occurring and closely related big-eye trevally (*C. sexfasciatus*) by its much prominent, larger dark patch over opercular area, and shorter second dorsal-fin lobe without a white patch at the tip. Fin counts: D = VIII + I, 20-22; A = II + I, 16-18 (17). Maximum size 80 cm TL, most around 50 cm, and 7 kg. Tropical marine species widely distributed in the Indo-West Pacific region, common around coastal rocky and coral reefs to depths of 30-120 m (Smith-Vaniz, 1999; Gloerfelt-Tarp and Kailola, 1984; Allen, 2018).

Carangoides coeruleopinnatus – Coastal trevally

Figure 11. Coastal trevally, *Carangoides coeruleopinnatus* (Family Carangidae) from Huon Gulf (female 21.0 cm TL; 150 g).

Two specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (19.5 cm to 21.0 cm TL, 108 g to 150 g; Figure 11). Diagnostic characters: nearly ovate, greatly compressed body; very steep anterior head profile; long, thread-like filament projecting from second dorsal-fin lobe in juveniles, becoming shorter with age; and shorter filament projecting from anal-fin lobe. Fin counts: D = VIII + I, 20-23; A = II + I, 16-20 (17). Maximum length 41 cm TL, most around 30 cm. Tropical marine species distributed throughout the Indo-West Pacific region, common in coastal rocky and coral reefs to a depth of 60 m; adults are commonly found over deeper coastal reefs and rarely inshore. Also known as “onion trevally” (Smith-Vaniz, 1999; Gloerfelt-Tarp and Kailola, 1984; Allen, 2018).

3.1.4 Family Muraenesocidae – Pike congers

Muraenesox bagio – Common pike conger

Figure 12. Common pike conger, *Muraenesox bagio* (Family Muraenesocidae) from Huon Gulf – head and anterior trunk; female 95.0 cm TL; 1,100 g).

Four specimens caught along coastal waters between Labu Tale and Lae in the western Huon Gulf, and sourced whole from the DCA Point street market at Lae (87.0 cm to 101.2 cm TL, 763 g to 1,800 g; Figure 12). Diagnostic characters: cylindrical, silver to grey eel-shaped body; very large mouth with elongate jaws armed with powerful canine teeth; posterior nostrils only slightly nearer to eye than to anterior nostrils; small, pale pectoral fins; 33-39 lateral-line pores; and 47-49 dorsal-fin rays before anus. Marine demersal species widespread throughout most of the Indo-Pacific, largely nocturnal and common in coastal waters including estuaries to a depth of 100 m. Maximum length 200 cm TL (Gloerfelt-Tarp and Kailola, 1984).

3.1.5 Family Serranidae – Groupers, rockcods

Epinephelus polystigma – White-dotted grouper

Figure 13. White-spotted grouper, *Epinephelus polystigma* (Family Serranidae) from Labu Lakes (37.4 cm TL; 683 g).

Two specimens sourced whole from Labu Lakes (31.1 cm to 37.4 cm TL, 387 g to 683 g; Figure 13). Diagnostic characters: dark brown to nearly blackish color covered with small white to yellowish-white dots (absent in preserved specimens); and small white dots on dorsal, anal, pectoral and caudal fins. Fin counts: D = XI, 15-16; A = III, 8. Known only from the western Pacific, including PNG, New Ireland and Solomon Islands, and found almost exclusively in brackish to freshwater areas, particularly in mangrove habitats in estuaries. Known to forms large aggregations in shallow areas of river mouths, prior to new moon. Maximum length 48.0 cm TL. Also known as “whitedotted grouper” (Heemstra and Randall, 1993, 1999).

3.1.6 Family Eleotridae – Gudgeons

Ophiocara porocephala – Spangled gudgeon

Figure 14. Spangled gudgeon, *Ophiocara porocephala* (Family Eleotridae) from Labu Lakes (29.0 cm TL; 262 g).

One specimen sourced whole from Labu Lakes (29.0 cm TL, 262 g; Figure 14). Diagnostic characteristics: cylindrical body with anteriorly flattened head and posteriorly compressed tail region, mostly dark brown or blackish overall; small, oblique mouth with forward-protruding lower jaw; lateral line absent; 33-42 scales along mid-lateral series; two separate dorsal fins; and rounded caudal fin. Fin counts: D = VI + I, 8-9; A = I, 7-9. Tropical species recorded throughout the Indo-Pacific region, with adults preferring brackish estuaries, river mouths and freshwater creeks, often upstream from the tidal zone. Maximum length 34 cm TL. Also known as “northern mud gudgeon” (Larson and Murdy, 2001; Allen *et al*., 2002).

3.1.7 Family Mugilidae – Mullets

Ellochelon vaigiensis – Squaretail mullet

Figure 15. Squaretail mullet, *Ellochelon vaigiensis* (Family Mugilidae) from Labu Lakes (25.0 cm TL; 159 g).

One specimen sourced from Labu Lakes (25.0 cm TL, 159 g, gutted; Figure 15). Diagnostic characters: two separate dorsal fins, origin of first dorsal fin closer to caudal-fin base than tip of snout; anal fin with 8 soft rays in adults, usually 9 soft rays in juveniles $\leq$30 mm standard length (third anal-fin ray ossifies and becomes spine); square-shaped caudal fin, with a nearly straight posterior margin; pectoral fins black, lower section yellowish in adults; and 24-27scales along the lateral line. Fin counts (adults): D = IV + I, 7; A = III, 8. Widely distributed throughout the Indo-Pacific region, common along shallow coastal areas and protected sandy shores in estuaries and lagoons, and tidal rivers up to 10 km upstream. Maximum length 60 cm TL, most around 35 cm. Also known as "diamond-scale mullet" (Harrison and Senou, 1999; Allen, 2018).

3.2 Crustaceans (Class Malacostraca, Order Decapoda)

3.2.1 Family Portunidae – swimming crabs

Scylla serrata – Giant mud crab

Figure 16. Giant mud crab, *Scylla serrata* (Family Portunidae) from Labu Lakes (dorsal view male, 10.2 cm carapace width; top left); ventral view of male showing narrow abdomen (top right); ventral view of 11.5 cm carapace width female showing wider abdomen (bottom left).

Thirteen specimens sourced from Labu Lakes (9.5 cm to 12.8 cm carapace width; Figure 16). Diagnostic characters: transversely hexagonal top ovate carapace, deep green to almost black; 5 to 9 teeth on each anterolateral margin; last pair of legs paddle-like (swimmers); well-developed spines on outer surface of each cheliped, as well as anterior and posterior dorsal parts of claw palms; and male abdominal segments 3 to 5 completely fused (immovable). Regarded as important resource of mangrove fisheries throughout the Indo-Pacific region, giant mud crabs are commonly found in muddy bottoms in estuaries and mangrove areas, but also recorded up to 50 km offshore during spawning migrations. Maximum carapace width 25.0 cm -28.8 cm (males); maximum weight 2 kg - 3 kg. Also known as “mangrove and/or black crab” (Ng, 1998).

3.3 Molluscs (Class Bivalvia)

3.3.1 Family Lucinidae – Lucinas

Anodontia edentula – Mangrove mud clam

Figure 17. Mangrove mud clam, *Anodontia edentula* from Labu Lakes (7.0 cm shell length).

Twelve specimens sourced from Labu Lakes (Figure 17). Diagnostic characters: Shell anteriorly rounded, very inflated (globose) and moderately thin; outside of shell dull white (darker due to mud overgrowth rings); posterior margin slightly convex dorsally and sloping posteriorly; and outer surface of valves with dense, irregular concentric growth lines. Burrowing, detritus-feeding bivalve widely distributed in the Indo-West Pacific region, including Madagascar and the Red Sea, typically buried just under the substrate in muddy bottoms of estuarine and mangrove areas. Maximum shell length 7.5 cm, commonly 5.0 cm (Poutiers, 1998).

3.4 Metals – Fishes

3.4.1 Arsenic (As)

Arsenic (as total As) was detected in muscle samples and livers of all fish species tested (Table 6). Mean total As concentrations in muscle tissues ranged from 0.10 mg kg^{-1} in squaretail mullet to 39.57 mg kg^{-1} in common pike conger, with a maximum total As concentration of 90.20 mg kg^{-1} recorded in muscle tissue of a common pike conger (Table 6).

Mean total As concentrations in livers ranged from 0.14 mg kg^{-1} in the spangled gudgeon to 14.12 mg kg^{-1} in saddletail snappers. A maximum total As concentration of 33.30 mg kg^{-1} in liver was obtained from a common pike conger.

Inorganic As concentrations in muscle tissues of fish species were estimated from total As concentrations by applying a conversion factor of 4.2% (Table 5), i.e., inorganic As = total As × 0.042. Mean inorganic As concentrations ranged from <0.005 mg kg^{-1} in squaretail mullet to 1.66 mg kg^{-1} in common pike conger. Maximum inorganic As concentrations in muscle tissues ranged from 0.01 mg kg^{-1} in white-dotted grouper to 3.79 mg kg^{-1} in a common pike conger (Tables 6, 15).

Table 6. Concentrations of arsenic (total As; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study. Values in brackets for muscle correspond to mean concentrations of inorganic As (mg kg^{-1} ww) estimated from mean total As using a conversion factor of 4.2% (0.042; refer to Table 5).

Arsenic (LOR 0.05 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	6.82 (0.29)	3.72	10.40	8	1.95	0	6.18	3.92	12.20	9	2.52	0
Yellowbelly threadfin bream	2.20 (0.09)	1.10	4.10	6	1.21	0	4.22	2.65	9.26	6	2.53	0
Doublewhip threadfin bream	2.41 (0.10)	1.54	3.28	2	1.23	0	2.70	-	-	1	-	-
Fivelined threadfin bream	1.96 (0.08)	1.16	2.76	2	1.13	0	3.27	2.01	4.53	2	1.78	0
Saddletail snapper	5.34 (0.22)	2.18	6.78	11	1.35	0	14.12	6.37	21.90	11	5.06	0
Mangrove jack (LL)	0.30 (0.01)	0.09	0.65	5	0.23	0	0.41	0.28	0.48	3	0.11	0
Sunbeam snapper	5.24 (0.22)	5.04	5.35	3	0.17	0	3.01	1.73	4.28	2	1.80	0
Malabar trevally	2.60 (0.11)	1.47	4.33	6	1.05	0	2.87	1.94	4.02	6	0.81	0
Tille trevally	0.29 (0.01)	0.19	0.38	2	0.13	0	0.63	0.60	0.66	2	0.04	0
Coastal trevally	1.18 (0.05)	0.77	1.59	2	0.58	0	1.93	1.57	2.29	2	0.51	0
Common pike conger	39.57 (1.66)	4.06	90.20	4	36.25	0	13.56	2.04	33.30	4	13.92	0
White-dotted grouper	0.15 (0.01)	0.07	0.22	2	0.11	0	0.24	-	-	1	-	-
Spangled gudgeon (LL)	0.36 (0.02)	-	-	1	-	-	0.14	-	-	1	-	-
Squaretail mullet (LL)	0.10 (0.00)	-	-	1	-	-	-	-	-	N/A	-	-

3.4.2 Cadmium (Cd)

Cadmium (Cd) was undetectable in muscle tissues of almost all fish species tested (<LOR of 0.01 mg kg^{-1}). However, a maximum Cd concentration of 0.05 mg kg^{-1} was recorded in muscle tissue from a yellowbelly threadfin bream (Table 7).

Detectable Cd concentrations (>LOR of 0.01 mg kg^{-1}) were recorded in the livers of all 13 fish species tested (Table 7). Mean Cd concentrations in livers ranged from 0.13 mg kg^{-1} in mangrove jack to 3.96 mg kg^{-1} in common pike conger, with maximum Cd concentrations of 10.70 mg kg^{-1} and 10.90 mg kg^{-1} obtained in a saddletail snapper and a Malabar trevally, respectively (Table 7).

Table 7. Concentrations of cadmium (Cd; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Cadmium (LOR 0.01 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	<0.01	<0.01	<0.01	0	0.00	8	2.04	0.63	4.71	9	1.48	0
Yellowbelly threadfin bream	0.05	<0.01	0.05	1	0.00	5	1.84	0.84	3.42	6	0.99	0
Doublewhip threadfin bream	<0.01	<0.01	<0.01	0	0.00	2	1.02	-	-	1	-	-
Fivelined threadfin bream	<0.01	<0.01	<0.01	0	0.00	2	2.31	1.20	3.41	2	1.56	0
Saddletail snapper	<0.01	<0.01	<0.01	0	0.00	11	2.63	1.13	10.70	11	2.73	0
Mangrove jack (LL)	<0.01	<0.01	<0.01	0	0.00	5	0.13	0.06	0.23	3	0.09	0
Sunbeam snapper	<0.01	<0.01	<0.01	0	0.00	3	0.17	0.08	0.26	2	0.13	0
Malabar trevally	0.01	<0.01	0.01	1	0.00	5	3.47	0.99	10.90	6	3.87	0
Tille trevally	<0.01	<0.01	<0.01	0	0.00	2	0.44	0.40	0.48	2	0.06	0
Coastal trevally	<0.01	<0.01	<0.01	0	0.00	2	1.22	0.64	1.79	2	0.81	0
Common pike conger	<0.01	<0.01	<0.01	0	0.00	4	3.96	0.61	7.86	4	3.17	0
White-dotted grouper	<0.01	<0.01	<0.01	0	0.00	2	0.12	-	-	1	-	-
Spangled gudgeon (LL)	<0.01	-	-	1	-	-	0.09	-	-	1	-	-
Squaretail mullet (LL)	<0.01	-	-	1	-	-	-	-	-	N/A	-	-

3.4.3 Chromium (Cr)

Chromium (Cr) was undetectable (<LOR of 0.05 mg kg^{-1}) in muscle tissues of eight of the 14 fish species tested, and was present at very low concentrations in muscle tissues of the remaining six fish species (Table 8). Mean Cr concentrations in the latter species ranged from 0.06 mg kg^{-1} in doublewhip threadfin bream to 2.43 mg kg^{-1} in Malabar trevally, with a maximum Cr concentration of 4.77 mg kg^{-1} recorded in muscle tissue of a Malabar trevally (Table 8).

Chromium (Cr) was only marginally detectable in livers of 10 of the 13 fish species tested (Table 8). Mean Cr concentrations in livers ranged from 0.08 mg kg^{-1} in teardrop threadfin bream to 0.37 mg kg^{-1} in sunbeam snappers, with a maximum Cr concentration of 1.31 mg kg^{-1} recorded in the liver of a coastal trevally (Table 8).

Table 8. Concentrations of chromium (Cr; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Chromium (LOR 0.05 mg kg^{-1})	Muscle						Liver					
Species	Mean	Min	Max	n	SD	n<LOR	Mean	Min	Max	n	SD	n<LOR
Teardrop threadfin bream	<0.05	<0.05	<0.05	0	0.00	8	0.08	<0.05	0.13	4	0.03	5
Yellowbelly threadfin bream	0.20	<0.05	0.20	1	0.00	5	0.19	0.07	0.46	6	0.15	0
Doublewhip threadfin bream	0.06	<0.05	0.06	1	0.00	1	0.15	-	-	1	-	-
Fivelined threadfin bream	<0.05	<0.05	<0.05	0	0.00	2	0.27	<0.05	0.27	1	0.00	1
Saddletail snapper	0.10	<0.05	0.15	2	0.07	9	0.23	<0.05	0.86	6	0.31	5
Mangrove jack (LL)	<0.05	<0.05	<0.05	0	0.00	5	0.27	<0.05	0.38	2	0.16	1
Sunbeam snapper	0.08	<0.05	0.09	2	0.02	1	0.53	0.37	0.69	2	0.23	0
Malabar trevally	2.43	<0.05	4.77	2	3.31	4	0.12	<0.05	0.18	4	0.05	2
Tille trevally	<0.05	<0.05	<0.05	0	0.00	2	<0.05	<0.05	<0.05	0	0.00	2
Coastal trevally	<0.05	<0.05	<0.05	0	0.00	2	0.72	0.12	1.31	2	0.84	0
Common pike conger	<0.05	<0.05	<0.05	0	0.00	4	<0.05	<0.05	<0.05	0	0.00	4
White-dotted grouper	<0.05	<0.05	<0.05	0	0.00	2	0.09	-	-	1	-	-
Spangled gudgeon (LL)	0.17	-	-	1	-	-	<0.05	-	-	1	-	-
Squaretail mullet (LL)	<0.05	-	-	1	-	-	-	-	-	N/A	-	-

3.4.4 Copper (Cu)

Copper (Cu) was detected in very low concentrations in muscle tissues from all fish species (>LOR of 0.1 mg kg^{-1}) except five of the six saddletail snappers tested (Table 9). Mean Cu concentrations in muscle tissue ranged from 0.10 mg kg^{-1} to 0.46 mg kg^{-1} in fivelined and teardrop threadfin breams, respectively (Table 9).

Compared to muscle tissues, Cu was detected in high concentrations in livers of all 13 fish species tested, with mean concentrations noticeably greater in liver than muscle of the same species (Table 9). Mean Cu concentrations in livers ranged from 0.85 mg kg^{-1} in sunbeam snapper to 67.00 mg kg^{-1} in common pike conger. Maximum Cu concentrations of 109.00 mg kg^{-1} and 57.40 mg kg^{-1} were recorded in livers of a common pike conger and a fivelined threadfin bream, respectively, with both species showing a substantial variation in Cu levels across respective specimens tested (Table 9).

Table 9. Concentrations of copper (Cu; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Copper (LOR 0.10 mg kg^{-1})	Muscle						Liver					
Species	Mean	Min	Max	n	SD	n<LOR	Mean	Min	Max	n	SD	n<LOR
Teardrop threadfin bream	0.46	0.10	2.40	8	0.79	0	18.30	1.60	56.40	9	17.91	0
Yellowbelly threadfin bream	0.15	0.10	0.20	6	0.05	0	6.40	2.20	12.50	6	4.33	0
Doublewhip threadfin bream	0.25	0.20	0.30	2	0.07	0	6.80	-	-	1	-	-
Fivelined threadfin bream	0.10	0.10	0.10	2	0.00	0	31.60	5.80	57.40	2	36.49	0
Saddletail snapper	0.15	<0.10	0.20	6	0.05	5	4.28	2.80	5.80	11	0.75	0
Mangrove jack (LL)	0.22	0.20	0.30	5	0.04	0	8.50	5.20	12.40	3	3.64	0
Sunbeam snapper	0.17	0.10	0.20	3	0.06	0	0.85	0.40	1.30	2	0.64	0
Malabar trevally	0.33	0.20	0.50	6	0.10	0	5.25	3.00	9.60	6	2.54	0
Tille trevally	0.35	0.30	0.40	2	0.07	0	2.30	2.20	2.40	2	0.14	0
Coastal trevally	0.45	0.40	0.50	2	0.07	0	17.00	6.50	27.50	2	14.85	0
Common pike conger	0.20	0.20	0.20	4	0.00	0	67.00	31.40	109.00	4	31.92	0
White-dotted grouper	0.20	0.20	0.20	2	0.00	0	7.60	-	-	1	-	-
Spangled gudgeon (LL)	0.20	-	-	1	-	-	7.30	-	-	1	-	-
Squaretail mullet (LL)	0.20	-	-	1	-	-		-	-	N/A	-	-

3.4.5 Lead (Pb)

Lead (Pb) was detected either in very low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1}) in muscle tissues and livers of almost all fish species tested during this study (Table 10). A maximum Pb concentration of 0.22 mg kg^{-1} was recorded in muscle tissue of a teardrop threadfin bream (Table 10).

