Environmental Baseline Metal Levels in Fishes and Invertebrates Sold at Public Markets in Lae (DCA Point) and Port Moresby (Koki), Papua New Guinea – May/June 2022 Post-EIS Study

Final Report

532-8223-EN-REP-40009

Prepared for Wafi-Golpu Joint Venture (WGJV)

Neira Marine Sciences Consulting (Marscco)

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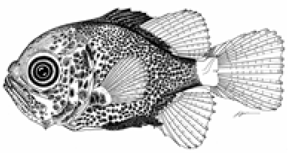

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Neira Marine Sciences Consulting (Marscco) – March 2023

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 site 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 Permit for the WGJV Project was granted by the Conservation and Environment Protection Agency (CEPA) of PNG on 18 December 2020, following a rigorous assessment of the Environmental Impact Statement (EIS) submitted by the WGJV to CEPA on 25 June 2018.

Overview

This report documents the second major post-EIS baseline study of levels of metals in fishes and invertebrates (mud crabs and mud clams) caught by the local artisanal fishery in coastal waters of the western Huon Gulf, including Labu Lakes, and sold for human consumption at the DCA Point market in Lae. The study was undertaken by Marscco in May/June 2022 and complements the study on metals in market species from the same region undertaken in May 2019 (Marscco, 2020) and those completed for the EIS in November 2016 and May 2017. This second baseline study forms part of the ongoing WGJV Project commitment to build a scientifically robust database of metals from which comparisons can be made in future monitoring studies to support the EIS prediction that the local fisheries resources will not be adversely impacted and addresses one of the key concerns of coastal communities that the fish and invertebrates sold at local markets will remain safe to eat.

For this study, the survey was extended to include two other geographical areas, namely (i) Wara Waria, located approximately 145 km to the southeast of Lae in the Morobe Province and just outside of the Huon Gulf; and (ii) an area along PNG's Central Province comprising various coastal locations of the eastern Gulf of Papua that are proximate to Port Moresby. As with the May 2019 study, fishes from the western Huon Gulf originate from the coastal area between Labu Tale and Lae and were sourced at the DCA Point market in Lae, while fishes from Wara Waria were sourced directly from local artisanal fishers who operate in coastal waters outside the Waria River entrance. Fish representing the eastern Gulf of Papua were sourced at the Koki Fish market in Port Moresby which constitutes the main supply market of marine produce for PNG's Central Province. In this report, western Huon Gulf is regarded as the "study area", noting that the local artisanal fishery operates in coastal areas outside of the predicted DSTP deep water canyon receiving environment, whereas Wara Waria and eastern Gulf of Papua are regarded as "control areas" as they are remote from mining influences.

Fishes and invertebrates selected from the study area are typically sold for human consumption and there is understandable interest across local communities that levels of metals in species consumed by the population remain within current food standard and expected levels (Food Standards Australia and New Zealand (FSANZ)) and therefore pose no risk to public health. As such, the addition of two control areas located geographically far removed from the main study area and future planned DSTP operations will allow comparative within-country benchmarks to be used in future studies to monitor/compare metal levels across fish and invertebrate species between areas.

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 and the 2019 baseline study (Marscco, 2020) were compared against the recommended guidelines of the joint Food Standard Australian and New Zealand (FSANZ) 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 90^{th} percentile concentrations under the FSANZ Generally Expected Levels (GELs) for metal contaminants (FSANZ, 2001). These guidelines were applied during the initial WGJV EIS as well as other metal fish surveys elsewhere in PNG (Coffey/Marscco, 2018).

Following this second post-EIS study, the extensive WGJV's database currently comprises data of metal levels in muscle tissue samples and livers of 194 fish specimens from 30 fish species, including four species of deep-sea sharks and 26 species of bony fishes, as well as of soft tissues from 22 local giant mud crabs and 23 mangrove mud clams.

Objectives

The general objectives of this second post-EIS baseline study were to:

(a) assess natural variability in baseline levels of metals in fishes and invertebrates (giant mud crabs and mangrove mud clams) from the study area and two control areas that are typically consumed by local coastal communities.

(b) compare metal levels in muscle samples of fishes and invertebrates against current international food guidelines (FSANZ Standard 1.4.1 and FSANZ GELs) to identify levels that may pose a risk to public health from consumption of fishes, mud crabs, and mud clams on a regular basis. Comparisons of metals in fish livers against FSANZ guidelines were not made as these only apply to the portion of food that is ordinarily consumed, i.e., muscle tissue (flesh).

(c) continue assembling a robust baseline database of metal levels in market fishes and invertebrates from coastal waters of the western Huon Gulf and control sites within PNG, building on previous surveys conducted in November 2016 and May 2019.

Methodology

The methodology employed during this second post-EIS baseline study is the same as that applied during the May 2019 study, including sample purchasing process and species identifications, tissue dissections and sample handling and transport. During this study, the 12 metals analysed comprised: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se) Silver (Ag) and Zinc (Zn). In this report, the term "level" is used interchangeably with "concentration" when referring to metal amounts (mg kg^{-1}).

The study design sought to target similar commonly consumed fish species from each of the three locations, i.e., western Huon Gulf, Wara Waria and eastern Gulf of Papua. However, this proved challenging due to irregular fish availability, as well as different species diversity associated with differing coastal habitats. For instance, the Waria Waria region has clearer waters with coral reef species which rarely occur in the western Huon Gulf due to the high suspended sediment loads from the Markham and Busu rivers.

For this study, a total of 64 specimens representing 17 species from eight families of marine bony fishes were examined and individually dissected to remove muscle tissue samples and livers for metal analysis. Of these, 29 specimens from 10 species were sourced from artisanal fishers at the DCA Point market in Lae and represent species normally caught between Labu Tale and Lae in the western Huon Gulf. Another 15 specimens from six fish species were sourced directly from fishers operating in coastal waters of the Wara Waria region, while a further 20 specimens from four fish species, including top food-chain predators such as mackerel tuna and Spanish mackerel, were sourced at the Koki Fish market in Port Moresby, and represent species normally found in coastal waters of the eastern Gulf of Papua.

Key findings

Fish species tested

- A total of 64 fish specimens representing 17 marine species from eight families of bony fishes were examined during this second post-EIS baseline study. The number of fish specimens and species examined during this study was comparable to the 56 specimens from 14 species (8 families) tested during the first post-EIS baseline study completed in May 2019.
- The most abundant market fish species tested during this baseline study were the tropical lutjanid saddletail snapper (n = 9), the carangid Tille trevally (n = 8), and the scombrids mackerel tuna (n =

5) and Spanish mackerel (n = 5). Replicate samples of saddletail snapper and tille trevally were obtained for western Huon Gulf and eastern Gulf of Papua.

- The most abundant market fish species tested during this baseline study were the tropical lutjanid saddletail snapper (n = 9) and the carangid tille trevally (n = 8) from western Huon Gulf and eastern Gulf of Papua (replicate samples), and the scombrids mackerel tuna (n = 5) and Spanish mackerel (n = 5) from eastern Gulf of Papua. No specimens of any of these four species were obtained from the Wara Waria region in the Huon Gulf.
- Fishes sourced for this baseline study did not include species from the proposed DSTP outfall and tailings placement area to the south of Lae since the artisanal fishery does not operate in that area due to increased depth of water column (>150 m) and lack of seabed structures that support species typically targeted for human consumption. This was also the case during the May 2019 baseline study.

Metal levels in fish muscle tissues

- Metal levels in muscle tissues of all 64 fish specimens 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 being highly species-specific, age-and-size specific and tissue-specific. Sources of metal variability include a combination of factors ranging from natural local sources to a range of anthropogenic activities.
- Of the 12 metals tested in muscle tissues across all fish species combined, Cd, Pb and Ag were undetectable (<LORs) whereas Cr and Ni were detected in single samples (1>LOR) and at very low levels.
- Cu, Hg and Mn were detected in many tissue samples whereas total As along with Fe, Se and Zn were detected in all samples. Levels of total As were of similar magnitude in all 64 muscle samples tested across the three study areas except for the elevated level recorded in a single common conger pike sampled from western Huon Gulf (26.80 mg kg^{-1}).
- Mercury (Hg) was detected at levels slightly above the 0.10 mg kg^{-1} LOR in almost half of the specimens tested from western Huon Gulf (16>LOR) and Wara Waria (6>LOR) but in only one mackerel tuna from eastern Gulf of Papua.

Comparisons of metal levels against FSANZ Standard and FSANZ GELs

- The FSANZ Standard for As pertains to inorganic As, and not to total As which is typically measured during laboratory analyses. Therefore, to compare As levels with the FSANZ Standard, total As concentrations in fish species obtained 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 (inorganic As, Pb, Hg) for which FSANZ Standard have been established for fishes (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates may be expected to pose a risk to public health from regular consumption of fish:

  - Estimated inorganic As levels did not exceed the FSANZ Standard listed for fishes (maximum level 2 mg kg^{-1}) in muscle tissues of any of the 64 fish specimens tested during this study.
  - The maximum estimated inorganic As concentration of 1.12 mg kg^{-1} was recorded in muscle tissue of the predatory common pike conger from western Huon Gulf, corresponding to 4.2% of a total As of 26.8 mg kg^{-1}, i.e., well below the FSANZ Standard maximum level for inorganic As listed for fishes.
  - Based on the low levels of estimated inorganic As in muscle tissues estimated during this 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 regular consumption of flesh from any of the fish tested.
- Lead (LOR 0.05 mg kg^{-1}) was not detected in any of the muscle tissue samples from all 64 fish specimens tested during this study (64<LOR), and consequently did not exceed the FSANZ Standard of 0.5 mg kg^{-1} for Pb listed for fishes. Therefore, Pb levels during this baseline study are not expected to pose a risk to public health from the regular consumption of flesh from any of the fish species tested.
- Mercury (LOR 0.1 mg kg^{-1}) did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or maximum level of 1 mg kg^{-1} for Hg listed for fishes in muscle tissues of any of the 64 fish specimens tested during this study. Therefore, Hg levels detected during this baseline study are not expected to pose a risk to public health from the regular consumption of flesh from any of the fish species tested.

- Essential metals (Cu, Se, Zn) for which FSANZ GELs (90^{th} percentiles) have been established for fishes:

  - Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 2 mg kg^{-1} for Cu listed for fishes in muscle tissues of any of the 64 fishes tested during this study and were therefore well within the range of generally expected levels.

- Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 2 mg kg^{-1} for Se listed for fishes in muscle tissues of any of the 64 fishes tested during this study and were therefore well within the range of generally expected levels.
- Zinc (LOR 0.5 mg kg^{-1}) did not exceed the FSANZ GEL of 15 mg kg^{-1} for Zn listed for fishes in muscle tissues of any of the 64 fish specimens tested during this study and were therefore well within the range of generally expected levels.

• Other metals (Cd, Cr, Fe, Mn, Ni, Ag) for which no FSANZ Standard or FSANZ GELs have been established for fishes:

- Neither Cd (LOR 0.01 mg kg^{-1}) nor Ag (LOR 0.1 mg kg^{-1}) were detected in muscle tissues of any of the 64 fish specimens tested during this study.
- Chromium (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of only two of the 64 fish specimens tested during this study, i.e., a teardrop threadfin bream from western Huon Gulf and a thumbprint emperor (Family Lethrinidae) from Wara Waria.
- Iron (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of all 64 fish specimens tested during this study, with most under 5.5 mg kg^{-1} except for higher levels recorded in one teardrop threadfin bream from western Huon Gulf (16.9 mg kg^{-1}) and one mackerel tuna from Fishermen Island in the eastern Gulf of Papua (14.2 mg kg^{-1}). Iron is an essential element in fish as it plays an integral role in biochemical processes such as cellular respiration and vascular transport (hemoglobin) and storage (myoglobin) of oxygen.
- Manganese (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of most fishes sampled from western Huon Gulf (24>LOR) and Wara Waria (12>LOR) but in none of the 20 fish specimens tested from eastern Gulf of Papua. Where detected, Mn levels were low and in the range of 0.05-0.34 mg kg^{-1} across all fishes tested.
- Nickel (LOR 0.05 mg kg^{-1}) was detected in a muscle tissue sample from only one of the 64 fishes tested during this study, i.e., a teardrop threadfin bream from western Huon Gulf.

Metal levels in giant mud crabs

- Metal testing of the left cheliped muscle and hepatopancreas (digestive gland) was carried out on five giant mud crab specimens sourced from each of Labu Lakes in the western Huon Gulf and Manu Mana in the eastern Gulf of Papua. The findings outlined below focus only on muscle tissue, which is the edible part of cooked mud crabs consumed by the local coastal community.

- Non-essential metals (As, Hg) for which FSANZ Standard have been established for crustaceans (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates may be expected to pose a risk to human health from regular consumption of mud crabs:

- Estimated inorganic As levels did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for inorganic As listed for crustaceans in the left cheliped muscle samples of any of the mud crabs tested during this study (0.06-0.34 mg kg^{-1}). Therefore, estimated levels of inorganic As are not expected to pose a risk to public health from regular consumption of mud crabs from Labu Lakes or Manu Mana.
- Mercury (LOR 0.1 mg kg^{-1}) was not detected in any of the cheliped muscle samples of mud crabs tested during this study and consequently did not exceed the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum level of 1 mg kg^{-1} for Hg listed for crustaceans. Therefore, Hg levels are not expected to pose a risk to public health from regular consumption of mud crabs from Labu Lakes or Manu Mana.

- Essential metals (Cu, Se, Zn) for which FSANZ GELs (90^{th} percentiles) have been established for crustaceans:

  - Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 20 mg kg^{-1} for Cu listed for crustaceans in cheliped muscle tissues of any of the mud crabs tested during this study and were therefore well within the range of generally expected levels.
  - Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 1 mg kg^{-1} for Se listed for crustaceans in cheliped muscle tissues of any of the mud crabs tested during this study and were therefore well within the range of generally expected levels.
  - Zinc (LOR 0.5 mg kg^{-1}) exceeded the FSANZ GEL of 40 mg kg^{-1} for Zn listed for crustaceans in most samples of cheliped muscle of mud crabs tested during this study from both Labu Lakes (90^{th} percentile = 65.4 kg^{-1}) and Manu Mana (90^{th} percentile = 67.4 mg kg^{-1}).
  - Elevated Zn levels in cheliped muscles are associated to the burrowing habits of mud crabs in soft/muddy sediments typical of coastal areas and have been found in the same species of crab in other coastal habitats worldwide where no adverse health risks to consumers have been reported.
  - Given the key role of Zn in diverse metabolic body functions, the elevated levels of Zn detected during this study are not expected to pose a risk to public health from the regular consumption of mud crabs from Labu Lakes or Manu Mana.

- Other metals (Cd, Cr, Fe, Pb, Mn, Ni, Ag) for which no FSANZ Standard or FSANZ GELs have been established for crustaceans:

  - Chromium (LOR 0.05 mg kg^{-1}), Pb (0.05 mg kg^{-1}), Ni (LOR 0.05 mg kg^{-1}) and Ag (0.1 mg kg^{-1}) were not detected in cheliped muscle tissues of any of the mud crabs tested during this study.
  - Cadmium (LOR 0.01 mg kg^{-1}) was detected in cheliped muscle samples of only two of the five mud crabs sampled during this study from Labu Lakes.
  - Iron (LOR 0.05 mg kg^{-1}) was detected in cheliped muscle tissues of all mud crabs tested during this study, with most levels under 5.0 mg kg^{-1}. Iron is an essential element and plays an integral

role in biochemical processes such as cellular respiration and vascular transport (haemoglobin) and storage (myoglobin) of oxygen.

- Manganese (LOR 0.05 mg kg^{-1}) was detected in cheliped muscle tissues of all mud crabs tested during this study, with levels of mostly below 5.2 mg kg^{-1}. Levels of this essential metal were lower than the 8.0-13.0 mg kg^{-1} reported for the same species in other studies (Mortimer, 2000; Zhang *et al*., 2019).

Metal levels in mangrove mud clams

- Metal testing was carried out on whole specimens of five mangrove mud clams sourced from each of Labu Lakes in western Huon Gulf and Lea Lea in eastern Gulf of Papua.

- Non-essential metals (As, Cd, Pb, Hg) for which FSANZ Standard have been established for molluscs (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates would be expected to pose a risk to human health from consumption of mangrove mud clams:

  - Estimated inorganic As levels did not exceed the FSANZ Standard maximum level of 1 mg kg^{-1} for inorganic As listed for molluscs in any of the mud clams tested during this study (0.01-0.06 mg kg^{-1}). Therefore, estimated levels of inorganic As are not expected to pose a risk to public health from regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Cadmium (LOR 0.01 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Cd listed for molluscs in any of the mud clams tested during this study. Thus, Cd levels are not expected to pose a risk to public health from the regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Mercury (LOR 0.1 mg kg^{-1}) was detected in only one mud clam from Labu Lakes and did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum level of 1.0 mg kg^{-1} for Hg listed in molluscs. Therefore, Hg levels are not expected to pose a risk to public health from regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Lead (LOR 0.05 mg kg^{-1}) was detected in only one mud clam from each of Labu Lakes and Lea Lea and did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Pb listed in molluscs. Therefore, Pb levels are not expected to pose a risk to public health from the regular consumption of mud clams from Labu Lakes or Lea Lea.

- Essential metals (Cu, Se) for which FSANZ GELs (90^{th} percentiles) have been established for molluscs:

  - Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 30 mg kg^{-1} for Cu listed for molluscs in any of the mud clams tested during this study and were therefore well within the range of generally expected levels.

- Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 1 mg kg^{-1} for Se listed for molluscs in any of the mud clams tested during this study and were therefore well within the range of generally expected levels.

• Other metals (Cr, Fe, Mn, Ni, Ag, Zn) for which no FSANZ Standard or FSANZ GELs have been established for molluscs:

- Chromium (LOR 0.05 mg kg^{-1}), was detected in all mud clams from Labu Lakes but in only one mud clam from Lea Lea, at levels of 0.05-0.76 mg kg^{-1}.
- Iron (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with levels as high as 436.00 mg kg^{-1} which are common in clams and other bivalve molluscs that are known to have elevated Fe levels. Clams are regarded as one of the best food sources of iron, and there is no risk to public health associated with such high Fe levels in the mud clams tested during this study.
- Manganese (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with average levels being significantly higher in mud clams from Labu Lakes than from Lea Lea, i.e., 18.3 mg kg^{-1} vs 2.90 mg kg^{-1}.
- Nickel (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with levels recorded under 0.9 mg kg^{-1} across all mud clams tested during this study.
- Silver (LOR 0.1 mg kg^{-1}) was detected in only two mud clams from Labu Lakes, at levels just above the LOR (0.10-0.20 mg kg^{-1}).
- Zinc (LOR 0.5 mg kg^{-1}) was detected in all mud clams tested during this study, at levels of 9.40-17.60 mg kg^{-1} across all mud clams.

Comparisons with previous baseline market fish surveys

- This and the May 2019 study constitute the major post-EIS baseline market studies completed to date on metal levels in fishes from the study area in western Huon Gulf and which are normally sold for human consumption at the DCA Point market in Lae. Data of metal levels in muscle tissue samples from the above studies were statistically compared over time for all fishes tested by location/year, including the data collected during the November 2016 EIS (14 specimens from five fish species), and the data reported during this study for fishes tested from the two control areas, i.e., Wara Waria and eastern Gulf of Papua.
- Based on the available data, levels of estimated inorganic As and of Hg and Cu levels in muscle tissue samples from all fishes sampled during this and earlier baseline studies did not differ significantly across all survey localities and year.
- Levels of Se were significantly higher in muscle tissue samples of fish specimens sampled in the study area during both the November 2016 EIS and May 2019 baseline studies than in May/June 2022 in the study and control areas (this study), while Zn levels were significantly higher during the May 2019 baseline study.

- The differences in Se and Zn levels observed during this study could be attributed to natural variability, including natural factors such as interspecific as well intraspecific variability in metal bioaccumulation which is highly species- and age/size-specific and typical of marine fishes occurring in coastal habitats. Furthermore, such natural variability has been well described in literature pertaining to metals in fish elsewhere in PNG.
- To date, only replicate samples of saddletail snapper (*Lutjanus malabaricus*) have been tested for metals based on specimens sourced from western Huon Gulf in November 2016 (n = 5) and May 2019 (n = 11), and from western Huon Gulf (n = 4) and eastern Gulf of Papua (n = 5) during this study. Based on the available data, levels of estimated inorganic As and of Se in muscle tissue samples of this tropical snapper were significantly higher in May 2019 compared to May/June 2022 while Zn levels but did not differ significantly across all surveyed localities.
- Levels of estimated inorganic As and of Se and Zn in saddletail snapper reported in this study were well below their respective accepted FSANZ standards therefore no risk to human health is expected from the regular consumption of flesh of this tropical snapper by local communities.
- The present baseline study included testing of metals in two common invertebrate species consumed by local populations, namely giant mud crab and mangrove mud clam, with testing carried out in five specimens of each species from western Huon Gulf (study area) and eastern Gulf of Papua (control area). Representatives of both species from the study area were also tested for metals during the May 2019 market study.
- Based on detectable levels in cheliped muscle samples of giant mud crabs, levels of estimated inorganic As reported in this study were significantly lower in May 2019 than in May/June 2022. Moreover, estimated inorganic As levels were well below FSANZ Standard listed for crustaceans for inorganic As therefore no risk to human health is expected from the regular consumption of muscle of mud crabs by local communities.
- Levels of Cu detected in cheliped muscle samples of giant mud crabs were significantly lower in crabs from western Huon Gulf in May 2019 (study area) than in crabs from eastern Gulf of Papua (control area) in June 2022. Figure ES1 (next page) shows an example of a plot of copper (Cu) levels in the cheliped muscle of giant mud crabs and mangrove mud clams obtained during May 2019 and the present baseline study.
- No significant differences were found in Se levels detected in cheliped muscle samples of giant mud crabs from the study area and the control area in eastern Gulf of Papua (Manu Mana), whereas Zn levels were significantly higher in May 2019 than in May/June 2022.
- Levels of inorganic As estimated in this study in whole mangrove mud clams were statistically similar across all samples from western Huon Gulf (study area) and eastern Gulf of Papua (Lea Lea; control area), i.e., no differences across survey localities and year. Moreover, inorganic As levels were well below FSANZ Standard for inorganic As listed for molluscs therefore no risk to human health is expected from the regular consumption of mud clams by local communities.

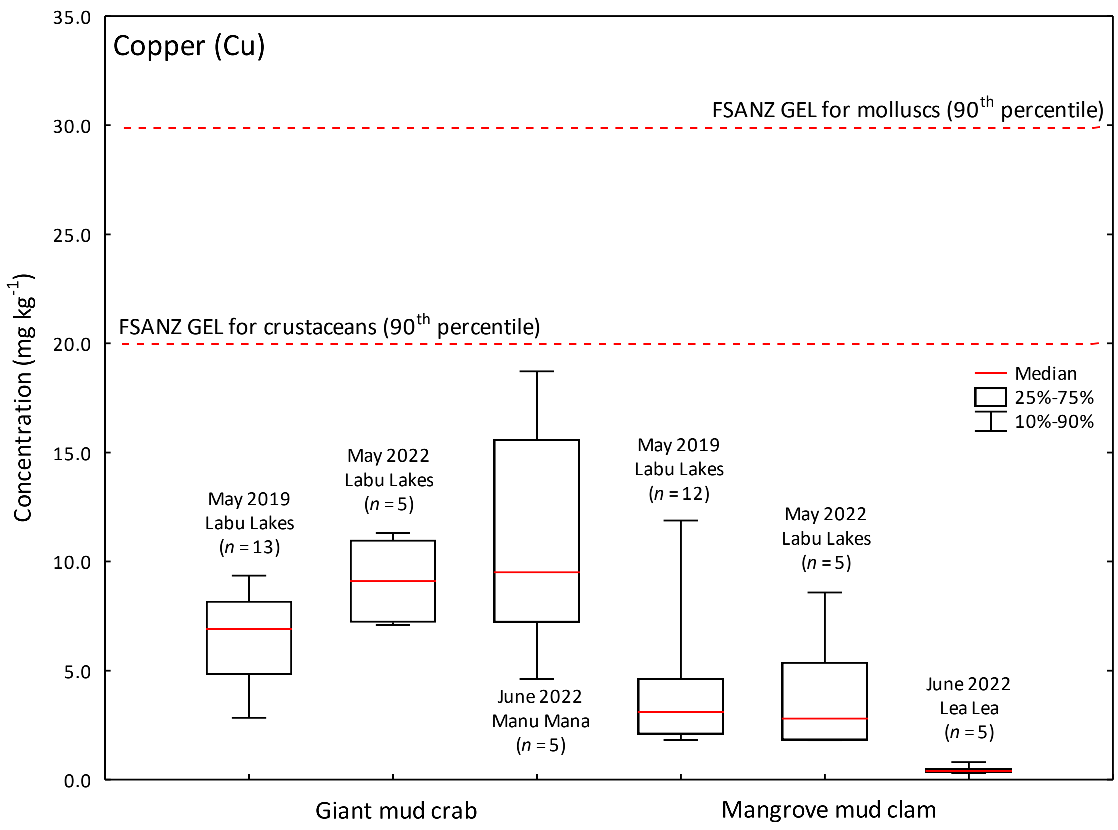

Figure ES1. Box and whisker plot of copper (Cu) concentrations in cheliped muscle of giant mud crabs and mangrove mud clams from western Huon Gulf (Labu Lakes) in May 2019 and 2022, and eastern Gulf of Papua (Manu Mana and Lea Lea) in June 2022, with their respective listed FSANZ Generally Expected Levels.

- Levels of Cu detected in whole mud clams were significantly higher in samples from western Huon Gulf (study area) in May 2019 and May 2022 than in samples from eastern Gulf of Papua (control area) in June 2022 (Figure ES1), while Se levels differed significantly across localities and year. Despite such differences, Cu and Se levels were well below FSANZ GELs for both metals listed for molluscs therefore no risk to human health is expected from the regular consumption of mud clams by local communities.
- As with fishes, natural differences in levels of metals in mud crabs and mud clams are expected and can be attributed to factors such burrowing behavior, metal availability in sediments typical of their soft, muddy habitats, as well as variability in metal bioaccumulation through ingestion of enriched particulate matter and sediments.

Fishing practices and catch per unit of effort (CPUE)

- Observations made during the process of sourcing fishes and invertebrates for this baseline study indicate that artisanal fishing within the study area in the western Huon Gulf is irregular and does not take place daily since fishes are not always available for sale at the DCA Point fish market in Lae. Indeed, of the 64 fish specimens tested for metals during this baseline survey, the study team only managed to obtain 26 fish specimens from DCA Point market over seven days, which constituted most of the fish available for sale at that time.

- In contrast, fish and other marine produce sold at the main Koki Fish market in Port Moresby are available daily except Sundays. Fish and various shellfish species sold at the Koki fish market originate from coastal waters of the eastern Gulf of Papua along PNG's Central Province, and arrive at least twice daily, i.e., early morning and after 4pm in the afternoon.
- For this study, locations where fishes were caught in western Huon Gulf and eastern Gulf of Papua were kindly provided by individual fishers and/or vendors during the purchasing process along with date, fishing time (effort), approximate depth and fishing gear used. However, total catch of individual fishers per fishing session was not disclosed so the data provided pertains only to specific fish samples purchased to be tested for metals for the study and not the entire catch.
- In general, fishes and invertebrates tested during this and previous baseline studies originate mostly from coastal marine waters to maximum depths of 50 m. Fish sold at the DCA Point Fish market originate predominantly from the coastal area between Labu Tale and Lae in the western Huon Gulf, including Labu Lakes, and therefore well outside the predicted DSTP deep water canyon receiving environment.
- The lack of actual information on total catch per day/session, coupled with highly variable fishing times of between 15 minutes and 2 days provided by individual fishers consulted, precludes at this time an estimation of catch per unit of effort (CPUE) necessary to provide a useful assessment of local fish abundances.

1 INTRODUCTION

1.1 Background

Wafi-Golpu Joint Venture (hereafter "WGJV") proposes to implement deep-sea tailings placement (DSTP) system to manage tailings generated from an underground copper-gold mine at Mt Golpu. The mine site 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 Permit for the WGJV Project was granted by the Conservation and Environment Protection Agency (CEPA) of Papua New Guinea on 18 December 2020, following a rigorous assessment of the Environmental Impact Statement (EIS) submitted to CEPA on 25 June 2018.

The EIS included a comprehensive baseline study of metal levels in fishes of the western Huon Gulf as a first step toward assembling a scientifically robust database to compare against future operational monitoring. 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. This included fishes directly caught both in the DSTP deep-water canyon receiving environment and western Huon Gulf coastal reference areas (see Figure 1), and fishes caught by the local artisanal fishery in the western Huon Gulf (n = 12) and sold in fish markets in Lae for human consumption.

To build a more comprehensive, robust baseline dataset, a further post-EIS study was commissioned to Marscco by WGJV in May 2019 to assess metal levels in representative fishes and invertebrates caught by the local coastal artisanal fishery and sold for human consumption at the local fish market in Lae (DCA Point). The study was undertaken during 6 to 11 May 2019 and described levels of 9 metals in tissues of a mud crab and mud clam species, as well as muscle tissues and livers from 14 species from seven families of bony fishes (Marscco, 2020) (refer to section 1.2 below for details).

The WGJV Project continues to undertake extensive consultation with coastal communities around DSTP and the results of its ongoing scientific studies such as these fish market surveys and ongoing oceanographic studies. 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 2022, the WGJV again commissioned Marscco to undertake a second comprehensive baseline study on metal levels in fishes and invertebrates typically caught by the local coastal artisanal fisheries in the western Huon Gulf (Morobe Province) and, for comparison, the eastern Gulf of Papua (Central Province), and which are sold for human consumption at the respective local markets in Lae (DCA Point) and Port Moresby (Koki Fish Market). This report describes the findings of this second post-EIS baseline study conducted by Marscco between 25 May and 1 June 2022. Results of this study complement findings from previous studies undertaken by Marscco in May 2019 of local fishes from western Huon Gulf (Marscco, 2020), and previous studies submitted as part of the WGJV Project Feasibility Study and EIS (Coffey/Marscco, 2018; Section 1.2 below).

1.2 Previous fish baseline studies

Following this second post-EIS study, the WGJV's database is now extensive and comprises data of metal levels for 194 fish specimens from fish 30 species, including four species of deep-sea sharks and 26 species of bony fishes, as well as 22 giant mud crabs and 23 mangrove mud clams.

The earliest baseline studies of metal levels in local fishes from the western Huon Gulf were carried out in November 2016 and May 2017 to complement information on species diversity both in the proposed DSTP and study areas required for the WGJV Project EIS (Coffey/Marscco, 2018; Appendix P). Samples available for these studies comprised 55 deep-sea sharks and six bony fishes caught by the WGJV team in and around the proposed DSTP and study area off Lae, and 14 specimens from five species of bony fishes caught by local artisanal fishers and purchased at the DCA Point market in Lae. Of the deep-sea sharks, 50 corresponded to gulper sharks of the family Centrolophidae and the remaining five were spurdogs of the family Squalidae, none of which are caught by the local artisanal fishery nor consumed by the local population. The 14 bony fishes sourced at the DCA Point market examined in November 2016 included local representatives from the families Lutjanidae (tropical snappers) and Carangidae (trevallies) (Table 1), and muscle and liver tissue samples removed from each of the 14 specimens were analysed for 12 metals including As, Cu, Hg and Pb.

The second, major baseline study of metal levels in local invertebrates and fishes from the western Huon Gulf was completed in May 2019 and included specimens from the region between Labu Tale and Lae as well as Labu Lakes, an open coastal estuary-like system that supports an important local fishery (Marscco, 2020). Of the bony fishes examined, muscle tissues from two species of the Family Lutjanidae that were tested for metals during the present study were also tested during the November 2016 (EIS) and May 2019 (second) baseline studies, i.e., mangrove jack and saddletail snapper (Coffey/Marscco, 2018; Marscco, 2020) (Table 1). Furthermore, the same two species of invertebrates tested during the May 2019 baseline study, i.e., giant mud crab and mangrove mud clam, were also tested during the present study (Table 2).

Table 1. Summary of fish species sourced from public markets in Lae (DCA Point) and Port Moresby (Koki Fish market) and tested for metals during WGJV-commissioned post-EIS baseline studies in November 2016 (Coffey/Marscco, 2018), May 2019 (Marscco, 2020), and May/June 2022 (present study). Fishes sold at DCA Point originate from the western Huon Gulf and include coastal locations around Salamaua Peninsula and just outside Labu Lakes, while fishes sold at Koki Fish market come from the eastern Gulf of Papua and include coastal locations along the Central Province such as Fisherman Island and Kaparoko in the proximity of Port Moresby. Marine fishes from the Wara Waria region near Morobe were sourced directly from local fishers based at that locality.

Family – fishes	Species		Common name	Nov 2016	May 2019		May 2022				Total
				DCA Point	DCA Point	Labu Lakes	Wara Waria	Labu Lakes Entrance	DCA Point	Koki	
1 Carangidae	1	*Alectis ciliaris*	Threadfin	1							**1**
	2	*Carangoides coeruleopinnatus*	Coastal trevally		2						**2**
	3	*Carangoides malabaricus*	Malabar trevally		6				3		**9**
	4	*Caranx sexfasciatus*	Bigeye trevally	4							**4**
	5	*Caranx tille*	Tille trevally		2				3	5	**10**
2 Eleotridae	6	*Ophiocara porocephala*	Spangled gudgeon			1					**1**
3 Haemulidae	7	*Pomadasys argyreus*	Bluecheek javelin				3				**3**
4 Lethrinidae	8	*Lethrinus harak*	Thumbprint emperor				2				**2**
	9	*Lethrinus ornatus*	Ornate emperor				3				**3**
5 Lutjanidae	10	*Lutjanus argentimaculatus*	Mangrove jack	2		5			3		**10**
	11	*Lutjanus dodecacanthoides*	Sunbeam snapper		3						**3**
	12	*Lutjanus gibbus*	Paddletail				3				**3**
	13	*Lutjanus goldiei*	Black bass					3			**3**
	14	*Lutjanus malabaricus*	Saddletail snapper	5	11				4	5	**25**
	15	*Lutjanus timoriensis*	Timor snapper				2				**2**

Family – fishes	Species		Common name	Nov 2016	May 2019		May 2022				Total
				DCA Point	DCA Point	Labu Lakes	Wara Waria	Labu Lakes Entrance	DCA Point	Koki	
	16	*Pristipomoides typus*	Sharptooth jobfish	2							**2**
6 Mugilidae	17	*Ellochelon vaigiensis*	Squaretail mullet			1					**1**
7 Muraenesocidae	18	*Muraenesox bagio*	Common pike conger		4				1		**5**
8 Nemipteridae	19	*Nemipterus bathybius*	Yellowbelly threadfin bream		6				4		**10**
	20	*Nemipterus isacanthus*	Teardrop threadfin bream		9				4		**13**
	21	*Nemipterus nematophorus*	Doublewhip threadfin bream		2				2		**4**
	22	*Nemipterus tambuloides*	Fivelined threadfin bream		2						**2**
9 Serranidae	23	*Epinephelus polystigma*	White-dotted grouper			2					**2**
10 Sciaenidae	24	*Otolithes ruber*	Tigertooth croaker				2		2		**4**
11 Scombridae	25	*Euthynnus affinis*	Mackerel tuna							5	**5**
	26	*Scomberomorus commerson*	Spanish mackerel							5	**5**
			Total specimens tested	**14**	**47**	**9**	**15**	**3**	**26**	**20**	**134**

Table 2. Summary of invertebrate species sourced from public markets in Lae (DCA Point) and Port Moresby (Koki Fish market) and tested for metals during WGJV-commissioned post-EIS baseline studies in May 2019 (Marscco, 2020) and May/June 2022 (present study); no invertebrates were tested in the November 2016 baseline study. All clams and crabs sold at DCA Point originate from within Labu Lakes, while specimens of these species sourced from the Koki Fish market originate from coastal locations along the eastern Gulf of Papua such as Lea Lea (clams) and Manu Mana (crabs) in the proximity of Port Moresby.

Family – clams	Species	Common name	May 2019		May 2022				
			DCA Point	Labu Lakes	Wara Waria	Labu Lakes Entrance	DCA Point	Koki	Total
1 Lucinidae	1 *Anodontia edentula*	Mangrove mud clam	-	12	-	-	5	5	**22**
		Total specimens tested	**-**	**12**	**-**	**-**	**5**	**5**	**22**
Family – crabs	**Species**	**Common name**	**DCA Point**	**Labu Lakes**	**Wara Waria**	**Labu Lakes Entrance**	**DCA Point**	**Koki**	**Total**
1 Portunidae	1 *Scylla serrata*	Giant mud crab	-	13	-	-	5	5	**23**
		Total specimens tested	**-**	**13**	**-**	**-**	**5**	**5**	**23**

In the absence of human health standards or guidelines for metal levels in marine produce in PNG (fish, crustaceans, molluscs), metal levels in fish and invertebrate samples reported in this and the 2019 baseline study (Marscco, 2020) were compared against the recommended guidelines of the joint Food Standard Australian and New Zealand (FSANZ). The FSANZ guidelines include maximum limits and means under the FSANZ Standard 1.4.1 (FSANZ, 2016), and 90th percentile values 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).

Of the metals measured during the May 2019 baseline study and regarded as of concern to regular human consumption, mean levels did not exceed the FSANZ Standards listed for fishes for estimated inorganic arsenic (As) or mercury (Hg), indicating that no adverse health issues would be expected to manifest in the local community from the regular consumption of flesh from the fish species tested (refer to Section 2.5.1. below for details on FSANZ Standards). Furthermore, mean levels did not exceed the FSANZ GELs 90th percentile listed for fishes for copper (Cu) or selenium (Se), while levels of lead (Pb), cadmium (Cd) and chromium (Cr) in muscle tissues of all fish species tested were either undetectable or very low. It was thus concluded that levels of Cd, Cr, Cu, Pb and Se reported during the May 2019 baseline study were not expected to pose a risk to public health from the regular consumption of flesh from any of the fish species tested (Marscco, 2020).