Table 10. Concentrations of lead (Pb; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Lead (LOR 0.05 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	0.22	<0.05	0.22	1	0.00	7	0.08	<0.05	0.08	1	0.00	8
Yellowbelly threadfin bream	<0.05	<0.05	<0.05	0	0.00	6	0.11	<0.05	0.14	3	0.03	3
Doublewhip threadfin bream	<0.05	<0.05	<0.05	0	0.00	2	0.13	-	-	1	-	-
Fivelined threadfin bream	<0.05	<0.05	<0.05	0	0.00	2	<0.05	<0.05	<0.05	0	0.00	2
Saddletail snapper	0.11	<0.05	0.11	1	0.00	10	0.08	<0.05	0.08	2	0.00	9
Mangrove jack (LL)	<0.05	<0.05	<0.05	0	0.00	5	0.36	<0.05	0.50	2	0.20	1
Sunbeam snapper	0.08	<0.05	0.09	2	0.01	1	<0.05	<0.05	<0.05	0	0.00	2
Malabar trevally	<0.05	<0.05	<0.05	0	0.00	6	<0.05	<0.05	<0.05	0	0.00	6
Tille trevally	<0.05	<0.05	<0.05	0	0.00	2	<0.05	<0.05	<0.05	0	0.00	2
Coastal trevally	<0.05	<0.05	<0.05	0	0.00	2	0.08	<0.05	0.08	1	0.00	1
Common pike conger	<0.05	<0.05	<0.05	0	0.00	4	0.11	<0.05	0.16	2	0.08	2
White-dotted grouper	<0.05	<0.05	<0.05	0	0.00	2	<0.05	-	-	1	-	1
Spangled gudgeon (LL)	<0.05	-	-	1	-	-	<0.05	-	-	1	-	-
Squaretail mullet (LL)	<0.05	-	-	1	-	-	-	-	-	N/A	-	-

3.4.6 Mercury (Hg)

Mercury (Hg) was present at detectable levels (>LOR of 0.01 mg kg^{-1}) in muscle tissues from all fish species tested except squaretail mullet. Mean Hg concentrations in muscle tissues ranged from 0.02 mg kg^{-1} in white-dotted grouper to 0.40 mg kg^{-1} in Malabar trevally, and a maximum Hg concentration of 0.60 mg kg^{-1} was recorded in muscle of a teardrop threadfin bream (Table 11).

Mean Hg concentrations in livers ranged from 0.04 mg kg^{-1} in spangled gudgeon to 1.21 mg kg^{-1} in saddletail snapper (Table 11). Maximum Hg liver concentrations of 7.9 mg kg^{-1} and 1.50 mg kg^{-1} were recorded in a saddletail snapper and a teardrop threadfin bream, respectively (Table 11).

Table 11. Concentrations of mercury (Hg; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Mercury (LOR 0.01 mg kg^{-1})	Muscle						Liver					
Species	Mean	Min	Max	n	SD	n<LOR	Mean	Min	Max	n	SD	n<LOR
Teardrop threadfin bream	0.25	0.10	0.60	8	0.15	0	0.56	0.20	1.50	9	0.45	0
Yellowbelly threadfin bream	0.06	0.03	0.10	6	0.03	0	0.35	0.20	0.60	6	0.15	0
Doublewhip threadfin bream	0.30	0.20	0.40	2	0.14	0	0.60	-	-	1	-	-
Fivelined threadfin bream	0.25	0.10	0.40	2	0.21	0	0.65	0.20	1.10	2	0.64	0
Saddletail snapper	0.20	0.09	0.50	11	0.13	0	1.21	0.20	7.90	11	2.24	0
Mangrove jack (LL)	0.03	0.02	0.05	5	0.01	0	0.06	<0.01	0.06	1	0.00	2
Sunbeam snapper	0.08	0.05	0.10	3	0.03	0	0.40	0.30	0.50	2	0.14	0
Malabar trevally	0.40	0.30	0.50	6	0.06	0	0.50	0.30	0.70	6	0.17	0
Tille trevally	0.09	0.07	0.10	2	0.02	0	0.14	0.08	0.20	2	0.08	0
Coastal trevally	0.05	0.03	0.06	2	0.02	0	0.08	0.07	0.09	2	0.01	0
Common pike conger	0.33	0.20	0.50	4	0.15	0	0.53	0.20	0.90	4	0.33	0
White-dotted grouper	0.02	0.01	0.03	2	0.01	0	0.06	-	-	1	-	-
Spangled gudgeon (LL)	0.02	-	-	1	-	-	0.04	-	-	1	-	-
Squaretail mullet (LL)	<0.01	-	-	1	-	-	-	-	-	N/A	-	-

3.4.7 Nickel (Ni)

Nickel (Ni) was undetectable in muscle tissues from most of the 14 fish species tested during this study (<LOR of 0.05 mg kg^{-1}) except in a sunbeam snapper (0.09 mg kg^{-1}) and a Malabar trevally (0.40 mg kg^{-1}). In contrast, Ni detected in livers was present mostly in exceptionally low concentrations, reaching a maximum of 0.37 mg kg^{-1} in a yellowbelly threadfin bream (Table 12).

Table 12. Concentrations of nickel (Ni; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Nickel (LOR 0.05 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	<0.05	<0.05	<0.05	0	0.00	8	0.08	<0.05	0.13	4	0.03	5
Yellowbelly threadfin bream	<0.05	<0.05	<0.05	0	0.00	6	0.19	0.08	0.37	6	0.12	0
Doublewhip threadfin bream	<0.05	<0.05	<0.05	0	0.00	2	0.08	-	-	1	-	-
Fivelined threadfin bream	<0.05	<0.05	<0.05	0	0.00	2	0.08	<0.05	0.08	1	0.00	1
Saddletail snapper	<0.05	<0.05	<0.05	0	0.00	11	0.09	<0.05	0.12	4	0.03	7
Mangrove jack (LL)	<0.05	<0.05	<0.05	0	0.00	5	0.09	<0.05	0.09	2	0.01	1
Sunbeam snapper	0.09	<0.05	0.09	1	0.00	2	0.11	<0.05	0.11	1	0.00	1
Malabar trevally	0.40	<0.05	0.40	1	0.00	5	0.08	<0.05	0.08	1	0.00	5
Tille trevally	<0.05	<0.05	<0.05	0	0.00	2	<0.05	<0.05	<0.05	0	0.00	2
Coastal trevally	<0.05	<0.05	<0.05	0	0.00	2	0.12	0.06	0.17	2	0.08	0
Common pike conger	<0.05	<0.05	<0.05	0	0.00	4	<0.05	<0.05	<0.05	0	0.00	4
White-dotted grouper	<0.05	<0.05	<0.05	0	0.00	2	<0.05	-	-	1	-	1
Spangled gudgeon (LL)	<0.05	-	-	1	-	-	<0.05	-	-	1	-	-
Squaretail mullet (LL)	<0.05	-	-	1	-	-	-	-	-	N/A	-	-

3.4.8 Selenium (Se)

Selenium (Se) was present at detectable levels (>LOR of 0.05 mg kg^{-1}) in muscle tissues and livers from all fish species tested during this study. Mean Se concentrations in muscle tissues ranged from 0.13 mg kg^{-1} in spangled gudgeon to 0.79 mg kg^{-1} in sunbeam snapper, with a maximum Se concentration of 1.01 mg kg^{-1} recorded in muscle of a teardrop threadfin bream (Table 13).

Mean Se concentrations in livers ranged from 0.61 in spangled gudgeon to 5.93 mg kg^{-1} in coastal trevally, with a maximum concentration of 9.78 mg kg^{-1} recorded in liver of a saddletail snapper. Detected Se concentrations were consistently higher in liver than muscle tissues in all fish species tested except sunbeam snapper, where the mean Se concentration in liver (0.71 mg kg^{-1}) was slightly lower than the mean Se concentration in muscle (0.79 mg kg^{-1}) (Table 13).

Table 13. Concentrations of selenium (Se; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Selenium (LOR 0.05 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	0.77	0.62	1.01	8	0.14	0	2.37	1.66	3.44	9	0.58	0
Yellowbelly threadfin bream	0.57	0.46	0.64	6	0.07	0	2.55	1.75	3.13	6	0.62	0
Doublewhip threadfin bream	0.59	0.57	0.61	2	0.03	0	3.24	-	-	1	-	-
Fivelined threadfin bream	0.60	0.59	0.61	2	0.01	0	2.69	1.41	3.96	2	1.80	0
Saddletail snapper	0.73	0.59	0.87	11	0.08	0	4.09	2.61	9.78	11	2.01	0
Mangrove jack (LL)	0.38	0.18	0.62	5	0.18	0	1.49	0.83	2.03	3	0.61	0
Sunbeam snapper	0.79	0.66	0.89	3	0.12	0	0.71	0.36	1.06	2	0.49	0
Malabar trevally	0.59	0.43	0.72	6	0.12	0	4.69	3.68	6.13	6	1.02	0
Tille trevally	0.42	0.29	0.55	2	0.18	0	2.51	1.59	3.43	2	1.30	0
Coastal trevally	0.49	0.44	0.54	2	0.07	0	5.93	3.38	8.47	2	3.60	0
Common pike conger	0.69	0.63	0.76	4	0.06	0	2.48	2.22	3.03	4	0.37	0
White-dotted grouper	0.33	0.32	0.34	2	0.01	0	2.20	-	-	1	-	-
Spangled gudgeon (LL)	0.13	-	-	1	-	-	0.61	-	-	1	-	-
Squaretail mullet (LL)	0.17	-	-	1	-	-	-	-	-	N/A	-	-

3.4.9 Zinc (Zn)

Zinc (Zn) was present at detectable levels (>LOR of 0.5 mg kg^{-1}) in muscle tissues and livers from all 14 fish species tested during this study, though mean concentrations varied widely both within species (high intraspecific variation) and across species (high interspecific variation).

Mean Zn concentrations in muscle tissues ranged from 3.05 mg kg^{-1} in fivelined threadfin bream to 17.10 mg kg^{-1} in squaretail mullet, with a maximum Zn concentration of 26.20 mg kg^{-1} recorded in muscle tissue of a sunbeam snapper (Table 14).

Mean Zn concentrations in livers were noticeably higher than mean Zn concentrations in muscle tissues of the same species and ranged from 14.4 mg kg^{-1} in sunbeam snapper to 112.97 mg kg^{-1} in mangrove jack. A maximum Zn concentration of 188.00 mg kg^{-1} in liver tissue was recorded for a yellowbelly threadfin bream, respectively (Table 14).

Table 14. Concentrations of zinc (Zn; mg kg^{-1} ww) in muscle and liver of 56 fish specimens sourced at the DCA Point and Lae markets (LL = Labu Lakes) during the May 2019 study.

Zinc (LOR 0.50 mg kg^{-1})	Muscle						Liver					
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min**	**Max**	**n**	**SD**	**n<LOR**
Teardrop threadfin bream	6.59	2.80	16.00	8	5.48	0	46.04	15.00	96.10	9	25.62	0
Yellowbelly threadfin bream	11.27	2.70	17.80	6	6.45	0	101.25	19.60	188.00	6	71.61	0
Doublewhip threadfin bream	11.15	3.00	19.30	2	11.53	0	105.00	-	-	1	-	-
Fivelined threadfin bream	3.05	2.80	3.30	2	0.35	0	48.00	22.30	73.70	2	36.35	0
Saddletail snapper	6.83	2.50	20.00	11	6.40	0	42.41	31.50	55.40	11	8.83	0
Mangrove jack (LL)	15.24	14.00	17.30	5	1.45	0	112.97	80.80	168.00	3	47.89	0
Sunbeam snapper	16.47	4.80	26.20	3	10.83	0	14.40	13.20	15.60	2	1.70	0
Malabar trevally	3.95	2.80	4.90	6	0.77	0	45.73	31.30	67.50	6	16.56	0
Tille trevally	9.80	5.00	14.60	2	6.79	0	50.25	41.70	58.80	2	12.09	0
Coastal trevally	15.40	14.10	16.70	2	1.84	0	106.30	66.60	146.00	2	56.14	0
Common pike conger	16.08	15.20	17.90	4	1.27	0	100.33	66.40	127.00	4	25.57	0
White-dotted grouper	12.95	12.10	13.80	2	1.20	0	85.40	-	-	1	-	-
Spangled gudgeon (LL)	15.40	-	-	1	-	-	38.60	-	-	1	-	-
Squaretail mullet (LL)	17.10	-	-	1	-	-	-	-	-	N/A	-	-

3.4.10 Comparisons with FSANZ Standard and GELs – fishes

This section compares concentrations of selected metals in muscle tissue samples taken from all fish species tested during this study and current FSANZ Standard (As, Pb, Hg) and FSANZ GEL guidelines (Cu, Hg, Se, Zn), and the results are summarized in Table 15. Values for the FSANZ Standard (maximum limits and means) and FSANZ GELs (90^{th} percentiles) are listed in Table 4 (Section 2.5.1), noting that no FSANZ Standard or FSANZ GELs for Cd, Cr or Ni are available for fishes.

Arsenic (As) – Mean concentrations of inorganic As in muscle tissues of all fish species tested did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for inorganic As listed for fishes (Table 6). However, the maximum concentration of inorganic As of 3.79 mg kg^{-1} in the muscle tissue of a common pike conger, estimated following a conversion from a maximum total As of 90.20 mg kg^{-1} (Table 16), slightly exceeded the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for inorganic As listed for fishes (Table 4).

Copper (Cu) – Only FSANZ GEL guidelines for Cu are available for fishes (Table 4). Mean Cu concentrations detected in muscle tissues of all fish species tested did not exceed the FSANZ GEL 90^{th} percentile concentration of 2.0 mg kg^{-1} for Cu listed for fishes (Tables 9, 15).

Lead (Pb) – Maximum Pb concentrations detected in muscle tissues of all fish species tested did not exceed the FSANZ Standard of 0.5 mg kg^{-1} for Pb listed for fishes (Tables 10, 15).

Mercury (Hg) – Concentrations of Hg detected in muscle tissues of all fish species tested did not exceed the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum limit of 1.0 mg kg^{-1} for Hg listed for fishes (Table 15). Similarly, mean Hg concentrations in muscle tissues of all species tested did not exceed the FSANZ GEL 90^{th} percentile concentration of 2.0 mg kg^{-1} for Hg listed for fishes (Table 4).

Selenium (Se) – Only FSANZ GEL guidelines for Se are available for fishes (Table 4). Mean Se concentrations detected in muscle tissues of all fish species tested did not exceed the FSANZ GEL 90^{th} percentile value of 2.0 mg kg^{-1} for Se listed for fishes (Tables 13, 15).

Zinc (Zn) – Only FSANZ GEL guidelines for Se are available for fishes (Table 4). Mean Zn concentrations detected in muscle tissues of six of the 14 fish species tested during this study slightly exceeded the FSANZ GEL 90^{th} percentile concentration of 15 mg kg^{-1} of Zn listed for fishes (Table 4), including mangrove jack, sunbeam snapper and common pike conger (Table 15).

Maximum Zn concentrations detected in muscle tissues of 10 of the 14 fish species tested exceeded the FSANZ GEL 90^{th} percentile concentration of 15 mg kg^{-1} (Table 4), with highest exceedances of 26.60 mg kg^{-1} and 20.00 mg kg^{-1} recorded in a sunbeam snapper and a saddletail snapper, respectively (Table 15).

Table 15. Comparison of fish muscle tissue concentrations ($mg\ kg^{-1}$ ww) with FSANZ Standard (maximum limits, mean) and FSANZ GELs (90^{th} percentiles) in all fish species tested during this study. Values in red indicate concentrations exceeding FSANZ Standard or FSANZ GELs for listed metal.

FSANZ Standard 1.4.1 Maximum values or means	Number examined	**Inorganic Arsenic*** 2.0 $mg\ kg^{-1}$ (maximum limit)	**Lead** 0.5 $mg\ kg^{-1}$ (maximum limit)	**Mercury** 0.5 $mg\ kg^{-1}$ (mean)	**Mercury** 1.0 $mg\ kg^{-1}$ (maximum limit)
Saddletail snapper	11	0.28	0.11	0.20	0.50
Teardrop threadfin bream	8	0.44	0.22	0.25	0.60
Malabar trevally	6	0.18	<LOR 0.05	0.40	0.50
Yellowbelly threadfin bream	6	0.17	<LOR 0.05	0.06	0.10
Mangrove jack	5	0.03	<LOR 0.05	0.03	0.05
Common pike conger	4	3.79	<LOR 0.05	0.33	0.50
Sunbeam snapper	3	0.22	0.09	0.08	0.10
Doublewhip threadfin bream	2	0.14	<LOR 0.05	0.30	0.40
Fivelined threadfin bream	2	0.12	<LOR 0.05	0.25	0.40
Tille trevally	2	0.02	<LOR 0.05	0.09	0.10
Coastal trevally	2	0.07	<LOR 0.05	0.05	0.06
White-dotted grouper	2	0.01	<LOR 0.05	0.02	0.03
Spangled gudgeon (LL)	1	-	<LOR 0.05	0.02	0.02
Squaretail mullet (LL)	1	-	<LOR 0.05	<LOR	-

FSANZ GELs** Means and maximum values	Number examined	**Copper** 2.0 $mg\ kg^{-1}$ (90^{th} percentile)		**Mercury** 2.0 $mg\ kg^{-1}$ (90^{th} percentile)		**Selenium** 2.0 $mg\ kg^{-1}$ (90^{th} percentile)		**Zinc** 15.0 $mg\ kg^{-1}$ (90^{th} percentile)	
		Mean	Max	Mean	Max	Mean	Max	Mean	Max
Saddletail snapper	11	0.15	0.20	0.20	0.50	0.73	0.87	6.83	20.00
Teardrop threadfin bream	8	0.46	2.40	0.25	0.60	0.77	1.01	6.59	16.00
Malabar trevally	6	0.33	0.50	0.40	0.50	0.59	0.72	3.95	4.90
Yellowbelly threadfin bream	6	0.15	0.20	0.06	0.10	0.57	0.64	11.27	17.80
Mangrove jack	5	0.22	0.30	0.03	0.05	0.38	0.62	15.24	17.30
Common pike conger	4	0.20	0.20	0.33	0.50	0.69	0.76	16.08	17.90
Sunbeam snapper	3	0.17	0.20	0.08	0.10	0.79	0.89	16.47	26.20
Doublewhip threadfin bream	2	0.25	0.30	0.30	0.40	0.59	0.61	11.15	19.30
Fivelined threadfin bream	2	0.10	0.10	0.25	0.40	0.60	0.61	3.05	3.30
Tille trevally	2	0.35	0.40	0.09	0.10	0.42	0.55	9.80	14.60
Coastal trevally	2	0.45	0.50	0.05	0.06	0.49	0.54	15.40	16.70
White-dotted grouper	2	0.20	0.20	0.02	0.03	0.33	0.34	12.95	13.80
Spangled gudgeon (LL)	1	0.20	0.20	0.02	0.02	0.13	0.13	15.40	15.40
Squaretail mullet (LL)	1	0.20	0.20	<LOR	-	0.17	0.17	17.10	17.10

*The FSANZ Standard maximum level of 2.0 $mg\ kg^{-1}$ for bony fish is for inorganic As. Therefore, maximum total As values in Table 15 have been converted to inorganic As, i.e., total As × 0.042 (see Table 5) for comparison with the FSANZ Standard.
** Values provided to compare against 90^{th} percentiles correspond to mean and maximum concentrations of listed metals in muscle tissue samples of each species tested.