The results of metal levels in the single species of mud crab and mud clam reported in the May 2019 baseline study were almost identical to those reported in fishes and were therefore not expected to pose a risk to public health from the consumption of either invertebrate species. The main findings indicated that metal levels did not exceed the FSANZ Standard listed for crustaceans and molluscs for estimated inorganic arsenic (As) or mercury (Hg), the FSANZ Standard for molluscs for cadmium (Cd) or lead (Pb) or the FSANZ GELs 90th percentile for copper (Cu) or selenium (Se), while levels of chromium (Cr) in tissues of the two species were either undetectable or very low (Marscco, 2020).

1.3 Scope of work

The objectives of this additional baseline study were to (i) further describe baseline levels (concentrations) of selected metals in marine fish species caught by the local coastal artisanal fishery in the western Huon Gulf outside of the predicted DSTP outfall and tailings placement area (the study area) and sold at the DCA Point fish market in Lae; and (ii) to compare metal levels in fish and invertebrates from the study area with metal levels in similar biota from two control areas, namely: coastal waters along the eastern Gulf of Papua close to Port Moresby (POM) and which are sold at the Koki fish market in POM, and Wara Waria, located south of the Salamaua Peninsula in the western Huon Gulf, approximately 145 km to the southeast of Lae in the Morobe Province.
In addition to fishes, metal levels were also analysed in the tissues of the same two invertebrate species studied during the May 2019 baseline study, i.e., giant mud crab and mangrove mud clam.

Specific objectives of this second post-EIS baseline study are outlined below:

1. Select representative common fish species sold daily for human consumption at the DCA Point market in Lae (study area) and the Koki Fish market in Port Moresby (control area), and purchase specimens for metal analysis.
2. For comparative purposes and subject to market availability, selection of fish species from western Huon Gulf to include species already tested in previous studies (i.e., November 2016 and May 2019) as well as same fish species likely to be found at Koki Fish market.
3. Identify all fishes sourced at the DCA Point and Koki Fish markets, as well as Wara Waria, to species level and provide descriptions of key morphological characters and photographs of each species to complement descriptive identification guide being assembled in previous studies (November 2016 and May 2019) to be used in future baseline and monitoring surveys of market fishes commissioned by the WGJV.
4. Where possible, for each species obtain information from fishers and/or vendors on location of capture as well as date, depth (m) and fishing method (gear) and, if available, data on effort in terms of time to estimate catch per unit of effort (CPUE).
5. Record morphological and biological characteristics of each fish specimens sourced for the study, including total length (cm), weight (g), sex (M, F, or immature), and reproductive condition.
6. Collect samples of muscle tissues and livers from all fish specimens sourced from the DCA Point and Koki fish markets, as well as of all fish specimens from Wara Waria, and transport samples frozen back to the accredited ALS Global laboratory in Sydney, Australia, for metal analysis.
7. Describe levels of each of the 12 metals selected for this baseline study by species and sampling location using appropriate descriptive statistics and compare values with data available from earlier studies in the western Huon Gulf in November 2016, May 2017, and in May 2019.
8. Source an adequate number of replicate samples of giant mud crabs and mangrove mud clams from Labu Lakes (western Huon Gulf) and Koki Fish market (eastern Gulf or Papua) and process all specimens for metal analysis; tissues tested in mud crabs comprise the entire left cheliped muscle and digestive gland (hepatopancreas) whereas the whole animal is tested in mud clams.
9. Compare metal levels in muscle samples of fishes and invertebrates against current international food guidelines (FSANZ Standard 1.4.1 and FSANZ GELs). Comparison of metal levels in fish livers against FSANZ guidelines were omitted since maximum levels only apply to the portion of food that is ordinarily consumed, i.e., muscle tissue (flesh).
10. Compare results of metal levels in muscle samples of fishes and invertebrates against data available from previous baseline studies in western Huon Gulf (November 2016 and May 2019), and between the study area (western Huon Gulf) and control areas (Wara Waria and eastern Gulf of Papua) sampled during this study.

2 METHODOLOGY

2.1 Fish sample collection

2.1.1 Sources of fish samples

All fishes examined for this baseline study comprise marine species sold for human consumption and originated from three main areas, namely (1) coastal waters of the western Huon Gulf in the Morobe Province between Labu Tale and Lae, including the entrance to Labu Lakes; (2) coastal region around the Waria River mouth located approximately 145 km to the southeast of Lae, and also within the western Huon Gulf (referred to as Wara Waria); and (3) coastal waters of the eastern Gulf of Papua comprising various locations along the Central Province in the proximity of Port Moresby (Figure 1).

Fishes from the western Huon Gulf were purchased from fishers at the DCA Point fish market in Lae as well as directly from fishers operating in the Wara Waria region (Table 3). Fishes from the eastern Gulf of Papua were purchased at the Koki Fish market in Port Moresby and originate from various locations along the Central Province including Fisherman Island, Kaparoko and Hula. Locations where fishes were caught in the western Huon Gulf and eastern Gulf of Papua, were kindly provided by individual fishers and/or vendors during the purchasing process along with date, fishing time (effort), approximate depth and fishing gear used. However, total catch of individual fishers per fishing session was not disclosed so data provided pertains only to specific fish samples purchased for metal testing and not the entire catch. The lack of information on total catch per day/session, coupled with highly variable fishing times of between 15 minutes and 2 days provided by fishers consulted (Appendices 1-3), precluded the estimation of catch per unit of effort (CPUE). In addition, the local artisanal fishing fleet operating in western Huon Gulf is relatively small and fishing effort is highly weather-dependent thereby resulting in an irregular supply of fish to the DCA Point market, a fact which is likely to preclude future CPEU estimation to be statistically valid as a long-term baseline.

Fishes from the western Huon Gulf and Wara Waria are caught by the local artisanal fishery at depths of approximately 100 m or less from either small outrigger sailboats or motorised banana boats; a few fish samples also originated from the entrance to the shallow Labu Lakes, where the depth of water averages 2 m. Exact latitude and longitude positions (coordinates) of fishing locations in the western Huon Gulf are unavailable as fishers lack access to GPS units onboard their vessels. No fishing takes place over or nearby the predicted tailings outfall area (Figure 1) due to the depth of the water column in that region of the continental slope (>100 m), lack of deep-water fishing gear and absence of seabed slope features that support fish species typically targeted for human consumption, i.e., deep rocky reefs. For the purposes of this study, and the statistical analyses (Section 2.4), the western Huon Gulf area between Labu Tale and Lae is regarded as the "study area" whereas the coastal regions around Wara Waria and along the eastern Gulf of Papua in the Central Province are regarded as "control areas".

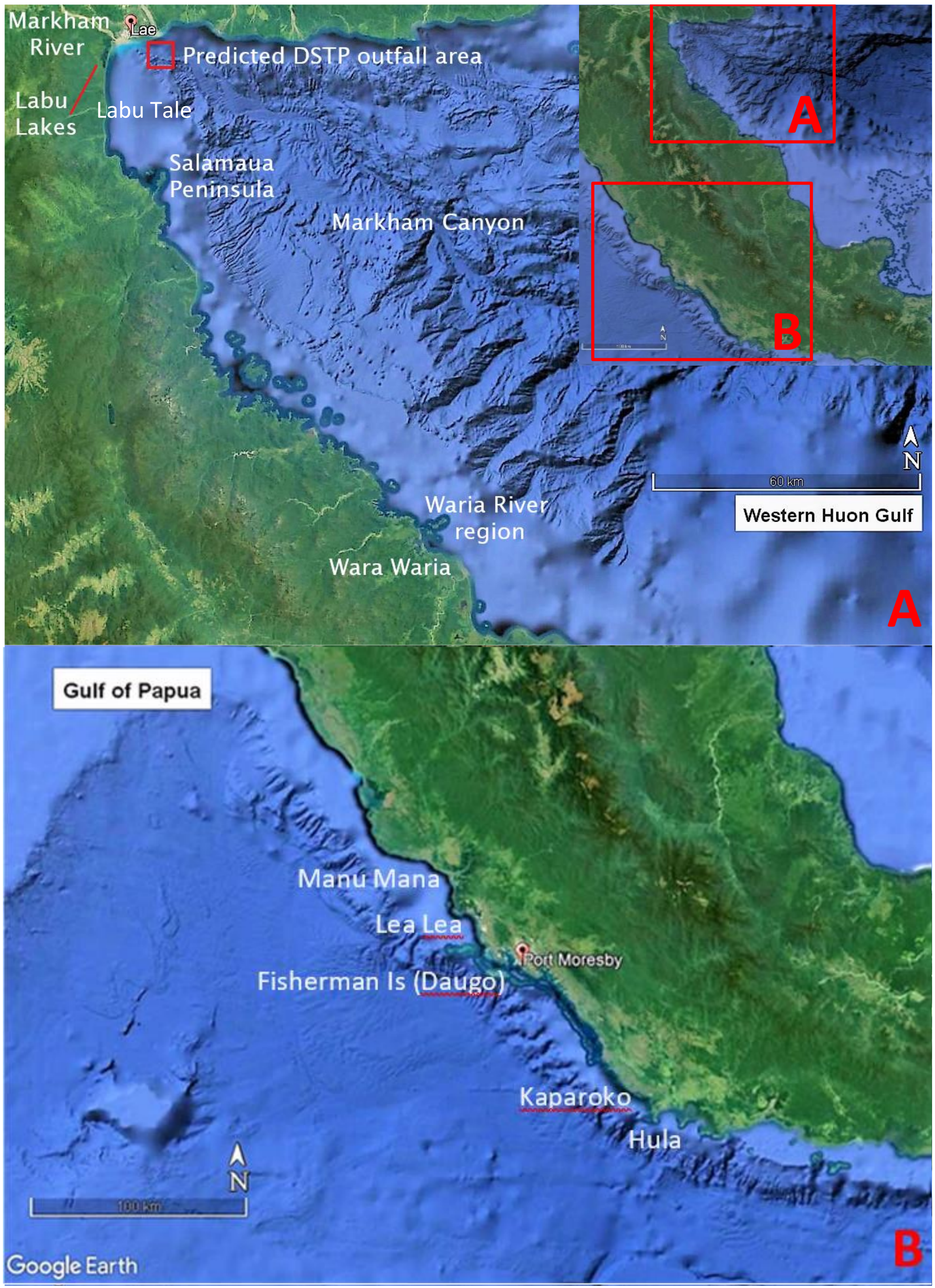

Figure 1. Locations in Papua New Guinea where fish and invertebrate samples originated for the May/June 2022 baseline study. A – section of western Huon Gulf along the Morobe Province; B – section of eastern Gulf of Papua in the Central Province.

2.1.2 Selected market fish species

Sixty-four specimens representing 17 species from eight families of bony fishes (teleosts) were examined during the study period, i.e., 25 May to 1 June 2022 (Table 3). These include various species from locally abundant families such as Lutjanidae (tropical snappers, 5 species), Nemipteridae (threadfin breams, 3 species), Lethrinidae (emperors, 2 species) and Carangidae (trevallies, 2 species).

Table 3. Summary of fish families and species sampled during this post-EIS baseline study to determine tissue metal levels.

Family	*N*	Species	Common name	Origin (market)	Numbers sampled	Total length (cm)	Total weight (g)
1. Carangidae	1	*Carangoides malabaricus*	Malabar trevally	Huon Gulf (DCA Point)	3	24.8 - 31.6	195 - 415
	2	*Caranx tille*	Tille trevally	Huon Gulf (DCA Point)	3	30.9 - 60.4	365 - 2,610
				Kaparoko-Hula (Koki Fish)	5	31.5 - 40.5	480 - 760
2. Haemulidae	3	*Pomadasys argyreus*	Bluecheek javelin	Wara Waria	3	17.4 - 19.5	95 - 130
3. Lethrinidae	4	*Lethrinus harak*	Thumbprint emperor	Wara Waria	2	21.3 - 24.5	180 - 225
	5	*Lethrinus ornatus*	Ornate emperor	Wara Waria	3	17.3 - 23.5	125 - 255
4. Lutjanidae	6	*Lutjanus argentimaculatus*	Mangrove jack	Huon Gulf (DCA Point)	3	58.5 - 60.2	2,675 - 2,850
	7	*Lutjanus gibbus*	Paddletail	Wara Waria	3	15.7 - 21.5	80 - 145
	8	*Lutjanus goldiei*	Black bass	Labu Lakes Entrance	3	53.8 - 60.7	2,840 - 3,915
	9	*Lutjanus malabaricus*	Saddletail snapper	Huon Gulf (DCA Point)	4	23.5 - 36.2	195 - 645
				Abau District coast (Koki Fish)	5	39.4 - 42.3	800 - 985
	10	*Lutjanus timoriensis*	Timor snapper	Wara Waria	2	16.5 - 20.5	75 - 135
5. Muraenesocidae	11	*Muraenesox bagio*	Common pike conger	Huon Gulf (DCA Point)	1	112.5	2,255
6. Nemipteridae	12	*Nemipterus bathybius*	Yellowbelly threadfin bream	Huon Gulf (DCA Point)	4	23.5 - 29.6	125 - 200
	13	*Nemipterus isacanthus*	Teardrop threadfin bream	Huon Gulf (DCA Point)	4	26.9 - 30.5	170 - 270
	14	*Nemipterus nematophorus*	Doublewhip threadfin bream	Huon Gulf (DCA Point)	2	24.5 - 26.2	110 - 120
7. Sciaenidae	15	*Otolithes ruber*	Tigertooth croaker	Wara Waria	2	24.3 - 27.8	125 - 190
				Huon Gulf (DCA Point)	2	31.5 - 33.1	280 - 320
8. Scombridae	16	*Euthynnus affinis*	Mackerel tuna	Fisherman Island (Koki Fish)	5	43.0 - 74.2	925 - 4,475
	17	*Scomberomorus commerson*	Spanish mackerel	Kaparoko-Hula (Koki Fish)	5	63.5 - 79.2	1,480 - 2,790
				TOTAL	**64**		

Table 4. Summary of invertebrate families and species sampled during this post-EIS baseline study to determine tissue metal levels.

Family	*N*	Species	Common name	Origin (market)	Numbers sampled	Carapace length (cm)	Total weight (g)
1. Portunidae	1	*Scylla serrata*	Giant mud crab	Labu Lakes Body (DCA Point)	5	10.3 - 16.0	170 - 625
				Manu Mana (Koki Fish)	5	11.9 - 12.4	300 - 510
				TOTAL	**10**		
Family	***N***	**Species**	**Common name**	**Origin**	**Numbers sampled**	**Shell length (cm)**	**Weight animal (g)**
2. Lucinidae	1	*Anodontia edentula*	Mangrove mud clam	Labu Lakes Body (DCA Point)	5	5.4 - 6.6	65 - 105
				Lea Lea (Koki Fish)	5	7.6 - 9.3	135 - 350
				TOTAL	**10**		

2.1.3 Fish identifications

All marine 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 comprised trevallies of the Family Carangidae (Smith-Vaniz, 1999), emperors of the family Lethrinidae (Carpenter and Allen, 1989), snappers of the Family Lutjanidae (Allen, 1985; Anderson and Allen, 2001), threadfin breams of the Family Nemipteridae (Russell, 1990, 2001), and tunas and mackerels of the family Scombridae (Collette and Nauen, 1983; Collette, 2001). Fish species identification atlases encompassing PNG in the Indo-Pacific region included those published by the Food and Agriculture Organisation (FAO) for the Western Central Pacific (Carpenter and Niem, 2001), and those of Gloerfelt-Tarp and Kailola (1984), Randall *et al*. (1990), Harrison *et al*. (1999) and Allen (2018).

Short descriptive summaries are provided in Section 3.1 for 9 of the 15 fish species examined for this study along with photographs of fresh specimens prior to dissections; descriptions and photographs of the remaining six fish species from the western Huon Gulf were included in the May 2019 baseline study report (Marscco, 2020). Where appropriate, common names employed in descriptions correspond to main English names adopted by the 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 species name, location of capture and sex of each fish examined during this study is provided in Appendix 1.

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 indetermined (Ind) and comprised mostly immature individuals where gonadal development has not yet commenced.

2.1.5 Sampling of fish tissues

Dissections of fishes and invertebrate specimens from the western Huon Gulf and the Wara Waria region were performed at a laboratory-adapted room at the Crossroads Transit Hotel (9 Mile) in Lae, while dissections of specimens from the eastern Gulf of Papua were undertaken at a laboratory-adapted room of the Holiday Inn Hotel in Port Moresby. Measures of quality assurance to maintain highest possible sterile conditions and avoid cross-contamination at both locations 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/invertebrate, i.e., single-use only; and (d) using 98% ethanol to sterilize scalpel handles, as well as stainless steel forceps and scissors between dissections. All dissections were carried out using sterilised carbon steel surgical blades size 23.

Samples of muscle tissues (flesh) and whole livers were obtained from all 64 fish specimens examined during the present study (Appendix 1), and subsequently tested for a selected 12 metals (Section 2.3.2 below). Muscle comprises the edible part of fishes consumed by the local population whereas fish livers are not consumed. However, the liver is considered as the main organ for metabolic and detoxification functions and hence a site of metal bioaccumulation[1] and biomagnification[2] for metals such as copper, lead, and zinc. The monitoring of metals in livers is thus considered relevant as it provides information as to what prey fishes consume and what is bio-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 3.9 g and 33.0 g depending on fish size were removed from the top left side of the trunk region, i.e., above the left pectoral fin base. Livers from all fish specimens examined were removed whole for analysis and ranged between 0.2 g and 29.0 g in weight (Appendix 1). Muscle and liver tissue samples were each weighed to the nearest 0.1 g using a high-precision balance, and immediately placed inside individual zip-lock plastic bags labelled with specimen number, tissue type, and date and site fished, and subsequently stored in a freezer.

2.2 Sampling of invertebrate species

Two invertebrate species were examined for this baseline study, i.e., giant mud crab, *Scylla serrata* (Family Portunidae) and mangrove mud clam, *Anodontia edentula* (Family Lucinidae) (Table 4). Specimens of these two species were also tested for metals during the May 2019 baseline study (Table 3), with the report also including a brief description and photograph of each species (Marscco, 2020). The mud crab (Subphylum Crustacea, Class Malacostraca, Oder Decapoda) and mud clam

[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.

(Phylum Mollusca, Class Bivalvia) were respectively identified to family and species level following the taxonomic keys of Poutiers (1998) and Ng (1998).

A total of 20 specimens were tested for metals during this study comprising five of mud crab and five of mud clam from Labu Lakes in the western Huon Gulf and sourced from the DCA Point market in Lae, and five of each species from Manu Mana and Lea Lea in the eastern Gulf of Papua (Figure 1) and sourced from the Koki Fish market in Port Moresby.

Tissue samples from clams and crabs were treated following the same approach applied to fishes (Section 2.1.5) and subsequently tested for the same 12 metals. Tissues from mud crabs include the entire muscle from the left cheliped (propodus, carpus and merus), and the hepatopancreas (digestive gland) (Pinheiro *et al*., 2012). In the case of mud clams, the whole animal was removed after opening the two valves and subsequently washed with distilled water to remove excess mud. Weights of left cheliped muscle and hepatopancreas samples from crabs were 9.2-28.7 g and 0.4-9.5 g, respectively (Appendix 2) while whole clams (without shell) weighed 7.8-33.1 g (Appendix 3).

2.3 Transport of samples and laboratory analysis

The combined 158 fish and invertebrate tissue samples collected during the study were taken frozen by the author (FJN) on 3 June 2022 from Port Moresby to the Brisbane International Airport. The samples were collected by a representative from the Australian Laboratory Services Pty Ltd ('ALS Global') in Brisbane along with the respective Chain of Custody form following inspection by airport staff from the Department of Agriculture and the Environment (DAWE), and subsequently posted frozen to the ALS Sydney-Environmental facility in New South Wales for metal analysis.

Tissue samples from fishes and mud crabs, along with whole mud clams, were analysed by the ALS Sydney-Environmental laboratory (NSW), 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 Environmental Division Sydney ('ALS Environmental) on 8 June 2022, and the results of the metal analysis emailed to Marscco on 30 June 2022.

2.3.1 Chain of custody

Sample Receipt Notification (SRN) reports provided by ALS Environmental are included as Appendices 4 and 5 at the end of this report. These consist of two separate SRN reports namely Work Order (WO) ES2220138 (Appendix 4), which includes fish tissue samples from the Wara Waria region labelled WW-1 to 16-M/L (M, muscle; L, liver); western Huon Gulf fish samples HG-17 to 26-M/L, HG-30 to 31-M/L, HG-37-M/L; Labu Lakes entrance samples LLE-27 to 29-M/L; and Labu Lakes crab samples LLB-32 to 36-M/HP (M, left cheliped muscle; HP, hepatopancreas); and WO ES2220136 (Appendix 5), corresponding to western Huon Gulf fish samples HG-38 to 43-M/L; Labu Lakes clam samples LLB-44 to 48-C; Huon Gulf fish samples HG-51 to 57-M/L; Gulf or Papua fish samples GPK-58 to 67-M/L; Gulf of Papua clam samples GPK-68 to 72-M; Gulf of Papua crab samples GPK-73 to 77-M/HP; and Gulf or Papua fish samples GPK-78 to 87-M/L.

2.3.2 Metal analysis

Muscle tissue and livers of fishes, as well as cheliped muscle and hepatopancreas of mud crabs and whole mud clams, were analysed for total levels (mg kg^{-1} wet weight; ww) of the following 10 metals and two metalloids (Table 5): Arsenic (As); Cadmium (Cd); Chromium (Cr); Copper (Cu); Iron (Fe); Lead (Pb); Manganese (Mn); Mercury (Hg); Nickel (Ni); Selenium (Se); Silver (Ag); and Zinc (Zn). For convenience, both metals and metalloids (i.e., As and Se) are referred to as '*metals'* throughout this report, and all metals concentrations (mg kg^{-1}) refer to wet weight (ww); the terms '*levels'* and '*concentrations'* are used interchangeably throughout this report.

Limits of Reporting (LOR in mg kg^{-1} ww) for each metal were: 0.01 for Cd; 0.05 for As, Cr, Pb, Mn, Ni and Se; 0.1 for Ag, Cu and Hg; and 0.5 for Fe and Zn. The reported LOR for Hg during the May 2019 study was 0.01 mg kg^{-1}, i.e., higher than the requested LOR of 0.1 mg kg^{-1} for the analyte (ALS Sydney-Environmental comment, 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) to achieve a LOR of 0.1 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 Environmental Certificate of Analysis emailed to Marscco, 30 June 2022).

Liver volumes of 11 specimens from six fish species were regarded as insufficient for metal analyses and therefore no concentration data could be obtained for these specimens because of their small livers (Appendix 1). These comprised eight relatively small specimens from Wara Waria (e.g., ornate emperor, Timor snapper) and three from the western Huon Gulf (e.g., doublewhip threadfin bream, tigertooth croaker) which ranged in size between 15.7 cm and 33.1 cm TL (75 g - 320 g). Similarly, volumes of hepatopancreas tissue from four of the five giant mud crabs sampled from the Labu Lakes in the western Huon Gulf were considered insufficient for metal analysis (Appendix 2).

2.3.3 Quality assurance and quality control

The quality assurance/quality control (QA/QC) protocol implemented by ALS Environmental to determine metal levels in fish and invertebrate tissues used Supersoil Standard as Certified Reference Material (CRM). The use of CRMs for QC is essential for metal analyses, especially to assess calibration of analytical instruments and to validate analytical measurements. This rigorous test of the analytical method for determining metal levels in a fish tissue matrix compares metal analysis results against the Supersoil Standard CRM values for each metal (Table 5). The ALS Laboratory Control Spike (LCS) reports obtained during this study (Appendix 8) showed spikes recoveries (%) well within the acceptable limits of 70% to 130% for all metals tested (Table 5).

Table 5. Laboratory control spike recoveries (%) reported by ALS Environmental for 8 metals and one metalloid using Supersoil Standard values as control reference material (CRM) during this post-EIS baseline study; no spike recovery data was reported for manganese (Mn), selenium (Se) or silver (Ag).

Metal	Type*	CRM: Supersoil Standard – certified value (mg kg^{-1})	ALS analytical result – spike concentration (mg kg^{-1})	Laboratory Control Spike (LCS) Spike Recovery (%)
Arsenic (As)	Non-essential metalloid	102.35	98.00	72.4 - 83.1
Cadmium (Cd)	Non-essential metal	1.36	0.74	95.1 - 111.0
Chromium (Cr)	Essential metal	17.93	15.40	98.8 - 121.0
Copper (Cu)	Essential metal	48.71	48.00	83.7 - 100.0
Iron (Fe)	Essential metal	26,322.50	27,922.00	77.3 - 99.2
Lead (Pb)	Non-essential metal	61.00	50.00	103.0 - 125.0
Manganese (Mn)	Essential metal	522.38	-	-
Mercury (Hg)	Non-essential metal	0.099	0.087	78.2 - 104.0
Nickel (Ni)	Non-essential metal	13.70	12.4	98.2 - 117.0
Selenium (Se)	Essential metalloid	0.59	-	-
Silver (Ag)	Non-essential metal	2.72	-	-
Zinc (Zn)	Essential metal	166.32	115.00	94.4 - 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 QA/QC applied by ALS 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 samples WO # ES2220138 and WO # ES2220136, 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 for each species tested in Section 3.2 (fishes) and Section 3.3 (invertebrates). 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 levels to be below the LOR for the corresponding metal (n<LOR). In addition, 90th percentile values are provided for Cu (fishes, crabs, clams), Se (fishes, crabs, clams) and Zn (fishes, crabs) to compare against FSANZ GEL values (Section 2.5 – Table 6).

Box and whisker plots provided for metals with current FSANZ Standard and FSANZ GELs (refer to Section 2.5.1, Table 6) are provided for muscle tissues sampled from fishes and invertebrates to compare levels across three localities/markets, i.e., the study area (western Huon Gulf/DCA Point) and two control areas (Wara Waria and eastern Gulf of Papua/Koki Fish market) and survey dates (November 2016, May 2019, and this study) (Section 3.4). Where data were available, e.g., concentrations >LORs, plots were constructed using the statistical software STATISTICA 7 and comprise (1) mean concentrations + standard error (SE) (box) and minimum/maximum (whiskers) for As (fishes, crabs, clams), Cd (clams) and Hg (fishes, crabs, clams); and (2) medians, 25%-75% quartiles (box), and 10%-90% percentiles (whiskers) for Cu (fishes, crabs, clams), Se (fishes, crabs, clams) and Zn (fishes, crabs). All plotted data were subjected to single-factor analysis of variance (ANOVA) at the 5% level of significance ($P<0.05$) to determine significance of differences, if any, in the levels of selected metals in muscle tissues of sampled biota (fishes, crab, clam) between sampling localities and survey dates. Results of ANOVA are provided in Table 27 for each metal, along with Post Hoc comparison tests (Least Significant Difference – LSD) between localities and survey dates (year).

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 baseline study, along with tissue samples from the single species of giant mud crab (cheliped muscle) and mangrove mud clam (whole animal), were compared to the standard levels specified by the joint Australia New Zealand Food Standards Code under Food Standards Australia New Zealand (FSANZ) Act 1991 (FSANZ Act) for fishes, crustaceans (crabs) and molluscs (clams). The Standards comprise legislative instruments under the *Legislation Act 2003* while the FSANZ is an independent statutory agency established by the FSANZ Act (www.foodstandards.gov.au/code/Pages/default.aspx).

Comparisons of metal levels in fish livers against the FSANZ standard 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 same approach was applied to the hepatopancreas tissue of mangrove mud crabs.
Metal levels published under the FSANZ Standard 1.4.1 (Schedule 19-4 and 19-7) and FSANZ Generally Expected Levels (GELs) are presented in Table 6. 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'.

The standards include FSANZ Standard 1.4.1 – Contaminants and Natural Toxicants (1 March 2016): **Schedule 19**: Maximum Levels of Contaminants and Natural Toxins (FSANZ, 2016; Code Revision 2020; start date: 3 June 2021; https://www.legislation.gov.au/Details/F2021C00628), and the *Generally Expected Levels* (GELs) for Metal Contaminants (FSANZ, 2001). **Schedule 19** of the FSANZ Standard 1.4.1 states: (1) *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/F2021C00757). Additional information on Schedule 22 and other aspects of the standards are provided in the May 2019 baseline report (Marscco, 2020).

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); (c) comparable past baseline fish metal studies in PNG (e.g., NSR, 1988, 1996; Coffey, 2012); and the May 2019 baseline metal study of market-sourced fishes and invertebrates (mud crab and mud clam) from western Huon Gulf (Marscco, 2020).

Of the 12 metals analysed during the present baseline study, FSANZ Standard (maximum limits and/or means) for fish are available for As, Pb and Hg, while FSANZ GELs (90th percentiles) are available for Cu, Se, and Zn (Table 6). For crustaceans and molluscs, FSANZ Standard are available for As and Hg (crustaceans, molluscs), Cd (molluscs) and Pb (molluscs), while FSANZ GELs are available for Cu and Se (crustaceans, molluscs), and Zn (crustaceans). No FSANZ Standard or FSANZ GELs are available for Cr, Fe, Mn, Ni or Ag for fishes, crustaceans, or molluscs (Table 6).

Levels 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 6) to determine exceedances, if any (Section 3.2.13; Table 20). In the case of As, total As concentrations in muscle tissue samples 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). Levels of Pb and Hg in muscle tissues were compared with maximum limits and means (FSANZ Standard), while levels of Cu, Se and Zn were compared with 90th percentiles (FSANZ GELs).

Levels of As and Hg in the left cheliped muscle from crabs, as well as levels of As, Cd, Pb and Hg in whole clams, were compared against maximum limits listed for these metals under the FSANZ Standard (Table 6); 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 (refer to Section 2.5.2). Levels of Cu, Se, and Zn in the respective tissues from crabs and whole clams were compared to 90th percentile values under FSANZ GELs (Table 6). Results are described separately for crabs in Section 3.5.1 and Section 3.5.2, respectively.

Table 6. Current 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	Biota	**FSANZ Standard 1.4.1**[a] Schedule 19-4 and 197 Maximum level (mg kg^{-1})	**FSANZ GEL**[b] 90th percentile (mg kg^{-1})
Arsenic (inorganic)	Crustacea Molluscs Fish	2.0 1.0 2.0	- -
Cadmium	Molluscs	2.0	
Chromium	-	-	-
Copper	Crustacea Molluscs Fish	- - -	20.0 30.0 2.0
Iron	-	-	-
Lead	Molluscs Fish	2.0 0.5	- -
Manganese	-	-	-
Mercury [c]	Crustacea, molluscs, and fish	0.5 (mean)[d] 1.5 (maximum level)[e] 0.5 (mean)[f] 1.0 (maximum level)[g]	-
Nickel	-	-	-
Selenium	Crustacea Molluscs Fish	- - -	1.0 1.0 2.0
Silver	-	-	-
Zinc	Crustacea Fish	- -	40.0 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 in tissue samples obtained during this study correspond to 'total As' levels 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 arsenic concentrations are provided as total As in this study, the FSANZ Standard recommended for fishes, crustaceans and molluscs pertains to inorganic As (FSANZ, 2016). Therefore, to allow a direct comparison between total As detected in muscle tissues and the maximum limits specified under the FSANZ Standard (Table 6), 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 7. 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. The same ratio was used as conversion factor during the May 2019 baseline study (Marscco, 2020).

Table 7. 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 17 species of bony fishes from eight families were dissected to remove muscle samples and livers during this study (Table 1). The four most abundant species tested were saddletail snapper (n = 9), tille trevally (n = 8), and mackerel tuna and Spanish mackerel (n = 5 each).

Photographs and brief descriptions of eight of the fish species sampled during the present baseline study are provided in the May 2020 baseline study report (Marscco, 2020), including the lujtanids saddletail snapper (*Lutjanus malabaricus*) and mangrove jack (*L. argentimaculatus*); the carangid tille trevally (*Caranx tille*), and the nemipterids teardrop threadfin bream (*Nemipterus isacanthus*) and yellowbelly threadfin bream (*N. bathybius*).

Sections 3.1.1 through to 3.1.5 below provide a general description of each of the remaining 9 fish species examined during this baseline study, along with notes on their main distinguishing morphological features and geographical distribution.

3.1.1 Family Haemulidae – Sweetlips

Pomadasys argyreus – Bluecheek javelin

Three specimens caught in coastal waters of the Wara Waria region in western Huon Gulf and sourced directly from local fishers (17.4 cm to 19.5 cm TL, 95 g to 130 g; Figure 2).

Diagnostic characters: deep body, with blunt head profile and small mouth. Colour: silvery, with dark blotch over gill cover and anterior pelvic and anal fins yellow. Fin counts: D = XII, 13; A = III, 7.

Recorded in coastal inshore waters of India, Sri Lanka, upper Queensland to Papua New Guinea. Maximum length to 40 cm TL. Also known as bluecheek silver grunt (McKay, 2001).

Figure 2. Bluecheek javelin, *Pomadasys argyreus* (Family Haemulidae) from Wara Waria region, western Huon Gulf (female 19.5 cm TL; 130 g).

3.1.2 Family Lethrinidae – Emperors

Lethrinus harak – Thumbprint emperor

Two specimens caught in coastal waters of the Wara Waria region in western Huon Gulf and sourced directly from local fishers (21.3 cm to 24.5 cm TL, 180 g to 225 g; Figure 3).

Diagnostic characters: body moderately deep, with slightly convex head. Colour: olive/gray above to silvery white below with a large, distinct elliptical black blotch on side of body directly below lateral line and near posterior tip of pectoral fins, pinkish dorsal and anal fins, and orange to reddish caudal fin. No scales under eye on cheek, and usually 46-47 lateral line scales. Fin counts: D = X, 9; A = III, 8.

Widely distributed throughout Indo-West Pacific, including north-eastern Australia and Papua New Guinea, in shallow sand-rubble and weedy areas inshore and adjacent to coral reefs. Maximum length to 50 cm TL, commonly 20 cm-30 cm TL (Carpenter and Allen, 1989; Carpenter, 2001; Allen 2018).

Figure 3. Thumbprint emperor, *Lethrinus harak* (Family Lethrinidae) from Wara Waria region, western Huon Gulf (female 24.5 cm TL; 225 g).

Lethrinus ornatus – Ornate emperor

Three specimens caught in coastal waters of the Wara Waria region in western Huon Gulf and sourced directly from local fishers (17.3 cm to 23.5 cm TL, 125 g to 255 g; Figure 4).

<u>Diagnostic characters</u>: body relatively deep, with nearly straight or slightly concave head. Colour: dusky whitish above and lighter below, with bright red preopercular and opercular margins, 5-6 distinct yellow to orange stripes along lateral surface of trunk ending at caudal peduncle, pinkish dorsal and anal fins, and orange to reddish caudal fin. No scales under eye on cheek, and usually 46-47 lateral line scales. Fin counts: D = X, 9; A = III, 8.

Widely distributed throughout East Indian Ocean and West Pacific, including north-eastern Australia and Papua New Guinea, in shallow sandy and weedy areas adjacent to coral reefs. Maximum length to 40 cm TL (Carpenter and Allen, 1989; Carpenter, 2001; Allen 2018).

Figure 4. Ornate emperor, *Lethrinus ornatus* (Family Lethrinidae) from Wara Waria region, western Huon Gulf (23.5 cm TL; 255 g).

3.1.3 Family Lutjanidae – Tropical snappers

Lutjanus gibbus – Paddletail

Three specimens caught in coastal waters of the Wara Waria region in western Huon Gulf and sourced directly from local fishers (15.7 cm to 21.5 cm TL, 80 g to 145 g; Figure 5).

Diagnostic characters: Body relatively deep, steeply sloped head with distinct notch along rear margin of cheek (preopercle) and forked caudal fin with rounded lobes. Colour: mostly red all over, darker dorsally along upper surface of head and trunk, and narrow white margins along soft part of dorsal fin, anal and caudal fins. Fin counts: D = X, 13-14; A = III, 8-9.

Widespread in the Indo-West Pacific, including tropical Australia and Papua New Guinea, mostly around offshore coral reef habitats to average depths of 30 m (maximum recorded depth to 150 m). Maximum length to 50 cm TL, commonly to 35 cm. Also known as humpback red snapper (Allen, 1985, 2018; Anderson and Allen, 2001).

Figure 5. Paddletail, *Lutjanus gibbus* (Family Lutjanidae) from Wara Waria region, western Huon Gulf (21.5 cm TL; 145 g).

Lutjanus goldiei – Black bass

Three specimens caught in shallow waters (<2 m) at the entrance of Labu Lakes in the western Huon Gulf and sourced directly from local fishers (53.8 cm to 60.7 cm TL, 2,840 g to 3,915 g; Figure 6).

Diagnostic characters: Body relatively deep with steeply sloped head, scale rows along trunk parallel to lateral line, rounded posterior profile of dorsal and anal fins, and truncate caudal fin. Colour: dark brown to charcoal grey on upper trunk and upper sides, golden brown to whitish along lower sides and ventral surface. Fin counts: D = X, 13-14; A = III, 8-9.

Known only from southern Papua New Guinea between the Central District (Port Moresby) and Fly River area, in large freshwater streams and shallow brackish habitats (estuaries). Also known as Papuan black snapper. Maximum length to about 100 cm TL, commonly to 60 cm TL (Allen, 1985; Anderson and Allen, 2001).

Figure 6. Black bass (also known as Papuan black snapper), *Lutjanus goldiei* (Family Lutjanidae) from Labu Lakes entrance, western Huon Gulf (male 53.8 cm TL; 2,850 g).

Lutjanus timoriensis – Timor snapper

Two specimens caught in coastal waters of the Wara Waria region in western Huon Gulf and sourced directly from local fishers (16.5 cm to 20.5 cm TL, 75 g to 135 g; Figure 7).

Diagnostic characters: Body relatively deep with steeply sloped head, scale rows along trunk rising obliquely above lateral line, and truncate or slightly emarginate caudal fin. Colour: reddish trunk and upper sides, with a black spot at upper insertion of pectoral fins (axil), a distinct pearly white blotch at the posterior end of the second (soft) dorsal fin and a dark blotch dorsally on the caudal peduncle (saddle), and a red or pinkish to silvery white along lower sides and ventral surface. Fin counts: D = X, 14-15; A = III, 8.

Distributed throughout the western Pacific Ocean from Fiji Islands to Malay Peninsula, including Papua New Guinea, in coral and rubble reefs at depths of about 20 m to at least 130 m. Maximum length to 50 cm TL, commonly to 30 cm TL (Anderson *et al*., 2001; Allen, 1985, 2018).

Figure 7. Timor snapper, *Lutjanus timoriensis* (Family Lutjanidae) from Wara Waria region, western Huon Gulf (20.5 cm TL; 135 g).

3.1.4 Family Sciaenidae – Croakers, jewfishes

Otolithes ruber – Tigertooth croaker

Four specimens from western Huon Gulf, two from the Wara Waria region and sourced directly from local fishers, and two from the area between Labu Tale and Lae and sourced from the DCA Point market (24.3 cm to 33.1 cm TL, 125 g to 320 g; Figure 8).

Diagnostic characters: medium to large-sized species with a slender, cylindrical body, a large, strongly oblique mouth with 1 or 2 pairs of strong canines at front of one or both jaws, and a conspicuous lateral line that extend pass the caudal peduncle and continues posterior end of caudal fin. Colour: grey to brownish dorsally and golden to silvery ventrally. Fin counts: D = IX-X (IX) + I, 26-30; A = II, 7.

Coastal species widely distributed throughout the Indian Ocean and West Pacific, including tropical northern Australia and southern Papua New Guinea. Also known as silver teraglin. Maximum length to 70 cm SL, commonly to 40 cm SL (Sasaki, 2001).

Figure 8. Tigertooth croaker, *Otolithes ruber* (Family Sciaenidae) from Wara Waria region, western Huon Gulf (female 27.8 cm TL; 190 g).

3.1.5 Family Scombridae – Tunas, mackerels

Euthynnus affinis – Mackerel tuna

Five specimens from Fisherman Island off the Central District in the eastern Gulf of Papua, sourced at the Koki Fish market in Port Moresby (43.0 to 74.2 cm TL, 925 to 4,475 g; Figure 9).

Diagnostic characters: medium-sized tuna with a robust, fusiform body, short pectoral fins never reaching the interspace between the two dorsal fins, distinct bifid interpelvic process formed by two pointy flaps, and a very slender caudal peduncle with a prominent lateral keel between two small keels at the base of caudal fin. Colour: dark blue dorsally with an intricate striped pattern which does not extend anteriorly pass the middle of first dorsal fin, silvery white ventrally, and several dark spots between the pelvic and pectoral fins. Fin counts: D = XI-XIV + I, 11-15 + 8-10 finlets, both dorsal fins separated by a narrow interspace; A = 11-15 + 6-8 finlets.

Pelagic schooling species found throughout warm waters of the Indo-West Pacific, including tropical northern Australia and around Papua New Guinea, around all oceanic islands and archipelagos. Maximum length about 100 cm FL, commonly to 60 cm FL. Also known as kawakawa (Collette and Nauen, 1983; Collette, 2001; Allen, 2018).

Figure 9. Mackerel tuna, *Euthynnus affinis* (Family Scombridae) from Fisherman Island, eastern Gulf of Papua (male 74.2 cm TL; 4,475 g).

Scomberomorus commerson – Spanish mackerel

Five specimens caught around the Kaparoko-Hula area off the Central District in the eastern Gulf of Papua and sourced at the Koki Fish market in Port Moresby (63.5 cm to 79.2 cm TL, 1,480 g to 2,790 g; Figure 10).

<u>Diagnostic characters</u>: body elongate and strongly fusiform, upper jaw reaching to posterior margin of eye or slightly beyond, lateral line sharply bent downward below end of second (soft) dorsal fin, and strongly forked caudal fin. Colour: blue grey dorsally and laterally, with numerous wavy vertical bars along the sides which increase in number with length (at least 65 in specimens >100 cm). Fin counts: D = XV-XVIII, 15-20 + 8-11 finlets; A = 16-21 + 7-12 finlets.

Pelagic species commonly found throughout warmer coastal waters of the Indo-West Pacific Ocean region, including along the western, northern, and eastern coasts of Australia and around Papua New Guinea, and all oceanic offshore islands and archipelagos in the region. Maximum length to 240 cm FL, commonly to 90 cm FL, and 70 kg. Also known as narrow-barred mackerel (Collette and Nauen, 1983; Collette, 2001; Allen, 2018).

Figure 10. Spanish mackerel, *Scomberomorus commerson* (Family Scombridae) from the Kaparoko-Hula region, eastern Gulf of Papua (male 70.6 cm TL; 1,910 g).

3.2 Metals – Fishes

3.2.1 Arsenic (As)

Arsenic (as total As) was detected in muscle tissue samples of all 64 fish specimens from the 17 species tested during this study (>LOR 0.05 mg kg^{-1}), with mean total As concentrations ranging between 0.31 mg kg^{-1} in tille trevally and 26.80 mg kg^{-1} in the large predatory common pike conger from western Huon Gulf (Table 8).

Inorganic As levels in muscle tissues of all fish species were estimated from total As concentrations by applying a conversion factor of 4.2% (Table 7), i.e., inorganic As = total As × 0.042. Mean inorganic As levels ranged between 0.01 mg kg^{-1} in tille trevally and 1.13 mg kg^{-1} in common pike conger from western Huon Gulf (Table 8).

Table 8. Levels of arsenic (total As; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Values in brackets for muscle correspond to mean values of inorganic As (mg kg^{-1} ww) estimated from total As concentrations using a conversion factor of 4.2% (0.042; Table 7). Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Arsenic (LOR 0.05 mg kg^{-1})											
Western Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	1.68 (0.07)	0.90 - 2.53	3	0.82	0	3.64	2.08 - 5.65	3	1.83	0
	Tille trevally	0.31 (0.01)	0.21 - 0.38	3	0.09	0	1.06	0.79 - 1.35	3	0.28	0
Lutjanidae	Mangrove jack	0.74 (0.03)	0.18 - 1.62	3	0.77	0	2.83	2.34 - 3.80	3	0.84	0
	Black bass	0.53 (0.02)	0.18 - 0.90	3	0.36	0	1.49	0.84 - 2.26	3	0.72	0
	Saddletail snapper	3.20 (0.13)	2.61 - 3.90	4	0.57	0	10.88	8.41 - 12.9	4	2.06	0
Muraenesocidae	Common pike conger	26.80 (1.13)	26.80	1	0.00	0	2.53	2.53	1	-	0
Nemipteridae	Yellowbelly threadfin bream	2.45 (0.10)	0.42 - 6.37	4	2.68	0	3.22	1.77 - 4.92	4	1.31	0
	Teardrop threadfin bream	4.77 (0.20)	3.54 - 5.74	4	1.01	0	7.09	5.32 - 8.82	4	1.45	0
	Doublewhip threadfin bream	2.19 (0.09)	1.84 - 2.53	2	0.49	0					
Sciaenidae	Tigertooth croaker	0.38 (0.02)	0.17 - 0.59	2	0.30	0	1.70	1.70	1	0.00	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	6.80 (0.29)	6.50 - 7.02	3	0.27	0	4.95	4.95	1	-	0
Lethrinidae	Thumbprint emperor	1.99 (0.08)	1.28 - 2.70	2	1.00	0	4.23	2.19 - 6.27	2	2.88	0
	Ornate emperor	3.21 (0.13)	2.62 - 4.00	3	0.71	0	4.38	4.20 - 4.55	2	0.25	0
Lutjanidae	Paddletail	4.86 (0.20)	1.95 - 6.46	3	2.53	0					
	Timor snapper	3.08 (0.13)	3.01 - 3.14	2	0.09	0	2.74	2.74	1	-	0
Sciaenidae	Tigertooth croaker	0.82 (0.03)	0.66 - 0.98	2	0.23	0	1.77	1.77	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	0.39 (0.02)	0.17 - 0.57	5	0.15	0	1.25	0.74 - 1.69	5	0.37	0
Lutjanidae	Saddletail snapper	1.63 (0.07)	0.72 - 3.85	5	1.29	0	6.90	3.88 - 10.60	5	2.55	0
Scombridae	Mackerel tuna	0.80 (0.03)	0.66 - 1.11	5	0.18	0	2.30	1.94 - 2.86	5	0.46	0
	Spanish mackerel	1.27 (0.05)	0.91 - 1.47	5	0.23	0	3.05	2.90 - 3.20	5	0.12	0

3.2.2 Cadmium (Cd)

Cadmium was undetectable in muscle tissue samples of all 64 fish specimens tested during this study (<LOR 0.01 mg kg^{-1}) (Table 9).

Table 9. Levels of cadmium (Cd; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Cadmium (LOR 0.01 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	-	-	0	-	3	1.50	1.24 - 1.86	3	0.32	0
	Tille trevally	-	-	0	-	3	1.02	0.63 - 1.50	3	0.44	0
Lutjanidae	Mangrove jack	-	-	0	-	3	7.39	3.22 - 10.60	3	3.78	0
	Black bass	-	-	0	-	3	0.55	0.42 - 0.70	3	0.14	0
	Saddletail snapper	-	-	0	-	4	1.80	0.37 - 3.59	4	1.59	0
Muraenesocidae	Common pike conger	-	-	0	-	1	6.47	6.47	1	-	0
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	1.91	0.78 - 3.20	4	1.12	0
	Teardrop threadfin bream	-	-	0	-	4	1.91	1.03 - 4.42	4	1.67	0
	Doublewhip threadfin bream	-	-	0	-	2					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	0.62	0.62	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	-	-	0	-	3	0.14	0.14	1	-	0
Lethrinidae	Thumbprint emperor	-	-	0	-	2	4.05	0.23 - 7.87	2	5.40	0
	Ornate emperor	-	-	0	-	3	3.13	2.32 - 3.94	2	1.15	0
Lutjanidae	Paddletail	-	-	0	-	3					
	Timor snapper	-	-	0	-	2	0.26	0.26	1	-	0
Sciaenidae	Tigertooth croaker	-	-	0	-	2	0.65	0.65	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	2.87	1.74 - 5.04	5	1.31	0
Lutjanidae	Saddletail snapper	-	-	0	-	5	2.11	0.98 - 3.12	5	0.80	0
Scombridae	Mackerel tuna	-	-	0	-	5	1.17	0.58 - 2.46	5	0.75	0
	Spanish mackerel	-	-	0	-	5	0.86	0.62 - 1.21	5	0.21	0

3.2.3 Chromium (Cr)

Chromium was undetectable in muscle tissue samples of all except two of the 64 fish specimens tested during this study (LOR 0.05 mg kg^{-1}), i.e., teardrop threadfin bream from western Huon Gulf and thumbprint emperor from Wara Waria. Where detected, Cr was recorded at levels just above the LOR (Table 10).

Table 10. Levels of chromium (Cr; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Chromium (LOR 0.05 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	-	-	0	-	3	0.08	0.08	1	-	2
	Tille trevally	-	-	0	-	3	-	-	0	-	3
Lutjanidae	Mangrove jack	-	-	0	-	3	-	-	0	-	3
	Black bass	-	-	0	-	3	-	-	0	-	3
	Saddletail snapper	-	-	0	-	4	-	-	0	-	4
Muraenesocidae	Common pike conger	-	-	0	-	1	-	-	0	-	1
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	-	-	0	-	4
	Teardrop threadfin bream	0.06	0.06	1	-	3	-	-	0	-	4
	Doublewhip threadfin bream	-	-	0	-	2					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Wara Waria	**Species**	**Mean**	**Min - Max**	**N**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	-	-	0	-	3	0.06	0.06	1	-	0
Lethrinidae	Thumbprint emperor	0.07	0.07	1	-	1	0.05	0.05	1	-	1
	Ornate emperor	-	-	0	-	3	-	-	0	-	2
Lutjanidae	Paddletail	-	-	0	-	3					
	Timor snapper	-	-	0	-	2	-	-	0	-	1
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	-	-	0	-	5
Lutjanidae	Saddletail snapper	-	-	0	-	5	-	-	0	-	5
Scombridae	Mackerel tuna	-	-	0	-	5	-	-	0	-	5
	Spanish mackerel	-	-	0	-	5	0.55	0.55	1	-	4

3.2.4 Copper (Cu)

Copper was detected at very low levels in muscle tissue samples of 46 of the 64 fish specimens tested during this study (>LOR 0.10 mg kg^{-1}) and ranged between 0.10 mg kg^{-1} in 11 of the 17 species and 0.52 mg kg^{-1} in mackerel tuna from Fisherman Is in the eastern Gulf of Papua (Table 11).

Table 11. Levels of copper (Cu; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Copper (LOR 0.10 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	0.20	0.20 - 0.20	3	0.00	0	4.93	3.80 - 6.00	3	1.10	0
	Tille trevally	0.20	0.20 - 0.30	3	0.10	0	2.80	2.60 - 3.10	3	0.26	0
Lutjanidae	Mangrove jack	0.10	0.10	1	-	2	28.93	17.30 - 43.20	3	13.15	0
	Black bass	0.10	0.10 - 0.10	3	0.00	0	23.40	12.30 - 37.30	3	12.73	0
	Saddletail snapper	-	-	0	-	4	3.58	3.00 - 4.40	4	0.69	0
Muraenesocidae	Common pike conger	0.10	0.10	1	-	0	49.20	49.20	1	-	0
Nemipteridae	Yellowbelly threadfin bream	0.10	0.10 - 0.10	2	0.00	2	5.03	2.40 - 8.00	4	2.45	0
	Teardrop threadfin bream	0.10	0.10 - 0.20	4	0.10	0	3.00	2.10 - 3.40	4	0.61	0
	Doublewhip threadfin bream	0.10	0.10 - 0.10	2	0.00	0					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	5.80	5.80	1	-	1
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	0.20	0.20 - 0.20	3	0.00	0	1.80	1.80	1	-	0
Lethrinidae	Thumbprint emperor	0.10	0.10 - 0.10	2	0.00	0	5.10	2.20 - 8.00	2	4.10	0
	Ornate emperor	0.10	0.10 - 0.10	3	0.00	0	10.45	7.10 - 13.80	2	4.74	0
Lutjanidae	Paddletail	0.10	0.10 - 0.10	2	0.00	1					
	Timor snapper	0.10	0.10	1	0.00	1	3.40	3.40	1	-	0
Sciaenidae	Tigertooth croaker	-	-	0	-	2	7.30	7.30	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	0.32	0.20 - 0.40	5	0.08	0	6.92	5.50 - 8.50	5	1.12	0
Lutjanidae	Saddletail snapper	0.10	0.10	1	0.00	4	6.86	5.10 - 9.50	5	1.84	0
Scombridae	Mackerel tuna	0.52	0.50 - 0.60	5	0.04	0	2.14	1.40 - 2.60	5	0.49	0
	Spanish mackerel	0.20	0.20 - 0.20	5	0.00	0	6.94	3.90 - 12.50	5	3.39	0

3.2.5 Iron (Fe)

Iron was detected in muscle tissue samples of all 64 fish specimens tested during this study (LOR>0.50 mg kg^{-1}), with mean Fe levels ranging between 1.00 mg kg^{-1} in a common pike conger from western Huon Gulf and 5.68 mg kg^{-1} in teardrop threadfin bream from Wara Waria (Table 12).

Table 12. Levels of iron (Fe; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Iron (LOR 0.50 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	2.13	1.50 - 2.90	3	0.71	0	271.57	81.70 - 376.00	3	164.70	0
	Tille trevally	2.60	2.00 - 3.10	3	0.56	0	411.67	329.00 - 495.00	3	83.00	0
Lutjanidae	Mangrove jack	1.57	0.90 - 2.40	3	0.76	0	1,199.33	128.00 - 1,890.00	3	940.66	0
	Black bass	2.93	2.30 - 3.80	3	0.78	0	633.33	416.00 - 928.00	3	264.62	0
	Saddletail snapper	1.60	1.10 - 2.00	4	0.47	0	213.75	144.00 - 277.00	4	60.73	0
Muraenesocidae	Common pike conger	1.00	1.00	1	-	0	478.00	478.00	1	-	0
Nemipteridae	Yellowbelly threadfin bream	2.20	1.70 - 2.90	4	0.50	0	257.00	122.00 - 460.00	4	157.97	0
	Teardrop threadfin bream	5.68	1.60 - 16.90	4	7.49	0	250.00	106.00 - 397.00	4	120.92	0
	Doublewhip threadfin bream	1.60	1.30 - 1.90	2	0.42	0					
Sciaenidae	Tigertooth croaker	2.60	1.90 - 3.30	2	0.99	0	337.00	337.00	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	3.17	2.00 - 5.30	3	1.85	0	138.00	138.00	1	-	0
Lethrinidae	Thumbprint emperor	2.30	1.20 - 3.40	2	1.56	0	297.05	58.10 - 536.00	2	337.93	0
	Ornate emperor	1.47	1.20 - 1.70	3	0.25	0	1,135.00	1,130.00 - 1,140.00	2	7.07	0
Lutjanidae	Paddletail	1.67	1.40 - 2.00	3	0.31	0					
	Timor snapper	1.10	0.70 - 1.50	2	0.57	0	120.00	120.00	1	-	0
Sciaenidae	Tigertooth croaker	1.30	1.20 - 1.40	2	0.14	0	546.00	546.00	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	3.94	2.40 - 5.40	5	1.24	0	392.60	251.00 - 544.00	5	121.22	0
Lutjanidae	Saddletail snapper	1.78	1.10 - 2.60	5	0.54	0	256.04	67.20 - 363.00	5	118.52	0
Scombridae	Mackerel tuna	7.68	4.30 - 14.20	5	3.90	0	54.38	41.30 - 89.20	5	19.64	0
	Spanish mackerel	1.86	1.60 - 2.00	5	0.17	0	191.20	122.00 - 292.00	5	63.93	0

3.2.6 Lead (Pb)

Lead was undetectable in muscle tissue samples of all 64 fish specimens tested during this study (<LOR 0.05 mg kg^{-1}) (Table 13).

Table 13. Levels of lead (Pb; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Lead (LOR 0.05 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	-	-	0	-	3	-	-	0	-	3
	Tille trevally	-	-	0	-	3	-	-	0	-	3
Lutjanidae	Mangrove jack	-	-	0	-	3	0.06	0.06-0.07	2	0.01	2
	Black bass	-	-	0	-	3	-	-	0	-	3
	Saddletail snapper	-	-	0	-	4	-	-	0	-	4
Muraenesocidae	Common pike conger	-	-	0	-	1	-	-	0	-	1
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	0.06	0.06	1	-	3
	Teardrop threadfin bream	-	-	0	-	4	-	-	0	-	4
	Doublewhip threadfin bream	-	-	0	-	2					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	-	-	0		3	0.18	0.18	1	-	0
Lethrinidae	Thumbprint emperor	-	-	0		2	0.12	0.12	1	-	1
	Ornate emperor	-	-	0		3	0.10	0.10	2	0.00	0
Lutjanidae	Paddletail	-	-	0		3					
	Timor snapper	-	-	0		2	-	-	0	-	1
Sciaenidae	Tigertooth croaker	-	-	0		2	-	-	0	-	1
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	-	-	0	-	5
Lutjanidae	Saddletail snapper	-	-	0	-	5	-	-	0	-	5
Scombridae	Mackerel tuna	-	-	0	-	5	-	-	0	-	5
	Spanish mackerel	-	-	0	-	5	-	-	0	-	5

3.2.7 Manganese (Mn)

Manganese was detected in muscle tissue samples of all except eight of the 64 fish specimens tested during this study (LOR 0.05 mg kg^{-1}) and, where present, it occurred at mean levels between 0.05 mg kg^{-1} both in mangrove jack from western Huon Gulf and ornate emperor from Wara Waria, and 0.27 mg kg^{-1} in common pike conger from western Huon Gulf (Table 14).

Table 14. Levels of manganese (Mn; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Manganese (LOR 0.05 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	0.09	0.09 - 0.09	2	0.00	1	1.32	1.14 - 1.60	3	0.24	0
	Tille trevally	0.11	0.09 - 0.14	3	0.03	0	1.64	1.54 - 1.75	3	0.11	0
Lutjanidae	Mangrove jack	0.05	0.05	1	-	2	1.36	1.14 - 1.79	3	0.37	0
	Black bass	0.07	0.06 - 0.08	2	0.01	1	1.99	1.64 - 2.65	3	0.57	0
	Saddletail snapper	0.07	0.06 - 0.08	3	0.01	1	1.61	1.25 - 2.07	4	0.34	0
Muraenesocidae	Common pike conger	0.27	0.27	1	-	0	0.96	0.96	1	-	0
Nemipteridae	Yellowbelly threadfin bream	0.10	0.09 - 0.12	4	0.01	0	1.81	1.50 - 2.22	4	0.30	0
	Teardrop threadfin bream	0.11	0.09 - 0.13	4	0.02	0	2.11	1.64 - 2.53	4	0.38	0
	Doublewhip threadfin bream	0.08	0.05 - 0.11	2	0.04	0					
Sciaenidae	Tigertooth croaker	0.20	0.06 - 0.34	2	0.20	0	1.30	1.30	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	0.22	0.15 - 0.29	2	0.10	1	2.18	2.18	1	-	0
Lethrinidae	Thumbprint emperor	0.08	0.08	1	-	1	1.47	0.85 - 2.09	2	0.88	0
	Ornate emperor	0.05	0.05 - 0.06	3	0.01	0	2.12	1.72 - 2.52	2	0.57	0
Lutjanidae	Paddletail	0.09	0.07 - 0.11	2	0.03	1					
	Timor snapper	0.08	0.07 - 0.09	2	0.01	0	1.46	1.46	1	-	0
Sciaenidae	Tigertooth croaker	0.08	0.07 - 0.08	2	0.01	0	1.51	1.51 - 1.51	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**N**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	0.10	0.08 - 0.12	5	0.02	0	1.53	1.36 - 1.72	5	0.14	0
Lutjanidae	Saddletail snapper	0.08	0.08 - 0.10	5	0.01	0	1.48	1.27 - 1.93	5	0.27	0
Scombridae	Mackerel tuna	0.13	0.12 - 0.15	5	0.02	0	0.84	0.68 - 1.11	5	0.17	0
	Spanish mackerel	0.14	0.09 - 0.19	5	0.04	0	1.45	1.19 - 1.71	5	0.24	0

3.2.8 Mercury (Hg)

Mercury was undetectable in muscle tissue samples of 41 of the 64 fish specimens tested during this study (LOR 0.1 mg kg^{-1}) and, where detected, it was present at mean levels ranging between 0.10 mg kg^{-1} across several species and 0.50 mg kg^{-1} in common conger pike from western Huon Gulf (Table 15).

Table 15. Levels of mercury (Hg; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Mercury (LOR 0.1 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	0.20	0.20	1	-	2	0.35	0.10 - 0.60	2	0.35	1
	Tille trevally	0.30	0.30	1	-	2	0.60	0.60	1	-	2
Lutjanidae	Mangrove jack	0.40	0.30 - 0.50	3	0.10	0	9.87	7.50 - 11.50	3	2.10	0
	Black bass	0.15	0.10 - 0.20	2	0.07	1	1.17	0.80 - 1.40	3	0.32	0
	Saddletail snapper	0.10	0.10	1	-	3	0.40	0.40 - 0.40	2	0.00	2
Muraenesocidae	Common pike conger	0.50	0.50	1	-	0	0.80	0.80	1	-	0
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	0.43	0.20 - 0.60	4	0.17	0
	Teardrop threadfin bream	0.13	0.10 - 0.20	3	0.06	1	0.50	0.30 - 1.10	4	0.40	0
	Doublewhip threadfin bream	0.10	0.10	2	0.00	0					
Sciaenidae	Tigertooth croaker	0.10	0.10	2	0.00	0	0.30	0.30	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	0.20	0.20 - 0.20	3	0.00	0	0.40	0.40	1	-	0
Lethrinidae	Thumbprint emperor	0.10	0.10 - 0.10	1	-	1	0.40	0.40	1	-	1
	Ornate emperor	0.10	0.10 - 0.10	2	0.00	1	0.45	0.30 - 0.60	2	0.21	0
Lutjanidae	Paddletail	-	-	0	-	3					
	Timor snapper	-	-	0	-	2	0.20	0.20	1	-	0
Sciaenidae	Tigertooth croaker	-	-	0	-	2	0.20	0.20	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**N**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	0.13	0.10 - 0.20	4	0.05	1
Lutjanidae	Saddletail snapper	-	-	0	-	5	0.26	0.10 - 0.50	5	0.15	0
Scombridae	Mackerel tuna	0.30	0.30	1	-	4	0.30	0.30	1	-	4
	Spanish mackerel	-	-	0	-	5	0.10	0.10	1	-	4

3.2.9 Nickel (Ni)

Nickel was undetectable in muscle tissue samples of all except one of the 64 fish specimens tested during this study (LOR 0.05 mg kg^{-1}), i.e., teardrop threadfin bream (Table 16).

Table 16. Levels of nickel (Ni; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Nickel (LOR 0.05 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	-	-	0	-	3	-	-	0	-	3
	Tille trevally	-	-	0	-	3	-	-	0	-	3
Lutjanidae	Mangrove jack	-	-	0	-	3	-	-	0	-	3
	Black bass	-	-	0	-	3	-	-	0	-	3
	Saddletail snapper	-	-	0	-	4	-	-	0	-	4
Muraenesocidae	Common pike conger	-	-	0	-	1	-	-	0	-	1
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	0.06	0.05 - 0.08	3	0.02	1
	Teardrop threadfin bream	0.10	0.10	1	-	3	0.13	0.13	1	-	3
	Doublewhip threadfin bream	-	-	0	-	2					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	1	-	1
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	-	-	0	-	3	0.16	0.16	1	-	0
Lethrinidae	Thumbprint emperor	-	-	0	-	2	0.05	0.05	1	-	1
	Ornate emperor	-	-	0	-	3	0.45	0.12 - 0.77	2	0.46	0
Lutjanidae	Paddletail	-	-	0	-	3					
	Timor snapper	-	-	0	-	2	-	-	0	-	1
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	0.06	0.06	1	-	4
Lutjanidae	Saddletail snapper	-	-	0	-	5	0.05	0.05	1	-	4
Scombridae	Mackerel tuna	-	-	0	-	5	0.05	0.05	1	-	4
	Spanish mackerel	-	-	0	-	5	0.13	0.13	1	-	4

3.2.10 Selenium (Se)

Selenium was detected in muscle tissue samples of all 64 fish specimens tested during this study (>LOR 0.05 mg kg^{-1}), with mean levels ranging between 0.15 mg kg^{-1} in thumbprint emperor from Wara Waria to 0.38 mg kg^{-1} in mangrove jack from western Huon Gulf (Table 17).

Table 17. Levels of selenium (Se; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Selenium (LOR 0.05 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	0.31	0.29 - 0.33	3	0.02	0	2.59	2.33 - 3.08	3	0.42	0
	Tille trevally	0.23	0.23 - 0.23	3	0.00	0	1.63	1.35 - 2.02	3	0.35	0
Lutjanidae	Mangrove jack	0.38	0.32 - 0.49	3	0.09	0	4.11	3.35 - 4.61	3	0.67	0
	Black bass	0.34	0.3 - 0.38	3	0.04	0	2.29	2.03 - 2.59	3	0.28	0
	Saddletail snapper	0.30	0.28 - 0.31	4	0.02	0	1.71	1.29 - 2.39	4	0.50	0
Muraenesocidae	Common pike conger	0.28	0.28 - 0.28	1	0.00	0	1.22	1.22	1	-	0
Nemipteridae	Yellowbelly threadfin bream	0.27	0.23 - 0.31	4	0.04	0	1.46	1.42 - 1.50	4	0.04	0
	Teardrop threadfin bream	0.35	0.33 - 0.39	4	0.03	0	1.65	1.30 - 1.95	4	0.27	0
	Doublewhip threadfin bream	0.22	0.20 - 0.24	2	0.03	0					
Sciaenidae	Tigertooth croaker	0.37	0.36 - 0.38	2	0.01	0	0.96	0.96	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	0.20	0.19 - 0.22	3	0.02	0	0.55	0.55	1	-	0
Lethrinidae	Thumbprint emperor	0.15	0.11 - 0.18	2	0.05	0	0.98	0.95 - 1.01	2	0.04	0
	Ornate emperor	0.16	0.13 - 0.20	3	0.04	0	1.77	1.65 - 1.89	2	0.17	0
Lutjanidae	Paddletail	0.21	0.17 - 0.26	3	0.05	0					
	Timor snapper	0.23	0.20 - 0.26	2	0.04	0	0.73	0.73	1	-	0
Sciaenidae	Tigertooth croaker	0.29	0.25 - 0.33	2	0.06	0	0.99	0.99	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	0.24	0.20 - 0.29	5	0.04	0	1.61	1.52 - 1.72	5	0.07	0
Lutjanidae	Saddletail snapper	0.27	0.24 - 0.30	5	0.03	0	1.41	1.02 - 1.66	5	0.25	0
Scombridae	Mackerel tuna	0.37	0.35 - 0.39	5	0.02	0	1.94	1.82 - 2.25	5	0.18	0
	Spanish mackerel	0.25	0.22 - 0.27	5	0.02	0	4.34	3.50 - 5.19	5	0.64	0

3.2.11 Silver (Ag)

Silver was undetectable in muscle tissue samples of all 64 fish specimens tested during this study (<LOR 0.1 mg kg^{-1}) (Table 18).

Table 18. Levels of silver (Ag; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Silver (LOR 0.1 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	-	-	0	-	3	-	-	0	-	3
	Tille trevally	-	-	0	-	3	-	-	0	-	3
Lutjanidae	Mangrove jack	-	-	0	-	3	0.85	0.10 - 1.60	2	1.06	1
	Black bass	-	-	0	-	3	-	-	0	-	3
	Saddletail snapper	-	-	0	-	4	-	-	0	-	4
Muraenesocidae	Common pike conger	-	-	0	-	1	0.20	0.20	1	-	0
Nemipteridae	Yellowbelly threadfin bream	-	-	0	-	4	-	-	0	-	4
	Teardrop threadfin bream	-	-	0	-	4	-	-	0	-	4
	Doublewhip threadfin bream	-	-	0	-	2					
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	-	-	0	-	3	-	-	0	-	1
Lethrinidae	Thumbprint emperor	-	-	0	-	2	-	-	0	-	2
	Ornate emperor	-	-	0	-	3	-	-	0	-	2
Lutjanidae	Paddletail	-	-	0	-	3					
	Timor snapper	-	-	0	-	2	-	-	0	-	1
Sciaenidae	Tigertooth croaker	-	-	0	-	2	-	-	0	-	1
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	-	-	0	-	5	-	-	0	-	5
Lutjanidae	Saddletail snapper	-	-	0	-	5	-	-	0	-	5
Scombridae	Mackerel tuna	-	-	0	-	5	-	-	0	-	5
	Spanish mackerel	-	-	0	-	5	-	-	0	-	5

3.2.12 Zinc (Zn)

Zinc was detected in muscle tissue samples of all 64 fish specimens tested during this study (>LOR 0.5 mg kg^{-1}), with mean levels ranging between 2.25 mg kg^{-1} in Timor snapper from Wara Waria and 4.92 mg kg^{-1} in mackerel tuna from Fisherman Is in the eastern Gulf of Papua (Table 19).

Table 19. Levels of zinc (Zn; mg kg^{-1} ww) in muscle and livers of fishes from western Huon Gulf (DCA Point market, n = 29), Wara Waira region (n = 15) and eastern Gulf of Papua (Koki fish market, n = 20) during the May/June 2022 study. Liver data are not available for three and eight specimens from western Huon Gulf and Wara Waria, respectively (see Section 2.3.2).

Zinc (LOR 0.5 mg kg^{-1})											
Huon Gulf (DCA Point)		**Muscle**					**Liver**				
Family	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Malabar trevally	2.87	2.80 - 3.00	3	0.12	0	35.07	31.20 - 41.20	3	5.370	0
	Tille trevally	3.00	2.90 - 3.10	3	0.10	0	30.37	26.40 - 33.50	3	3.62	0
Lutjanidae	Mangrove jack	2.30	2.20 - 2.50	3	0.17	0	50.47	36.90 - 70.30	3	17.56	0
	Black bass	4.33	3.40 - 5.30	3	0.95	0	61.33	40.30 - 80.90	3	20.34	0
	Saddletail snapper	2.45	2.30 - 2.80	4	0.24	0	36.88	28.80 - 43.30	4	7.21	0
Muraenesocidae	Common pike conger	2.70	2.70	1	-	0	77.30	77.30	1	-	0
Nemipteridae	Yellowbelly threadfin bream	2.55	2.10 - 2.90	4	0.34	0	31.35	23.80 - 35.70	4	5.23	0
	Teardrop threadfin bream	2.60	2.30 - 3.00	4	0.32	0	26.28	20.50 - 34.00	4	5.81	0
	Doublewhip threadfin bream	2.45	2.40 - 2.50	2	0.07	0					
Sciaenidae	Tigertooth croaker	3.00	2.70 - 3.30	2	0.42	0	24.20	24.20	1	-	0
Wara Waria	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Haemulidae	Bluecheek silver grunt	3.67	3.30 - 4.00	3	0.35	0	17.00	17.00	1	-	0
Lethrinidae	Thumbprint emperor	3.55	3.10 - 4.00	2	0.64	0	57.75	21.30 - 94.20	2	51.55	0
	Ornate emperor	3.90	3.30 - 4.30	3	0.53	0	71.70	44.20 - 99.20	2	38.89	0
Lutjanidae	Paddletail	2.67	2.40 - 3.10	3	0.38	0					
	Timor snapper	2.25	2.10 - 2.40	2	0.21	0	33.70	33.70	1	-	0
Sciaenidae	Tigertooth croaker	2.35	2.20 - 2.50	2	0.21	0	30.10	30.10	1	-	0
Gulf of Papua (Koki)	**Species**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**	**Mean**	**Min - Max**	**n**	**SD**	**n<LOR**
Carangidae	Tille trevally	3.24	2.60 - 4.30	5	0.67	0	38.46	31.70 - 43.40	5	4.78	0
Lutjanidae	Saddletail snapper	2.46	2.10 - 3.10	5	0.39	0	39.00	35.20 - 43.10	5	3.58	0
Scombridae	Mackerel tuna	4.92	3.60 - 7.30	5	1.47	0	522.80	310.00 - 852.00	5	235.86	0
	Spanish mackerel	4.10	2.90 - 5.30	5	1.06	0	28.92	25.60 - 35.50	5	3.90	0

3.2.13 Comparisons with FSANZ Standard and GELs – fishes

This section compares estimated levels of inorganic As and levels of Pb and Hg detected in muscle tissue samples of all 64 fish specimens tested during this study against the FSANZ Standard listed for each metal for fishes (maximum levels and/or means). It also compares 90th percentile values of Cu, Se, and Zn against 90th percentiles listed for each metal under the FSANZ GELs for fishes; no FSANZ Standard or FSANZ GELs are available for Cd, Cr, Fe, Mn, Ni or Ag for fishes (Table 6, Section 2.5.1). Results of comparisons are summarized in Table 20.

Arsenic – Maximum levels of inorganic As estimated from total As concentrations (Section 2.5.2) in muscle tissue samples of all 64 fish specimens tested during this study did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for inorganic As listed for fishes (Tables 6, 8, 20).

Copper – Cu levels detected in muscle tissue samples of 46 fish specimens tested during this study did not exceed the FSANZ GEL 90th percentile of 2 mg kg^{-1} for Cu listed for fishes (Tables 11, 20).

Lead – Pb levels in muscle tissue samples of all 64 fish specimens tested during this study were below the detectable level (<LOR of 0.05 mg kg^{-1}) and therefore did not exceed the FSANZ Standard maximum level of 0.5 mg kg^{-1} for Pb listed for fishes (Tables 13, 20).

Mercury – Hg levels detected in muscle tissue samples of 41 fish specimens tested during this study did not exceed the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum level of 1 mg kg^{-1} for Hg listed for fishes (Tables 15, 20).

Selenium – Se levels detected in muscle tissue samples of all 64 fish specimens tested during this study did not exceed the FSANZ GEL 90th percentile of 2 mg kg^{-1} for Se listed for fishes (Tables 17, 20).

Zinc – Zn levels detected in muscle tissue samples of all 64 fish specimens tested during this study did not exceed the FSANZ GEL 90th percentile of 15 mg kg^{-1} of Zn listed for fishes (Tables 19, 20).

Table 20. Levels of selected metals in muscle samples of all 64 fish specimens from the 17 bony fish species tested during this study against FSANZ Standard (maximum levels or mean) and FSANZ GELs (90th percentiles). Metal levels did not exceed FSANZ Standard or FSANZ GELs for the listed metals in any of the fish species tested.