3.5 Metals – Invertebrates

3.5.1 Giant mud crab – *Sylla serrata* (Crustacea)

All metals except Pb were detected in the left cheliped muscle of the 13 giant mud crabs tested (>LORs), with Pb undetectable in any of the crabs (<LOR of 0.05 mg kg^{-1}). In contrast, all 9 metals were detected in the hepatopancreas of the mud crabs tested, with concentrations above their respective detection limits (Table 16).

Metal concentrations differed slightly between cheliped muscle and hepatopancreas in all cases except Cu and Zn. Ranges in Cu concentrations were 2.30-13.70 mg kg^{-1} in cheliped muscle and 9.30-188.00 mg kg^{-1} in hepatopancreas, while ranges in Zn concentration were 54.80-121.00 mg kg^{-1} in cheliped muscle and 31.30-236.00 mg kg^{-1} in hepatopancreas (Table 16).

Based on the same factor applied to fishes to convert total As to inorganic As, i.e., 4.2% (Table 5), maximum estimated concentrations of inorganic As were 0.05 mg kg^{-1} in cheliped muscle and 0.09 mg kg^{-1} in hepatopancreas (Table 16).

Table 16. Concentrations of 9 selected metals (mg kg^{-1} ww) in left cheliped muscle and hepatopancreas of 13 giant mud crabs sourced from Labu Lakes during the May 2019 study.

Metal	Left cheliped muscle						Hepatopancreas					
(LOR mg kg^{-1})	Mean	Min	Max	n	SD	n<LOR	Mean	Min	Max	n	SD	n<LOR
Arsenic (0.05)	0.70	0.35	1.28	13	0.32	0	1.18	0.46	2.31	13	0.47	0
Cadmium (0.01)	0.01	<0.01	0.01	2	0.00	11	1.33	0.13	5.32	13	1.67	0
Chromium (0.05)	0.14	<0.05	0.44	8	0.13	5	0.65	0.06	3.24	13	0.84	0
Copper (0.10)	6.61	2.30	13.70	13	3.09	0	44.87	9.30	188.00	13	49.31	0
Lead (0.05)	<0.05	<0.05	<0.05	0	0.00	13	0.11	<0.05	0.19	12	0.04	1
Mercury (0.01)	0.03	<0.01	0.04	4	0.01	9	0.04	<0.01	0.06	3	0.03	10
Nickel (0.05)	0.26	<0.05	0.39	2	0.19	11	0.26	0.06	0.70	13	0.17	0
Selenium (0.05)	0.39	0.17	0.75	13	0.15	0	0.93	0.37	1.68	13	0.36	0
Zinc (0.50)	81.81	54.80	121.00	13	19.97	0	94.65	31.30	236.00	13	57.04	0

3.5.2 Mangrove mud clam – *Anodontia edentula* (Mollusca)

All 9 metals were detected in all 12 mangrove mud clams tested during this study (>LORs). However, Pb was undetectable (<LOR of 0.05 mg kg^{-1}) in seven of the clams tested (Table 17).

Metal concentrations detected in mud clams differed notably by metal and were highest for Cu (1.20-13.80 mg kg^{-1}) and Zn (16.30-68.90 mg kg^{-1}), and lowest for Hg (<0.01-0.06 mg kg^{-1}).

Based on the same factor applied to fishes to convert total As to inorganic As, i.e., 4.2% (Table 5), the maximum estimated concentration of inorganic As in mud crabs was 0.05 mg kg^{-1} (Table 17).

Table 17. Concentrations of 9 selected metals (mg kg^{-1} ww) in 12 mangrove mud clams (whole animals) sourced from Labu Lakes during the May 2019 study.

Metal (LOR mg kg^{-1})	Mangrove mud clam (whole)					
	Mean	Min	Max	n	SD	n<LOR
Arsenic (0.05)	0.59	0.32	0.99	12	0.24	0
Cadmium (0.01)	0.05	0.02	0.07	12	0.02	0
Chromium (0.05)	0.25	<0.05	1.16	10	0.34	2
Copper (0.10)	4.68	1.20	13.8	12	4.23	0
Lead (0.05)	0.12	<0.05	0.24	5	0.08	7
Nickel (0.05)	0.51	0.16	1.18	12	0.34	0
Mercury (0.01)	0.03	<0.01	0.06	11	0.01	1
Selenium (0.05)	0.45	0.31	0.65	12	0.10	0
Zinc (0.50)	41.57	16.30	68.90	12	18.15	0

3.5.3 Comparisons with FSANZ Standard and GELs – crustaceans and molluscs

Giant mud crabs

This section compares concentrations of As and Hg detected in cheliped muscle and hepatopancreas of giant mud crab (crustacean) with maximum limits listed for these metals under the FSANZ Standard, and maximum concentrations of Cu, Se and Zn with 90th percentile concentrations listed under the FSANZ GELs; no FSANZ standards or GELs are available for Cd, Cr, Pb or Ni for crustaceans (Table 4).

Arsenic (As) – The maximum concentration of inorganic As of 0.05 mg kg^{-1} in the cheliped muscle of mud crabs, estimated following a conversion from the maximum total As of 1.28 mg kg^{-1} (Table 16), did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for inorganic As listed for crustaceans (Table 4). The same was true for maximum concentration of inorganic As in the hepatopancreas, i.e., 0.10 mg kg^{-1}.

Mercury (Hg) – Mean and maximum Hg concentrations detected both in the cheliped muscle and hepatopancreas of mud crabs did not exceed the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum limit of 1.0 mg kg^{-1} for Hg listed for crustaceans (Tables 4, 16).

Copper (Cu) – The maximum Cu concentration of 13.70 mg kg^{-1} detected in the cheliped muscle of mud crabs (Table 16) did not exceed the FSANZ GEL 90th percentile concentration of 20.00 mg kg^{-1} for Cu listed for crustaceans (Table 4). However, the maximum Cu concentration of 188.00 mg kg^{-1} detected in the hepatopancreas of mud crabs significantly exceeded the FSANZ GEL 90th percentile concentration of 20.00 mg kg^{-1} for Cu listed for crustaceans (Table 4).

Selenium (Se) – The maximum Se concentration of 0.75 mg k^{-1} detected in the cheliped muscle of mud crabs did not exceed the FSANZ GEL 90th percentile concentration of 1.00 mg kg^{-1} for Se listed for crustaceans (Table 4). However, the maximum Se concentration of 1.68 mg kg^{-1} detected in the hepatopancreas of mud crabs slightly exceeded the FSANZ GEL 90th percentile concentration of 1.00 mg kg^{-1} for Se listed for crustaceans (Table 4).

Zinc (Zn) – The maximum Zn concentration of 121.00 mg kg^{-1} detected in the cheliped muscle of mud crabs, as well as the maximum Zn concentration of 236.00 mg kg^{-1} in the hepatopancreas (Table 16), greatly exceeded the FSANZ GEL 90th percentile concentration of 40.00 mg kg^{-1} for Zn listed for crustaceans (Table 4).

Mangrove mud clams

The section compares concentrations of As, Cd, Pb and Hg detected in whole mangrove mud clam (mollusc) with maximum limits listed for these metals under the FSANZ Standard, and maximum concentrations of Cu and Se with 90th percentile concentrations under the FSANZ GELs; no FSANZ standards or GELs are available for Cr, Ni or Zn for molluscs (Table 4).

Arsenic (As) – The maximum concentration of inorganic As of 0.04 mg kg^{-1} in mud clams, estimated following a conversion from the maximum total As of 0.99 mg kg^{-1} (Table 17), did not exceed the FSANZ Standard maximum limit of 1.0 mg kg^{-1} for inorganic As listed for molluscs (Table 4).

Cadmium (Cd) – The maximum Cd concentration of 0.07 mg kg^{-1} detected in mud clams (Table 17) did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Cd listed for molluscs (Table 4).

Copper (Cu) – The maximum Cu concentration of 13.8 mg kg^{-1} detected in mud clams (Table 17) did not exceed the FSANZ GEL 90th percentile concentration of 30.0 mg kg^{-1} for Cu listed for molluscs (Table 4).

Lead (Pb) – The maximum Pb concentration of 0.24 mg kg^{-1} detected in mud clams (Table 17) did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Pb listed for molluscs (Table 4).

Mercury (Hg) – Mean and maximum Hg concentrations detected in mud clams (Table 17) did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum limit of 1.0 mg kg^{-1} for Hg listed for molluscs (Table 4).

Selenium (Se) – The maximum Se concentration of 0.65 mg kg^{-1} detected in mud crabs (Table 17) did not exceed the FSANZ GEL 90th percentile concentration of 1.0 mg kg^{-1} for Se listed for molluscs (Table 4).

4 DISCUSSION

This study was carried out to describe baseline levels of selected metals in muscle and liver samples taken from representative fishes caught by the local artisanal fishery in waters of the western Huon Gulf outside the predicted DSTP outfall and tailings placement area. Fish species selected for this baseline study are typically sold for local human consumption in Lae, and there is understandable interest across the local community that concentrations of metals in fishes that are consumed are within the range of expected food standard limits (FSANZ Standard and FSANZ GELs) and therefore pose no risk to public health. This baseline study also included samples of two species of invertebrates from Labu Lakes and targeted for human consumption, namely a crustacean (giant mud crab) and a mollusc bivalve (mangrove mud clam).

Market fishes sourced for this baseline study did not include samples from the predicted DSTP outfall area to the south of Lae, as no artisanal fishing takes place in such area due to depth of the water column (>100 m) and lack of seabed structures that support fish species usually targeted for human consumption.

This baseline study was commissioned by WGJV with the purpose of building a scientifically robust database of metals that can be accessed to compare against future monitoring of fishes sourced from local markets, as well as other environmental projects.

4.1 Metals in representative market fishes

The present baseline study generated data on concentrations of 9 selected metals in muscle tissues and livers taken from 14 species representing seven families of bony fishes sourced at local markets in Lae in May 2019. Metal concentration data in muscle tissues and livers are also available for two of these species from a baseline study undertaken in November 2016 on local markets fishes in Lae, i.e., saddletail snapper (n=5) and mangrove jack (n=2) (Table 18). Data from the earlier study were obtained during the main fish characterisation survey undertaken to inform the WGJV Project Feasibility Study and EIS (Coffey/Marscco, 2018), and are discussed in Section 4.2 below.

Of the 9 metals tested, Cr, Cd, Ni and Pb occurred either in low to exceptionally low concentrations or were undetectable (<LORs) in the muscle of most fish species tested. Similarly, Cu, Se and Hg were detected in mostly low to very low concentrations (<0.80 mg kg^{-1}) in muscle across all fish species tested.

Total As was detected in much higher concentrations than all other metals both in muscle tissues and livers, with a maximum concentration of 90.20 mg kg^{-1} recorded in muscle of a common conger pike (Family Muraenesocidae). While As is toxic in its inorganic form, total As in fishes is mostly present as the organoarsenic compound arsenobetaine which is a non-toxic organic form of As

(Ciardullo *et al*., 2010; Sevcikova *et al*., 2011). Since fishes exhibit little or no bioaccumulation of inorganic As, it is assumed that organic forms of As are accumulated in fish via trophic transfer, i.e., diet (Neff, 2002). Total As concentrations in muscle tissues were converted to inorganic As concentrations for all fish species tested during this baseline study by applying a conservative ratio of 0.042, i.e., 4.2% of total As concentrations, based on laboratory work on various marine species (Uneyama *et al*., 2007). Results indicate that estimated inorganic As concentrations in muscle fall well under the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for inorganic As listed for fishes (see Section 4.3 for details). The very low inorganic As concentrations in muscle tissues implies that there is presently a very low risk to local community health from the consumption of muscle (flesh) from any of the fish species tested.

As with total As, Zn in muscle tissues and livers was likewise detected in greater concentrations than all other metals, maximum concentrations of 26.20 mg kg^{-1} and 20.00 mg kg^{-1} recorded in muscle of a sunbeam snapper and saddletail snapper (Family Lutjanidae), respectively. High levels of Zn (an essential metal) have been reported in similar fish surveys (e.g., Yipel *et al*., 2016). However, maximum Zn concentrations detected in fish muscle tissues of most fish species tested were comparably higher than Zn levels reported for several marine fishes in the north-east Atlantic, i.e., 2.5-8.6 mg kg^{-1} (Celik and Oehlenschlager, 2004). Zinc is an essential metal with a variety of nutritional roles including as a component of metalloenzymes and as a catalyst for regulating activity of specific zinc-dependent enzymes. Thus, the high Zn concentrations detected during this study are not expected to pose a risk to local community health from the consumption of muscle (flesh) from the fish species tested.

4.2 Variability in baseline metal concentrations

4.2.1 Fishes

Metal levels obtained during this study varied greatly between individuals of the same species, i.e., large mean standard deviations (SDs), as well as across species of same genus and species from different families. Such intraspecific and interspecific variability has previously been described in the literature for metals in fish muscle and liver (e.g., Swales *et al*., 1998), and is evident when comparing both same and close-related species from the same locality as well as separate geographical locations (Table 18). For example, mean Cu concentrations in fish muscle tissues were of similarly low magnitudes in lutjanids (snappers) and nemipterids (threadfin breams) from the western Huon Gulf and the Egyptian Red Sea (El-Moselhy *et al*., 2014), whereas mean Cu concentrations in livers were higher but also highly variable within and across species of these two reef-associated fish families.

Mean Zn concentrations also varied greatly between and across species, especially in muscle tissue of mangrove jack caught in the western Huon Gulf in November 2016 (2.70 mg kg^{-1}) versus the same species caught in Labu Lakes in May 2019 (15.24 mg kg^{-1}). The higher mean Zn concentrations in muscle of mangrove jack from Labu Lakes is likely to reflect exposure to enriched, suspended sediment-bound metals in brackish waters typical of mangrove habitats favoured by this valued recreational species. The same applies to Zn in muscle of *Nemipterus* spp. (threadfin breams), with concentrations of 2.22-2.70 mg kg^{-1} reported in *N. japonicus* from the Egyptian Red Sea compared to 6.59 mg kg^{-1} in *N. isacanthus* (teardrop threadfin bream) and 11.27 mg kg^{-1} in *N. bathybius* (yellowbelly threadfin bream) from the western Huon Gulf tested during this study (Table 18).

Greater mean concentrations of metals were found in livers than in muscle tissues in almost all fish species tested, particularly in the case of Cu and Zn. Higher metal levels in livers were also reported in previous market fish surveys in the western Huon Gulf (Coffey/Marscco, 2018), and have been reported in baseline assessment surveys of wild fish populations elsewhere in PNG, including Woodlark, Misima and Lihir islands (Coffey/Marscco, 2018) and the Fly River System (Swales *et al*., 1998), as well as marine and estuarine fish species in Malaysia (Agusa *et al*., 2005), the Egyptian Red Sea (El-Moselhy *et al*., 2014) and both Imo River (Etesin and Benson, 2007) and Lake Geriyo in Nigeria (Bawuro *et al*., 2018). Higher concentrations of metals in livers is to be expected, given that the liver has a significant function in basic metabolism, contaminant storage, redistribution, detoxification, and or transformation of metals (Etesin and Benson, 2007; El-Moselhy *et al*., 2014; Bawuro *et al*., 2018).

Liver in fishes is regarded as the “target organ” for bioaccumulation of Cu and Zn, and high levels of these two essential metals are linked with its exchange-depositing role and other metabolic functions (El-Moselhy *et al*., 2014; Bawuro *et al*., 2018). Metal uptake in fishes is highly species-specific, and the distinct variability in the levels of various metals between muscle and liver can be attributed to different bioaccumulation, biomagnification and bioregulation rates which in turn depend on factors including biotype, i.e., habitat (e.g., benthic, demersal), feeding habits (e.g., trophic position along food chain, prey items, etc.), age, sex and reproductive cycle.

Concentrations of metals in muscle tissues from fishes sourced at the DCA Point market in Lae during the November 2016 baseline survey and reported in the WGJV EIS (Coffey/Marscco, 2018) were of similar magnitude to those obtained during the present study for a given species (Table 19). For example, ranges of inorganic As, and Cu and Hg in muscle of saddletail snapper in November 2016 were 0.10-0.26 mg kg^{-1}, 0.08-0.14 mg kg^{-1} and 0.19-0.36 mg kg^{-1}, respectively (Table 19), while ranges for the same three metals in May 2019 were 0.09-0.28 mg kg^{-1}, <0.10-0.20 mg kg^{-1} and 0.09-0.50 mg kg^{-1}, respectively (Tables 6, 9, 11).

A similar magnitude and variability in baseline concentrations of Cu and Hg were observed in muscle of mangrove jack from Labu Lakes in November 2016 and in May 2019. However, baseline Zn concentrations in muscle showed a notably lower magnitude and smaller range in mangrove jack

Table 18. Mean concentrations (mg kg^{-1} ± SD ww) of selected metals in closely related species from two bony fish families sourced at markets in Lae (Coffey/Marscco, 2018) and two fish landing locations in the Egyptian Red Sea (El-Moselhy *et al.*, 2014). No SDs are provided where data correspond to one sample. PQL = Practical quantitation limit; LOR – Limit of reporting.

Family/ Genus	**Location/ Date**	**Species (n)**	**Muscle**				**Liver**			
			Cd	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**
Lutjanidae	**Western Huon Gulf**									
Lutjanus	Nov 2016	*L. malabaricus* (5)	<0.05 (PQL)	0.10 ± 0.02	<0.01 (PQL)	2.60 ± 0.47	2.00 ± 0.52	2.92 ± 1.07	<0.01 (PQL)	33.40 ± 9.63
	Nov 2016	*L. argentimaculatus* (2)	<0.05 (PQL)	0.12 ± 0.01	<0.01 (PQL)	2.70 ± 0.14	0.26 ± 0.14	11.80 ± 7.35	<0.01 (PQL)	44.50 ± 14.85
	May 2019	*L. malabaricus* (11)	<0.01 (LOR)	0.15 ± 0.05	0.11	6.83 ± 6.40	2.63 ± 2.73	4.28 ± 0.75	0.08	42.41 ± 8.83
	May 2019 (Labu Lakes)	*L. argentimaculatus* (5)	<0.01 (LOR)	0.22 ± 0.04	<0.05 (LOR)	15.24 ± 1.45	0.13 ± 0.09	8.50 ± 3.64	0.36 ± 0.20	112.97 ± 47.89
	Red Sea (Egypt)									
	Dec 2010 – Jan 2011 (Shalateen)	*L. bohar* (4)	0.03 ± 0.02	0.24 ± 0.11	0.51 ± 0.05	2.08 ± 0.28	0.86 ± 0.01	4.41 ± 0.36	0.83 ± 0.03	36.02 ± 0.26
Nemipteridae	**Western Huon Gulf**									
Nemipterus	May 19	*N. isacanthus* (9)	<0.01 (LOR)	0.46 ± 0.79	0.22	6.59 ± 5.48	2.04 ± 1.48	18.30 ± 17.91	0.08	46.04 ± 25.62
	May 19	*N. bathybius* (6)	0.05	0.15 ± 0.05	<0.05 (LOR)	11.27 ± 6.45	1.84 ± 0.99	6.40 ± 4.33	<0.05 (LOR)	101.25 ± 71.61
	Red Sea (Egypt)									
	Dec 2010 – Jan 2011 (Shalateen)	*N. japonicus* (10)	0.06 ± 0.02	0.29 ± 0.04	0.46 ± 0.15	2.22 ± 0.21	0.40 ± 0.15	2.15 ± 0.29	0.17 ± 0.02	42.50 ± 10.08
	Dec 2010 – Jan 2011 (Suez)	*N. japonicus* (10)	0.04 ± 0.01	0.20 ± 0.09	0.28 ± 0.01	2.70 ± 0.09	0.15 ± 0.03	17.54 ± 5.42	0.39 ± 0.08	60.90 ± 15.76

tested in November 2016 (2.60-2.80 mg kg-1; Table 19) compared to mangrove jack tested during the present study (14.00-17.30 mg kg-1; Table14). The same was true for Zn obtained in muscle samples of saddletail snapper tested in November 2016 (2.20-3.40 mg kg^{-1}; Table 19) compared to saddletail snapper tested in May 2019 (2.50-20.0 mg kg^{-1}; Table 14). The higher Zn concentration in muscle tissues of mangrove jack during this baseline study could be attributed to natural between-year variability from bioaccumulation and/or biomagnification. However, sampling location is likely to be a major contributing factor as all mangrove jacks tested during this study (n=5) originated from Labu Lakes, where food prey and exposure to enriched, suspended sediment-bound metals in brackish habitats could account for this finding, whereas those tested in 2016 (n=2) came from coastal marine waters in the western Huon Gulf outside Labu Lakes (Coffey/Marscco, 2018).