Location	Species	Total muscle samples tested (*n*)	FSANZ Standard 1.4.1 (Maximum limits or mean)				FSANZ GELs (90th percentile)		
			Inorganic Arsenic* (2.0 mg kg^{-1}) Maximum level (*n*)	**Lead** (0.5 mg kg^{-1}) Maximum level	**Mercury** (0.5 mg kg^{-1}) Mean (*n*)	**Mercury** (1.0 mg kg^{-1}) Maximum level (*n*)	**Copper**** (2.0 mg kg^{-1})	**Selenium**** (2.0 mg kg^{-1})	**Zinc**** (15.0 mg kg^{-1})
Huon Gulf (DCA Point)	Malabar trevally	3	0.11 (3)	<LOR 0.05 mg kg^{-1}	0.20 (1)	0.20 (1)	0.20 (3)	0.32 (3)	2.96 (3)
	Tille trevally	3	0.02 (3)	<LOR 0.05 mg kg^{-1}	0.30 (1)	0.30 (1)	0.28 (3)	0.23 (3)	3.08 (3)
	Mangrove jack	3	0.07 (3)	<LOR 0.05 mg kg^{-1}	0.40 (3)	0.50 (3)	0.10 (1)	0.46 (3)	2.44 (3)
	Black bass	3	0.04 (3)	<LOR 0.05 mg kg^{-1}	0.15 (2)	0.20 (2)	0.10 (3)	0.37 (3)	5.10 (3)
	Saddletail snapper	4	0.17 (4)	<LOR 0.05 mg kg^{-1}	0.10 (1)	0.10 (1)	<LOR 0.1 mg kg^{-1}	0.31 (4)	2.68 (4)
	Common pike conger	1	1.13 (1)	<LOR 0.05 mg kg^{-1}	0.50 (1)	0.50 (1)	0.10 (1)	0.28 (1)	2.70 (1)
	Yellowbelly threadfin bream	4	0.27 (4)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.10 (2)	0.31 (4)	2.84 (4)
	Teardrop threadfin bream	4	0.25 (4)	<LOR 0.05 mg kg^{-1}	0.14 (3)	0.20 (3)	0.17 (4)	0.37 (4)	2.91 (4)
	Doublewhip threadfin bream	2	0.11 (2)	<LOR 0.05 mg kg^{-1}	0.10 (2)	0.10 (2)	0.10 (2)	0.23 (2)	2.49 (2)
	Tigertooth croaker	2	0.03 (2)	<LOR 0.05 mg kg^{-1}	0.10 (2)	0.10 (2)	<LOR 0.1 mg kg^{-1}	0.38 (2)	3.24 (2)
Wara Waria	Bluecheek silver grunt	3	0.3 (3)	<LOR 0.05 mg kg^{-1}	0.20 (3)	0.20 (3)	0.20 (3)	0.21 (3)	3.94 (3)
	Thumbprint emperor	2	0.12 (2)	<LOR 0.05 mg kg^{-1}	0.10 (1)	0.10 (1)	0.10 (2)	0.17 (2)	3.91 (2)
	Ornate emperor	3	0.17 (3)	<LOR 0.05 mg kg^{-1}	0.10 (2)	0.10 (2)	0.10 (3)	0.19 (3)	4.26 (3)
	Paddletail	3	0.28 (3)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.10 (2)	0.25 (3)	2.98 (3)
	Timor snapper	2	0.14 (2)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.10 (1)	0.25 (2)	2.37 (2)
	Tigertooth croaker	2	0.05 (2)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.32 (2)	2.47 (2)
Gulf of Papua (Koki)	Tille trevally	5	0.03 (5)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.40 (5)	0.28 (5)	3.94 (5)
	Saddletail snapper	5	0.17 (5)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.10 (1)	0.29 (5)	2.86 (5)
	Mackerel tuna	5	0.05 (5)	<LOR 0.05 mg kg^{-1}	0.30 (1)	0.30 (1)	0.56 (5)	0.39 (5)	6.50 (5)
	Spanish mackerel	5	0.07 (5)	<LOR 0.05 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	<LOR 0.1 mg kg^{-1}	0.20 (5)	0.26 (5)	5.10 (5)

* FSANZ Standard maximum level for inorganic As for bony fish is 2.0 mg kg^{-1}. Maximum total As values in Table 20 above were converted to inorganic As, i.e., total As × 0.042 (Table 6) for comparison with FSANZ Standard.

** Values provided for each species correspond to 90th percentiles in muscle samples to compare against the 90th percentile GEL for listed metals; values in brackets correspond to number of samples tested.

3.3 Metals – Invertebrates

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

Chromium, Pb, Hg, Ni and Ag were undetectable in left cheliped muscle of giant mud crabs from Labu Lakes in western Huon Gulf and Manu Mana in eastern Gulf of Papua (<LORs), along with Cd in crab muscle from the latter locality (Table 21). In contrast, total As, Cu, Se and Zn were each detected above their respective detection limits (>LORs) in cheliped muscle of all mud crabs tested during this study. Respective mean concentrations of Cu and Zn were 9.16 mg kg^{-1} and 44.56 mg kg^{-1} in cheliped muscle of crab from Labu Lakes, and 11.20 mg kg^{-1} and 55.50 mg kg^{-1} in cheliped muscle of crab from Manu Mana (Table 21).

Using the same factor applied to fishes to convert total As to inorganic As (4.2%; Table 7), estimated mean levels of inorganic As in cheliped muscle of all mud crabs tested during this study were low and ranged from 0.15 mg kg^{-1} to 0.20 mg kg^{-1} (Table 21).

Table 21. Levels of 12 selected metals (mg kg^{-1} ww) tested in left cheliped muscle and hepatopancreas of giant mud crabs from western Huon Gulf (Labu Lakes; n = 5) and eastern Gulf of Papua (Manu Mana; n = 5) during the May/June 2022 study. Hepatopancreas data are not available for four specimens from Labu Lakes in western Huon Gulf due to insufficient sample size (see Section 2.3.2).

Western Huon Gulf (Labu Lakes)										
Metal (LOR mg kg^{-1})	Left cheliped muscle					Hepatopancreas				
	Mean	Min - Max	n	SD	n<LOR	Mean	Min - Max	n	SD	n<LOR
Arsenic (0.05)	4.73	2.59 - 8.17	5	2.65	0	7.53	7.53	1	-	0
Arsenic (inorganic)	0.20	0.11 - 0.34	5	0.11	0	0.32	0.32	1	-	0
Cadmium (0.01)	0.34	0.03 - 0.64	2	0.43	3	3.18	3.18	1	-	0
Chromium (0.05)	-	-	0	-	5	-	-	0	-	1
Copper (0.1)	9.16	7.00 - 11.50	5	2.08	0	93.8	93.80	1	-	0
Iron (0.5)	2.94	1.50 - 4.70	5	1.18	0	207.00	207.00	1	-	0
Lead (0.05)	-	-	0	-	5	-	-	0	-	1
Manganese (0.05)	0.63	0.29 - 1.01	5	0.26	0	7.45	7.45	1	-	0
Mercury (0.1)	-	-	0	-	5	-	-	0	-	1
Nickel (0.05)	-	-	0	-	5	0.09	0.09	1	-	0
Selenium (0.05)	0.34	0.25 - 0.58	5	0.14	0	0.43	0.43	1	-	0
Silver (0.1)	-	-	0	-	5	0.50	0.50	1	-	0
Zinc (0.5)	44.56	26.80 - 77.50	5	19.94	0	49.20	49.20	1	-	0
Eastern Gulf of Papua (Manu Mana)										
Metal (LOR mg kg^{-1})	Left cheliped muscle					Hepatopancreas				
	Mean	Min - Max	n	SD	n<LOR	Mean	Min - Max	n	SD	n<LOR
Arsenic (0.05)	3.47	1.41 - 6.10	5	1.97	0	2.35	1.96 - 2.92	5	0.41	0
Arsenic (inorganic)	0.15	0.06 - 0.26	5	0.08	0	0.10	0.08 - 0.12	5	0.02	0
Cadmium (0.01)	-	-	0	-	5	2.15	0.12 - 3.72	5	1.65	0
Chromium (0.05)	-	-	0	-	5	0.14	0.14	1	-	4
Copper (0.1)	11.20	2.90 - 20.80	5	7.06	0	92.44	9.60 - 200.00	5	85.55	0
Iron (0.5)	2.60	1.40 - 3.30	5	0.78	0	190.60	137.00 - 284.00	5	57.86	0
Lead (0.05)	-	-	0	-	5	-	-	0	-	5
Manganese (0.05)	1.78	0.19 - 5.12	5	1.96	0	32.89	2.26 - 116.00	5	47.09	0
Mercury (0.1)	-	-	0	-	5	-	-	0	-	5
Nickel (0.05)	-	-	0	-	5	0.79	0.11 - 2.02	5	0.73	0
Selenium (0.05)	0.29	0.14 - 0.40	5	0.11	0	0.62	0.50 - 0.76	5	0.11	0
Silver (0.1)	-	-	0	-	5	1.04	0.20 - 1.90	5	0.80	0
Zinc (0.5)	55.50	45.00 - 75.60	5	11.86	0	26.26	9.90 - 59.60	5	20.24	0

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

All 12 metals were detected in mangrove mud clams tested from Labu Lakes in western Huon Gulf during this study (>LORs), and all except Hg and silver Ag were detected in mud clams from Lea Lea in the eastern Gulf of Papua (Table 22).

Levels of Cu and Mn differed significantly in mangrove mud clams from Labu Lakes and Lea Lea ($P<0.05$), with mean values of 4.50 mg kg^{-1} vs. 0.50 mg kg^{-1} for Cu and 18.27 mg kg^{-1} vs. 2.89 mg kg^{-1} for Mn, respectively. In contrast, mean Zn levels were similar in mud clams from the two localities, i.e., 15.12 mg kg^{-1} and 11.54 mg kg^{-1} (Table 22).

Using the same factor applied to fishes and giant mud crabs to convert total As to inorganic As (4.2%; Table 7), estimated mean levels of inorganic As of all mangrove mud clams tested during this study was very low and ranged from 0.02 mg kg^{-1} to 0.03 mg kg^{-1} (Table 22).

Table 22. Levels of 12 selected metals (mg kg^{-1} ww) tested in mangrove mud clams (whole animals) from western Huon Gulf (Labu Lakes; n = 5) and eastern Gulf of Papua (Lea Lea; n = 5) during the May/June 2022 study.

Metal LOR (mg kg^{-1})	Western Huon Gulf (Labu Lakes)					Eastern Gulf of Papua (Lea Lea)				
	Mean	Min - Max	n	SD	n<LOR	Mean	Min - Max	n	SD	n<LOR
Arsenic (0.05)	0.44	0.19 - 0.71	5	0.22	0	0.78	0.60 - 1.37	5	0.33	0
Arsenic (inorganic)	0.02	0.01 - 0.03	5	0.01	0	0.03	0.03 - 0.06	5	0.01	0
Cadmium (0.01)	0.13	0.04 - 0.16	5	0.05	0	0.05	0.01 - 0.09	2	0.06	3
Chromium (0.05)	0.11	0.05 - 0.20	5	0.07	0	0.76	0.76	1	-	4
Copper (0.1)	4.50	1.80 - 10.70	5	3.77	0	0.50	0.30 - 1.00	5	0.29	0
Iron (0.5)	180.64	66.20 - 436.00	5	147.17	0	73.34	7.80 - 277.00	5	115.04	0
Lead (0.05)	0.09	0.09	1	-	4	0.09	0.09	1	-	4
Manganese (0.05)	18.27	3.56 - 31.4	5	12.35	0	2.89	0.17 - 11.80	5	5.03	0
Mercury (0.1)	0.10	0.10	1	-	4	-	-	0	-	5
Nickel (0.05)	0.22	0.19 - 0.27	5	0.04	0	0.35	0.20 - 0.89	5	0.30	0
Selenium (0.05)	0.26	0.12 - 0.37	5	0.09	0	0.13	0.09 - 0.18	5	0.03	0
Silver (0.1)	0.15	0.10 - 0.20	2	0.07	3	-	-	0	-	5
Zinc (0.50)	15.12	11.50 - 17.60	5	2.25	0	11.54	9.40 - 12.50	5	1.23	0

3.3.3 Comparisons with FSANZ Standard and GELs – crustaceans and molluscs

Giant mud crabs

This section compares estimated levels of inorganic As and levels of Hg detected in left cheliped muscle samples of all giant mud crab tested during this study against maximum levels listed for these two metals under the FSANZ Standard for crustaceans. It also compares 90th percentile values of Cu, Se, and Zn against the 90th percentiles listed for each metal under the FSANZ GEL for crustaceans. No FSANZ Standard or FSANZ GELs are available for Cd, Cr, Fe, Pb, Mn, Ni or Ag for crustaceans (Table 6).

Arsenic – Maximum levels of inorganic As estimated in cheliped muscle samples of all mud crabs tested during this study from Labu Lakes (0.20 mg kg^{-1}) and Manu Mana (0.15 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for inorganic As listed for crustaceans (Tables 6, 21).

Mercury – Hg levels in cheliped muscle samples of all mud crabs tested during this study were below the detectable level (<LOR 0.10 mg kg^{-1}) and thus did not exceed the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum level of 1 mg kg^{-1} for Hg listed for crustaceans (Tables 6, 21).

Copper – Cu levels in cheliped muscle samples of all mud crabs tested during this study from Labu Lakes (90th percentile = 11.30 mg kg^{-1}) and Manu Mana (90th percentile = 18.72 mg kg^{-1}) did not exceed the FSANZ GEL 90th percentile of 20 mg kg^{-1} for Cu listed for crustaceans (Tables 6, 21).

Selenium – Se levels in cheliped muscle samples of all mud crabs tested during this study from Labu Lakes (90th percentile = 0.49 mg kg^{-1}) and Manu Mana (90th percentile = 0.39 mg kg^{-1}) did not exceed the FSANZ GEL 90th percentile of 1 mg kg^{-1} for Se listed for crustaceans (Tables 6, 21).

Zinc – Zn levels in cheliped muscle samples of all mud crabs tested during this study from Labu Lakes (90th percentile = 65.42 mg kg^{-1}) and Manu Mana (90th percentile = 67.44 mg kg^{-1}) exceeded the FSANZ GEL 90th percentile of 40 mg kg^{-1} for Zn listed for crustaceans (Tables 6, 21).

Mangrove mud clams

The section compares estimated levels of inorganic As, and levels of Cd, Pb and Hg detected in all mangrove mud clams tested during this study against maximum levels listed for each metal under the FSANZ Standard for molluscs. It also compares 90th percentile values of Cu and Se against 90th percentile values listed for these metals under the FSANZ GELs for molluscs. No FSANZ Standard or FSANZ GELs are available for Cr, Fe, Mn, Ni, Ag, or Zn for molluscs (Table 6).

Arsenic – Maximum levels of inorganic As estimated in mud clams from Labu Lakes (0.03 mg kg^{-1}) and Lea Lea (0.06 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 1 mg kg^{-1} for inorganic As listed for molluscs (Tables 6, 22).

Cadmium – Maximum Cd levels in mud clams from Labu Lakes (0.16 mg kg^{-1}) and Lea Lea (0.09 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Cd listed for molluscs (Tables 6, 22).

Copper – Cu levels in mud clams from Labu Lakes (90^{th} percentile = 8.58 mg kg^{-1}) and Lea Lea (90^{th} percentile = 0.80 mg kg^{-1}) did not exceed the FSANZ GEL 90^{th} percentile of 30 mg kg^{-1} for Cu listed for molluscs (Tables 6, 22).

Lead – Maximum Pb levels in mud clams from Labu Lakes and Manu Mana (0.09 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Pb listed for molluscans (Tables 6, 22).

Mercury – Maximum Hg levels in mud clams from Labu Lakes (0.10 mg kg^{-1}) did not exceed the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum level of 1 mg kg^{-1} for Hg listed for molluscs; Hg levels in all five mud clams from Manu Mana were below the detectable level (<LOR) of 0.10 mg kg^{-1} (Tables 6, 22).

Selenium – Se levels in mud clams from Labu Lakes (90^{th} percentile = 0.35 mg kg^{-1}) and Lea Lea (90^{th} percentile = 0.16 mg kg^{-1}) did not exceed the FSANZ GEL 90^{th} percentile of 1 mg kg^{-1} for Cu listed for molluscs (Tables 6, 22).

3.4 Comparisons with previous market surveys

Fishes

Metal levels in muscle tissue samples of fishes sourced at the DCA Point market in Lae (western Huon Gulf) during this study (Table 23) were compared with those of fishes from the same market reported in studies completed in November 2016 (Coffey/Marscco, 2018), and May 2019 (Marscco, 2020) (Table 24), as well as against data from the two control areas from which fish were sampled for this study, i.e., Wara Waria to the southeast of Lae and Koki Fish market in POM; no fishes were sampled from Wara Waria or the Koki Fish market in November 2016 and May 2019 (Table 24).

Statistical analyses (single-factor ANOVA) of data from all fish species combined (Table 25) indicate that levels of inorganic As, Cu and Hg in muscle tissues did not differ significantly ($P>0.05$) between all three locations and survey dates, i.e., western Huon Gulf (November 2016, May 2019, and May 2022), Wara Waria (May 2022) and eastern Gulf of Papua (June 2022). However, levels of Se and Zn differed significantly between locations ($P<0.05$), particularly of Zn in fishes from western Huon Gulf

Table 23. Summary statistics of levels of 12 metals in muscle tissues tested in all market fish species sampled during the May/June 2022 survey. FSANZ standards published for six metals (in bold) are provided in the smaller table below for comparison with values in main table.

Western Huon Gulf (10 species)						**Wara Waria (6 species)**					**Gulf of Papua (4 species)**				
Samples tested	*n* = 29		Mean ± SD	Range	90th percentile	*n* = 15		Mean ± SD	Range	90th percentile	*n* = 20		Mean ± SD	Range	90th percentile
Metal (LOR mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
Total Arsenic (0.05)	0	29	2.87 ± 4.49	0.17 - 26.80		0	15	3.76 ± 2.26	0.66 - 7.02		0	20	1.02 ± 0.78	0.17 - 3.85	
Inorganic Arsenic			0.12 ± 0.21	0.01 - 1.13				0.16 ± 0.10	0.03 - 0.29				0.04 ± 0.03	0.01 - 0.16	
Cadmium (0.01)	29	0				15	0				20	0			
Chromium (0.05)	28	1	0.06	0.06		14	1	0.07	0.07		20	0			
Copper (0.1)	10	19	0.14 ± 0.06	0.10 - 0.30	**0.20**	4	11	0.13 ± 0.05	0.10 - 0.20	**0.20**	4	16	0.33 ± 0.15	0.10 - 0.60	**0.50**
Iron (0.05)	0	29	2.59 ± 2.84	0.90 - 16.90		0	15	1.89 ± 1.13	0.70 - 5.30		0	20	3.82 ± 3.10	1.10 - 14.20	
Lead (0.05)	29	0				15	0				20	0			
Manganese (0.05)	5	24	0.11 ± 0.07	0.05 - 0.34		3	12	0.10 ± 0.07	0.05 - 0.29		0	20	0.11 ± 0.03	0.08 - 0.19	
Mercury (0.1)	13	16	0.21 ± 0.15	0.10 - 0.50		9	6	0.15 ± 0.5	0.10 - 0.20		19	1	0.3	0.3	
Nickel (0.05)	28	1	0.1	0.1		15	0				20	0			
Selenium (0.05)	0	29	0.31 ± 0.06	0.20 - 0.49	**0.38**	0	15	0.20 ± 0.06	0.11 - 0.33	**0.26**	0	20	0.28 ± 0.06	0.20 - 0.39	**0.37**
Silver (0.1)	29	0				15	0				20	0			
Zinc (0.5)	0	29	2.81 ± 0.66	2.10 - 5.30	**3.32**	0	15	3.13 ± 0.76	2.10 - 4.30	**4.06**	0	20	3.68 ± 1.31	2.10 - 7.30	**5.30**

FSANZ Standard	**FSANZ Standard 1.4.1**		**FSANZ GELs**
	Maximum level (mg kg^{-1})	Mean (mg kg^{-1})	90th percentile (mg kg^{-1})
Inorganic Arsenic	2		
Copper			2
Lead	0.5		
Mercury	1	0.5	
Selenium			2
Zinc			15

Table 24. Summary statistics of levels of metals in muscle tissues tested in fish species sampled from the DCA Point market in Lae (western Huon Gulf) during the November 2016 and May 2019 surveys; only 9 metals were tested in 2019. FSANZ standards published for six metals (in bold) are provided in the smaller table below for comparison with values in main table. *Reported LOR of mercury (Hg) in May 2019 (0.01 mg kg^{-1}) was higher than requested LOR of 0.1 mg kg^{-1}.

November 2016 (5 species)						**May 2019 (12 species)**					
Samples tested	*n* = 14		Mean ± SD	Range	90th percentile	Muscle samples tested	*n* = 53		Mean ± SD	Range	90th percentile
Metal (PQL mg kg^{-1})	n<PQL	n>PQL	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	**Metal (LOR mg kg^{-1})**	<LOR	>LOR	(mg kg^{-1})	(mg/kg)	(mg kg^{-1})
Arsenic (0.4)	1	13	2.61 ± 2.10	0.40 - 6.20		Total Arsenic (0.05)	0	53	6.22 ± 13.22	0.07 - 90.20	
Inorganic As			0.11 ± 0.09	0.02 - 0.26		**Inorganic Arsenic**	0	53	0.27 ± 0.56	0.003 - 3.79	
Cadmium (0.05)	14	0				Cadmium (0.01)	51	2	0.03 ± 0.03	0.01 - 0.05	
Chromium (0.1)	14	0				Chromium (0.05)	45	8	0.69 ± 1.66	0.05 - 4.77	
Copper (0.05)	0	14	0.23 ± 0.20	0.08 - 0.66	**0.54**	**Copper (0.1)**	5	48	0.27 ± 0.34	0.10 - 2.40	**0.40**
Iron (0.5)	0	14	3.26 ± 4.44	0.56 - 16.00		Iron (0.05)	N/A	-	-	-	
Lead (0.1)	14	0				**Lead (0.05)**	49	4	0.13 ± 0.07	0.07 - 0.22	
Manganese (0.1)	12	2	0.11 ± 0.01	0.10 - 0.10		Manganese (0.05)	N/A	-	-	-	
Mercury (0.01)	0	14	0.29 ± 0.20	0.03 - 0.71		***Mercury (0.01)**	0	53	0.19 ± 0.16	0.01 - 0.60	
Nickel (0.06)	14	0				Nickel (0.05)	51	2	0.25 ± 0.22	0.09 - 0.40	
Selenium (0.5)	8	6	0.74 ± 0.23	0.50 - 1.10	**0.99**	**Selenium (0.05)**	0	53	0.63 ± 0.18	0.18 - 1.01	**0.82**
Silver (0.1)	14	0				Silver (0.1)	N/A	-	-	-	
Zinc (0.2)	0	14	3.09 ± 0.85	2.20 - 4.80	**4.34**	**Zinc (0.5)**	0	53	9.70 ± 6.62	2.50 - 26.2	**17.70**

FSANZ Standard	**FSANZ Standard 1.4.1**		**FSANZ GELs**
	Maximum level (mg kg^{-1})	Mean (mg kg^{-1})	90th percentile (mg kg^{-1})
Inorganic Arsenic	2		
Copper			2
Lead	0.5		
Mercury	1	0.5	
Selenium			2
Zinc			15

Table 25. Results of ANOVA at 5% level of significance (*P*<0.05) and Least Significant Difference (LSD) Post Hoc pairwise comparison tests of metal levels obtained in muscle tissue samples by survey locality and date (year) since the initial EIS baseline study in November 2016. Abbreviations: EGP = Eastern Gulf of Papua; WHG = western Huon Gulf; NS = not significant; ND = No data to test; S = significant; WW = Wara Waria.

Biota	Metal	Locality/ year	Post Hoc LSD tests – Locality/year				
			WHG Nov 16	WHG May 19	WHG May 22	WW May 22	EGP June 22
All fishes	Inorganic Arsenic	All localities/year	NS				
	Mercury	All localities/year	NS				
	Copper	All localities/year	NS				
	Selenium	WHG Nov 16	-	NS	S	S	S
		WHG May 19	NS	-	S	S	S
		WHG May 22	S	S	-	S	NS
		WW May 22	S	S	S	-	NS
		EGP June 22	S	S	NS	NS	-
	Zinc	WHG Nov 16	-	S	NS	NS	NS
		WHG May 19	S	-	S	S	S
		WHG May 22	NS	S	-	NS	NS
		WW May 22	NS	S	NS	-	NS
		EGP June 22	NS	S	NS	NS	-
Saddletail snapper	Inorganic Arsenic	WHG Nov 16	-	NS	NS	-	S
		WHG May 19	NS	-	S	ND	S
		WHG May 22	NS	S	-	ND	NS
		EGP June 22	S	S	NS	ND	-
	Selenium	WHG Nov 16	ND	ND	ND	ND	ND
		WHG May 19	ND	-	S	ND	S
		WHG May 22	ND	S	-	ND	NS
		EGP June 22	ND	S	NS	ND	-
	Zinc	All localities/year	NS				
Mud crabs	Inorganic Arsenic	WHG May 19	ND	-	S	ND	S
		WHG May 22	ND	S	-	ND	NS
		EGP June 22	ND	S	NS	ND	-
	Copper	WHG May 19	ND	-	NS	ND	S
		WHG May 22	ND	NS	-	ND	NS
		EGP June 22	ND	S	NS	ND	-
	Selenium	All localities/year	NS				
	Zinc	WHG May 19	ND	-	S	ND	S
		WHG May 22	ND	S	-	ND	NS
		EGP June 22	ND	S	NS	ND	-
Mud clams	Inorganic Arsenic	All localities/year	NS				
	Copper	WHG May 19	ND	-	NS	ND	S
		WHG May 22	ND	NS	-	ND	NS
		EGP June 22	ND	S	NS	ND	-
	Selenium	WHG May 19	ND	-	S	ND	S
		WHG May 22	ND	S	-	ND	S
		EGP June 22	ND	S	S	ND	-
	Zinc	WHG May 19	ND	-	S	ND	S
		WHG May 22	ND	S	-	ND	NS
		EGP June 22	ND	S	NS	ND	-

in May 2019 (Table 25; Figures 11-15). The high Zn levels in muscle samples reported in western Huon Gulf fishes in May 2019 can be attributed to comparatively high values in the 17.30 mg kg^{-1} to 26.20 mg kg^{-1} range obtained in six bony fish species including common pike conger, saddletail snapper and sunbeam snapper (Marscco, 2020).

For metals with current FSANZ guidelines (Tables 6, 23, 24), levels in muscle samples of all fishes combined did not exceed the accepted levels of inorganic As or Hg listed for fishes by the FSANZ Standard 1-4-1 (Figures 11, 12), or the accepted levels of Cu or Se listed for fishes under the GELs (Figures 13, 14) except from the exceedance of Zn in May 2019 (Figure 15).

Based on available data above the LOR, intraspecific comparisons of muscle tissue samples across localities were only possible for replicates of saddletail snapper (*Lutjanus malabaricus*; Table 1) and only for estimated inorganic As, and for Se and Zn. Levels of estimated inorganic As and of Se in muscle tissue samples of saddletail snapper differed significantly across all localities ($P<0.05$) but did not differ significantly for Zn (Table 25; Figures 16, 17, 18).

Other metals

Cadmium – Cd was undetectable in muscle tissues of all fishes sampled from western Huon Gulf (29<LOR), Wara Waria (15<LOR) and eastern Gulf of Papua (20<LOR) in May/June 2022, and all fishes sampled from western Huon Gulf in November 2016 (14<LOR). However, Cd was present at levels slightly above the 0.01 mg kg^{-1} LOR in two specimens from western Huon Gulf in May 2019 (51<LOR) (Tables 9, 23, 24).

Chromium – Cr was undetectable in muscle tissues of all fishes sampled from eastern Gulf of Papua (20<LOR) in June 2022 and all fishes from western Huon Gulf in November 2016 (14<LOR). However, Cr was present at low levels in a few fishes from western Huon Gulf in May 2019 (45<LOR) and May 2022 (28<LOR), and from Wara Waria in May 2022 (14<LOR) (Tables 10, 23, 24).

Iron – Fe was detected in muscle tissues of all fishes sampled from western Huon Gulf (29>LOR), Wara Waria (15>LOR) and eastern Gulf of Papua (20>LOR) in May/June 2022, and all fishes sampled from western Huon Gulf in November 2016 (14>LOR); Fe was not tested in fishes from western Huon Gulf in May 2019. Levels of Fe were of similar magnitude across all locations except in fishes from Wara Waria where levels were slightly lower overall (Tables 12, 23, 24).

Lead – Pb was undetectable in muscle tissues of all fishes sampled from western Huon Gulf (29<LOR), Wara Waria (15<LOR) and eastern Gulf of Papua (20<LOR) in May/June 2022, and all fishes from western Huon Gulf in November 2016 (14<LOR). However, Pb was present at levels just above the 0.05 mg kg^{-1} LOR in four specimens from western Huon Gulf in May 2019 (49<LOR) (Tables 13, 23, 24).

Manganese – Mn was detected in muscle tissues of nearly all fishes sampled from western Huon Gulf (24>LOR), Wara Waria (12>LOR) and eastern Gulf of Papua (20>LOR) in May/June 2022, but in only two fishes from western Huon Gulf in November 2016 (2>LOR); Mn was not tested in fishes from western Huon Gulf in May 2019. Levels of Mn were of similar magnitude across all locations and, where detected, levels were slightly higher than the 0.05 mg kg^{-1} LOR (Tables 14, 23, 24).

Nickel – Ni was undetectable in muscle tissues of nearly all fishes sampled from western Huon Gulf (28<LOR), Wara Waria (15<LOR) and eastern Gulf of Papua (20<LOR) in May/June 2022, and all fishes from western Huon Gulf in November 2016 (14<LOR) and May 2019 (51<LOR). Where detected, Ni levels were very low (Tables 16, 23, 24).

Silver – Ag was undetectable in muscle tissues of all fishes sampled from western Huon Gulf (29<LOR), Wara Waria (15<LOR) and eastern Gulf of Papua (20<LOR) in May/June 2022, and all fishes from western Huon Gulf in November 2016 (14<LOR); Ag was not tested in fishes from western Huon Gulf in May 2019 (Tables 18, 23, 24).

Crustaceans – Giant mud crabs

Metal levels in left cheliped muscle tissues of giant mud crabs sampled from Labu Lakes (western Huon Gulf) and Manu Mana (eastern Gulf of Papua) during this study were compared with samples from Labu Lakes reported in May 2019 (Marscco, 2020) (Table 26). At present, data of metals in cheliped muscle of mud crabs are only available for samples from Labu Lakes (May 2019, May 2022) and for mud crabs from the eastern Gulf of Papua sourced at the Koki Fish market in POM (June 22).

Levels of Se in cheliped muscle from mud crabs did not differ significantly between Labu Lakes (May 2019, 2022) and Manu Mana (June 2022). However, levels of estimated inorganic As, and of Cu and Zn differed significantly between locations ($P<0.05$) (Table 25). Mean inorganic As levels were significantly lower in mud crabs from Labu Lakes in May 2019 (0.0.3 mg kg^{-1}) than Labu Lakes in May 2022 (0.20 mg kg^{-1}) and Manu Mana (0.15 mg kg^{-1}), whereas mean Cu levels were significantly higher in mud crabs from Manu Mana (11.2 mg kg^{-1}) than Labu Lakes in May 2019 (6.6 mg kg^{-1}). Mean Zn levels were higher in Labu Lakes in May 2019 (81.2 mg kg^{-1}) than in Labu Lakes in May 2022 (44.5 mg kg^{-1}) and Manu Mana (55.5 mg kg^{-1}) (Tables 25, 26; Figures 19-22).

For metals with current FSANZ guidelines (Tables 6, 23, 24), levels in cheliped muscle samples did not exceed the accepted levels of inorganic As listed for crustaceans under the FSANZ Standard (Figure 19), or the accepted levels of Cu and Se listed for crustaceans under the FSANZ GELs (Figures 20, 21) except for Zn in Labu Lakes in May 2019 and 2022 and Manu Mana in June 2022 (Figure 22).

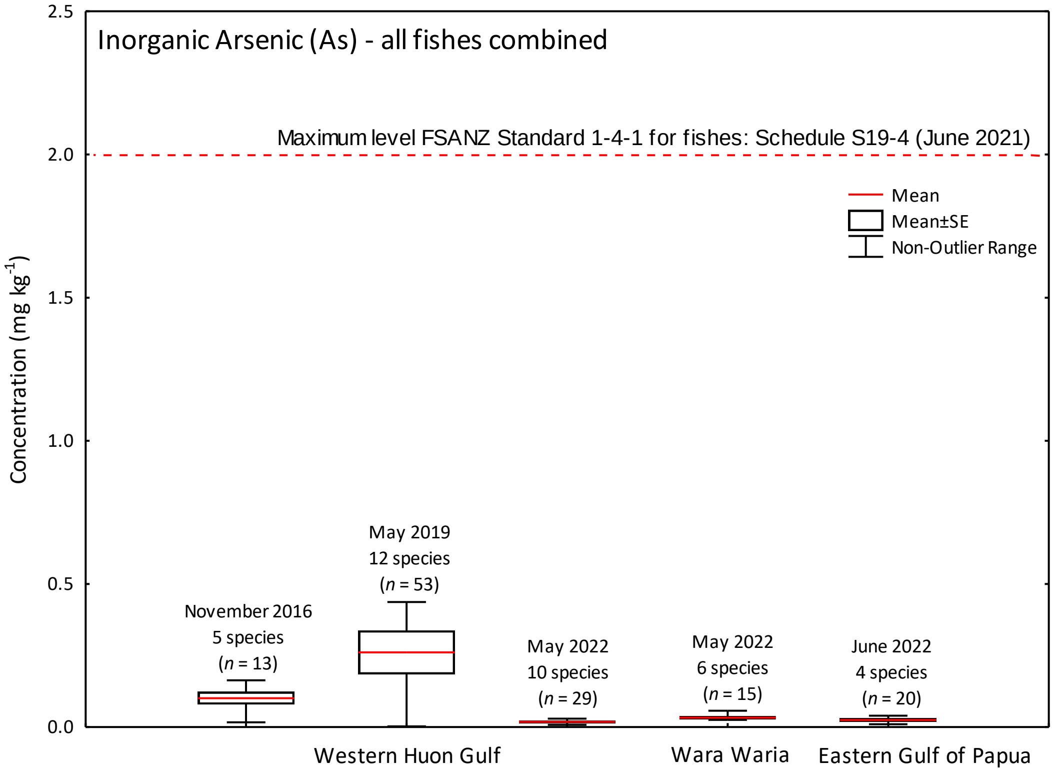

Figure 11. Box and whisker plot of concentrations of inorganic arsenic (As) estimated in muscle tissue samples of all fish species combined across all locations since November 2016.

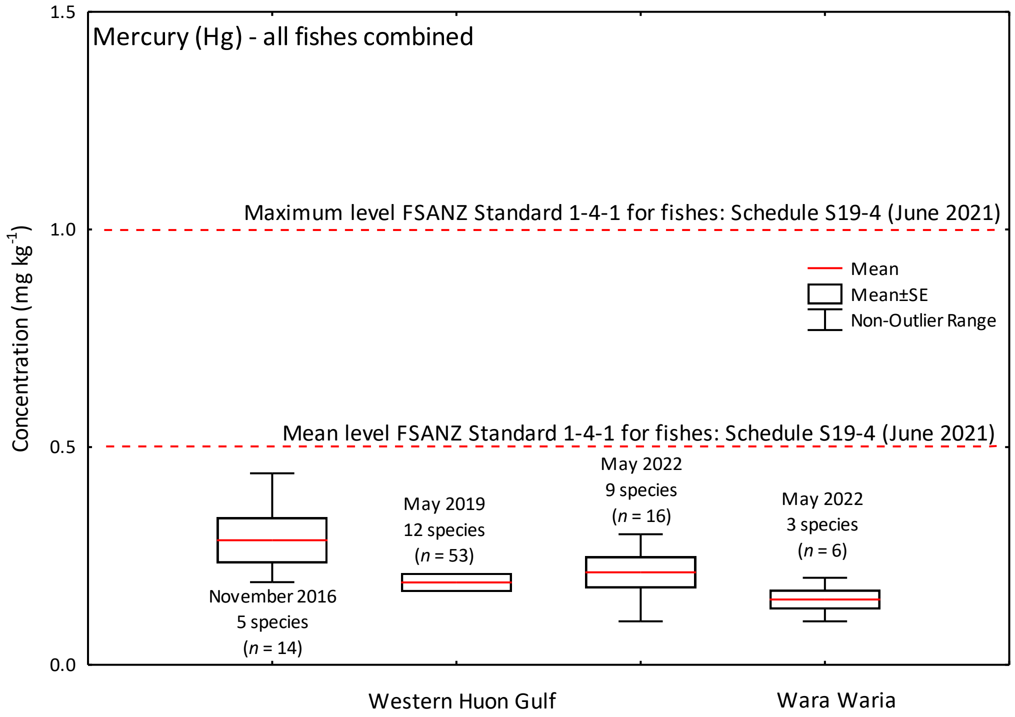

Figure 12. Box and whisker plot of mercury (Hg) concentrations in muscle tissue samples of all fish species combined across all locations since November 2016; Hg data of all fishes tested from eastern Gulf of Papua in June 2022 were under the Limit of Reporting (LOR) except for one mackerel tuna specimen (0.3 mg kg^{-1}).

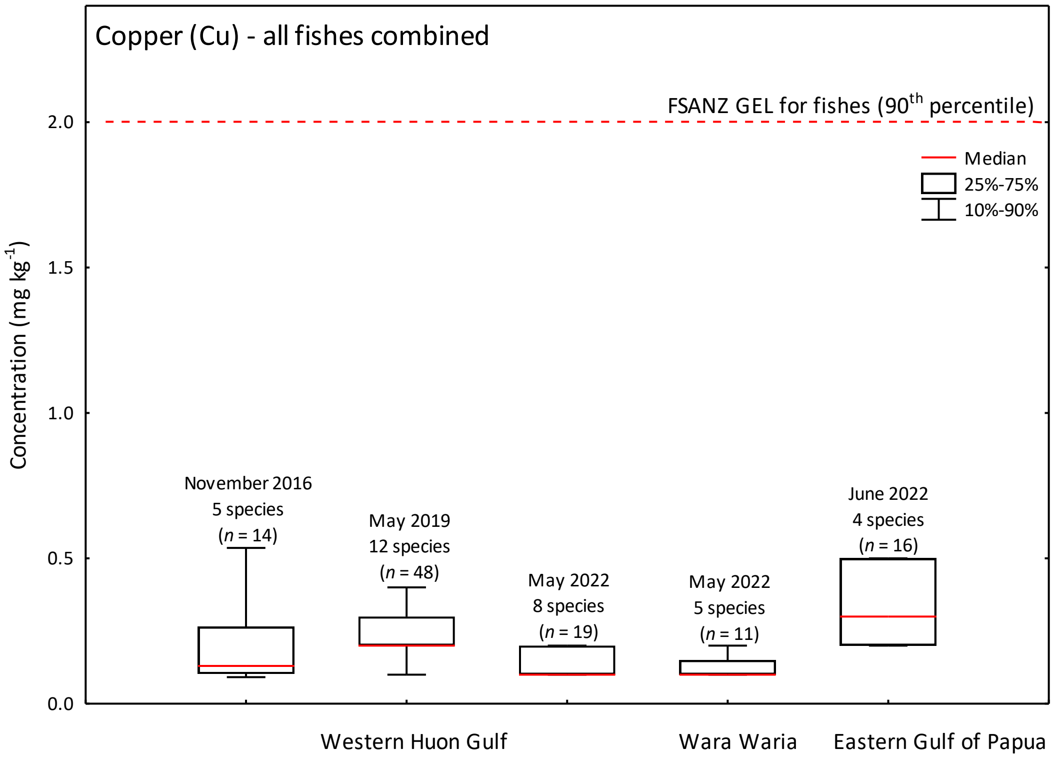

Figure 13. Box and whisker plot of copper (Cu) concentrations in muscle tissue samples of all fish species combined across all locations since November 2016.