Table 19. Mean concentrations (mg kg^{-1} ww) of metals in muscle and liver tissue samples of five fish species from the families Lutjanidae and Carangidae sourced at the DCA Point market (Lae) in November 2016. Values in red indicate mean concentrations exceeding the FSANZ Standard for listed metal (Table 4) and have only been provided for muscle as the edible component in fishes. PQL = Practical quantitation limit; SD = standard deviation (after Coffey/Marscco, 2018).

Arsenic* (PQL 0.40 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper (Lutjanidae)	0.18	0.10	0.26	5	1.60	0.46	0.15	0.67	5	4.67
Bigeye trevally (Carangidae)	0.02	0.02	0.03	4	0.10	0.06	0.03	0.10	4	0.70
Mangrove jack (Lutjanidae)	0.06	0.02	0.11	2	1.55	0.12	0.05	0.18	2	2.05
Sharptooth jobfish (Lutjanidae)	0.06	0.03	0.08	2	0.69	0.15	0.11	0.18	2	1.27
Pennantfish (Carangidae)	0.21	0.21	0.21	1	-	0.32	0.32	0.32	1	-
Cadmium (PQL 0.05 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**		**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	<0.4	<0.4	<0.4	5	0.00	2.00	1.40	2.80	5	0.52
Bigeye trevally	<0.4	<0.4	<0.4	4	0.00	1.99	0.74	2.80	4	0.94
Mangrove jack	<0.4	<0.4	<0.4	2	0.00	0.26	0.16	0.36	2	0.14
Sharptooth jobfish	<0.4	<0.4	<0.4	2	0.00	5.90	5.50	6.30	2	0.57
Pennantfish	<0.4	<0.4	<0.4	1	-	1.30	1.30	1.30	1	-
Chromium (PQL 0.10 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	<0.4	<0.4	<0.4	5	0.00	<0.4	<0.4	<0.4	5	0.00
Bigeye trevally	<0.4	<0.4	<0.4	4	0.00	<0.4	<0.4	<0.4	4	0.00
Mangrove jack	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Sharptooth jobfish	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Pennantfish	<0.4	<0.4	<0.4	1	-	<0.4	<0.4	<0.4	1	-
Copper (PQL 0.05 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	0.10	0.08	0.14	5	0.02	2.92	1.80	4.70	5	1.07
Bigeye trevally	0.49	0.29	0.66	4	0.17	4.23	2.60	5.70	4	1.65
Mangrove jack	0.12	0.11	0.12	2	0.01	11.80	6.60	17.00	2	7.35
Sharptooth jobfish	0.14	0.11	0.16	2	0.04	4.70	4.30	5.10	2	0.57
Pennantfish	0.19	0.19	0.19	1	-	2.70	2.70	2.70	-	0.00
Lead (PQL 0.10 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	<0.4	<0.4	<0.4	5	0.00	<0.4	<0.4	<0.4	5	0.00
Bigeye trevally	<0.4	<0.4	<0.4	4	0.00	<0.4	<0.4	<0.4	4	0.00
Mangrove jack	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Sharptooth jobfish	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Pennantfish	<0.4	<0.4	<0.4	1	-	<0.4	<0.4	<0.4	1	-

Table 19. Mean concentrations (mg kg-1 ww) of metals…cont.

Mercury (PQL 0.10 mg kg^{-1})	Muscle					Liver				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	0.24	0.19	0.36	5	0.07	1.02	0.40	1.90	5	0.54
Bigeye trevally	0.52	0.34	0.71	4	0.16	1.38	0.73	2.00	4	0.66
Mangrove jack	0.04	0.03	0.05	2	0.01	0.44	0.16	0.72	2	0.40
Sharptooth jobfish	0.20	0.05	0.35	2	0.21	0.85	0.40	1.30	2	0.64
Pennantfish	0.25	0.25	0.25	1	-	0.51	0.51	0.51	1	-
Nickel (PQL 0.06 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	<0.4	<0.4	<0.4	5	0.00	0.06	0.06	0.06	5	0.00
Bigeye trevally	<0.4	<0.4	<0.4	4	0.00	<0.4	<0.4	<0.4	4	0.00
Mangrove jack	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Sharptooth jobfish	<0.4	<0.4	<0.4	2	0.00	<0.4	<0.4	<0.4	2	0.00
Pennantfish	<0.4	<0.4	<0.4	1	-	<0.4	<0.4	<0.4	1	-
Selenium (PQL 0.50 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	<0.4	<0.4	<0.4	5	0.00	2.08	1.70	2.80	5	0.43
Bigeye trevally	0.84	0.67	1.10	4	0.19	3.13	2.90	3.70	4	0.39
Mangrove jack	0.52	0.50	0.53	2	0.02	2.00	1.30	2.70	2	0.99
Sharptooth jobfish	<0.4	<0.4	<0.4	2	0.00	3.20	2.20	4.20	2	1.41
Pennantfish	<0.4	<0.4	<0.4	1	-	2.80	2.80	2.80	1	-
Zinc (PQL 0.20 mg kg^{-1})	**Muscle**					**Liver**				
Species	**Mean**	**Min**	**Max**	**n**	**SD**	**Mean**	**Min**	**Max**	**n**	**SD**
Saddletail snapper	2.60	2.20	3.40	5	0.47	33.40	22.00	48.00	5	9.63
Bigeye trevally	4.20	3.40	4.80	4	0.59	41.00	35.00	49.00	4	6.06
Mangrove jack	2.70	2.60	2.80	2	0.14	44.50	34.00	55.00	2	14.85
Sharptooth jobfish	2.45	2.40	2.50	2	0.07	53.50	49.00	58.00	2	6.36
Pennantfish	3.10	3.10	3.10	1	-	35.00	35.00	35.00	1	-

*Arsenic (As) values correspond to inorganic As following conversion from total As, i.e., total As × 0.042 (see Table 5).
Note: Two fish species listed in Table 19, i.e., saddletail snapper and mangrove jack, were also sampled in May 2019 baseline survey (this baseline study).

4.2.2 Crustaceans – giant mud crabs

All metals except Pb were detected in the left cheliped muscle tissue of the 13 giant mud crabs tested during the study; Pb was undetectable in the left cheliped muscle of all crabs (<LOR).

Mean concentrations of Cu and Cr in the cheliped muscle of giant mud crabs tested during this study were of similar magnitude to those reported in the mangrove crab *Ucides cordatus* (Family Ucididae) from the Santos-Sao Vicente estuary in Brazil (Pinheiro *et al*., 2012). However, mean Cu levels in the hepatopancreas of mud crabs from Labu Lakes was almost seven times greater than that obtained in mangrove crabs from the Brazilian estuary, i.e., 44.87 mg kg^{-1} vs. 6.64 mg kg^{-1} (Pinheiro *et al*., 2012). The finding of high levels of Cu in the hepatopancreas of giant mud crabs is associated to the role of Cu as an essential component of the crab's respiratory pigment haemocyanin (Young, 1972).

The mean Zn concentration detected in cheliped muscle of giant mud crabs from Labu Lakes (54.80 – 121.00 mg kg-1) falls within the range of that reported in the same species of giant mud crab (*Scylla serrata*) from the Fly River delta in PNG, i.e., 41.0 – 90.0 mg kg^{-1} (mean = 68.9 mg kg^{-1}; Maunsell & Partners, 1982) and coastal waters of Tanzania, i.e., 70.8 $\pm$ 9 mg kg^{-1} (Rumisha *et al*., 2017), but was much lower than mean concentrations of 170 ± 39 mg kg^{-1} and 362 ± 27 mg kg^{-1} reported in giant mud crabs from estuaries in north-eastern Australia (Mortimer, 2000) and Malaysia (Kamaruzzaman *et al*., 2012), respectively. As with giant mud crabs tested elsewhere in the word, the elevated Zn concentrations detected in cheliped muscle (and also hepatopancreas) during this baseline study can be associated with the burrowing habits of these crabs and exposure to sediment-bound metals in muddy bottoms typical of mangrove areas within Labu Lakes.

4.2.3 Molluscs – mangrove mud clams

All nine metals were detected in the 12 mangrove mud clams sourced from Labu Lakes (whole animals). However, Pb was undetectable (<LOR of 0.05 mg kg^{-1}) in seven of the 12 mud clams.

Mean concentrations of Cd, Cu, Ni and Zn detected in mud clams tested during this study were generally much lower than concentrations of these metals reported in 12 species of clams from 34 sampling sites along coastal waters of Malaysia, including *Anadara granosa* and *Marcia marmorata* (Hossen *et al*., 2015). For example, concentration ranges of 0.02-0.07 mg kg^{-1} for Cd and 16.30-68.90 mg kg^{-1} for Zn were found in mud clams from Labu Lakes, in contrast to 0.18–8.51 mg kg^{-1} for Cd and 24.13–368.00 mg kg^{-1} for Zn in clams from Malaysia (Hossan *et al*., 2015). However, the range in Cu concentration of 1.20-13.8 mg kg^{-1} detected in mud clams from Labu Lakes was comparable to the range of 0.84–36.00 mg kg^{-1} reported for Cu in clams from Malaysia (Hossan *et al*., 2015).

The overall lower concentrations of these metals in mangrove mud clams is indicative of reduced anthropogenic impacts in Labu Lake compared to the Malaysian coast, which has been affected from increased use of coastal resources leading to environmental degradation and other ecological issues (Hossan *et al*., 2015). Clams are benthic filter feeders and thus capable of ingesting metal-enriched particles directly from the water column, making them ideal target species to monitor concentrations of metals in mangrove habitats and estuaries (e.g., Adjei-Boateng *et al*., 2010). While the quantity of mangrove mud clams tested during this baseline study was relatively small (i.e., n = 12), the results indicate that metal bioaccumulation in Labu Lakes clams appears to be comparably lower than that reported in highly impacted areas such as the coast of Malaysia and, as such, should be included in future monitoring surveys of metals in Labu Lakes along with other bivalve molluscs representative of coastal waters of the western Huon Gulf.

4.3 Comparisons with FSANZ Standards and FSANZ GELs

4.3.1 Market fishes

Fish species selected for metal testing during this baseline study are representative of market species normally consumed by the local community of Lae, and hence deemed appropriate to monitor levels of trace metals that may impacts on public health associated with fish consumption.

This is especially the case with regularly available species such as saddletail snapper, teardrop threadfin beam, Malabar trevally, yellowbelly threadfin bream and mangrove jack.

In the absence of food standards or guidelines for metals in marine produce in PNG, metal concentrations obtained in muscle samples of all fish species tested during this pre-DSTP baseline study were compared against two sets of limits recommended by the joint Food Standards Australia and New Zealand (FSANZ) Act 1991 (Tables 4, 15). These comprise FSANZ Standard listed for As, Pb and Hg (maximum limits and/or means), and FSANZ GELs (90^{th} percentile concentrations) listed for Cu, Hg, Se and Zn.

No FSANZ Standard or FSANZ GELs are available for Cd, Cr or Ni for fishes. While guidelines for metals in marine products (fish, crustaceans, molluscs) are available for various regions/countries elsewhere in the world (e.g., MFR, 1985 in Hossen *et al*., 2015; EC, 2006; FAO/WHO, 1984, 2011a, b; PCR, 2012; US Environmental Protection Agency – USEPA), these were not applied during this baseline study to maintain consistency with the approach adopted for the WGJV EIS and previous metal fish surveys in PNG based on FSANZ Standard and FSANZ GELs (Coffey/Marscco, 2018).

Comparisons of metal concentration against the FSANZ standards and guidelines were limited to fish muscle tissues as limits only apply to the “portion of food that is ordinarily consumed” (FSANZ, 2001, 2016), i.e., fish flesh. Fish livers are not consumed by the local community therefore no comparisons were made of metal concentrations in fish livers against FSANZ standards in this report. However, collecting baseline data on metal concentrations in fish livers is still required for subsequent comparison with post-DSTP surveys as the fish liver is a major site of metal bioaccumulation and therefore useful in metal biomonitoring.

No exceedance of the FSANZ Standard for inorganic As (maximum limit of 2.0 mg kg^{-1}) was found in muscle tissue of fish species tested during this baseline study except for a muscle from a common pike conger, where the estimated inorganic As concentration of 3.79 mg kg^{-1} slightly exceeded the FSANZ Standard for inorganic As listed for fishes (Table 4).

No exceedances of the FSANZ Standard for Hg (mean of 0.5 mg kg^{-1} or maximum limit of 1.0 mg kg^{-1}) or the FSANZ GELs for Hg (90^{th} percentile concentrations) were found in muscle tissues of any of the 14 fish species tested during this study. Likewise, no exceedances of the FSANZ GELs for either Cu or Se (90^{th} percentile concentrations of 2.0 mg kg^{-1}) were found in muscle tissues of any of the fish species tested. However, exceedances of the FSANZ GELs for Zn (90^{th} percentile concentration of 15.0 mg kg^{-1}) were found in muscle tissues of eight of the 14 fish species tested during the study, including saddletail snapper, mangrove jack, sunbeam snapper and common pike conger.

No exceedances of the FSANZ Standard were recorded in muscle tissues in fish samples sourced from the DCA Point market in Lae during the November 2016 survey and tested to inform the EIS

(Table 19). Additional information on metals in market-sourced and field-caught fishes tested to inform the Wafi-Golpu Project Feasibility Study and EIS is provided in and Appendix P of the WGJV EIS, including detailed comparisons of metal levels with FSANZ guidelines (Coffey/Marscco, 2018), while a review of metal bioaccumulation and biomagnification from DSTP in the Huon Gulf is provided in Appendix N (Tetra Tech Inc., 2018)

4.3.2 Giant mud crabs

Edible parts of boiled giant mud crabs consumed by the local coastal communities in the western Huon Gulf include muscles inside chelipeds and walking legs, but not the hepatopancreas (digestive gland). Consequently, this section focuses only on cheliped muscle. Comparisons of metal concentrations in mud crabs sourced from Labu Lakes were made against FSANZ Standard maximum limits (As, Hg) and FSANZ GELs 90th percentile concentrations (Cu, Se, Zn) available for crustaceans (Table 4).

Total As was detected at exceptionally low concentrations in the left cheliped muscle and the hepatopancreas of all 13 mud crabs tested for this baseline study. Converting total As to inorganic As by applying the same conversion factor used in fishes, i.e., 4.2% of total As, inorganic As in the cheliped muscle (range 0.01-0.05 mg kg^{-1}) did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for inorganic As listed for crustaceans (Table 4). This finding indicates that the concentrations of inorganic As in the cheliped muscle of mud crabs are not expected to pose a risk to public health from consumption of crab meat.

Concentrations of Hg, Cu and Se detected in the cheliped muscle of the giant mud crabs tested for this baseline study did not exceed the FSANZ Standard (maximum limits, mean) or FSANZ GELs (90th percentile concentrations) for any of these three metals listed for crustaceans (Table 4). These findings indicate that Hg concentrations in cheliped muscle of mud crabs are not expected to pose a risk to public health from consumption of crab meat, while Cu and Se concentrations were below the generally expected levels for these metals in crustaceans.

The maximum Zn concentration of 121.00 mg kg^{-1} detected in the cheliped muscle of mud crabs (mean = 81.81 mg kg^{-1}) greatly exceeded the FSANZ GEL 90th percentile concentration of 40.00 mg kg^{-1} for Zn listed for crustaceans (Table 4). The maximum Zn concentration in cheliped muscle of mud crabs is almost half of that detected in the hepatopancreas (i.e., maximum of 236.00 mg kg^{-1}), which is expected given its role as main digestive gland in crustaceans. Such high Zn concentrations can be attributed to the burrowing habits of mud crabs in muddy sediments typical of mangrove areas within Labu Lakes, in particular exposure to and ingestion of enriched particulate matter while mobilising sediment-bound metals during feeding (Rumisha *et al*., 2017). Elevated Zn concentrations have been found in the same species of edible giant mud crab from other estuarine/coastal marine environments worldwide and have reported to cause no adverse health risks to shellfish consumers in those locations (e.g., Maunsell & Partners, 1982; Mortimer, 2000; Kamaruzzaman *et al*., 2012; Rumisha *et al*., 2017). Given the variety of nutritional and metabolic functions of Zn, the elevated concentrations of Zn detected during this study are not expected to pose a risk to public health from consumption of mud crabs from Labu Lakes.

4.3.3 Mangrove mud clams

Comparisons of metal concentrations in whole mangrove mud clams sourced from Labu Lakes were made against the FSANZ Standard maximum limits (As, Cd, Pb, Hg) and FSANZ GELs 90th percentile concentrations (Cu, Se) available for molluscs (Table 4).

No exceedances of the FSANZ Standard or FSANZ GELs were found for inorganic As, or for Cd, Cu, Pb, Hg and Se detected in any of the 12 mangrove mud clams tested during this baseline study. These findings indicate that As, Pb and Hg concentrations in mangrove mud clams are not expected to pose a risk to public health from consumption of mud clams, while Cd, Cu and Se concentrations were below the generally expected levels for these metals in molluscs.

4.4 Key findings

The main findings of this second local artisanal fishery baseline study on metals in selected coastal market fish species and invertebrates from the western Huon Gulf are outlined below.

4.4.1 Fish species tested

- The 14 species of bony fishes tested for metals during this baseline study are typically caught by the local artisanal fishery in waters of the western Huon Gulf, including Labu Lakes, outside the predicted DSTP deep water canyon receiving environment. All fish species tested are regarded as representatives of the Huon Gulf and therefore suitable for future metal biomonitoring surveys.

- Fishes sourced for this study did not include samples from the predicted DSTP outfall and tailings placement area to the south of Lae as no fishing takes place in that area due to depth of the water column (>100 m) and lack of seabed rocky reef structures that support fish species typically captured for human consumption.

- The most abundant market fish species tested during this baseline study were mangrove jack from Labu Lakes (n = 5), and saddletail snapper (n = 11), teardrop threadfin bream (n = 9), Malabar trevally (n = 6), yellowbelly threadfin bream (n = 6) and common pike conger (n = 4) from inshore waters off Lae outside Labu Lakes.

4.4.2 Metal concentrations in fish tissues

- Nine metals were tested in muscle tissue samples and livers of 56 specimens from 14 bony fish species sourced for this baseline study: Arsenic (As); Cadmium (Cd); Chromium (Cr); Copper (Cu); Lead (Pb); Mercury (Hg); Nickel (Ni); Selenium (Se); and Zinc (Zn). Based on published work, Cr, Cu, Se and Zn are considered essential metals, whereas As, Cd, Pb, Hg and Ni are considered non-essential metals.

- Metal concentrations in muscle tissues and livers of all 14 fish species tested varied between individuals of the same species (intraspecific variability) as well as across species of the same genus and species from different families (interspecific variability). Variability was significant in some cases, based on large standard deviations (SDs) of means.

- Intraspecific and interspecific variability in metal bioaccumulation is typical of marine and estuarine fishes occurring in coastal environments elsewhere in PNG, and has been well described in literature pertaining to metals in fishes as highly species-specific, age-and-size specific and tissue-specific.

- The variability in metal levels observed during this study can be attributed to a combination of factors including natural local sources (e.g., continuous sediment loading from rivers discharging into the western Huon Gulf), anthropogenic activities (e.g., port shipping, existing wastewater discharges from Lae), and contaminated sediment from existing mines and small-scale mining operations in the Markham river catchment.

- Overall, higher metal concentrations were detected in livers than in muscle tissues of almost all fish species tested during this baseline study, particularly for essential metals Cu and Zn.

- Higher concentrations of metals in fish livers compared to muscle tissues were also described in the initial baseline survey of market fishes from the western Huon Gulf tested to inform the EIS, and have been reported in baseline surveys of wild-caught fishes elsewhere in PNG (e.g., Woodlark, Misima and Lihir islands, Fly River System) and other localities worldwide.

- The higher metal concentrations in liver can be attributed to the range of metabolic, storage and detoxification functions of the liver in fishes, as well as different bioaccumulation, biomagnification and bioregulation rates which in turn depend on factors including biotype (i.e., habitat), feeding habits (e.g., trophic level along food chain), age, sex and reproductive cycle.

- Fish livers are not consumed by the local community. However, testing of metal concentrations in fish livers is being included in baseline monitoring surveys for comparison with future post-DSTP surveys as the liver is a major site of metal bioaccumulation and hence useful in metal biomonitoring for changes over time.

- Of the nine metals tested, Cr, Cd, Ni and Pb in muscle tissues of most fish species tested were detected in extremely low concentrations or were undetectable, i.e., below the Limit of Reporting (<LOR). Similarly, Cu, Se and Hg were present in low concentrations in muscle tissues of most fish species tested.

- Arsenic (measured as total As) and Zn were detected in much higher concentrations than all other metals in muscle tissue of all fish species tested, with highest As and Zn levels recorded in muscle tissues of a sunbeam snapper (Family Lutjanidae) and a common pike conger (Family Muraenesocidae), respectively.

Comparisons with FSANZ Standard and FSANZ GELs

- Concentrations of metals in muscle tissues from all fish species tested during this baseline study were checked against the recommended guidelines for metal contaminants in marine produce listed by the FSANZ Standard (FSANZ, 2016) and the FSANZ GELs.

- Guidelines for various metals in marine produce are available for various regions and/or countries elsewhere in the world. However, these were not consulted during this study in order to maintain consistency with the EIS approach and other metal fish surveys conducted elsewhere in PNG.

- No FSANZ Standard or FSANZ GELs are available for Cd, Cr or Ni for fishes.

- Comparisons of metal concentration against the FSANZ standards and guidelines were limited to fish muscle tissue as limits only apply to the portion of food that is typically consumed by the local community, i.e., fish flesh. Fish livers are not consumed by the local community, therefore no comparisons of metal concentrations in fish livers with FSANZ standards are reported.

- The FSANZ Standard for As pertains to inorganic As, and not to total As as measured in metal analysis. Therefore, to compare As levels with the FSANZ Standard, total As concentrations detected in fish species during this study were converted to inorganic As using a conservative ratio of 0.042 (i.e., 4.2% of total As) derived from published laboratory work on several marine fish species independent to this study.

- Non-essential metals (As, Pb, Hg) for which maximum limits have been set by FSANZ Standard for fishes, and whose potential toxicity and bioaccumulation rates would be expected to pose a risk to public health from consumption of fish:

- Mean concentrations of inorganic As in muscle tissues of all fish species tested during this baseline study did not exceed the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for fishes.
- The maximum estimated inorganic As concentration of 3.79 mg kg^{-1} in the muscle tissue of one common pike conger, corresponding to 4.2% of a total As of 90.20 mg kg^{-1}, slightly exceeded the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for fish muscle.
- Based on the low levels of inorganic As in muscle tissues estimated during this baseline study, and the fact that As in fish is mostly present in a non-toxic organic form, no adverse health issues are expected to manifest in the local community from the consumption of muscle (flesh) from any of the fish species tested.
- Concentrations of Pb in muscle tissues of almost all fish species tested were undetectable (<LOR of 0.05 mg kg^{-1}), and consequently did not exceed the FSANZ Standard of 0.5 mg kg^{-1} for Pb listed for fishes. Therefore, Pb concentrations detected during this baseline study are not expected to pose a risk to public health from the consumption of muscle (flesh) from fish species tested.
- Mean Hg concentrations in muscle tissues of all fish species tested did not exceed either the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum limit of 1.0 mg kg^{-1} for Hg listed for fish. Therefore, Hg concentrations detected during this baseline study are not expected to pose a risk to public health from the consumption of muscle (flesh) from fish species tested.
- Maximum Hg concentrations in muscle tissues did not exceed the recommended FSANZ GELs 90^{th} percentile concentration of 2.0 mg kg^{-1} for fish muscle in any of the fish species tested and were therefore within the range of generally expected levels.

• Essential metals (Cu, Se and Zn) for which FSANZ GELs guidelines have been established by for fishes:

- Mean and maximum Cu concentrations in muscle tissues of all fish species tested did not exceed the FSANZ GELs 90^{th} percentile concentration of 2.0 mg kg^{-1} for Cu listed for fishes, and were therefore within the range of generally expected levels.
- Concentrations of Se detected in muscle tissues of all fish species tested did not exceed the FSANZ GELs 90^{th} percentile concentration of 2.0 mg kg^{-1} for Se listed for fishes and were therefore within the range of generally expected levels.
- Maximum Zn concentrations detected in muscle tissues of eight of the 14 fish species tested exceeded the FSANZ GELs 90^{th} percentile concentration of 15.0 mg kg^{-1} for Zn and were therefore outside the range of generally expected levels. Exceedances in maximum Zn concentrations were found in species such as teardrop threadfin bream (16.0 mg kg^{-1}), yellowbelly threadfin bream (17.8 mg kg^{-1}), common pike conger (17.9 mg kg^{-1}), saddletail snapper (20.0 mg kg^{-1}) and sunbeam snapper (26.20 mg kg^{-1}).
- Zinc is an essential metal required for various biochemical and physiological functions including as a component of metalloenzymes and as a catalyst for regulating activity of many specific

zinc-dependent enzymes. Given the key role of Zn in diverse metabolic body functions, the elevated maximum Zn concentrations detected in some fish species during this study are not expected to pose a risk to local community health from the consumption of muscle (flesh) from the species tested.

- Other metals (Cd, Cr, Ni) for which no FSANZ Standard or FSANZ GELs guidelines have been established for fishes:

  - Cadmium (Cd) was undetectable (<LOR of 0.01 mg kg^{-1}) in muscle tissues of almost all fish species tested.
  - Chromium (Cr) was detected at very low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1}) in muscle tissues of all fish species tested except Malabar trevally, which returned a maximum muscle Cr concentration of 4.77 mg kg^{-1}.
  - Nickel (Ni) was undetectable (<LOR of 0.05 mg kg^{-1}) in muscle tissues of most fish species tested except for very low Ni concentrations of 0.09 mg kg^{-1} detected in muscle tissue of a sunbeam snapper and 0.40 mg kg^{-1} detected in muscle tissue of a Malabar trevally.

Comparisons with previous baseline market fish survey reported in the WGJV EIS

- Concentrations of Zn in muscle tissues from mangrove jack (Family Lutjanidae) reported in this baseline study were significantly higher than those obtained in muscle of this species tested during the initial baseline survey carried out in November 2016 to inform the WGJV EIS, i.e., 14.0-17.30 mg kg^{-1} in May 2019 (this study) vs. 2.60-2.80 mg kg^{-1} in 2016.

- The higher Zn concentrations detected in mangrove jack during this study can be attributed to natural between-year variability from bioaccumulation and/or biomagnification. However, sampling location is possibly a major contributing factor as all mangrove jack tested during this study (n=5) originated from Labu Lakes, where food prey and exposure to enriched, suspended sediment-bound metals in brackish habitats could account for the higher Zn levels, whereas the mangrove jack in 2016 (n=2) were fished from coastal marine waters in the western Huon Gulf outside Labu Lakes.

4.4.3 Metal concentrations in mud crab tissues

- Metal testing of the left cheliped muscle and hepatopancreas (digestive gland) was carried out on a single species of giant mud crab sourced from Labu Lakes. The findings outlined below focus only on muscle tissue as the edible part of boiled mud crabs consumed by the local coastal community.

- Non-essential metals (As, Hg) for which maximum limits have been set by FSANZ Standard for crustaceans, and whose potential toxicity and bioaccumulation rates would be expected to pose a risk to human health from consumption of mud crabs:
  - The maximum estimated inorganic As concentration of 0.05 mg kg^{-1} in the left cheliped muscle of mud crabs tested, corresponding to 4.2% of a total As of 1.28 mg kg^{-1}, did not exceed the FSANZ Standard maximum level of 2.0 mg kg^{-1} for inorganic As listed for crustaceans. Therefore, inorganic As concentrations estimated in cheliped muscle of mud crabs during this study are not expected to pose a risk to public health from consumption of meat from Labu Lakes mud crabs.
  - Concentrations of Hg detected in cheliped muscle of mud crabs tested did not exceed either the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum limit of 1.0 mg kg^{-1} for Hg listed for crustaceans. Therefore, Hg concentrations detected in cheliped muscle of mud crabs during this study are not expected to pose a risk to public health from consumption of meat from Labu Lakes mud crabs.

- Essential metals (Cu, Se and Zn) for which FSANZ GELs guidelines have been established by for crustaceans:

  - Concentrations of Cu detected in cheliped muscle of all mud crabs tested (maximum of 13.70 mg kg^{-1}) did not exceed the FSANZ GELs 90^{th} percentile concentration of 20.0 mg kg^{-1} for Cu listed for crustaceans, and were therefore within the range of generally expected levels.
  - Concentrations of Se detected in cheliped muscle of all mud crabs tested (maximum of 0.75 mg kg^{-1}) did not exceed the FSANZ GELs 90^{th} percentile concentration of 1.0 mg kg^{-1} for Se listed for crustaceans, and were therefore within the range of generally expected levels.
  - Concentrations of Zn detected in cheliped muscle of all mud crabs tested (maximum of 121.00 mg kg^{-1}) greatly exceeded the FSANZ GELs 90^{th} percentile concentration of 40.0 mg kg^{-1} for Zn listed for crustaceans, and were therefore well outside the range of generally expected levels.
  - The elevated Zn concentrations in cheliped muscle (and hepatopancreas) can be directly associated to the burrowing habits of mud crabs in muddy sediments typical of mangrove areas within Labu Lakes, as well as ingestion of enriched particulate matter while mobilising sediments during feeding.
  - Elevated Zn concentrations have been found in the same species of edible giant mud crab (*Scylla serrata*) from other estuarine/coastal environments worldwide and have reported to cause no adverse health risks to shellfish consumers in those locations. Given the key role of Zn in diverse metabolic body functions, the elevated concentrations of Zn detected during this study are not expected to pose a risk to public health from the consumption of meat from Labu Lakes mud crabs.

- Other metals (Cd, Cr, Pb, Ni) for which no FSANZ Standard or FSANZ GEL guidelines have been established for crustaceans:

- Cadmium (Cd) in cheliped muscle was undetectable (<LOR of 0.01 mg kg^{-1} in 11 of 13 samples) in almost all mud crabs tested.
- Chromium (Cr) in cheliped muscle of mud crabs was detected at exceptionally low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1} in 5 of 13 samples); the maximum Cr concentration detected was 0.44 mg kg^{-1}.
- Lead (Pb) in cheliped muscle was undetectable (<LOR of 0.05 mg kg^{-1}) in all mud crabs tested.
- Nickel (Ni) in cheliped muscle was undetectable (<LOR of 0.05 mg kg^{-1} in 11 of 13 samples) in almost all mud crabs tested; the maximum Ni concentration detected was 0.39 mg kg^{-1}.

4.4.3 Metal concentrations in mud clams

- Metal testing of soft tissues was carried out on a single species of mangrove mud clam (whole animal) sourced from Labu Lakes.

- Non-essential metals (As, Cd, Pb, Hg) for which maximum limits have been set by FSANZ Standard for molluscs, and whose potential toxicity and bioaccumulation rates are expected to pose a risk to human health from consumption of mud clams:

  - The maximum estimated concentration of inorganic As of 0.04 mg kg^{-1} in mud clams, corresponding to 4.2% of a total As of 0.99 mg kg^{-1}, did not exceed the FSANZ Standard maximum limit of 1.0 mg kg^{-1} for inorganic As listed for molluscs. Therefore, inorganic As concentrations estimated in mud clams during this study are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
  - The maximum Cd concentration of 0.07 mg kg^{-1} detected in mud clams did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Cd listed for molluscs. Therefore, Cd concentrations detected in mud clams during this study are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
  - Concentrations of Hg detected in mud clams did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum limit of 1.0 mg kg^{-1} for Hg listed for molluscs. Therefore, Hg concentrations detected in mud clams during this study are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.
  - The maximum Pb concentration of 0.24 mg kg^{-1} detected in mud clams did not exceed the FSANZ Standard maximum limit of 2.0 mg kg^{-1} for Pb listed for molluscs. Therefore, Pb concentrations detected in mud clams during this study are not expected to pose a risk to public health from consumption of Labu Lakes mud clams.

- Essential metals (Cu, Se) for which FSANZ GELs guidelines have been established by for molluscs:

- Concentrations of Cu detected in mud clams (maximum of 13.8 mg kg^{-1}) did not exceed the FSANZ GEL 90^{th} percentile concentration of 30.0 mg kg^{-1} for Cu listed for molluscs, and were therefore within the range of generally expected levels.
- Concentrations of Se detected in mud crabs (maximum of 0.65 mg kg^{-1}) did not exceed the FSANZ GEL 90^{th} percentile concentration of 1.0 mg kg^{-1} for Se listed for molluscs, and were therefore within the range of generally expected levels.

• Other metals (Cr, Ni, Zn) for which no FSANZ Standard or FSANZ GEL guidelines have been established for molluscs:

- Chromium (Cr) in mud clams was detected at low concentrations or was undetectable (<LOR of 0.05 mg kg^{-1} in 2 of 13 samples); the maximum Cr concentration detected was 1.16 mg kg^{-1}.
- Nickel (Ni) was detected in all 13 mud clams and ranged from 0.16 to 1.18 mg kg^{-1} (mean of 0.51 mg kg^{-1}).
- Zinc (Zn) was detected in all 13 mud clams and ranged from 16.30 to 68.90 mg kg^{-1} (mean of 41.57 mg kg^{-1}).

5 UNITS AND ABBREVIATIONS

As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
DCA	Department of Civil Aviation
DSTP	Deep-sea tailings placement
EIS	Environmental Impact Statement
FSANZ	Food Standards Australia New Zealand
GEL	Generally expected level
Hg	Mercury
LOR	Limit of reporting
mg kg^{-1}	milligram per kilogram
n	number of samples
Ni	Nickel
Pb	Lead
PNG	Papua New Guinea
PQL	Practical quantitation limit
SD	Standard deviation
Se	Selenium
ww	wet weight
WGJV	Wafi-Golpu Joint Venture
Zn	Zinc

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8 APPENDICES

Appendix 1

Quantity of muscle and liver tissues collected from market-sourced fishes for heavy metals analysis; N/A = not available.

Appendix 2

Quantity of left cheliped muscle and hepatopancreas tissues obtained from giant mud crabs sourced from Labu Lakes on 4 May 2019 for metal analysis.

Appendix 3

Total number of mangrove mud clams sourced from Labu Lakes on 4 May 2019 and processed whole for metals analysis.

Appendix 4

ALS Global Sample Receipt Notification (SRN) corresponding to Work Order ES1914646.

Appendix 5

ALS Global Sample Receipt Notification (SRN) corresponding to Work Order ES1914661

Appendix 6

ALS Global QA/QC Compliance Assessment to assist with Quality Review for Work Order ES1914646.

Appendix 7

ALS Global QA/QC Compliance Assessment to assist with Quality Review for Work Order ES1914661.

Appendix 8

ALS Global Quality Control Report for Work Order ES1914646.

Appendix 9

ALS Global Quality Control Report for Work Order ES1914661.

Appendix 1. Quantity of muscle and liver tissues collected from market-sourced fishes for heavy metals analysis; N/A = not available.