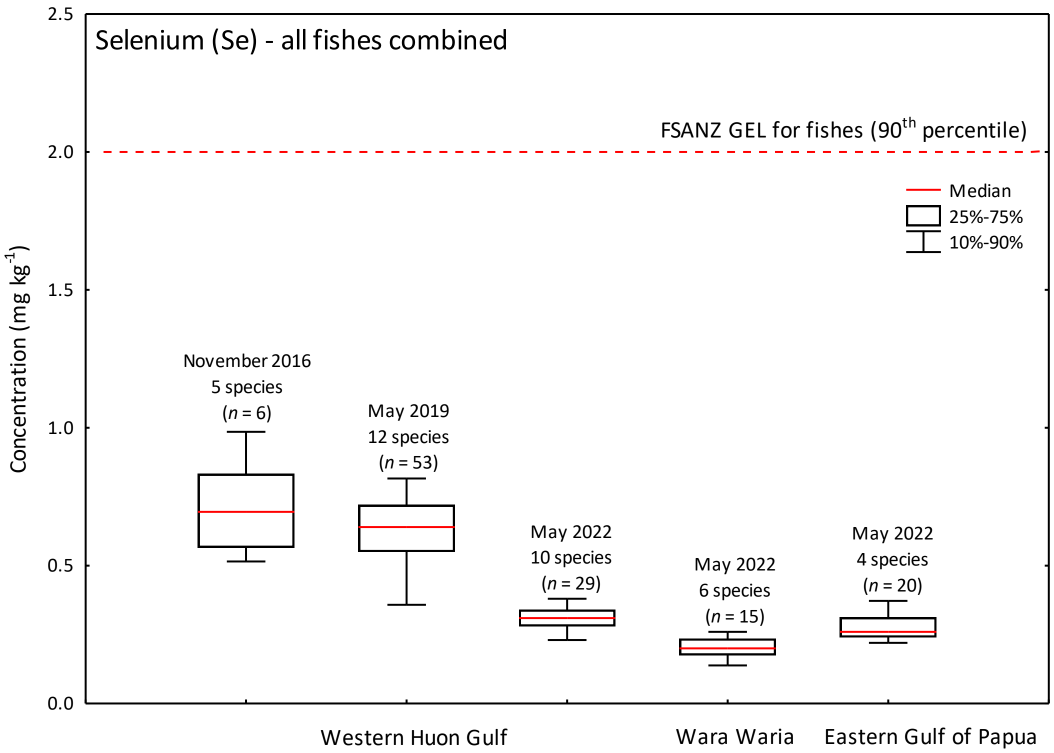

Figure 14. Box and whisker plot of selenium (Se) concentrations in muscle tissue samples of all fish species combined across all locations since November 2016.

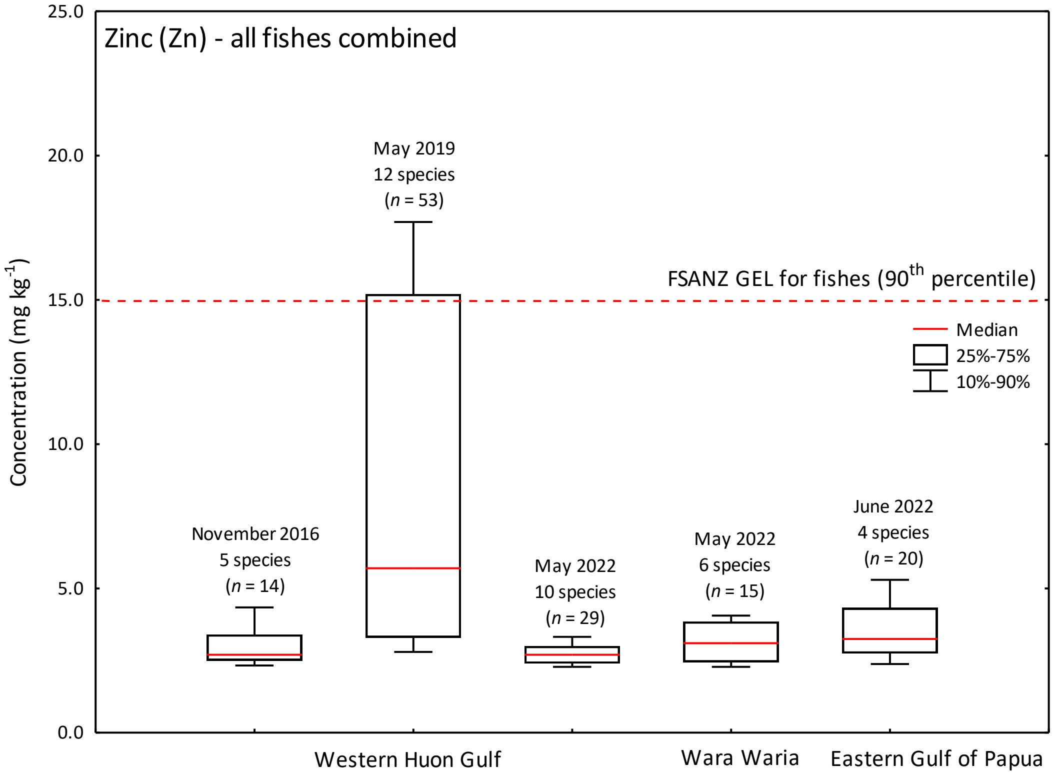

Figure 15. Box and whisker plot of zinc (Zn) concentrations in muscle tissue samples of all fish species combined across all locations since November 2016.

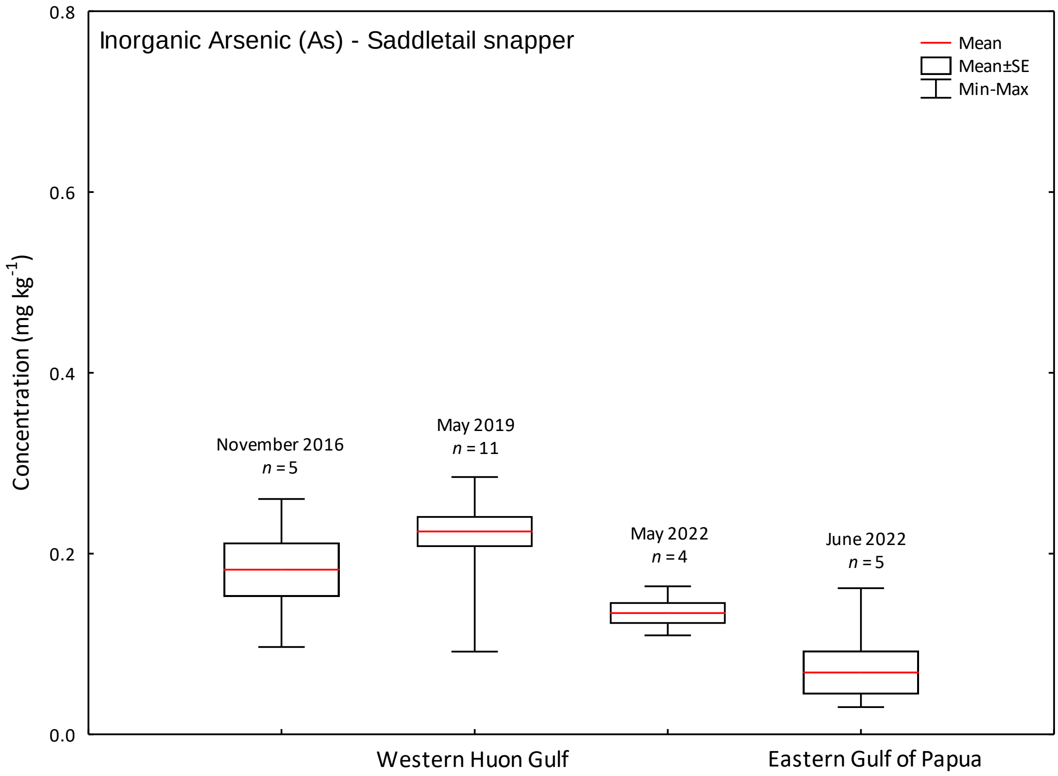

Figure 16. Box and whisker plot of levels of inorganic arsenic (As) estimated in muscle tissue samples of saddletail snapper (*Lutjanus malabaricus*) across all locations since November 2016; no saddletail snapper were obtained from Wara Waria region in south-western Huon Gulf.

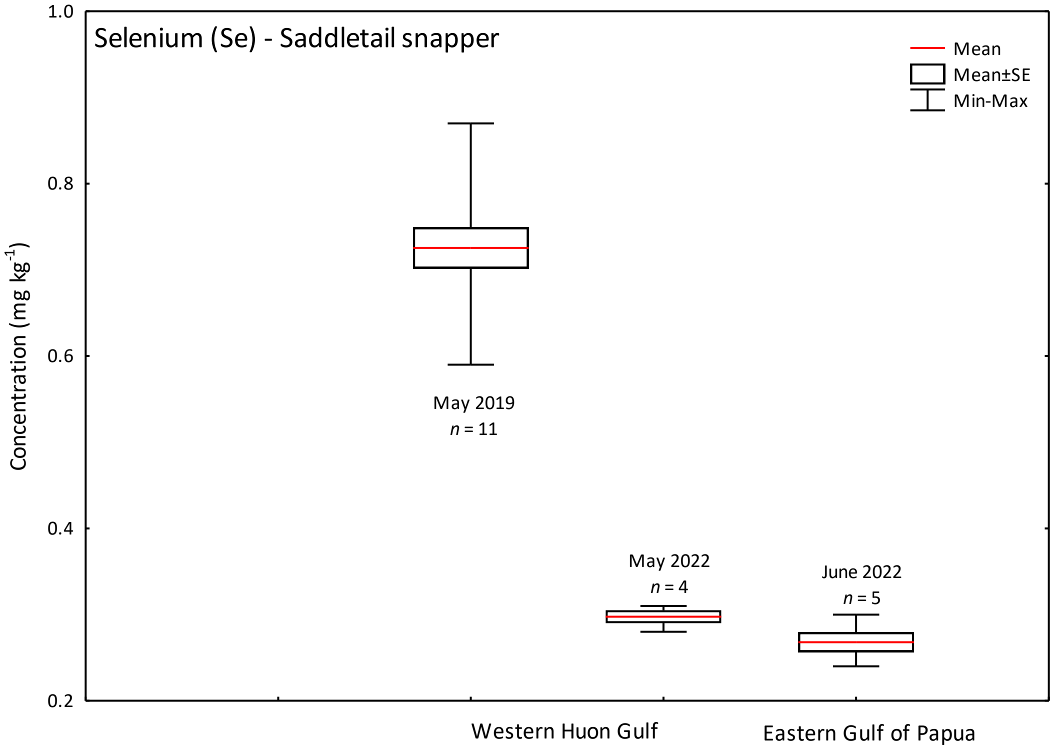

Figure 17. Box and whisker plot of selenium (Se) concentrations in muscle tissue samples of saddletail snapper (*Lutjanus malabaricus*) since May 2019; Se data from western Huon Gulf in November 2016 were under the Limit of Reporting (LOR).

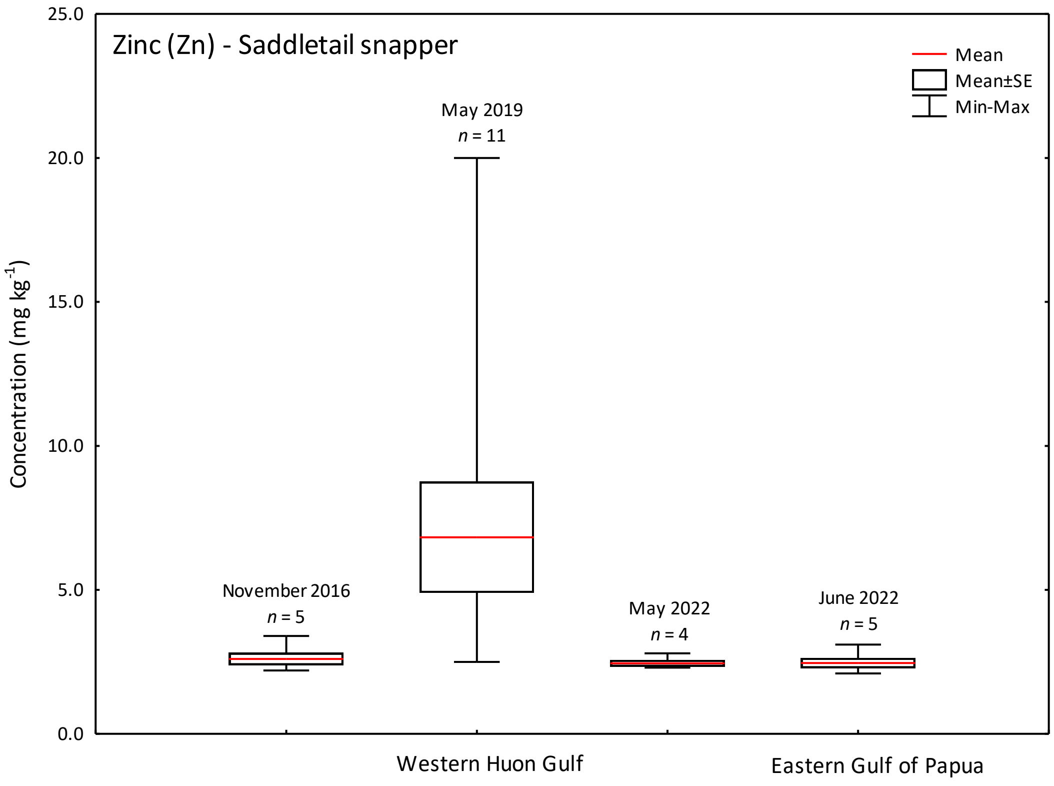

Figure 18. Box and whisker plot of zinc (Zn) concentrations in muscle tissue samples of saddletail snapper (*Lutjanus malabaricus*) across all locations since November 2016.

Other metals

Cadmium – Cd was undetectable in cheliped muscle of nearly all mud crabs from Labu Lakes (3<LOR) and eastern Gulf of Papua (5<LOR) in May/June 2022, and all mud crabs from Labu Lakes in May 2019 (11<LOR). Where detected, Cd levels were low and mostly slightly above the 0.01 mg kg^{-1} LOR (Tables 21, 25).

Chromium – Cr was undetectable in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022 but was present at very low levels in eight of the 13 mud crabs from Labu Lakes in May 2019 (Tables 21, 25).

Iron – Fe was detected in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022; Fe was not tested in mud crabs from Labu Lakes in May 2019. Where detected, Fe levels were of similar magnitude in mud crabs from both locations (Tables 21, 25).

Lead – Pb was undetectable in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022, and all mud crabs from Labu Lakes in May 2019 (13<LOR) (Tables 21, 25).

Manganese – Mn was detected in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022; Mn was not tested in mud crabs from Labu Lakes in May 2019. Where detected, Mn levels were higher in mud crabs from eastern Gulf of Papua (Tables 21, 25).

Mercury – Hg was undetectable in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022 and was undetectable in most mud crabs from Labu Lakes in May 2019 (9<LOR). Where detected, Hg levels were very low and barely above the 0.01 mg kg^{-1} LOR in May 2019 (Tables 21, 25).

Nickel – Ni was undetectable in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022, as well as in 11 of the 13 mud crabs from Labu Lakes in May 2019 (11<LOR) (Tables 21, 25).

Silver – Ag was undetectable in cheliped muscle of all mud crabs from Labu Lakes and eastern Gulf of Papua in May/June 2022; Ag was not tested in mud crabs from Labu Lakes in May 2019 (Tables 21, 25).

Molluscs – Mangrove mud clams

Metal levels in whole mangrove mud clams from Labu Lakes (western Huon Gulf) and Lea Lea (eastern Gulf of Papua) during this study were compared with samples from Labu Lakes reported in May 2019 (Marscco, 2020) (Table 27). At present, metal data are only available for mangrove mud clams from Labu Lakes (May 2019, May 2022) and specimens from coastal waters of the eastern Gulf of Papua sourced at the Koki Fish market in POM (June 22).

Levels of estimated inorganic As did not differ significantly in mud clams from Labu Lakes (May 2019 and 2022) and Lea Lea (June 2022) (Figure 19). However, levels of Cu, Se and Zn differed significantly between locations ($P<0.05$) (Table 25). Mean Cu levels were significantly higher in mud clams from Labu Lakes in May 2019 (4.7 mg kg^{-1}) than in mud clams from Lea Lea (0.50 mg kg^{-1}), whereas mean Se levels differed significantly across the three localities, being highest in mud clams from Labu Lakes in May 2019 and lowest in mud clams from Lea Lea (Table 25; Figures 20, 21). Mean Zn levels were significantly higher in mud clams from Labu Lakes in May 2019 (41.6 mg kg^{-1}) than in mud clams from Labu Lakes in May 2022 (15.1 mg kg^{-1}) and Lea Lea (11.5 mg kg^{-1}) (Table 25; Figure 22).

For metals with current FSANZ guidelines (Tables 6, 26, 27), metal levels in mud clams did not exceed the accepted levels of inorganic As listed for molluscs under the FSANZ Standard (Figure 19), or the accepted levels of Cu and Se listed for molluscs under the FSANZ GELs (Figures 20, 21).

Other metals

Cadmium – Cd was detected in most mud clams sampled from Labu Lakes (5>LOR) and eastern Gulf of Papua (2>LOR) in May/June 2022, and all mud crabs from Labu Lakes in May 2019 (12>LOR). Where detected, Cd levels were very low and barely above the 0.01 mg kg^{-1} LOR (Tables 22, 26).

Chromium – Cr was detected in most mud clams from Labu Lakes in May 2019 (10>LOR) and in all samples in May 2022 (5>LOR). However, Cr was detected in only one mud clam from eastern Gulf of Papua (4<LOR) in June 2022. Where detected, Cr levels were generally low (Tables 22, 26).

Iron – Fe was detected in all mud clams from Labu Lakes and eastern Gulf of Papua in May/June 2022; Fe was not tested in mud clams from Labu Lakes in May 2019. Where detected, Fe levels were noticeable greater in mud clams from Labu Lakes (Tables 22, 26).

Lead – Pb was undetectable in most mud clams from Labu Lakes (4<LOR) and eastern Gulf of Papua (4<LOR) in May/June 2022, and in seven of the 12 mud clams from Labu Lakes in May 2019. Where detected, Pb levels were low and slightly above the of 0.05 mg kg^{-1} LOR (Tables 22, 26).

Manganese – Mn was detected in all mud clams from Labu Lakes and eastern Gulf of Papua in May/June 2022; Mn was not tested in mud clams from Labu Lakes in May 2019. Where detected, Mn levels were significantly higher in mud clams from Labu Lakes (Tables 22, 26).

Mercury – Hg was undetectable in most mud clams from Labu Lakes (4<LOR) and eastern Gulf of Papua (5<LOR) in May/June 2022. However, Hg was detected in nearly all mud clams from Labu Lakes in May 2019 (11>LOR) but at levels barely above the 0.01 mg kg^{-1} LOR (Tables 22, 26).

Nickel – Ni was detected in all mud clams from Labu Lakes and eastern Gulf of Papua in May/June 2022, and all mud clams from Labu Lakes in May 2019 (13>LOR). Levels of Ni detected were low and did not exceed a mean of 0.5 mg kg^{-1} (Tables 22, 26).

Silver – Ag was undetectable in most mud clams from Labu Lakes (3<LOR) and all mud clams from eastern Gulf of Papua (5<LOR) in May/June 2022; Ag was not tested in mud crabs from Labu Lakes in May 2019. Where detected, Ag levels were very low and barely above the 0.1 mg kg^{-1} LOR (Tables 22, 26).

Zinc – Zn was detected in all mud clams from Labu Lakes and eastern Gulf of Papua in May/June 2022, and all mud clams from Labu Lakes in May 2019 (12>LOR). Levels of Zn were significantly greater in mud clams from Labu Lakes in May 2019 than in May 2022 and mud clams from eastern Gulf of Papua in June 2022 (Tables 22, 26; Figure 22).

Table 26. Summary statistics of levels of 12 metals in cheliped muscle tissue tested in giant mud crabs sampled during the May 2019 and May/June 2022 surveys; only 9 metals were tested in 2019. FSANZ standards published for five metals (in bold) are provided in the smaller table below for comparison with values in main table. *Reported LOR of mercury (Hg) in May 2019 (0.01 mg kg^{-1}) was higher than requested LOR of 0.1 mg kg^{-1}.

Western Huon Gulf (Labu Lakes) – May 2019						Western Huon Gulf (Labu Lakes) – May 2022					Gulf of Papua (Manu Mana) – June 2022				
Samples tested	*n* = 13		Mean ± SD	Range	90th percentile	*n* = 5		Mean ± SD	Range	90th percentile	*n* = 5		Mean ± SD	Range	90th percentile
Metal (LOR mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
Total Arsenic (0.05)	0	13	0.7 ± 0.31	0.35 - 1.28		0	5	4.73 ± 2.65	2.59 - 8.17		0	5	3.47 ± 1.98	1.41 - 6.10	
Inorganic Arsenic	0	13	0.03 ± 0.02	0.01 - 0.05				0.20 ± 0.12	0.11 - 0.35				0.15 ± 0.09	0.06 - 0.26	
Cadmium (0.01)	11	2	0.01	0.01		3	2	0.34 ± 0.43	0.03 - 0.64		5	0			
Chromium (0.05)	5	8	0.14 ± 0.13	0.05 - 0.44		5	0				5	0			
Copper (0.1)	0	13	6.61 ± 2.98	2.30 - 13.70	9.36	0	5	9.16 ± 2.08	7.00 - 11.50	11.3	0	5	11.20 ± 7.06	2.90 - 20.80	18.72
Iron (0.05)	N/A	-	-	-		0	5	2.94 ± 1.18	1.50 - 4.70		0	5	2.60 ± 0.79	1.40 - 3.30	
Lead (0.05)	13	0				5	0				5	0			
Manganese (0.05)	N/A	-	-	-		0	5	0.63 ± 0.26	0.29 - 1.01		0	5	1.79 ± 1.96	0.19 - 5.12	
***Mercury (0.01)**	9	4	0.03 ± 0.02	0.01 - 0.04		-	-				-	-			
Mercury (0.1)	-	-				5	0				5	0			
Nickel (0.05)	11	2	0.26 ± 0.14	0.12 - 0.39		5	0				5	0			
Selenium (0.05)	0	13	0.39 ± 0.15	0.17 - 0.75	0.51	0	5	0.34 ± 0.14	0.25 - 0.58	0.49	0	5	0.30 ± 0.11	0.14 - 0.40	0.39
Silver (0.1)	N/A	-	-	-		5	0				5	0			
Zinc (0.5)	0	13	81.81 ± 19.19	54.80 - 121.00	109.20	0	5	44.56 ± 19.94	26.80 - 77.50	65.42	0	5	55.50 ± 11.87	45.00 - 75.60	67.44

FSANZ Standard	FSANZ Standard 1.4.1		FSANZ GELs
	Maximum level (mg kg^{-1})	Mean (mg kg^{-1})	90th percentile (mg kg^{-1})
Inorganic Arsenic	2		
Copper			20
Mercury	1	0.5	
Selenium			1
Zinc			40

Table 27. Summary statistics of levels of 12 metals in mangrove mud clams sampled during the May 2019 and May/June 2022 surveys; only 9 metals were tested in 2019. FSANZ standards published for six metals (in bold) are provided in the smaller table below for comparison with values in main table. *Reported LOR of mercury (Hg) in May 2019 (0.01 mg kg^{-1}) was higher than requested LOR of 0.1 mg kg^{-1}.

Western Huon Gulf (Labu Lakes) – May 2019						**Western Huon Gulf (Labu Lakes) – May 2022**					**Gulf of Papua (Lea Lea) – June 2022**				
Animals tested	*n* = 12		Mean ± SD	Range	90th percentile	*n* = 5		Mean ± SD	Range	90th percentile	*n* = 5		Mean ± SD	Range	90th percentile
Metal (LOR mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	<LOR	>LOR	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
Total Arsenic (0.05)	0	12	0.60 ± 0.25	0.32 - 0.99		0	5	0.45 ± 0.22	0.19 - 0.71		0	5	0.79 ± 0.34	0.60 - 1.37	
Inorganic Arsenic			0.03 ± 0.02	0.01 - 0.04				0.02 ± 0.01	0.01 - 0.03				0.03 ± 0.01	0.03 - 0.06	
Cadmium (0.01)	0	12	0.05 ± 0.02	0.02 - 0.07		0	5	0.13 ± 0.05	0.04 - 0.16		3	2	0.05 ± 0.06	0.01 - 0.09	
Chromium (0.05)	2	10	0.26 ± 0.34	0.06 - 1.16		0	5	0.11 ± 0.08	0.05 - 0.20		4	1	0.76	0.76	
Copper (0.1)	0	12	4.69 ± 4.23	1.20 - 13.80	**11.88**	0	5	4.50 ± 3.77	1.80 - 10.70	**8.58**	0	5	0.50 ± 0.30	0.30 - 1.00	**0.80**
Iron (0.05)	N/A	-	-	-		0	5	180.64 ± 147.18	66.20 – 436.00		0	5	73.34 ± 115.04	7.80 - 277.00	
Lead (0.05)	7	5	0.13 ± 0.08	0.05 - 0.24		4	1	0.09	0.09		4	1	0.09	0.09	
Manganese (0.05)	N/A	-	-	-		0	5	18.28 ± 12.35	3.56 - 31.40		0	5	2.90 ± 5.04	0.17 - 11.80	
***Mercury (0.01)**	1	11	0.03 ± 0.02	0.02 - 0.06		-	-				-	-			
Mercury (0.1)	-	-				4	1	0.10	0.10		5	0			
Nickel (0.05)	0	12	0.52 ± 0.35	0.16 - 1.18		0	5	0.22 ± 0.04	0.19 - 0.27		0	5	0.36 ± 0.31	0.20 - 0.89	
Selenium (0.05)	0	12	0.45 ± 0.10	0.31 - 0.65	**0.56**	0	5	0.27 ± 0.10	0.12 - 0.37	**0.35**	0	5	0.14 ± 0.04	0.09 - 0.18	**0.16**
Silver (0.1)	N/A	-	-	-		3	2	0.15 ± 0.08	0.10 - 0.20		5	0			
Zinc (0.5)	0	12	41.57 ± 18.16	16.30 - 68.90		0	5	15.12 ± 2.26	11.50 - 17.60		0	5	11.54 ± 1.24	9.40 - 12.50	

FSANZ Standard	**FSANZ Standard 1.4.1**		**FSANZ GELs**
	Maximum level (mg kg^{-1})	Mean (mg kg^{-1})	90th percentile (mg kg^{-1})
Inorganic Arsenic	1		
Cadmium, Lead	2		
Copper			30
Mercury	1	0.5	
Selenium			1

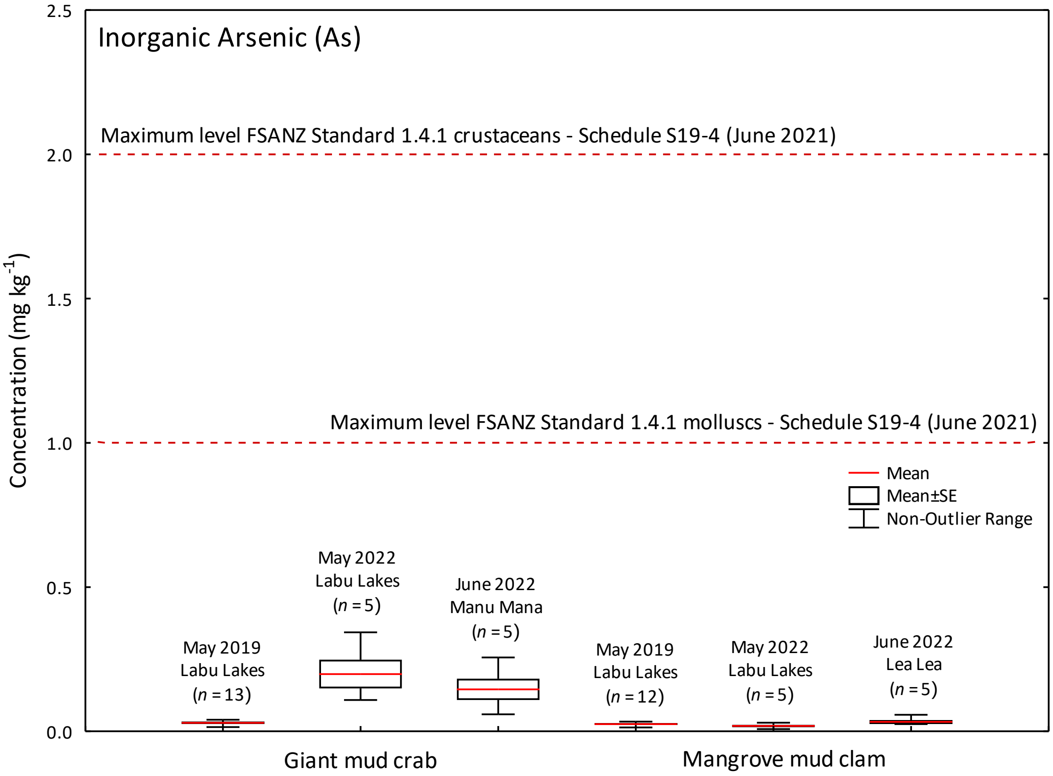

Figure 19. Box and whisker plot of levels of inorganic arsenic (As) estimated in cheliped muscle of giant mud crabs and mangrove mud clams from western Huon Gulf (Labu Lakes) in May 2019 and 2022, and eastern Gulf of Papua (Manu Mana and Lea Lea) in June 2022.

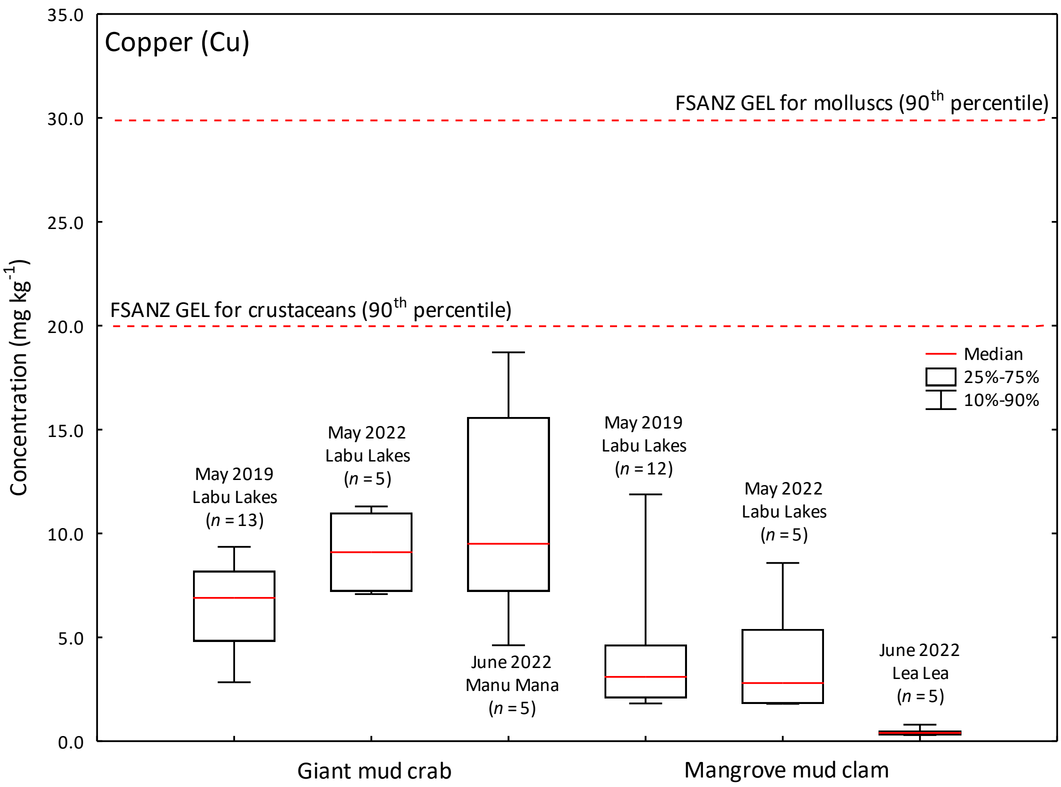

Figure 20. Box and whisker plot of copper (Cu) concentrations in cheliped muscle of giant mud crabs and mangrove mud clams from western Huon Gulf (Labu Lakes) in May 2019 and 2022, and eastern Gulf of Papua (Manu Mana and Lea Lea) in June 2022.

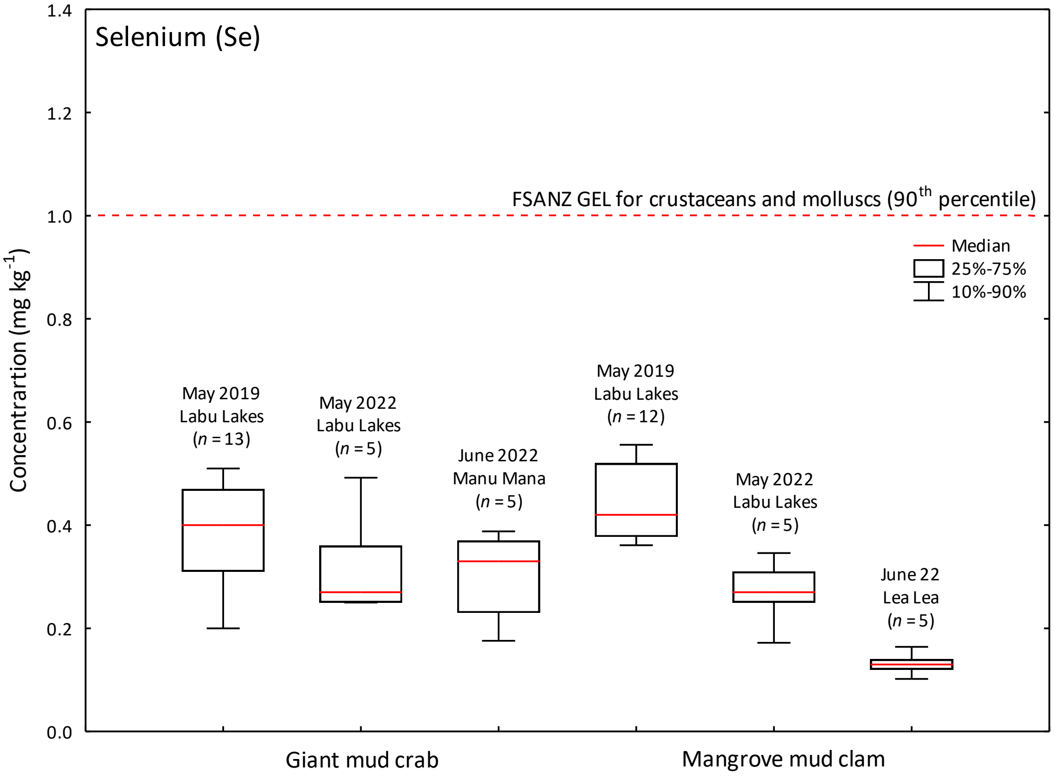

Figure 21. Box and whisker plot of selenium (Se) concentrations in cheliped muscle of giant mud crabs and mangrove mud clams from western Huon Gulf (Labu Lakes) in May 2019 and 2022, and eastern Gulf of Papua (Manu Mana and Lea Lea) in June 2022.

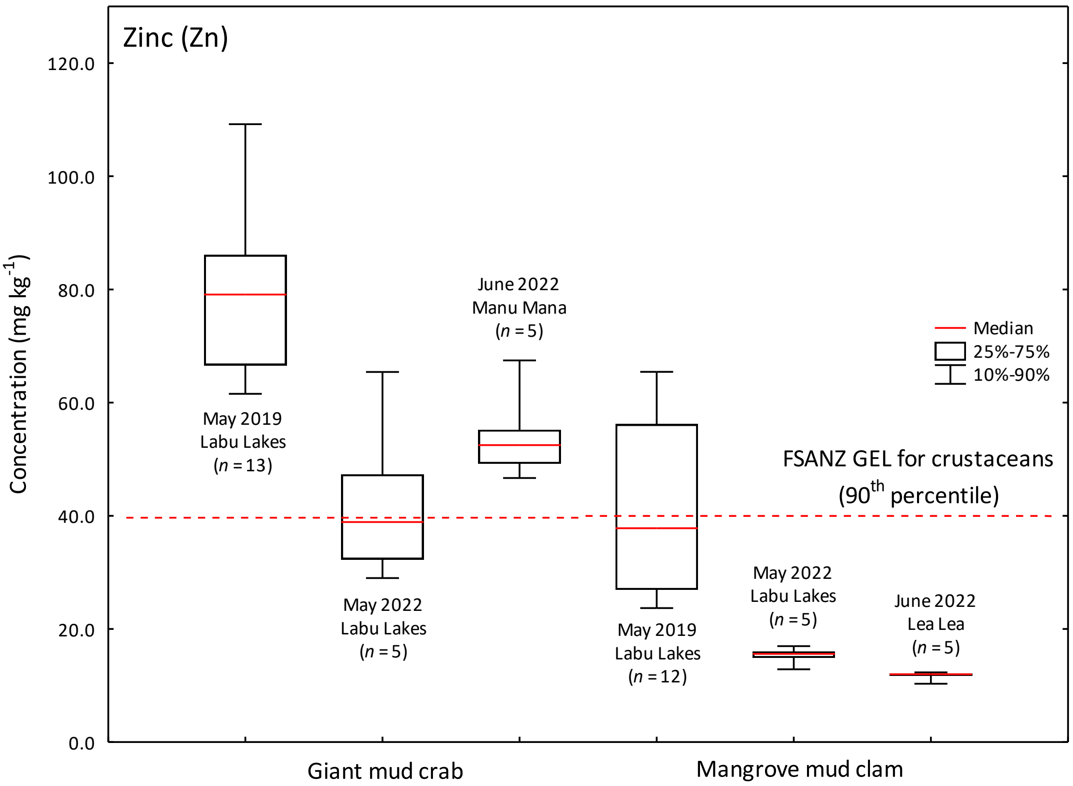

Figure 22. Box and whisker plot of zinc (Zn) concentrations in cheliped muscle of giant mud crabs from western Huon Gulf (Labu Lakes) in May 2019 and 2022, and eastern Gulf of Papua (Manu Mana) in June 2022; data for mangrove mud clams was plotted to compare with giant mud crabs (no FSANZ GELs for Zn are listed for molluscs).

4 DISCUSSION

4.1 Samples and extension of survey geographical coverage

This report documents the second post-EIS baseline study of levels of metals in fishes and invertebrates caught by the local artisanal fishery in coastal waters of the western Huon Gulf, including Labu Lakes, and sold for human consumption at the DCA Point market in Lae. The study was undertaken by Marscco in May/June 2022 and complements the study on metals in market species from the same region completed in May 2019 (Marscco, 2020) and the two studies completed for the EIS in November 2016 and May 2017 (Coffey/Marscco, 2018). The study forms part of the ongoing WGJV objective to build a scientifically robust database of metals from which comparisons can be made in future monitoring studies to support the EIS prediction that the fishery resources will not be adversely impacted and addresses one of the key concerns of coastal communities that the fish and invertebrates sold at local markets will remain safe to eat.

For this study, the survey coverage was extended to include two other geographical areas, namely (i) Wara Waria, located approximately 145 km to the southeast of Lae in the Morobe Province and outside of the Huon Gulf, and (ii) an area along PNG's Central Province comprising various coastal locations of the eastern Gulf of Papua that are close to Port Moresby. As with the May 2019 study, fishes from the western Huon Gulf were sourced at the DCA Point market in Lae while fishes from Wara Waria were sourced directly from local artisanal fishers who operate in coastal waters outside the Waria River entrance. Fishes representing the eastern Gulf of Papua were sourced at the Koki Fish market in Port Moresby which constitutes the main supply market of marine produce of PNG's Central Province. In this report, western Huon Gulf is regarded as the "study area", noting that the local artisanal fishery operates mostly in coastal areas outside the predicted DSTP deep water canyon receiving environment, whereas Wara Waria and eastern Gulf of Papua are regarded as "control areas" as they are remote from mining influences.

Following the May 2019 study, the present baseline study also included two locally abundant invertebrate species targeted by the local artisanal fishery for human consumption, i.e., the giant mud crab (crustacean) and mangrove mud clam (mollusc). Samples of these species were obtained from Labu Lakes in the western Huon Gulf and coastal localities in the eastern Gulf of Papua.

Fishes and invertebrates selected from the study area are typically sold for human consumption and there is understandable interest across local communities that levels of metals in species consumed by the population remain well within current food standard and expected levels (FSANZ Standard and GELs) and therefore pose no risk to public health. As such, the addition of two control areas remote from the main study area and future planned DSTP operations, will allow comparative within-country benchmarks to be used in future studies to monitor/compare metal levels across fish and invertebrate species between areas.

Marine fishes from the western Huon Gulf sourced for this baseline study were caught by the local artisanal fishery in coastal waters between Labu Tale and Lae using mostly handlines to maximum depths of 50 m (Appendix 1). As such, sampled fishes did not include species from the proposed DSTP outfall and tailings placement area to the south of Lae since the artisanal fishery does not operate in that area due to increased depth of water column (>150 m) and lack of seabed structures that support species typically targeted for human consumption. This was also the case during the May 2019 baseline study.

4.2 Variability in metal levels in market fishes and invertebrates

The discussion below focusses exclusively on metal levels in muscle tissues of fishes and excludes livers as well as the hepatopancreas in the case of giant mud crabs. Main reasons for excluding livers are (i) neither fish livers nor hepatopancreas are consumed by the local communities; and (ii) maximum levels published by FSANZ (Standard 1.4.1 and GELs) only apply to the "*portion of food that is ordinarily consumed*" (FSANZ, 2001, 2016), and hence pertain only to muscle (flesh). Metal testing in fish livers will nevertheless continue to be included in baseline studies for comparison with future post-DSTP surveys as the liver is a major bioaccumulation site and hence useful to monitor changes in metal levels over time.

In general, levels of metals most frequently tested in fishes are consistently higher in livers than in muscle tissues, a fact reported in market surveys in the western Huon Gulf and elsewhere in PNG including Woodlark, Misima and Lihir islands (Coffey/Marscco, 2018; Marscco, 2020), and can be demonstrated by the considerable higher concentrations of Cu, Fe and Zn in livers than muscle tissues of the same species reported in this study. Information on metals in fish livers in comparable studies, including main metabolic and storage functions and importance of liver as a target organ for bioaccumulation of various metals, can be found in the May 2019 report (Marscco, 2020).

The present baseline study generated data on levels of 12 metals in muscle tissues of 64 specimens from 17 species representing eight bony fish families sourced at the DCA Point market in Lae and Wara Waria (May 2022), and the Koki Fish market in Port Moresby (June 2022). Metals tested during this study include three metals that were omitted during the May 2019 study but included in the November 2016 study, namely iron (Fe), manganese (Mn) and silver (Ag). Thus, in addition to data on the 12 metals collected during this study (Table 23), comparable muscle data are available for 12 metals in 14 specimens from five fish species sourced at the DCA Point market in November 2016 (Coffey/Marscco, 2018) and 9 metals in 56 specimens from 14 fish species also sourced at the DCA Point market in May 2019 (Marscco, 2020; Table 24).

The present baseline study also generated data on levels of 12 metals in cheliped muscle of giant mud carbs and of whole mangrove mud clams from Labu Lakes in western Huon Gulf and eastern

Gulf of Papua. Nine of the 12 metals were also tested in samples of these two species from Labu Lakes during the May 2019 study.

Based on the extent of the data collected to date during this and the November 2016 and May 2019 baseline studies, Section 4.3 below centres on comparing levels of metals in fishes and invertebrates sampled across baseline surveys. A detailed discussion of metals in fishes and invertebrates, including literature information on each of the 9 metals tested in fish muscle tissues and livers during the May 2019 baseline study, and hepatopancreas of giant mud crabs, is provided in the 2020 report (Marscco, 2020).

As with the May 2019 study (Marscco, 2020), metal levels obtained during this study varied between individuals of the same species and across species from the same families. Such intra- and interspecific variability is expected and has been well described for metals in fish muscles (e.g., Swales *et al*., 1998).

Of the 12 metals tested in muscle tissues across all fish species combined, Cd, Pb and Ag were undetectable (<LORs) whereas Cr and Ni were detected in single samples (1>LOR) and at very low levels. In contrast, Cu, Hg and Mn were detected in many samples whereas total As along with Fe, Se and Zn were detected in all samples tested. Mercury (Hg) was detected in concentrations slightly above the 0.10 mg kg^{-1} LOR in almost half of the specimens from western Huon Gulf (16>LOR) and Wara Waria (6>LOR) but in only one mackerel tuna from the eastern Gulf of Papua. Levels of total As were of similar magnitude in all 64 muscle samples tested across the three locations except for the elevated level recorded in a large predatory common conger pike from western Huon Gulf, i.e., 26.80 mg kg^{-1} (Table 23).

Of the 12 metals tested in cheliped muscle of giant mud crabs from Labu Lakes in western Huon Gulf and Manu Mana in eastern Gulf of Papua, Cd, Cr, Pb, Hg, Ni and Ag were undetectable (<LORs) except for Cd in two samples from western Huon Gulf. In contrast, total As along with Cu, Fe, Mn, Se and Zn were detected in all 10 samples (Table 25). All 12 metals were likewise detected in whole mangrove mud clams except for Ag and Hg in samples from Lea Lea in the Gulf of Papua (5<LOR).

Iron (Fe) was detected in all mud clams tested during the study, with levels ranging from as low as 7.80 mg kg^{-1} in a mud clam from Lea Lea, to as high as 436.00 mg kg^{-1} in a mud clam from Labu Lakes (Tables 22, 26). Such range is comparable to that reported of a popular edible clam from sites not impacted by anthropogenic activities in Baja California (Mexico), i.e., 154 mg kg^{-1} to 558 mg kg^{-1} (Méndez *et al*., 2006). Clams and other bivalve molluscs are regarded as excellent sources of Fe and high Fe levels are common in clams (Lai *et al*., 2012).

Lead was detected in a single sample from each survey region while Hg was detected in a single sample from Labu Lakes (Table 26).

4.3 Comparisons across baseline surveys

4.3.1 Fishes

Data on metals in muscle tissues from all fish species combined to date during baseline surveys in November 2016 and May 2019 (western Huon Gulf) and May/June 2022 (western Huon Gulf, Wara Waria and eastern Gulf of Papua) allows for comparisons and general inferences. Cadmium (Cd), along with Cr, Pb, Ni and Ag were either undetectable or present at very low levels across all surveys (Ag was not tested in May 2019) while levels of estimated inorganic As, and of Cu, Fe, Mn, and Hg were not significantly different across surveys (neither Fe nor Mn were tested in May 2019). However, significant statistical differences were found in Se and Zn levels between areas, particularly for Zn which was higher in May 2019 in fishes from western Huon Gulf. While differences in Se are likely due to the slightly higher mean levels recorded during November 2016 (0.74 mg kg^{-1}) and May 2019 (0.63 mg kg^{-1}) compared with May/June 2022 (0.20-0.31 mg kg^{-1}), the difference in Zn can be attributed to the higher mean level in western Huon Gulf fishes in May 2019 (9.7 mg kg^{-1}) than in November 2016 (3.1 mg kg^{-1}) and May/June 2022 (2.8-3.7 mg kg^{-1}) (Coffey/Marscco, 2018; Marscco, 2020).

Results of this study show no major differences in metal levels in muscle tissues of all fish species combined between the main study area the two control areas except for differences in Se and Zn levels across all five locations. Such differences are minor and expected and can be attributed to interspecific as well intraspecific variability in metal bioaccumulation which is highly species-specific and age/size specific and typical of marine fishes occurring in coastal environments as has been reported for fishes elsewhere in PNG.

4.3.2 Crustaceans and molluscs

Results of this study show no significant differences in metal levels in cheliped muscle tissue of giant mud crabs between the study area in western Huon Gulf (Labu Lakes, May 2019 and May 2022) and the control area in eastern Gulf of Papua (Manu Mana, June 2022) except in the case of estimated inorganic As and of Cu and Zn. Levels of Zn detected in cheliped muscle of mud crabs from Labu Lakes fall within ranges reported for the same species from the Fly River in PNG (Maunsell & Partners, 1982) and coastal waters of Tanzania (Rumisha *et al*., 2017), and can be associated with their burrowing habits and exposure to sediment-bound metals in muddy bottoms typical of shallow coastal areas where they occur. Levels of Mn, on the other hand, were mostly under 5.2 mg kg^{-1} and lower than 8-13 mg kg^{-1} levels published for the same species of mud crab in comparable studies (Mortimer, 2000; Zhang *et al*., 2019).

Based on the available data, results of this study indicate no significant differences in metal levels in whole mangrove mud clams between the study area in western Huon Gulf (Labu Lakes, May 2019 and May 2022) and the control area in eastern Gulf of Papua (Lea Lea, June 2022) except for Cu, Se, and Zn. As obligatory suspension filter feeders, clams are capable of ingesting metal-enriched particles directly from the water column thus making them ideal indicator species to monitor metal levels in estuaries and other shallow coastal habitats.

4.4 Comparisons against food FSANZ standards

4.4.1 Market fishes

Market fishes selected for metal testing during this baseline study represent species normally consumed by the local communities of Lae and Wara Waria in the Morobe Province, and communities along the Central Province close to Port Moresby. Hence, these species are deemed appropriate to monitor levels of metals that may pose risks to public health associated with regular fish consumption, and include regularly available species such as saddletail snapper, mangrove jack, teardrop and yellowbelly threadfin breams, mackerel tuna and Spanish mackerel.

In the absence of food standards for metals in marine produce in PNG, concentrations of selected metals in muscle samples of all fish species tested during this study were compared against guidelines developed by the joint Food Standards Australia and New Zealand (FSANZ) Act 1991, namely FSANZ Standard 1.4.1 for inorganic As, Pb and Hg (maximum levels and/or means), and FSANZ GELs (90^{th} percentile concentrations) listed for Cu, Se, and Zn (Tables 6, 20). No FSANZ Standard or FSANZ GELs are available for Cd, Cr, Fe, Mn, Ni or Ag 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 consulted during this study to maintain consistency with the approach adopted for the WGJV EIS and other metal fish surveys in PNG based on FSANZ Standard and GELs (Coffey/Marscco, 2018; Marscco, 2020).

No exceedance of FSANZ Standard was found for estimated inorganic As (maximum level of 2.0 mg kg^{-1}) estimated in muscle tissues of any of the 64 fish tested during this baseline study, implying that there is presently a very low or no risk to public health in local communities from the regular consumption of muscle (flesh) from any of the fish species tested. While As is toxic in its inorganic form, total As concentration is measured during laboratory analysis which in fishes is mostly present as the non-toxic organoarsenic compound *arsenobetaine* (Ciardullo *et al*., 2010; Sevcikova *et al*., 2011). Thus, total As concentrations were converted to inorganic As by applying the conservative ratio of 0.042 (4.2%) based on published laboratory work on various marine fish species independent of this study (Uneyama *et al*., 2007; Table 7).

No exceedance of FSANZ Standard was found for Hg (mean 0.5 mg kg^{-1} or maximum level 1 mg kg^{-1}) in muscle tissues of any of the 17 fish species tested during this baseline study (Table 20), implying that the regular consumption of muscle (flesh) from any of the fish species tested is expected to pose no risk to public health in local communities. Likewise, no exceedances of the FSANZ GELs were found for Cu, Se or Zn (90th percentiles of 2, 2 and 15 mg kg^{-1}, respectively; Table 20) in muscle tissues of any of the fish species tested, supporting the conclusion that the regular consumption of flesh from any of the fish species tested poses no risk to public health in local communities. In contrast to this study, however, Zn levels were found to slightly exceed the FSANZ GEL of 15 mg kg^{-1} in muscle tissues of a few species during the May 2019 study in western Huon Gulf, including mangrove jack (90th percentile = 16.7 mg kg^{-1}) and yellowfin threadfin bream (90th percentile = 16.6 mg kg^{-1}) (Marscco, 2020).

Of the seven metals with current FSANZ guidelines and thus of concern to public health (Table 6), Pb was not detected in any of the fish muscle tissue samples tested during this study (64<LOR; Table 23). Similarly, Pb was undetectable in fish muscle samples from the western Huon Gulf in November 2016 (14<LOR; Coffey/Marscco, 2018) and was only detected in four of the 53 muscle samples tested in fishes from western Huon Gulf (49<LOR; Table 24) in May 2019 albeit at very low levels which did not exceed the FSANZ Standard of 0.5 mg kg^{-1} (Marscco, 2020). This finding indicates that the regular consumption of flesh from any of the fish species tested during this study poses no risk to public health in local communities.

Iron was detected in all muscle tissue samples tested during this and the November 2016 study while Mn was present in two of the 14 samples tested in November 2016 and 56 of the 64 muscle tissue samples tested across all fish species combined during this study (Tables 23, 24). Iron is an essential element in all forms of life and in fishes plays an integral role in biochemical processes such as cellular respiration and vascular transport (haemoglobin) and storage (myoglobin) of oxygen (Bury and Grosell, 2003; Beard et al., 1996). Manganese is likewise an essential metal component of many enzymes and plays a significant role as a cofactor or activator of different enzymatic reactions in animals (Baden and Eriksson, 2006; Rajkowska and Protasowicki, 2013; Zhang *et al*., 2019) though at elevated levels is regarded as a contaminant of mine water discharges (Hardford *et al*., 2015).

No exceedances of FSANZ Standard were reported in muscle tissues of fishes sampled from the DCA Point market in Lae during the November 2016 study to inform the EIS. 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 Appendix P of the WGJV EIS, including detailed comparisons of metal levels with FSANZ guidelines (Coffey/Marscco, 2018).

4.4.2 Giant mud crabs

Giant mud crabs are boiled and crushed to remove muscles inside chelipeds (pincers) and walking legs for consumption by local communities, but not the hepatopancreas (digestive gland). Metal levels in left cheliped muscle samples of mud crabs sourced from Labu Lakes (western Huon Gulf) and Manu Mana (eastern Gulf of Papua) were compared against FSANZ Standard for inorganic As and against the FSANZ GELs for Cu, Se, and Zn listed for crustaceans (Table 6); Hg was not detected in any of the mud crabs tested from either Labu Lakes or Manu Mana during the study (Table 21).

No exceedance of the FSANZ Standard was found for levels of estimated inorganic As (maximum level of 2.0 mg kg^{-1}) estimated in muscle samples of any of the mud crabs tested during this study, implying that the regular consumption of crab meat (flesh) is not expected to pose a risk to public health in local communities. Similarly, no exceedances of the FSANZ GELs were found for Cu or Se (90^{th} percentile concentrations of 20 and 1 mg kg^{-1}, respectively) in cheliped muscle of mud crabs tested.

Levels of Zn in cheliped muscle samples of all mud crabs from Labu Lakes (90^{th} percentile = 65.4 mg kg^{-1}) and Manu Mana (90^{th} percentile = 67.4 mg kg^{-1}) during this study exceeded the FSANZ GEL 90^{th} percentile recommended for crustacea (90^{th} percentile = 40 mg kg^{-1}), which was also the case of mud crabs from Labu Lakes during the May 2019 study (109.2 mg kg^{-1}) (Marscco, 2020). Elevated Zn levels can be attributed to the burrowing habits of mud crabs in muddy sediments typical of shallow coastal areas, and the exposure to and ingestion of enriched particulate matter while mobilising sediment-bound metals during feeding (Rumisha *et al*., 2017). Elevated Zn levels have been found in the same mud crab species in other estuarine and coastal marine habitats and have reported to cause no adverse health risks to consumers in those locations (e.g., Maunsell & Partners, 1982; Mortimer, 2000; Kamaruzzaman *et al*., 2012; Rumisha *et al*., 2017). Given the 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 the regular consumption of mud crab meat.

4.4.3 Mangrove mud clams

Comparisons of metal levels in mangrove mud clams from Labu Lakes (western Huon Gulf) and Lea Lea (eastern Gulf of Papua) were made against the FSANZ Standard for inorganic As, Cd, Hg and Pb and against the FSANZ GELs for Cu and Se listed for molluscs (Table 6). No exceedances of the FSANZ Standard or FSANZ GELs were found for inorganic As, or for Cd, Cu, Pb, Hg and Se in any of the mud clams from Labu Lakes and Lea Lea tested during this study. These findings indicate that regular consumption of mud clams from either locality is not expected to pose a risk to public health in local communities.

4.5 Key findings

4.5.1 Fish species tested

- A total of 64 fish specimens representing 17 species from eight families of marine coastal bony fishes were examined during this second post-EIS baseline study for metal analysis. The number of fish specimens and species examined during this study was comparable to the 56 specimens from 14 species (8 families) tested during the first post-EIS baseline study in May 2019.
- Fish samples originated from the study area in the western Huon Gulf and two control areas, namely Wara Waria in the Mororbe Province and outside the Huon Gulf and the eastern Gulf of Papua close to Port Moresby. While the study design sought to target similar commonly consumed fish species from each of these three locations, this proved challenging due to inconsistent fish availability, as well as different species diversity associated with differing coastal habitats. For instance, the Waria Waria region has clearer waters with coral reef species which rarely occur in the western Huon Gulf due to the high suspended sediment loads from the Markham and Busu rivers.
- Sampled fishes did not include species from the proposed DSTP outfall and tailings placement area to the south of Lae since the artisanal fishery does not operate in that area due to increased depth of water column (>150 m) and lack of seabed structures that support species typically targeted for human consumption. This was also the case during the May 2019 baseline study.
- The most abundant market fish species tested during this baseline study were the tropical lutjanid saddletail snapper (n = 9) and the carangid tille trevally (n = 8) from western Huon Gulf and eastern Gulf of Papua (replicate samples), and the scombrids mackerel tuna (n = 5) and Spanish mackerel (n = 5) from eastern Gulf of Papua. No specimens from any of these four species were obtained from Wara Waria in the Huon Gulf.

4.5.2 Metal levels in fish muscle tissues

- Metal levels in muscle tissues of all 64 fish specimens 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 being highly species-specific, age-and-size specific and tissue-specific. Sources of metal variability include a combination of factors ranging from natural local sources to anthropogenic activities.
- Of the 12 metals tested in muscle tissues across all fish species combined, Cd, Pb and Ag were undetectable (<LORs) whereas Cr and Ni were detected in single samples (1>LOR) and at very low levels.

- Cu, Hg and Mn were detected in many tissue samples whereas total As along with Fe, Se and Zn were detected in all samples. Levels of total As were of similar magnitude in all 64 muscle samples tested across the three study areas except for the elevated level recorded in a single common conger pike sampled from western Huon Gulf (26.80 mg kg^{-1}).
- Mercury (Hg) was detected at levels slightly above the 0.10 mg kg^{-1} LOR in almost half of the specimens tested from western Huon Gulf (16>LOR) and Wara Waria (6>LOR) but in only one mackerel tuna from eastern Gulf of Papua.

Comparisons against FSANZ Standard and FSANZ GELs

- Non-essential metals (inorganic As, Pb, Hg) for which FSANZ Standard have been established for fishes (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates would be expected to pose a risk to public health from regular consumption of fish:

  - Estimated inorganic As levels did not exceed the FSANZ Standard listed for fishes (maximum level 2 mg kg^{-1}) in muscle tissues of any of the 64 fish specimens tested during this study.
  - The maximum estimated inorganic As concentration of 1.12 mg kg^{-1} was recorded in muscle tissue of a large predatory common pike conger from western Huon Gulf, corresponding to 4.2% of a total As of 26.8 mg kg^{-1}, i.e., well below the FSANZ Standard maximum level for inorganic As listed for fishes.
  - Based on the low levels of inorganic As in muscle tissues estimated during this 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 regular consumption of flesh from any of the species tested.
  - Lead (LOR 0.05 mg kg^{-1}) was not detected in any of the muscle tissue samples from all 17 fish species tested during this study (64<LOR), and consequently did not exceed the FSANZ Standard of 0.5 mg kg^{-1} for Pb listed for fishes. Therefore, Pb levels during this baseline study are not expected to pose a risk to public health from the regular consumption of flesh from any of the species tested.
  - Mercury (LOR 0.1 mg kg^{-1}) did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or maximum level of 1 mg kg^{-1} for Hg listed for fishes in muscle tissues of any of the 17 fish species tested during this study. Therefore, Hg levels detected during this baseline study are not expected to pose a risk to public health from the regular consumption of flesh from any of the species tested.

- Essential metals (Cu, Se, Zn) for which FSANZ GELs (90th percentiles) have been established for fishes:

  - Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 2 mg kg^{-1} for Cu listed for fishes in muscle tissues of any of the 64 fish specimens tested during this study and were therefore well within the range of generally expected levels.
  - Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 2 mg kg^{-1} for Se listed for fishes in muscle tissues of any of the 64 fish specimens tested during this study and were therefore well within the range of generally expected levels.
  - Zinc (LOR 0.5 mg kg^{-1}) did not exceed the FSANZ GEL of 15 mg kg^{-1} for Zn listed for fishes in muscle tissues of any of the 64 fish specimens tested during this study and were therefore well within the range of generally expected levels.

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

  - Neither Cd (LOR 0.01 mg kg^{-1}) nor Ag (LOR 0.1 mg kg^{-1}) were detected in muscle tissues of any of the 64 fish specimens tested during this study.
  - Chromium (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of only two of the 64 fish specimens tested during this study, i.e., a teardrop threadfin bream from western Huon Gulf and a thumbprint emperor (Family Lethrinidae) from Wara Waria.
  - Iron (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of all 17 species tested during this study, with most under 5.5 mg kg^{-1} except for higher levels recorded in one teardrop threadfin bream from western Huon Gulf (16.9 mg kg^{-1}) and one mackerel tuna from Fishermen Is in the eastern Gulf of Papua (14.2 mg kg^{-1}). Iron is an essential element in fish as it plays an integral role in biochemical processes such as cellular respiration and vascular transport (hemoglobin) and storage (myoglobin) of oxygen.
  - Manganese (LOR 0.05 mg kg^{-1}) was detected in muscle tissues of most fishes from western Huon Gulf (24>LOR) and Wara Waria (12>LOR) but in none of the 20 specimens tested from eastern Gulf of Papua. Where detected, Mn levels were low and in the range of 0.05-0.34 mg kg^{-1} across all species combined.
  - Nickel (LOR 0.05 mg kg^{-1}) was detected in a muscle tissue sample from only one of the 64 fish specimens tested during this study, i.e., a teardrop threadfin bream from western Huon Gulf.

4.5.3 Metal levels in giant mud crabs

- Metal testing of the left cheliped muscle and hepatopancreas (digestive gland) was carried out on five giant mud crab specimens sourced from each of Labu Lakes in the western Huon Gulf and Manu Mana in the eastern Gulf of Papua. The findings outlined below focus only on muscle tissue, which is the edible part of cooked mud crabs consumed by the local coastal community.

- Non-essential metals (As, Hg) for which FSANZ Standard have been established for crustaceans (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates may be expected to pose a risk to human health from regular consumption of mud crabs:

  - Estimated inorganic As levels did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for inorganic As listed for crustaceans in the left cheliped muscle samples of any of the mud crabs tested during this study (0.06-0.34 mg kg^{-1}). Therefore, estimated levels of inorganic As are not expected to pose a risk to public health from regular consumption of mud crabs from Labu Lakes or Manu Mana.
  - Mercury (LOR 0.1 mg kg^{-1}) was not detected in any of the cheliped muscle samples of mud crabs tested during this study and consequently did not exceed the FSANZ Standard mean of 0.50 mg kg^{-1} or maximum level of 1 mg kg^{-1} for Hg listed for crustaceans. Therefore, Hg levels are not expected to pose a risk to public health from regular consumption of mud crabs from Labu Lakes or Manu Mana.

- Essential metals (Cu, Se, Zn) for which FSANZ GELs (90th percentiles) have been established for crustaceans:

  - Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 20 mg kg^{-1} for Cu listed for crustaceans in cheliped muscle tissues of any of the mud crabs tested during this study and were therefore well within the range of generally expected levels.
  - Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 1 mg kg^{-1} for Se listed for crustaceans in cheliped muscle tissues of any of the mud crabs tested during this study and were therefore well within the range of generally expected levels.
  - Zinc (LOR 0.5 mg kg^{-1}) exceeded the FSANZ GEL of 40 mg kg^{-1} for Zn listed for crustaceans in most samples of cheliped muscle of mud crabs tested during this study from both Labu Lakes (90th percentile = 65.4 kg^{-1}) and Manu Mana (90th percentile = 67.5 mg kg^{-1}).
  - Elevated Zn levels in cheliped muscles are associated to the burrowing habits of mud crabs in soft/muddy sediments typical of coastal areas and have been found in the same species of crab in other coastal habitats worldwide where no adverse health risks to consumers have been reported.
  - Given the key role of Zn in diverse metabolic body functions, the elevated levels of Zn detected during this study are not expected to pose a risk to public health from the regular consumption of mud crabs from Labu Lakes or Manu Mana.

- Other metals (Cd, Cr, Fe, Pb, Mn, Ni, Ag) for which no FSANZ Standard or FSANZ GELs have been established for crustaceans:

  - Chromium (LOR 0.05 mg kg^{-1}), Pb (0.05 mg kg^{-1}), Ni (LOR 0.05 mg kg^{-1}) and Ag (0.1 mg kg^{-1}) were not detected in cheliped muscle tissues of any of the mud crabs tested during this study.

- Cadmium (LOR 0.01 mg kg^{-1}) was detected in cheliped muscle samples of only two of the five mud crabs sampled during this study from Labu Lakes.
- Iron (LOR 0.05 mg kg^{-1}) was detected in cheliped muscle tissues of all mud crabs tested during this study, with most levels under 5.0 mg kg^{-1}. Iron is an essential element and plays an integral role in biochemical processes such as cellular respiration and vascular transport (haemoglobin) and storage (myoglobin) of oxygen.
- Manganese (LOR 0.05 mg kg^{-1}) was detected in cheliped muscle tissues of all mud crabs tested during this study, with levels of mostly below 5.2 mg kg^{-1}. Levels of this essential metal were lower than the 8.0-13.0 mg kg^{-1} reported for the same species in other studies (Mortimer, 2000; Zhang *et al*., 2019).

4.5.4 Metal levels in mangrove mud clams

- Metal testing was carried out on whole specimens of five mangrove mud clam sourced from each of Labu Lakes in western Huon Gulf and Lea Lea in eastern Gulf of Papua.

- Non-essential metals (As, Cd, Pb, Hg) for which FSANZ Standard have been established for molluscs (maximum levels and/or means), and whose potential toxicity and bioaccumulation rates would be expected to pose a risk to human health from consumption of mangrove mud clams:

  - Estimated inorganic As levels did not exceed the FSANZ Standard maximum level of 1 mg kg^{-1} for inorganic As listed for molluscs in any of the mud clams tested during this study (0.01-0.06 mg kg^{-1}). Therefore, estimated levels of inorganic As are not expected to pose a risk to public health from regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Cadmium (LOR 0.01 mg kg^{-1}) did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Cd listed for molluscs in any of the mud clams tested during this study. Thus, Cd levels are not expected to pose a risk to public health from the regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Mercury (LOR 0.1 mg kg^{-1}) was detected in only one mud clam from Labu Lakes and did not exceed either the FSANZ Standard mean of 0.5 mg kg^{-1} or the maximum level of 1.0 mg kg^{-1} for Hg listed in molluscs. Therefore, Hg levels are not expected to pose a risk to public health from regular consumption of mud clams from Labu Lakes or Lea Lea.
  - Lead (LOR 0.05 mg kg^{-1}) was detected in only one mud clam from each of Labu Lakes and Lea Lea and did not exceed the FSANZ Standard maximum level of 2 mg kg^{-1} for Pb listed in molluscs. Therefore, Pb levels are not expected to pose a risk to public health from the regular consumption of mud clams from Labu Lakes or Lea Lea.

• Essential metals (Cu, Se) for which FSANZ GELs (90th percentiles) have been established for molluscs:

- Copper (LOR 0.1 mg kg^{-1}) did not exceed the FSANZ GEL of 30 mg kg^{-1} for Cu listed for molluscs in any of the mud clams tested during this study and were therefore well within the range of generally expected levels.
- Selenium (LOR 0.05 mg kg^{-1}) did not exceed the FSANZ GEL of 1 mg kg^{-1} for Se listed for molluscs in any of the mud clams tested during this study and were therefore well within the range of generally expected levels.

• Other metals (Cr, Fe, Mn, Ni, Ag, Zn) for which no FSANZ Standard or FSANZ GELs have been established for molluscs:

- Chromium (LOR 0.05 mg kg^{-1}), was detected in all mud clams from Labu Lakes but in only one mud clam from Lea Lea, at levels of 0.05-0.76 mg kg^{-1}.
- Iron (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with levels as high as 436.00 mg kg^{-1} which are common in clams and other bivalve molluscs that are known to have elevated Fe levels. Clams are regarded as one of the best food sources of iron, and there is no risk to public health associated with such high Fe levels in the mud clams tested during this study.
- Manganese (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with levels being significantly higher in mud clams from Labu Lakes.
- Nickel (LOR 0.05 mg kg^{-1}) was detected in all mud clams tested during this study, with levels recorded under 0.9 mg kg^{-1} across all mud clams tested during this study.
- Silver (LOR 0.1 mg kg^{-1}) was detected in only two mud clams from Labu Lakes, at levels just above the LOR (0.10-0.20 mg kg^{-1}).
- Zinc (LOR 0.5 mg kg^{-1}) was detected in all mud clams tested during this study, at levels of 9.40-17.60 mg kg^{-1} across all mud clams.

4.6 Comparisons with previous baseline market fish surveys

- This and the May 2019 study constitute the major post-EIS baseline market studies completed to date on metal levels in fishes from the study area in western Huon Gulf and which are normally sold for human consumption at the DCA Point market in Lae. Data of metal levels in muscle tissue samples from the above studies were statistically compared over time for all fishes tested by location/year, including the data collected during the November 2016 EIS (14 specimens from five fish species), and the data reported during this study for fishes tested from the two control areas, i.e., Wara Waria and eastern Gulf of Papua.

- Based on the available data, levels of estimated inorganic As and of Hg and Cu levels in muscle tissue samples from all fishes sampled during this and earlier baseline studies did not differ significantly across all survey localities and year.
- Levels of Se were significantly higher in muscle tissue samples of fish specimens sampled in the study area during both the November 2016 EIS and May 2019 baseline studies than in May/June 2022 in the study and control areas in (this study), while Zn levels were significantly higher during the May 2019 baseline study.
- The differences in Se and Zn levels observed during this study could be attributed to natural variability, including natural factors such as interspecific as well intraspecific variability in metal bioaccumulation which is highly species- and age/size-specific and typical of marine fishes occurring in coastal habitats. Furthermore, such natural variability has been well described in literature pertaining to metals in fish elsewhere in PNG.
- To date, only replicate samples of saddletail snapper (*Lutjanus malabaricus*) have been tested for metals based on specimens sourced from western Huon Gulf in November 2016 (n = 5) and May 2019 (n = 11), and from western Huon Gulf (n = 4) and eastern Gulf of Papua (n = 5) during this study. Based on the available data, levels of estimated inorganic As and of Se in muscle tissue samples of this tropical snapper were significantly higher in May 2019 compared to May/June 2022 while Zn levels but did not differ significantly across all surveyed localities.
- Levels of estimated inorganic As and of Se and Zn in saddletail snapper reported in this study were well below their respective accepted FSANZ standards therefore no risk to human health is expected from the regular consumption of flesh of this tropical snapper by local communities.
- The present baseline study included testing of metals in two common invertebrate species consumed by local populations, namely giant mud crab and mangrove mud clam, with testing carried out in five specimens of each species from western Huon Gulf (study area) and eastern Gulf of Papua (control area). Representatives of both species from the study area were also tested for metals during the May 2019 market study.
- Based on detectable levels in cheliped muscle samples of giant mud crabs, levels of estimated inorganic As reported in this study were significantly lower in May 2019 than in May/June 2022. Moreover, estimated levels of inorganic As were well below FSANZ Standard listed for crustaceans for inorganic As therefore no risk to human health is expected from the regular consumption of muscle of mud crabs by local communities.
- Levels of Cu detected in cheliped muscle samples of giant mud crabs were significantly lower in crabs from western Huon Gulf in May 2019 (study area) than in crabs from eastern Gulf of Papua (control area) in June 2022.
- No significant differences were found in Se levels detected in cheliped muscle samples of giant mud crabs from the study area and the control area in eastern Gulf of Papua (Manu Mana), whereas Zn levels were significantly higher in May 2019 than in May/June 2022.
- Levels of inorganic As estimated in this study in whole mangrove mud clams were statistically similar across all samples from western Huon Gulf (study area) and eastern Gulf of Papua (Lea Lea; control area), i.e., no differences across survey localities and year. Moreover, inorganic As

levels were well below FSANZ Standard for inorganic As listed for molluscs therefore no risk to human health is expected from the regular consumption of mud clams by local communities.

- Levels of Cu detected in whole mud clams were significantly higher in samples from western Huon Gulf (study area) in May 2019 and May 2022 than in samples from eastern Gulf of Papua (control area) in June 2022, while Se levels differed significantly across localities and year. Despite such differences, Cu and Se levels were well below FSANZ GELs for both metals listed for molluscs therefore no risk to human health is expected from the regular consumption of mud clams by local communities.
- As with fishes, natural differences in levels of metals in mud crabs and mud clams are expected and can be attributed to factors such burrowing behavior, metal availability in sediments typical of their soft, muddy habitats, as well as variability in metal bioaccumulation through ingestion of enriched particulate matter and sediments.

4.7 Fishing practices and catch per unit of effort (CPUE)

- Observations made during the process of sourcing fishes and invertebrates for this baseline study indicate that artisanal fishing within the study area in the western Huon Gulf is irregular and does not take place daily since fishes are not always available for sale at the DCA Point fish market in Lae. Indeed, of the 64 fish specimens tested during this baseline survey, the study team only managed to obtain 26 fish specimens from DCA Point market over seven days, which constituted most of the fish available for sale at that time.
- In contrast, fish and other marine produce sold at the main Koki Fish market in Port Moresby are available daily except Sundays. Fish and various shellfish species sold at the Koki fish market originate from coastal waters of the eastern Gulf of Papua along PNG's Central Province, and arrive at least twice daily, i.e., early morning and after 4pm in the afternoon.
- For this study, locations where fishes were caught in western Huon Gulf and eastern Gulf of Papua were kindly provided by individual fishers and/or vendors during the purchasing process along with date, fishing time (effort), approximate depth and fishing gear used. However, total catch of individual fishers per fishing session was not disclosed so the data provided pertains only to specific fish samples purchased to be tested for metals for the study and not the entire catch.
- In general, fishes and invertebrates tested during this and previous baseline studies originate mostly from coastal marine waters to maximum depths of 50 m. Fish sold at the DCA Point Fish market originate predominantly from the coastal area between Labu Tale and Lae in the western Huon Gulf, including Labu Lakes, and therefore well outside the predicted DSTP deep water canyon receiving environment.
- The lack of actual information on total catch per day/session, coupled with highly variable fishing times of between 15 minutes and 2 days provided by individual fishers consulted, precludes at this time an estimation of catch per unit of effort (CPUE) necessary to provide a useful assessment of local fish abundances.

5 UNITS AND ABBREVIATIONS

Ag	Silver
As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
DCA	Department of Civil Aviation
DSTP	Deep-sea Tailings Placement
EIS	Environmental Impact Statement
Fe	Iron
FL	Fork Length
FSANZ	Food Standards Australia New Zealand
GEL	Generally Expected Level
Hg	Mercury
LOR	Limit of Reporting
Mn	Manganese
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
SL	Standard Length
TL	Total Length
WGJV	Wafi-Golpu Joint Venture
ww	wet weight
Zn	Zinc

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8 APPENDICES

Appendix 1

Quantity of muscle tissues and livers (grams, g) collected during this study from market-sourced fishes for metals analysis. F, female; M, male, Inm = immature.

Appendix 2

Quantity of left cheliped muscle and hepatopancreas tissue obtained during this study from giant mud crabs (*Scylla serrata*, Family Portunidae) sourced from Labu Lakes (western Huon Gulf) and Manu Mana (Central Province, eastern Gulf of Papua) for metals analysis.