Fish No.	Date processed	Location (origin)	Common name	Total length (cm)	Weight (g)	Sex	Otoliths	Muscle tissue		Liver tissue	
								Sample	Quantity (g)	Sample	Quantity (g)
1	6-May-19	Labu Lakes	White-dotted grouper	37.4	683.0	N/A	+	LL-1-M	20.25	LL-1-L	1.24
2	6-May-19	Labu Lakes	White-dotted grouper	31.1	387.0	N/A	+	LL-2-M	23.40	N/A	N/A
3	6-May-19	Labu Lakes	Mangrove jack	29.0	397.0	M	+	LL-3-M	25.85	N/A	N/A
4	6-May-19	Labu Lakes	Mangrove jack	36.0	770.0	M	+	LL-4-M	35.52	LL-4-L	5.72
5	6-May-19	Labu Lakes	Squaretail mullet	25.0	158.9	N/A	+	LL-5-M	8.14	N/A	N/A
6	6-May-19	Labu Lakes	Spangled gudgeon	29.0	262.0	N/A	+	LL-6-M	8.75	LL-6-L	4.20
7	7-May-19	Huon Gulf	Saddletail snapper	36.0	734.2	F	+	HG-1-M	32.20	HG-1-L	4.31
8	7-May-19	Huon Gulf	Saddletail snapper	355.2	670.0	F	+	HG-2-M	29.95	HG-2-L	3.04
9	7-May-19	Huon Gulf	Saddletail snapper	475.0	1,700.0	M	+	HG-3-M	44.47	HG-3-L	11.23
10	7-May-19	Huon Gulf	Teardrop threadfin bream	320.0	308.2	M	+	HG-4 -M	19.14	HG-4-L	4.42
11	7-May-19	Huon Gulf	Teardrop threadfin bream	305.0	284.2	F	+	HG-5-M	16.91	HG-5-L	3.84
12	7-May-19	Huon Gulf	Malabar trevally	330.0	500.0	M	-	HG-6-M	23.23	HG-6-L	3.94
13	9-May-19	Labu Lakes	Mangrove jack	21.8	167.0	I	+	LL-7-M	7.91	LL-7-L	0.25
14	9-May-19	Labu Lakes	Mangrove jack	21.3	165.8	I	+	LL-8-M	10.15	N/A	N/A
15	9-May-19	Labu Lakes	Mangrove jack	20.4	150.5	I	+	LL-9-M	10.09	LL-9-L	0.76
16	9-May-19	Huon Gulf	Teardrop threadfin bream	30.0	223.0	I	+	HG-7-M	11.44	HG-7-L	2.62
17	9-May-19	Huon Gulf	Teardrop threadfin bream	31.0	275.1	M	+	HG-8-M	16.25	HG-8-L	1.98
18	9-May-19	Huon Gulf	Yellowbelly threadfin bream	29.5	202.6	I	+	HG-9-M	8.88	HG-9-L	1.10
19	9-May-19	Huon Gulf	Teardrop threadfin bream	26.1	155.5	F	+	HG-10-M	10.79	HG-10-L	1.98
20	9-May-19	Huon Gulf	Yellowbelly threadfin bream	27.5	159.5	I	+	HG-11-M	7.19	HG-11-L	0.96
21	9-May-19	Huon Gulf	Firelined threadfin bream	26.0	171.9	I	+	HG-12-M	10.50	HG-12-L	1.38
22	9-May-19	Huon Gulf	Firelined threadfin bream	24.7	151.3	I	+	HG-13-M	9.71	HG-13-L	1.15

Fish No.	Date processed	Location (origin)	Common name	Total length (cm)	Weight (g)	Sex	Otoliths	Muscle tissue		Liver tissue	
								Sample	Quantity (g)	Sample	Quantity (g)
23	9-May-19	Huon Gulf	Teardrop threadfin bream	26.5	176.8	F	+	HG-14-M	11.09*	HG-14-L	1.79
24	9-May-19	Huon Gulf	Teardrop threadfin bream	25.3	154.0	I	-	HG-15-M	10.27	HG-15-L	2.06
25	9-May-19	Huon Gulf	Doublewhip threadfin bream	21.6	85.1	I	+	HG-16-M	7.02	HG-16-L	0.40**
26	10-May-19	Huon Gulf	Saddletail snapper	34.7	651.7	I	+	HG-17-M	36.60	HG-17-L	2.33
27	10-May-19	Huon Gulf	Saddletail snapper	29.0	407.2	I	+	HG-18-M	21.00	HG-18-L	1.70
28	10-May-19	Huon Gulf	Saddletail snapper	28.1	347.5	F	+	HG-19-M	22.84	HG-19-L	1.32
29	10-May-19	Huon Gulf	Saddletail snapper	25.0	231.2	F	+	HG-20-M	16.34	HG-20-L	0.76
30	10-May-19	Huon Gulf	Saddletail snapper	27.7	343.1	F	+	HG-21-M	22.20	HG-12-L	1.57
31	10-May-19	Huon Gulf	Malabar trevally	39.8	859.1	M	-	HG-22-M	40.88	HG-22-L	5.52
32	10-May-19	Huon Gulf	Malabar trevally	35.5	676.0	F	-	HG-23-M	33.58	HG-23-L	7.26
33	10-May-19	Huon Gulf	Malabar trevally	34.0	592.6	M	-	HG-24-M	28.45	HG-24-L	5.51
34	10-May-19	Huon Gulf	Malabar trevally	28.5	318.2	I	-	HG-25-M	18.04	HG-25-L	2.01
35	10-May-19	Huon Gulf	Malabar trevally	28.0	322.9	F	-	HG-26-M	15.75	HG-26-L	3.78
36	10-May-19	Huon Gulf	Tille trevally	32.5	440.3	I	-	HG-27-M	21.50	HG-27-L	5.10
37	10-May-19	Huon Gulf	Tille trevally	29.3	336.5	I	-	HG-28-M	18.20	HG-28-L	2.92
38	10-May-19	Huon Gulf	Coastal trevally	21.0	149.8	F	-	HG-29-M	11.06	HG-29-L	1.47
39	10-May-19	Huon Gulf	Coastal trevally	19.5	108.2	F	-	HG-30-M	6.57	HG-30-L	0.52
40	10-May-19	Huon Gulf	Sunbeam snapper	18.0	90.6	F	+	HG-31-M	7.60	HG-31-L	0.46
41	10-May-19	Huon Gulf	Sunbeam snapper	15.1	50.6	F	+	HG-32-M	4.08	HG-32-L	0.22**
42	10-May-19	Huon Gulf	Sunbeam snapper	17.6	85.4	M	+	HG-33-M	7.01	HG-33-L	0.54
43	10-May-19	Huon Gulf	Saddletail snapper	67.0	4,100.0	M	+	HG-34-M	30.00	HG-34-L	22.30
44	11-May-19	Huon Gulf	Saddletail snapper	41.0	1,093.0	F	+	HG-35-M	54.4	HG-35-L	5.29
45	11-May-19	Huon Gulf	Saddletail snapper	50.0	1,750.0	M	+	HG-36-M	37.86	HG-36-L	7.48
46	11-May-19	Huon Gulf	Yellowbelly threadfin bream	27.0	158.8	F	+	HG-37-M	8.84	HG-37-L	0.95
47	11-May-19	Huon Gulf	Yellowbelly threadfin bream	23.0	102.4	M	+	HG-38-M	5.24	HG-38-L	0.27

Fish No.	Date processed	Location (origin)	Common name	Total length (cm)	Weight (g)	Sex	Otoliths	Muscle tissue		Liver tissue	
								Sample	Quantity (g)	Sample	Quantity (g)
48	11-May-19	Huon Gulf	Yellowbelly threadfin bream	21.0	90.9	I	+	HG-39-M	5.50	HG-39-L	0.62
49	11-May-19	Huon Gulf	Yellowbelly threadfin bream	20.1	79.0	I	+	HG-40-M	6.34	HG-40-L	0.22
50	11-May-19	Huon Gulf	Doublewhip threadfin bream	25.0	100.2	M	+	HG-41-M	9.36	HG-41-L	0.52
51	11-May-19	Huon Gulf	Teardrop threadfin bream	24.0	139.4	F	+	HG-42-M	9.81	HG-42-L	1.81
52	11-May-19	Huon Gulf	Teardrop threadfin bream	23.0	112.8	F	+	HG-43-M	8.61	HG-43-L	1.55
53	11-May-19	Huon Gulf	Common pike conger	95.0	1,000.0	F	+	HG-44-M	24.05	HG-44-L	7.12
54	11-May-19	Huon Gulf	Common pike conger	101.2	1,800.0	M	+	HG-45-M	28.45	HG-45-L	13.09
55	11-May-19	Huon Gulf	Common pike conger	87.0	877.0	M	+	HG-46-M	15.07	HG-46-L	11.63
56	11-May-19	Huon Gulf	Common pike conger	93.0	763.0	M	+	HG-47-M	18.23	HG-47-L	11.30

Notes:

* Sample lost

** Insufficient sample for analysis

Appendix 2. Quantity of left cheliped muscle and hepatopancreas tissues obtained from giant mud crabs sourced from Labu Lakes on 4 May 2019 for metal analysis.

Crab No.	Date processed	Carapace length (mm)	Total weight (g)	Sex	Cheliped muscle		Hepatopancreas	
					Sample	Quantity (g)	Sample	Quantity (g)
1	6-May-19	102	186.5	M	LL-C-1-CM	8.10	LL-C-1-H	1.15
2	6-May-19	115	213.5	F	LL-C-2-CM	3.81	LL-C-2-H	4.88
3	6-May-19	116	201.6	M	LL-C-3-CM	4.14	LL-C-3-H	6.35
4	6-May-19	101	187.5	F	LL-C-4-CM	9.24	LL-C-4-H	3.27
5	6-May-19	105	170.7	F	LL-C-5-CM	5.21	LL-C-5-H	2.13
6	6-May-19	128	204.1	M	LL-C-6-CM	3.85	LL-C-6-H	2.18
7	6-May-19	106	168.4	F	LL-C-7-CM	5.86	LL-C-7-H	1.17
8	6-May-19	112	197.8	M	LL-C-8-CM	5.95	LL-C-8-H	1.69
9	6-May-19	95	110.7	F	LL-C-9-CM	1.84	LL-C-9-H	1.60
10	6-May-19	112	180.8	M	LL-C-10-CM	3.87	LL-C-10-H	1.34
11	6-May-19	112	141.7	F	LL-C-11-CM	0.91	LL-C-11-H	4.11
12	8-May-19	125	376.9	M	LL-C-12-CM	11.68	LL-C-12-H	6.62
13	8-May-19	113	314.9	M	LL-C-13-CM	8.83	LL-C-13-H	6.01

Appendix 3. Total number of mangrove mud clams sourced from Labu Lakes on 4 May 2019 and processed whole for metals analysis.

Clam No.	Date processed	Total weight (+ shell; g)	Whole animal	
			Sample	Quantity (g)
1	6-May-19	54.3	LL-K-1	10.05
2	6-May-19	55.4	LL-K-2	5.24
3	6-May-19	41.1	LL-K-3	6.45
4	6-May-19	33.2	LL-K-4	5.76
5	6-May-19	23.7	LL-K-5	3.51
6	6-May-19	30.6	LL-K-6	6.16
7	6-May-19	26.5	LL-K-7	4.52
8	6-May-19	20.0	LL-K-8	2.48
9	6-May-19	11.3	LL-K-9	1.63
10	6-May-19	16.2	LL-K-10	2.34
11	6-May-19	17.0	LL-K-11	2.47
12	6-May-19	13.8	LL-K-12	1.36

Appendix 4

ALS Global Sample Receipt Notification (SRN) for Work Order ES1914646.

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES1914646**		
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Contact	: Customer Services ES
Address	: LEVEL 2 189 CORONATION DRIVE MILTON QLD, AUSTRALIA 4064	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: Tim.Wrigley@WafiGolpuJV.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: PNG Fish sample metal testing study	Page	: 1 of 7
Order number	:	Quote number	: ES2019WAFGOL0001 (SY/206/19)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRS		

Dates

Date Samples Received	: 15-May-2019 10:00	Issue Date	: 31-May-2019
Client Requested Due Date	: 30-May-2019	Scheduled Reporting Date	: **30-May-2019**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: -3.2 - Ice present
Receipt Detail	:	No. of samples received / analysed	: 84 / 84

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **This work order has been split into ES1914661.**
- **All samples on COC page number 16 were prawns, which were confiscated. ALS has not received these samples.**
- **Sample 'HG - 14 - M' was not received.**
- **Sample 'HG - 17 - M' has the ID 'HG - 17 - L' on the sampling bags, however the weight matches the weight on the COC.**
- **31/5/19 - This is an updated SRN. Metals (EG094) cannot be conducted for samples @27, 32 and 64 due to insufficient sample.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

Method *Client sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-MS : EG094-B		
HG - 1 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 1 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 2 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 2 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 3 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 3 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 4 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 4 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 5 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 5 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 6 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 7 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 7 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 8 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 8 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 9 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 9 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 10 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 10 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 11 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 11 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 12 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 12 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 13 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 13 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 14 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 15 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 15 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 16 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 17 - M HG - 17 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 17 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 18 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 18 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 19 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 19 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 20 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 20 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 21 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 21 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 22 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 22 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 23 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 23 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 24 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 24 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 25 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 25 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 26 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 26 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 27 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 27 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 28 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 28 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 29 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 29 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 30 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 30 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 31 - M	- Snap Lock Bag - frozen	- Frozen Sample

Method *Client sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-MS : EG094-B		
HG - 31 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 32 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 33 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 33 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 34 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 34 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 35 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 35 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 36 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 36 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 37 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 37 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 38 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 38 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 39 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 39 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 40 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 40 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 41 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 41 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 42 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 42 - L	- Snap Lock Bag - frozen	- Frozen Sample
Total Mercury by FIMS : EG035-B		
HG - 1 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 1 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 2 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 2 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 3 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 3 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 4 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 4 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 5 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 5 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 6 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 7 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 7 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 8 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 8 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 9 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 9 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 10 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 10 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 11 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 11 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 12 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 12 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 13 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 13 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 14 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 14 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 15 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 15 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 16 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 16 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 17 - M HG - 17 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 17 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 18 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 18 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 19 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 19 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 20 - M	- Snap Lock Bag - frozen	- Frozen Sample

Method *Client sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Total Mercury by FIMS : EG035-B		
HG - 20 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 21 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 21 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 22 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 22 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 23 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 23 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 24 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 24 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 25 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 25 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 26 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 26 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 27 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 27 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 28 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 28 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 29 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 29 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 30 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 30 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 31 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 31 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 32 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 32 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 33 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 33 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 34 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 34 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 35 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 35 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 36 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 36 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 37 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 37 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 38 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 38 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 39 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 39 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 40 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 40 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 41 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 41 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 42 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 42 - L	- Snap Lock Bag - frozen	- Frozen Sample

Any sample identifications that cannot be displayed entirely in the analysis summary table will be listed below.

ES1914646-033 : 10-May-2019 09:00 : HG - 17 - M - HG - 17 - L

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **BIOTA**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)	BIOTA - EG094-B Metals in Biota by ICP-MS
ES1914646-001	07-May-2019 08:00	HG - 1 - M	✓	✓
ES1914646-002	07-May-2019 08:00	HG - 1 - L	✓	✓
ES1914646-003	07-May-2019 08:00	HG - 2 - M	✓	✓
ES1914646-004	07-May-2019 08:00	HG - 2 - L	✓	✓
ES1914646-005	07-May-2019 08:00	HG - 3 - M	✓	✓
ES1914646-006	07-May-2019 08:00	HG - 3 - L	✓	✓
ES1914646-007	07-May-2019 08:00	HG - 4 - M	✓	✓
ES1914646-008	07-May-2019 08:00	HG - 4 - L	✓	✓
ES1914646-009	07-May-2019 08:00	HG - 5 - M	✓	✓
ES1914646-010	07-May-2019 08:00	HG - 5 - L	✓	✓
ES1914646-011	07-May-2019 08:00	HG - 6 - M	✓	✓
ES1914646-012	07-May-2019 08:00	HG - 6 - L	✓	✓
ES1914646-013	09-May-2019 19:00	HG - 7 - M	✓	✓
ES1914646-014	09-May-2019 19:00	HG - 7 - L	✓	✓
ES1914646-015	09-May-2019 19:00	HG - 8 - M	✓	✓
ES1914646-016	09-May-2019 19:00	HG - 8 - L	✓	✓
ES1914646-017	09-May-2019 19:00	HG - 9 - M	✓	✓
ES1914646-018	09-May-2019 19:00	HG - 9 - L	✓	✓
ES1914646-019	09-May-2019 19:00	HG - 10 - M	✓	✓
ES1914646-020	09-May-2019 19:00	HG - 10 - L	✓	✓
ES1914646-021	09-May-2019 19:00	HG - 11 - M	✓	✓
ES1914646-022	09-May-2019 19:00	HG - 11 - L	✓	✓
ES1914646-023	09-May-2019 19:00	HG - 12 - M	✓	✓
ES1914646-024	09-May-2019 19:00	HG - 12 - L	✓	✓
ES1914646-025	09-May-2019 19:00	HG - 13 - M	✓	✓
ES1914646-026	09-May-2019 19:00	HG - 13 - L	✓	✓
ES1914646-027	09-May-2019 19:00	HG - 14 - M	✓	✓
ES1914646-028	09-May-2019 19:00	HG - 14 - L	✓	✓
ES1914646-029	09-May-2019 19:00	HG - 15 - M	✓	✓
ES1914646-030	09-May-2019 19:00	HG - 15 - L	✓	✓
ES1914646-031	09-May-2019 19:00	HG - 16 - M	✓	✓
ES1914646-032	09-May-2019 19:00	HG - 16 - L	✓	✓
ES1914646-033	10-May-2019 09:00	HG - 17 - M HG - 17...	✓	✓
ES1914646-034	10-May-2019 09:00	HG - 17 - L	✓	✓
ES1914646-035	10-May-2019 09:00	HG - 18 - M	✓	✓
ES1914646-036	10-May-2019 09:00	HG - 18 - L	✓	✓
ES1914646-037	10-May-2019 09:00	HG - 19 - M	✓	✓
ES1914646-038	10-May-2019 09:00	HG - 19 - L	✓	✓
ES1914646-039	10-May-2019 09:00	HG - 20 - M	✓	✓
ES1914646-040	10-May-2019 09:00	HG - 20 - L	✓	✓
ES1914646-041	10-May-2019 09:00	HG - 21 - M	✓	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)	BIOTA - EG094-B Metals in Biota by ICP-MS
ES1914646-042	10-May-2019 09:00	HG - 21 - L	✓	✓
ES1914646-043	10-May-2019 09:00	HG - 22 - M	✓	✓
ES1914646-044	10-May-2019 09:00	HG - 22 - L	✓	✓
ES1914646-045	10-May-2019 09:00	HG - 23 - M	✓	✓
ES1914646-046	07-May-2019 09:00	HG - 23 - L	✓	✓
ES1914646-047	10-May-2019 09:00	HG - 24 - M	✓	✓
ES1914646-048	10-May-2019 09:00	HG - 24 - L	✓	✓
ES1914646-049	10-May-2019 09:00	HG - 25 - M	✓	✓
ES1914646-050	10-May-2019 09:00	HG - 25 - L	✓	✓
ES1914646-051	10-May-2019 09:00	HG - 26 - M	✓	✓
ES1914646-052	10-May-2019 09:00	HG - 26 - L	✓	✓
ES1914646-053	10-May-2019 09:00	HG - 27 - M	✓	✓
ES1914646-054	10-May-2019 09:00	HG - 27 - L	✓	✓
ES1914646-055	10-May-2019 09:00	HG - 28 - M	✓	✓
ES1914646-056	10-May-2019 09:00	HG - 28 - L	✓	✓
ES1914646-057	10-May-2019 09:00	HG - 29 - M	✓	✓
ES1914646-058	10-May-2019 09:00	HG - 29 - L	✓	✓
ES1914646-059	10-May-2019 09:00	HG - 30 - M	✓	✓
ES1914646-060	10-May-2019 09:00	HG - 30 - L	✓	✓
ES1914646-061	10-May-2019 09:00	HG - 31 - M	✓	✓
ES1914646-062	10-May-2019 09:00	HG - 31 - L	✓	✓
ES1914646-063	10-May-2019 09:00	HG - 32 - M	✓	✓
ES1914646-064	10-May-2019 09:00	HG - 32 - L	✓	✓
ES1914646-065	10-May-2019 09:00	HG - 33 - M	✓	✓
ES1914646-066	10-May-2019 09:00	HG - 33 - L	✓	✓
ES1914646-067	10-May-2019 09:00	HG - 34 - M	✓	✓
ES1914646-068	10-May-2019 09:00	HG - 34 - L	✓	✓
ES1914646-069	11-May-2019 10:00	HG - 35 - M	✓	✓
ES1914646-070	11-May-2019 10:00	HG - 35 - L	✓	✓
ES1914646-071	11-May-2019 10:00	HG - 36 - M	✓	✓
ES1914646-072	11-May-2019 10:00	HG - 36 - L	✓	✓
ES1914646-073	11-May-2019 10:00	HG - 37 - M	✓	✓
ES1914646-074	11-May-2019 10:00	HG - 37 - L	✓	✓
ES1914646-075	11-May-2019 10:00	HG - 38 - M	✓	✓
ES1914646-076	11-May-2019 10:00	HG - 38 - L	✓	✓
ES1914646-077	11-May-2019 10:00	HG - 39 - M	✓	✓
ES1914646-078	11-May-2019 10:00	HG - 39 - L	✓	✓
ES1914646-079	11-May-2019 10:00	HG - 40 - M	✓	✓
ES1914646-080	11-May-2019 10:00	HG - 40 - L	✓	✓
ES1914646-081	11-May-2019 10:00	HG - 41 - M	✓	✓
ES1914646-082	11-May-2019 10:00	HG - 41 - L	✓	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)	BIOTA - EG094-B Metals in Biota by ICP-MS
ES1914646-083	11-May-2019 10:00	HG - 42 - M	✓	✓
ES1914646-084	11-May-2019 10:00	HG - 42 - L	✓	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

INVOICES

- A4 - AU Tax Invoice (INV)	Email	invoicecontrol@wafigolpujv.com

PANCHO NEIRA

- *AU Certificate of Analysis - NATA (COA)	Email	pancho.neira@marscco.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	pancho.neira@marscco.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	pancho.neira@marscco.com.au
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	pancho.neira@marscco.com.au
- Chain of Custody (CoC) (COC)	Email	pancho.neira@marscco.com.au
- EDI Format - ENMRG (ENMRG)	Email	pancho.neira@marscco.com.au
- EDI Format - ESDAT (ESDAT)	Email	pancho.neira@marscco.com.au

TIM WRIGLEY

- A4 - AU Tax Invoice (INV)	Email	Tim.Wrigley@WafiGolpuJV.com

Appendix 5

ALS Global Sample Receipt Notification (SRN) for Work Order ES1914661

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES1914661**

Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Contact	: Customer Services ES
Address	: LEVEL 2 189 CORONATION DRIVE MILTON QLD, AUSTRALIA 4064	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: Tim.Wrigley@WafiGolpuJV.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: PNG Fish sample metal testing study	Page	: 1 of 6
Order number	:	Quote number	: ES2019WAFGOL0001 (SY/206/19)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRA		

Dates

Date Samples Received	: 15-May-2019 10:00	Issue Date	: 15-May-2019
Client Requested Due Date	: 29-May-2019	Scheduled Reporting Date	: **29-May-2019**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: -3.2 - Ice present
Receipt Detail	:	No. of samples received / analysed	: 62 / 62

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **This work order is split from ES1914646.**
- **All samples on COC page number 16 were prawns, which were confiscated. ALS has not received these samples.**
- **Sample 'LL - 6 - M' has the ID 'LL - 6 - L' on the sampling bags, however the weight matches the weight on the COC.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

Method *Client sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-MS : EG094-B		
HG - 43 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 43 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 44 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 44 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 45 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 45 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 46 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 46 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 47 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 47 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 1 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 1 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 2 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 3 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 4 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 4 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 5 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 6 - M LL - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 7 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 7 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 8 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 9 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 9 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 1 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 2 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 3 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 4 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 5 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 6 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 7 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 8 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 9 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 10 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 11 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 12 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 13 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 1 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 2 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 3 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 4 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 5 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 6 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 7 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 8 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 9 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 10 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 11 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 12 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 13 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 1	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 2	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 3	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 4	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 5	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 6	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 7	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 8	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 9	- Snap Lock Bag - frozen	- Frozen Sample

Method *Client sample ID*	**Sample Container Received**	**Preferred Sample Container for Analysis**
Metals in Biota by ICP-MS : EG094-B		
LL - K - 10	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 11	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 12	- Snap Lock Bag - frozen	- Frozen Sample
Total Mercury by FIMS : EG035-B		
HG - 43 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 43 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 44 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 44 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 45 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 45 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 46 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 46 - L	- Snap Lock Bag - frozen	- Frozen Sample
HG - 47 - M	- Snap Lock Bag - frozen	- Frozen Sample
HG - 47 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 1 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 1 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 2 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 3 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 4 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 4 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 5 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 6 - M LL - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 6 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 7 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 7 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - 8 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 9 - M	- Snap Lock Bag - frozen	- Frozen Sample
LL - 9 - L	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 1 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 2 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 3 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 4 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 5 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 6 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 7 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 8 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 9 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 10 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 11 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 12 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 13 - CM	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 1 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 2 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 3 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 4 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 5 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 6 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 7 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 8 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 9 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 10 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 11 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 12 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - C - 13 - H	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 1	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 2	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 3	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 4	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 5	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 6	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 7	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 8	- Snap Lock Bag - frozen	- Frozen Sample

Method / Client sample ID	Sample Container Received	Preferred Sample Container for Analysis
Total Mercury by FIMS : EG035-B		
LL - K - 9	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 10	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 11	- Snap Lock Bag - frozen	- Frozen Sample
LL - K - 12	- Snap Lock Bag - frozen	- Frozen Sample

Any sample identifications that cannot be displayed entirely in the analysis summary table will be listed below.

ES1914661-018 : 06-May-2019 10:00 : LL - 6 - M - LL - 6 - L

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **BIOTA**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)	BIOTA - EG094-B Metals in Biota by ICP-MS
ES1914661-001	11-May-2019 10:00	HG - 43 - M	✓	✓
ES1914661-002	11-May-2019 10:00	HG - 43 - L	✓	✓
ES1914661-003	11-May-2019 10:00	HG - 44 - M	✓	✓
ES1914661-004	11-May-2019 10:00	HG - 44 - L	✓	✓
ES1914661-005	11-May-2019 10:00	HG - 45 - M	✓	✓
ES1914661-006	11-May-2019 10:00	HG - 45 - L	✓	✓
ES1914661-007	11-May-2019 10:00	HG - 46 - M	✓	✓
ES1914661-008	11-May-2019 10:00	HG - 46 - L	✓	✓
ES1914661-009	11-May-2019 10:00	HG - 47 - M	✓	✓
ES1914661-010	11-May-2019 10:00	HG - 47 - L	✓	✓
ES1914661-011	06-May-2019 10:00	LL - 1 - M	✓	✓
ES1914661-012	06-May-2019 10:00	LL - 1 - L	✓	✓
ES1914661-013	06-May-2019 10:00	LL - 2 - M	✓	✓
ES1914661-014	06-May-2019 10:00	LL - 3 - M	✓	✓
ES1914661-015	06-May-2019 10:00	LL - 4 - M	✓	✓
ES1914661-016	06-May-2019 10:00	LL - 4 - L	✓	✓
ES1914661-017	06-May-2019 10:00	LL - 5 - M	✓	✓
ES1914661-018	06-May-2019 10:00	LL - 6 - M LL - 6 -...	✓	✓
ES1914661-019	06-May-2019 10:00	LL - 6 - L	✓	✓
ES1914661-020	09-May-2019 10:00	LL - 7 - M	✓	✓
ES1914661-021	09-May-2019 10:00	LL - 7 - L	✓	✓
ES1914661-022	09-May-2019 10:00	LL - 8 - M	✓	✓
ES1914661-023	09-May-2019 10:00	LL - 9 - M	✓	✓
ES1914661-024	09-May-2019 10:00	LL - 9 - L	✓	✓
ES1914661-025	06-May-2019 10:00	LL - C - 1 - CM	✓	✓
ES1914661-026	06-May-2019 10:00	LL - C - 2 - CM	✓	✓
ES1914661-027	06-May-2019 10:00	LL - C - 3 - CM	✓	✓
ES1914661-028	06-May-2019 10:00	LL - C - 4 - CM	✓	✓
ES1914661-029	06-May-2019 10:00	LL - C - 5 - CM	✓	✓
ES1914661-030	06-May-2019 10:00	LL - C - 6 - CM	✓	✓
ES1914661-031	06-May-2019 10:00	LL - C - 7 - CM	✓	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)	BIOTA - EG094-B Metals in Biota by ICP-MS
ES1914661-032	06-May-2019 10:00	LL - C - 8 - CM	✓	✓
ES1914661-033	06-May-2019 10:00	LL - C - 9 - CM	✓	✓
ES1914661-034	06-May-2019 10:00	LL - C - 10 - CM	✓	✓
ES1914661-035	06-May-2019 10:00	LL - C - 11 - CM	✓	✓
ES1914661-036	09-May-2019 10:00	LL - C - 12 - CM	✓	✓
ES1914661-037	09-May-2019 10:00	LL - C - 13 - CM	✓	✓
ES1914661-038	06-May-2019 10:00	LL - C - 1 - H	✓	✓
ES1914661-039	06-May-2019 10:00	LL - C - 2 - H	✓	✓
ES1914661-040	06-May-2019 10:00	LL - C - 3 - H	✓	✓
ES1914661-041	06-May-2019 10:00	LL - C - 4 - H	✓	✓
ES1914661-042	06-May-2019 10:00	LL - C - 5 - H	✓	✓
ES1914661-043	06-May-2019 10:00	LL - C - 6 - H	✓	✓
ES1914661-044	06-May-2019 10:00	LL - C - 7 - H	✓	✓
ES1914661-045	06-May-2019 10:00	LL - C - 8 - H	✓	✓
ES1914661-046	06-May-2019 10:00	LL - C - 9 - H	✓	✓
ES1914661-047	06-May-2019 10:00	LL - C - 10 - H	✓	✓
ES1914661-048	06-May-2019 10:00	LL - C - 11 - H	✓	✓
ES1914661-049	09-May-2019 10:00	LL - C - 12 - H	✓	✓
ES1914661-050	09-May-2019 10:00	LL - C - 13 - H	✓	✓
ES1914661-051	06-May-2019 10:00	LL - K - 1	✓	✓
ES1914661-052	06-May-2019 10:00	LL - K - 2	✓	✓
ES1914661-053	06-May-2019 10:00	LL - K - 3	✓	✓
ES1914661-054	06-May-2019 10:00	LL - K - 4	✓	✓
ES1914661-055	06-May-2019 10:00	LL - K - 5	✓	✓
ES1914661-056	06-May-2019 10:00	LL - K - 6	✓	✓
ES1914661-057	06-May-2019 10:00	LL - K - 7	✓	✓
ES1914661-058	06-May-2019 10:00	LL - K - 8	✓	✓
ES1914661-059	06-May-2019 10:00	LL - K - 9	✓	✓
ES1914661-060	06-May-2019 10:00	LL - K - 10	✓	✓
ES1914661-061	06-May-2019 10:00	LL - K - 11	✓	✓
ES1914661-062	06-May-2019 10:00	LL - K - 12	✓	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

INVOICES		
- A4 - AU Tax Invoice (INV)	Email	invoicecontrol@wafigolpujv.com
PANCHO NEIRA		
- *AU Certificate of Analysis - NATA (COA)	Email	pancho.neira@marscco.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	pancho.neira@marscco.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	pancho.neira@marscco.com.au
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	pancho.neira@marscco.com.au
- Chain of Custody (CoC) (COC)	Email	pancho.neira@marscco.com.au
- EDI Format - ENMRG (ENMRG)	Email	pancho.neira@marscco.com.au
- EDI Format - ESDAT (ESDAT)	Email	pancho.neira@marscco.com.au
TIM WRIGLEY		
- A4 - AU Tax Invoice (INV)	Email	Tim.Wrigley@WafiGolpuJV.com

Appendix 6

ALS Global QA/QC Compliance Assessment to assist with Quality Review for Work Order ES1914646.

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES1914646**	Page	: 1 of 7
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Telephone	: +61-2-8784 8555
Project	: PNG Fish sample metal testing study	Date Samples Received	: 15-May-2019
Site	: ----	Issue Date	: 03-Jun-2019
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRS	No. of samples received	: 84
Order number	:	No. of samples analysed	: 81

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **Duplicate outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Work Order : ES1914646
Client : WAFI GOLPU SERVICES LIMITED
Project : PNG Fish sample metal testing study

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **BIOTA**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Duplicate (DUP) RPDs							
EG094: Metals in Biota by ICPMS	ES1914646--061	HG - 31 - M	**Zinc**	7440-66-6	46.3 %	0% - 20%	**RPD exceeds LOR based limits**

Outliers : Frequency of Quality Control Samples

Matrix: **BIOTA**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Matrix Spikes (MS)					
Metals in Biota by ICP-MS	4	97	4.12	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		Sample Date	Extraction / Preparation			Analysis		
Container / Client Sample ID(s)			*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EG035T: Total Recoverable Mercury by FIMS								
Snap Lock Bag - frozen (EG035-B)								
HG - 1 - M,	HG - 1 - L,	**07-May-2019**	**25-May-2019**	03-Nov-2019	✓	**27-May-2019**	03-Nov-2019	✓
HG - 2 - M,	HG - 2 - L,							
HG - 3 - M,	HG - 3 - L,							
HG - 4 - M,	HG - 4 - L,							
HG - 5 - M,	HG - 5 - L,							
HG - 6 - M,	HG - 6 - L							
Snap Lock Bag - frozen (EG035-B)								
HG - 23 - L		**07-May-2019**	**25-May-2019**	03-Nov-2019	✓	**28-May-2019**	03-Nov-2019	✓
Snap Lock Bag - frozen (EG035-B)								
HG - 7 - M,	HG - 7 - L,	**09-May-2019**	**25-May-2019**	05-Nov-2019	✓	**27-May-2019**	05-Nov-2019	✓
HG - 8 - M,	HG - 8 - L,							
HG - 9 - M,	HG - 9 - L,							
HG - 10 - M,	HG - 10 - L,							
HG - 11 - M,	HG - 11 - L,							
HG - 12 - M,	HG - 12 - L,							
HG - 13 - M,	HG - 13 - L,							
HG - 14 - L,	HG - 15 - M,							
HG - 15 - L,	HG - 16 - M							

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG035T: Total Recoverable Mercury by FIMS - Continued								
Snap Lock Bag - frozen (EG035-B)								
HG - 17 - M - HG - 17 - L,	HG - 17 - L,	**10-May-2019**	**25-May-2019**	06-Nov-2019	✓	**27-May-2019**	06-Nov-2019	✓
HG - 18 - M,	HG - 18 - L,							
HG - 19 - M,	HG - 19 - L,							
HG - 20 - M,	HG - 20 - L							
Snap Lock Bag - frozen (EG035-B)								
HG - 21 - M,	HG - 21 - L,	**10-May-2019**	**25-May-2019**	06-Nov-2019	✓	**28-May-2019**	06-Nov-2019	✓
HG - 22 - M,	HG - 22 - L,							
HG - 23 - M,	HG - 24 - M,							
HG - 24 - L,	HG - 25 - M,							
HG - 25 - L,	HG - 26 - M,							
HG - 26 - L,	HG - 27 - M,							
HG - 27 - L,	HG - 28 - M,							
HG - 28 - L,	HG - 29 - M,							
HG - 29 - L,	HG - 30 - M,							
HG - 30 - L,	HG - 31 - M,							
HG - 31 - L,	HG - 32 - M,							
HG - 33 - M,	HG - 33 - L,							
HG - 34 - M,	HG - 34 - L							
Snap Lock Bag - frozen (EG035-B)								
HG - 35 - M,	HG - 35 - L,	**11-May-2019**	**25-May-2019**	07-Nov-2019	✓	**28-May-2019**	07-Nov-2019	✓
HG - 36 - M,	HG - 36 - L,							
HG - 37 - M,	HG - 37 - L,							
HG - 38 - M,	HG - 38 - L,							
HG - 39 - M,	HG - 39 - L,							
HG - 40 - M,	HG - 40 - L							
Snap Lock Bag - frozen (EG035-B)								
HG - 41 - M,	HG - 41 - L,	**11-May-2019**	**26-May-2019**	07-Nov-2019	✓	**28-May-2019**	07-Nov-2019	✓
HG - 42 - M,	HG - 42 - L							

Matrix: **BIOTA** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG094: Metals in Biota by ICPMS								
Snap Lock Bag - frozen (EG094-B)								
HG - 1 - M,	HG - 1 - L,	**07-May-2019**	**25-May-2019**	03-Nov-2019	✓	**26-May-2019**	03-Nov-2019	✓
HG - 2 - M,	HG - 2 - L,							
HG - 3 - M,	HG - 3 - L,							
HG - 4 - M,	HG - 4 - L,							
HG - 5 - M,	HG - 5 - L,							
HG - 6 - M,	HG - 6 - L,							
HG - 23 - L								
Snap Lock Bag - frozen (EG094-B)								
HG - 7 - M,	HG - 7 - L,	**09-May-2019**	**25-May-2019**	05-Nov-2019	✓	**26-May-2019**	05-Nov-2019	✓
HG - 8 - M,	HG - 8 - L,							
HG - 9 - M,	HG - 9 - L,							
HG - 10 - M,	HG - 10 - L,							
HG - 11 - M,	HG - 11 - L,							
HG - 12 - M,	HG - 12 - L,							
HG - 13 - M,	HG - 13 - L,							
HG - 14 - L,	HG - 15 - M,							
HG - 15 - L,	HG - 16 - M							
Snap Lock Bag - frozen (EG094-B)								
HG - 17 - M - HG - 17 - L,	HG - 17 - L,	**10-May-2019**	**25-May-2019**	06-Nov-2019	✓	**26-May-2019**	06-Nov-2019	✓
HG - 18 - M,	HG - 18 - L,							
HG - 19 - M,	HG - 19 - L,							
HG - 20 - M,	HG - 20 - L,							
HG - 21 - M,	HG - 21 - L,							
HG - 22 - M,	HG - 22 - L,							
HG - 23 - M,	HG - 24 - M,							
HG - 24 - L,	HG - 25 - M,							
HG - 25 - L,	HG - 26 - M,							
HG - 26 - L,	HG - 27 - M,							
HG - 27 - L,	HG - 28 - M,							
HG - 28 - L,	HG - 29 - M,							
HG - 29 - L,	HG - 30 - M,							
HG - 30 - L,	HG - 31 - M,							
HG - 31 - L,	HG - 32 - M,							
HG - 33 - M,	HG - 33 - L,							
HG - 34 - M,	HG - 34 - L							
Snap Lock Bag - frozen (EG094-B)								

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG094: Metals in Biota by ICPMS - Continued								
HG - 35 - M, HG - 36 - M, HG - 37 - M, HG - 38 - M, HG - 39 - M, HG - 40 - M,	HG - 35 - L, HG - 36 - L, HG - 37 - L, HG - 38 - L, HG - 39 - L, HG - 40 - L	**11-May-2019**	**25-May-2019**	07-Nov-2019	✓	**26-May-2019**	07-Nov-2019	✓
Snap Lock Bag - frozen (EG094-B)								
HG - 41 - M, HG - 42 - M,	HG - 41 - L, HG - 42 - L	**11-May-2019**	**26-May-2019**	07-Nov-2019	✓	**26-May-2019**	07-Nov-2019	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **BIOTA**

Evaluation: ✘ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Metals in Biota by ICP-MS	EG094-B	10	97	**10.31**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	10	97	**10.31**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Metals in Biota by ICP-MS	EG094-B	5	97	**5.15**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	97	**5.15**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Metals in Biota by ICP-MS	EG094-B	5	97	**5.15**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	97	**5.15**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Metals in Biota by ICP-MS	EG094-B	4	97	**4.12**	**5.00**	✘	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	97	**5.15**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Total Mercury by FIMS	EG035-B	BIOTA	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve.
Metals in Biota by ICP-MS	* EG094-B	BIOTA	#

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Hot Block Digest for metals in biota	EN69	BIOTA	In house: Referenced to USEPA 200.2 Mod. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils.