Appendix 3

Quantity of mangrove mud clams (*Anadontia edentula*, Family Lucinidae) sourced during this study from Labu Lakes (western Huon Gulf) and Lea Lea (Central Province, eastern Gulf of Papua) and processed whole for metals analysis.

Appendix 4

ALS Environmental Sample Receipt Notification (SRN) corresponding to Work Order ES2220138.

Appendix 5

ALS Environmental Sample Receipt Notification (SRN) corresponding to Work Order ES2220136.

Appendix 6

ALS Environmental QA/QC Compliance Assessment to assist with Quality Review for Work Order ES2220138.

Appendix 7

ALS Environmental QA/QC Compliance Assessment to assist with Quality Review for Work Order ES2220136.

Appendix 8

ALS Environmental Quality Control Report for Work Order ES2220138.

Appendix 9

ALS Environmental Quality Control Report for Work Order ES2220136.

Appendix 1. Quantity of muscle tissues and livers (grams, g) collected during this study from market-sourced fishes for metals analysis. F, female; M, male, Ind = indeterminate.

Fish No.	Date caught	Location	Method	Fishing time	Depth (m)	Species	Common name	Family	Date processed	Total Length (cm)	Weight (g)	Sex	Muscle tissue		Liver tissue	
													Sample	Quantity (g)	Sample	Quantity (g)
1	22-May-22	Wara Waria	Handline	20 min	20 m	*Lethrinus harak*	Thumbprint emperor	Lethrinidae	25-May-22	22.5	225	F2	WW-1-M	6.1	WW-1-L	1.2
2	22-May-22	Wara Waria	Handline	20 min	20 m	*Lethrinus harak*	Thumbprint emperor	Lethrinidae	25-May-22	21.3	180	F2	WW-2-M	6.0	WW-2-L	0.6
3	22-May-22	Wara Waria	Handline	30 min	20 m	*Lethrinus ornatus*	Ornate emperor	Lethrinidae	25-May-22	18.2	150	Ind	WW-4-M	7.0	WW-4-L	0.2*
4	22-May-22	Wara Waria	Handline	30 min	20 m	*Lethrinus ornatus*	Ornate emperor	Lethrinidae	25-May-22	21.3	255	Ind	WW-5-M	8.9	WW-5-L	1.1
5	22-May-22	Wara Waria	Handline	30 min	20 m	*Lethrinus ornatus*	Ornate emperor	Lethrinidae	25-May-22	17.3	125	Ind	WW-6-M	8.7	WW-6-L	0.6
6	22-May-22	Wara Waria	Handline	15 min	20 m	*Pomadasys argyreus*	Bluecheek javelin	Haemulidae	25-May-22	19.5	130	F2	WW-7-M	6.3	WW-7-L	0.2
7	22-May-22	Wara Waria	Handline	15 min	20 m	*Pomadasys argyreus*	Bluecheek javelin	Haemulidae	25-May-22	17.4	95	F2	WW-8-M	6.1	WW-8-L	0.4*
8	22-May-22	Wara Waria	Handline	15 min	20 m	*Pomadasys argyreus*	Bluecheek javelin	Haemulidae	25-May-22	17.5	100	F2	WW-9-M	6.5	WW-9-L	0.3*
9	22-May-22	Wara Waria	Handline	15 min	20 m	*Otolithes ruber*	Tigertooth croaker	Sciaenidae	25-May-22	27.8	190	F2	WW-10-M	16.1	WW-10-L	0.6
10	22-May-22	Wara Waria	Handline	15 min	20 m	*Otolithes ruber*	Tigertooth croaker	Sciaenidae	25-May-22	24.3	125	F2	WW-11-M	18.1	WW-11-L	0.5*
11	22-May-22	Wara Waria	Handline	30 min	20 m	*Lutjanus gibbus*	Paddletail	Lutjanidae	25-May-22	19.5	130	Ind	WW-12-M	11.7	WW-12-L	0.5*
12	22-May-22	Wara Waria	Handline	30 min	20 m	*Lutjanus gibbus*	Paddletail	Lutjanidae	25-May-22	19.8	145	Ind	WW-13-M	13.1	WW-13-L	0.9*
13	22-May-22	Wara Waria	Handline	30 min	20 m	*Lutjanus gibbus*	Paddletail	Lutjanidae	25-May-22	15.7	80	Ind	WW-14-M	6.5	WW-14-L	0.4*
14	22-May-22	Wara Waria	Handline	30 min	20 m	*Lutjanus timoriensis*	Timor snapper	Lutjanidae	25-May-22	20.5	135	Ind	WW-15-M	11.2	WW-15-L	0.6
15	22-May-22	Wara Waria	Handline	30 min	20 m	*Lutjanus timoriensis*	Timor snapper	Lutjanidae	25-May-22	16.5	75	Ind	WW-16-M	6.3	WW-16-L	0.3*
16	22-May-22	Huon Gulf	Handline	30 min	40 m	*Lutjanus argentimaculatus*	Mangrove jack	Lutjanidae	25-May-22	59.7	2,700	M2	HG-17-M	31.5	HG-17-L	14.8
17	22-May-22	Huon Gulf	Handline	30 min	40 m	*Lutjanus argentimaculatus*	Mangrove jack	Lutjanidae	25-May-22	58.5	2,675	M2	HG-18-M	29.7	HG-18-L	12.7
18	25-May-22	Huon Gulf	Handline	30 min	30 m	*Nemipterus isacanthus*	Teardrop threadfin bream	Nemipteridae	26-May-22	30.0	235	M1	HG-19-M	13.4	HG-19-L	2.6

Fish No.	Date caught	Location	Method	Fishing time	Depth (m)	Species	Common name	Family	Date processed	Total Length (cm)	Weight (g)	Sex	Sample	Muscle (g)	Sample	Liver (g)
19	25-May-22	Huon Gulf	Handline	30 min	30 m	*Nemipterus nematophorus*	Doublewhip threadfin bream	Nemipteridae	26-May-22	24.5	120	M1	HG-20-M	7.7	HG-20-L	0.5*
20	25-May-22	Huon Gulf	Handline	30 min	30 m	*Carangoides malabaricus*	Malabar trevally	Carangidae	26-May-22	31.6	415	F	HG-21-M	11.0	HG-21-L	1.1
21	25-May-22	Huon Gulf	Handline	30 min	30 m	*Carangoides malabaricus*	Malabar trevally	Carangidae	26-May-22	24.8	195	F	HG-22-M	8.2	HG-22-L	0.9
22	25-May-22	Huon Gulf	Handline	30 min	30 m	*Carangoides malabaricus*	Malabar trevally	Carangidae	26-May-22	24.9	200	F	HG-23-M	7.9	HG-23-L	1.3
23	25-May-22	Huon Gulf	Handline	30 min	50 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	26-May-22	35.1	605	M1	HG-24-M	12.5	HG-24-L	2.2
24	25-May-22	Huon Gulf	Handline	30 min	50 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	26-May-22	36.2	645	M3	HG-25-M	12.8	HG-25-L	2.7
25	25-May-22	Huon Gulf	Handline	30 min	30 m	*Caranx tille*	Tille trevally	Carangidae	26-May-22	30.9	365	M1	HG-26-M	12.1	HG-26-L	2.8
26	25-May-22	Labu Lakes entrance	Handline	45 min	<2 m	*Lutjanus goldiei*	Black bass	Lutjanidae	26-May-22	53.8	2,850	M2	LLE-27-M	30.2	LLE-27-L	6.6
27	25-May-22	Labu Lakes entrance	Handline	45 min	<2 m	*Lutjanus goldiei*	Black bass	Lutjanidae	26-May-22	54.0	2,840	M2	LLE-28-M	27.7	LLE-28-L	11.0
28	26-May-22	Labu Lakes entrance	Handline	45 min	<2 m	*Lutjanus goldiei*	Black bass	Lutjanidae	26-May-22	60.7	3,915	M2	LLE-29-M	33.0	LLE-29-L	29.0
29	26-May-22	Huon Gulf	Net 2 inches	3 hours	<2 m	*Otolithes ruber*	Tigertooth croaker	Sciaenidae	26-May-22	33.1	320	F2	HG-30-M	8.7	HG-30-L	1.4*
30	26-May-22	Huon Gulf	Net 2 inches	3 hours	<2 m	*Otolithes ruber*	Tigertooth croaker	Sciaenidae	26-May-22	31.5	280	F2	HG-31-M	10.4	HG-31-L	1.6
31	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Nemipterus bathybius*	Yellowbelly threadfin bream	Nemipteridae	27-May-22	29.6	195	M1	HG-37-M	5.1	HG-37-L	0.7
32	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Nemipterus bathybius*	Yellowbelly threadfin bream	Nemipteridae	27-May-22	28.6	200	M1	HG-38-M	3.9	HG-38-L	1.5
33	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Nemipterus bathybius*	Yellowbelly threadfin bream	Nemipteridae	27-May-22	24.4	130	M1	HG-39-M	4.2	HG-39-L	0.5
34	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Nemipterus bathybius*	Yellowbelly threadfin bream	Nemipteridae	27-May-22	23.5	125	M1	HG-40-M	4.0	HG-40-L	0.7
35	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Caranx tille*	Tille trevally	Carangidae	27-May-22	32.0	385	M2	HG-41-M	9.5	HG-41-L	3.1

Fish No.	Date caught	Location	Method	Fishing time	Depth (m)	Species	Common name	Family	Date processed	Total Length (cm)	Weight (g)	Sex	Sample	Muscle (g)	Sample	Liver (g)
36	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Muraenesox bagio*	Common pike conger	Muraeneso-cidae	27-May-22	112.5	2,255	F2	HG-42-M	20.1	HG-42-L	24.1
37	26-May-22	Huon Gulf	Handline	2 hours	45 m	*Lutjanus argentimaculatus*	Mangrove jack	Lutjanidae	27-May-22	60.2	2,850	F3	HG-43-M	29.8	HG-43-L	12.5
38	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Nemipterus isacanthus*	Teardrop threadfin bream	Nemipteridae	28-May-22	30.5	270	M1	HG-51-M	6.7	HG-51-L	1.3
39	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Nemipterus isacanthus*	Teardrop threadfin bream	Nemipteridae	28-May-22	27.5	200	M1	HG-52-M	6.5	HG-52-L	1.4
40	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Nemipterus isacanthus*	Teardrop threadfin bream	Nemipteridae	28-May-22	26.9	170	M1	HG-53-M	5.2	HG-53-L	1.5
41	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	28-May-22	27.3	300	M1	HG-54-M	9.7	HG-54-L	1.7
42	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	28-May-22	23.5	195	M1	HG-55-M	6.1	HG-55-L	1.4
43	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Nemipterus nematophorus*	Doublewhip threadfin bream	Nemipteridae	28-May-22	26.2	110	M1	HG-56-M	5.2	HG-56-L	0.3*
44	28-May-22	Huon Gulf	Handline	3 hours	40 m	*Caranx tille*	Tille trevally	Carangidae	28-May-22	60.4	2,610	F3	HG-57-M	16.0	HG-57-L	22.5
45	29-May-22	Abau, Gulf of Papua	Handline	2 days catch	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	30-May-22	39.4	800	Ind	GPK-58-M	17.6	GPK-58-L	3.3
46	29-May-22	Abau, Gulf of Papua	Handline	2 days catch	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	30-May-22	42.3	985	Ind	GPK-59-M	19.6	GPK-59-L	3.2
47	29-May-22	Abau, Gulf of Papua	Handline	2 days catch	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	30-May-22	39.5	850	F1	GPK-60-M	17.9	GPK-60-L	4.3
48	29-May-22	Abau, Gulf of Papua	Handline	2 days catch	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	30-May-22	41.0	865	M1	GPK-61-M	17.0	GPK-61-L	4.8
49	29-May-22	Abau, Gulf of Papua	Handline	2 days catch	40 m	*Lutjanus malabaricus*	Saddletail snapper	Lutjanidae	30-May-22	40.7	960	M1	GPK-62-M	19.2	GPK-62-L	5.2
50	1-Jun-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	Surface trolling	*Scomberomorus commerson*	Spanish mackerel	Scombridae	1-Jun-22	70.6	1,910	M1	GPK-63-M	8.1	GPK-63-L	9.7
51	1-Jun-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	Surface trolling	*Scomberomorus commerson*	Spanish mackerel	Scombridae	1-Jun-22	64.6	1,480	M1	GPK-64-M	15.2	GPK-64-L	8.7
52	1-Jun-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	Surface trolling	*Scomberomorus commerson*	Spanish mackerel	Scombridae	1-Jun-22	63.5	1,485	M1	GPK-65-M	16.2	GPK-65-L	9.2

Fish No.	Date caught	Location	Method	Fishing time	Depth (m)	Species	Common name	Family	Date processed	Total Length (cm)	Weight (g)	Sex	Sample	Muscle (g)	Sample	Liver (g)
53	1-Jun-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	Surface trolling	*Scomberomorus commerson*	Spanish mackerel	Scombridae	1-Jun-22	73.5	2,105	M1	GPK-66-M	15.0	GPK-66-L	10.5
54	1-Jun-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	Surface trolling	*Scomberomorus commerson*	Spanish mackerel	Scombridae	1-Jun-22	79.2	2,790	M1	GPK-67-M	16.6	GPK-67-L	14.9
55	31-May-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	20-30 m	*Caranx tille*	Tille trevally	Carangidae	31-May-22	40.1	760	Ind	GPK-78-M	12.6	GPK-78-L	6.8
56	31-May-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	20-30 m	*Caranx tille*	Tille trevally	Carangidae	31-May-22	40.5	740	Ind	GPK-79-M	13.6	GPK-79-L	5.7
57	31-May-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	20-30 m	*Caranx tille*	Tille trevally	Carangidae	31-May-22	36.2	520	F1	GPK-80-M	9.7	GPK-80-L	4.2
58	31-May-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	20-30 m	*Caranx tille*	Tille trevally	Carangidae	31-May-22	31.5	485	F1	GPK-81-M	12.1	GPK-81-L	4.2
59	31-May-22	Kaparoko-Hula, Gulf of Papua	Handline	5pm to 3am	20-30 m	*Caranx tille*	Tille trevally	Carangidae	31-May-22	34.6	480	F1	GPK-82-M	12.3	GPK-82-L	4.6
60	31-May-22	Fisherman Is Gulf of Papua	Handline	No info	Surface trolling	*Euthynnus affinis*	Mackerel tuna	Scombridae	31-May-22	74.2	4,475	M1	GPK-83-M	20.8	GPK-83-L	6.9
61	31-May-22	Fisherman Is Gulf of Papua	Handline	No info	Surface trolling	*Euthynnus affinis*	Mackerel tuna	Scombridae	31-May-22	43.9	1,060	Ind	GPK-84-M	14.8	GPK-84-L	4.9
62	31-May-22	Fisherman Is Gulf of Papua	Handline	No info	Surface trolling	*Euthynnus affinis*	Mackerel tuna	Scombridae	31-May-22	43.7	1,005	Ind	GPK-85-M	10.9	GPK-85-L	2.8
63	31-May-22	Fisherman Is Gulf of Papua	Handline	No info	Surface trolling	*Euthynnus affinis*	Mackerel tuna	Scombridae	31-May-22	43.7	1,030	Ind	GPK-86-M	12.6	GPK-86-L	4.1
64	31-May-22	Fisherman Is Gulf of Papua	Handline	No info	Surface trolling	*Euthynnus affinis*	Mackerel tuna	Scombridae	31-May-22	43.0	925	Ind	GPK-87-M	10.8	GPK-87-L	3.8

* Quantity considered insufficient for analysis

Appendix 2. **Quantity of left cheliped muscle and hepatopancreas tissue obtained during this study from giant mud crabs (Scylla serrata, Family Portunidae) sourced from Labu Lakes (western Huon Gulf) and Manu Mana (Central Province, eastern Gulf of Papua) for metals analysis.**

Crab No.	Date caught	Location	Method	Depth (m)	Date processed	Carapace width (cm)	Weight (g)	Sex	Left cheliped muscle		Hepatopancreas	
									Sample	Quantity (g)	Sample	Quantity (g)
1	22-May-22	Labu Lakes	Traps	Mud	26-May-22	16.0	625	F	LLB-32-M	23.7	LLB-32-HP	9.5
2	22-May-22	Labu Lakes	Traps	Mud	26-May-22	12.5	280	F	LLB-33-M	9.2	LLB-33-HP	4.8*
3	22-May-22	Labu Lakes	Traps	Mud	26-May-22	11.4	245	F	LLB-34-M	9.7	LLB-34-HP	2.1*
4	22-May-22	Labu Lakes	Traps	Mud	26-May-22	10.3	170	F	LLB-35-M	12.4	LLB-35-HP	1.0*
5	22-May-22	Labu Lakes	Traps	Mud	26-May-22	11.0	220	F	LLB-36-M	10.3	LLB-36-HP	0.4*
6	27-May-22	Manu Mana, Gulf of Papua	Hand	Mangroves	31-May-22	12.4	510	M	GPK-73-M	28.7	GPK-73-HP	5.4
7	27-May-22	Manu Mana, Gulf of Papua	Hand	Mangroves	31-May-22	11.9	305	F	GPK-74-M	15.5	GPK-74-HP	3.6
8	27-May-22	Manu Mana, Gulf of Papua	Hand	Mangroves	31-May-22	12.0	300	F	GPK-75-M	14.3	GPK-75-HP	4.3
9	27-May-22	Manu Mana, Gulf of Papua	Hand	Mangroves	31-May-22	12.1	430	M	GPK-76-M	27.3	GPK-76-HP	8.3
10	27-May-22	Manu Mana, Gulf of Papua	Hand	Mangroves	31-May-22	12.3	310	F	GPK-77-M	19.1	GPK-77-HP	5.5

* Quantity considered insufficient for analysis

Appendix 3. Quantity of mangrove mud clams (*Anadontia edentula*, Family Lucinidae) sourced during this study from Labu Lakes (western Huon Gulf) and Lea Lea (Central Province, eastern Gulf of Papua) and processed whole for metals analysis.

Clam No.	Date caught	Location	Method	Depth (m)	Date processed	Shell length (cm)	Weight with shell (g)	Whole animal (No shell)	
								Sample	Quantity (g)
1	27-May-22	Labu Lakes	Hand	Mangroves	28-May-22	6.6	105	LLB-44-M	7.8
2	27-May-22	Labu Lakes	Hand	Mangroves	28-May-22	6.5	90	LLB-45-M	8.3
3	27-May-22	Labu Lakes	Hand	Mangroves	28-May-22	6.4	75	LLB-46-M	8.4
4	27-May-22	Labu Lakes	Hand	Mangroves	28-May-22	5.4	65	LLB-47-M	9.5
5	27-May-22	Labu Lakes	Hand	Mangroves	28-May-22	6.3	85	LLB-48-M	8.2
6	30-May-22	Lea Lea, Gulf of Papua	Hand	Mangroves	30-May-22	9.3	350	GPK-68-M	33.1
7	30-May-22	Lea Lea, Gulf of Papua	Hand	Mangroves	30-May-22	8.6	240	GPK-69-M	26.2
8	30-May-22	Lea Lea, Gulf of Papua	Hand	Mangroves	30-May-22	8.6	215	GPK-70-M	24.0
9	30-May-22	Lea Lea, Gulf of Papua	Hand	Mangroves	30-May-22	8.5	210	GPK-71-M	18.9
10	30-May-22	Lea Lea, Gulf of Papua	Hand	Mangroves	30-May-22	7.6	135	GPK-72-M	16.6

Appendix 4

ALS Environmental Sample Receipt Notification (SRN) corresponding to Work Order ES2220138.

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES2220138**

Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Dr Grant Batterham	Contact	: Customer Services ES
Address	: PO Box 4552 Lae, Morobe Province PNG	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: grant.batterham@wafigolpujv.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: Fish Muscle and Liver Tissue Analysis	Page	: 1 of 6
Order number	: 722892	Quote number	: ES2022WAFGOL0001_V3 (SY/119/22_V3)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: Francis Neira		

Dates

Date Samples Received	: 08-Jun-2022 14:00	Issue Date	: 08-Jun-2022
Client Requested Due Date	: 30-Jun-2022	Scheduled Reporting Date	: **30-Jun-2022**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 5.9'C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 72 / 72

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
- **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 laboratory will process these samples unless instructions are received from you indicating you do not wish to proceed. 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 *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-AES : EG005-B		
WW-1-M	- Snap Lock Bag	- Frozen Sample
WW-1-L	- Snap Lock Bag	- Frozen Sample
WW-2-M	- Snap Lock Bag	- Frozen Sample
WW-2-L	- Snap Lock Bag	- Frozen Sample
WW-4-M	- Snap Lock Bag	- Frozen Sample
WW-4-L	- Snap Lock Bag	- Frozen Sample
WW-5-M	- Snap Lock Bag	- Frozen Sample
WW-5-L	- Snap Lock Bag	- Frozen Sample
WW-6-M	- Snap Lock Bag	- Frozen Sample
WW-6-L	- Snap Lock Bag	- Frozen Sample
WW-7-M	- Snap Lock Bag	- Frozen Sample
WW-7-L	- Snap Lock Bag	- Frozen Sample
WW-8-M	- Snap Lock Bag	- Frozen Sample
WW-8-L	- Snap Lock Bag	- Frozen Sample
WW-9-M	- Snap Lock Bag	- Frozen Sample
WW-9-L	- Snap Lock Bag	- Frozen Sample
WW-10-M	- Snap Lock Bag	- Frozen Sample
WW-10-L	- Snap Lock Bag	- Frozen Sample
WW-11-M	- Snap Lock Bag	- Frozen Sample
WW-11-L	- Snap Lock Bag	- Frozen Sample
WW-12-M	- Snap Lock Bag	- Frozen Sample
WW-12-L	- Snap Lock Bag	- Frozen Sample
WW-13-M	- Snap Lock Bag	- Frozen Sample
WW-13-L	- Snap Lock Bag	- Frozen Sample
WW-14-M	- Snap Lock Bag	- Frozen Sample
WW-14-L	- Snap Lock Bag	- Frozen Sample
WW-15-M	- Snap Lock Bag	- Frozen Sample
WW-15-L	- Snap Lock Bag	- Frozen Sample
WW-16-M	- Snap Lock Bag	- Frozen Sample
WW-16-L	- Snap Lock Bag	- Frozen Sample
HG-17-M	- Snap Lock Bag	- Frozen Sample
HG-17-L	- Snap Lock Bag	- Frozen Sample
HG-18-M	- Snap Lock Bag	- Frozen Sample
HG-18-L	- Snap Lock Bag	- Frozen Sample
HG-19-M	- Snap Lock Bag	- Frozen Sample
HG-19-L	- Snap Lock Bag	- Frozen Sample
HG-20-M	- Snap Lock Bag	- Frozen Sample
HG-20-L	- Snap Lock Bag	- Frozen Sample
HG-21-M	- Snap Lock Bag	- Frozen Sample
HG-21-L	- Snap Lock Bag	- Frozen Sample
HG-22-M	- Snap Lock Bag	- Frozen Sample
HG-22-L	- Snap Lock Bag	- Frozen Sample
HG-23-M	- Snap Lock Bag	- Frozen Sample
HG-23-L	- Snap Lock Bag	- Frozen Sample
HG-24-M	- Snap Lock Bag	- Frozen Sample
HG-24-L	- Snap Lock Bag	- Frozen Sample
HG-25-M	- Snap Lock Bag	- Frozen Sample
HG-25-L	- Snap Lock Bag	- Frozen Sample
HG-26-M	- Snap Lock Bag	- Frozen Sample
HG-26-L	- Snap Lock Bag	- Frozen Sample
LLE-27-M	- Snap Lock Bag	- Frozen Sample
LLE-27-L	- Snap Lock Bag	- Frozen Sample
LLE-28-M	- Snap Lock Bag	- Frozen Sample
LLE-28-L	- Snap Lock Bag	- Frozen Sample
LLE-29-M	- Snap Lock Bag	- Frozen Sample
LLE-29-L	- Snap Lock Bag	- Frozen Sample
HG-30-M	- Snap Lock Bag	- Frozen Sample
HG-30-L	- Snap Lock Bag	- Frozen Sample
HG-31-M	- Snap Lock Bag	- Frozen Sample

Method *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-AES : EG005-B		
HG-31-L	- Snap Lock Bag	- Frozen Sample
LLB-32-M	- Snap Lock Bag	- Frozen Sample
LLB-32-HP	- Snap Lock Bag	- Frozen Sample
LLB-33-M	- Snap Lock Bag	- Frozen Sample
LLB-33-HP	- Snap Lock Bag	- Frozen Sample
LLB-34-M	- Snap Lock Bag	- Frozen Sample
LLB-34-HP	- Snap Lock Bag	- Frozen Sample
LLB-35-M	- Snap Lock Bag	- Frozen Sample
LLB-35-HP	- Snap Lock Bag	- Frozen Sample
LLB-36-M	- Snap Lock Bag	- Frozen Sample
LLB-36-HP	- Snap Lock Bag	- Frozen Sample
HG-37-M	- Snap Lock Bag	- Frozen Sample
HG-37-L	- Snap Lock Bag	- Frozen Sample
Total Mercury by FIMS : EG035-B		
WW-1-M	- Snap Lock Bag	- Frozen Sample
WW-1-L	- Snap Lock Bag	- Frozen Sample
WW-2-M	- Snap Lock Bag	- Frozen Sample
WW-2-L	- Snap Lock Bag	- Frozen Sample
WW-4-M	- Snap Lock Bag	- Frozen Sample
WW-4-L	- Snap Lock Bag	- Frozen Sample
WW-5-M	- Snap Lock Bag	- Frozen Sample
WW-5-L	- Snap Lock Bag	- Frozen Sample
WW-6-M	- Snap Lock Bag	- Frozen Sample
WW-6-L	- Snap Lock Bag	- Frozen Sample
WW-7-M	- Snap Lock Bag	- Frozen Sample
WW-7-L	- Snap Lock Bag	- Frozen Sample
WW-8-M	- Snap Lock Bag	- Frozen Sample
WW-8-L	- Snap Lock Bag	- Frozen Sample
WW-9-M	- Snap Lock Bag	- Frozen Sample
WW-9-L	- Snap Lock Bag	- Frozen Sample
WW-10-M	- Snap Lock Bag	- Frozen Sample
WW-10-L	- Snap Lock Bag	- Frozen Sample
WW-11-M	- Snap Lock Bag	- Frozen Sample
WW-11-L	- Snap Lock Bag	- Frozen Sample
WW-12-M	- Snap Lock Bag	- Frozen Sample
WW-12-L	- Snap Lock Bag	- Frozen Sample
WW-13-M	- Snap Lock Bag	- Frozen Sample
WW-13-L	- Snap Lock Bag	- Frozen Sample
WW-14-M	- Snap Lock Bag	- Frozen Sample
WW-14-L	- Snap Lock Bag	- Frozen Sample
WW-15-M	- Snap Lock Bag	- Frozen Sample
WW-15-L	- Snap Lock Bag	- Frozen Sample
WW-16-M	- Snap Lock Bag	- Frozen Sample
WW-16-L	- Snap Lock Bag	- Frozen Sample
HG-17-M	- Snap Lock Bag	- Frozen Sample
HG-17-L	- Snap Lock Bag	- Frozen Sample
HG-18-M	- Snap Lock Bag	- Frozen Sample
HG-18-L	- Snap Lock Bag	- Frozen Sample
HG-19-M	- Snap Lock Bag	- Frozen Sample
HG-19-L	- Snap Lock Bag	- Frozen Sample
HG-20-M	- Snap Lock Bag	- Frozen Sample
HG-20-L	- Snap Lock Bag	- Frozen Sample
HG-21-M	- Snap Lock Bag	- Frozen Sample
HG-21-L	- Snap Lock Bag	- Frozen Sample
HG-22-M	- Snap Lock Bag	- Frozen Sample
HG-22-L	- Snap Lock Bag	- Frozen Sample
HG-23-M	- Snap Lock Bag	- Frozen Sample
HG-23-L	- Snap Lock Bag	- Frozen Sample
HG-24-M	- Snap Lock Bag	- Frozen Sample
HG-24-L	- Snap Lock Bag	- Frozen Sample
HG-25-M	- Snap Lock Bag	- Frozen Sample
HG-25-L	- Snap Lock Bag	- Frozen Sample

Method *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Total Mercury by FIMS : EG035-B		
HG-26-M	- Snap Lock Bag	- Frozen Sample
HG-26-L	- Snap Lock Bag	- Frozen Sample
LLE-27-M	- Snap Lock Bag	- Frozen Sample
LLE-27-L	- Snap Lock Bag	- Frozen Sample
LLE-28-M	- Snap Lock Bag	- Frozen Sample
LLE-28-L	- Snap Lock Bag	- Frozen Sample
LLE-29-M	- Snap Lock Bag	- Frozen Sample
LLE-29-L	- Snap Lock Bag	- Frozen Sample
HG-30-M	- Snap Lock Bag	- Frozen Sample
HG-30-L	- Snap Lock Bag	- Frozen Sample
HG-31-M	- Snap Lock Bag	- Frozen Sample
HG-31-L	- Snap Lock Bag	- Frozen Sample
LLB-32-M	- Snap Lock Bag	- Frozen Sample
LLB-32-HP	- Snap Lock Bag	- Frozen Sample
LLB-33-M	- Snap Lock Bag	- Frozen Sample
LLB-33-HP	- Snap Lock Bag	- Frozen Sample
LLB-34-M	- Snap Lock Bag	- Frozen Sample
LLB-34-HP	- Snap Lock Bag	- Frozen Sample
LLB-35-M	- Snap Lock Bag	- Frozen Sample
LLB-35-HP	- Snap Lock Bag	- Frozen Sample
LLB-36-M	- Snap Lock Bag	- Frozen Sample
LLB-36-HP	- Snap Lock Bag	- Frozen Sample
HG-37-M	- Snap Lock Bag	- Frozen Sample
HG-37-L	- Snap Lock Bag	- Frozen Sample

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	*Sampling date / time*	*Sample ID*	BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220138-001	25-May-2022 00:00	WW-1-M	✓
ES2220138-002	25-May-2022 00:00	WW-1-L	✓
ES2220138-003	25-May-2022 00:00	WW-2-M	✓
ES2220138-004	25-May-2022 00:00	WW-2-L	✓
ES2220138-005	25-May-2022 00:00	WW-4-M	✓
ES2220138-006	25-May-2022 00:00	WW-4-L	✓
ES2220138-007	25-May-2022 00:00	WW-5-M	✓
ES2220138-008	25-May-2022 00:00	WW-5-L	✓
ES2220138-009	25-May-2022 00:00	WW-6-M	✓
ES2220138-010	25-May-2022 00:00	WW-6-L	✓
ES2220138-011	25-May-2022 00:00	WW-7-M	✓
ES2220138-012	25-May-2022 00:00	WW-7-L	✓
ES2220138-013	25-May-2022 00:00	WW-8-M	✓
ES2220138-014	25-May-2022 00:00	WW-8-L	✓
ES2220138-015	25-May-2022 00:00	WW-9-M	✓
ES2220138-016	25-May-2022 00:00	WW-9-L	✓
ES2220138-017	25-May-2022 00:00	WW-10-M	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220138-018	25-May-2022 00:00	WW-10-L	✓
ES2220138-019	25-May-2022 00:00	WW-11-M	✓
ES2220138-020	25-May-2022 00:00	WW-11-L	✓
ES2220138-021	25-May-2022 00:00	WW-12-M	✓
ES2220138-022	25-May-2022 00:00	WW-12-L	✓
ES2220138-023	25-May-2022 00:00	WW-13-M	✓
ES2220138-024	25-May-2022 00:00	WW-13-L	✓
ES2220138-025	25-May-2022 00:00	WW-14-M	✓
ES2220138-026	25-May-2022 00:00	WW-14-L	✓
ES2220138-027	25-May-2022 00:00	WW-15-M	✓
ES2220138-028	25-May-2022 00:00	WW-15-L	✓
ES2220138-029	25-May-2022 00:00	WW-16-M	✓
ES2220138-030	25-May-2022 00:00	WW-16-L	✓
ES2220138-031	25-May-2022 00:00	HG-17-M	✓
ES2220138-032	25-May-2022 00:00	HG-17-L	✓
ES2220138-033	25-May-2022 00:00	HG-18-M	✓
ES2220138-034	25-May-2022 00:00	HG-18-L	✓
ES2220138-035	26-May-2022 00:00	HG-19-M	✓
ES2220138-036	26-May-2022 00:00	HG-19-L	✓
ES2220138-037	26-May-2022 00:00	HG-20-M	✓
ES2220138-038	26-May-2022 00:00	HG-20-L	✓
ES2220138-039	26-May-2022 00:00	HG-21-M	✓
ES2220138-040	26-May-2022 00:00	HG-21-L	✓
ES2220138-041	26-May-2022 00:00	HG-22-M	✓
ES2220138-042	26-May-2022 00:00	HG-22-L	✓
ES2220138-043	26-May-2022 00:00	HG-23-M	✓
ES2220138-044	26-May-2022 00:00	HG-23-L	✓
ES2220138-045	26-May-2022 00:00	HG-24-M	✓
ES2220138-046	26-May-2022 00:00	HG-24-L	✓
ES2220138-047	26-May-2022 00:00	HG-25-M	✓
ES2220138-048	26-May-2022 00:00	HG-25-L	✓
ES2220138-049	26-May-2022 00:00	HG-26-M	✓
ES2220138-050	26-May-2022 00:00	HG-26-L	✓
ES2220138-051	26-May-2022 00:00	LLE-27-M	✓
ES2220138-052	26-May-2022 00:00	LLE-27-L	✓
ES2220138-053	26-May-2022 00:00	LLE-28-M	✓
ES2220138-054	26-May-2022 00:00	LLE-28-L	✓
ES2220138-055	26-May-2022 00:00	LLE-29-M	✓
ES2220138-056	26-May-2022 00:00	LLE-29-L	✓
ES2220138-057	26-May-2022 00:00	HG-30-M	✓
ES2220138-058	26-May-2022 00:00	HG-30-L	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220138-059	26-May-2022 00:00	HG-31-M	✓
ES2220138-060	26-May-2022 00:00	HG-31-L	✓
ES2220138-061	26-May-2022 00:00	LLB-32-M	✓
ES2220138-062	26-May-2022 00:00	LLB-32-HP	✓
ES2220138-063	26-May-2022 00:00	LLB-33-M	✓
ES2220138-064	26-May-2022 00:00	LLB-33-HP	✓
ES2220138-065	26-May-2022 00:00	LLB-34-M	✓
ES2220138-066	26-May-2022 00:00	LLB-34-HP	✓
ES2220138-067	26-May-2022 00:00	LLB-35-M	✓
ES2220138-068	26-May-2022 00:00	LLB-35-HP	✓
ES2220138-069	26-May-2022 00:00	LLB-36-M	✓
ES2220138-070	26-May-2022 00:00	LLB-36-HP	✓
ES2220138-071	27-May-2022 00:00	HG-37-M	✓
ES2220138-072	27-May-2022 00:00	HG-37-L	✓

Proactive Holding Time Report

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

Requested Deliverables

Dr Grant Batterham

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

Francis Neira

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

INVOICES

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

Appendix 5

ALS Environmental Sample Receipt Notification (SRN) corresponding to Work Order ES2220136.