Appendix 7

ALS Global QA/QC Compliance Assessment to assist with Quality Review for Work Order ES1914661.

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES1914661**	Page	: 1 of 6
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Telephone	: +61-2-8784 8555
Project	: PNG Fish sample metal testing study	Date Samples Received	: 15-May-2019
Site	: ----	Issue Date	: 31-May-2019
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRA	No. of samples received	: 62
Order number	:	No. of samples analysed	: 62

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

Matrix: **BIOTA**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Laboratory Duplicates (DUP)					
Metals in Biota by ICP-MS	5	66	7.58	10.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	5	66	7.58	10.00	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)					
Metals in Biota by ICP-MS	3	66	4.55	5.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	3	66	4.55	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		Sample Date	Extraction / Preparation			Analysis		
***Container** / Client Sample ID(s)*			***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG035T: Total Recoverable Mercury by FIMS								
Snap Lock Bag - frozen (EG035-B)								
LL - 1 - M,	LL - 1 - L,	**06-May-2019**	**26-May-2019**	02-Nov-2019	✓	**28-May-2019**	02-Nov-2019	✓
LL - 2 - M,	LL - 3 - M,							
LL - 4 - M,	LL - 4 - L,							
LL - 5 - M,	LL - 6 - M - LL - 6 - L,							
LL - 6 - L,	LL - C - 1 - CM,							
LL - C - 2 - CM,	LL - C - 3 - CM,							
LL - C - 4 - CM,	LL - C - 5 - CM,							
LL - C - 6 - CM,	LL - C - 7 - CM,							
LL - C - 8 - CM,	LL - C - 9 - CM,							
LL - C - 10 - CM,	LL - C - 11 - CM							
Snap Lock Bag - frozen (EG035-B)								

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Evaluation	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Evaluation
EG035T: Total Recoverable Mercury by FIMS - Continued								
LL - C - 1 - H, LL - C - 3 - H, LL - C - 5 - H, LL - C - 7 - H, LL - C - 9 - H, LL - C - 11 - H, LL - K - 2, LL - K - 4, LL - K - 6, LL - K - 8, LL - K - 10, LL - K - 12	LL - C - 2 - H, LL - C - 4 - H, LL - C - 6 - H, LL - C - 8 - H, LL - C - 10 - H, LL - K - 1, LL - K - 3, LL - K - 5, LL - K - 7, LL - K - 9, LL - K - 11,	**06-May-2019**	**29-May-2019**	02-Nov-2019	✓	**30-May-2019**	02-Nov-2019	✓
Snap Lock Bag - frozen (EG035-B)								
LL - 7 - M, LL - 8 - M, LL - 9 - L,	LL - 7 - L, LL - 9 - M, LL - C - 12 - CM	**09-May-2019**	**26-May-2019**	05-Nov-2019	✓	**28-May-2019**	05-Nov-2019	✓
Snap Lock Bag - frozen (EG035-B)								
LL - C - 13 - CM, LL - C - 13 - H	LL - C - 12 - H,	**09-May-2019**	**29-May-2019**	05-Nov-2019	✓	**30-May-2019**	05-Nov-2019	✓
Snap Lock Bag - frozen (EG035-B)								
HG - 43 - M, HG - 44 - M, HG - 45 - M, HG - 46 - M, HG - 47 - M,	HG - 43 - L, HG - 44 - L, HG - 45 - L, HG - 46 - L, HG - 47 - L	**11-May-2019**	**26-May-2019**	07-Nov-2019	✓	**28-May-2019**	07-Nov-2019	✓

Matrix: **BIOTA**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EG094: Metals in Biota by ICPMS								
Snap Lock Bag - frozen (EG094-B)								
LL - 1 - M,	LL - 1 - L,	**06-May-2019**	**26-May-2019**	02-Nov-2019	✓	**26-May-2019**	02-Nov-2019	✓
LL - 2 - M,	LL - 3 - M,							
LL - 4 - M,	LL - 4 - L,							
LL - 5 - M,	LL - 6 - M - LL - 6 - L,							
LL - 6 - L,	LL - C - 1 - CM,							
LL - C - 2 - CM,	LL - C - 3 - CM,							
LL - C - 4 - CM,	LL - C - 5 - CM,							
LL - C - 6 - CM,	LL - C - 7 - CM,							
LL - C - 8 - CM,	LL - C - 9 - CM,							
LL - C - 10 - CM,	LL - C - 11 - CM							
Snap Lock Bag - frozen (EG094-B)								
LL - C - 1 - H,	LL - C - 2 - H,	**06-May-2019**	**29-May-2019**	02-Nov-2019	✓	**30-May-2019**	02-Nov-2019	✓
LL - C - 3 - H,	LL - C - 4 - H,							
LL - C - 5 - H,	LL - C - 6 - H,							
LL - C - 7 - H,	LL - C - 8 - H,							
LL - C - 9 - H,	LL - C - 10 - H,							
LL - C - 11 - H,	LL - K - 1,							
LL - K - 2,	LL - K - 3,							
LL - K - 4,	LL - K - 5,							
LL - K - 6,	LL - K - 7,							
LL - K - 8,	LL - K - 9,							
LL - K - 10,	LL - K - 11,							
LL - K - 12								
Snap Lock Bag - frozen (EG094-B)								
LL - 7 - M,	LL - 7 - L,	**09-May-2019**	**26-May-2019**	05-Nov-2019	✓	**26-May-2019**	05-Nov-2019	✓
LL - 8 - M,	LL - 9 - M,							
LL - 9 - L,	LL - C - 12 - CM							
Snap Lock Bag - frozen (EG094-B)								
LL - C - 13 - CM,	LL - C - 12 - H,	**09-May-2019**	**29-May-2019**	05-Nov-2019	✓	**30-May-2019**	05-Nov-2019	✓
LL - C - 13 - H								
Snap Lock Bag - frozen (EG094-B)								
HG - 43 - M,	HG - 43 - L,	**11-May-2019**	**26-May-2019**	07-Nov-2019	✓	**26-May-2019**	07-Nov-2019	✓
HG - 44 - M,	HG - 44 - L,							
HG - 45 - M,	HG - 45 - L,							
HG - 46 - M,	HG - 46 - L,							
HG - 47 - M,	HG - 47 - L							

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **BIOTA**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Metals in Biota by ICP-MS	EG094-B	5	66	**7.58**	**10.00**	×	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	66	**7.58**	**10.00**	×	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Metals in Biota by ICP-MS	EG094-B	4	66	**6.06**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	4	66	**6.06**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Metals in Biota by ICP-MS	EG094-B	4	66	**6.06**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	4	66	**6.06**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Metals in Biota by ICP-MS	EG094-B	3	66	**4.55**	**5.00**	×	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	3	66	**4.55**	**5.00**	×	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Total Mercury by FIMS	EG035-B	BIOTA	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve.
Metals in Biota by ICP-MS	* EG094-B	BIOTA	#

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Hot Block Digest for metals in biota	EN69	BIOTA	In house: Referenced to USEPA 200.2 Mod. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils.

Appendix 8

ALS Global Quality Control Report for Work Order ES1914646.

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES1914646**	Page	: 1 of 7
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Contact	: Customer Services ES
Address	: LEVEL 2 189 CORONATION DRIVE MILTON QLD, AUSTRALIA 4064	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PNG Fish sample metal testing study	Date Samples Received	: 15-May-2019
Order number	:	Date Analysis Commenced	: 25-May-2019
C-O-C number	: ----	Issue Date	: 03-Jun-2019
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRS		
Site	: ----		
Quote number	: SY/206/19		
No. of samples received	: 84		
No. of samples analysed	: 81		

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ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key :
- Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
- CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
- LOR = Limit of reporting
- RPD = Relative Percentage Difference
- # = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **BIOTA**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368573)									
ES1914646-001	HG - 1 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.1	0.1	0.00	0% - 50%
ES1914646-011	HG - 6 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.5	0.4	0.00	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368575)									
ES1914646-021	HG - 11 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.08	0.08	0.00	No Limit
ES1914646-031	HG - 16 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.4	0.3	0.00	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368622)									
ES1914646-041	HG - 21 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.00	0% - 50%
ES1914646-051	HG - 26 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.4	0.3	0.00	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368624)									
ES1914646-061	HG - 31 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.1	0.2	0.00	0% - 50%
ES1914646-071	HG - 36 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.5	0.5	0.00	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368983)									
ES1914646-081	HG - 41 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.00	0% - 50%
ES1914661-007	Anonymous	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.00	0% - 20%
EG094: Metals in Biota by ICPMS (QC Lot: 2368572)									
ES1914646-001	HG - 1 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	4.49	4.71	4.78	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.74	0.71	4.34	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.5	2.5	32.4	No Limit
ES1914646-011	HG - 6 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG094: Metals in Biota by ICPMS (QC Lot: 2368572) - continued									
ES1914646-011	HG - 6 - M	EG094-B: Arsenic	7440-38-2	0.05	mg/kg	4.33	4.34	0.316	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.72	0.68	5.85	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	2.8	2.4	14.6	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 2368574)									
ES1914646-021	HG - 11 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	1.58	1.49	6.06	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	0.07	30.1	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.64	0.60	7.02	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.1	0.1	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	2.7	2.8	0.00	No Limit
ES1914646-031	HG - 16 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	3.28	3.44	4.66	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.61	0.59	2.83	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.0	3.5	14.2	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 2368621)									
ES1914646-041	HG - 21 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	5.07	5.16	1.76	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.15	<0.05	102	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.59	0.61	2.75	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.1	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.4	3.6	8.43	No Limit
ES1914646-051	HG - 26 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	3.22	3.21	0.348	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.46	0.45	0.00	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.3	0.3	0.00	No Limit

ALS

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG094: Metals in Biota by ICPMS (QC Lot: 2368621) - continued									
ES1914646-051	HG - 26 - M	EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.6	3.0	16.5	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 2368623)									
ES1914646-061	HG - 31 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	5.32	5.60	5.18	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.89	0.91	2.96	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.1	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	26.2	# 16.3	46.3	0% - 20%
ES1914646-071	HG - 36 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	5.00	4.82	3.57	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	0.11	<0.05	75.6	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.80	0.61	27.0	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	20.0	18.8	6.17	0% - 20%
EG094: Metals in Biota by ICPMS (QC Lot: 2368982)									
ES1914646-081	HG - 41 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	1.54	1.58	2.06	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.06	0.11	66.5	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.57	0.57	0.00	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.3	0.3	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	19.3	17.2	11.4	0% - 20%
ES1914661-007	Anonymous	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	30.9	28.0	9.67	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	0.48	162	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.76	0.75	1.65	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	15.2	17.5	14.2	0% - 20%

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **BIOTA**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368573)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	82.9	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368575)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	78.0	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368622)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	71.4	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368624)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	70.6	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368983)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	74.8	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368572)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	97.2	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	94.0	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	76.5	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	91.9	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	91.2	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	106	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	88.8	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368574)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	109	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	102	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	80.6	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	103	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	100	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	114	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	97.5	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368621)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	92.3	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	97.8	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	74.9	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	87.8	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----

Sub-Matrix: **BIOTA**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Recovery Limits (%) Low	Recovery Limits (%) High
EG094: Metals in Biota by ICPMS (QCLot: 2368621) - continued								
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	90.4	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	81.9	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	107	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368623)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	104	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	108	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	85.6	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	102	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	114	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	112	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	110	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368982)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	104	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	101	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	76.6	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	103	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	91.8	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	117	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	94.8	70	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368573)							
ES1914646-001	HG - 1 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	100	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368575)							
ES1914646-021	HG - 11 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	105	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368622)							
ES1914646-041	HG - 21 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	87.0	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368624)							
ES1914646-061	HG - 31 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	92.2	70	130

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368983)							
ES1914646-081	HG - 41 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	106	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368572)							
ES1914646-001	HG - 1 - M	EG094-B: Arsenic	7440-38-2	25 mg/kg	112	70	130
		EG094-B: Cadmium	7440-43-9	6.25 mg/kg	95.9	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	102	70	130
		EG094-B: Copper	7440-50-8	25 mg/kg	105	70	130
		EG094-B: Lead	7439-92-1	25 mg/kg	111	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	95.5	70	130
		EG094-B: Zinc	7440-66-6	25 mg/kg	91.9	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368574)							
ES1914646-021	HG - 11 - M	EG094-B: Arsenic	7440-38-2	25 mg/kg	115	70	130
		EG094-B: Cadmium	7440-43-9	6.25 mg/kg	98.2	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	104	70	130
		EG094-B: Copper	7440-50-8	25 mg/kg	109	70	130
		EG094-B: Lead	7439-92-1	25 mg/kg	116	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	110	70	130
		EG094-B: Zinc	7440-66-6	25 mg/kg	94.3	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368621)							
ES1914646-041	HG - 21 - M	EG094-B: Arsenic	7440-38-2	25 mg/kg	107	70	130
		EG094-B: Cadmium	7440-43-9	6.25 mg/kg	98.4	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	126	70	130
		EG094-B: Copper	7440-50-8	25 mg/kg	104	70	130
		EG094-B: Lead	7439-92-1	25 mg/kg	109	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	118	70	130
		EG094-B: Zinc	7440-66-6	25 mg/kg	112	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368982)							
ES1914646-081	HG - 41 - M	EG094-B: Arsenic	7440-38-2	25 mg/kg	106	70	130
		EG094-B: Cadmium	7440-43-9	31.25 mg/kg	75.5	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	102	70	130
		EG094-B: Copper	7440-50-8	125 mg/kg	105	70	130
		EG094-B: Lead	7439-92-1	125 mg/kg	112	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	94.4	70	130
		EG094-B: Zinc	7440-66-6	125 mg/kg	99.0	70	130

Appendix 9

ALS Global Quality Control Report for Work Order ES1914661.

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES1914661**	Page	: 1 of 6
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: TIM WRIGLEY	Contact	: Customer Services ES
Address	: LEVEL 2 189 CORONATION DRIVE MILTON QLD, AUSTRALIA 4064	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PNG Fish sample metal testing study	Date Samples Received	: 15-May-2019
Order number	:	Date Analysis Commenced	: 26-May-2019
C-O-C number	: ----	Issue Date	: 31-May-2019
Sampler	: MARSCCO - Marine Sciences Consulting, PANCHO NEIRA		
Site	: ----		
Quote number	: SY/206/19		
No. of samples received	: 62		
No. of samples analysed	: 62		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **BIOTA**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368983)									
ES1914646-081	Anonymous	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.00	0% - 50%
ES1914661-007	HG - 46 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.00	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2368985)									
ES1914661-017	LL - 5 - M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.01	<0.01	0.00	No Limit
ES1914661-027	LL - C - 3 - CM	EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.02	<0.02	0.00	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 2376129)									
ES1914661-037	LL - C - 13 - CM	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.03	0.02	0.00	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 2368982)									
ES1914646-081	Anonymous	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	1.54	1.58	2.06	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.06	0.11	66.5	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.57	0.57	0.00	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.3	0.3	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	19.3	17.2	11.4	0% - 20%
ES1914661-007	HG - 46 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	30.9	28.0	9.67	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	0.48	162	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.76	0.75	1.65	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	15.2	17.5	14.2	0% - 20%

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG094: Metals in Biota by ICPMS (QC Lot: 2368984)									
ES1914661-017	LL - 5 - M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	0.10	0.10	0.00	No Limit
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.17	0.16	0.00	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.00	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	17.1	17.9	4.36	0% - 20%
ES1914661-027	LL - C - 3 - CM	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	0.61	0.59	2.92	0% - 50%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.05	<0.05	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.47	0.49	5.59	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	6.3	6.4	0.00	0% - 20%
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	70.1	62.9	10.9	0% - 20%
EG094: Metals in Biota by ICPMS (QC Lot: 2376128)									
ES1914661-037	LL - C - 13 - CM	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	0.54	0.56	3.73	0% - 50%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.44	0.44	0.00	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.00	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	0.12	0.09	35.0	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.52	0.55	5.73	0% - 50%
		EG094-B: Copper	7440-50-8	0.1	mg/kg	7.5	7.1	5.62	0% - 20%
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	66.6	68.6	3.00	0% - 20%

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **BIOTA**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368983)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	74.8	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368985)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	86.2	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2376129)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	83.2	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2376131)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.41 mg/kg	77.7	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368982)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	104	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	101	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	76.6	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	103	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	91.8	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	117	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	94.8	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368984)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	110	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	107	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	108	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	110	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	115	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	126	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	97.2	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2376128)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	110	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	116	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	86.9	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	93.6	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	122	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	125	70	130

Sub-Matrix: **BIOTA**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG094: Metals in Biota by ICPMS (QCLot: 2376128) - continued								
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	114	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2376130)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	6.8 mg/kg	114	70	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.306 mg/kg	115	70	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	1.87 mg/kg	81.9	70	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	15.9 mg/kg	95.7	70	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	1.36 mg/kg	114	70	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	3.56 mg/kg	121	70	130
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	52.2 mg/kg	115	70	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **BIOTA**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368983)							
ES1914646-081	Anonymous	EG035-B: Mercury	7439-97-6	5 mg/kg	106	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2368985)							
ES1914661-017	LL - 5 - M	EG035-B: Mercury	7439-97-6	5 mg/kg	104	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 2376129)							
ES1914661-037	LL - C - 13 - CM	EG035-B: Mercury	7439-97-6	5 mg/kg	95.8	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368982)							
ES1914646-081	Anonymous	EG094-B: Arsenic	7440-38-2	25 mg/kg	106	70	130
		EG094-B: Cadmium	7440-43-9	31.25 mg/kg	75.5	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	102	70	130
		EG094-B: Copper	7440-50-8	125 mg/kg	105	70	130
		EG094-B: Lead	7439-92-1	125 mg/kg	112	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	94.4	70	130
		EG094-B: Zinc	7440-66-6	125 mg/kg	99.0	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2368984)							
ES1914661-017	LL - 5 - M	EG094-B: Arsenic	7440-38-2	25 mg/kg	109	70	130
		EG094-B: Cadmium	7440-43-9	6.25 mg/kg	99.4	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	105	70	130
		EG094-B: Copper	7440-50-8	25 mg/kg	111	70	130

Sub-Matrix: **BIOTA**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report: Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG094: Metals in Biota by ICPMS (QCLot: 2368984) - continued							
ES1914661-017	LL - 5 - M	EG094-B: Lead	7439-92-1	25 mg/kg	118	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	98.1	70	130
		EG094-B: Zinc	7440-66-6	25 mg/kg	87.6	70	130
EG094: Metals in Biota by ICPMS (QCLot: 2376128)							
ES1914661-037	LL - C - 13 - CM	EG094-B: Arsenic	7440-38-2	25 mg/kg	126	70	130
		EG094-B: Cadmium	7440-43-9	6.25 mg/kg	115	70	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	109	70	130
		EG094-B: Copper	7440-50-8	25 mg/kg	94.2	70	130
		EG094-B: Lead	7439-92-1	25 mg/kg	119	70	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	89.0	70	130
		EG094-B: Zinc	7440-66-6	25 mg/kg	120	70	130