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES2220136**

Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Francis Neira	Contact	: Customer Services ES
Address	: PO Box 4552 Lae, Morobe Province PNG	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: francis.neira@marscco.com.au	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: Fish Muscle and Liver Tissue Analysis	Page	: 1 of 7
Order number	: 722892	Quote number	: ES2022WAFGOL0001_V3 (SY/119/22_V3)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: Francis Neira		

Dates

Date Samples Received	: 08-Jun-2022 14:00	Issue Date	: 08-Jun-2022
Client Requested Due Date	: 30-Jun-2022	Scheduled Reporting Date	: **30-Jun-2022**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 5.9 - Ice present
Receipt Detail	:	No. of samples received / analysed	: 86 / 86

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
- **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 laboratory will process these samples unless instructions are received from you indicating you do not wish to proceed. 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 *Sample ID*	**Sample Container Received**	**Preferred Sample Container for Analysis**
Metals in Biota by ICP-AES : EG005-B		
HB-38-M Received as HG-38-M	- Snap Lock Bag	- Frozen Sample
HB-38-L Received as HG--38-L	- Snap Lock Bag	- Frozen Sample
HB-39-M Received as HG-39-M	- Snap Lock Bag	- Frozen Sample
HB-39-L Received as HG-39-L	- Snap Lock Bag	- Frozen Sample
HB-40-M Received as HG-40-M	- Snap Lock Bag	- Frozen Sample
HB-40-L Received as HG-40-L	- Snap Lock Bag	- Frozen Sample
HB-41-M Received as HG-41-M	- Snap Lock Bag	- Frozen Sample
HB-41-L Received as HG-41-L	- Snap Lock Bag	- Frozen Sample
HB-42-M Received as HG-42-M	- Snap Lock Bag	- Frozen Sample
HB-42-L Received as HG-42-L	- Snap Lock Bag	- Frozen Sample
HB-43-M Received as HG-43-M	- Snap Lock Bag	- Frozen Sample
HB-43-L Received as HG-43-L	- Snap Lock Bag	- Frozen Sample
LLB-44-C	- Snap Lock Bag	- Frozen Sample
LLB-45-C	- Snap Lock Bag	- Frozen Sample
LLB-46-C	- Snap Lock Bag	- Frozen Sample
LLB-47-C	- Snap Lock Bag	- Frozen Sample
LLB-48-C	- Snap Lock Bag	- Frozen Sample
HG-51-M	- Snap Lock Bag	- Frozen Sample
HG-51-L	- Snap Lock Bag	- Frozen Sample
HG-52-M	- Snap Lock Bag	- Frozen Sample
HG-52-L	- Snap Lock Bag	- Frozen Sample
HG-53-M	- Snap Lock Bag	- Frozen Sample
HG-53-L	- Snap Lock Bag	- Frozen Sample
HG-54-M	- Snap Lock Bag	- Frozen Sample
HG-54-L	- Snap Lock Bag	- Frozen Sample
HG-55-M	- Snap Lock Bag	- Frozen Sample
HG-55-L	- Snap Lock Bag	- Frozen Sample
HG-56-M	- Snap Lock Bag	- Frozen Sample
HG-56-L	- Snap Lock Bag	- Frozen Sample
HG-57-M	- Snap Lock Bag	- Frozen Sample
HG-57-L	- Snap Lock Bag	- Frozen Sample
GPK-58-M	- Snap Lock Bag	- Frozen Sample
GPK-58-L	- Snap Lock Bag	- Frozen Sample
GPK-59-M	- Snap Lock Bag	- Frozen Sample
GPK-59-L	- Snap Lock Bag	- Frozen Sample
GPK-60-M	- Snap Lock Bag	- Frozen Sample
GPK-60-L	- Snap Lock Bag	- Frozen Sample
GPK-61-M	- Snap Lock Bag	- Frozen Sample
GPK-61-L	- Snap Lock Bag	- Frozen Sample
GPK-62-M	- Snap Lock Bag	- Frozen Sample
GPK-62-L	- Snap Lock Bag	- Frozen Sample
GPK-63-M	- Snap Lock Bag	- Frozen Sample
GPK-63-L	- Snap Lock Bag	- Frozen Sample
GPK-64-M	- Snap Lock Bag	- Frozen Sample
GPK-64-L	- Snap Lock Bag	- Frozen Sample
GPK-65-M	- Snap Lock Bag	- Frozen Sample
GPK-65-L	- Snap Lock Bag	- Frozen Sample
GPK-66-M	- Snap Lock Bag	- Frozen Sample
GPK-66-L	- Snap Lock Bag	- Frozen Sample
GPK-67-M	- Snap Lock Bag	- Frozen Sample
GPK-67-L	- Snap Lock Bag	- Frozen Sample
GPK-68-M	- Snap Lock Bag	- Frozen Sample
GPK-69-M	- Snap Lock Bag	- Frozen Sample
GPK-70-M	- Snap Lock Bag	- Frozen Sample
GPK-71-M	- Snap Lock Bag	- Frozen Sample
GPK-72-M	- Snap Lock Bag	- Frozen Sample
GPK-73-M	- Snap Lock Bag	- Frozen Sample
GPK-73-HP	- Snap Lock Bag	- Frozen Sample
GPK-74-M	- Snap Lock Bag	- Frozen Sample

Method / *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Metals in Biota by ICP-AES : EG005-B		
GPK-74-HP	- Snap Lock Bag	- Frozen Sample
GPK-75-M	- Snap Lock Bag	- Frozen Sample
GPK-75-HP	- Snap Lock Bag	- Frozen Sample
GPK-76-M	- Snap Lock Bag	- Frozen Sample
GPK-76-HP	- Snap Lock Bag	- Frozen Sample
GPK-77-M	- Snap Lock Bag	- Frozen Sample
GPK-77-HP	- Snap Lock Bag	- Frozen Sample
GPK-78-M	- Snap Lock Bag	- Frozen Sample
GPK-78-L	- Snap Lock Bag	- Frozen Sample
GPK-79-M	- Snap Lock Bag	- Frozen Sample
GPK-79-L	- Snap Lock Bag	- Frozen Sample
GPK-80-M	- Snap Lock Bag	- Frozen Sample
GPK-80-L	- Snap Lock Bag	- Frozen Sample
GPK-81-M	- Snap Lock Bag	- Frozen Sample
GPK-81-L	- Snap Lock Bag	- Frozen Sample
GPK-82-M	- Snap Lock Bag	- Frozen Sample
GPK-82-L	- Snap Lock Bag	- Frozen Sample
GPK-83-M	- Snap Lock Bag	- Frozen Sample
GPK-83-L	- Snap Lock Bag	- Frozen Sample
GPK-84-M	- Snap Lock Bag	- Frozen Sample
GPK-84-L	- Snap Lock Bag	- Frozen Sample
GPK-85-M	- Snap Lock Bag	- Frozen Sample
GPK-85-L	- Snap Lock Bag	- Frozen Sample
GPK-86-M	- Snap Lock Bag	- Frozen Sample
GPK-86-L	- Snap Lock Bag	- Frozen Sample
GPK-87-M	- Snap Lock Bag	- Frozen Sample
GPK-87-L	- Snap Lock Bag	- Frozen Sample
Total Mercury by FIMS : EG035-B		
HB-38-M Received as HG-38-M	- Snap Lock Bag	- Frozen Sample
HB-38-L Received as HG--38-L	- Snap Lock Bag	- Frozen Sample
HB-39-M Received as HG-39-M	- Snap Lock Bag	- Frozen Sample
HB-39-L Received as HG-39-L	- Snap Lock Bag	- Frozen Sample
HB-40-M Received as HG-40-M	- Snap Lock Bag	- Frozen Sample
HB-40-L Received as HG-40-L	- Snap Lock Bag	- Frozen Sample
HB-41-M Received as HG-41-M	- Snap Lock Bag	- Frozen Sample
HB-41-L Received as HG-41-L	- Snap Lock Bag	- Frozen Sample
HB-42-M Received as HG-42-M	- Snap Lock Bag	- Frozen Sample
HB-42-L Received as HG-42-L	- Snap Lock Bag	- Frozen Sample
HB-43-M Received as HG-43-M	- Snap Lock Bag	- Frozen Sample
HB-43-L Received as HG-43-L	- Snap Lock Bag	- Frozen Sample
LLB-44-C	- Snap Lock Bag	- Frozen Sample
LLB-45-C	- Snap Lock Bag	- Frozen Sample
LLB-46-C	- Snap Lock Bag	- Frozen Sample
LLB-47-C	- Snap Lock Bag	- Frozen Sample
LLB-48-C	- Snap Lock Bag	- Frozen Sample
HG-51-M	- Snap Lock Bag	- Frozen Sample
HG-51-L	- Snap Lock Bag	- Frozen Sample
HG-52-M	- Snap Lock Bag	- Frozen Sample
HG-52-L	- Snap Lock Bag	- Frozen Sample
HG-53-M	- Snap Lock Bag	- Frozen Sample
HG-53-L	- Snap Lock Bag	- Frozen Sample
HG-54-M	- Snap Lock Bag	- Frozen Sample
HG-54-L	- Snap Lock Bag	- Frozen Sample
HG-55-M	- Snap Lock Bag	- Frozen Sample
HG-55-L	- Snap Lock Bag	- Frozen Sample
HG-56-M	- Snap Lock Bag	- Frozen Sample
HG-56-L	- Snap Lock Bag	- Frozen Sample
HG-57-M	- Snap Lock Bag	- Frozen Sample
HG-57-L	- Snap Lock Bag	- Frozen Sample
GPK-58-M	- Snap Lock Bag	- Frozen Sample
GPK-58-L	- Snap Lock Bag	- Frozen Sample
GPK-59-M	- Snap Lock Bag	- Frozen Sample

Method *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Total Mercury by FIMS : EG035-B		
GPK-59-L	- Snap Lock Bag	- Frozen Sample
GPK-60-M	- Snap Lock Bag	- Frozen Sample
GPK-60-L	- Snap Lock Bag	- Frozen Sample
GPK-61-M	- Snap Lock Bag	- Frozen Sample
GPK-61-L	- Snap Lock Bag	- Frozen Sample
GPK-62-M	- Snap Lock Bag	- Frozen Sample
GPK-62-L	- Snap Lock Bag	- Frozen Sample
GPK-63-M	- Snap Lock Bag	- Frozen Sample
GPK-63-L	- Snap Lock Bag	- Frozen Sample
GPK-64-M	- Snap Lock Bag	- Frozen Sample
GPK-64-L	- Snap Lock Bag	- Frozen Sample
GPK-65-M	- Snap Lock Bag	- Frozen Sample
GPK-65-L	- Snap Lock Bag	- Frozen Sample
GPK-66-M	- Snap Lock Bag	- Frozen Sample
GPK-66-L	- Snap Lock Bag	- Frozen Sample
GPK-67-M	- Snap Lock Bag	- Frozen Sample
GPK-67-L	- Snap Lock Bag	- Frozen Sample
GPK-68-M	- Snap Lock Bag	- Frozen Sample
GPK-69-M	- Snap Lock Bag	- Frozen Sample
GPK-70-M	- Snap Lock Bag	- Frozen Sample
GPK-71-M	- Snap Lock Bag	- Frozen Sample
GPK-72-M	- Snap Lock Bag	- Frozen Sample
GPK-73-M	- Snap Lock Bag	- Frozen Sample
GPK-73-HP	- Snap Lock Bag	- Frozen Sample
GPK-74-M	- Snap Lock Bag	- Frozen Sample
GPK-74-HP	- Snap Lock Bag	- Frozen Sample
GPK-75-M	- Snap Lock Bag	- Frozen Sample
GPK-75-HP	- Snap Lock Bag	- Frozen Sample
GPK-76-M	- Snap Lock Bag	- Frozen Sample
GPK-76-HP	- Snap Lock Bag	- Frozen Sample
GPK-77-M	- Snap Lock Bag	- Frozen Sample
GPK-77-HP	- Snap Lock Bag	- Frozen Sample
GPK-78-M	- Snap Lock Bag	- Frozen Sample
GPK-78-L	- Snap Lock Bag	- Frozen Sample
GPK-79-M	- Snap Lock Bag	- Frozen Sample
GPK-79-L	- Snap Lock Bag	- Frozen Sample
GPK-80-M	- Snap Lock Bag	- Frozen Sample
GPK-80-L	- Snap Lock Bag	- Frozen Sample
GPK-81-M	- Snap Lock Bag	- Frozen Sample
GPK-81-L	- Snap Lock Bag	- Frozen Sample
GPK-82-M	- Snap Lock Bag	- Frozen Sample
GPK-82-L	- Snap Lock Bag	- Frozen Sample
GPK-83-M	- Snap Lock Bag	- Frozen Sample
GPK-83-L	- Snap Lock Bag	- Frozen Sample
GPK-84-M	- Snap Lock Bag	- Frozen Sample
GPK-84-L	- Snap Lock Bag	- Frozen Sample
GPK-85-M	- Snap Lock Bag	- Frozen Sample
GPK-85-L	- Snap Lock Bag	- Frozen Sample
GPK-86-M	- Snap Lock Bag	- Frozen Sample
GPK-86-L	- Snap Lock Bag	- Frozen Sample
GPK-87-M	- Snap Lock Bag	- Frozen Sample
GPK-87-L	- Snap Lock Bag	- Frozen Sample

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

ES2220136-001	: [27-May-2022]	: HB-38-M - Received as HG-38-M
ES2220136-002	: [27-May-2022]	: HB-38-L - Received as HG--38-L
ES2220136-003	: [27-May-2022]	: HB-39-M - Received as HG-39-M
ES2220136-004	: [27-May-2022]	: HB-39-L - Received as HG-39-L
ES2220136-005	: [27-May-2022]	: HB-40-M - Received as HG-40-M
ES2220136-006	: [27-May-2022]	: HB-40-L - Received as HG-40-L
ES2220136-007	: [27-May-2022]	: HB-41-M - Received as HG-41-M

ES2220136-008	: [27-May-2022]	: HB-41-L - Received as HG-41-L
ES2220136-009	: [27-May-2022]	: HB-42-M - Received as HG-42-M
ES2220136-010	: [27-May-2022]	: HB-42-L - Received as HG-42-L
ES2220136-011	: [27-May-2022]	: HB-43-M - Received as HG-43-M
ES2220136-012	: [27-May-2022]	: HB-43-L - Received as HG-43-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	*Sampling date / time*	*Sample ID*	BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220136-001	27-May-2022 00:00	HB-38-M Received as...	✓
ES2220136-002	27-May-2022 00:00	HB-38-L Received as...	✓
ES2220136-003	27-May-2022 00:00	HB-39-M Received as...	✓
ES2220136-004	27-May-2022 00:00	HB-39-L Received as...	✓
ES2220136-005	27-May-2022 00:00	HB-40-M Received as...	✓
ES2220136-006	27-May-2022 00:00	HB-40-L Received as...	✓
ES2220136-007	27-May-2022 00:00	HB-41-M Received as...	✓
ES2220136-008	27-May-2022 00:00	HB-41-L Received as...	✓
ES2220136-009	27-May-2022 00:00	HB-42-M Received as...	✓
ES2220136-010	27-May-2022 00:00	HB-42-L Received as...	✓
ES2220136-011	27-May-2022 00:00	HB-43-M Received as...	✓
ES2220136-012	27-May-2022 00:00	HB-43-L Received as...	✓
ES2220136-013	28-May-2022 00:00	LLB-44-C	✓
ES2220136-014	28-May-2022 00:00	LLB-45-C	✓
ES2220136-015	28-May-2022 00:00	LLB-46-C	✓
ES2220136-016	28-May-2022 00:00	LLB-47-C	✓
ES2220136-017	28-May-2022 00:00	LLB-48-C	✓
ES2220136-018	28-May-2022 00:00	HG-51-M	✓
ES2220136-019	28-May-2022 00:00	HG-51-L	✓
ES2220136-020	28-May-2022 00:00	HG-52-M	✓
ES2220136-021	28-May-2022 00:00	HG-52-L	✓
ES2220136-022	28-May-2022 00:00	HG-53-M	✓
ES2220136-023	28-May-2022 00:00	HG-53-L	✓
ES2220136-024	28-May-2022 00:00	HG-54-M	✓
ES2220136-025	28-May-2022 00:00	HG-54-L	✓
ES2220136-026	28-May-2022 00:00	HG-55-M	✓
ES2220136-027	28-May-2022 00:00	HG-55-L	✓
ES2220136-028	28-May-2022 00:00	HG-56-M	✓
ES2220136-029	28-May-2022 00:00	HG-56-L	✓
ES2220136-030	28-May-2022 00:00	HG-57-M	✓
ES2220136-031	28-May-2022 00:00	HG-57-L	✓
ES2220136-032	30-May-2022 00:00	GPK-58-M	✓
ES2220136-033	30-May-2022 00:00	GPK-58-L	✓
ES2220136-034	30-May-2022 00:00	GPK-59-M	✓
ES2220136-035	30-May-2022 00:00	GPK-59-L	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220136-036	30-May-2022 00:00	GPK-60-M	✓
ES2220136-037	30-May-2022 00:00	GPK-60-L	✓
ES2220136-038	30-May-2022 00:00	GPK-61-M	✓
ES2220136-039	30-May-2022 00:00	GPK-61-L	✓
ES2220136-040	30-May-2022 00:00	GPK-62-M	✓
ES2220136-041	30-May-2022 00:00	GPK-62-L	✓
ES2220136-042	01-Jun-2022 00:00	GPK-63-M	✓
ES2220136-043	01-Jun-2022 00:00	GPK-63-L	✓
ES2220136-044	01-Jun-2022 00:00	GPK-64-M	✓
ES2220136-045	01-Jun-2022 00:00	GPK-64-L	✓
ES2220136-046	01-Jun-2022 00:00	GPK-65-M	✓
ES2220136-047	01-Jun-2022 00:00	GPK-65-L	✓
ES2220136-048	01-Jun-2022 00:00	GPK-66-M	✓
ES2220136-049	01-Jun-2022 00:00	GPK-66-L	✓
ES2220136-050	01-Jun-2022 00:00	GPK-67-M	✓
ES2220136-051	01-Jun-2022 00:00	GPK-67-L	✓
ES2220136-052	30-May-2022 00:00	GPK-68-M	✓
ES2220136-053	30-May-2022 00:00	GPK-69-M	✓
ES2220136-054	30-May-2022 00:00	GPK-70-M	✓
ES2220136-055	30-May-2022 00:00	GPK-71-M	✓
ES2220136-056	30-May-2022 00:00	GPK-72-M	✓
ES2220136-057	31-May-2022 00:00	GPK-73-M	✓
ES2220136-058	31-May-2022 00:00	GPK-73-HP	✓
ES2220136-059	31-May-2022 00:00	GPK-74-M	✓
ES2220136-060	31-May-2022 00:00	GPK-74-HP	✓
ES2220136-061	31-May-2022 00:00	GPK-75-M	✓
ES2220136-062	31-May-2022 00:00	GPK-75-HP	✓
ES2220136-063	31-May-2022 00:00	GPK-76-M	✓
ES2220136-064	31-May-2022 00:00	GPK-76-HP	✓
ES2220136-065	31-May-2022 00:00	GPK-77-M	✓
ES2220136-066	31-May-2022 00:00	GPK-77-HP	✓
ES2220136-067	31-May-2022 00:00	GPK-78-M	✓
ES2220136-068	31-May-2022 00:00	GPK-78-L	✓
ES2220136-069	31-May-2022 00:00	GPK-79-M	✓
ES2220136-070	31-May-2022 00:00	GPK-79-L	✓
ES2220136-071	31-May-2022 00:00	GPK-80-M	✓
ES2220136-072	31-May-2022 00:00	GPK-80-L	✓
ES2220136-073	31-May-2022 00:00	GPK-81-M	✓
ES2220136-074	31-May-2022 00:00	GPK-81-L	✓
ES2220136-075	31-May-2022 00:00	GPK-82-M	✓
ES2220136-076	31-May-2022 00:00	GPK-82-L	✓

			BIOTA - EG005/EG035-B Metals in Biota (inc. mercury)
ES2220136-077	31-May-2022 00:00	GPK-83-M	✓
ES2220136-078	31-May-2022 00:00	GPK-83-L	✓
ES2220136-079	31-May-2022 00:00	GPK-84-M	✓
ES2220136-080	31-May-2022 00:00	GPK-84-L	✓
ES2220136-081	31-May-2022 00:00	GPK-85-M	✓
ES2220136-082	31-May-2022 00:00	GPK-85-L	✓
ES2220136-083	31-May-2022 00:00	GPK-86-M	✓
ES2220136-084	31-May-2022 00:00	GPK-86-L	✓
ES2220136-085	31-May-2022 00:00	GPK-87-M	✓
ES2220136-086	31-May-2022 00:00	GPK-87-L	✓

Proactive Holding Time Report

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

Requested Deliverables

Dr Grant Batterham

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

Francis Neira

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

INVOICES

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

Appendix 6

ALS Environmental QA/QC Compliance Assessment to assist with Quality Review for Work Order ES2220138.

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2220138**	Page	: 1 of 6
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Dr Grant Batterham	Telephone	: +61-2-8784 8555
Project	: Fish Muscle and Liver Tissue Analysis	Date Samples Received	: 08-Jun-2022
Site	: ----	Issue Date	: 30-Jun-2022
Sampler	: Francis Neira	No. of samples received	: 72
Order number	: 722892	No. of samples analysed	: 58

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.**
- **Matrix Spike 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.**

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
Matrix Spike (MS) Recoveries							
EG035T: Total Recoverable Mercury by FIMS	ES2220138--001	WW-1-M	**Mercury**	7439-97-6	59.1 %	70.0-130%	**Recovery less than lower data quality objective**
EG035T: Total Recoverable Mercury by FIMS	ES2220138--021	WW-12-M	**Mercury**	7439-97-6	63.4 %	70.0-130%	**Recovery less than lower data quality objective**

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	4	58	6.90	10.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	2	58	3.45	10.00	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)					
Metals in Biota by ICP-MS	2	58	3.45	5.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	2	58	3.45	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 (EG035-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
EG035T: Total Recoverable Mercury by FIMS - Continued								
WW-1-M, WW-2-M, WW-4-M, WW-5-L, WW-6-L, WW-7-L, WW-9-M, WW-10-L, WW-12-M, WW-14-M, WW-15-L, HG-17-M, HG-18-M,	WW-1-L, WW-2-L, WW-5-M, WW-6-M, WW-7-M, WW-8-M, WW-10-M, WW-11-M, WW-13-M, WW-15-M, WW-16-M, HG-17-L, HG-18-L	**25-May-2022**	**29-Jun-2022**	21-Nov-2022	✓	**29-Jun-2022**	21-Nov-2022	✓
Snap Lock Bag (EG035-B) HG-19-M, HG-20-M, HG-21-L, HG-22-L, HG-23-L, HG-24-L, HG-25-L, HG-26-L, LLE-27-L, LLE-28-L, LLE-29-L, HG-31-M, LLB-32-M, LLB-33-M, LLB-35-M,	 HG-19-L, HG-21-M, HG-22-M, HG-23-M, HG-24-M, HG-25-M, HG-26-M, LLE-27-M, LLE-28-M, LLE-29-M, HG-30-M, HG-31-L, LLB-32-HP, LLB-34-M, LLB-36-M	**26-May-2022**	**29-Jun-2022**	22-Nov-2022	✓	**29-Jun-2022**	22-Nov-2022	✓
Snap Lock Bag (EG035-B) HG-37-M,	 HG-37-L	**27-May-2022**	**29-Jun-2022**	23-Nov-2022	✓	**29-Jun-2022**	23-Nov-2022	✓

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 (EG094-B)								
WW-1-M,	WW-1-L,	**25-May-2022**	**29-Jun-2022**	21-Nov-2022	✓	**29-Jun-2022**	21-Nov-2022	✓
WW-2-M,	WW-2-L,							
WW-4-M,	WW-5-M,							
WW-5-L,	WW-6-M,							
WW-6-L,	WW-7-M,							
WW-7-L,	WW-8-M,							
WW-9-M,	WW-10-M,							
WW-10-L,	WW-11-M,							
WW-12-M,	WW-13-M,							
WW-14-M,	WW-15-M,							
WW-15-L,	WW-16-M,							
HG-17-M,	HG-17-L,							
HG-18-M,	HG-18-L							
Snap Lock Bag (EG094-B)								
HG-19-M,	HG-19-L,	**26-May-2022**	**29-Jun-2022**	22-Nov-2022	✓	**29-Jun-2022**	22-Nov-2022	✓
HG-20-M,	HG-21-M,							
HG-21-L,	HG-22-M,							
HG-22-L,	HG-23-M,							
HG-23-L,	HG-24-M,							
HG-24-L,	HG-25-M,							
HG-25-L,	HG-26-M,							
HG-26-L,	LLE-27-M,							
LLE-27-L,	LLE-28-M,							
LLE-28-L,	LLE-29-M,							
LLE-29-L,	HG-30-M,							
HG-31-M,	HG-31-L,							
LLB-32-M,	LLB-32-HP,							
LLB-33-M,	LLB-34-M,							
LLB-35-M,	LLB-36-M							
Snap Lock Bag (EG094-B)								
HG-37-M,	HG-37-L	**27-May-2022**	**29-Jun-2022**	23-Nov-2022	✓	**29-Jun-2022**	23-Nov-2022	✓

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	4	58	**6.90**	**10.00**	✗	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	2	58	**3.45**	**10.00**	✗	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Metals in Biota by ICP-MS	EG094-B	4	58	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	4	58	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Metals in Biota by ICP-MS	EG094-B	4	58	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	4	58	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Metals in Biota by ICP-MS	EG094-B	2	58	**3.45**	**5.00**	✗	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	2	58	**3.45**	**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 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 Environmental QA/QC Compliance Assessment to assist with Quality Review for Work Order ES2220136.

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2220136**	Page	: 1 of 7
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Francis Neira	Telephone	: +61-2-8784 8555
Project	: Fish Muscle and Liver Tissue Analysis	Date Samples Received	: 08-Jun-2022
Site	: ----	Issue Date	: 30-Jun-2022
Sampler	: Francis Neira	No. of samples received	: 86
Order number	: 722892	No. of samples analysed	: 85

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 / Method	Count QC	Count Regular	Rate (%) Actual	Rate (%) Expected	Quality Control Specification
Laboratory Duplicates (DUP)					
Metals in Biota by ICP-MS	0	85	0.00	10.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	0	85	0.00	10.00	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)					
Metals in Biota by ICP-MS	0	85	0.00	5.00	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	0	85	0.00	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 / 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								
Snap Lock Bag (EG035-B)								
GPK-63-M,	GPK-63-L,	**01-Jun-2022**	**27-Jun-2022**	28-Nov-2022	✓	**29-Jun-2022**	28-Nov-2022	✓
GPK-64-M,	GPK-64-L,							
GPK-65-M,	GPK-65-L,							
GPK-66-M,	GPK-66-L,							
GPK-67-M,	GPK-67-L							
Snap Lock Bag (EG035-B)								
HB-38-M - Received as HG-38-M,	HB-38-L - Received as HG--38-L,	**27-May-2022**	**27-Jun-2022**	23-Nov-2022	✓	**29-Jun-2022**	23-Nov-2022	✓
HB-39-M - Received as HG-39-M,	HB-39-L - Received as HG-39-L,							
HB-40-M - Received as HG-40-M,	HB-40-L - Received as HG-40-L,							
HB-41-M - Received as HG-41-M,	HB-41-L - Received as HG-41-L,							
HB-42-M - Received as HG-42-M,	HB-42-L - Received as HG-42-L,							
HB-43-M - Received as HG-43-M,	HB-43-L - Received as HG-43-L							
Snap Lock Bag (EG035-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
EG035T: Total Recoverable Mercury by FIMS - Continued								
LLB-44-C, LLB-46-C, LLB-48-C, HG-51-L, HG-52-L, HG-53-L, HG-54-L, HG-55-L, HG-57-M,	LLB-45-C, LLB-47-C, HG-51-M, HG-52-M, HG-53-M, HG-54-M, HG-55-M, HG-56-M, HG-57-L	**28-May-2022**	**27-Jun-2022**	24-Nov-2022	✓	**29-Jun-2022**	24-Nov-2022	✓
Snap Lock Bag (EG035-B)								
GPK-58-M, GPK-59-M, GPK-60-M, GPK-61-M, GPK-62-M, GPK-68-M, GPK-70-M, GPK-72-M	GPK-58-L, GPK-59-L, GPK-60-L, GPK-61-L, GPK-62-L, GPK-69-M, GPK-71-M,	**30-May-2022**	**27-Jun-2022**	26-Nov-2022	✓	**29-Jun-2022**	26-Nov-2022	✓
Snap Lock Bag (EG035-B)								
GPK-73-M, GPK-74-M, GPK-75-M, GPK-76-M, GPK-77-M, GPK-78-M, GPK-79-M, GPK-80-M, GPK-81-M, GPK-82-M, GPK-83-M, GPK-84-M,	GPK-73-HP, GPK-74-HP, GPK-75-HP, GPK-76-HP, GPK-77-HP, GPK-78-L, GPK-79-L, GPK-80-L, GPK-81-L, GPK-82-L, GPK-83-L, GPK-84-L	**31-May-2022**	**27-Jun-2022**	27-Nov-2022	✓	**29-Jun-2022**	27-Nov-2022	✓
Snap Lock Bag (EG035-B)								
GPK-85-M, GPK-86-M, GPK-87-M,	GPK-85-L, GPK-86-L, GPK-87-L	**31-May-2022**	**28-Jun-2022**	27-Nov-2022	✓	**29-Jun-2022**	27-Nov-2022	✓

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 (EG094-B)								
GPK-63-M, GPK-64-M, GPK-65-M, GPK-66-M, GPK-67-M,	GPK-63-L, GPK-64-L, GPK-65-L, GPK-66-L, GPK-67-L	**01-Jun-2022**	**27-Jun-2022**	28-Nov-2022	✓	**29-Jun-2022**	28-Nov-2022	✓
Snap Lock Bag (EG094-B)								
HB-38-M - Received as HG-38-M, HB-39-M - Received as HG-39-M, HB-40-M - Received as HG-40-M, HB-41-M - Received as HG-41-M, HB-42-M - Received as HG-42-M, HB-43-M - Received as HG-43-M,	HB-38-L - Received as HG--38-L, HB-39-L - Received as HG-39-L, HB-40-L - Received as HG-40-L, HB-41-L - Received as HG-41-L, HB-42-L - Received as HG-42-L, HB-43-L - Received as HG-43-L	**27-May-2022**	**27-Jun-2022**	23-Nov-2022	✓	**29-Jun-2022**	23-Nov-2022	✓
Snap Lock Bag (EG094-B)								
LLB-44-C, LLB-46-C, LLB-48-C, HG-51-L, HG-52-L, HG-53-L, HG-54-L, HG-55-L, HG-57-M,	LLB-45-C, LLB-47-C, HG-51-M, HG-52-M, HG-53-M, HG-54-M, HG-55-M, HG-56-M, HG-57-L	**28-May-2022**	**27-Jun-2022**	24-Nov-2022	✓	**29-Jun-2022**	24-Nov-2022	✓
Snap Lock Bag (EG094-B)								
GPK-58-M, GPK-59-M, GPK-60-M, GPK-61-M, GPK-62-M, GPK-68-M, GPK-70-M, GPK-72-M	GPK-58-L, GPK-59-L, GPK-60-L, GPK-61-L, GPK-62-L, GPK-69-M, GPK-71-M,	**30-May-2022**	**27-Jun-2022**	26-Nov-2022	✓	**29-Jun-2022**	26-Nov-2022	✓
Snap Lock Bag (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								
GPK-73-M,	GPK-73-HP,	**31-May-2022**	**27-Jun-2022**	27-Nov-2022	✓	**29-Jun-2022**	27-Nov-2022	✓
GPK-74-M,	GPK-74-HP,							
GPK-75-M,	GPK-75-HP,							
GPK-76-M,	GPK-76-HP,							
GPK-77-M,	GPK-77-HP,							
GPK-78-M,	GPK-78-L,							
GPK-79-M,	GPK-79-L,							
GPK-80-M,	GPK-80-L,							
GPK-81-M,	GPK-81-L,							
GPK-82-M,	GPK-82-L,							
GPK-83-M,	GPK-83-L,							
GPK-84-M,	GPK-84-L							
Snap Lock Bag (EG094-B)								
GPK-85-M,	GPK-85-L,	**31-May-2022**	**28-Jun-2022**	27-Nov-2022	✓	**29-Jun-2022**	27-Nov-2022	✓
GPK-86-M,	GPK-86-L,							
GPK-87-M,	GPK-87-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	0	85	**0.00**	**10.00**	×	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	0	85	**0.00**	**10.00**	×	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Metals in Biota by ICP-MS	EG094-B	5	85	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	85	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Metals in Biota by ICP-MS	EG094-B	5	85	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	5	85	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Metals in Biota by ICP-MS	EG094-B	0	85	**0.00**	**5.00**	×	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035-B	0	85	**0.00**	**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 APHA 3112 Hg - B (Flow-injection ($SnCl_2$)(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 $SnCl_2$ 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 Environmental Quality Control Report for Work Order ES2220138.

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES2220138**	Page	: 1 of 6
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Dr Grant Batterham	Contact	: Customer Services ES
Address	: PO Box 4552 Lae, Morobe Province PNG	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: Fish Muscle and Liver Tissue Analysis	Date Samples Received	: 08-Jun-2022
Order number	: 722892	Date Analysis Commenced	: 29-Jun-2022
C-O-C number	: ----	Issue Date	: 30-Jun-2022
Sampler	: Francis Neira		
Site	: ----		
Quote number	: SY/119/22_V3		
No. of samples received	: 72		
No. of samples analysed	: 58		

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, unless the sampling was conducted by ALS. 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*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 moisture content, insufficient sample (reduced weight employed) or matrix interference.

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	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 4426199)									
ES2220138-011	WW-7-M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.0	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 4426201)									
ES2220138-033	HG-18-M	EG035-B: Mercury	7439-97-6	0.1	mg/kg	0.4	0.3	0.0	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 4426198)									
ES2220138-001	WW-1-M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.0	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	2.70	2.53	6.5	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	0.07	<0.05	34.2	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Manganese	7439-96-5	0.05	mg/kg	0.08	<0.05	43.3	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.11	0.09	11.8	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.1	0.1	0.0	No Limit
		EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
		EG094-B: Iron	7439-89-6	0.5	mg/kg	3.4	2.0	51.1	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	4.0	3.4	16.4	No Limit
ES2220138-011	WW-7-M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.02	84.0	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	6.50	6.94	6.6	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Manganese	7439-96-5	0.05	mg/kg	0.15	<0.05	101	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.20	0.21	0.0	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.2	0.2	0.0	No Limit
		EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	0.0	No Limit

Sub-Matrix: **BIOTA**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
EG094: Metals in Biota by ICPMS (QC Lot: 4426198) - continued									
ES2220138-011	WW-7-M	EG094-B: Iron	7439-89-6	0.5	mg/kg	2.2	2.2	0.0	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.7	4.5	19.8	No Limit
EG094: Metals in Biota by ICPMS (QC Lot: 4426200)									
ES2220138-031	HG-17-M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.0	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	0.18	0.18	0.0	No Limit
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.34	0.32	6.7	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
		EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
		EG094-B: Iron	7439-89-6	0.5	mg/kg	0.9	1.2	31.8	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	2.2	2.1	0.0	No Limit
ES2220138-021	WW-12-M	EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	0.0	No Limit
		EG094-B: Arsenic	7440-38-2	0.05	mg/kg	6.18	6.09	1.5	0% - 20%
		EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Manganese	7439-96-5	0.05	mg/kg	0.11	0.06	62.9	No Limit
		EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	<0.05	0.0	No Limit
		EG094-B: Selenium	7782-49-2	0.05	mg/kg	0.26	0.25	0.0	No Limit
		EG094-B: Copper	7440-50-8	0.1	mg/kg	0.1	<0.1	0.0	No Limit
		EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
		EG094-B: Iron	7439-89-6	0.5	mg/kg	1.4	1.3	0.0	No Limit
		EG094-B: Zinc	7440-66-6	0.5	mg/kg	3.1	2.4	27.8	No Limit

Method Blank (MB) and Laboratory Control Sample (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 Sample (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 (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426199)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	83.3	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426201)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	78.2	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426209)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	95.4	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426211)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	90.2	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426198)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	79.0	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	98.3	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	113	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	89.2	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	89.8	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	104	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	104	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	94.8	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426200)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	83.1	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	100	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	118	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	90.8	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	92.2	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	107	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	108	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	100	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426208)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	80.3	70.0	130

Sub-Matrix: **BIOTA**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
				Result	Concentration	LCS	Low	High
EG094: Metals in Biota by ICPMS (QCLot: 4426208) - continued								
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	104	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	112	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	98.3	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	99.2	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	117	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	116	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	105	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426210)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	77.2	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	102	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	106	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	91.2	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	92.0	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	113	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	112	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	100	70.0	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	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
				Concentration	MS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426199)							
ES2220138-001	WW-1-M	EG035-B: Mercury	7439-97-6	2.5 mg/kg	# 59.1	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4426201)							
ES2220138-021	WW-12-M	EG035-B: Mercury	7439-97-6	2.5 mg/kg	# 63.4	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426198)							
ES2220138-001	WW-1-M	EG094-B: Arsenic	7440-38-2	25 mg/kg	88.5	70.0	130
		EG094-B: Cadmium	7440-43-9	25 mg/kg	106	70.0	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	93.2	70.0	130

Sub-Matrix: **BIOTA**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EG094: Metals in Biota by ICPMS (QCLot: 4426198) - continued							
ES2220138-001	WW-1-M	EG094-B: Copper	7440-50-8	100 mg/kg	125	70.0	130
		EG094-B: Lead	7439-92-1	100 mg/kg	123	70.0	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	100	70.0	130
		EG094-B: Zinc	7440-66-6	100 mg/kg	124	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4426200)							
ES2220138-021	WW-12-M	EG094-B: Arsenic	7440-38-2	25 mg/kg	71.2	70.0	130
		EG094-B: Cadmium	7440-43-9	25 mg/kg	86.4	70.0	130
		EG094-B: Chromium	7440-47-3	25 mg/kg	74.8	70.0	130
		EG094-B: Copper	7440-50-8	100 mg/kg	101	70.0	130
		EG094-B: Lead	7439-92-1	100 mg/kg	101	70.0	130
		EG094-B: Nickel	7440-02-0	25 mg/kg	81.3	70.0	130
		EG094-B: Zinc	7440-66-6	100 mg/kg	101	70.0	130

Appendix 9

ALS Environmental Quality Control Report for Work Order ES2220136.

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES2220136**	Page	: 1 of 5
Client	: **WAFI GOLPU SERVICES LIMITED**	Laboratory	: Environmental Division Sydney
Contact	: Francis Neira	Contact	: Customer Services ES
Address	: PO Box 4552 Lae, Morobe Province PNG	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: Fish Muscle and Liver Tissue Analysis	Date Samples Received	: 08-Jun-2022
Order number	: 722892	Date Analysis Commenced	: 27-Jun-2022
C-O-C number	: ----	Issue Date	: 30-Jun-2022
Sampler	: Francis Neira		
Site	: ----		
Quote number	: SY/119/22_V3		
No. of samples received	: 86		
No. of samples analysed	: 85		

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, unless the sampling was conducted by ALS. 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*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 moisture content, insufficient sample (reduced weight employed) or matrix interference.

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%.

- **No Laboratory Duplicate (DUP) Results are required to be reported.**

Method Blank (MB) and Laboratory Control Sample (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 Sample (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 (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4422880)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	81.6	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4422882)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	96.0	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4422885)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	88.5	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4422887)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	82.2	70.0	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 4422911)								
EG035-B: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.087 mg/kg	104	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4422879)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	80.7	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	111	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	116	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	100	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	95.5	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	121	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	115	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	107	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4422881)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	80.9	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	111	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	121	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	96.5	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	97.1	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	125	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	113	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	107	70.0	130

Sub-Matrix: **BIOTA**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG094: Metals in Biota by ICPMS (QCLot: 4422884)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	73.5	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	95.1	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	98.8	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	83.7	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	77.3	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	103	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	98.2	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	94.4	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4422886)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	83.0	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	101	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	118	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	93.7	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	91.2	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	120	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	117	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	102	70.0	130
EG094: Metals in Biota by ICPMS (QCLot: 4422910)								
EG094-B: Arsenic	7440-38-2	0.05	mg/kg	<0.05	98 mg/kg	72.4	70.0	130
EG094-B: Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.74 mg/kg	104	70.0	130
EG094-B: Chromium	7440-47-3	0.05	mg/kg	<0.05	15.4 mg/kg	117	70.0	130
EG094-B: Copper	7440-50-8	0.1	mg/kg	<0.1	48 mg/kg	94.7	70.0	130
EG094-B: Iron	7439-89-6	0.5	mg/kg	<0.5	27922 mg/kg	92.4	70.0	130
EG094-B: Lead	7439-92-1	0.05	mg/kg	<0.05	50 mg/kg	116	70.0	130
EG094-B: Manganese	7439-96-5	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Nickel	7440-02-0	0.05	mg/kg	<0.05	12.4 mg/kg	108	70.0	130
EG094-B: Selenium	7782-49-2	0.05	mg/kg	<0.05	----	----	----	----
EG094-B: Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
EG094-B: Zinc	7440-66-6	0.5	mg/kg	<0.5	115 mg/kg	100	70.0	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.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**